GEORGETOWN STEAM PLANT

HISTORIC STRUCTURE & CULTURAL LANDSCAPE REPORT

OCTOBER 9, 2013

BOLA ARCHITECTURE + PLANNING

159 WESTERN AVENUE WEST, SUITE 486, SEATTLE WA 98119 TEL 206.447.4749 FAX 206.447.6462

TABLE OF CONTENTS

TABLE OF FIGURES

1. INTRODUCTION

Executive Summary

This Historic Structure Report (HSR) was undertaken at the direction of Seattle City Light (SCL) to document the history and existing conditions of the Georgetown Steam Plant and to provide conservation recommendations for the exterior envelope, roof, and site and landscape features. The report integrates a Cultural Landscape Report (CLR) component and will also serve as a guide to address preservation issues, interpretation, and future uses. It is SCL's intent to rehabilitate the building's exterior and provide seismic and structural improvements, as well as to make limited improvements to the immediate site surrounding the building. We envision this document will be a planning and development tool for the protection of the Steam Plant and its site for enhanced use as a museum and interpretive facility.

The Georgetown Steam Plant is listed in the National Register of Historic Places and designated both a National Historic Landmark and a Seattle Landmark. It is a unique cultural resource that helps define the physical and visual form of power generation—first, as an early example of a reinforced concrete structure that houses one of the last operable examples of the "first generation" of large-scale, vertical steam turbine electric generators; and second, for its association with Frank Gilbreth, a nationally-recognized reinforced concrete expert and scientific management pioneer, who was in charge of the building's design and construction. This historical significance should be among the guiding factors in the decisions regarding ongoing maintenance, repairs, and development of design documents for rehabilitation, interpretation, and adaptive use of the building and site.

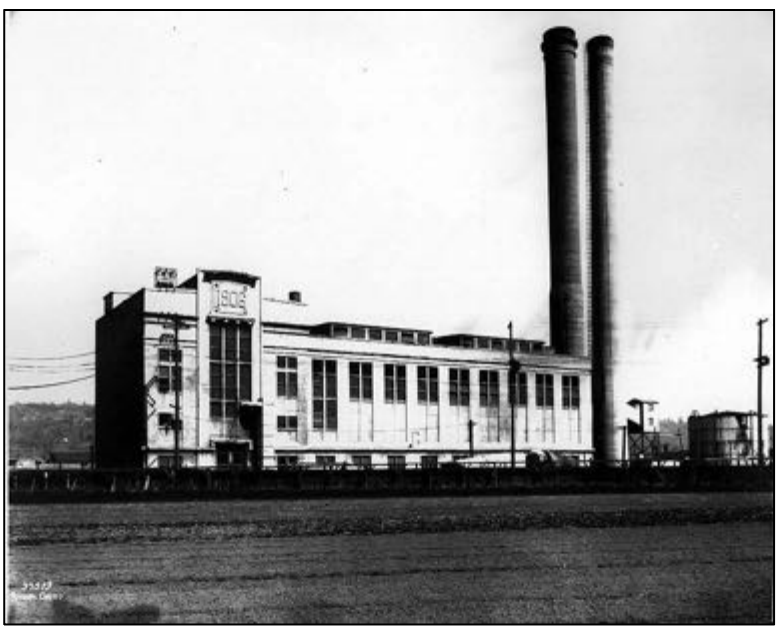


Figure 1: West façade, with two earlier masonry vent stacks, 1920. (University of Washington Libraries Special Collections, A. Curtis 39579)

The Georgetown Steam Plant has been extensively documented in a 1984 National Register of Historic Places Nomination and a 1982 - 1984 Historic American Engineering Record (HAER) report. This report summarizes previously established facts—beginning with the plant's establishment in 1906 and including the history of the site and building, as well as describing how the building fits into the regional development of power generation—and supplements them with further information and more recent data.

The HSR component presents in narrative form the history and significance of the property, identifying significant architectural spaces, elements, and features, which will allow for the protection and preservation of remaining historic fabric and provide standards for new construction, rehabilitation, and/or preservation. A current condition assessment of the building is also included, which provides a comprehensive survey of the exterior building conditions, including the roof, windows, structural integrity, and the presence of hazardous materials on the exterior surfaces. The

CLR component describes changes to the site and surrounding properties over time and provides recommendations for landscape and site improvements.

Seattle City Light has a large amount of archival information on the Georgetown Steam Plant, including original and later drawings, photographs, and previous reports, and the Seattle Municipal Archives has historic photographs as well as documents recording transactions, equipment, property, etc. related to the building site and associated structures. All of these items were helpful in ascertaining the developmental history. Drawing files contain documents outlining the design intent for the original construction of the Steam Plant (1906), the east addition (1918), removal of the stacks (1938), building repair (1968-69), and exterior rehabilitation (1985). The building appears to have been constructed as originally designed, with a few minor exceptions.

Fieldwork and research was carried out in June and July 2012. Although the building has not been used for power generation since 1953, and has not been operated since 1974, it is reasonably accessible for review. A lift with limited access on the north and west façades was used for examination of exterior walls and windows. Testing and sampling of select building materials was undertaken to assess the presence of hazardous materials and to determine building construction materials installed during previous scopes of work. The complete specialty conditions reports are included in an appendix to this report.

Historic Structure Report Methodology

A Historic Structure Report is intended as a written and illustrated working resource document that includes historical and architectural evaluations of a building, site, or structure that is listed in, or eligible for listing in, the National Register of Historic Places. The report methodology was developed by the National Park Service (NPS) in the 1970s to assist in its management of historic and pre-historic resources. It has since been used by public and private property owners as a comprehensive tool to address planning for and protection of significant historic and pre-historic properties.

An HSR is usually prepared prior to planning alterations, additions, rehabilitations, or restorations, and it is used to guide contemporary modifications. The document is generally required when performing work on federally-owned or funded landmark properties, and especially on those buildings or structures that have historic significance and/or community value.

As outlined in NPS Preservation Brief #43, *The Preparation and Use of Historic Structure Reports*, a typical report must include three elements—administrative data, history and building analyses, and supporting documentation.

This document is divided into six sections. The first is the introduction, which includes a summary of project data such as location, ownership, and landmark status of property and the methodology and project participants.

The second section describes the developmental history of the property and structure, and includes historical background and context statement, narrative and graphic description of the chronology of development and use, and a brief description of existing conditions.

The third section makes recommendations for general and specific scopes of work related to preservation, rehabilitation, restoration, or reconstruction of missing elements. It also includes general guidelines for the work such as code requirements and fire and life-safety upgrades, as well as suggestions for documentation, salvage, interpretation, and use and functional improvements. The fourth section describes the building's current exterior and structural conditions and specific recommended treatments. The intent of these two sections is to provide guidelines to protect and maintain historic material and character, where possible, and to provide for modifications and upgrades for continued or compatible new uses.

The bibliography is provided in the fifth section, citing research sources and repositories, documents, and interviews relating to the history of the site and building.

The sixth section consists of the appendices, which include copies of pertinent historic and record drawings, historic photographs, material analysis and engineering reports, and selected guidelines for the maintenance of the remaining historic materials.

Following completion of the work to be performed on the building, a final section—a Completion Report—should be provided. This will serve as a record of the work carried out, providing documentation of new physical evidence discovered during construction, and documenting any changes made to the preservation design during the course of the work. The Completion Report should also include field reports and notes, project correspondence, and construction documents.

Cultural Landscape Report and Methodology

The Cultural Landscape Report component was developed and provided by Karen Kiest Landscape Architects. The objective of the CLR is to support stewardship of the property by following the identified steps to document the history and current conditions, analyze landscape change and continuity, and to determine the preferred approach to preservation treatment. The CLR addresses the required aspects of a cultural landscape report in accordance with federal guidance for cultural landscape preservation, with primary reference to the *Secretary of the Interior's Standards for Historic Preservation with Guidelines for the Treatment of Cultural Landscapes*. A CLR strives to provide a comprehensive study of an historically significant property, creating a basis for a treatment that addresses contemporary needs while preserving cultural heritage.

Part 1 of a CLR researches property history and evolution, documenting existing character of the property and analyzing the integrity of the landscape today. Part 2 of a CLR investigates the application of the four preservation treatments to the property, identifies the most appropriate treatment, and provides recommendations for implementation. Part 3 of a CLR records the treatment undertaken. This Cultural Landscape Report encompasses Part 1 and provides a brief discussion of Part 2.

The research effort for the CLR involved the review of extensive available documentation provided by Seattle City Light from the agency archives and files; additional historic materials provided by the prime consultant; and review of available online archives, including Seattle Municipal Archives, University of Washington Libraries Special Collections and Manuscripts, Museum of History and Industry, and HistoryLink.org; as well as contact with persons associated with the property. Materials including published and unpublished text, historic photographs, historic aerial photographs, plans and surveys were reviewed to provide evidence of property character and physical conditions. Field survey work was undertaken in June 2012 to provide documentation of current site and landscape conditions.

Building Data

Historic Names:	Georgetown Power Station; Georgetown Steam Plant
Current Name:	Georgetown Steam Plant; Georgetown Power Plant Museum
Historic Uses:	Substation and Generating Station
Present Use:	Museum
Historic Register Status:	National Historic Landmark—Seattle Electric Company Georgetown Steam Plant (July 5, 1984); National Register—Seattle Electric Company Georgetown Steam Plant (August 1, 1978); City of Seattle Landmark (designation approved July 15, 1981; designating ordinance passed September 10, 1984)
Address:	6605 13th Avenue South (aka 1300 Greeley Street) Seattle, WA 98108
Location:	Approximately 5 miles south of downtown Seattle, on the east side of the Georgetown neighborhood and immediately northwest of Boeing Field/King County International Airport
King County Tax Parcel No.:	7006700570
Site Area:	317,500 sf / 7.29 acres (per King County Parcel Viewer, includes the flume property)
No. of Stories:	Two (2) + Five (5) in the North Gallery section
Building Area:	Basement / Ash Level Floor: 18,750 SF Engine Room Floor & Boiler Level Floor: 14,591 SF Roof: 19,746 SF
Construction:	
Structure:	Reinforced Concrete Foundation supported on driven piles
Walls:	Reinforced Concrete; Hollow Clay Tile
Roof:	Reinforced Concrete; Corrugated Sheet Metal
Siding:	Corrugated Sheet Metal
Windows:	Wood; Steel
Doors:	Wood; Metal-Clad
Chimneys:	Sheet Metal
Interior Walls:	Reinforced Concrete
Interior Ceilings:	Reinforced Concrete
Interior Floors:	Reinforced Concrete

Project Data

Owner:	Seattle City Light 700 5th Avenue, Suite 3200 PO Box 34023 Seattle, WA 98124-4023

Survey Date: June and July 2012

Proposed Treatment: Reroofing and Exterior Envelope Rehabilitation

Zoning: City of Seattle

Building Code: Seattle Building Code (SBC) 2009

Participants:

Seattle City Light: Ruth Meraz, Project Manager; Rebecca Ossa, Historic Resource Specialist; Blaine Olyano, Shops and Mobile Equipment Manager

BOLA Architecture + Planning: Rhoda Lawrence, Principal; Susan Boyle, Principal; Sonja Molchany, Preservation Planner; Matt Hamel, Project Architect; Abby Inpanbutr, Intern Architect

Karen Kiest | Landscape Architects: Karen Kiest, Principal

KPFF Consulting Engineers: Gregory L. Varney, Principal; John M. Hochwalt, Associate; Scott Neuman, Associate

Wetherholt and Associates, Inc.: Don Davis, Senior Field Engineer; Jose Laurean, Field Inspector

Argus Pacific, Hazardous Materials Training & Consulting: Scott R. Parker, Principal; Conor Foley, Field Inspector

WR Consulting, Inc.: John Rundall, Principal

Coffman Engineers: Jay Jack, Senior Electrical Engineer; Scott Leinenwever, Mechanical Engineer

Brian Allen Photo: Brian Allen

Acknowledgments

Many people contributed to this Historic Structure Report, both directly and indirectly. The survey team is grateful for the assistance provided by:

Seattle City Light

Seattle Municipal Archives

University of Washington Libraries Special Collections

Lily Tellefson, Director Georgetown Power Plant Museum

2. DEVELOPMENTAL HISTORY

Urban Electrification in Seattle[1]

Horse-drawn trolleys and gas lighting characterized Seattle into the mid-1880s, but things quickly changed as electricity came into use. In 1886, the Seattle Electric Light Company acquired a permit for street lighting, and several years later Seattle became the fourth city in the world to establish an electric street railway system. In 1887, a prototype electric streetcar had been introduced in Richmond, Virginia, and "electric traction" was soon a primary market for new electric utilities.

By 1892, two early local firms had merged to become the Union Electric Company, which became a principal one of many electric generating and distribution companies vying for a share of the market in Seattle. Numerous small operators established localized steam plants in downtown building basements, and the field was characterized by mergers and reorganizations.

Union Electric was acquired in 1899 by the Boston-based engineering company Stone & Webster, which was quickly on the rise as a national power corporation. By the following year, Stone & Webster, in conjunction with prominent Seattle resident Jacob Furth, had consolidated operations of virtually all the existing lighting, traction, and related subsidiary businesses in Seattle—nearly 20 locally-based utility companies—under the aegis of the Seattle Electric Company.

The Seattle Electric Company was able to obtain a franchise from the City for the street railway system, gaining the firm exclusive operation of the system. Despite opposition from parties concerned about private utility ownership and Seattle Electric Company's monopoly, the consolidated system was improved and extended under the new management.

Meanwhile, populist sentiment and support for a municipal utility system was growing. In 1902, Seattle residents approved a $590,000 bond issue to develop a hydroelectric facility on the Cedar River, inaugurating public power in Seattle. The Cedar River plant, located 30 miles southeast of Seattle, first generated power in 1905 and was the first municipally-owned hydroelectric project in the country. The City's distribution station was located downtown at Yesler Way and Seventh Avenue. Initially the Cedar River project was under the control of the City Water Department, but as a result of good performance and high demand for power, a separate lighting department was created on April 1, 1910.

Hydroelectric power produces electricity from the energy of falling water. Its superiority over steam power production became apparent in its greater efficiency, resulting in lower rates for consumers. Prior to the construction of the Cedar River plant, engineer Charles Baker had begun construction on his Snoqualmie Falls Hydroelectric Project in April 1898. In 1904, Stone & Webster followed suit, creating the Puget Sound Power Company to establish a major hydroelectric plant at Electron, on the Puyallup River.

Although hydroelectric facilities by 1905 provided the power to meet most of Seattle's needs, steam plants still had a role. Constructed as auxiliary power sources to provide back-up power and to meet peak load capacity, steam plants were a key element in a system that could offer uninterrupted electrical power. As electricity became an aspect of daily life, customers became intolerant of power failures. The Seattle Electric Company recognized the importance of establishing a steam plant to manage peak load, developing the Georgetown Steam Plant in 1906.

[1] Expanded context statements including more detailed history of the development of electrical power can be found in both the HAER and the National Register Nomination. A briefer history is included in this HSR to provide the general context for the subject building.

Stone & Webster again consolidated in 1912, merging their Seattle Electric Company with the Seattle-Tacoma Power Company (Snoqualmie Falls), the Pacific Coast Power Company, the Puget Sound Power Company, and the Whatcom County Railway and Light Company. The new corporation—called Puget Sound Traction, Light and Power—consisted of four major hydroelectric plants in addition to four steam plants in Seattle and Tacoma, establishing regional electrical service. This resulted in better dependability and lower rates for customers, and the company continued to acquire small utilities in the region. In 1919, Puget Sound Traction, Light and Power sold the electric streetcar system to the City of Seattle, dropping the "traction" and becoming Puget Sound Power and Light. In 1934, the Stone & Webster "cartel" was broken up by the federal government, and Puget Sound Power and Light was reorganized under a local board of directors. In Seattle, private and municipal electric utilities continued to compete until Seattle City Light acquired Puget Sound Power and Light's Seattle-area properties in 1951, after voters approved municipal acquisition of private power assets within city limits, unifying service under Seattle City Light.

Stone & Webster

Charles A. Stone and Edwin S. Webster, two electrical engineering graduates from the Massachusetts Institute of Technology, started a firm together in 1889 after finishing school. The Massachusetts Electrical Engineering Company, as they initially called it, undertook equipment testing and feasibility studies in Boston. A year after opening, they had their first significant contract—to design and install a direct current hydroelectric generating plant in Maine.

By the early 1900s, the Stone & Webster firm was a power plant specialist, involved in engineering, building, and managing power plants. The firm had also gained recognition for its ability to build and operate integrated systems, and interests extended to lighting systems and electric street railway systems. Due to its heavy project load, in 1906 Stone & Webster formed a subsidiary, the Stone & Webster Engineering Corporation. This arm managed all engineering, construction, and purchasing activities, including construction of the Georgetown Steam Plant.

Stone & Webster developed projects across the country, and as of 1910, 14% of the nation's total electrical generating capacity had been designed, engineered, and built by the firm. In addition to the Georgetown Steam Plant, Stone & Webster served as the general managers and constructing engineers of numerous utility companies throughout the country including the Pacific Coast Power Company, the Seattle Electric Company, the Puget Sound Electric Railway, Whatcom County Railway and Light Company, the Galveston-Houston Electric Company, Savannah Electric Company, Tampa Electric Company, the Minneapolis General Electric Company, and Cape Breton Electric Company Limited, to cite a few. The company continued to grow during the 1920s and remained active through the 1930s.

Heavily involved in wartime projects in the 1940s, Stone and Webster remained involved in power generation after the war and did much work with nuclear power generation. The firm continued work in power generation and petrochemical plant construction into the 1990s, adding environmental services as well. Stone & Webster was acquired by the Shaw Group in 2000 and remains a subsidiary working on construction and engineering projects, hazardous waste management, and environmental services.

Frank B. Gilbreth and Construction of the Building

Seattle Electric Company's Board of Directors voted to approve the construction of a Georgetown plant on August 26, 1906. The company had streetcar barns in Georgetown, and the location was along the transmission line of the Electron hydroelectric station. The earliest original drawings for the project date

Figure 2: Frank and Lillian Gilbreth, 1931. (Purdue School of Industrial Engineering, Gilbreth Library)

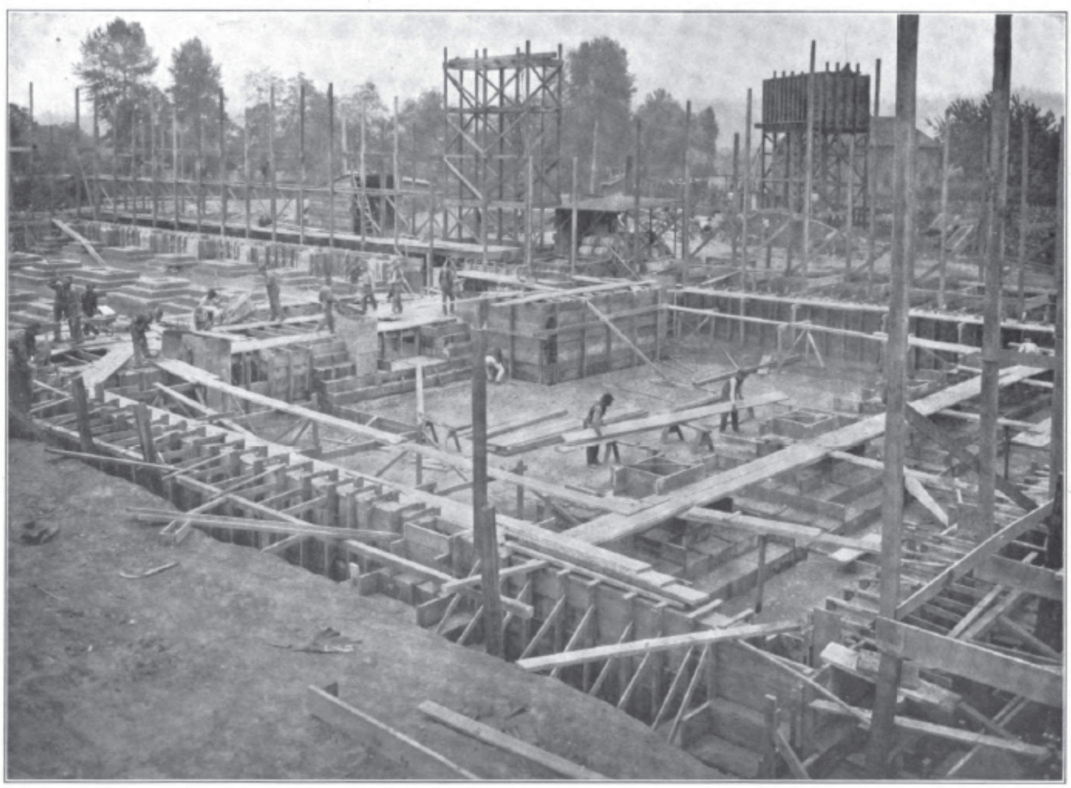
from March 1906. The Stone & Webster Construction Company had purview over design and construction services, and Frank B. Gilbreth was hired to design and erect the building. Frank Bunker Gilbreth, Sr. (1868–1924) was born in Fairfield, Maine, and went to school in Boston. There he began as a bricklayer and became a self-taught mechanical engineer and contractor. With only a high school education, Frank Gilbreth started as a bricklaying apprentice at age 17, becoming a bricklayer and then a contractor. In 1899 he received a patent for a portable gravity concrete mixer, which was a great financial success for him. Gilbreth married Lillian Moller in 1904, and together they formed a professional partnership in science and engineering, collaborating on the development of motion study as engineering and management technique. The Gilbreths became renowned for their work in the field of scientific management as well as time and motion study, fatigue study, work simplification, and ergonomics. They focused on streamlining the actions of the worker for efficiency, emphasizing also the worker's physical comfort and satisfaction, and thus overall job performance. In addition, the pair did pioneering work with disabled veterans and vocational rehabilitation.

In his work as a contractor, Gilbreth devised a system of running projects that increased efficiency, identified and encouraged best practices, and rewarded ingenuity and accomplishment. Gilbreth had clearly established company rules about how to run a job, and also developed specific systems for different types of construction.

In his 1908 publication *Concrete System*, Gilbreth used the Georgetown Steam Plant as one of several illustrated examples of reinforced concrete construction. He noted that the building was originally to be constructed of steel and brick, but the San Francisco earthquake (on April 18, 1906) was the impetus for the decision to use reinforced concrete instead. This change in plans caused some delay, but Gilbreth made use of the time nonetheless. He described the beginning of the project as follows:

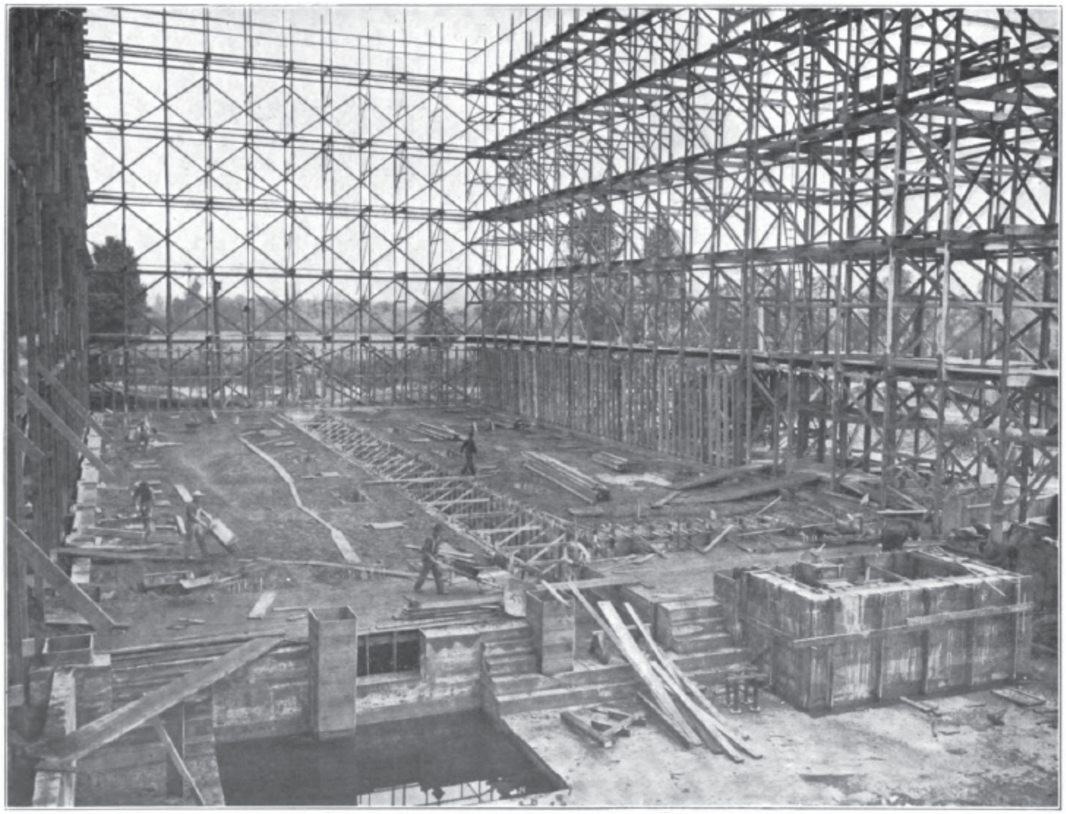
> The cellar was dug with drag scrapers until it was excavated down nearly to the water level. The balance of the excavation was done by centrifugal pumps, and the pumping of the sand and water was done simultaneously. As soon as part of the excavation was completed, two pile drivers were started to working simultaneously. One half of the pile driving was allotted to each machine, and a series of athletic contests was begun. Meanwhile a gravel unloader was erected for unloading scows…While waiting [for drawings to be changed and steel reinforcement rods to be ordered from Pittsburgh] we finished the piling and foundations, installed a water supply, constructed the cofferdams, built intake and condenser tunnels into the river, and completed the staging to the top of the building. Holes were left in the foundation piers to receive column reinforcement. (p. 131)

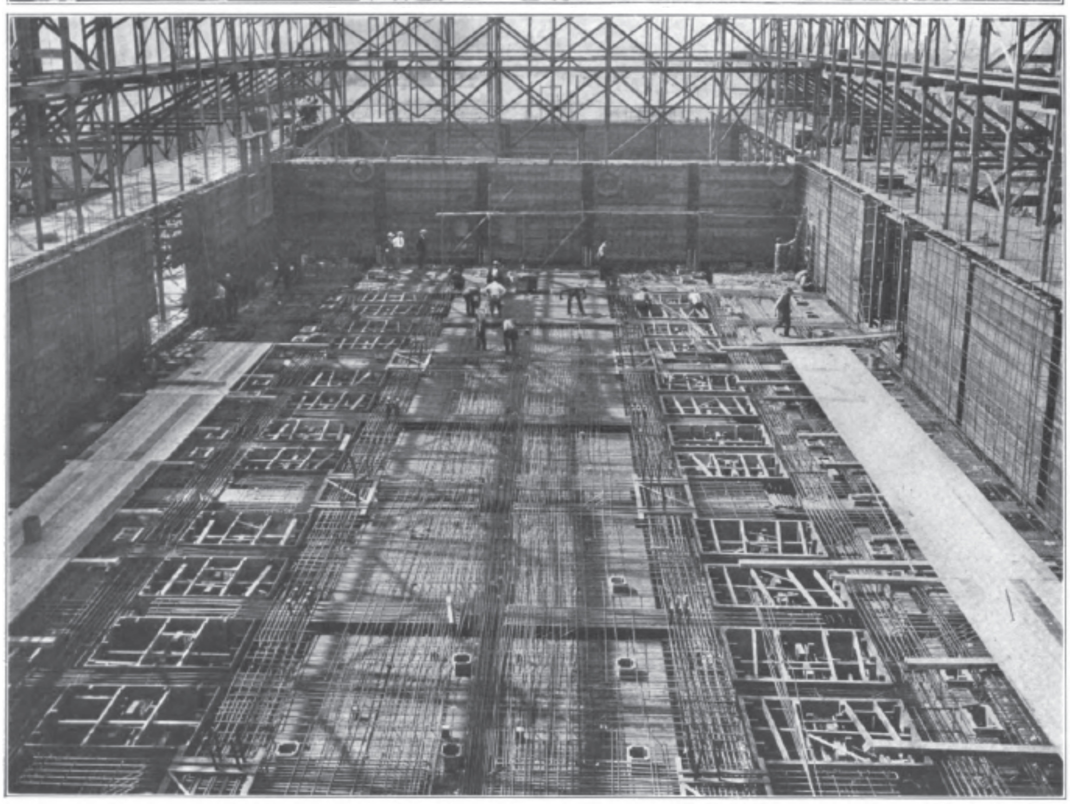
Construction photographs in the same publication (on the following pages) date from May 18, 1906, to November 10, 1906, at which time the concrete work was complete. Equipment had not yet been installed, but it does appear that at least some windows were in place by that date. The first vertical generator was installed by the end of 1906, and by March 1907 a second was ordered. The completion date of the plant with its two generators was January 1908. A third, horizontal, unit was added in 1918 and ready for use by May 1919. While the plant was constructed with the capacity to burn both coal and oil, it began as an oil-fired plant and was converted to coal-fired in 1917, when oil was in short supply. A conveyor supplying coal was added, entering the building at the central upper portion of the south façade. In the late 1940s, the boilers were converted back to oil-fired.



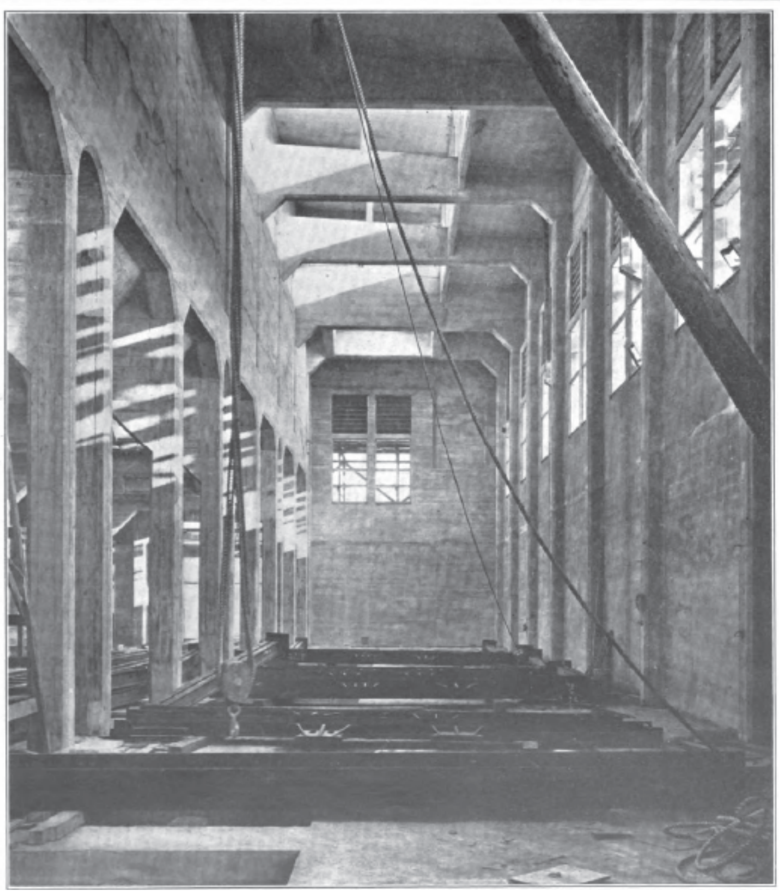
Figures 3 and 4
May 18, 1906
May 30, 1906

(These and the figures on the following pages are from Frank Gilbreth's 1908 publication, Concrete System.)

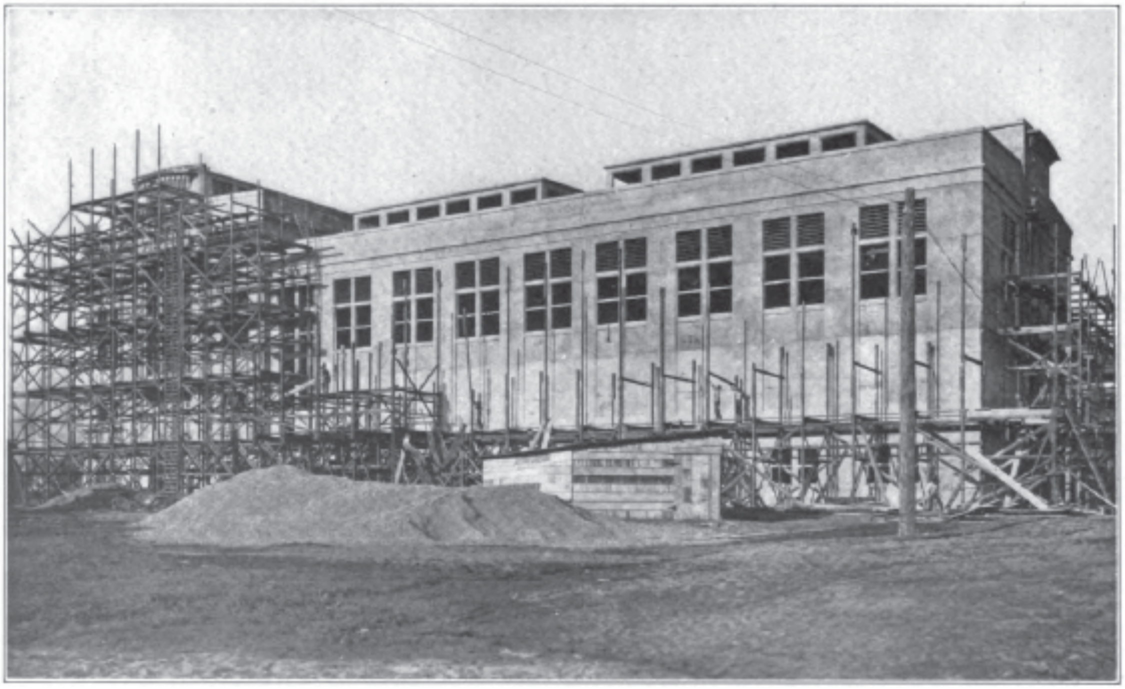


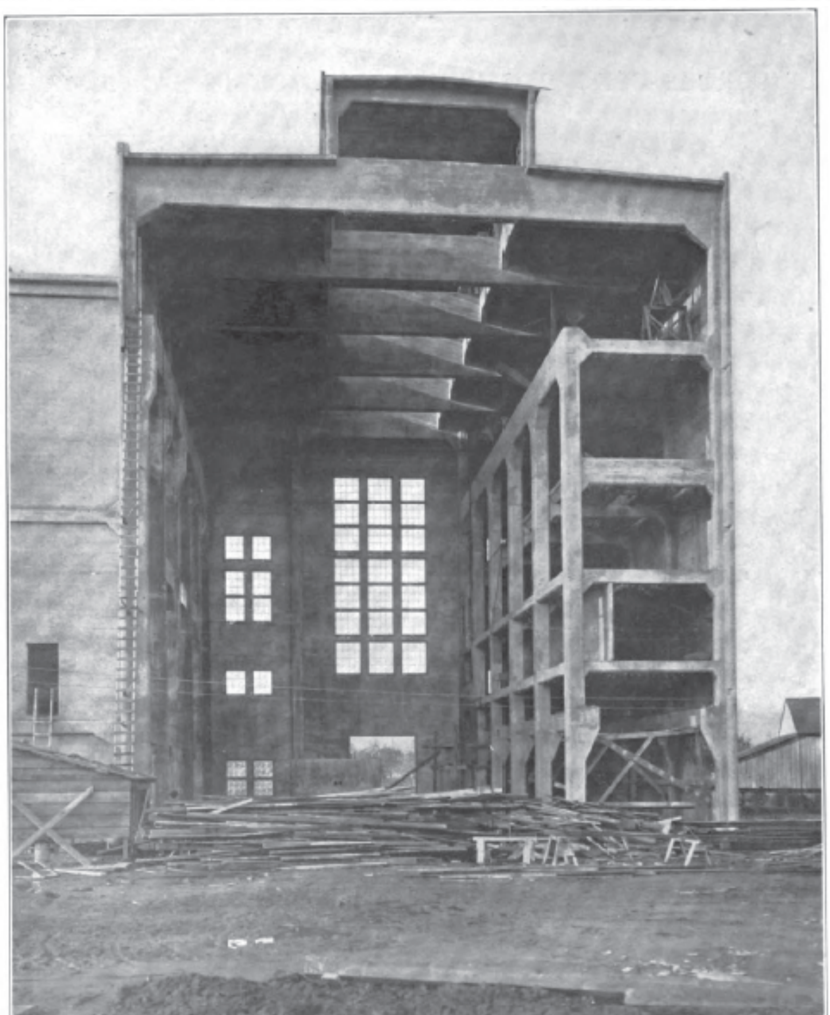


Figures 5 and 6
June 15, 1906
July 25, 1906



Figures 7 and 8
September 24, 1906
September 28, 1906





Figures 9 and 10
October 1, 1906
November 10, 1906

The Georgetown Steam Plant was constructed for use as a peaking facility, operating primarily when demand was the heaviest in the morning and late afternoon to evening. It also ran more when water for the hydroelectric plants was low—in fall and winter. Demand for power increased greatly in the 1920s, and several hydroelectric plants were increased in size to meet the need. When Puget Sound Power & Light constructed the new Shuffleton Steam Plant in Renton in 1930, the Georgetown Steam Plant's role as a backup facility was largely taken over by the new plant. The last production run of the Georgetown Steam Plant was during a major water shortage, from November 1952 to January 1953. Into the 1970s, the plant was maintained as a standby facility, for which Seattle City Light got a credit from the Bonneville Power Authority.

Power House Design

Much as they are today, guiding principles of power house design in the late 19th and early 20th century were largely simplicity, efficiency, and economy. The size and mass of the machinery enclosed in a power house also dictated design elements. "While such a building is essentially an engineering structure, inclosed [sic] by protecting walls, its size and prominence make it imperative that its exterior shall be given an architectural character suited to its dimensions and purpose. The design of the building is developed in a plain substantial manner expressive of power."[2] In addition to the large volume, power houses also required ample ventilation and natural light, resulting in generous fenestration. The monumentality of structure necessitated by the machinery and crane requirements seem to correspond also with the significance of the engineering achievements within.

Figure 11: White River Power House. This power house was designed by Stone & Webster and constructed by the Pacific Coast Power Company in 1909-1911. (University of Washington Libraries Special Collections, PH Coll 269.995)

A development in construction technology played a major role in shaping the look of power houses in the 20th century. Reinforced concrete came into use in the Seattle area in the first decades of the 20th century, and was first employed for building types that were also new – power houses and fuel storage buildings.[3] (Poured-in-place concrete offered an economy in the construction process, protection from combustibility, and also allowed for some historical detailing.)

A comparison of power houses in Washington State demonstrates consistent qualities among them. Namely, they tend to be of reinforced concrete construction; monumental in scale; symmetrically designed with a clear pattern of repetitive bays; vertically divided into the traditional building elements of base, shaft, and capital or crown; and have very large, operable windows.

[2] *NYT*, January 15, 1899.
[3] Boyle and Deines, p. 103.

Architectural Description

The Georgetown Steam Plant is a reinforced concrete-frame building, distinguished by its monumentality and stripped classicism. It is a T-shaped building, composed of the Engine Room at the north end and the Boiler Room perpendicular to it at the south. The Steam Plant is characterized on the exterior by its concrete massing, tall windows or blind openings in recessed panels between concrete pilasters, rhythm of nine bays along the east and west façades of the Boiler Room, and rhythm of three bays at the west end of the Engine Room and south end of the Boiler Room. The west and south façades are architecturally the primary façades and faced the Duwamish River in its original location, until it was channelized between 1914 and 1920. Classical features on these façades include symmetrical arrangement, a prominent water table above the basement level, a simple frieze band with plain cornice above, and the use of entablature elements in the large medallions—one at the west façade of the Engine Room and the other at the south façade of the Boiler Room. The medallions are lent additional prominence by their location at the ends of the roof monitors, which gives them added height above the basic roofline. Each one has text projecting from the surface in cast concrete: the west medallion reads "1906" and the south reads "No. 1." Rectangular block modillions are located along the bottom edge of each medallion element. The north and east façades are utilitarian, without any embellishment and with limited fenestration.

The Engine Room is the shorter wing, measuring 64' (north-south) by 79' (east-west), with a 36' addition at the east end for an overall dimension of 115' east-west. The Boiler Room measures 153' (north-south) by 76' (east-west). The Georgetown Steam Plant was described in the June 1908 issue of *Engineering Record*, quoted in the 1984 HAER document:

> The station building is a reinforced-concrete structure, 80 x 218 feet in plan, and with a height of 68.25 feet from the ground line to the top of the roof. The reinforced-concrete frame, and the side and end walls of the building, stand on spread footings of concrete carried by piles driven to refusal, 1,800 piles being used to secure a stable foundation for the building and equipment. The side walls of the building are 10 inch reinforced-concrete slabs carried by columns spaced 16 feet apart on centers; the end walls are 6 inches thick and are carried by columns spaced 15 feet 1 inch apart on centers. The roof consists of 5 inch reinforced-concrete slabs carried by beams and girders resting on the wall columns and on rows of columns in the interior of the building.
>
> The building is divided by a transverse 6 inch reinforced-concrete wall into a boiler room and a generator room, the former being 153 feet 10 inches long, and the latter occupying the remainder of the building. A basement, with its floor at the ground level, extends under the entire boiler room. The boilers are on a reinforced-concrete floor over this basement, which floor is carried by reinforced-concrete columns on spread footings on piles.
>
> …The floor of the generator room is carried by 65 foot span reinforced-concrete girders, exiting from the transverse partition wall to the end wall of the building, so this room is entirely free of columns. The switchboard, wiring connections, switches, transformers and electric auxiliaries are at the opposite side of the generator room from the boilers, in a reinforced-concrete gallery having four floors above the generator room floor.[4]

Initially the Engine room was planned to contain one generator, but the Seattle Electric Company made a decision in March 1907 to order and install a second generator. The building design anticipated such expansion, and there was room for the new unit as well as its boilers and auxiliary equipment. The small addition to the east end of the Engine Room was made to accommodate a third unit in 1918. The east

[4] HAER, pp. 10-11

wall of the Engine Room was always designed to allow for easy future expansion. Original drawings note "corrugated iron covering," and today the east façade is sheathed with corrugated steel, which was installed in 1985.

Original architectural drawings provide detailed information about each façade. On the primary west and south façades, the top of the water table is approximately 15' above grade. The shaft of the building is approximately 38'-9" tall, and the "cap" of the frieze and cornice band is approximately 8'-8" tall. The medallion at the Engine Room parapet is approximately 17' tall, while that at the Boiler Room is approximately 15' tall. The roof monitor along the Boiler Room rises 9'-5" above the main roofline.

The west façade of the Engine Room is divided into three bays—a 25'-wide center bay flanked by a 19'-5"-wide bay to each side. The center bay contains a 15'-6"-tall and 12'-wide pair of doors, each leaf glazed with a 12-light fixed window in the upper portion. Between the water table and the cornice line, the central portion of the west Engine Room façade is primarily glazed with an assembly of 4'-9"-wide divided light wood windows with pivot operation. The rows and groups of windows are slightly recessed in the wall plane, giving the effect of a concrete grid around them. The lowest row consists of three blind openings. Above that, the next row of three 16-light windows is 5'-11" tall. Above that are three 13'-8"-tall sets of three vertically stacked 12-light windows. Another 13'-8"-tall set is above the first. At each side bay, a slightly recessed panel 8'-4" wide contains four pairs of 9-light wood windows with pivot operation.

The west façade of the Boiler Room is composed of nine bays, 16'-6" on center. Each bay contains a slightly recessed panel, 10'-8" wide by 32'-3" tall. These are divided down the center by a 13 ½" concrete vertical member. At all but the northernmost bay, the lower 17'-1" of the recess consists of a blind opening. Above this is a 9'-2" tall pair of window openings, each containing two vertically stacked 12-light pivot windows. At the top of the recess in each bay is a pair of 6'-tall metal louvers. The northernmost bay contains additional stacked 16' light windows where the other bays have blind openings. Basement window openings are 8'-4" wide by 6'-7" tall and each contains a pair of two vertically stacked 6-light pivot windows.

The south façade of the boiler room is divided into three bays and has similar architectural detailing. A 12'-tall pair of doors with 12-light glazed upper portion is centrally located at the basement level, which is at grade. Above the water table is another pair of 12'-tall doors. Above the doors is a 9'-2"-tall row of three window openings, each containing two vertically stacked 12-light wood pivot windows. Above the windows is a 5'-tall row of three square blind openings. Original drawings indicate a row of 7'-7" tall metal louvers above, but these have been removed. The side bays each have a recess with a lower blind opening, central stacked windows, and upper louver (now removed), very similar to the bays on the west façade. Near the outer edge of the end bays, drawings note a 7'-6"-wide by 15'-tall arched opening that was left for a flue and "filled temporarily with a 2" cement plaster on metal mesh flush with the outside." This feature is visible as a rougher texture than the surrounding poured concrete exterior. At the basement level each side bay has a pair of wood doors with 9-light glazing in the upper portion.

The north and east façades are entirely utilitarian in comparison to the west and south façades. Original drawings show the north façade consists of five bays on 15'-1" centers. The vertical concrete frame members are visible and there is no fenestration on this façade. The east façade of the Engine Room was always designed to allow future expansion, and original drawings show it with corrugated iron cladding and limited fenestration. The east façade of the Boiler Room consists of nine bays and, like the north façade, lacks fenestration and clearly exhibits the concrete frame.

The 1918 Engine Room addition originally re-used the corrugated iron, door, and sash from the east façade. On the north side, the addition had hollow clay tile walls between the concrete columns, stuccoed on the exterior. Three industrial steel sash window assemblies were inserted on this façade. At the shorter portion of the addition, on the south side of the Engine Room, new galvanized corrugated iron was used for cladding and two 3' by 7' wood doors with glazed upper portions were installed at the east façade.

In 1936, Puget Sound Power & Light solicited bids for removal of the two large chimney stacks and installation of induced draft fans at the Georgetown Steam Plant. The impetus for this change was primarily the proximity of Boeing Field/King County International Airport, for which the stacks consistently presented a flight hazard. The work was carried out in 1938, and the eight draft fans are visible as vertical projections from the Boiler Room roof.

Building Equipment / Power-Generating Components

The building equipment and power generation / transmission components are thoroughly described in the HAER and are not included in this report

Chronology of Changes to the Building

The chronology below was developed through review of available historic photographs, written documentation, and historic construction documents. A few of the dates could not be verified exactly, but the list serves as a comprehensive inventory of significant architectural changes and documented repairs to the building.

1906	Original Construction with steel chimney stack (125')
1907	Construction of first masonry chimney stack (268')
1907	Addition of second vertical turbogenerator
1917	Boiler fuel source changed from oil to coal; addition of coal conveyor on south end of Boiler Room.
1917	Duwamish River route altered; new pumphouse built on the bank of the waterway; old connections for boiler and condenser water were replaced with a wood-stave pipe for intake condenser water and an open wood-lined trench for exhaust water
1918	Addition to Engine Room for third (horizontal) turbogenerator; addition of two additional boilers; construction of second masonry chimney stack (225') off the south end of Boiler Room; addition of penthouse access to roof from Engine Room
Pre-1920	Installation of rooftop electrical equipment at NW corner of Engine Room main roof
1916-1920	Removal of 125' steel stack at southwest corner of Boiler Room
1920-1938	Selective replacement of select monitor windows with door/fan vented window sets
1938-1950	Select replacement of wood, center-pivot monitor windows with paired casements
1937-1950	Installation of transformer support structure mid-wall on west elevation
1937-1954	Installation of transformer equipment on north elevation
1937-1972	Installation of fire escape on west side of Engine Room
1938	Removal of masonry chimney stacks and replacement with (8) rooftop induced draft fan stacks; masonry infill at arched flue openings in south wall of Boiler Room
Pre-1950	Construction of small shed roof over piping at south end of west wall of Boiler Room
Pre-1950	Addition of roof railings
Pre-1950	Addition of air beacon lights
Pre-1950	External scupper box and downspout on east facade of Boiler Room (only one, mid-wall)
Ca. 1940	Removal of coal conveyor on south end of Boiler Room
1953	Installation of Air Raid Siren

1969 Exterior building and roofing repair
- Installation of corrugated fiberglass panels and wood-framed sub structure over most monitor walls and windows
- Covering of select window openings with flat fiberglass panels
- Installation of plywood panels over single-raised panel monitor doors
- Coating of the building with vinyl /plastic paint
- Removal of select abandoned metal attachments

1950-1970 Removal of transformer support structure

Pre-1972 Removal of rooftop electrical equipment at NW corner of Engine Room main roof

1983 Roofing repairs
- Replacement of low-pitch roofing system and addition of cant strips, flashings and counter flashings
- Infill of original integral gutters and replacement of roof drains
- Installation of eave gutters and external downspouts on monitor roofs and east side of main Boiler Room roof
- Replacement of stack cover at southwest corner of Boiler Room
- Replacement of roof ladders
- Addition of air raid siren supports at east end of Engine Room monitor roof

1985 Exterior building renovation
- Repair of concrete spalls and cracks;
- Glass replacement with wire glass at Ground Floor, in-kind glass replacement at upper windows
- Window sash repairs
- Removal of fiberglass panels from window openings
- Replacement of corrugated metal siding and shed roofing on east and south side of 1918 Addition
- Infill /restoration of cast concrete opening at "No. 1" on south end of Boiler Room
- Repair and of wood doors and frames at south and west facades
- Installation of metal flashing at monitor door thresholds and vented window sills
- Installation of interior metal cover plates over louvers
- Replacement and repair of wood framing at east and south walls of 1918 addition
- Replacement of two steel sash windows in 1918 Addition (one each at north and east walls)
- Removal of select abandoned attachments including bolts, conduit, insulators, and miscellaneous metal
- Coating with vinyl paint

After 1985 Removal of small shed roof over piping at south end of west wall of Boiler Room

After 1985 Removal of duct hood over air intake shed on east end of 1918 Addition

Unknown Removal of air raid siren on east end of Engine Room monitor roof

2009 Removal of flume

Early Site and Landscape History

The National Register nomination identifies the period of significance for the Georgetown Steam Plant as the years 1906-08, when the plant construction was completed, and 1917, when a third turbine generator was installed and the plant was expanded to the east. This time period roughly coincides with the decade when the Steam Plant played a primary role as a "peaking" facility, before new hydropower sources were available. 1917 also marks the year the straightening of the Duwamish was completed, and the building was marooned ½ mile from the nearest available water source for plant operations.

The primary period of significance for the plant corresponds to the initial plant construction and start up, as well as to this relationship of the steam plant to the Duwamish waterfront site, and the Seattle Electric Company's rail lines and the growing Georgetown community on the north bank of the Duwamish (as clarified in several maps and plans). Available documentation for the property in this decade of site development is restricted to plans and maps for the property and as well as maps for the immediate area and region. Photographs with the plant in the distance, as well as news reporting of area events and activities, provide additional context. See Figures 12-19, describing the original relationships between plant, rail, river, and city.

<u>Electric Car and Interurban Rail</u>

In 1906-1907, when the Georgetown Steam Plant was constructed, the electric car and the interurban rail were at peak service. The Seattle Electric Company operated 155 miles of track and provided service to 246,000 people. By 1912, the profitability had declined, and Stone & Webster deferred maintenance, reviving local sympathy for municipal ownership. In 1919, the City purchased the entire system from Stone & Webster. With no additional investment over the next 20 years, the Seattle Municipal Street Railway system seriously declined and ceased operations in 1941.

<u>Plant Role and Operations</u>

The Georgetown Steam Plant was used as a 'peaking' facility, operating between 6 o'clock and 10 o'clock in the morning and 5 o'clock to 8 o'clock in the afternoon and evening when power demand was greatest, and in fall and winter, when hydroelectric power generation was lower. The 1912 consolidation of several power companies led the Georgetown Plant to be used only as an emergency backup; by the 1930s the plant's role as standby facility was taken over by the newer Renton Shuffleton facility. Owned by the City of Seattle Department of Lighting (Seattle City Light) since 1951, the plant was occasionally operated through the 1950s when low water restricted hydropower output, and was last run was in the winter of 1964. The plant was occasionally tested and operated from 1971 until 1977 when it was officially retired.

The Georgetown Steam Plant was designed to burn either coal or oil. Oil was stored in a 150,000-gallon steel tank immediately east and pumped into the plant. A coal delivery system was constructed in 1917 and the Georgetown Steam Plant then switched from oil to coal. Coal was delivered to the site via the Seattle Electric Company's street railways from the east. A conveyor belt at the rear (southeast) corner of the plant delivered the coal to the top floor. Ash exited the base of the plant and was removed via the rail tracks. The plant switched back to oil in the late 1940s.

<u>Site Context</u>

In the decades following, only gradual changes have altered the immediate setting. Like the interior, the site has been generally fixed in time, with few alterations or improvements since the period of significance.

However, the broader physical context of the plant has been radically altered, up to the present decade. The history of the Georgetown Steam Plant site and landscape is defined by the dramatic changes in the larger physical context of the facility relative to the channelization of the Duwamish River, and the early development of Georgetown.

<u>Duwamish</u>

The story of the site is first the story of the Duwamish River. The river created a series of meanders or bends in the general vicinity of the Steam Plant. With the Georgetown Steam Plant situated along the north bank of the Duwamish, the river was used for transporting construction materials and provided a direct source for water for cooling condensers and for discharging wastewater.

The building was oriented directly towards the Duwamish, and the originally river-facing south and west façades are the detailed façades. The earliest images of the site are from this aspect, looking upriver, with the west and south façades clearly visible. Straightening of the Duwamish was first proposed in 1906; dredging began in 1913 and was completed by 1917. The primary vista of the structure has been significantly altered since construction, when the principal view of the structure was heading upstream along the Duwamish River.

The realignment of the river ended a primary waterway for the plant and necessitated the extension of a flume to provide water for cooling for the now landlocked plant. By 1917 a pump house was built northwest of the end of the old riverbed, named Slip 4, to supply feed water to the steam plant boilers. The flume was constructed to carry the cooling water back to the waterway. While detailed discussion of the flume is not included here (it has been documented in several previous reports), this was the last property purchased for the Georgetown Steam Plant. Since 1952, Boeing has leased portions of the property.

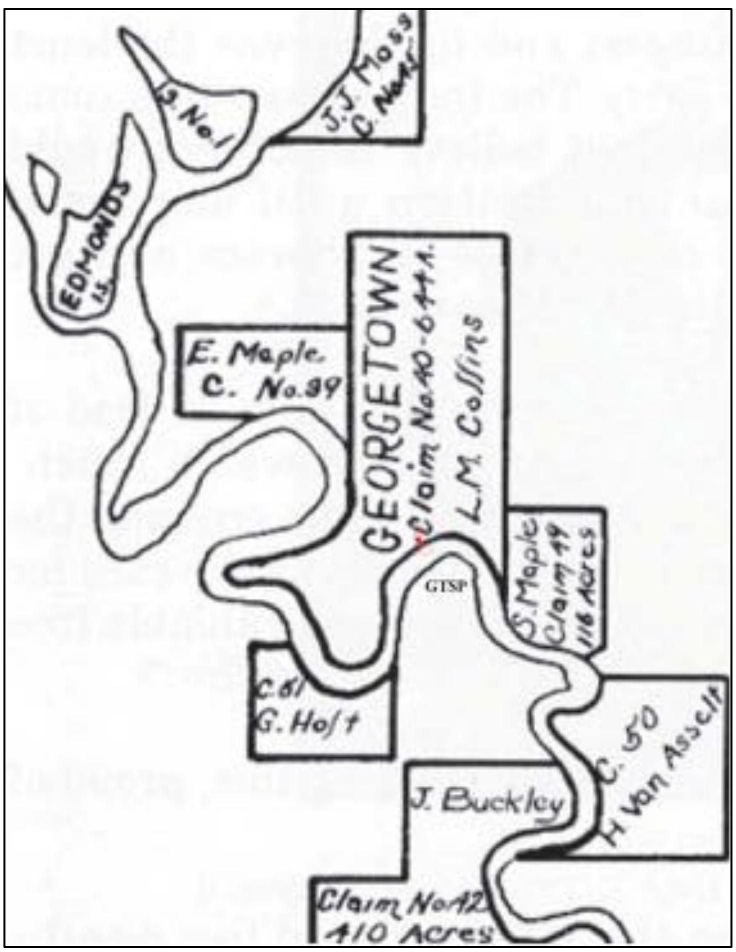


Figure 12: Early Seattle claim map, including he then-winding Duwamish River, 1850s (from HistoryLink essay 9291)

<u>Georgetown</u>

Named Georgetown after developer Julius Horton's son, the town was situated on the oldest settlement property in Puget Sound, the L.M. Collins homestead, established in 1851, one week ahead of the Denny Party's landing at Alki Point in what is now West Seattle (Figure 12). Georgetown was incorporated as a city in 1904, and voted for annexation to Seattle in 1910.

Purchase of the property and construction of the steam plant occurred in 1906. Several factors supported selection and development at the Georgetown location: Georgetown property was readily available, the site was located on the route of the transmission line from Stone & Webster's hydroelectric facility at Electron, and the company's electric car barns and maintenance facilities were located nearby. The growing industrial town also included an available work force. The 1901 census lists Seattle Electric Car Company employees located where the company car barns and interurban station were located. Larger car barns employing 200 men were built in 1906 in conjunction with the construction of the Steam Plant.

The town grew south and west to the river. Along the margins, the rich river bottomland, easy river and later rail access supported the development of truck farms. When the river was rerouted, immigrants of Italian and Japanese origin farmed the old Collins and Van Asselt claims and reclaimed land, hauled their produce to Seattle, and sold it at the newly opened Pike Place Market.

By 1920, Malmo & Company which sold seeds and nursery stock from its corner store on Seattle's 6th Avenue and Stewart Street, at Westlake, had an established nursery operation in Georgetown on Ellis Avenue immediately west of the Georgetown Steam Plant (Figures 18, 20). The 1923 planting guide invited visitors to take the local interurban train down to Chicago Street, to visit the rhodies at "blossom time," in late May:

> You will find our trees, evergreens and shrubs growing in well-prepared soil in our nursery at Georgetown, or at our large sales yard, a block from our store…We grow all kinds of nursery stock extensively at our Georgetown nursery and invite our customers to inspect the same. When in full bloom, our field of several thousand rhododendrons presents a massive floral display of over 100,000 blossoms in fifteen different shades and colors.[5]

The Georgetown Steam Plant, put into operation at the primary period of development of Georgetown, became tightly knit into the fabric of Georgetown. Sited on the riverbank, the GTSP would remain the southern backdrop for Georgetown, comfortably situated between truck farms, plant nurseries, and streets of homes connecting the Plant to the center of Georgetown to the north.

Historic Site and Landscape

This section provides a description of the Georgetown Steam Plant site and landscape circa 1917. The date corresponds to the building's period of significance and was selected to represent the historic character of the site and landscape after a study of the property's history. By 1908 the initial construction of the plant was complete. However, there are not sufficient sources from that period that would allow a detailed historic plan to be created. As discussed above, the next period of the property's history was primarily a site response to the re-routing of the Duwamish River. By 1917 there were numerous plans and photographs documenting the site conditions. (Figures 13-16.)

An important aspect for considering the duration of the period of significance is the determination of the timing of the final set of changes to the property that contribute to its historical importance and the point at which changes to the property begin to alter initial site features and character. At the Georgetown Steam Plant, the first substantial alterations to site character occur in the 1930s with the expansion of Boeing Field. Therefore, the period of significance for the property extends at least to the late 1930s, and could be considered to extend to 1963, when the eastern portion of the property was sold to King County.

[5] HistoryLink.org, "Puget Sound Gardening with Charles Malmo."

Figure 13: View of NE façade of Plant, showing towers still in construction. Farm near Seattle Electric Power Plant, Georgetown, 1907. (Museum of History and Industry, image no. 1974.5868.233)

Figure 14: View of W façade from E Marginal Way, Rerouting of Duwamish underway, April 24, 1916. (Seattle Municipal Archives image no. 990)

Figure 15: Georgetown Shops and Car-Barns, Portion of plan, 1915. (Seattle Municipal Archives, item no. 1248)

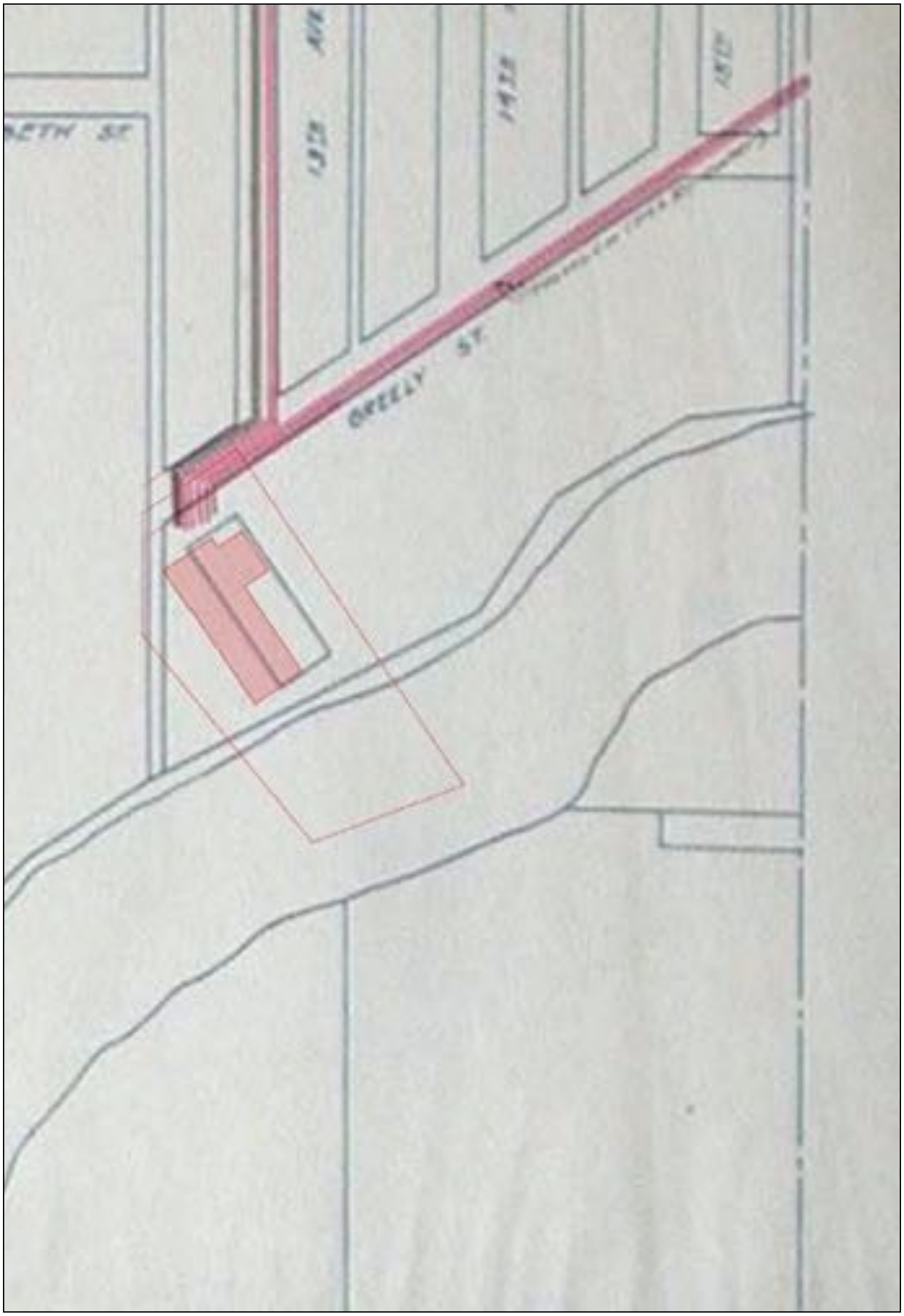


Figure 16: 1916 Municipal Street Map, portion of plan, with street access to the Steam Plant highlighted. (Seattle Municipal Archives, item no. 1208)

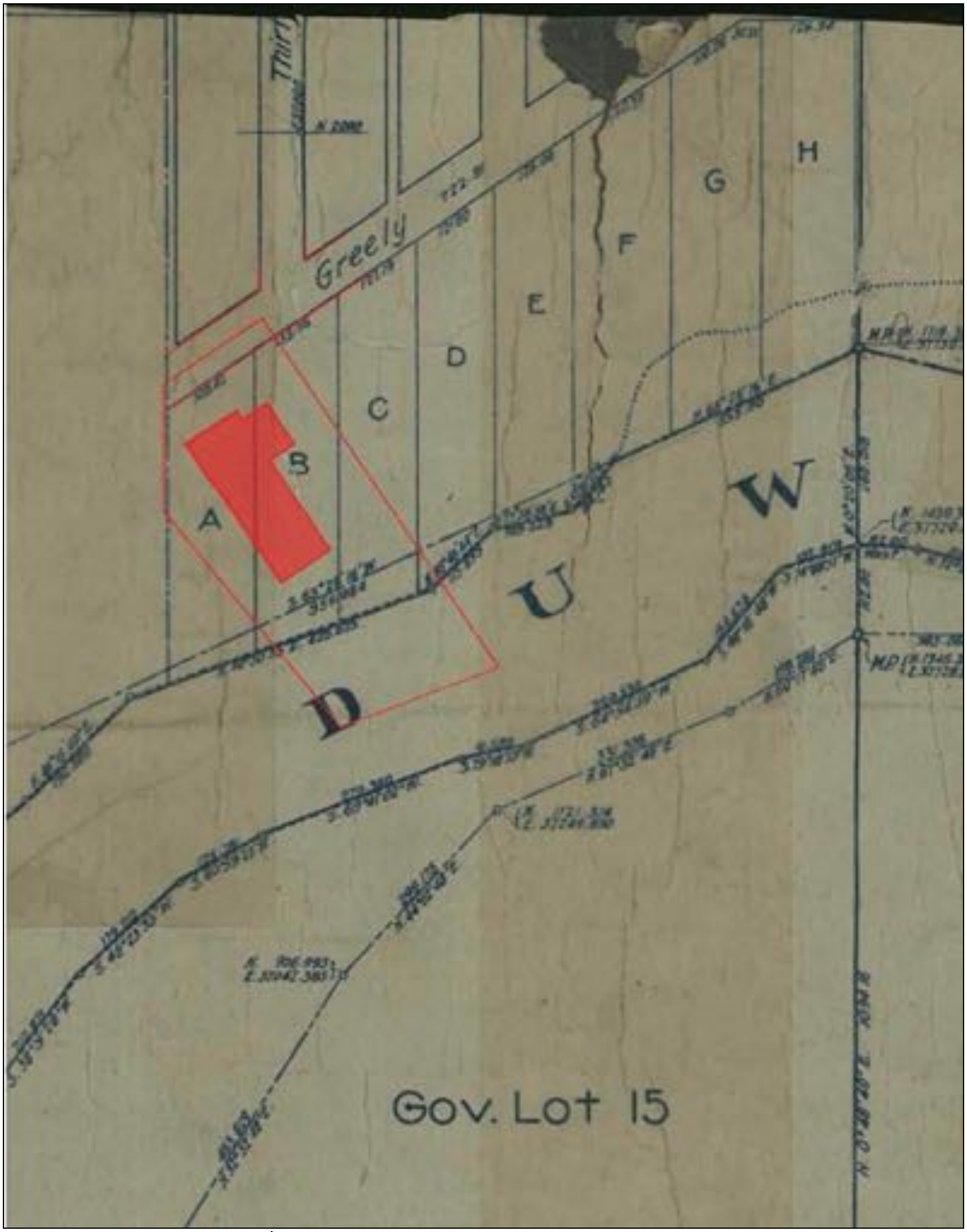


Figure 17: 1917 Duwamish & Land Claims, portion of plan. (Seattle Municipal Archives, item no. 1527)

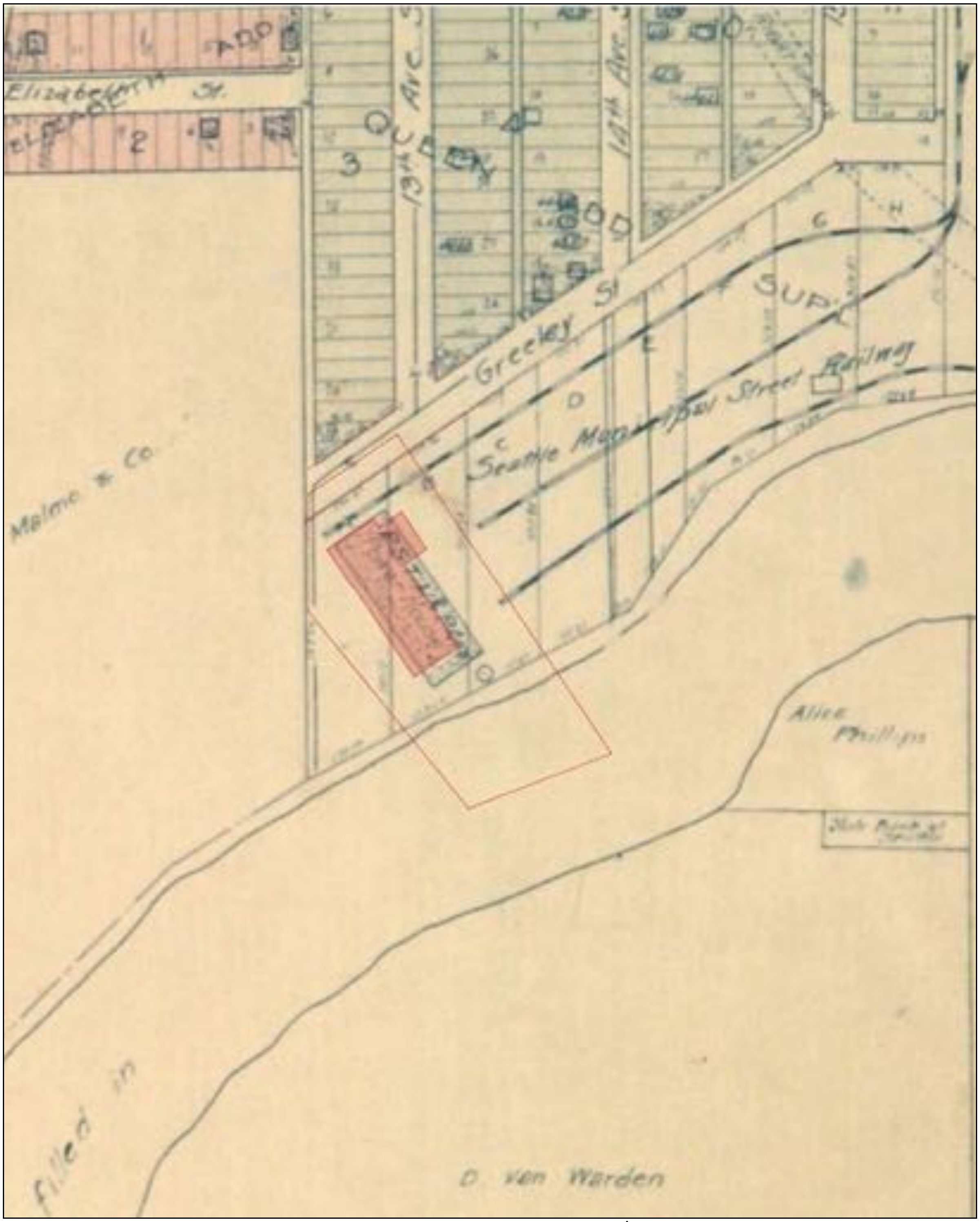


Figure 18: 1920 Kroll Map 67E, portion of plan, indicating Malmo & Co. property and Duwamish filled in. (Seattle Municipal Archives, item no. 1911)

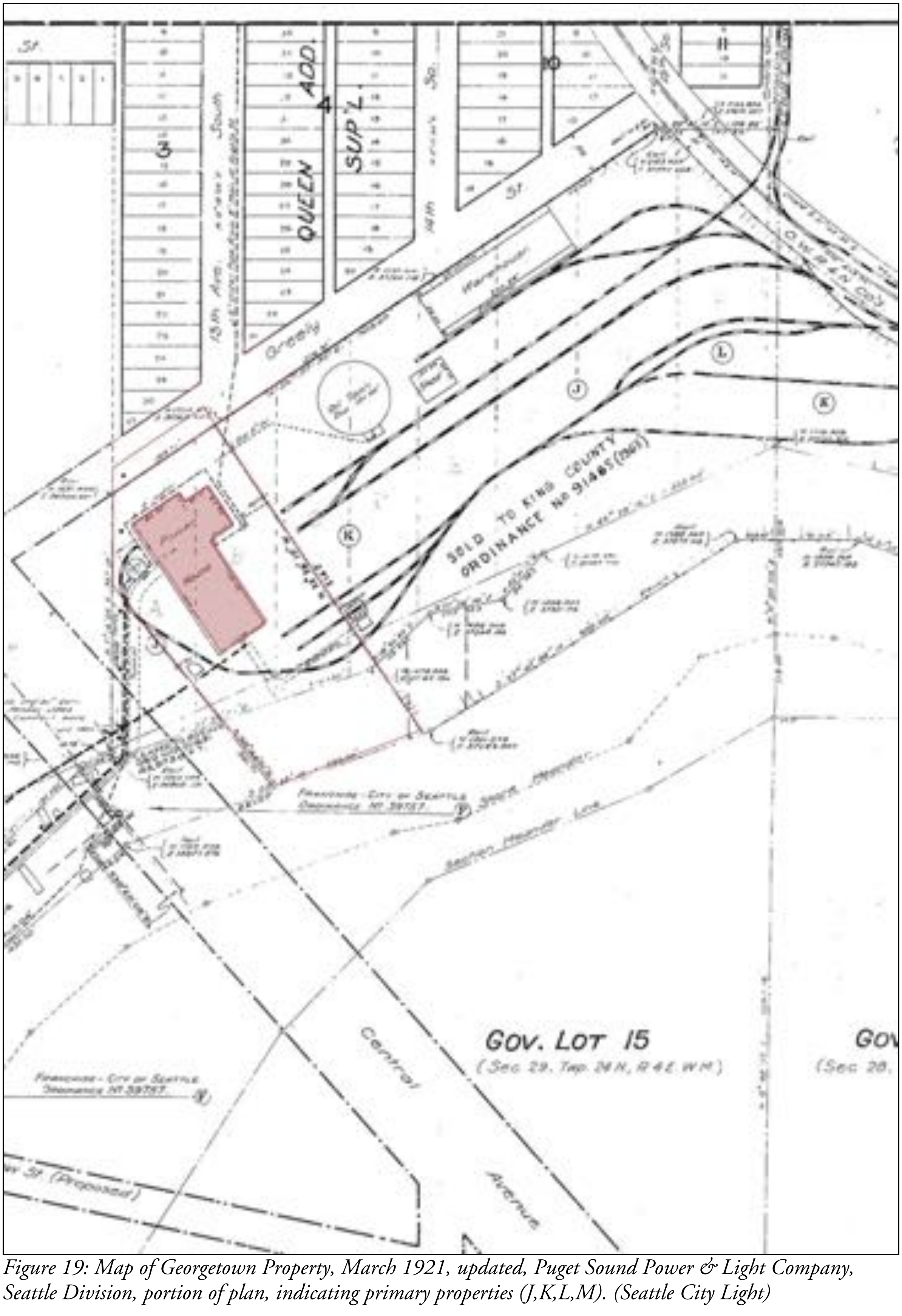


Figure 19: Map of Georgetown Property, March 1921, updated, Puget Sound Power & Light Company, Seattle Division, portion of plan, indicating primary properties (J,K,L,M). (Seattle City Light)

Figure 20: Sanborn, 1929 vol. 8, Sheet 1316, portion of plan, identifying Malmo & Co. Florist and nearby residences. (Sanborn Map Company)

Figure 21: 1940 Boeing Aerial Map, portion of plan, indicating Airport Turning and Approach Area Height Map and legislated height districts. Even with the 225'-tall and 268'-tall chimney stacks removed in 1938 the Steam Plant is 80' in height in a 40' height zone. (Seattle Municipal Archives, item no. 1467)

Available documentation for the property in this decade of site development is restricted to plans and maps for the property and as well as maps for the immediate area and region. Photographs with the plant in the distance, along with news reporting of area events and activities, provide additional context. The Map of Georgetown Property, published in 1921 by the Puget Sound Power & Light Company after taking ownership of the facilities, provides the most complete record of historic conditions at the site and environs and is included here for reference (Figures 19, 27).

Although facing the river to the south and west, plant access from Georgetown would have been from the land side, along the growing network of roads that quickly became the establishment of Georgetown. Greeley Street (also spelled Greely) was platted parallel to the River. Thirteenth Avenue South extended the Seattle grid. The original address of the plant was 1300 South Greeley Street.

The original east property line extended to the Interurban railway right-of-way, and included the Georgetown Shops and Car-Barns. In 1915 these properties were sold to the City of Seattle. Until 1963, the property extended to the Oregon-Washington Railroad & Navigation Company (O.W.R. & N. Co., now Burlington Northern Santa Fe and Union Pacific) railway right-of-way, when the warehouses and properties were sold to King County.

Photographs of the site were regularly taken from the eastern extent (Figures 35-37). Oil was stored in a 150,000-gallon steel tank immediately east. A coal delivery system constructed in 1917 delivered coal via rail lines to a coal hopper, transferred to a conveyor belt at the southeast corner of the plant. Ash exited the base of the plant and was removed via the rail tracks.

The south side of the site originally extended to the Duwamish; when the river was re-routed the centerline of the meander became the south property line. The river provided a direct source of water for cooling condensers and for discharging wastewater. Supply 'feed' water for the steam boilers came directly from the river, via a 10" pipe located in a concrete-lined 6 x 10 foot trench. Water for the condensers was drawn from a 16" pipe.

The earliest images of the site are looking upriver, with the west façades clearly visible. Taken from a distance, there is no detail of the ground condition. (Figures 13-14) By 1917, the primary vista of the structure had been significantly altered, when the river was straightened and relocated into the Duwamish Waterway.

The west property line separated the site from the former Malmo Nursery, established off of Ellis Avenue by 1920 (Figures 18, 20). The condensing water tank with 36" wood stave line to the Duwamish River would have provided water for cooling and operating the plant.

Flume

After the realignment of the Duwamish River in 1917, a ½-mile-long flume extended from the Steam Plant to the Duwamish Waterway. The story of this element provides a unique narrative of the plant's necessary relationship with the Duwamish River for cooling of the steam turbines for the 100-year period when the site was physically disconnected from the River. The line of the flume followed the original river meander. In 1919 property that was a portion of the filled bed of Duwamish River, 7.742 acres, was joined to the Georgetown Steam Plant site. Additional parcels were acquired between 1914 through 1919 to complete the flume operations. By 1917 a pump house was built northwest of the end of old riverbed, at Slip 4, to supply feed water to the steam plant boilers. The Georgetown Pumping Station was constructed on the Duwamish on property acquired in 1914.

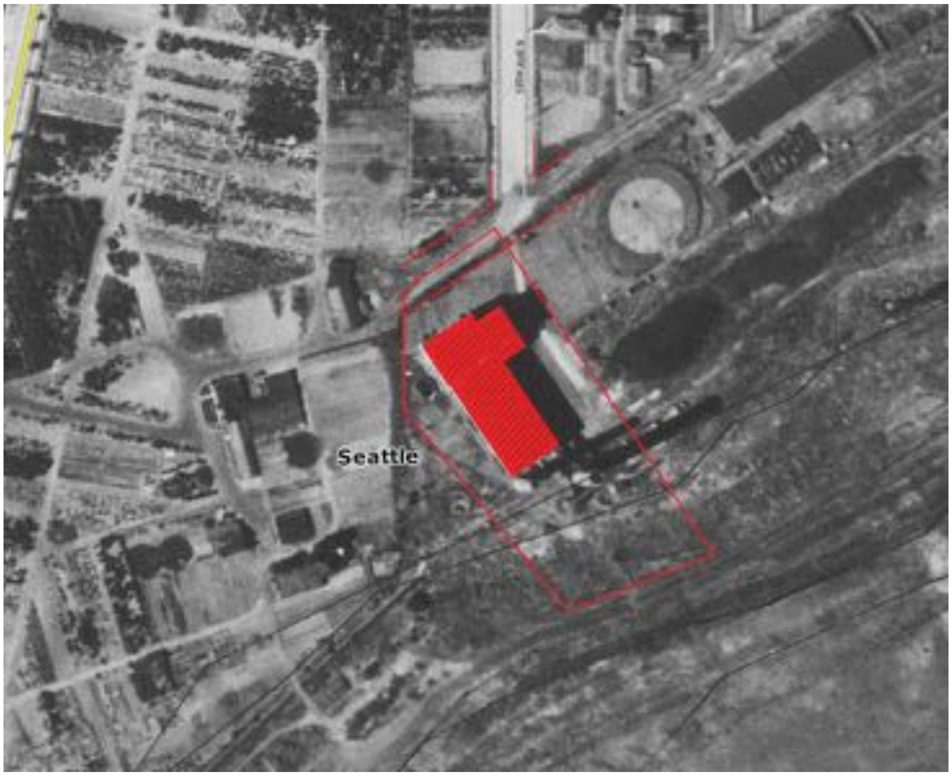


Figure 22:
1936 Aerial
(King County iMAP)

Figure 23:
1946 Aerial (SCL)

Figure 24:
1960 Aerial (SCL)

Figure 25:
2005 Aerial
(King County iMAP)

Figure 26:
2009 Aerial
(King County iMAP)

HISTORIC SITE FEATURES

North Side of Building

L Greely St. R.O.W.

East Side of Building

A Trolley Barns, Warehouses Site, Sold to King County 1963

B Oil Tank with Old 8" Dia. Pipe

C Track Connections to Steam & Electric Railway (Perpetual Right)

D Hopper and Shed

South Side of Building

E Conveyor

F Section Meander Line

G South Property Line - Original Duwamish Centerline

West Side of Building

H Oil House

I Flume Tunnel approximate Location

J Tank

K West PL

Figure 27: Historic Site Features

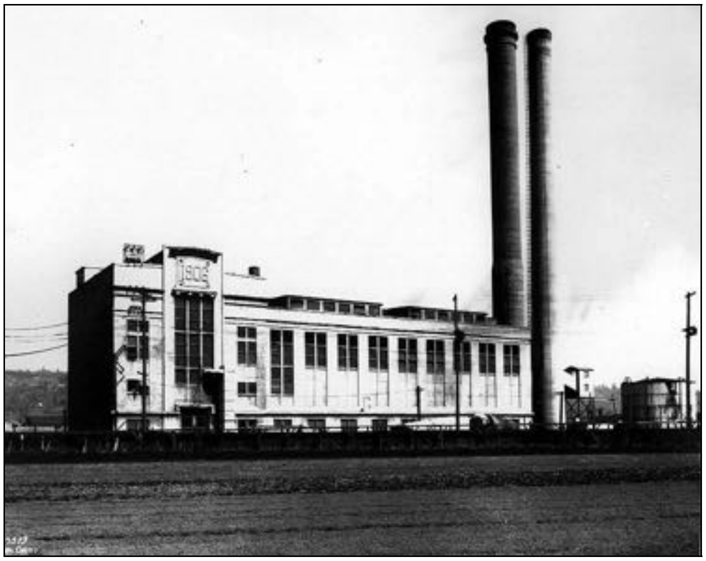


Figure 28 (left): View of the west façade, 1920. (University of Washington Libraries Special Collections, A. Curtis 39579)

Figure 29 (below left): Undated view, looking northeast toward the Steam Plant. (University of Washington Libraries Special Collections)

Figure 30 (below right): View looking along the west side of the property in 1950, the landscape appears not maintained. (Seattle Municipal Archives, item no. 22430)

Figure 31 (left): View of the west and south façades, 1979. (HAER documentation)

Figure 32: View looking at the north and east façades from Greeley Street and 13th Avenue, 1938. Property line planting obscure view of the building base. (Puget Sound Regional Archives)

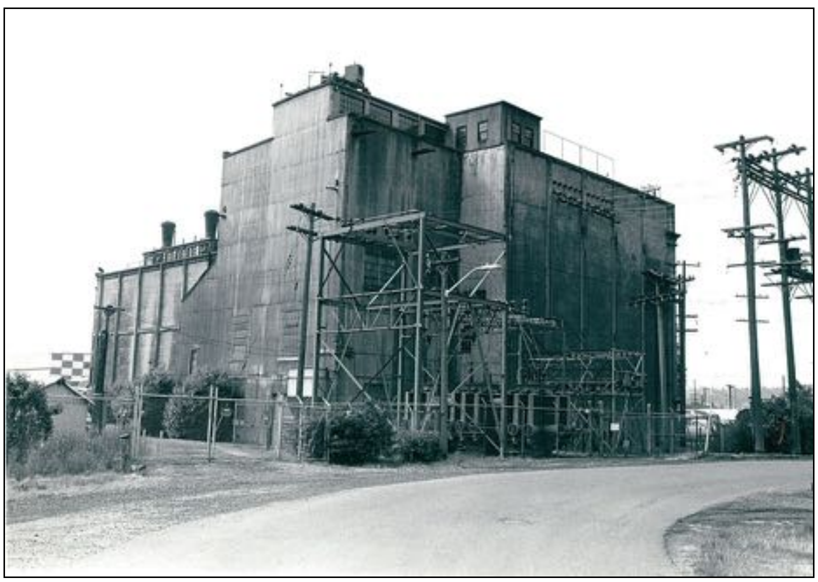


Figure 33: Similar view looking southwest from Greeley Street and 13th Avenue, early 1960s.View of fenced transformer pad and overgrown laurels beyond. (Seattle City Light)

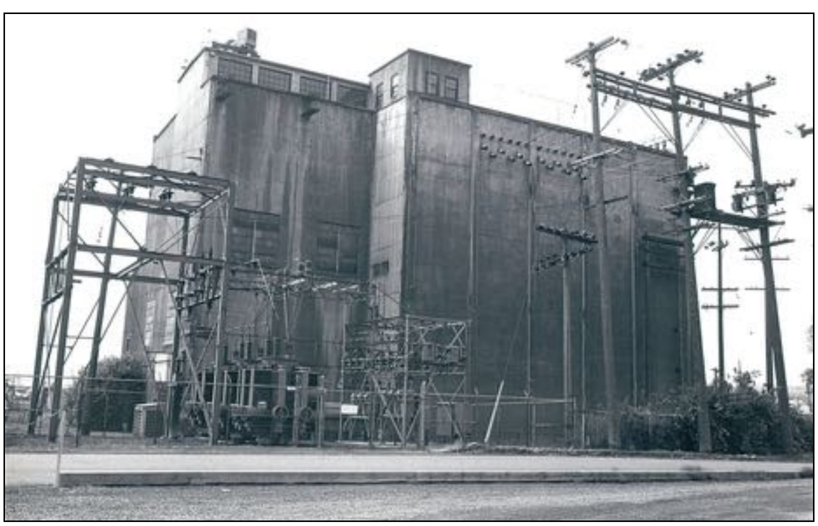


Figure 34: Oblique view of the north façade from Greeley Street and 13th Avenue, 1970s. Note the fenced transformer pad and overgrown laurels beyond.(Seattle City Light)

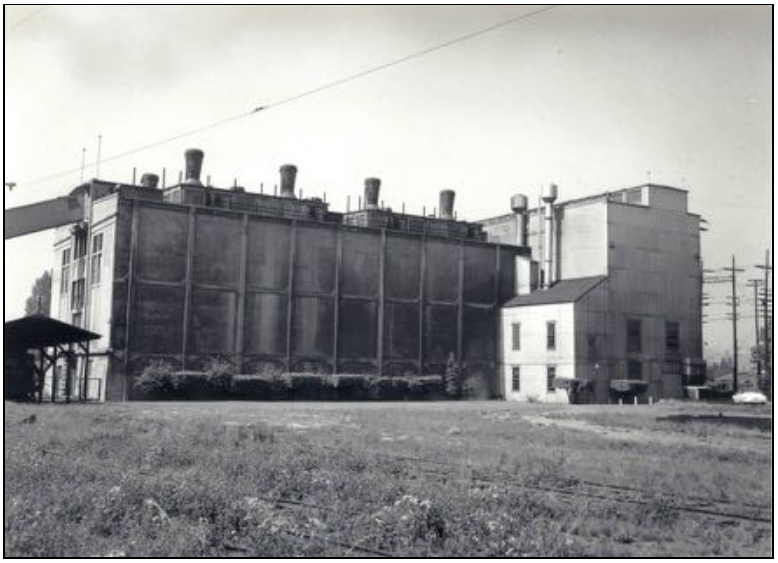


Figure 35: Looking northwest from the east property line, toward the east façade, with an oblique view of the south façade, 1950. Rail tracks are in the foreground in the grass. Laurel plants with small trees located between them are visible. (Seattle Municipal Archives, item no. 22426)

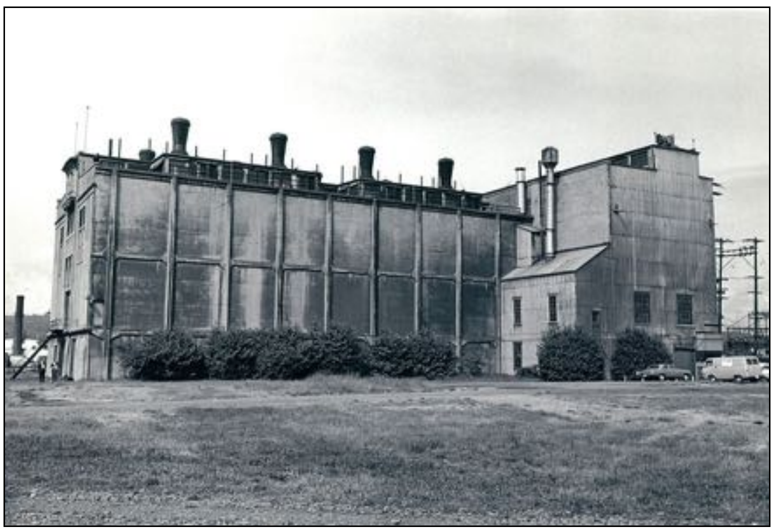


Figure 36: Similar view in the early 1960s.Trees have been removed, and the laurel hedge is not maintained. (SCL)

Figure 37: Similar view, 1979. The laurel hedge at this time is well maintained. (HAER documentation)

Landscape Changes from 1917 to 2012

The story of the site in the nearly century-long period since 1917 has been closely related to the history of the Boeing Company and the associated development of Boeing Field. The fallow land that had been the Duwamish riverbed and bottomlands was not fallow for long. The abandoned Duwamish meander became available property. The Meadows Racetrack had been established about two miles south of the Georgetown Steam Plant (north of today's South Boeing Access Road) in 1909. In 1928, the area to the north of The Meadows was selected for the site of Seattle's first airport, Boeing Field.

For 85 years, the expansion of the airport has meant the restriction of the Steam Plant site – all occurring within the lost meanders of the Duwamish (Figures 22-26). A review of a 1936 aerial image (Figure 22) indicates that at that time, the Steam Plant was bounded by Malmo Nursery to the west and small truck farms to the north, and the airport property is clearly shown to the south of the Georgetown Steam Plant. The river meander is still visible in different growth pattern of grass, either due to grades, drainage or soil type. To the east, the property remains relatively unchanged, with the oil tank, warehouses and rail lines still visible.

However, the Georgetown Steam Plant and all of Georgetown was now located within the airplane approach zones. By1938, 225'-tall and 268'-tall chimney stacks had been removed and replaced with a series of smoke outlets, leaving the 80'-tall plant still an obstacle. A 1940 zoning map established height districts affecting all of Georgetown; the Georgetown Steam Plant and the neighborhood to the north were located within the 40' height zone (Figure 21).

Airport expansion of Boeing operations and Boeing Field as part of the war effort led to a dramatic transition in the landscape to the west, as the 1946 aerial indicates. Gone are most of the agricultural fields to the west and north, replaced by airplane related industrial facilities.

In the late 1950s, King County acquired all properties north of the Georgetown Steam Plant to Albro Place and removed the neighborhood, demolishing all residences and businesses. The community outrage saw the return of some businesses in long-term leases on County land. Julius Rosso Nursery had already lost original landholdings on Ellis Avenue to what is now the site of the Washington Air National Guard in the 1940s. In 1958, the Nursery began leasing the property at Ellis and Albro.[6]

Parcels to the east of the Steam Plant site remained relatively unchanged until after 1963. In 1963, the eastern portion of the original property, including the original 150,000-gallon oil storage tank, a warehouse, and a machinery shop, was sold to King County for airport use. Buildings were removed and the area developed as taxiway and parking for small planes. The most recent expansion of Boeing Field occurred in 2004-05. The blast fence was installed in 2005. While SCL still retains ownership of the 13th Avenue access and the southern half of Greeley Street, access to the Plant has been rerouted and is the subject of ongoing negotiations between SCL and King County to find a suitable alternative.

[6] telecom with Gene Rosso – King County has terminated the lease with the Nursery as of August 31, 2012

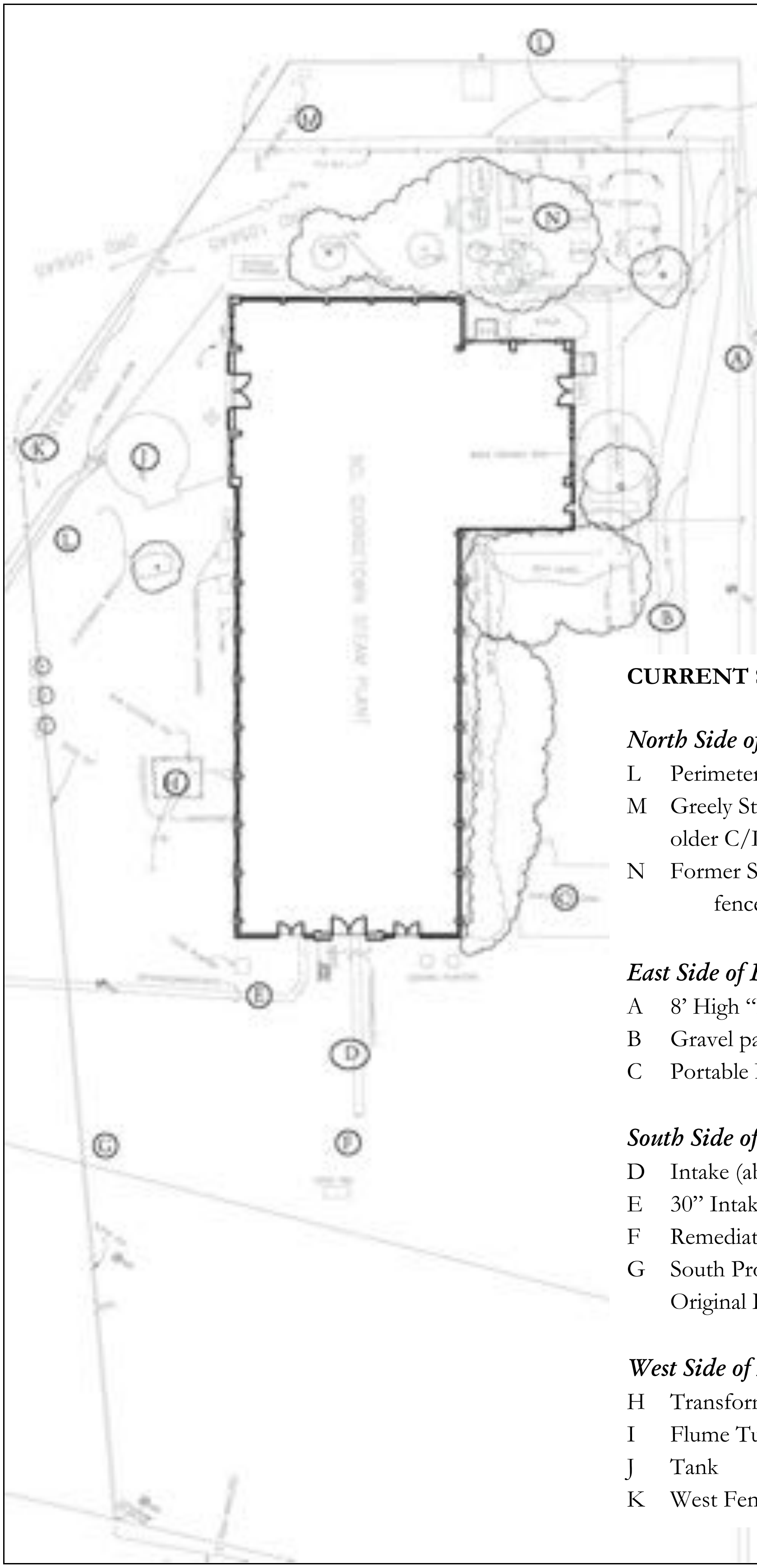


Figure 38: Current Site Conditions

CURRENT SITE CONDITIONS

North Side of Building

L Perimeter C/L Fence and Gate
M Greely St. R.O.W. (abandoned), AC Pavement, older C/L Fence and Gate
N Former Switchyard - concrete curb at original fenceline, concrete pads, gravel mulch

East Side of Building

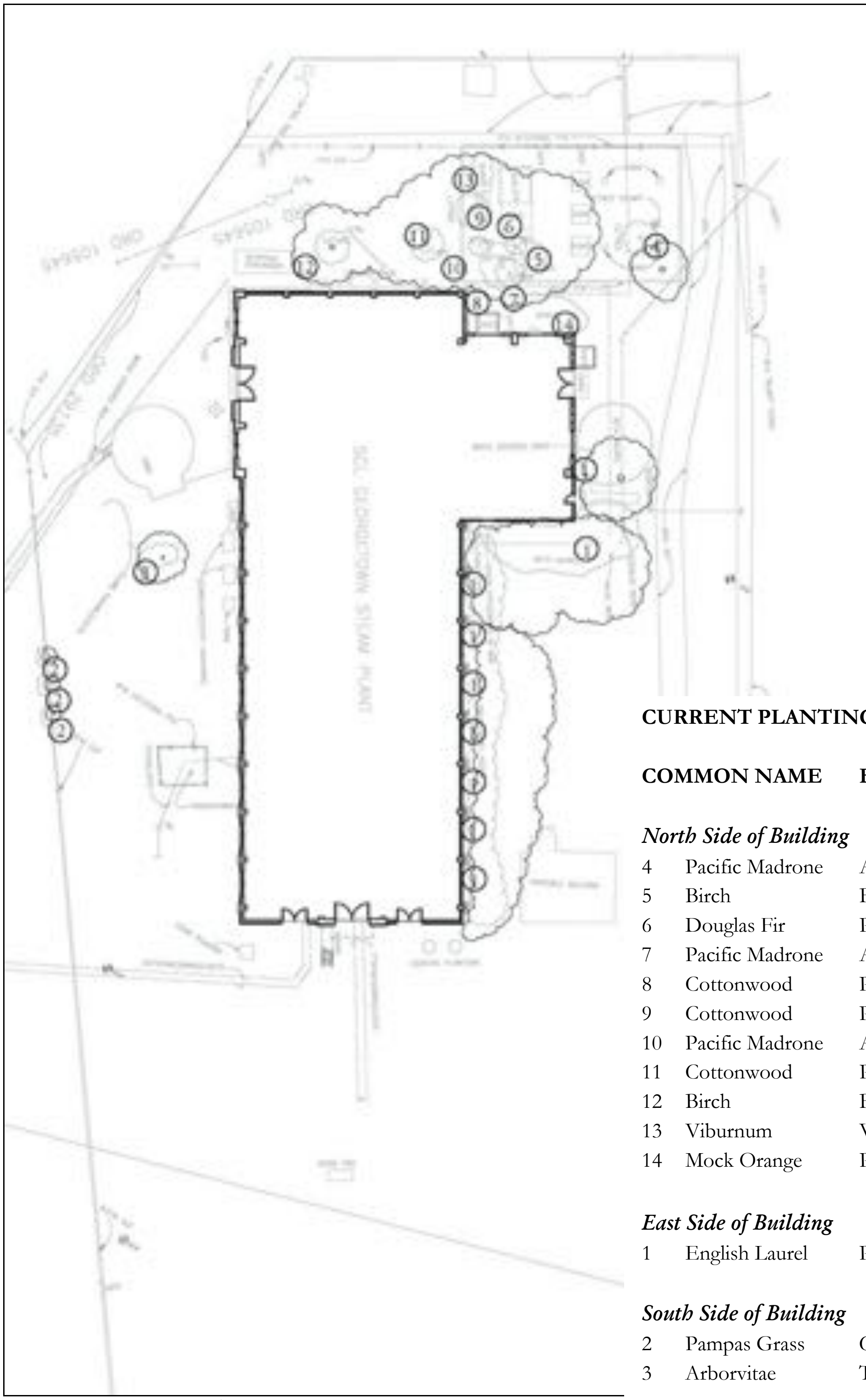
A 8' High "Blast" Fence, King County Airport
B Gravel pavements
C Portable Building

South Side of Building

D Intake (abandoned)
E 30" Intake (abandoned)
F Remediation Area
G South Property Line and Fence - Original Duwamish Shoreline Meander

West Side of Building

H Transformer
I Flume Tunnel approximate Location
J Tank
K West Fence



CURRENT PLANTINGS

COMMON NAME		BOTANICAL NAME
North Side of Building		
4	Pacific Madrone	Arbutus menziesii
5	Birch	Betula sp.
6	Douglas Fir	Pseudotsuga menziesii
7	Pacific Madrone	Arbutus menziesii
8	Cottonwood	Populus sp.
9	Cottonwood	Populus sp.
10	Pacific Madrone	Arbutus menziesii
11	Cottonwood	Populus sp.
12	Birch	Betula sp.
13	Viburnum	Viburnum sp.
14	Mock Orange	Philadelphus lewisii
East Side of Building		
1	English Laurel	Prunus laurocerasus
South Side of Building		
2	Pampas Grass	Cortaderia selloana
3	Arborvitae	Thuja occidentalis
West Side of Building		
2	Pampas Grass	Cortaderia selloana
3	Arborvitae	Thuja occidentalis

Figure 39: Current Plantings

Figure 40: View of various trees overgrowing north transformer pad. (KKLA)

Figure 41: View looking south from the Greeley right-of-way, showing older chain link fence and gates. (KKLA)

Figure 42: View of east entry door framed by Laurels. (KKLA)

Figure 43: View south along the east façade, showing the extent of Laurels. (KKLA)

Figure 44: (3) Arborvitae along the west fenceline. (KKLA)

Figure 45: View of Pampas Grass, west yard. (KKLA)

Current Site and Landscape

The north perimeter fence is located on the centerline of the Greeley Street right-of-way (vacated). The immediate vehicular north entry gate references the earlier site access, although the closure of access from 13th Avenue has removed the historic physical and symbolic connection to Georgetown. Property entry is instead a circuitous route through the parking lots of King County facilities accessed off Ellis Avenue. Inside the outer perimeter gate are remnants of earlier Greeley Street pavements, where materials have been stored. A second fence and gates, concrete curbing, concrete pads, and gravel paving represent the remains of the former substation, installed in 1953 and decommissioned as of 1991. The transformer pad was repurposed over the last several years to serve as a spot for gathering and picnics, etc. A shelter was erected with supports welded from available metal rails and parts. The area has been used as a shelter for picnics for museum visitors and others.

To the north of the building are several trees that are not indicated in the 1979 photos. Trees include Pacific Madrone (4, 7, and 10), Arbutus menziesii, Birch (5, 12), Betula sp., Douglas Fir (6), Pseudotsuga menziesii, Cottonwood (8, 9, and 11), and Populus sp. (Figure 39). Most of these trees have likely been established through wind and bird dispersion of seeds and through general neglect of the site in the period after the transformers were removed (1991).

At the northeast corner of the building, foundation plantings are visible in the 1938 photographs. Today these plants are likely remnants of the original installed foundation plantings, including Viburnum (13), Viburnum sp. and Mock Orange (14), Philadelphus lewisii.

The east property line was established in 1963, when the electric trolley barns and warehouses and properties were sold to King County. A new 8'-high slatted metal "blast" fence was installed along the east property line with King County International Airport in 2005. The fence prevents the long views to the east that previously existed, forcing a truncated view of the Georgetown Steam Plant and immediate environs. Recent gravel pavements generally follow previous circulation east of the building and provide access to the south of the site. A wood portable building was relocated to the property southeast of the Steam Plant to provide classroom space for the School of Technology.

English Laurels (1), Prunus laurocerasus, are the dominant plantings of the site on the east side. Laurels are a common hedging material, appreciated for their fast growth and adaptability. For hedging, laurel are planted tightly and clipped to form a single hedge. These laurels were originally installed singly, aligned with the building columns and clipped and maintained as individual specimens. The time of planting is not clear, since it is hard to see the base of the building in the 1938 photograph. The plants appear to have been installed several years before City acquisition of the property in 1951 – the plants were well established in the 1950 photograph. The photographs indicate the laurels were well maintained at least through 1980, as evidenced in the 1953, 1962 and 1979 photographs. The 1953 and 1962 photographs indicate some sort of trees was planted between each laurel. None remain. Today, the laurels are nearly all present, but have not been maintained in years. They are 30' high and as wide. For their age and care, the plantings are in relatively good health.

The entire south side of the site is now a wetlands remediation area. A site survey indicates a decommissioned 30" water intake that previously provided access to pumped water from the Duwamish River was capped as part of the remediation efforts. A chain link fence traces the south property line that is unchanged from 1906, when the line was established along the meandering centerline of the Duwamish River. Boeing facilities are located to the south.

The south side is currently planted in grasses as part of the remediation effort, with plans to provide additional plantings in the area. In many respects, even with the soils replacement and grading, the area presents what it might have looked when the Duwamish River still ran by.

The west side of the plant has changed little over the years, by comparison with the photograph from 1950. The west fence line separates the site from the former Malmo Nursery, property owned by King County since the 1950s. The condenser pit is original to the property, connected to the Georgetown Steam Plant flume and, until the 1960s, discharged cooling water from the steam plant to the flume.

The west landscape is mostly grasses that have invaded the site over the years. There is a clump of Pampas Grass (2), Cortaderia selloana and there are old installed Arborvitae (3), Thuja occidentalis along the fence line, which may date from the time the adjoining property was operated as a nursery, through the 1940s. In truth, this is the least disturbed part of the site. It would be interesting to review whether some of these plant seeds represent earlier plant communities than now existing in the immediate environs, or if material artifacts are present from an earlier period.

Now mostly leased to Boeing or King County, the flume properties are associated with the extensive cleanup effort of the Duwamish River. However, there are several points of existing or potential access. The outfall at East Marginal Way and Slip No. 4 (the original Duwamish meander) can be viewed / accessed at Othello Street. The Georgetown Pump Station, listed in the National Register of Historic Places due to its relationship to the Georgetown Steam Plant, was transferred to Seattle Parks and Recreation for open space, park, and recreation purposes in 2010, and is accessible from Carleton Avenue. The flume parcels can also be viewed / accessed from East Marginal Way, Myrtle Street. and Willow Street.

3. HISTORIC PRESERVATION TREATMENTS AND RECOMMENDED TREATMENT FOR THE GEORGETOWN STEAM PLANT

Architectural Treatment Approaches and Standards

The treatment approaches presented in this report are intended to cover a variety of future work necessary to stabilize, repair, maintain, and preserve and / or rehabilitate the property discussed in this document. Specific recommendations are included in the Condition Assessment section of this document and in the consultant reports and assessments in the Appendix. The recommendations are in response to the proposed current scope of rehabilitation work, and are in accordance with *The Secretary of the Interior's Standards for the Treatment of Historic Properties* and the definitions described below.

The treatment of historic buildings and structures is based on several interrelated issues:

- protection of historic material
- maintenance of historic character
- modifications for continued uses
- upgrades to allow for new compatible uses as well as fire and life safety and energy conservation

There are four approaches to the treatment of historic buildings and structures:

- Preservation
- Rehabilitation
- Restoration
- Reconstruction

The following definitions are taken from *The Secretary of the Interior's Standards for the Treatment of Historic Properties,* commonly referred to as The Secretary's Standards.

> **Preservation** is defined as the act or process of applying measures necessary to sustain the existing form, integrity, and materials of an historic property. Work, including preliminary measures to protect and stabilize the property, generally focuses upon the ongoing maintenance and repair of historic materials and features, rather than extensive replacement and new construction. New exterior additions are not within the scope of this treatment; however, the limited and sensitive upgrading of mechanical, electrical, and plumbing systems and other code-required work to make properties functional is appropriate within a preservation project. This is the preferred approach over restoration or reconstruction.
>
> The standards for **Preservation** call for:
> - retention of a property's historic use;
> - retention of a property's historic character;
> - recognition of a property as a physical record of its time and place;
> - recognition that changes to a property may have acquired significance in their own right;
> - preservation of distinctive materials, features, finishes, and construction techniques;
> - when necessary, repair or limited replacement in-kind to match old material in composition, design, color, and texture;
> - use of the gentlest chemical and physical treatments; and
> - protection and preservation of archaeological resources.

Rehabilitation is defined as the act or process of making possible a compatible use for a property through repair, alterations, and additions while preserving those portions or features which convey its historical, cultural, or architectural values. It may involve major repairs or additions. The approach is applicable if continued, efficient operation of a particular structure necessitates appropriate changes, for example.

The standards for **Rehabilitation** include all of the bulleted items listed above for preservation as well as the following:

- new additions and exterior alterations must be compatible in terms of materials, size, scale, proportion, and massing; and
- new additions and exterior alterations must be able to be removed without impairing the essential form and integrity of the historic property.

Restoration is defined as the act or process of accurately depicting the form, features, and character of a property as it appeared at a particular period of time by means of the removal of features from other periods in its history and reconstruction of missing features from the restoration period. The limited and sensitive upgrading of mechanical, electrical, and plumbing systems and other code-required work to make properties functional is appropriate within a restoration project.

The standards for **Restoration** include the following:

- retention of a property's historic use;
- retention of a property's historic features and character;
- recognition of a property as a physical record of its time and place;
- documentation of features from other historical periods shall be documented prior to their alteration or removal;
- preservation of distinctive materials, features, finishes, and construction techniques or examples of craftsmanship;
- when necessary, repair or limited replacement in-kind to match old material in composition, design, color, and texture;
- use of the gentlest chemical and physical treatments;
- protection and preservation of archaeological resources; and
- additions shall not be constructed if not historically executed.

Reconstruction is defined as the act or process of depicting, by means of new construction, the form, features, and detailing of a non-surviving site, landscape, building, structure, or object for the purpose of replicating its appearance at a specific period of time and in its historic location.

The standards for **Reconstruction** include the following:

- depiction of vanished or non-surviving portions of a property when documentary and physical evidence is available to permit accurate reconstruction, and such reconstruction is essential to the public understanding of the property;
- reconstruction in a resource's historic location will be preceded by a thorough archeological investigation;
- preservation of any remaining historic materials, features, and spatial relationships;
- accurate duplication of historic features based on documentary or physical evidence rather than on conjectural designs;
- clear identification as a contemporary re-creation; and
- designs that were never executed historically will not be constructed.

The program, preservation approach, and recommendations in this report for the Georgetown Steam Plant are based on historical research, site investigation and documentation, condition and structural analysis, code review, and the treatment guidelines. They take into account the building's current conditions and plans for its future uses.

Character-Defining Features and Historic Preservation Objectives

The Georgetown Steam Plant has features that define its historic character and embody its significance. The goal of the treatment and work recommendations is to preserve those character-defining features to the greatest extent possible, while providing new weather-tight exterior components such as roofing and flashing, rehabilitating exterior doors and windows, cleaning and protecting exterior concrete surfaces, improving seismic performance, and mitigating hazardous materials affected by the exterior envelope rehabilitation. Removal or alteration of the character-defining features would have a negative or adverse effect.

<u>Exterior</u>

- T-shaped massing
- Monumental building massing arranged vertically with classical division of base, shaft, and cap (west and south façades)
- Cast-in-place, board-formed concrete at exterior walls
- Cast concrete medallions at parapet (west façade of Engine Room and south façade of Boiler Room)
- Visible concrete frame (north façade of Engine Room and east façade of Boiler Room)
- Utilitarian, corrugated metal cladding (east end of Engine Room and roof and walls of adjacent south extension)
- Low slope roof with central roof monitor; plain perimeter parapet
- Series of recessed panels with tall windows or louvers above, set into large openings – three on the ends and nine on each side (west and south façades)
- Multi-light (6:6, 9:9, 12:12, 15-light and 18-light at the monitors), true-divided light wood windows with center pivot operation (a few are double-hung or fixed). The windows are operated by a mechanical system of chains, pulleys and handles
- Multi-light steel windows with center pivot section, typically 36-light
- Large, double-leaf wood doors with diagonal panels and true divided-light glazing in the top half
- Inverted cone-shaped draft fans on the Boiler Room roof

<u>Interior</u>

- Exposed reinforced concrete structure
- Unpainted concrete walls, floors, and ceilings
- Engine Room: extremely tall open volume, with mezzanines along north side
- 50-ton crane (Engine Room)
- Original generators, turbines, and switchgear
- Catwalks and pipe rails
- Coal bins and ash pits
- 5-story gallery

Programming/Use: Until a building use and feasibility study is undertaken, continued operation as a limited access museum and interpretive facility.

Preservation Approach: Preservation and Rehabilitation

Recommendations: Repair failing and deteriorated exterior envelope components, including concrete walls, windows and roof; undertake seismic and site improvements; repair miscellaneous metal elements, including railings, ductwork, and balconies; remove unrelated stored equipment and materials from the building; consider use of the building as an interpretive facility and industrial heritage center.

Requirements for Work: This section typically outlines the rules and regulations that would apply in the event that a building is to be preserved and/or rehabilitated.

- This building was reviewed for seismic integrity (ASCE 31-03 Tier 1 and Seismic Evaluation) and structural integrity, and determined to require structural upgrades for its continued preservation and for continued use as a publicly accessible facility.
- Repairs and new construction should comply with all applicable local, state and federal regulations.
- Structural, life safety, and exterior envelope and site improvements should be compatible with the historic character of the original construction.
- Hazardous materials should be abated from the building in a manner that does not adversely affect the historic integrity of the structure and the historic building materials.
- Since it is accessible to the public, the building should comply with the regulations of the Americans with Disabilities Act (ADA).
- All work should be carried out in accordance with *The Secretary of the Interior's Standards*.

Landscape Preservation Treatment Approach

Landscape preservation treatments seek to retain the remaining historic character and features, to mitigate negative changes and deterioration as possible, and to address the range of current and future use and maintenance issues affecting the property while achieving these purposes.

The *Secretary of the Interior's Standards for the Treatment of Historic Properties with Guidelines for the Treatment of Historic Landscapes (Guidelines)* recommends four possible preservation treatments for historic landscapes, summarized here with comments:

- Preservation: "generally focuses upon the ongoing maintenance and repair of historic materials and features rather than extensive replacement and new construction."

  Preservation is an appropriate choice when many elements are intact, interpretive goals can be met within the existing conditions, or when financial resources or staffing are limited. Preservation can also be viewed as an interim treatment, and is the basis for the other three more intensive treatments. Preservation alone does not address the present and future needs of the site users nor would it restore the GTSP site's lost historic character.

- Rehabilitation: "makes possible a compatible use for a property through repair, alterations, and additions while preserving those portions or features which convey its historical or cultural values."

  Rehabilitation blends the needs for historic preservation and interpretation with the access limitations, operational requirements and maintenance restrictions. With the baseline of Preservation, Rehabilitation is the best overall treatment for the Georgetown Steam Plant site and landscape.

- Restoration: "is the extensive process of accurately depicting the form, features, and character of a property as it appeared at a particular period of time by means of the removal of features from other periods in its history and reconstruction of missing features from the restoration period, with limited, sensitive upgrading of systems as required."

  Restoration treatment depends on considerable documentation to authentically recapture the historic condition. Restoration of the GTSP site and landscape is impractical, given the limited information available, and given the significant changes to the site and complete transformation of the environment.

- Reconstruction: "depicts, by means of new construction, the form, features, and detailing of a non-surviving site, landscape, building, structure, or object for the purpose of replicating its appearance at a specific period of time and in its historic location."

  Reconstruction requires detailed documentation, and is only recommended where interpretive potential is not possible without this effort to reconstruct. This is neither practical nor warranted with the site and landscape; in many ways the evolved nature of the site and landscape is its most interesting story to tell.

As described above, Rehabilitation is the recommended treatment for the Georgetown Steam Plant site and landscape.

Recommendations and Alternatives

<u>General Recommendations and Priorities for Building Rehabilitation</u>

Many areas and elements of the building require attention and modification to protect the building from the danger of collapse or severe damage from a seismic event and to improve the integrity of the exterior enclosure – walls, windows and roofs. These elements include:

- verification of positive structural attachments between the floor and roof diaphragms and the concrete walls
- strengthen columns at concrete demising wall between the Engine Room and Boiler Room
- repair and strengthen areas of masonry infill at south wall
- add lateral structural strengthening at east wall of the Engine Room
- removal of hazardous materials in the course of exterior envelope repairs
- add bracing at clerestory windows (this may have an adverse visual effect and additional investigation will be needed to minimize visual impact)
- brace hollow clay tile at north wall at the interior
- repair of damaged and deteriorated exterior concrete and removal of existing deleterious coating
- ongoing repair, maintenance and restoration of deteriorating exterior elements, particularly the wood windows and doors, steel windows, railings and miscellaneous metal fabrications
- ventilation and control of seasonal and daily temperature fluctuations
- upgrading to address accessibility, fire and life safety, and energy conservation concerns
- site improvements, such as grading, plantings, and paving

It is important that future changes to the building retain the remaining historic materials and minimize the impact on the historic integrity of the building. Recommendations for the work undertaken for the building stability and for improved functions should be made in accordance with *The Secretary of the Interior's Guidelines for Rehabilitation*. The first priority for the building is protection and maintenance of deteriorated or damaged architectural elements. The second priority is repair and replacement if the damaged historic material is first stabilized and protected from further deterioration or failure. The third level of work is the exterior and interior alterations needed for the physical and functional upgrade of the building. New work shall be clearly differentiated from the old and should not radically change, obscure or destroy character-defining features or materials.

PRIORITY 1: PROTECT, MAINTAIN, AND STABILIZE

The following actions are recommended to occur as soon as possible to address problems, which may cause continued damage to the physical characteristics of the Georgetown Steam Plant:

- reroof/repair of existing roofing, flashings, and perimeter sealants
- repair roof and underground storm drainage system
- regrading of surrounding grade around the building for positive drainage of water away from the foundation and to prevent further infiltration at door openings and wall-to-slab conditions
- replace deteriorated flashings and sealants at windows, doors and at roof / wall intersections
- provide repairs and weatherstripping at doors and windows
- establish a program to monitor the condition of exterior elements with periodic inspection, and provide cyclical maintenance
- address fire and life safety deficiencies, including egress plans and fire escapes

PRIORITY 2: REPAIR AND REPLACE

The following actions are recommended to occur within the next two years to assure continued preservation of the historic elements and protection of the building in a seismic event:

- remove deteriorated paint at windows, doors, trim and siding; repair rotten and deteriorated items and material; repaint
- repair doors and hardware; upgrade hardware as appropriate
- repair exterior fire escape and south balcony
- provide historically appropriate exterior light fixtures
- replace aircraft obstruction lighting and support system
- protect fused electrical panels and modify interior lighting controls
- examine electric steam boiler and make recommended repairs

PRIORITY 3: PHYSICAL AND FUNCTIONAL UPGRADE

The following recommendations respond to the issues of the desired building and program upgrades, and should be undertaken systematically, as budget and funding allows:

- address accessibility at building entries and interior spaces
- remove unrelated stored materials

- review life safety and accessibility codes at the entrances and facilities in the building, consider provisions for handicapped accessibility; this recommendation is in keeping with local and federal disabilities legislation
- upgrade security components (including alarms, motion detectors, lights, and sensors)

Recommended Rehabilitation Treatment for Landscape and Site

Today, the original approximately 15-acre site is less than 3 acres in size (not including leased or flume property). This remains an industrial building in an industrial context. Much of the treatment of the property should be in response to the original industrial function.

The building, aligned with the former riverbank of the Duwamish, is out of place in the current grid of streets and properties. The visual orientation and physical access to the building has been radically altered. While site access and setting has been significantly compromised, there are key elements that contribute to the potential for improved legibility and interpretation.

Visual and physical access from the community is the challenge that the north side of the site must answer. For workers, access to the site has evolved over the years. Original access was from the east along Greeley Street, where the rail yards and storage areas remained until the 1950s. Northward expansion of Boeing Field at that time cut off that direct access. The primary access to the site remained as 13th Avenue until recently (ca. 2005), when further airport expansion restricted access. Current restricted access from Ellis Street to the west through King County parking lots is confusing and is not ideal. If it were to remain the primary access for the future, clear signage and signed parking should be provided. A better point of access would be from properties directly west of the site.

It is the north side of the property, with the substation site recently used for picnics, etc., which is the most changed over the years. The trees have grown up in the 20 years since the substation was decommissioned in 1991. The trees, however, are in great contrast to the bare and service-oriented nature of the earlier functioning steam plant site.

Concern has also been raised that the trees are in conflict with King County Airport regulations regarding wildlife management; the intent is to reduce plant material that may attract animals (primarily birds) that could pose a safety hazard to airplanes in flight. The Airport's guidelines are not detailed; commonly reference is made to the Sea-Tac International Airport wildlife management criteria.[7] Reviewing the Sea-Tac wildlife management criteria, Cottonwood is on the list of rejected plants. Birch and Douglas Fir are on the Approved list. Pacific Madrone is not identified on either accepted or rejected plant lists; however, the trees produce berries, and birds are a primary agent of seed dispersal. Madrone remains the only tree of smaller stature on the site. Removal of the vegetation is warranted for safety concerns, and will provide original views of this striking structure. If the trees on the north side are reviewed and determined to be removed, the area can be cleaned up. The substation pad should be retained and reused as part of the history of the site.

The east side of the site, severely constricted by the expansion of Boeing Field ca. 2005, nonetheless retains plantings that have provided a formality and character to the base of this imposing structure for more than 60 years. There are multiple factors recommending removal of the English Laurel. First, the plants, with their berry fruit, have been identified as an animal attractant relative to Boeing Field. Actually, a close review of Sea-Tac International Airport wildlife management criteria indicates that Prunus laurocerasus 'Otto Luyken' – the dwarf form of English Laurel – is on the Approved Plant List.

[7] http://www.portseattle.org/Environmental/Water-Wetlands-Wildlife/Pages/Wildlife-Management.aspx.

These plants, with their high canopy and nesting branches, have nonetheless been identified as an animal attractant. Second, the plants long ago escaped management size. At their current height and girth, the plants may be compromising the lower façade of the steam plant, and at the very least, make maintenance of the building perimeter difficult. Removal of the plants is warranted.

While not present during the period of significance for the Georgetown Steam Plant, the clipped laurels are an enduring and recognizable element of the site. Given the duration of this single landscape element, replacement of the plants in the same location with a slower growing, more manageable species is recommended. Alternate species providing a scale to the Steam Plant base that also meet the Airport wildlife management criteria are not common. Additional research to determine suitable species is warranted.

The southern extent of the site remains nearly as extensive as the original site. If you stand at the southwest corner of the site, turning your back to Boeing's manufacturing yards, and look north, the steam plant is a commanding presence – even without the original smokestacks still one of the tallest structures south of downtown, and certainly in the immediate vicinity of Boeing Field. Perhaps the impact of the chemical hazard and cleanup has some benefit – it has protected the original north shore of the Duwamish, intact in configuration. There remains significant potential for using this vantage point for interpretation of the legacy of the plant. Completed plans for final grading and planting of the remediation site should be re-evaluated to see if slight modifications could provide a vantage point and landscape quality that referenced the site from 1906.

The west side of the plant remains relatively unchanged; in fact, the ruderal vegetation may represent original common species, now rare within the existing context. The need for a pathway providing year-round access has been identified – it would be good to consider placing the route towards the perimeter of the site, to permit more views to and of the upper heights of the building.

The flume segment can provide a unique interpretive opportunity, providing a tale of the Plant's relationship with the Duwamish River. Providing coordinated interpretive opportunities at existing access points at East Marginal Way, as well as Slip No. 4 and the new park at the Georgetown Pump Station, accessible from Carleton Avenue, is a first step. Improving access at public rights-of-way at Myrtle Street and Willow Street should be considered.

Museum Existing Conditions and Status and Interpretive Objectives

The Georgetown Steam Plant until recently housed a museum, with limited public access and admission. The historic integrity, significance, and public understanding of the building could be better presented if the building was adapted as a heritage center instead – as a compelling artifact itself and an intact example of industrial development rather than just an envelope in which collections are assembled, conserved, cared for and exhibited / interpreted. As an industrial heritage center, if there were an appropriate space available, a portion of it could serve as the venue for temporary exhibits on many topics relating to Seattle City Light: power generation, its history, the Duwamish, public power movement, and possibly labor history – along with numerous engineering and technology topics that are inextricably linked to the building, the surrounding community, and the City of Seattle.

After the building was decommissioned in the 1970s, Seattle City Light was left to consider the future use(s), if any, for the building. A Draft EIS was developed in 1981 to evaluate alternative uses for the site and structure.

Further study / planning is recommended to determine compatible objectives, uses, and programming for the continued and future use of the building. Also recommended is the resolution of permanent street access to this Landmark site. Both will be key to the building's future.

4. BUILDING CONDITION ASSESSMENT

INTRODUCTION

This Condition Assessment will serve a basis from which to develop an understanding of the current conditions at the Steam Plant and will be used to develop design and construction documents to improve the structural and exterior envelope integrity of the building. The survey is not an in-depth study of any one area, but rather seeks to identify apparent and reported exterior envelope – roof, walls, and window and door openings – conditions and deficiencies, as well as structural and seismic deficiencies. Conditions were observed from the ground, from roof locations, and through the use of a high-lift at the south and east elevations. Observations of the north and west elevations were limited due to electrical safety precautions, and large landscape plants and trees on the north side.

Currently, SCL's proposed scope of work will occur in three phases:

1) The reroofing phase will be publically bid, with anticipated project completion before the end of 2013;

2) The envelope restoration may be publicly bid or performed by SCL crews; and

3) The site rehabilitation may be either performed by City crews, or publicly bid.

Recommended actions to address each issue are included following each item discussed, along with specific structural, civil, envelope, and hazardous materials reports. Some scopes below are more thoroughly described in the engineers' and consultants' reports provided in the Appendix. The site observations and photographs date from the June and July of 2012, and all contemporary photos are by BOLA Architecture + Planning, unless otherwise noted.

Figure 46: West and north façades, ca. 1960. (Seattle Municipal Archives)

Documentation for the Condition Assessment was gathered from various sources and parties, and includes the following recent reports and documents:

- Archived construction drawings and specifications provided by Seattle City Light
- On-site observations and photographs in the spring / summer of 2012: June 15, June 26, and July 9
- Discussions with SCL Project Manager Ruth Meraz, and Shops and Mobile Equipment Supervisor Blaine Olyano; and Georgetown Power Plant Museum Director Lilly Tellefsen and volunteer, Ted Snyder, on several occasions
- 1969 Exterior Building Repairs at Georgetown and Lake Union Steam Plants, Specifications No. 2104, by the City of Seattle Board of Public Works, Department of Lighting
- 1969 Reroofing Georgetown Steam Plant, Specifications No. 2144, by the City of Seattle Board of Public Works, Department of Lighting
- 1981 Georgetown Steam Plant Adaptive Use Alternatives Draft EIS, by Seattle City Light
- 1983 Roof Rehabilitation of Georgetown Steam Plant, Specifications No. 2723, by the City of Seattle Board of Public Works, Department of Lighting
- 1985 Exterior Surface Restoration of Georgetown Steam Plant, Specifications No. 2806A, by the City of Seattle Board of Public Works, Department of Lighting
- 1985 Draft Physical Development Plan for the Georgetown Steam Plant Museum, by Stuart Grover and Makers Architecture and Urban Design
- 2005 Window Vibration Study, by Stickney Murphy Romine Architects
- 2007 Downspouts / Roof Drainage Schematic Condenser Pit Connections, SCL sketch
- 2010 Condition Assessment, by NW Archaeological Associates and KPFF Structural Engineers (included with this report for reference)

The report is organized by building components, such as exterior walls, roofing and drainage, doors and windows, miscellaneous metals and equipment, and exterior lighting. Within each sub-section, the building component as it exists is described, and apparent deficiencies, problems, or appropriateness to the period of historic significance are identified. This section of the report is supplemented by the reports included in the Appendix section.

SITE

The Steam Plant Building was originally constructed on the east bank of the Duwamish River in the Georgetown neighborhood of Seattle. When the river was straightened and diverted for navigation purposes, the building lost some of its historic site context. Historic context continues to be lost as sections of the site are sold or repurposed for other uses by surrounding property owners and tenants.

The structure is located at the north end of its approximately 2.61-acre (115,000 sq. ft) polygonal-shaped site. It is oriented about 45 degrees from the orthogonal north-south alignment (see the Existing Conditions Site Plan in the Appendix). The King County International Airport is located to the east, and a wetlands remediation zone is located to the south. Recent grading, paving and plantings along both of those sides have created conditions that direct ground water and storm runoff directly toward the building, in some cases directly to the interior.

There are a number of large shrubs and trees on the east and north sides of the building that are in contrast to the bare and service-oriented nature of the earlier functioning steam plant site. Many are overgrown and lack a sense of design or purpose, and warrant review in terms of function, appropriateness, visual effectiveness, and negative impact to the site, building and surroundings. (Comments, concerns and recommendations are further elaborated in the Cultural Landscape Report and attached Civil Engineering Report.)

Recommendations

No problems have been reported regarding underground utilities except storm water. Further information on site conditions and an up-to-date survey are needed to identify and resolve the specific problems contributing to the water inside the building. Additional survey information is needed to accurately assess site drainage patterns relative to the building finished floor elevations and develop designs to address the problems identified.

To provide SCL with a starting point to begin to address the water infiltration and drainage issues at the Steam Plant, we offer the following general recommendations:

1) To protect the building from further ground and storm water infiltration, regrading of the surrounding grade at the parking and drive aisles and adjacent to the building is strongly recommended, especially on the east and south sides. A drainage swale or perimeter tightline should be incorporated into landscape improvements to provide positive slope away from the exterior walls and door openings. Additional ground clearance should be provided below the corrugated metal panels to reduce the potential of water penetration into the building and rusting of the panels.

2) External downspouts should be repaired and provided with a positive connection to a functioning existing or new storm drains on all sides of the building. If a ground discharge is used, the discharge point should be graded to prevent standing water from accumulating or prevent drainage from flowing back toward the building.

3) Since the building is occasionally open to the public and operates intermittently as a museum, accessible parking and / or an accessible route to the building should be provided.

See also Section 3, Historic Preservation Treatments and Recommended Treatment for the Georgetown Steam Plant for further discussion on recommendations for site improvements and landscape treatments.

GENERAL OVERVIEW OF THE BUILDING

The massive Georgetown Steam Plant, constructed between 1906 and 1907, is composed of a reinforced concrete frame, with reinforced concrete walls and roof components. A small addition, also constructed primarily of concrete, but with hollow clay tile infill and a light-weight east end wall of wood and steel framing and metal sheathing, was completed in 1918. The main building is characterized by a Boiler Room on the south end and Engine Room on the north end, arranged in a T-shape, with the two large sections sharing a common wall. Each of the sections is topped with a roof monitor that provides additional natural light into the spaces—the Boiler Room rising approximately 69' at its tallest elevation, and the Engine Room rising approximately 82'. Even though concrete is generally considered a strong, permanent building material, it is subject to deterioration when poorly constructed, protected, or maintained.

From a structural perspective, the reinforced concrete building is in generally good condition with limited visible damage or failures. (See KPFF 2010 Condition Assessment and 2012 Addendum for further discussion and recommendations.) From an exterior envelope perspective, the building is in fair to poor condition, with failing exterior metal and concrete and coating surfaces, deteriorated door and window components, and significant evidence of water infiltration on the interior of the building from leaking roof surfaces and uncontrolled drainage issues. (See below and Wetherholt and Associates Roofing and Exterior Wall Condition Report 2012 for further discussion and recommendations.)

Figure 47: Example of coating cracks, concrete spalls and wood window deterioration.

The exterior concrete exhibits both large and hairline cracks and spalls and areas of delaminated coating, and the doors and windows have broken components and failing protective surfaces. These deteriorated conditions allow moisture to enter the walls, corroding reinforcing steel and metal attachments, and allowing migration to the interior of the building.

Figure 48: Example of vegetation on the building, biological growth and surface staining and deterioration.

There is biological growth on the lower surfaces where exposed to persistent moisture, and vegetation and plant growth are in close proximity to the concrete surfaces. This generally points to water infiltration, can hold moisture against the building surfaces, and also leads to surface staining. Organic debris and moss growth were also observed at the roof level and in the gutters and roof drains.

These and other exterior envelope conditions are further described below.

CONCRETE STRUCTURE

The building's structural system is largely composed of reinforced concrete supported on pile foundations. The lowest floor at the Ash Level is a reinforced slab on grade, and the upper floors and roof of the Boiler Room are also constructed of reinforced concrete, with deep roof beams and square or rectangular support columns. The north, Engine Room section, is a clear span without interior columns. The roof and floor of the 1918 addition is also concrete.

On the south and west sides of the building, windows are set into the punched openings in the concrete walls. These walls appear to be concrete filled, ascertained from the board forming and the crack patterns. The tall north wall appears to be hollow clay tile infill, parged on the exterior with stucco.

Recommendations

The structural recommendations below were provided by structural engineers, KPFF, and combine the recommendations from their 2010 report, the 2012 addendum to that report, and results of the 2012 Seismic Evaluation and ASCE 31-13 Tier 1 Report. It should be noted that since there is no proposed change of use, and no determination of Substantial Rehabilitation by the City of Seattle Department of Planning and Development, there is no code-based requirement for an Owner to address the seismic hazards, and any seismic mitigation work undertaken is considered voluntary. They are provided here as recommendations for the preservation of the structure.

- Restrict access to areas below the ash hoppers in the Boiler Room Basement; repair and/or mitigate the failed architectural and structural components
- Prevent water intrusion into the building from the exterior, including roof drainage repairs and concrete wall repairs
- Repair damaged and deteriorated metal fasteners and equipment hanger supports
- Stiffen wood and steel-framed east wall of the 1918 Addition
- Repair/certify fire escapes and south balcony; or restrict access
- Repair of wood-infilled stack opening in the SW Boiler Room roof.
- Repair masonry infill section and strengthen the South wall, which was determined to be in fair to poor condition
- Attach the concrete floor and roof diaphragms to the concrete walls, or verify existing attachments through radar or x-ray imaging
- Strengthen the columns along the wall that separates the Engine Room from the Boiler Room at the roof.
- Repair and strengthen the southern concrete wall.
- Add a line of lateral force resisting elements in the eastern portion of the Engine Room.
- Add braces at the clerestory windows where no concrete walls are present.

- Brace the clay tile walls on the north side of the building and at the Penthouse walls

These recommendations are not intended to improve the building's seismic performance to current building code requirements or compliance with ASCE 31 performance, but rather to mitigate the most critical deficiencies in an efficient, cost-effective manner.

EXTERIOR CONCRETE WALLS

The west, south, and majority of the east and north walls are cast-in-place concrete, with an evident horizontal board-form pattern, and relatively coarse surface texture. The texture appears to be the result of a thick plastic coating product called Vinalac 151, specified to be applied to a minimum of 16 mils dry film thickness. The formed concrete corners around the building, including pilasters, insets and punched openings have a smooth cast incised edge, approximately 1”x1” and inset approximately ¼”, which provides a finer scale of detail on some otherwise plain wall surfaces. Historic photographs of the building reveal that the wall concrete was poured in lifts. Many of the horizontal cold joints are clearly visible, particularly noticeable halfway up on the west and south facades. These joints do not appear to be caulked or sealed against water infiltration. Various cracks, from hairline to ¼ inch width can be found on each exposure, around the window and door openings, telegraphing from window head corners, and through concrete sills. Some of the cracks have been addressed previously, with cementitious or caulk-type sealants, while others, perhaps less accessible, remain untreated or are failing

Figure 49: Northwest corner of the Steam Plant, with a view of the west façade and a portion of the north façade.

Previous repairs, many of which are described in the 1985 Exterior Rehabilitation drawings, are evident as patches, or recurring, unremedied spalls. Some of the repairs have re-delaminated, and are projecting from the surface, and in some instances, the repaired areas poorly match the adjacent surface texture.

Figure 50: South façade, showing significant cracking throughout the wall areas.

Figure 51: Detail of south wall, showing horizontal cold joints, and various cracks treated with joint sealant.

Figure 52: Detail from the east wall, showing a previous patch that has delaminated again. Also visible is the typical incised corner detail.

Delamination of portions of concrete columns, pilasters and piers between windows is occurring on all facades of the building. In some cases, these same delamination can be seen in photos from the 1950s, such as those at the top of the north wall columns and adjacent to many of the monitor windows.

Figure 53: Detail of windows on the south wall. The concrete mullion is cracked and delaminating about an inch from the face of the wall.

Figure 54: Detail of east arched opening infill on the south wall, with mismatched texture.

The south concrete wall is in very poor condition, due primarily to weather exposure, corrosion of internal rebar, and poor construction of the masonry infill at two large arched openings, which previously served as flue penetrations for the original masonry stacks on the south end of the building. The texture and craftsmanship of the infills – including the formed concrete sections of a projecting coved cornice – are roughly finished and a likely source of water migration into the building. This is substantiated by the severe efflorescence on the inside face of the concrete wall, and long-term water ponding on the floor below. The water infiltration has also led to delamination and spalling of the concrete slab at the south end of the Boiler Room floor, and corrosion of metal anchors and attachments on the interior wall surface.

There is a repaired portion of the “No. 1” casting at the top center of the south wall, which has also previously contributed to water infiltration. Originally, this was a large, asymmetrically-located opening into the building to convey coal into the bins above the Boiler Room floor. When coal was no longer used to fuel the boilers, the opening was infilled with a temporary cover at two documented times before being restored with the current cast infill.

Figure 55: Detail of the "No. 1" casting at the top of the south wall.

Many of the horizontal skyfacing surfaces and the rounded water table band provide a condition where rain water splashes back onto vertical walls above and below, staining the surfaces and contributing to the collection of detritus and biological growth. These areas should be cleaned thoroughly, using the gentlest means possible, prior to new coatings.

Throughout the wall surfaces, multiple penetrations and projecting appurtenances such as threaded bolts left from previous attachments, vents, and drain pipe holes, can be seen in various locations. These should be evaluated for their functionality and contribution to historic character of the building, and if possible, removed to eliminate maintenance and susceptibility to water intrusion into the walls.

The exterior walls and windows at the roof monitors were covered with fiberglass panels in 1969. Temporary removal of eight of the panels reveal surfaces that are in very deteriorated condition, with loose, sandy concrete surfaces, cracks that reveal internal rebar, and large chunks of spalling material. Extensive use of a brittle cementitious patching material, black mastic, and miscellaneous caulk were used on the concrete around the windows and louvers at this level, prior to the installation of the fiberglass panels. These "repairs" were observed in pre-cladding photographs and during the recent investigation where select fiberglass panels were removed.

Figure 56: This undated photo shows an example of the extent of repairs to the monitor walls and windows prior to the installation of the fiberglass panels. (Photo courtesy of SCL)

Figure 57: Detail of Engine Room monitor wall with fiberglass panels partially removed. Note the mastic patching, the wood sills notched for the fiberglass support framing, and the framing bolted into the concrete.

Based on historic photographs and previous specifications provided by SCL, it appears that the concrete walls of the building were unpainted until 1969, when a vinyl plastic coating was applied to all concrete, stucco-clad masonry walls, some wood trim, and metal surfaces. Although not identified on the repair drawings and or in the specifications, observations on site reveal that the wood windows and doors are likely coated with this same vinyl plastic product. See Wood Windows Section for more detail.

Recommendations

Further testing should be provided to determine the best possible method to remove the plastic coating on the concrete and wood wall surfaces. Retention of this type of non-breathable coating will continue to deteriorate the concrete and wood surfaces on which it is applied and inhibit the efficacy of a newly installed breathable coating. The coating should be completely removed; all surfaces cleaned using approved methods and materials; and a new breathable coating, such as Tnemec Series 156 or 157 Enviro-Crete be applied.

Failed repairs and newer spalls should be removed and patched with appropriate methods and materials. All concrete surfaces should be sounded to confirm surface integrity and a good bond of the patched areas. Unsound areas should be repaired as necessary to retain the integrity of the wall surfaces and protect the internal reinforcing. Care should be taken to match adjacent surface texture and finishes. Cracks should be evaluated for cause, size and condition, and a program for repair – epoxy or urethane injection in larger cracks, and sealant in hairline cracks. In the larger cracks, the use of sealant is not recommended as it is prone to failure and periodic maintenance is required.

In some instances, especially around window openings, large areas of delaminated concrete should be removed and replaced in combination with the window rehabilitation. Consideration should be given to the use of cathodic protection or surface applied migrating corrosion inhibitor to slow on-going corrosion for the repairs of these large spalled areas. This method uses a direct current to restrict further corrosive action of the concrete through the use of a sacrificial anode inserted into the repair areas. This method has the advantage of allowing more of the existing materials to stay in place.

Conditions at the south wall require more extensive repairs, due to the lack of integrity of previous infills from earlier conveying and exhaust equipment. The arched masonry infills should be removed and replaced with structural material, the previous crack and patch repairs should be removed and replaced, and loose concrete at the failed window mullions should be replaced.

Removal of unused / abandoned penetrations, appurtenances and equipment, especially those that already exhibit deterioration rusting and failure, should be considered in light of the historic significance of each element. Significant items should be retained and repaired / treated as necessary, using approved materials and methods, and left in place.

Removal of all or select areas of the fiberglass panels should be considered and evaluated, but only in conjunction with the scope of the window rehabilitation. The panels were likely installed in 1969 as a less-expensive stop-gap measure to protect the monitor windows, in lieu of repair and restoration. Successful removal of the panels will require extensive concrete surface repairs, as well repairs and / or replacement of many of the windows and openings presently covered by the panels.

EXTERIOR CORRUGATED METAL SIDING AND ROOFING

The east and south walls of the 1918 Addition are framed with wood and limited steel framing, and clad with corrugated steel panels, measuring approximately 2' wide by 8' tall, with exposed fasteners. The lower 16' of wall is sheathed with building paper at the inside face. The drawings for the 1918 Addition indicate that the eastern wall of the original Engine Room, including the framing, cladding and windows, were to be disassembled and moved to the new wall location, approximately 37' east, but it is unclear from a review of the existing openings and framing if the wall materials were relocated or new materials were provided. Construction drawings and specifications from 1985 indicate that the corrugated metal siding and roofing were to be replaced as part of that scope of work.

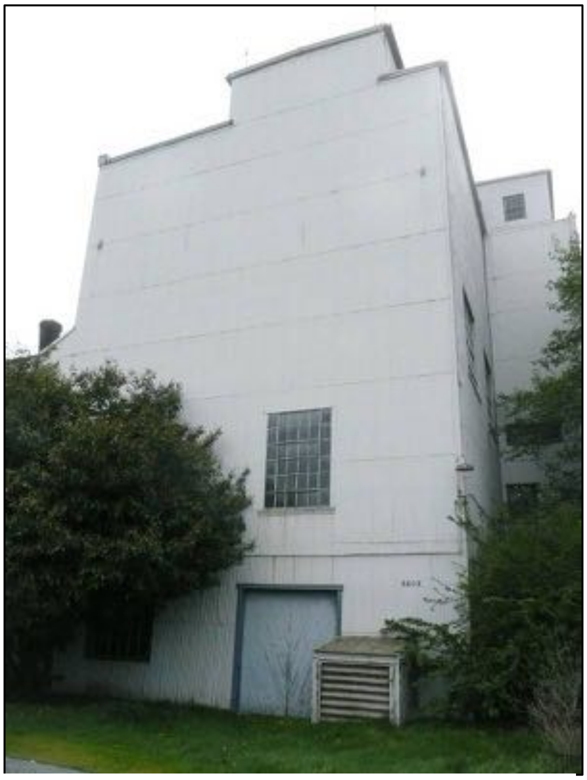


Figure 58: East wall of the 1918 Addition with corrugated metal cladding.

Figure 59: East and south walls of the 1918 Addition with corrugated metal cladding.

In many locations, the corrugated steel extends 1”-2” into the dirt at grade. No significant rusting or deterioration is apparent from the exterior, but the east-facing wall is noted in the 2010 Condition Assessment to be a source of water intrusion, potentially due to this detail. Water infiltration is compounded by grades around the building, which slopes toward the building, especially on the east side, which is adjacent to the airport runway and security fencing. The 1985 construction drawings also note to “replace sole plate” and “scab on to bottom end of exist. stud using preservative treated material” on the east and south corrugated metal walls, indicating the water migration into the building at this location may have been a longstanding condition. These walls are currently covered with building paper on the inside face, so the noted repair was not confirmed. During investigation from the high-lift, details of the lapping metal around the steel windows were observable. The configuration poorly protects the window openings from water intrusion, and is reliant on caulking in various window head locations, which is failing in many instances.

Figure 60: Detail of lapped flashing at steel window depends on caulk for water protection.

Recommendations

The corrugated metal roofs should be removed and replaced in-kind with new corrugated metal roof panels using concealed fasteners, if possible. New surface mounted or inset roof-to-wall flashings should be installed, in place of the existing lapped conditions. A fabricated sheet metal diverter flashing should be incorporated into the new roofing assembly at typical eave-to-rising wall interface with the column bump-out on the east elevation. Penetrations should be repaired where rusted through and properly flashed. Sealant and flashings should be replaced at the corrugated metal siding east wall where steel crane rails project through.

EXTERIOR STUCCO-CLAD HOLLOW CLAY TILE

The north wall of the 1918 Addition is framed with two bays of concrete, mimicking the original Engine Room structure, infilled with hollow clay tile and clad in rough-textured stucco on the exterior. The walls of the Penthouse above the Gallery are similarly constructed and detailed. On the large north wall, delamination of the stucco occurs vertically along up the middle column and the full height of the easternmost corner. Previous repairs are evident, but it appears that the surface repairs did not address the underlying causes. The western pair of the two high steel windows on the north wall has a visible bow in the mullion and frame, indicative of settlement/lack of support. There appears to be a concrete bond beam header, but the underlying cause should be evaluated by the structural engineer to determine a course of action.

Figure 61: Detail of northeast corner of the 1918 Addition, with corrugated metal and stucco-clad hollow clay tile. Delamination of the stucco is evident at the corner.

Figure 62: Looking southwest toward the north wall of the 1918 Addition, with stucco-clad hollow clay tile.

At the Penthouse, significant cracks are evident below the windows, indicating likely water migration through the deteriorated wood sills and into the masonry walls below.

Recommendations

In conjunction with the structural strengthening of the hollow clay tile recommend, loose parge coating should be removed and replaced, textured to match adjacent surfaces, and coated with new breathable coating. See Steel Window Section for recommendations on damaged windows in this location.

ROOFING AND DRAINAGE

Built-up Roofing

The coal tar pitch roofing and drainage details were upgraded in 1983-85, according to drawings and specifications from the SCL Archives. The drawing details and specifications appear consistent with existing conditions and configurations at the parapets, embedded metal eave flashings, gutters and downspouts. It does not appear that the 1" insulation board identified on the main roof areas in those drawings was installed as shown. Deterioration of the embedded metal eave flashings has allowed water to seep under the membrane, wetting the underlying fiberboard at these edges, and indicating a path of water infiltration.

The roof thickness at the roof monitors and east side of the main Boiler Room are thin – only slightly thicker than the 5" thick concrete roof deck that projects beyond the face of the wall. These edges typically have side-mounted sheet metal gutters and external metal downspouts. The north and south sides of the main Engine Room roof and west side of the main Boiler Room roof have low parapets, projecting approximately 12" above the height of the deck, and are capped with a painted standing seam sheet metal coping/counterflashing. These are generally poorly detailed and constructed, and exhibit many areas of failure or potential failure.

Figure 63: Detail showing the "low profile" eave gutter roof at the Engine Room monitor roof at left, and the raised profile of the parapet at the northwest corner of the Engine Room at right.

Roof Drainage

The Engine Room and Boiler Room monitor roofs both have embedded metal eave flashings with gravel stops and eave gutters, with external downspouts that empty onto splash blocks on the main roofs below. With a few exceptions, these appear to date from the 1969 scope of work. At the main roofs, the integral gutters, which were originally cast into the concrete roof slabs, have been infilled on the north and south sides of the Engine Room, and the west side of the Boiler Room. The revised roof drains function poorly at some locations, because of lack of slope between drains and accumulation of debris in the drain openings. Ponding water was evident at the edge of the roofs in the swale behind the parapets and at the shallow swale formed at the built-up edge of the embedded metal eave flashings.

On the east side of the Boiler Room roof, where there was no raised parapet originally, the original integral gutter has been infilled with concrete, and the roof drainage collected in an eave-mounted sheet metal gutter and external downspouts. These downspouts have become disconnected in some instances, resulting in water discharging directly to the ground below.

Figure 64: Typical roof monitor downspout and splash block draining onto the main Engine Room roof.

Figure 65: Detail of water ponding in the shallow swale at the edge of the embedded metal eave flashing, atop the Engine Room monitor roof.

Where eave gutters have been added to the building with embedded metal eave flashings and gravel stops, the gravel has overrun the gravel stops and collects in the gutters, which is likely a contributing factor to leaking or failing gutters.

The southwest corner of the main Engine Room roof has an interior drain that exits onto the roof of the Boiler Room at the wall between the two wings. The drain pipe turns out, and has been retrofitted with a 3"x4" corrugated downspout section which extends to a down-facing elbow over the west parapet edge of the Boiler Room, and freefalls approximately 60' to grade.

An available drawing dated 2007 provided by SCL indicates roof drain deficiencies, and a potential scope of repair. Per SCL, all of these repairs were undertaken in that year, with the exception of an internal leak on the horizontal drain line along the west wall of the Boiler Room, which currently has a sheet of plastic beneath to collect leak water, and has routed it to a ¾" garden hose for drainage conveyance.

Figure 66: Roof drain leak catcher at the west side of the Boiler Room (photo by Wetherholt and Associates)

Recommendations

The current roofing and drainage conditions were observed and evaluated by the architectural team, the envelope consultant, Wetherholt and Associates; the mechanical engineering consultant, Coffman Engineers; and the hazardous materials consultant, Argus Pacific. The recommendations below are a comprehensive list, and are discussed in greater detail in the consultant reports included in the Appendix.

The roof drainage system should be addressed immediately to prevent further water infiltration into the building. All existing roof drainage piping (interior and exterior) should be cleaned and repaired, except for those on the east side that are no longer in use. When the roofing is repaired or replaced, all roof drop drains that are in service should be replaced with new low-profile cast iron drains with flashing and gravel guards cast into the concrete such as Zurn Model Z100 or equal by JR Smith, Wade or Josam, and all drain lines should be tightlined where they extend into the building. Ideally, each primary drain should have an overflow, such as an adjacent scupper that extends through the parapet wall, but this recommendation needs to be reviewed in terms of the effect on the character-defining features of the structure.

The galvanized roof drain piping at the east side of the Engine Room should be replaced with cast iron pipe, the exterior wall penetration sealed, and the piping connected to the existing storm pipe below grade. The condition and routing of the subgrade storm lines should be verified before connecting new roof drainage. Open drains or clean-outs at grade should be plugged.

On the interior, the leaking horizontal pipe on the west side of the Boiler Room should be replaced, and new equipment hangers should be installed. It is also recommended that a hydrostatic test be performed on all of the roof drainage piping to identify and repair any other leaks that may not have been identified by the tenant or as a result of this survey.

Testing and evaluation of the existing roofing revealed that it is likely that the current roofing, copings and flashings were installed in 1983 by Emerald City Roofing. The existing, 4-ply built up roofing with Koppers Multipurpose Membrane (KMM) flashing, is in fair condition. Two options for treatment are provided here. The first option is to replace the low slope roof areas by removing the existing roof assembly and installing a new Styrene-Butadiene-Styrene (SBS) or Atactic Polypropylene (APP) modified bitumen system with new flashings and copings. A more economical approach may be to retain the existing field roofing in-place and provide new membrane base flashings, penetration flashings and sheet metal counter flashings. If the latter approach is taken, installation of fluid-applied membrane flashings would be beneficial at drains, roof-to-wall transitions, embedded edge metal and penetrations as needed for a weather-tight assembly. For improved drainage, it has also been suggested that the low perimeter edges and gutters on the north and east sides of the building be replaced with a slightly higher parapet and sidewall scuppers, utilizing crickets between the scuppers for drainage. Coping metal would replace the embedded edge metal, providing a functional long-term roofing application. While this is a preferable weatherproofing detail, this modification may have an adverse effect on the character-defining features of the building and needs to be carefully considered.

In many instances, the existing sheet metal flashings and copings are failing or poorly detailed and installed. They should be replaced as part of the comprehensive reroofing / repair project, and proper end cap flashings, wall termination flashings, and counter flashings provided to prevent continued water intrusion. Gutters should be cleaned and evaluated for slope toward the drains, and realigned to provide a positive slope and prevent ponding or standing water in the gutters. New external downspouts should be provided with tightline attachments to the subgrade piping, or provided with splash blocks that direct water away from the building walls and surfaces.

Where pitch pockets exist for the attachment of equipment on the roof, consideration should be given to their replacement with liquid resin membrane with reinforcing fabric, or modification of the penetrations to allow for the installation of lead flashings.

Note: Hazardous materials have been found to be present in the roofing materials and necessary precautions should be taken for remediation during any reroofing or repair work.

ROOF ACCESSORIES (EXHAUST STACKS, LADDERS, RAILINGS, VENTS, AIRPORT OBSTRUCTION LIGHTING)

The rooftop exhaust stacks and vents contribute to the industrial character and understanding of the function of the facility, while the ladders and railings provide accessibility and some level of safety for roof maintenance. The eight black exhaust stacks date from ca. 1939, when the original masonry stacks on the south end of the building were removed as part of FAA flight path mitigation. The access ladders to the various roof levels were replaced in 1984, according to SCL Archives drawing #D-20068. Painted steel angle railings, attached to large steel base plates in pitch pockets, are present on the east and west sides of the main roof of the boiler wing. The north end of the west railing is not attached to the terminating wall.

Figure 67: Steel angle railing on the east side of the Boiler Room roof, with steel mounting plates and pitch pockets.

Most of the miscellaneous exterior accessories and components are typically in a deteriorated state of repair, suffering from lack of maintenance and finish coatings. Components are rusted, in some cases through the base metal, and create a risk of water intrusion into the building, or at a minimum, ponding inside the equipment. Many of the attachments to the building are failing due to rusting and material expansion and also result in spalled areas of the concrete at the horizontal and vertical surfaces.

Recommendations

The metal should be repaired or replaced where eroded beyond repair, surface prepared, and painted. Asbestos paint coatings have been found on the large black exhaust stacks and adjacent vent stacks. Some of the equipment is provided with cable stays, secured to the roof, and terminated with pitch pockets. Pitch pockets are also used at the base of various penetrations and roof attachments. These pitch pockets should be replaced with a proper flashing to reduce risk of water infiltration.

Figure 68: Detail of exhaust vent where the sheet metal has rusted through, providing access for water and pests.

Figure 69: Eliminating penetrations where feasible due to disuse, and if not deemed character-defining features, will serve to protect the structure from further deterioration and reduce maintenance.

At the direction of SCL, the existing airport obstruction lighting at the south, east, and west ends of the building, and their associated cable stays are beyond their service life and should be replaced.

Review of fall protection and tie off requirements is beyond the scope of this report, but may be something that SCL wishes to consider for ongoing maintenance of the building.

WOOD WINDOWS

At the Steam Plant, the pivoting wood windows are a prominent feature of the west and south facades. The punched openings serve to characterize the board-formed concrete and provide tall, vertical elements in the otherwise strong, horizontal massing of the industrial structure. Additionally, the windows allow ample light into the Engine and Boiler Rooms, and provide a means for ventilation into the spaces.

This survey evaluated the overall condition of windows, doors and louvers that were accessible and visible to the project team. The wood windows, of which there are approximately 158, typically contain true divided lights and consist of a combination of double-hung, casement, center-pivot, and fixed sashes.

The primary issues with the overall deteriorated window condition are likely due to lack of periodic maintenance. Little to no paint is remaining on many of the wood sash and frames, and the glazing putty and sealants around the windows is in very poor condition. It also appears that a non-breathable elastomeric coating was applied in a continuous coating over concrete wall surface and the wood window components, in an attempt to achieve a weathertight enclosure. This resulted in moisture being trapped behind the coating and deteriorating the wood surfaces and the coating product. The wood surfaces have peeled the majority of their paint to bare wood, exposing the grain to the weather. This has resulted in raised grain and checking, most notably on the wood sills, and the bottom rails of both upper and lower sash where they occur. Many instances of loose or failing joints between the bottom rail and stiles are evident, some having been repaired with surface-mounted steel strapping. In some cases, the muntins of the true-divided sash are no longer properly attached or aligned, causing the glass to be loose in the openings, out of square, or cracked.

Figure 70: Detail of a window on the west facade, with little remaining paint, missing glazing, missing caulking, and previous repair at the bottom rail of the lower sash.

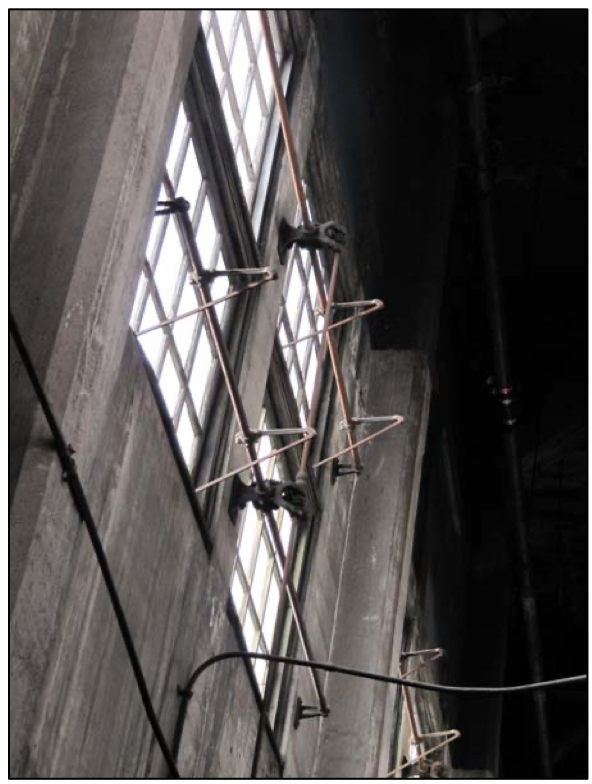
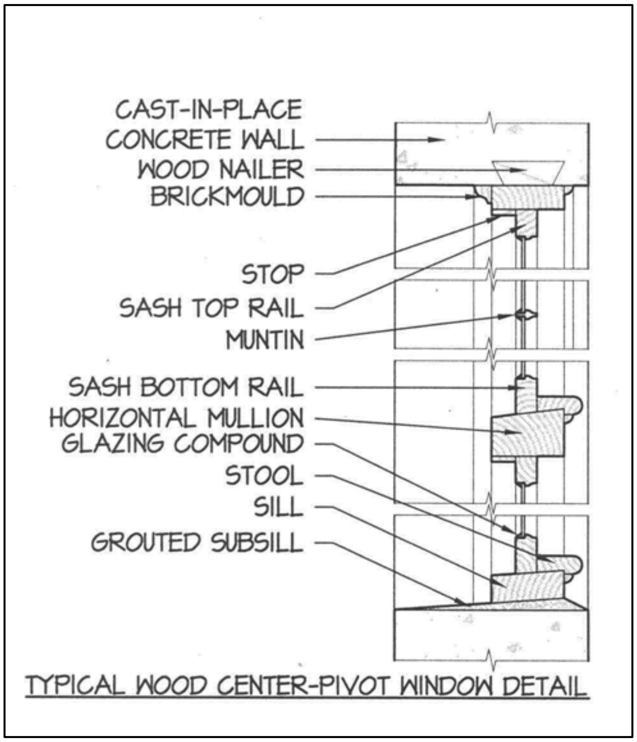


Figure 71: Interior detail of wood pivot window and internal operating mechanism.



The glass at the first floor windows has all been replaced with ¼" wire glass, as noted on construction drawings from 1985. Much of the glazing compound (presumably installed at that time) has failed by cracking, or delaminating from the adjacent muntins and frames. Glazing points were observed on one window where significant amounts of the glazing compound were missing. Over time, the glass appears to have been replaced with modern plate glass, and using a variety of glazing compounds and craftsmanship. Asbestos testing confirmed, or assumed at inaccessible locations, that nearly all the wood window glazing compound contains asbestos. (See Hazardous Materials Report in the Appendix for additional information.)

Figure 72: Detail of the sill of a ground floor window, with open grain, checked sill, and loose joint at the stile/bottom rail.

The window details in the original construction drawings indicate positive drainage away from the windows by means of either built-up parged sills, or sloping of the rough openings. In practice, it appears that some of the window openings exhibit flat, or even backsloping sills, contributing to the water migration to the interior, and rot of the sills. Two unique instances were observed on the south facade windows. At one, a cementitious "canted dam" was applied between the leading edge of the wood sill and the concrete sub sill, presumably to keep water on the concrete sub sill from backing up under the wood sill. In the other case, a smooth troweled slope was extended from the leading edge of the wood sill to the leading edge of the concrete sub sill, but water can still enter the gap between wood and concrete.

Figure 73: Detail showing existing window sill retrofits. The foreground window has a cementitious cant at the edge of the wood sill, and the background window has a newer sloped sill, which butts into the leading edge of the wood sill.

The majority of windows at the Engine Room and Boiler Room monitors were covered with corrugated fiberglass panels in 1969 (see Drawing D-25402). To assess the condition of the windows, some of the fiberglass panels were removed on each facade in 2012. The original installation of the fiberglass panels resulted in significant damage to the existing windows in the process of installing 2x4 nailers. Existing wood sills projecting beyond the face of the concrete were either sawn off flush, or notched to receive the vertical 2x4s. Some sills have been clad with lead flashing, presumably at an earlier time to remedy water infiltration. Many unsympathetic stop-gap measures were employed to repair these exposed windows over time, from cementitious patching around the rough openings and on the wood frames, to mastic applied to sash, frame, and glass cracks. The Engine Room monitor windows as visible from the interior of the penthouse show fastener holes, where the gear-driven crank operator was installed, but this was likely removed during the fiberglass paneling scope in 1969. Photographs provided by SCL which date from before the installation of the fiberglass panels show extensive deterioration and previous repairs to the concrete and windows with mastic and cementitious materials, seeming to indicate that it was not cost effective or feasible to holistically repair the monitors.

Figure 74: Detail of one of the roof monitor windows, on the south side, showing evidence of previous repairs and waterproofing attempts, including parging over the wood frame, and mastic applied over the frame and glass.

Figure 75: Some monitor window sills retain their original lead covers. In some instances, the wood sills and lead covers were notched or sawn off entirely in order to install the wood framing for the protective fiberglass panels.

Select wood windows and louvers in the lower walls were covered with flat fiberglass panels in the 1969 scope of repairs (Drawing D-25402), and were later removed in the 1985 Exterior Rehabilitation.

Recommendations

The wood windows on the west and south sides of the building at the Georgetown Steam Plant are the significant character-defining features. As such, it is important that their design, original features, and configuration be respected, retained and rehabilitated. To that end, the architectural team has started a window survey that will be utilized to generate the final scope of repair work. In general, if the units can be repaired rather than replaced, that is the preferred alternative. If the degree of deterioration is so severe, replacement of damaged elements or an entire unit may be warranted.

It is apparent that uncontrolled moisture and lack of periodic maintenance has been the primary cause of the poor condition of the wood windows. The repair methodology should include treatment of open cracks and joints, replacement of glazing putty, addition of a drip line at the underside of the wood sills (if none exists), repair with consolidation products or replacement in kind of severely deteriorated wood sash and frame members, weatherstripping, and new protective primer and top painting coats. If determined necessary, fungicide and wood preservatives may be considered for application during the repair process.

In addition to the exterior repairs, each window should be evaluated for operational soundness and functionality. The need for operability and the ease of operation should be considered.

In many locations, the window frames and sills are also damaged or deteriorated. Consideration should be given to providing appropriate and maintainable details to reduce the risk of water entry into the window and building. This may include a revised sill design and removal of the window frame to properly flash and seal the surrounds. Complete removal of the window sash and frames will allow for the repair work to be provided in a controlled, shop environment, while comprehensive repairs can be made to the surrounding deteriorated concrete openings along with installation of new flashings and sealants.

<u>STEEL WINDOWS</u>

For the most part, the steel windows appear to be in good condition, with minor rusting on exterior surfaces due to weathering and deteriorating paint finishes. Those observed were operable. The two sashes at the ground floor (east and north facades) were called for replacement in 1985. They are also not consistent in size / material with those described in the 1918 Addition drawings, indicating either a field modification during construction, or later replacement. Flashing details at the corrugated metal are not ideal in some instances, requiring dependence on caulking rather than positive drainage from lapped materials to prevent water intrusion. The western pair of the two high steel windows on the north wall exhibits significant bowing in the mullion and frame. Glazing putty is at the interior of window sash, and appears in good condition.

Figure 76: Steel window with bowed frame set in a stucco-clad hollow clay tile wall.

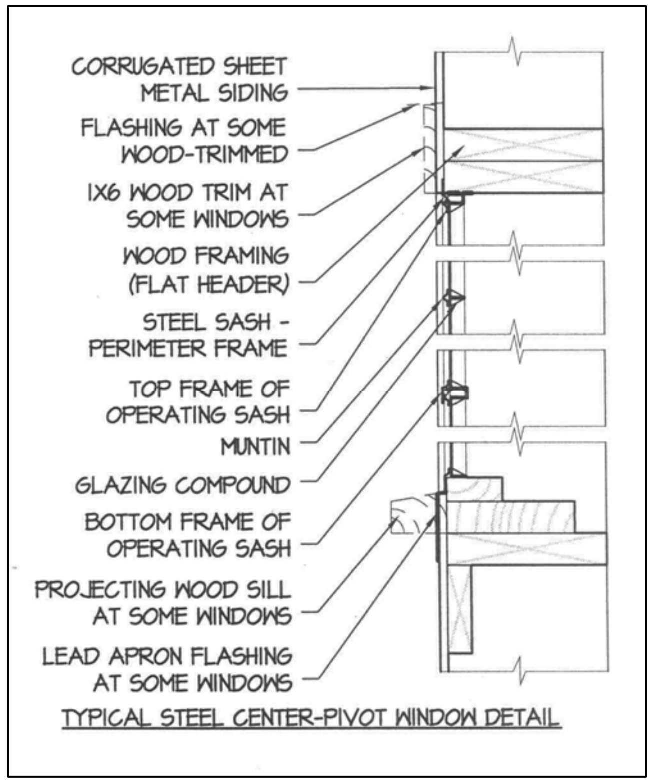


Figure 77: Detail of a steel window, with rust on the frame at the bottom, and a cracked concrete sill.

Recommendations

The limited number of steel windows in the Georgetown Steam Plant characterize the north and east facades of the 1918 Addition. For the most part, the steel windows on the east appear to be in fair condition, with minor rusting on exterior surfaces. Flashing elements are poorly installed and some parge-coated sills are in need of repair. In all locations existing sealants should be removed and replaced, and weatherstripping should be installed at the operable sections and around the window perimeters on the interior.

Preservation should be the first consideration in a rehabilitation project, but the steel window frames on the north elevation of the 1918 addition are severely deflected inward and rusted. The cause of the deflection has not been ascertained at this time, but alternatives (repairs, replacement in kind, or replacement with a substitute material) should be considered in conjunction with the proposed structural improvements at the hollow clay tile infill walls and the wood and steel framed construction of the east wall. A potential cause of the bowed sections should be determined prior to treatment.

In order for the windows to remain, corrosion should be treated using mechanical abrasion or chemical application; surfaces repaired using appropriate filler; surfaces prepped, primed and repainted; and operability assessed. Broken glass should be replaced in-kind, and a steel-sash specific glazing compound should be installed. Conditions that allow excess moisture to accumulate or be held against the steel surfaces should be mitigated, and a routine maintenance program developed and followed.

SHEET METAL LOUVERS

Drawings from the 1985 scope of work indicate that the louvers on the south and west facades were fitted with painted sheet metal blanks at the inside, and this was observed at the south elevation louvers. Aside from a need for paint, the louvers appear in good condition.

Figure 78: Detail of louvers in the south wall.

Recommendations

Most of the steel louvers at the Steamplant are integrated into the character-defining fenestration patterns on the building's west and south facades, and should be retained. Records indicate that metal panels were installed behind the large louvers, rendering them non-functional. The louvers should be retained, perimeter edges caulked and sealed, and new coating applied.

<u>WOOD DOORS</u>

Large double doors with glazed panels and decorative diagonal inset panels exist on the south and west facades of the building. In most instances, the doors that exit from the Ash Level / Basement and the Boiler Level have retained their original detail and hardware, based on a review of the original drawings. Those on the west side include small inset doors in the bottom panel of select doors. Various attachments can be seen in the concrete jambs, the function of which is no longer evident. Over time, wood elements particularly on the frames have been cut out and replaced with "Dutchmen" pieces, likely due to water damage, or damage from equipment going in and out of the building. Many structural repairs have been made to the door leafs themselves, with large horizontal steel straps bolted across the faces of the rail elements. In most cases, the latch hardware is in place, but was not verified in this survey for functionality.

Similar to the wood windows described above, it appears that an elastomeric coating was applied in a continuous coating over both concrete surfaces and the wood doors and frames, possibly to achieve a weathertight enclosure. The coating has encapsulated moisture in the existing wood, and has subsequently debonded and peeled away, leaving extensive paint blistering and bare exposed wood on most elements of the doors.

The thresholds of the doors are generally sloped concrete, some with a step at the face of the door to help restrict water entry.

Figure 79: Detail of the large door from the west side of the Engine Room.

Figure 80: Detail of the eastern door on the south façade.

The ten one- and two-panel wood doors that provide access from the main roof of the Boiler Room to the fan rooms were clad with 3/8" plywood in 1969. The door retrofit included an aluminum drip flashing, sandwiched into the bottom of the door between the original door and plywood. The plywood panels and door hardware are in poor condition. Most of the paint is missing, and the panels are not well affixed to the original doors. The original door handles were modified to accept the plywood, and are no longer functional, relying on hasps to secure the doors. There is no weatherstripping around the openings, and many of the doors do not fit tightly.

Recommendations

Like the wood windows, the wood doors provide significant character to the building exterior. Where feasible, all original wood elements should be repaired. Only if deterioration is beyond repair should replacement parts be installed. Perimeter sealants should be replaced and areas of spalled or deteriorated concrete at the punched openings should be repaired as part of the comprehensive door, window and exterior envelope repairs. Treatment recommendations are similar to those provided in the wood window section for evaluations, repair methods and materials, and operability.

Functionality could not be verified on any of the doors or hardware except the main entry door into the Turbine Room, and the doors at the roof level, as the large wooden doors are chained shut, ostensibly for security reasons. If it is the owner's wish to have these doors made functional once again, appropriate measures for security and weather protection must be made.

If public access and accessibility is intended through these doors, a fairly simple retrofit of concrete entry pads overlying the existing stepped sections could be added.

SOUTH BALCONY AND STAIR

There is a steel-framed and wood-decked balcony and stair at the south façade of the building. The deck boards are severely deteriorated and need to be replaced. There are missing pipe rail elements on the south edge, and the support steel is rusted to the point that it is jacking free of the wall at the brackets around the bull nose cornice band.

Figure 81: South balcony and stair with deteriorated wood decking and attachments, significant rust, and missing pipe rail elements.

Recommendations

Though a relatively small element on the south façade of the building, the balcony and stair are original to the building and are character-defining features. They should be documented and removed in their entirety for restoration to properly repair the salvageable elements, replace irreparable elements and to verify attachments. In-kind replacement of the missing components will not provide a code-compliant guard and handrail for public use, so if the building use changes, direction from SCL will be needed to address the code compliance of the balcony and stair elements.

EXTERIOR SHEET METAL AND METAL FABRICATIONS

The exterior facades of the Georgetown Steam Plant contain numerous metal equipment attachments, conduits, electrical connectors – some still functional, others abandoned. The exhaust and intake ductwork, fire escapes, and miscellaneous metal fabrications all contribute to the industrial character and understanding of the function of the facility. However, most are typically in a deteriorated state, suffering from lack of maintenance and finish coatings. Metal components are rusted, in some cases through the base metal, and create paths for water intrusion into the building at exterior cracks and spalls and around inadequately sealed penetrations. The attachments to the building are susceptible to spall and failure due to rusting and material expansion.

Figure 82: Metal exhaust duct and rusted, deteriorating attachments and support structure on the west side of the Engine Room.

Recommendations

The metal elements should be evaluated for historic or architectural significance and functionality, and either repaired or removed as determined appropriate. Metal items to remain should be repaired or replaced where beyond repair, surface prepared, and painted. Penetrations should be properly caulked.

EXTERIOR LIGHTING

There is limited exterior lighting on the building, but what does exist may be impacted by the scope of any envelope restoration and repairs at the roof level, at the concrete surfaces, and at the metal-sheathed walls. The existing fixtures appear to be original to the building and can be retained if refurbished and rewired. Obsolete and nonfunctional items should be replaced with appropriate fixtures for aesthetics, safety, and lamping consistency.

Figure 83: Exterior light at the northeast corner of the 1918 Addition, which is on in the middle of the day.

Recommendations

Refurbishment of decorative and security lighting is recommended. Any new fixtures should be historically appropriate. Depending on the use of the building and the desires of the SCL and the building tenant, the new and retained fixtures could be put on a photo sensor or time clock for added security and ease of operation. Building lighting could be tied in with existing or new site lighting.

BUILDING INTERIOR

The interior of the steam plant has two distinct portions – the Engine Room (the north wing) and the Boiler Room (the south wing). Each was designed for efficiency of operations. The large expanse of the Engine Room contained three steam turbines and the electrical gear to allow the plant to transmit power, located on a series of five gallery mezzanines at the northernmost end of the building. A 50-ton crane on tracks is supported on haunched concrete columns, 54' above the floor below.

The Boiler Room contains three levels: The coal pocket at the top stored coal, which was then gravity fed to supply the boilers on the level below. The boiler level contained two bays of eight boilers each, on the east and west sides of the floor, with an open area between, and small service areas behind, adjacent to the exterior walls for maintenance access. Below the boilers were a series of 16 ash hoppers to collect the spent coal ash, which was removed via carts run on rails embedded in the ash level/basement slab.

Many of the ash hoppers, visible from the ash level / basement, have been removed, leaving exposed and falling brick masonry holes in the floor. This presents a life safety hazard, as addressed in the Structural Condition Assessment from 2010. Drawings from 1952 show details of timber shoring designs to support the hoppers, but it is unclear whether this work was undertaken before or after the majority of the hoppers was removed. At present, seven of the hopper openings on the east side have a steel-framed, corrugated steel deck beneath, to prevent damage from falling debris. A similar wood-framed platform has been installed under three of the removed hoppers on the west side. Three of the remaining hoppers have timber-framed shoring, similar to that shown in the 1952 drawings, and three are unmitigated.

Recommendations

The remaining ash hoppers provide a visual understanding of the process-driven architecture of the building, and should be stabilized and maintained for interpretation.

BUILDING HEATING AND INTERIOR LIGHTING AND FUSE PANELS

As part of the condition survey, Coffman Engineers also included a cursory review of the electric steam boiler and the unit heater system. Both are in good condition, requiring limited repairs. The recommendations are as follows:

- The surface corrosion should be removed from the cases of the heating equipment, and the exterior and accessible areas inside of the boiler should be primed to minimize further corrosion.

- A qualified boiler contractor or the original manufacturer's representative should examine the boiler to confirm that there is no hidden interior problem. Boilers should be serviced to optimize operation. The missing access panels should be reinstalled.

The existing fused panels have glass covers, which if damaged or broken could result in exposed bus bars and could pose a shock hazard. Two options are recommended: 1) replace glass doors with non-breakable acrylic covers; and 2) de-energize the existing fused panel and replace it with a new panelboard, with existing circuits cut over to the new panelboard. The Fused Panels are original to the building and should remain for historic integrity. Changes to the panels, including decommissioning and feeder modifications, should be sensitive to their historic character, and a suitable location must be found if they are to be relocated. Care should be taken to minimize the use of new materials or conduits if needed, and should be reviewed for compatibility with the historic character of the adjacent original equipment. The Fused Panel should remain for historic integrity.

The existing lighting controls are switched by knife switches in fuse panels. This switching method poses a hazard of shock and arc flash from regular operation. It is recommended that a contactor be provided in the fused panels, with an adjacent light switch to operate lights and prevent regular exposure to live parts.

LIMITED BUILDING CODE REVIEW (2009 Seattle Building Code [SBC])

It is beyond the scope of this project to complete a full building code assessment for compliance with the existing building and site. However, a cursory review of issues related to life safety are considered here as part of the project, as they pertain to existing and potential occupancies, egress, and public access. Our understanding of the proposed scope of work would exempt the project from full code compliance in accordance with SBC Section 3404.8, as the work would not amount to substantial alteration or repair.

Occupancy (SBC Chapter 3)

We have been unable to determine if the building, or parts thereof, is currently permitted for use as a Museum (A-3 Occupancy) from records available at DPD, but given it has functioned as such for the past 15 or more years, we will evaluate it accordingly with regard to public access and safety and universal accessibility. Under the current code, portions of the building inaccessible to the public would be categorized as an F-1 Occupancy. We do not anticipate that the scope of work for this project would require a permitted change of use.

Means of Egress (SBC Chapter 10)

Currently, portions of the building serve as a museum, with limited guided tours of the public spaces. According to Ted Snyder, the accessible areas are typically limited to the Engine Room floor, the Boiler Room floor, and some of the catwalks across the Engine Room.

In most cases, stairs and railings are not compliant with requirements for public access, due to inadequate stair widths, size of landings, open risers, excessive opening sizes in railings, and discontinuous handrails.

Means of egress / fire escapes on the northwest and southwest sides and the South Balcony should be evaluated for necessity. If determined to be part of a fire and life safety pathway, the Seattle Fire Department Administrative Rule 9.02.09 requires regular testing and certification of certain fire and life safety equipment, including fire escapes, which must be Confidence Tested and Certified every 5 years.

Plumbing Fixtures (SBC Table 2902.1)

There appears to be only one restroom in the building, in the northwest corner of the Engine Room on the ground floor. A small single occupant restroom is shown on the original construction drawings in the northwest corner on the Wire Room floor of the gallery, but it was not located during this survey. A portable sanican is located outside, at the south east corner of the building, which is kept locked.

<u>LIMITED ADA/ACCESSIBILITY REVIEW (ICC/ANSI A117.1-2003)</u>

The Department of Justice (DOJ) Title III Regulations of the Americans with Disabilities Act requires public accommodations to provide goods and services to people with disabilities on an equal basis with the rest of the general public. The regulations require that architectural and communication barriers that are structural must be removed in public areas of existing facilities when their removal is *readily achievable* – in other words, easily accomplished and able to be carried out without much difficulty or expense. Several checklists are publicly available and would provide a good starting point for a comprehensive ADA compliance review, if SCL determines the current and future use to require upgrades for public occupancy.

The Georgetown Steam Plant's unique character and remaining industrial features were clearly designed for use by able-bodied workers. Today, with the building's use as a museum / interpretive facility for access by the public, minimal clearances, steep stairs, elevation changes, and proximity to hazardous high voltage equipment require careful negotiation of the spaces.

It is understood that guided tours of the building are offered, taking visitors through the main floor of the Engine Room, up to the Boiler Room level, and across the catwalks of the Engine Room to the Turbine Room (1918) at the northeast corner of the building. While it is beyond the scope of this condition assessment to provide an exhaustive inventory of deficiencies associated with access and means of egress, general issues to consider are listed below. If SCL pursues further interior modifications to improve access to public spaces, a more detailed review and assessment will need to be completed.

Accessibility Deficiencies to Evaluate

Routes to and through the building:

- No designated accessible parking was observed near the building
- Large ballast gravel driveway is unstable surface
- Door widths
- Door hardware
- Thresholds
- Vertical circulation (no accessible route to Boiler Room level)
- Code and exit signage
- Restrooms

Recommendations

The DOJ recommends prioritization of barrier removal in instance where all cannot be readily achieved:

- First priority - entry to the facility
- Second priority - providing access to those areas where goods and services are made available to the public
- Third priority - providing access to restrooms (if restrooms are provided for use by customers or clients)
- Fourth priority - removing any remaining barriers

LIMITED ENERGY CODE REVIEW (Seattle Energy Code 2009)

The existing building was designed and constructed in 1906 and 1918, long before the establishment of energy codes. The bare concrete, hollow clay tile and corrugated metal walls and concrete roofs were not insulated or covered, and the operation of the equipment in the space, along with operable windows, likely provided all the heat and cooling necessary for occupants.

Since the end of its service as a power generating facility, the building's use has changed to serve as a teaching facility and museum space, with public tours through portions of the building. Permit records indicate that in 1997 an electric boiler was added as a teaching tool.

Proposed rehabilitation of the historic structure includes alterations to the roof and envelope of the structure. Efforts will focus on weatherproofing the existing windows and doors, structural repairs, and replacement of failing roofing and flashings. The existing permitted electric boiler will be left intact and essentially undisturbed. Character defining features include the exposed interior surfaces, thin roof sections and existing single glazed windows, which limits the possibility of insulation and envelope improvements for energy efficiency.

As such, it is the consultant's opinion that the project may qualify for variance from full compliance via Section 101.3.2 and 101.3.2.2 of the Seattle Energy Code.

5. BIBLIOGRAPHY AND SOURCES

Argus Pacific. Letter to Fanny Nguyen, SCL, summarizing asbestos air sampling. May 21, 2013.

Birnbaum, Charles A. "Preservation Brief 36: Protecting Cultural Landscapes: Planning, Treatment and Management of Historic Landscapes." Washington, D.C.: U.S. Department of the Interior, National Park Service Cultural Resources, Preservation Assistance Division, 1994. http://www.nps.gov/hps/tps/briefs/brief36.htm

BOLA Architecture + Planning. "Snoqualmie Falls Project, Historic Structures Report." August 20, 2008.

City of Seattle.
Department of Planning and Development.
Online Mapping Service. http://www. seattle. gov/dpd/dpd/gis
Seattle City Light.
"A Brief History." http://www.seattle.gov/light/aboutus/history/ab5_brhs.htm
"Draft Environmental Impact Statement for the Georgetown Steam Plant Adaptive Use Alternatives." May 22, 1981.
Georgetown Steam Plant Archives.
Seattle Municipal Archives.
Clerk's Office, Comptroller Files.
Digital Photograph and Map Collections. http://www.seattle.gov/cityarchives/

Crowley, Walt. "City Light's Birth and Seattle's Early Power Struggles, 1886-1950." HistoryLink.org Essay 2318, April 26, 2000.

ENTRIX, Inc. "Cultural Resources Section 106 Technical Report Georgetown Steam Plant Flume Project—DAHP Log No. 030408—EPA Slip 4 Early Action Area, Lower Duwamish Waterway Superfund Site, Seattle, WA." November 2008.

Gilbreth, Frank B. *Concrete System*. New York: The Engineering News Publishing Company, 1908.

_____. "Reinforced Concrete Power Station." *California Journal of Technology* vol. 10, no. 5 (February 1908), pp. 23-28.

Grover, Stuart and Makers Architecture and Urban Design. "Physical Development Plan for the Georgetown Steam Plant Museum." Draft, December 24, 1985.

HistoryLink.org, the Free Online Encyclopedia of Washington State History. www. historylink. org
"Interurban Rail Transit in King County and the Puget Sound Region," Essay 2667.
"Puget Sound Gardening with Charles Malmo," Essay 8161.
"Seattle Neighborhoods: Georgetown -- Thumbnail History," Essay 2975.
"Straightening of Duwamish River begins on October 14, 1913," Essay 2986.
"Turning Point 15: Seattle's Other Birthplace: From Hop Field to Boeing Field," Essay 9291.

King County Assessor Records. (Available from Puget Sound Regional Archives.)

King County iMAP: Interactive Mapping Tool.
http://www.kingcounty.gov/operations/GIS/Maps/iMAP.aspx

Lubar, Steve, Flo Lentz, and T. Allan Comp. “Georgetown Steam Plant.” Historic American Engineering Record, 1984.

Moody’s Magazine. “The Seattle Power House.” July 1908, p. 30.

National Park Service. *The Secretary of the Interior’s Standards for the Treatment of Historic Properties + Guidelines for the Treatment of Cultural Landscapes*. Washington, D. C.: United States Department of the Interior, 1996. http://www.nps.gov/tps/standards/four-treatments/landscape-guidelines/index.htm

New York Times. “Bricklaying Yields to Science for the First Time.” April 2, 1911.

New York Times. “Maj. Gilbreth Dies in a Phone Booth.” June 15, 1924.

Northwest Archaeological Associates. “Addendum to Georgetown Steam Plant.” Historic American Engineering Record, 2009? VERIFY

“Pioneers in Improvement and our Modern Standard of Living.” *IW/SI News*, Issue 18 (September 1968), pp. 37-38.

Purdue Library, Archives and Special Collections. “Frank and Lillian Gilbreth Web Site.” http://www.lib.purdue.edu/spcol/manuscripts/fblg/

Rossi, Gene, telecon with Karen Kiest, August 2, 2012. Julius Rosso Nursery Relocating to Tukwila after August 31, 2012.

Sanborn Map Company. *Seattle Fire Insurance Map*, 1929, vol. 8 sheet 1316.

Stickney Murphy Romine Architects. “King County International Airport, Georgetown Steamplant Window Vibration Impact Study,” December 13, 2005.

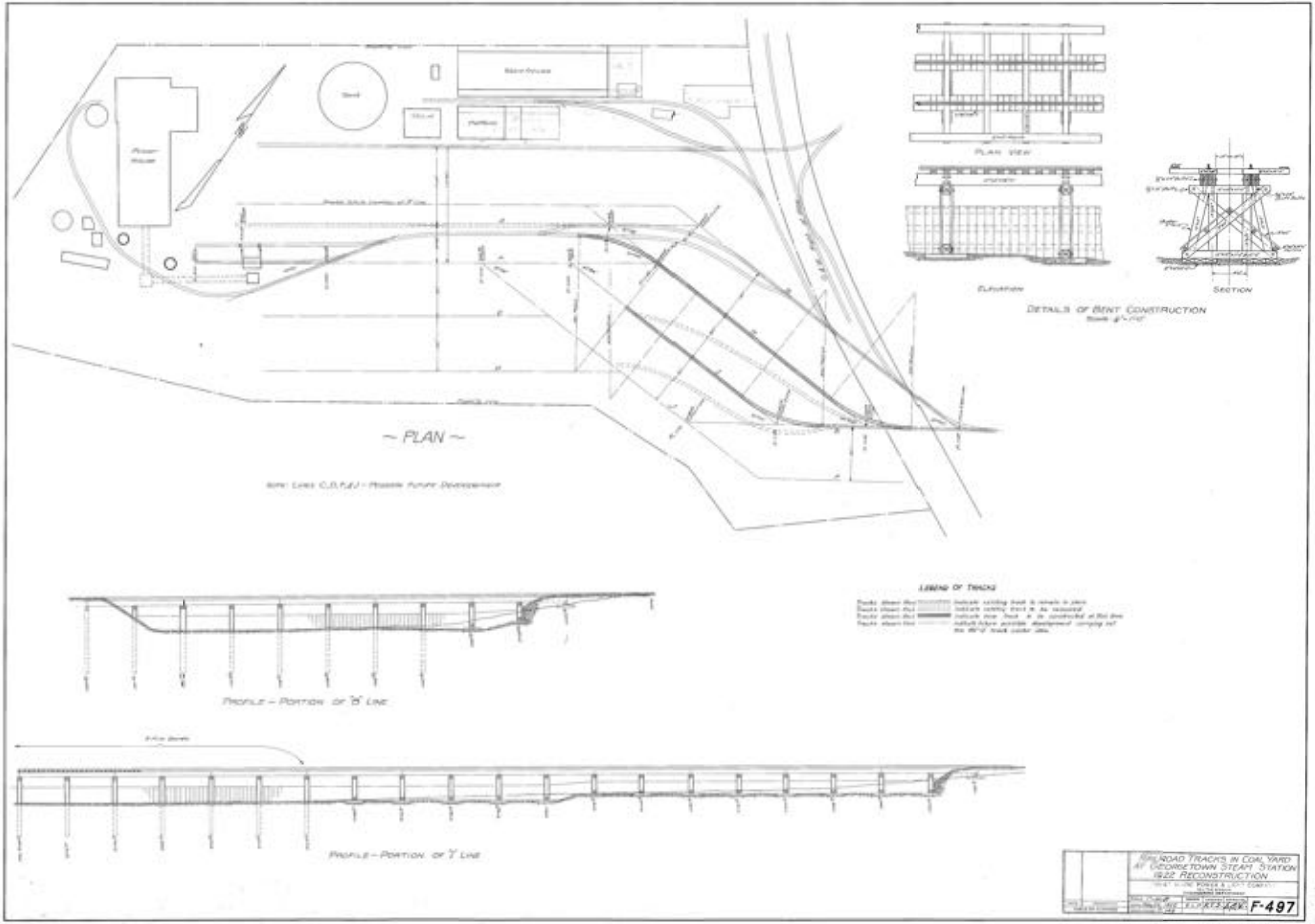
Thomas, Jacob, Office of Archaeology and Historic Preservation. “Seattle Electric Company Georgetown Steam Plant,” National Register of Historic Places Inventory—Nomination Form. October 28, 1977.

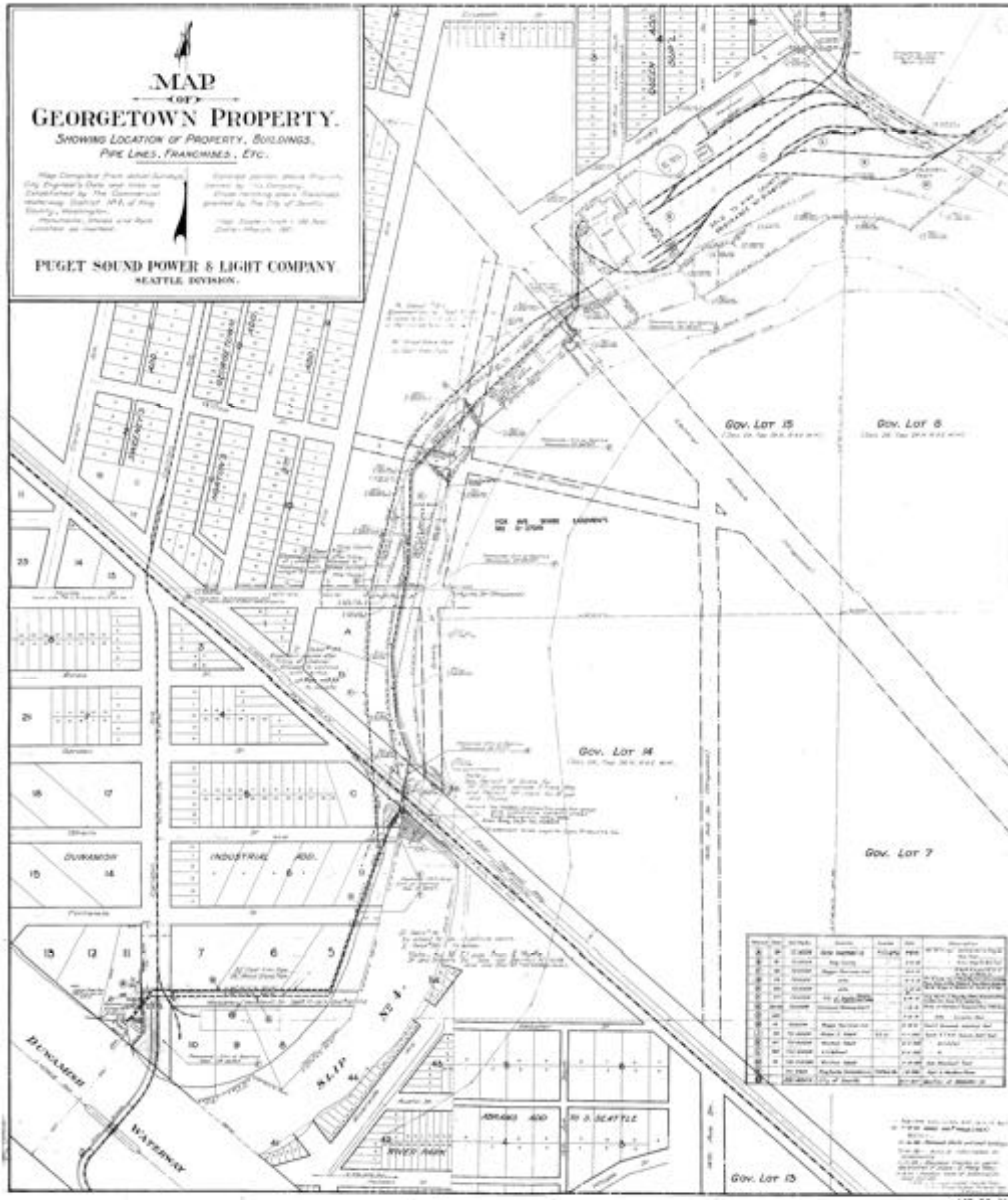
University of Washington Libraries, Special Collections and Manuscripts. Digital Photograph Collection. http://content.lib.washington.edu

APPENDIX A
HISTORIC & EXISTING CONDITIONS DRAWINGS

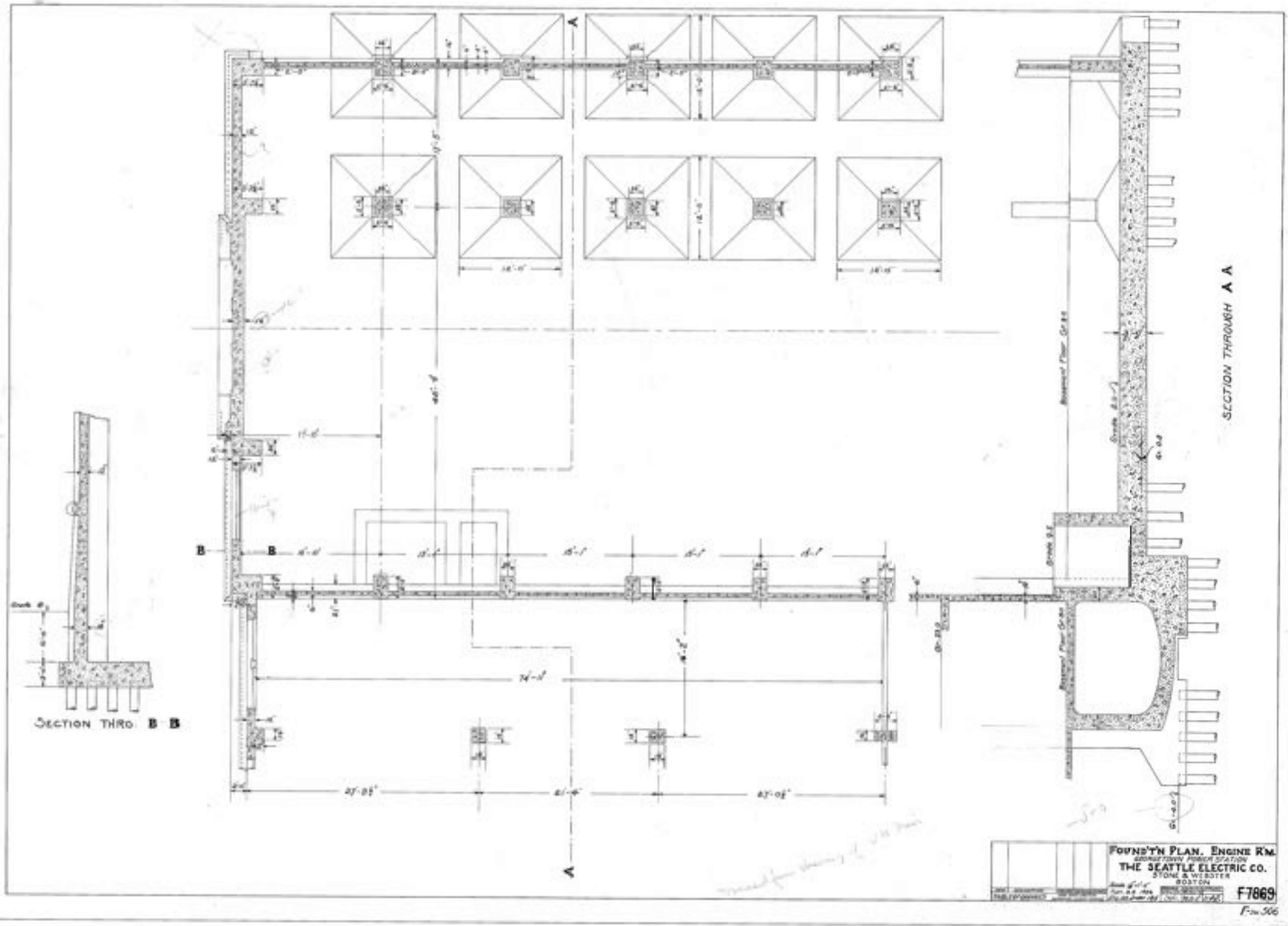

GREELY ST.
FUTURE DEVELOPMENT
BOILER ROOM
SUWAMISH RIVER
LOT PLAN
GEORGETOWN POWER STATION
THE SEATTLE ELECTRIC CO.
STONE & WEBSTER
BOSTON
F7631
Fsu 500

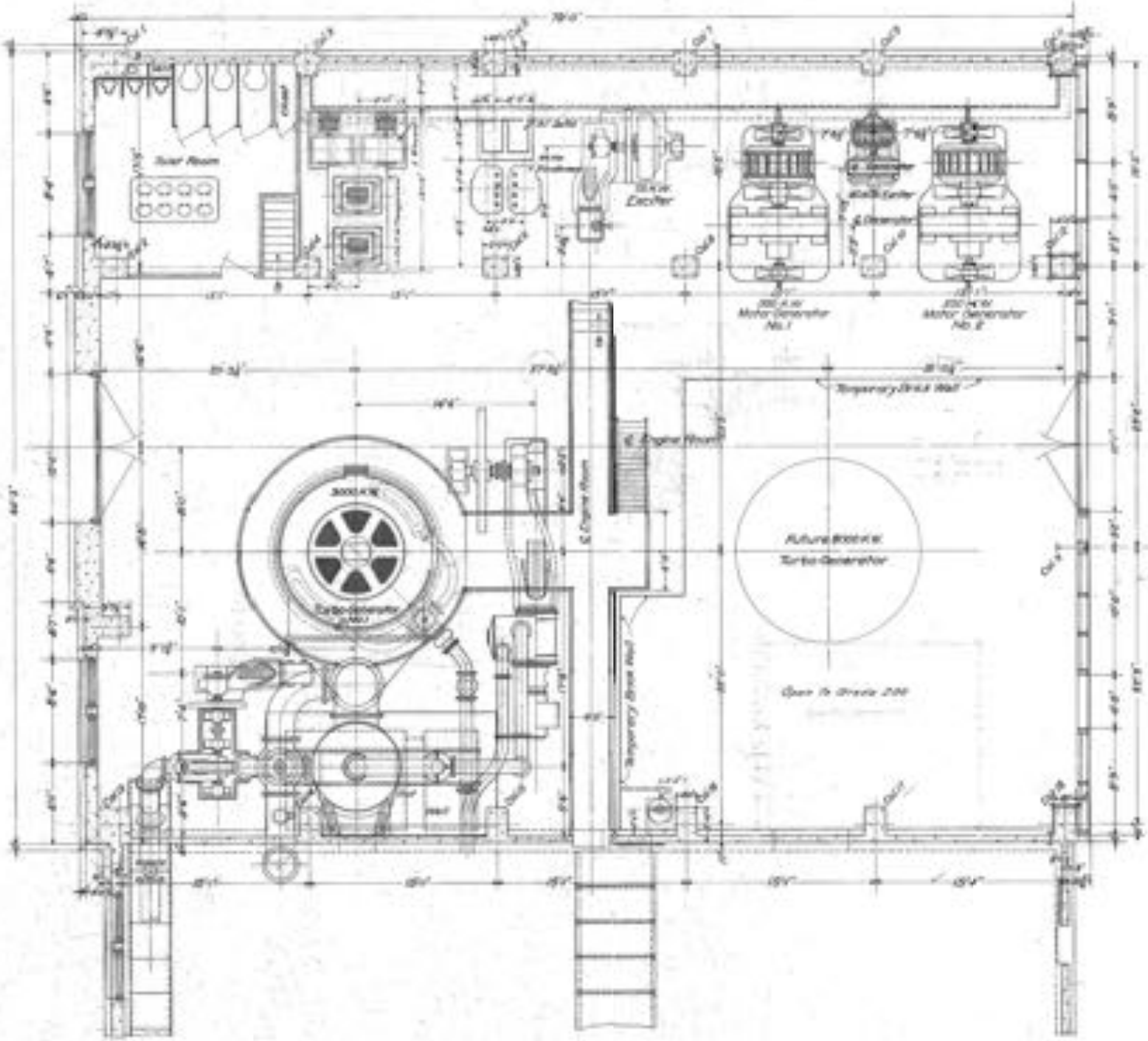

GREELY STREET
DUWAMISH
RIVER
COUNTY
ROAD
SUPERSEDED DRAWING F9281
LOT PLAN
GEORGETOWN (GREEN ADDITION)
THE SEATTLE ELECTRIC CO.
STONE & WEBSTER ENGINEERING CORP.
BOSTON
F9287
F-5w 499


PLAN VIEW
ELEVATION
SECTION
DETAILS OF BENT CONSTRUCTION
~ PLAN ~
LEGEND OF TRACKS
PROFILE – PORTION OF "B" LINE
PROFILE – PORTION OF "I" LINE
RAILROAD TRACKS IN COAL YARD
AT GEORGETOWN STEAM STATION
1922 RECONSTRUCTION
F-497


MAP
OF
GEORGETOWN PROPERTY.
SHOWING LOCATION OF PROPERTY, BUILDINGS,
PIPE LINES, FRANCHISES, ETC.
PUGET SOUND POWER & LIGHT COMPANY
SEATTLE DIVISION.
GOV. LOT 15
GOV. LOT 6
GOV. LOT 14
GOV. LOT 7
GOV. LOT 13
INDUSTRIAL ADD.
DUWAMISH
WATERWAY
SLIP NO 1.
RIVER PARK
ME-26-M.

ME 26-M


SECTION THROUGH A A
SECTION THRO. B B
FOUND'T'N PLAN. ENGINE R'M.
GEORGETOWN POWER STATION
THE SEATTLE ELECTRIC CO.
STONE & WEBSTER
BOSTON
F7869

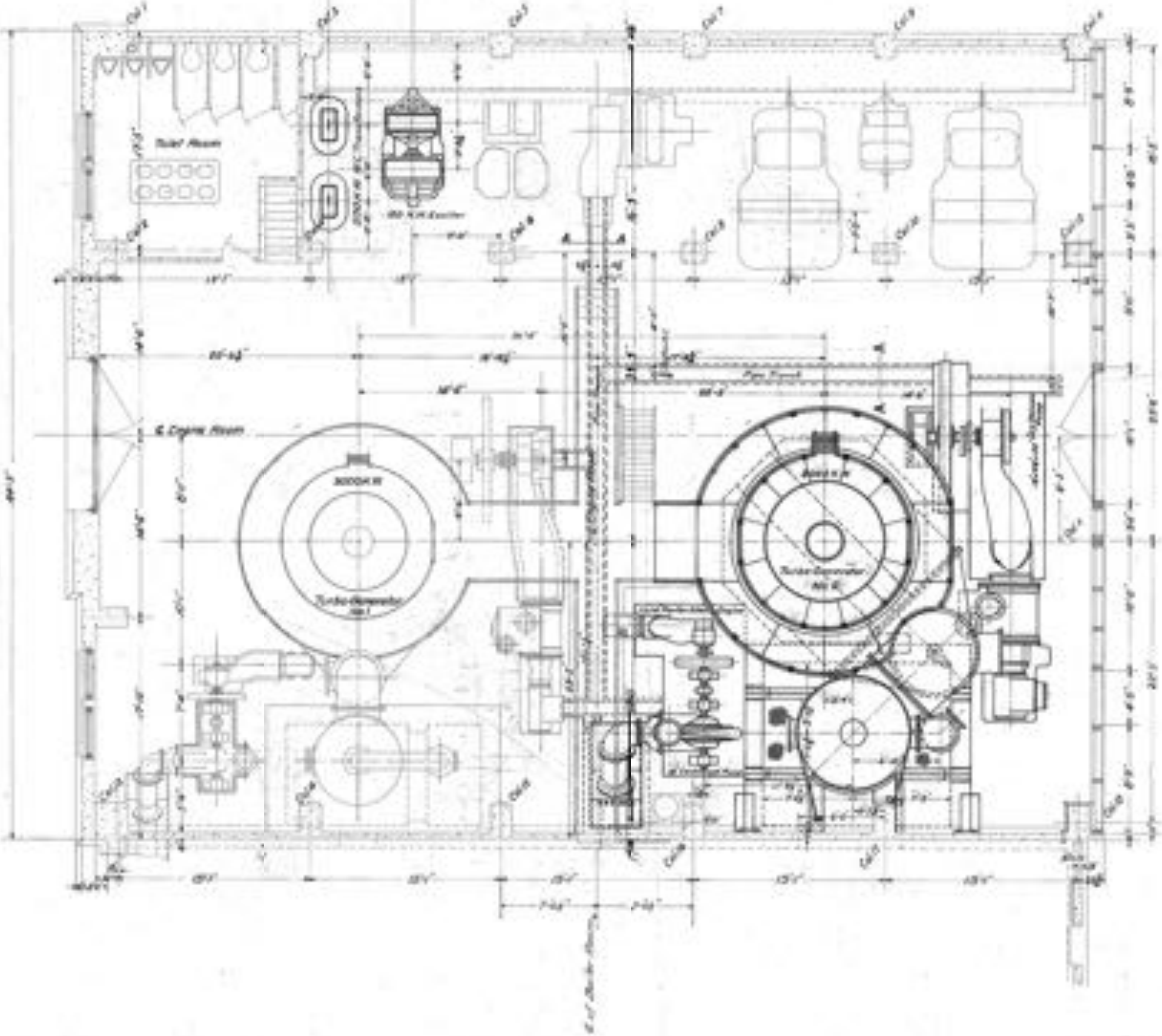


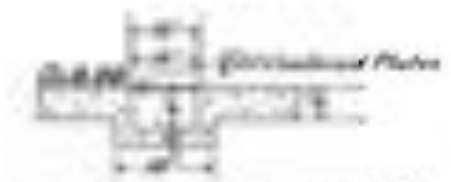
FLOOR PLAN, ENGINE ROOM
GEORGETOWN POWER STATION
THE SEATTLE ELECTRIC CO.
STONE & WEBSTER ENGINEERING CORP.
BOSTON.

July 26, 1906

F7814

F 552

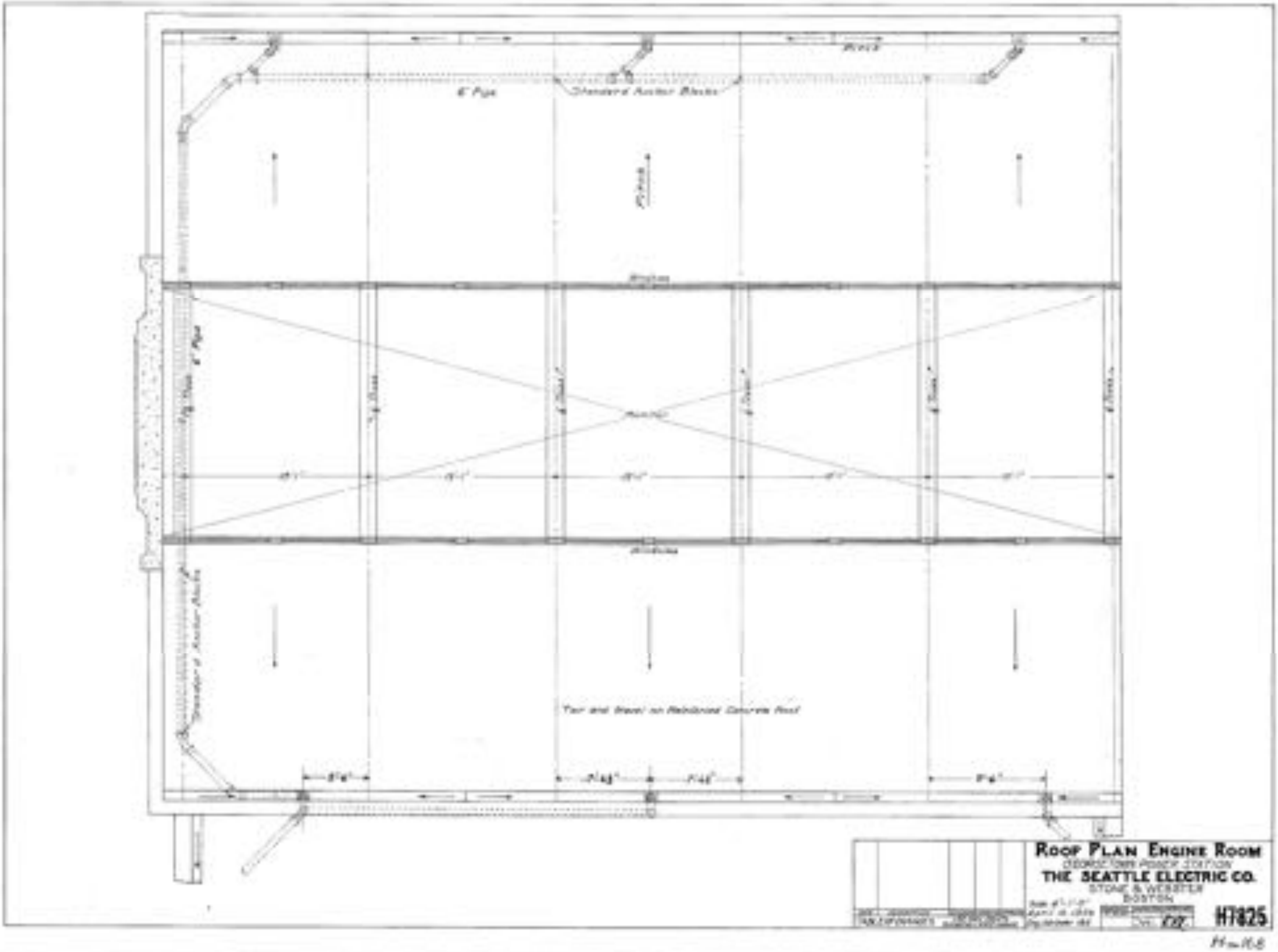




DETAIL OF TRENCH
AT A-A

FLOOR PLAN. ENGINE ROOM
STATION UNIT NO. 2
THE SEATTLE ELECTRIC CO.
STONE & WEBSTER ENGINEERING CORP.
BOSTON.
F10752

F-sw530
MICRO FILMED NOV 7



6" Pipe
Standard Anchor Blocks
Tar and Gravel on Reinforced Concrete Roof
ROOF PLAN ENGINE ROOM
GEORGETOWN POWER STATION
THE SEATTLE ELECTRIC CO.
STONE & WEBSTER
BOSTON
H7825


FLOOR REMOVED SHOWING
BASEMENT COLUMNS
FOUND'T'N PLAN BOILER R'M
GEORGETOWN POWER STATION
THE SEATTLE ELECTRIC CO.
STONE & WEBSTER
BOSTON
F7864
F-507


Pipe Trench
DETAIL OF TRENCH COVERS at A
DETAIL OF TRENCH COVERS at B
CROSS SECTION OF TRACK
CROSS SECTION OF PIPE TRENCH
BOILER R'M BASEMENT PLAN
GEORGETOWN POWER STATION
THE SEATTLE ELECTRIC CO.
STONE & WEBSTER
BOSTON
F8886
F-545

BOILER ROOM BASEMENT PLAN
GEORGETOWN STATION UNIT NO. 2
THE SEATTLE ELECTRIC CO.
STONE & WEBSTER ENGINEERING CORP.
BOSTON

F10639

F-535

MICRO FILMED

SUPERSEDES DR. Nº F7808

BOILER ROOM FLOOR PLAN

GEORGETOWN POWER STATION

THE SEATTLE ELECTRIC CO.

STONE & WEBSTER

BOSTON

F8909

F-Sm 344

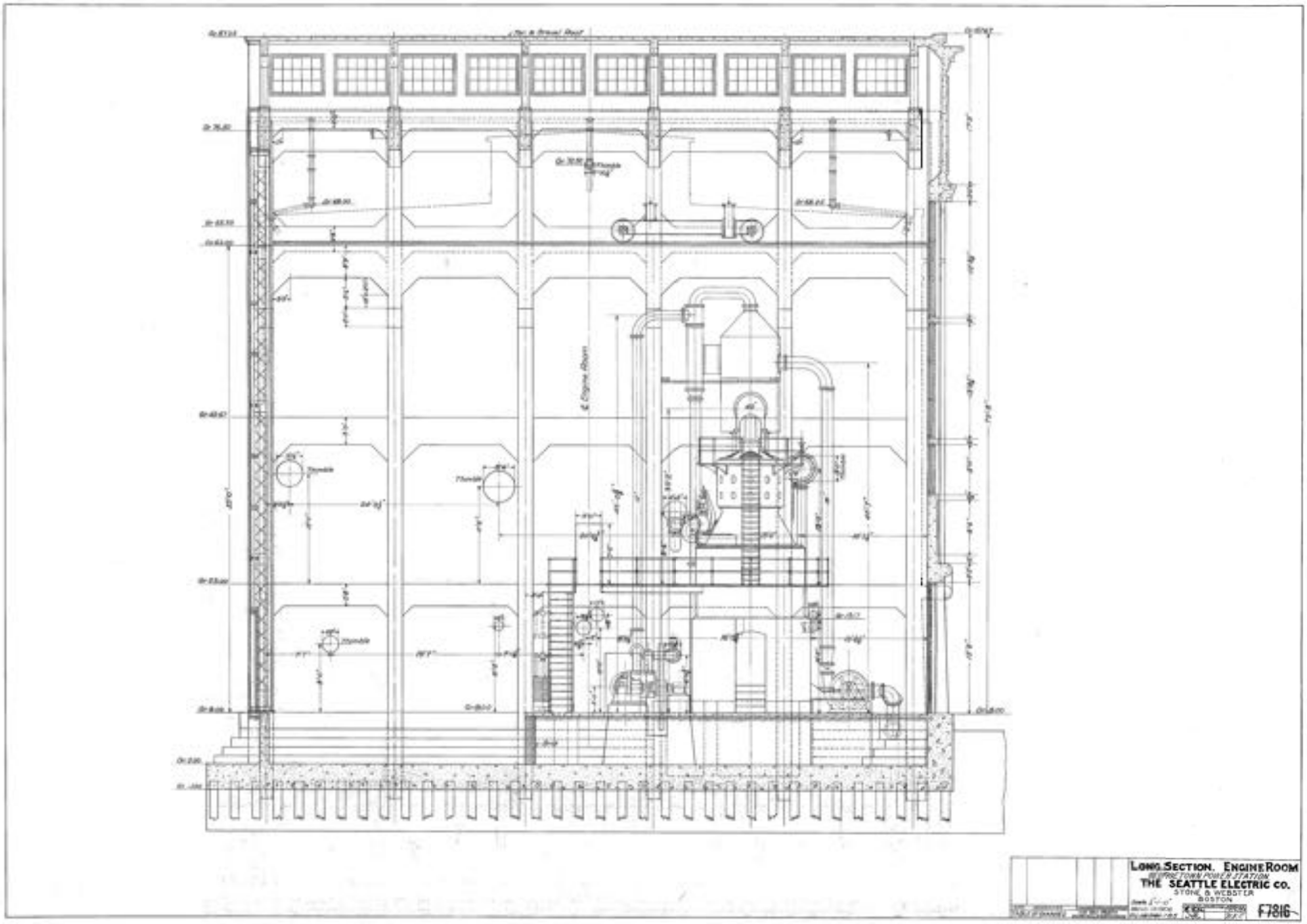
BOILER ROOM FLOOR PLAN
GEORGETOWN STATION UNIT NO. 2
THE SEATTLE ELECTRIC CO.
STONE & WEBSTER ENGINEERING CORP.
BOSTON

F10640

F-534

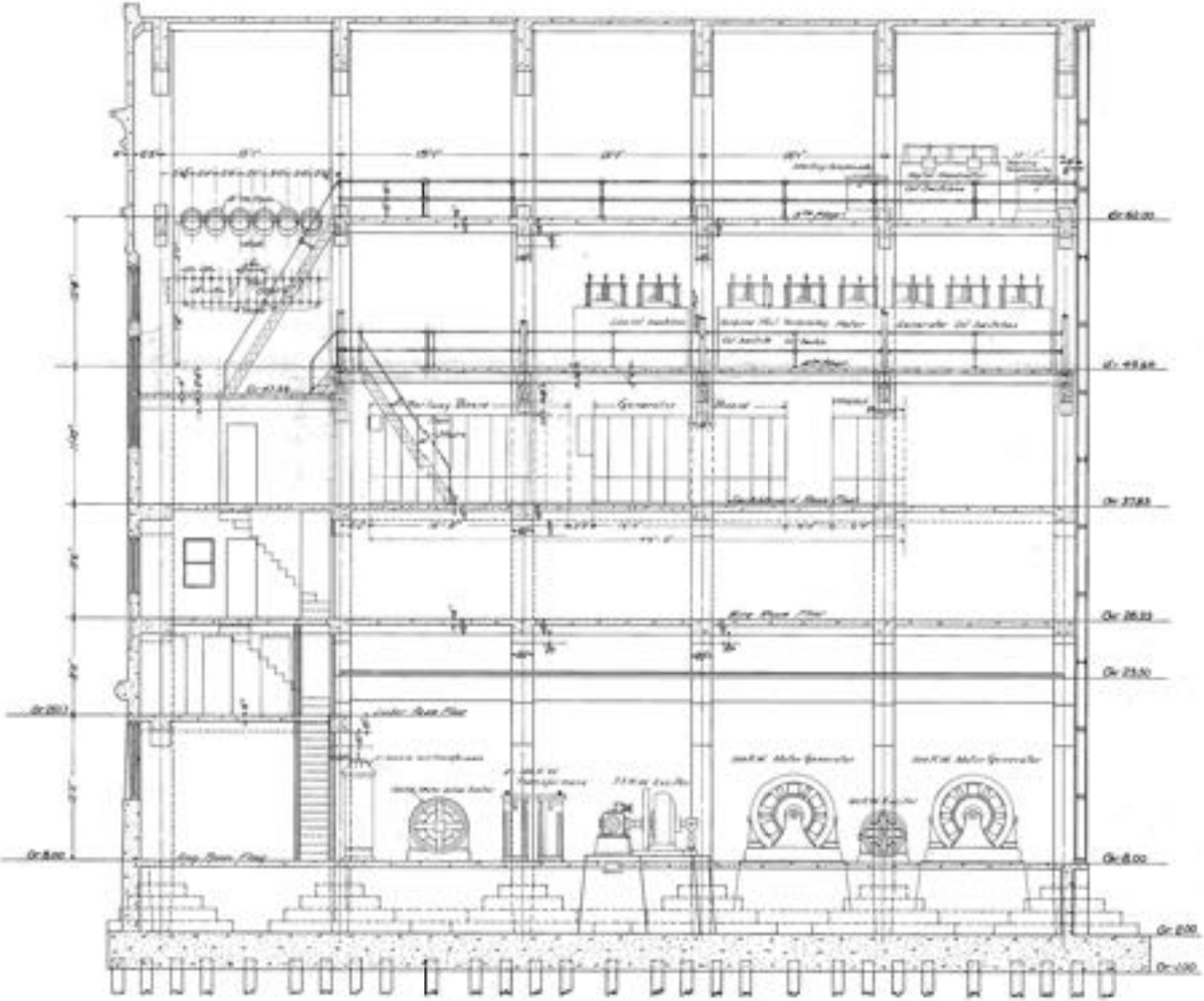
MICRO FILMED NOV 1


Standard Anchor Blocks
Monitor
Metal Louvres
Stack
Tar and Gravel on Reinforced Concrete Roof
ROOF PLAN BOILER ROOM.
GEORGETOWN POWER STATION
THE SEATTLE ELECTRIC CO.
STONE & WEBSTER
BOSTON
F7817
F 549



Tar & Gravel Roof
Engine Room
Thimble
LONG SECTION. ENGINE ROOM
POWER STATION
THE SEATTLE ELECTRIC CO.
STONE & WEBSTER
BOSTON
F7816

F. 550



SECTION THROUGH SWITCH-BOARD BAY
LOOKING NORTH

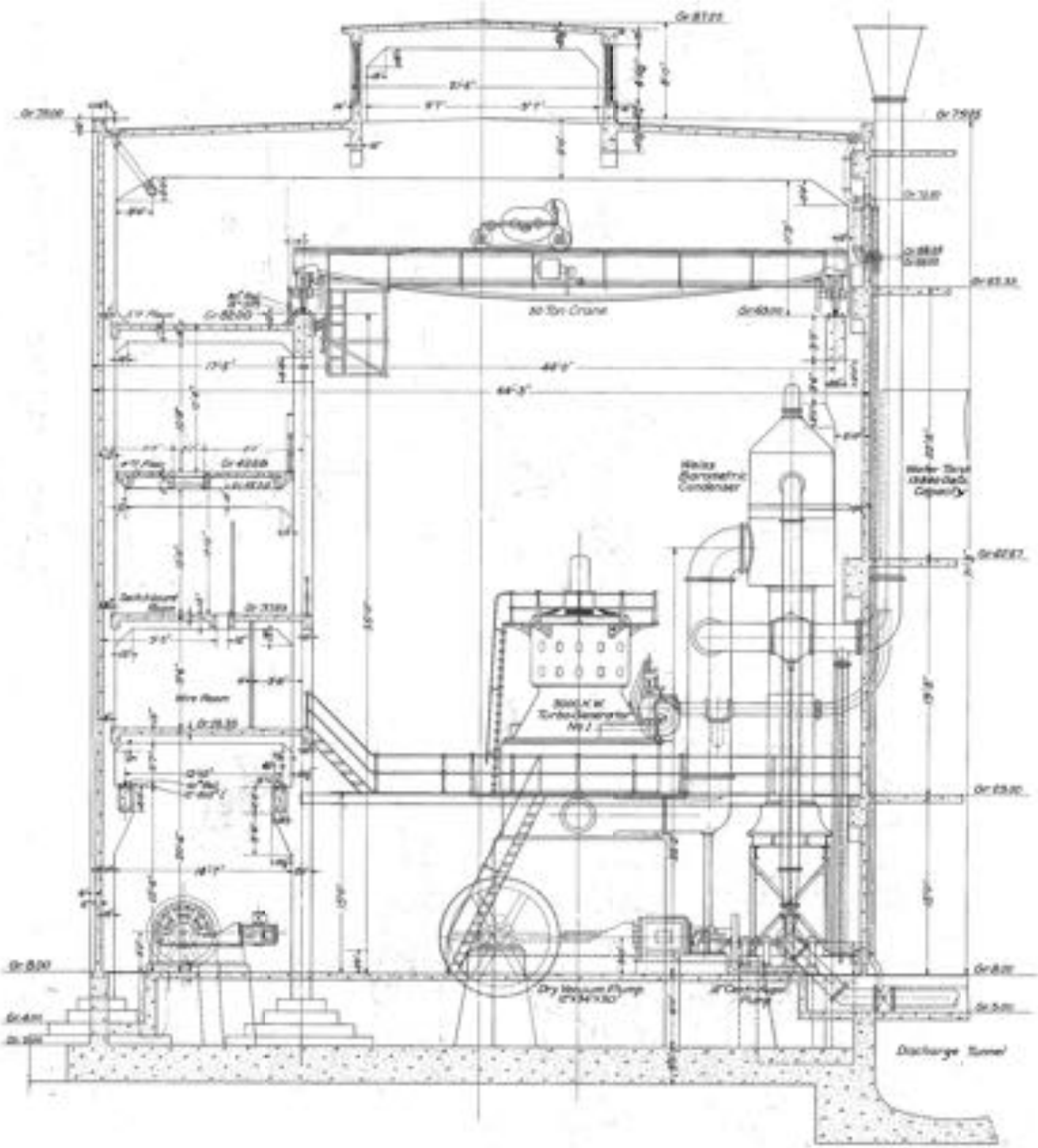
FOR CHANGES MADE IN FIELD SEE X 4220

LONG SECTION-ENGINE ROOM
GEORGETOWN POWER STATION
THE SEATTLE ELECTRIC CO.
STONE & WEBSTER ENGINEERING CORP.
BOSTON

F9354

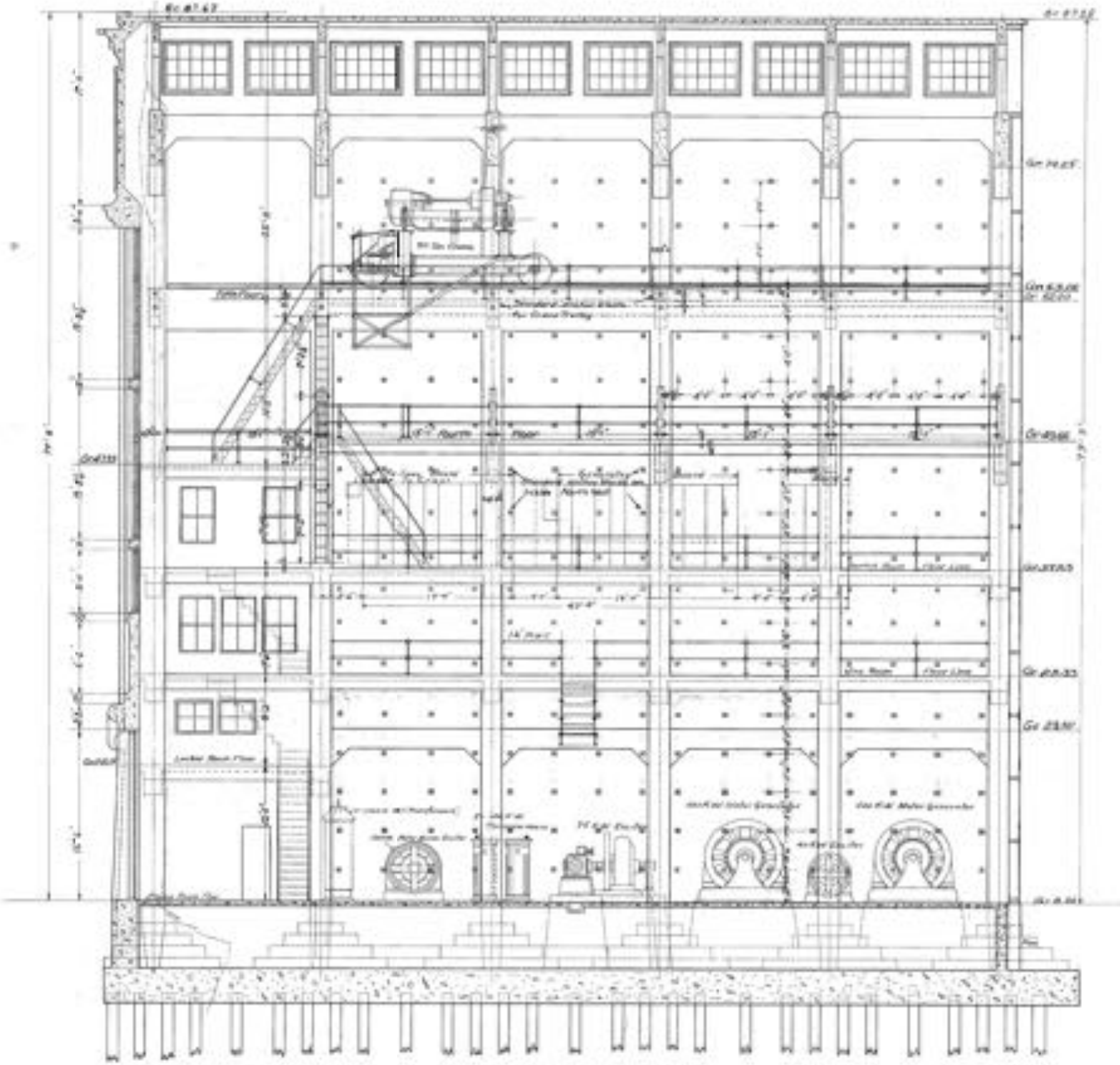
F-3w 536

MICRO FILMED



CROSS SECTION-ENGINE R'M.
GEORGETOWN POWER STATION
THE SEATTLE ELECTRIC CO.
STONE & WEBSTER ENGINEERING CORP.
BOSTON
F8266

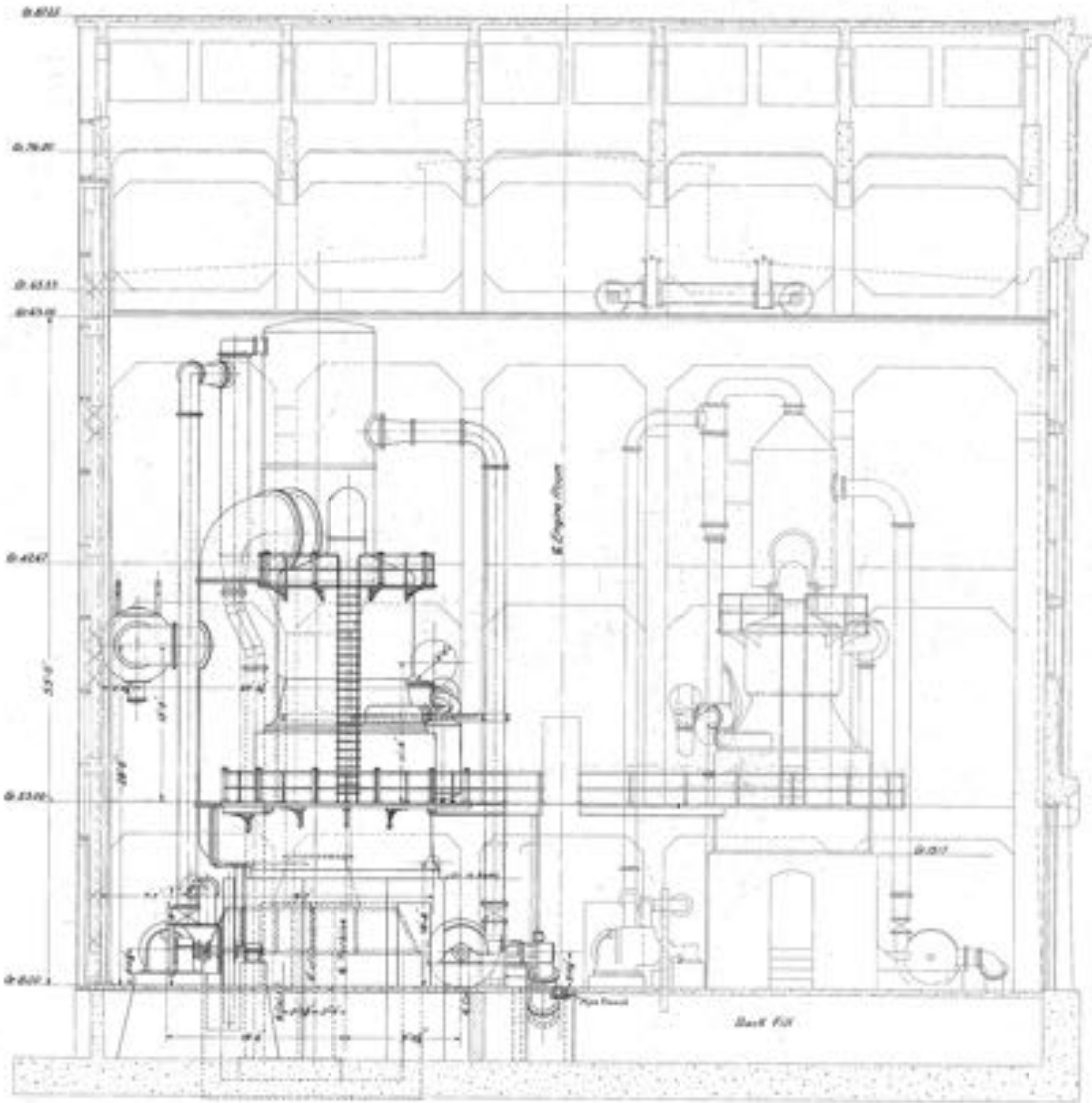
F-537



SECTION ON CENTER LINE OF ENGINE ROOM LOOKING NORTH

LONG SECTION. ENGINE ROOM
GEORGETOWN POWER STATION
THE SEATTLE ELECTRIC CO
STONE & WEBSTER ENGINEERING CORP.
BOSTON
F9045

F-538
MICRO FILMED

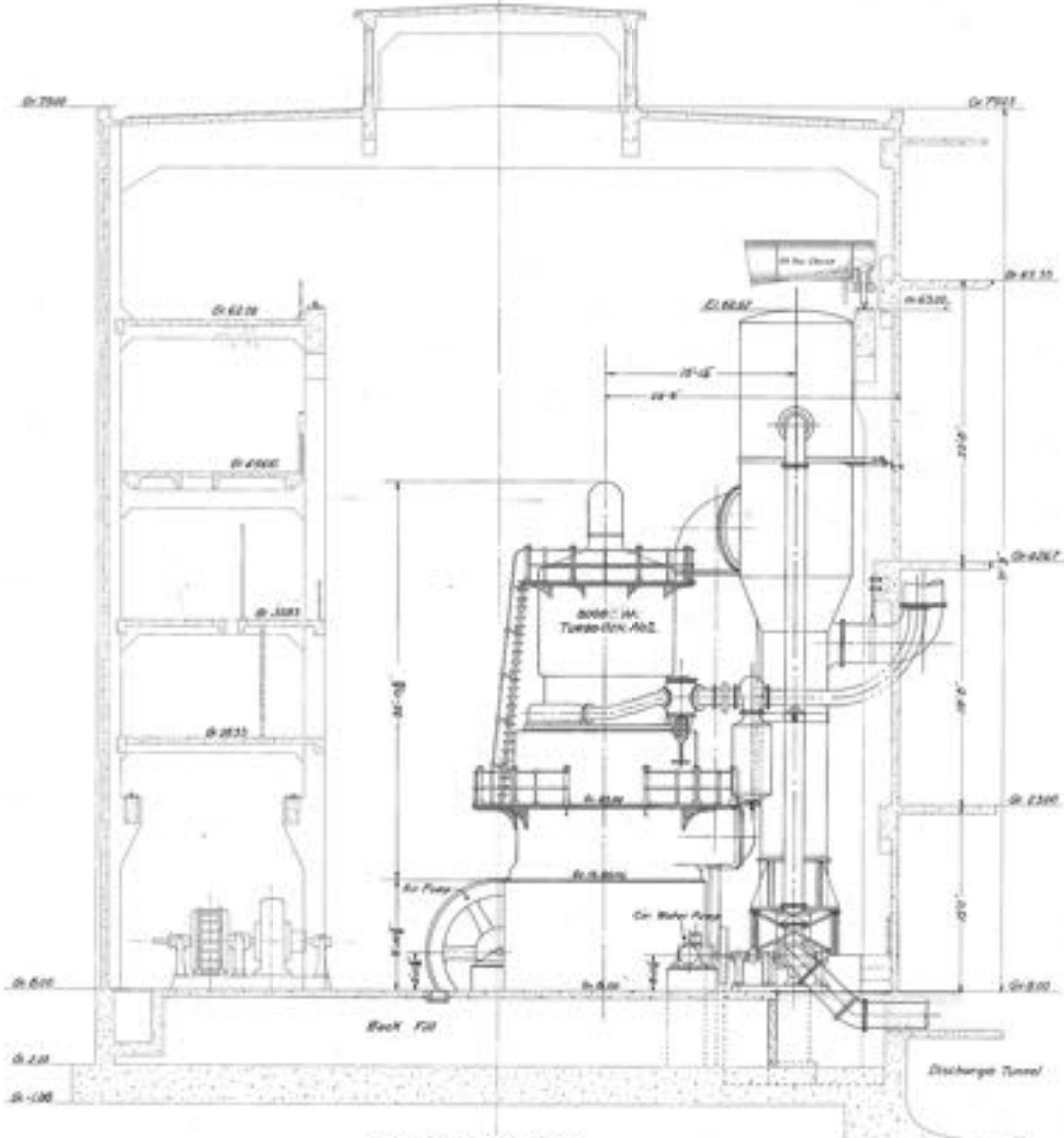


SECTION LOOKING SOUTH

LONG SECTION ENGINE ROOM
GEORGETOWN STATION UNIT No 2
THE SEATTLE ELECTRIC CO.
STONE & WEBSTER ENGINEERING CORP.
BOSTON

F10763

F-3a 528



SECTION LOOKING EAST

CROSS SECTION ENGINE ROOM
GEORGETOWN STATION UNIT No. 2
THE SEATTLE ELECTRIC CO.
STONE & WEBSTER ENGINEERING CORP.
BOSTON

F10753

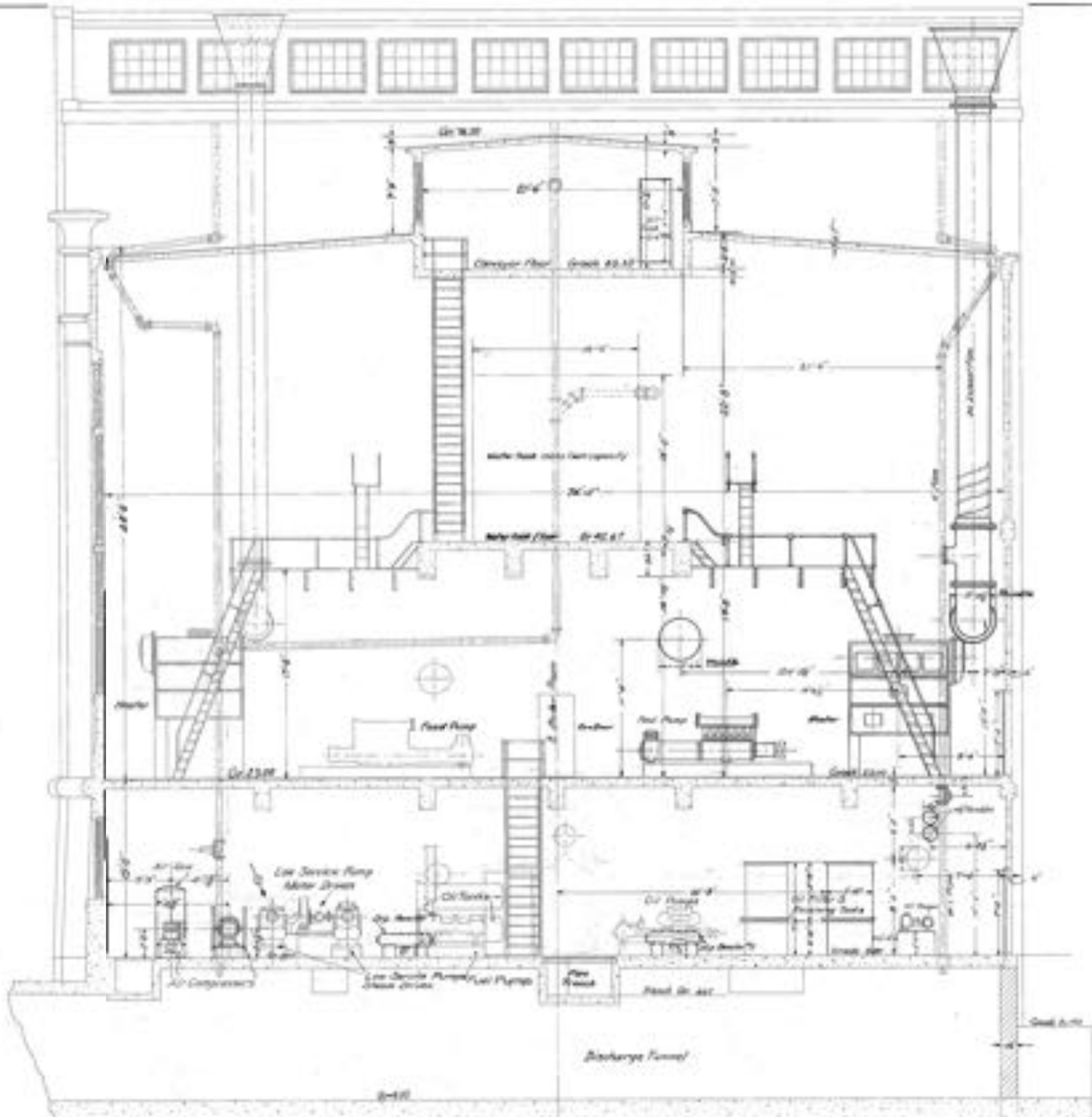
F-sw 529

MICRO FILMED NOV 1 - 1958


Coal Pocket
Water Tank
Low Service Pumps
Discharge Tunnel
LONG. SECTION BOILER ROOM
GEORGETOWN POWER STATION
THE SEATTLE ELECTRIC CO.
STONE & WEBSTER ENGINEERING CORP.
BOSTON
F7815

F-551


Coal Pocket.
Heater
Feed
Pump
Stirling
Battery
Discharge Tunnel
LOOKING EAST.
LONG. SECTION BOILER ROOM
THE SEATTLE ELECTRIC CO.
STONE & WEBSTER ENGINEERING CORP.
BOSTON
F10742
F-531

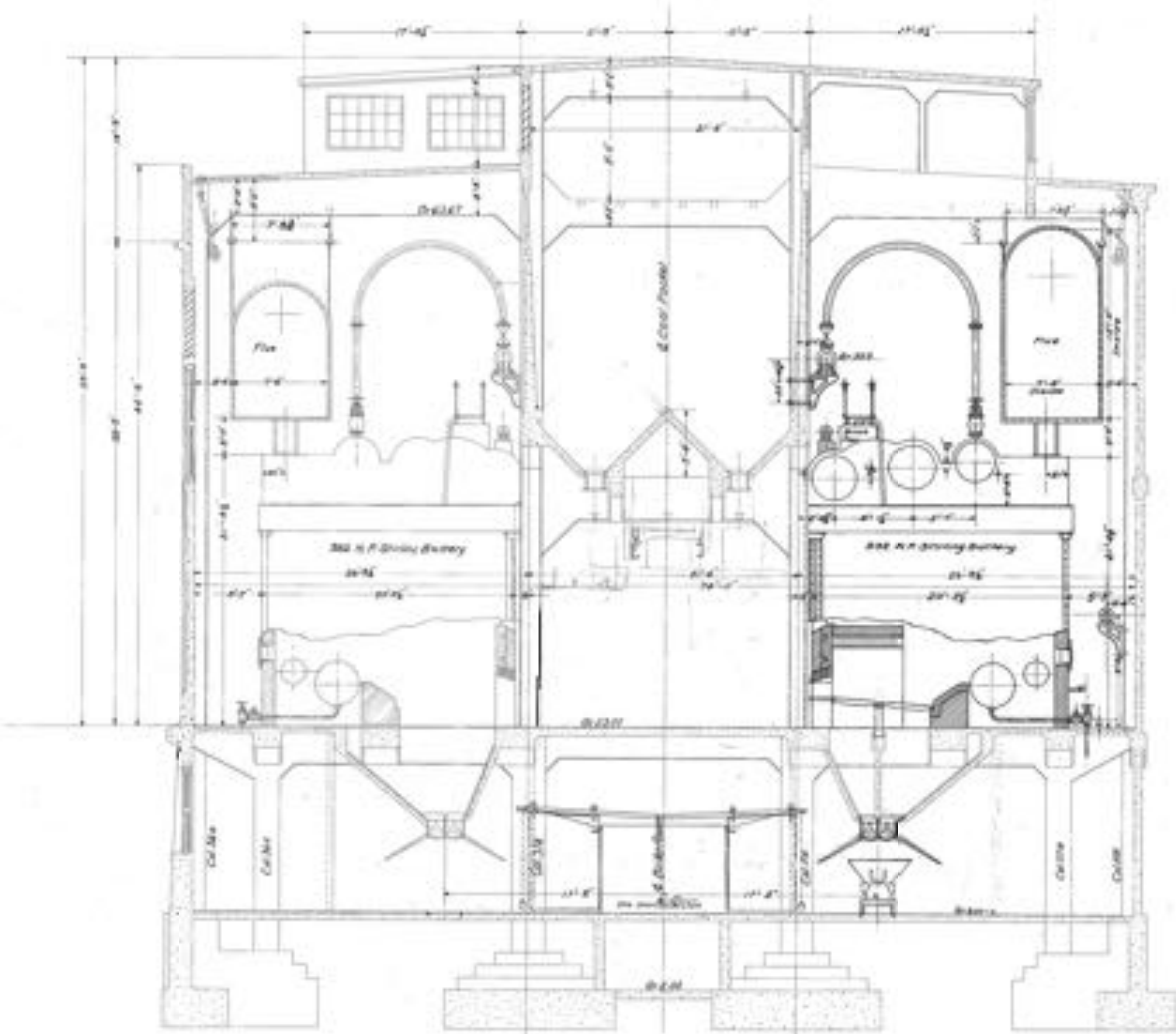


Cross Section Boiler Room
Georgetown Station Unit No. 2
The Seattle Electric Co.
Stone & Webster Engineering Corp.
Boston

F10686

F-532

MICRO FILMED



CROSS SECTION BOILER ROOM

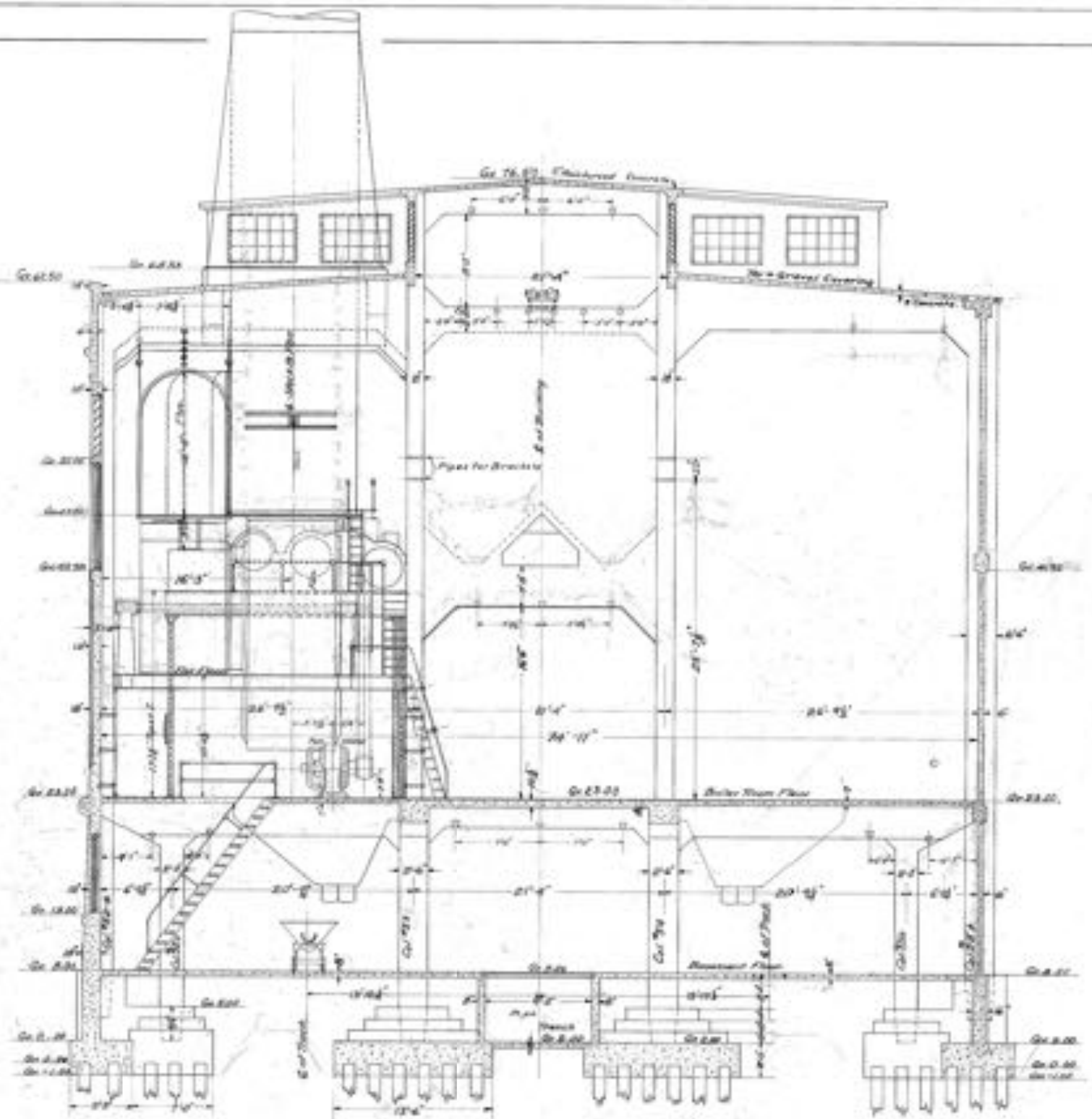
GEORGETOWN STATION UNIT NO 2

THE SEATTLE ELECTRIC CO

STONE & WEBSTER ENGINEERING CORP.
BOSTON

F10679

F 533

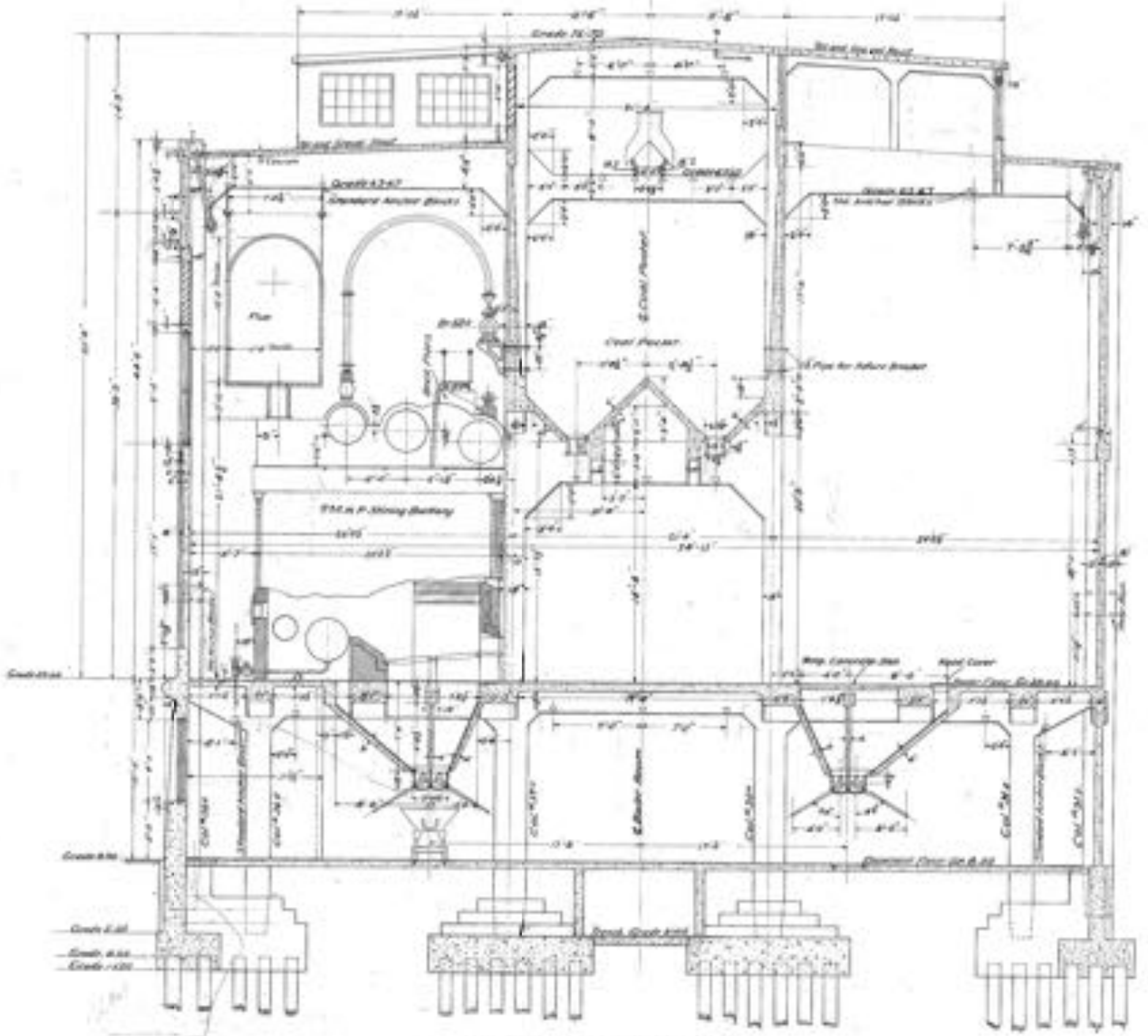


CROSS SECTION AT COLUMNS "32" & 55"

CROSS SECTION BOILER ROOM
GEORGETOWN POWER STATION
THE SEATTLE ELECTRIC CO.
STONE & WEBSTER
BOSTON

F8980

F-SW 540



CROSS SECTION AT COL. 3

CROSS SECTION BOILER ROOM

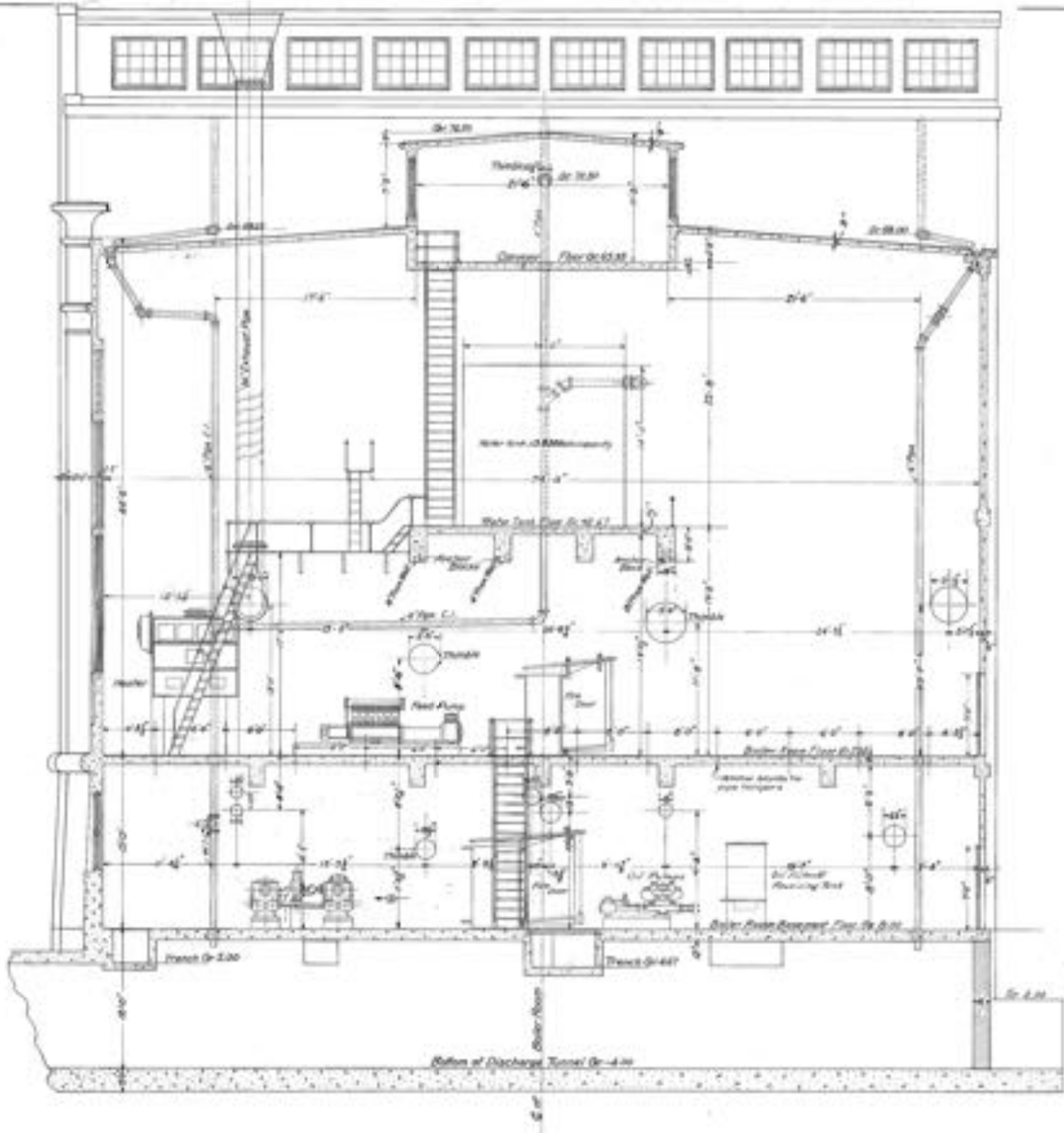
GEORGETOWN POWER STATION

THE SEATTLE ELECTRIC CO.

STONE & WEBSTER
BOSTON

F8972

F 341



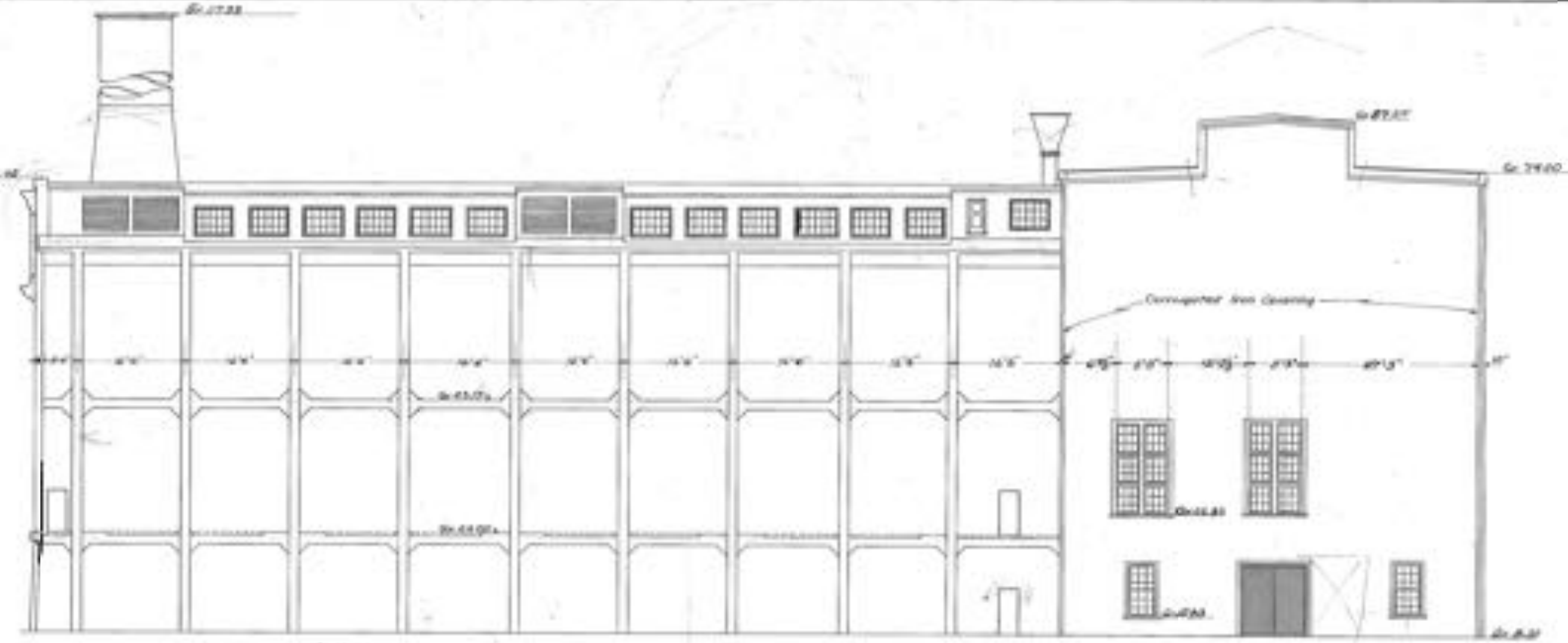
SECTION THROUGH NORTH BAY

CROSS SECTION BOILER ROOM
GEORGETOWN POWER STATION
THE SEATTLE ELECTRIC CO.
STONE & WEBSTER
BOSTON

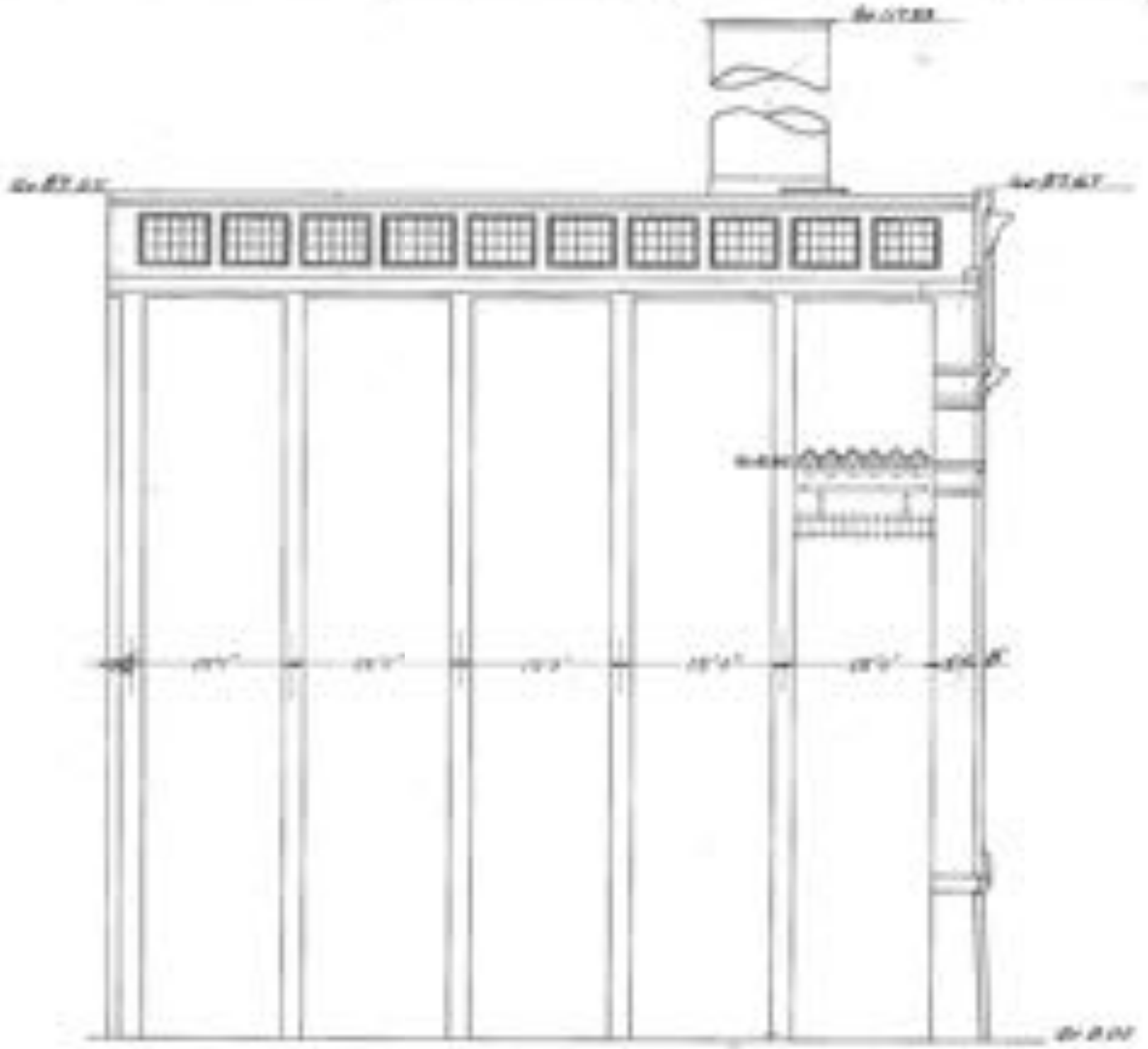
F8943

F-542


1906
No 1
WEST ELEVATION
SOUTH ELEVATION
DETAIL AT "C"
SECTION F-F
SECTION D-D
SECTION E-E
SECTION B-B
SECTION A-A
S. AND W. ELEVATIONS
POWER STATION
THE SEATTLE ELECTRIC CO.
STONE & WEBSTER
BOSTON
F7799
F-SW 553



EAST ELEVATION

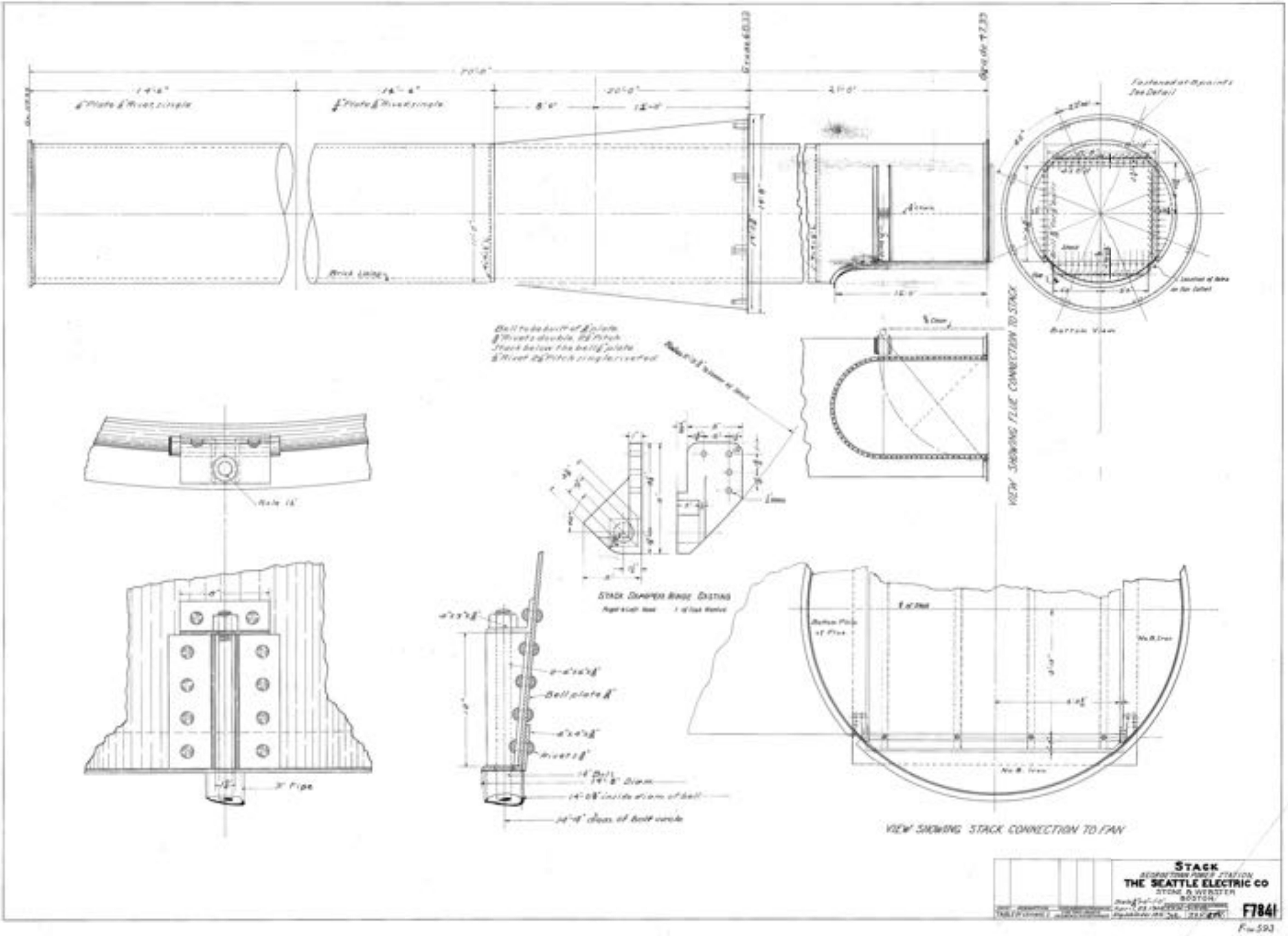


NORTH ELEVATION

N. & E. ELEVATION
GEORGETOWN POWER STATION
THE SEATTLE ELECTRIC CO.
STONE & WEBSTER ENGINEERING CORP.
BOSTON

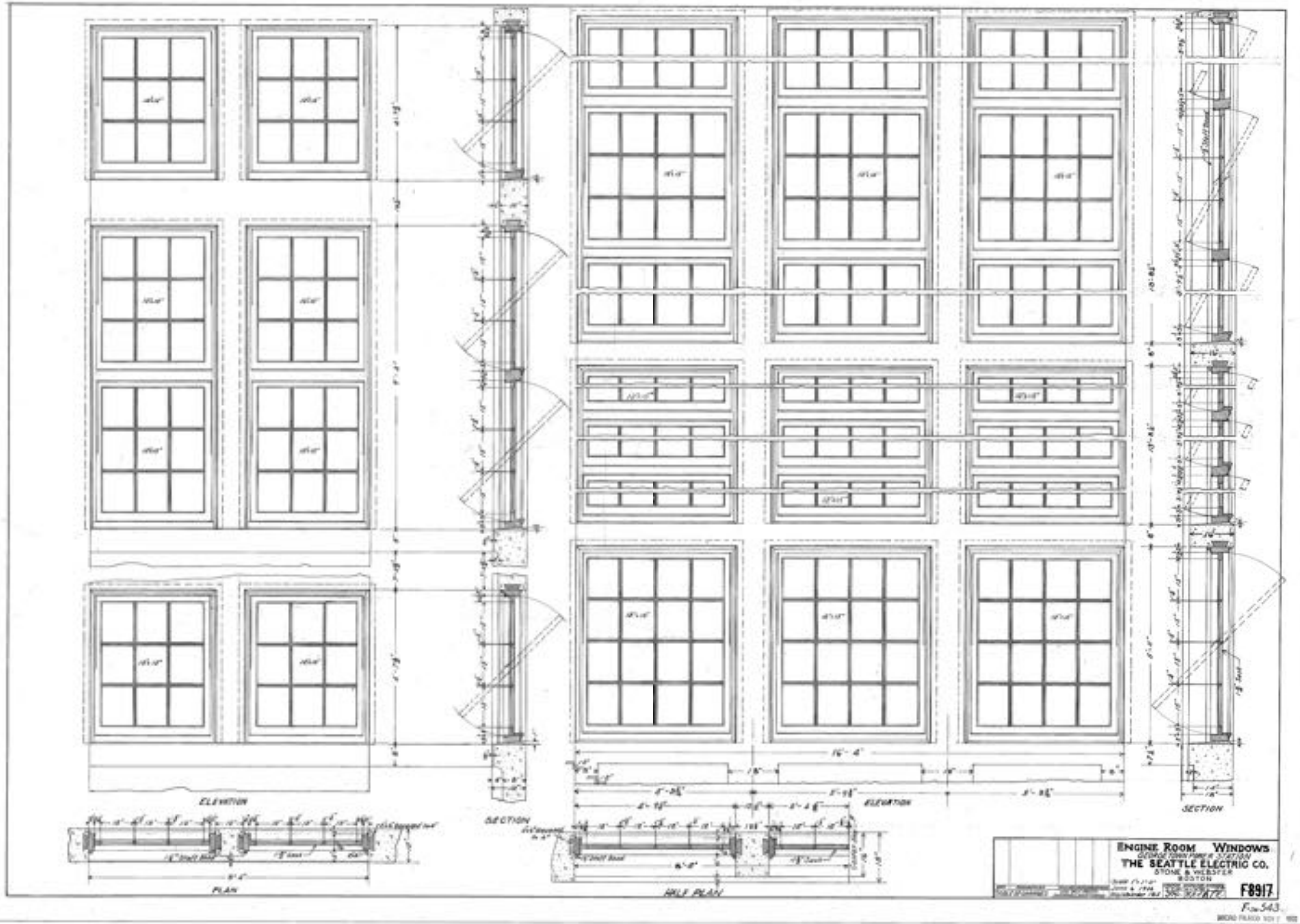
F9044

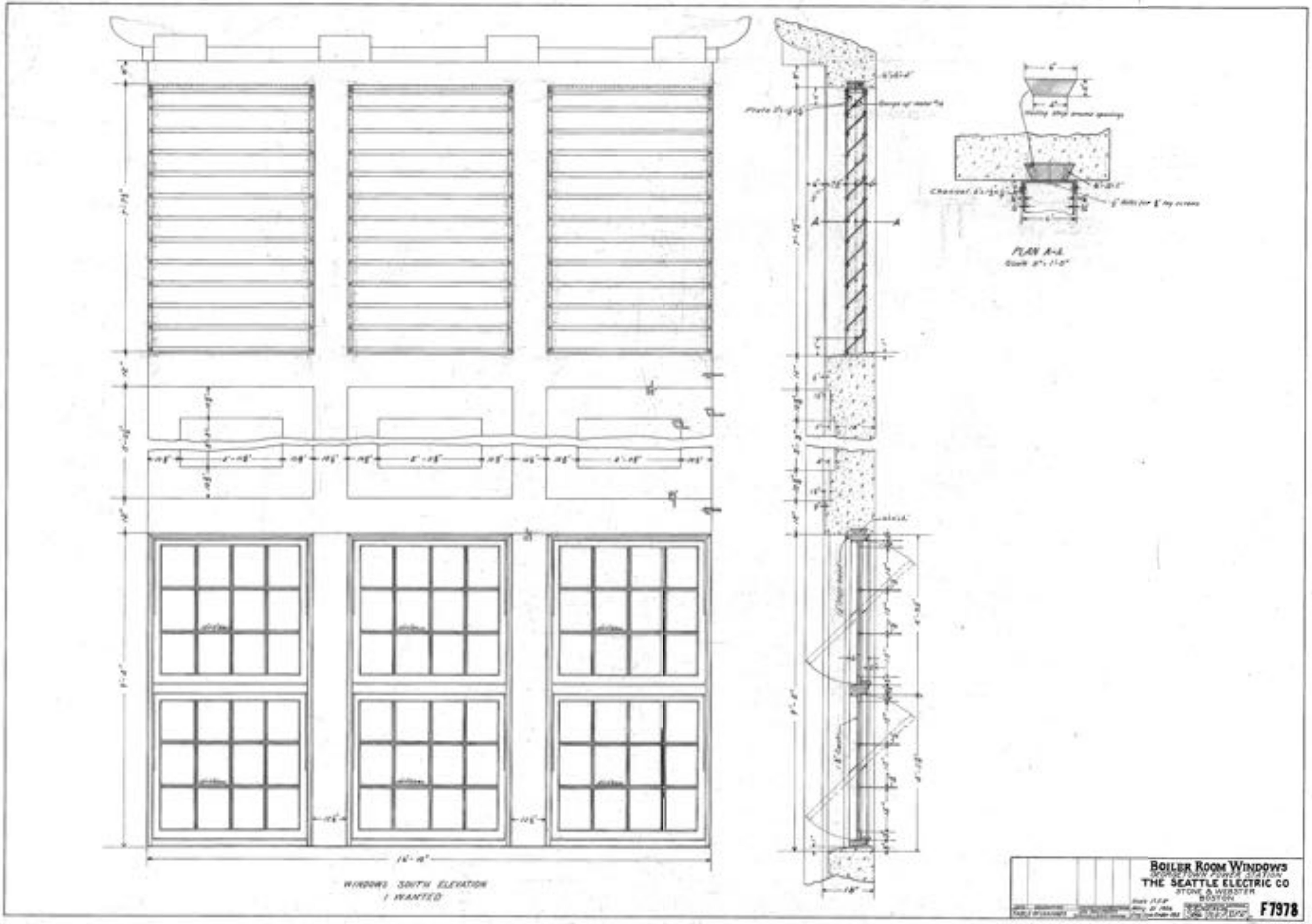
F-SW 539


Brick Lining
Bell to be built of ⅜ plate
Hole 1¼"
3" Pipe
Bell plate ⅜"
Rivets ⅞"
14'-0⅝" inside diam. of bell
14'-9" diam. of bolt circle
STACK DAMPER HINGE CASTING
VIEW SHOWING FLUE CONNECTION TO STACK
Bottom View
VIEW SHOWING STACK CONNECTION TO FAN
STACK
GEORGETOWN POWER STATION
THE SEATTLE ELECTRIC CO
STONE & WEBSTER
BOSTON
F7841
F-in 593

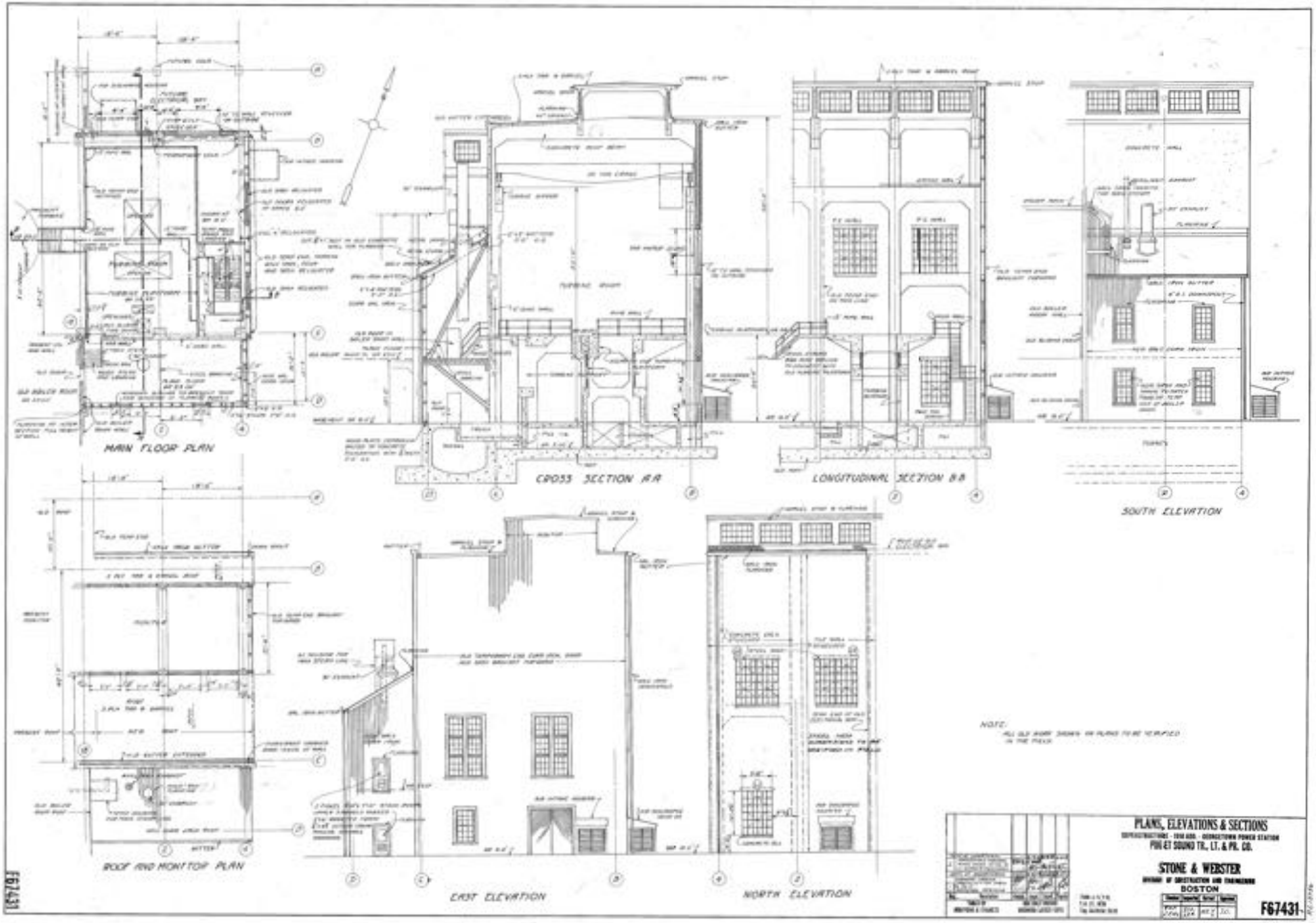

BOILER ROOM MONITOR WINDOW
GEORGETOWN POWER STATION
THE SEATTLE ELECTRIC CO.
STONE & WEBSTER
BOSTON
H7823
H-w169
10'-6" Between Trusses

ELEVATION
1 Wanted
SECTION
ELEVATION
PLAN ON SECTION 'A-A'
11 Wanted
ENG. R'M. DOOR & BASEMENT WINDOW
GEORGETOWN POWER STATION
THE SEATTLE ELECTRIC CO.
STONE & WEBSTER
BOSTON
H7819

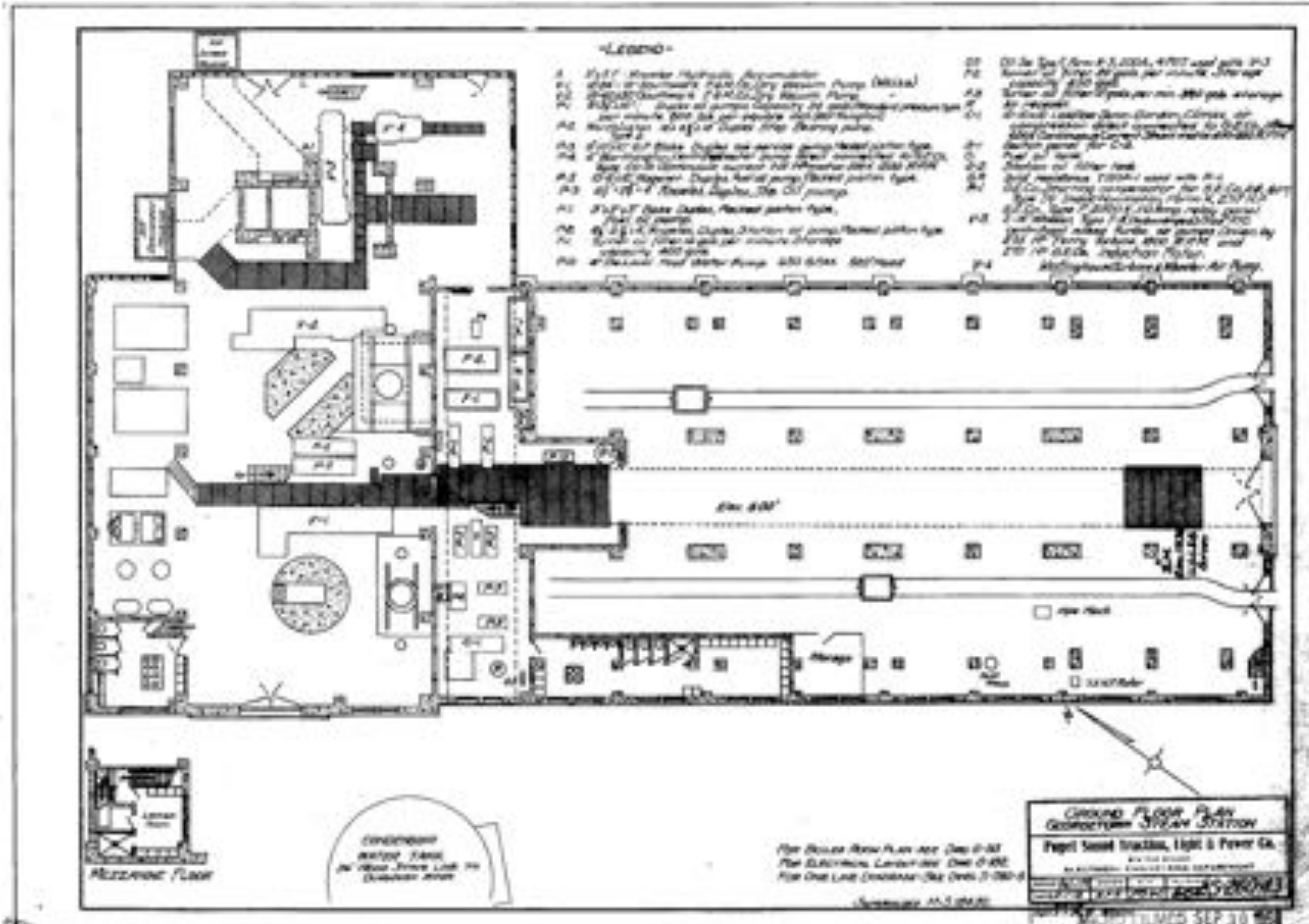

ELEVATION
SECTION
ELEVATION
SECTION
PLAN
HALF PLAN
16'- 4"
ENGINE ROOM WINDOWS
GEORGETOWN POWER STATION
THE SEATTLE ELECTRIC CO.
STONE & WEBSTER
BOSTON
F8917
F-543


PLAN A-A
A
A
WINDOWS SOUTH ELEVATION
1 WANTED
BOILER ROOM WINDOWS
GEORGETOWN POWER STATION
THE SEATTLE ELECTRIC CO
STONE & WEBSTER
BOSTON
F7978

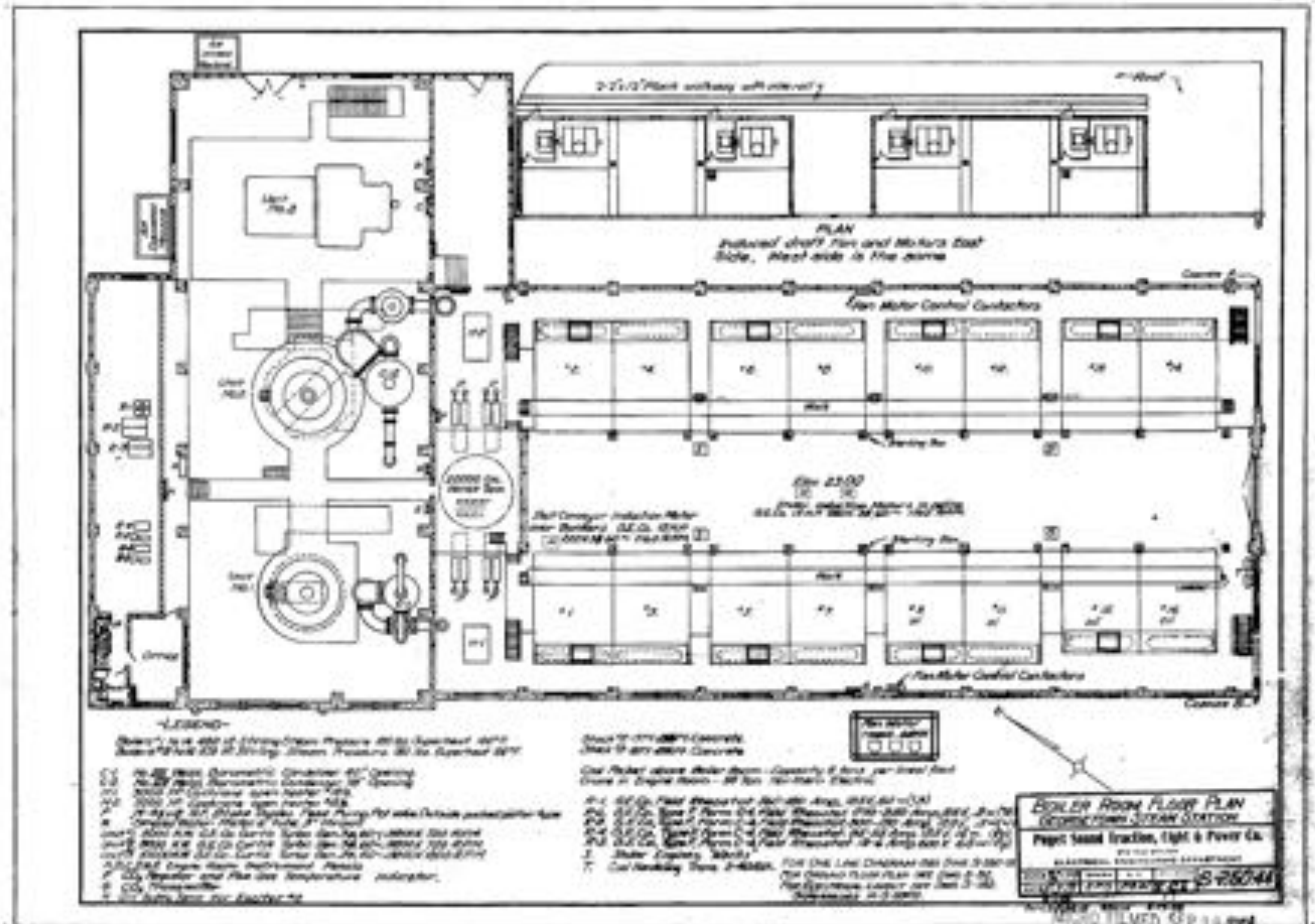

Lag Screw
BOILER ROOM WINDOWS
18 WANTED
WEST ELEVATION OF BOILER ROOM
1 WANTED
BOILER ROOM WINDOWS
GEORGETOWN POWER STATION
THE SEATTLE ELECTRIC CO
STONE & WEBSTER
BOSTON
F7827
F-348

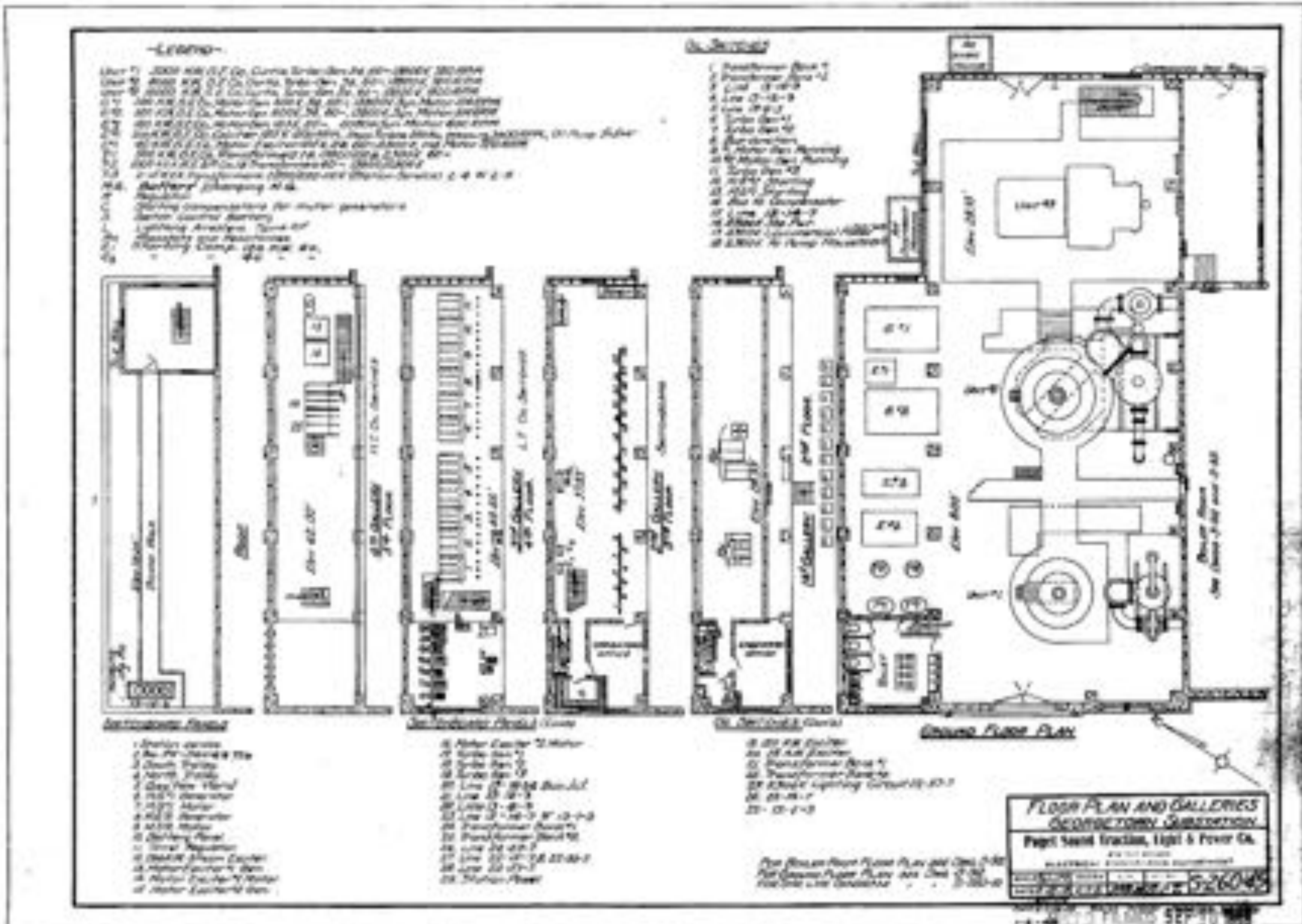


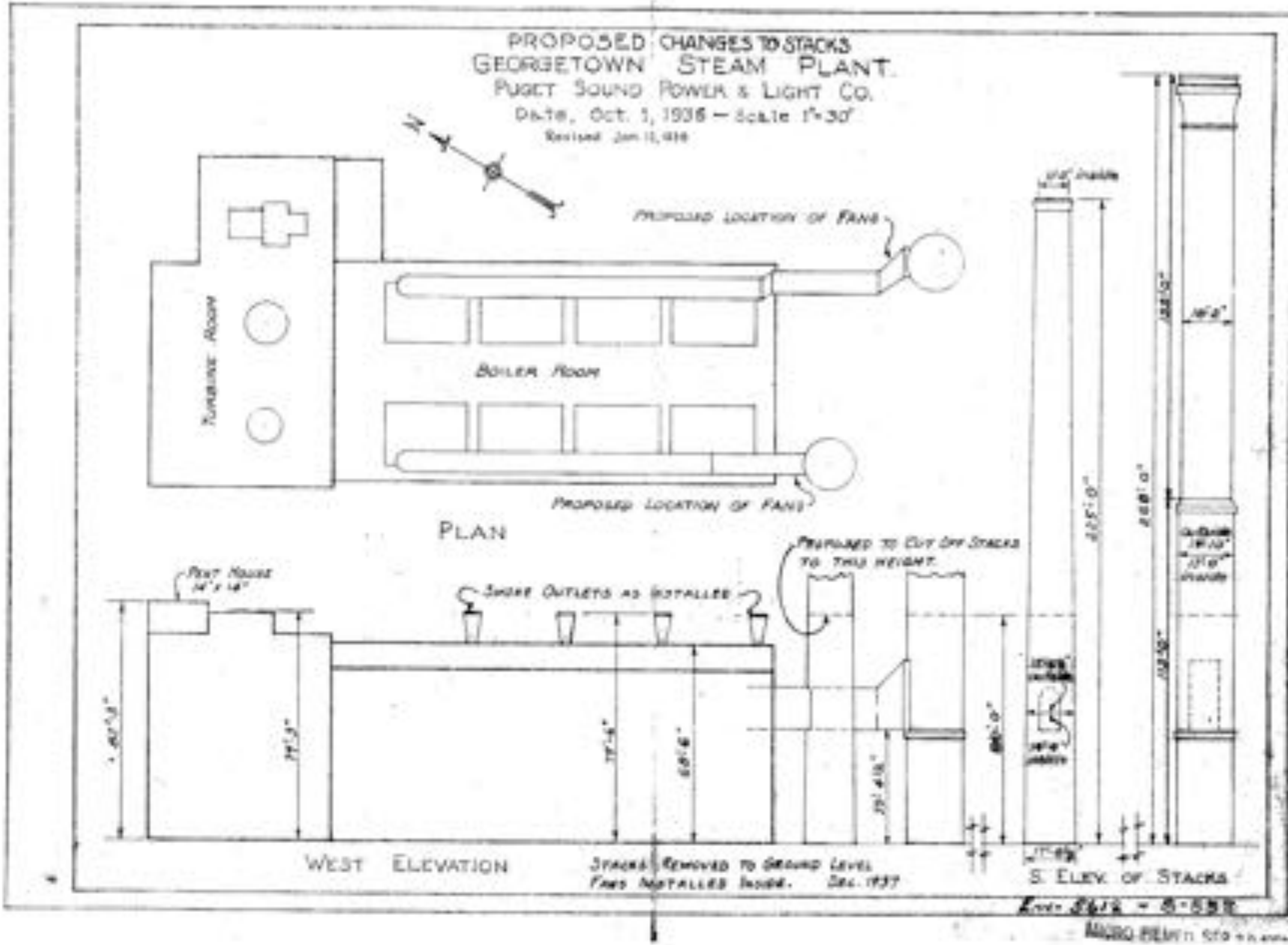
MAIN FLOOR PLAN
CROSS SECTION A-A
LONGITUDINAL SECTION B-B
SOUTH ELEVATION
ROOF AND MONITOR PLAN
EAST ELEVATION
NORTH ELEVATION
TURBINE ROOM
NOTE:
ALL OLD WORK SHOWN ON PLANS TO BE VERIFIED IN THE FIELD
PLANS, ELEVATIONS & SECTIONS
PUGET SOUND TR., LT. & PR. CO.
STONE & WEBSTER
BOSTON
F67431



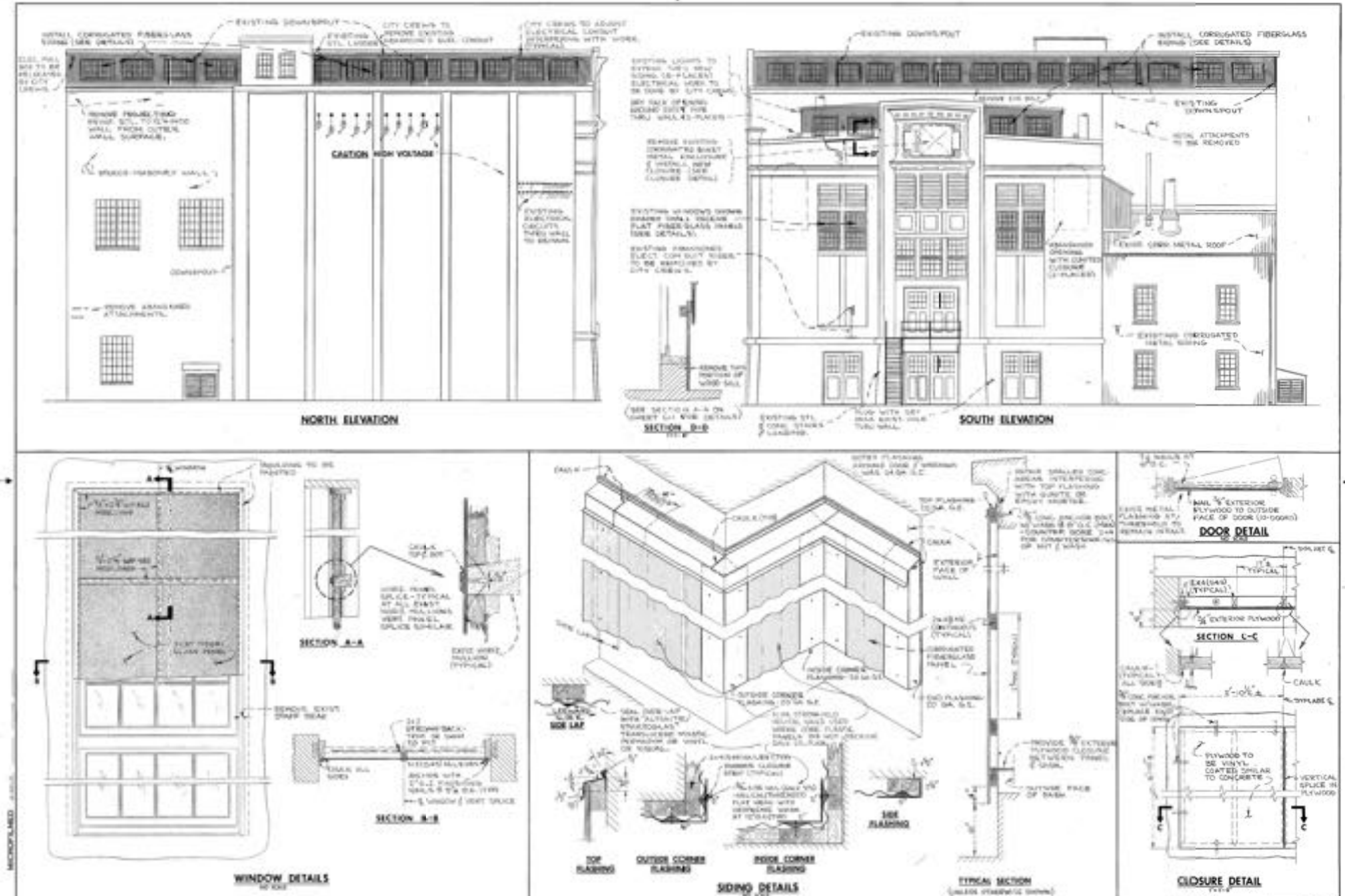
LEGEND
GROUND FLOOR PLAN
GEORGETOWN STEAM STATION
Puget Sound Traction, Light & Power Co.
MEZZANINE FLOOR
MICROFILMED SEP 30


PLAN
Induced draft Fan and Motors East Side, West side is the same
Fan Motor Control Contactors
Elev. 23.00
Starting Box
Fan Motor Control Contactors
-LEGEND-
Boiler Room Floor Plan
Georgetown Steam Station
Puget Sound Traction, Light & Power Co.


LEGEND
GROUND FLOOR PLAN
SWITCHBOARD PANELS
FLOOR PLAN AND GALLERIES
GEORGETOWN SUBSTATION
Puget Sound Traction, Light & Power Co.


PROPOSED CHANGES TO STACKS
GEORGETOWN STEAM PLANT
PUGET SOUND POWER & LIGHT CO.
Date, Oct. 1, 1936 — Scale 1"=30'
N
PROPOSED LOCATION OF FANS
TURBINE ROOM
BOILER ROOM
PROPOSED LOCATION OF FANS
PLAN
PENT HOUSE 14' x 14'
SMOKE OUTLETS AS INSTALLED
PROPOSED TO CUT OFF STACKS TO THIS HEIGHT
WEST ELEVATION
STACKS REMOVED TO GROUND LEVEL
FANS INSTALLED INSIDE. DEC. 1937
S. ELEV. OF STACKS
205'-0"
268'-0"
14'-2"
68'-6"

NOTES
EAST ELEVATION
WEST ELEVATION
SECTION A-A
CAUTION HIGH VOLTAGE AREA
CAUTION HIGH VOLTAGE AREA
EXISTING STEEL LADDER
EXIST. LADDER
FIBERGLASS PANEL
1906
DEPARTMENT OF LIGHTING
GEORGETOWN STEAM PLANT
BUILDING REPAIR
ELEVATIONS
C 1
D-25401
MICROFILMED



GEORGETOWN STEAM PLANT

DEPARTMENT OF LIGHTING

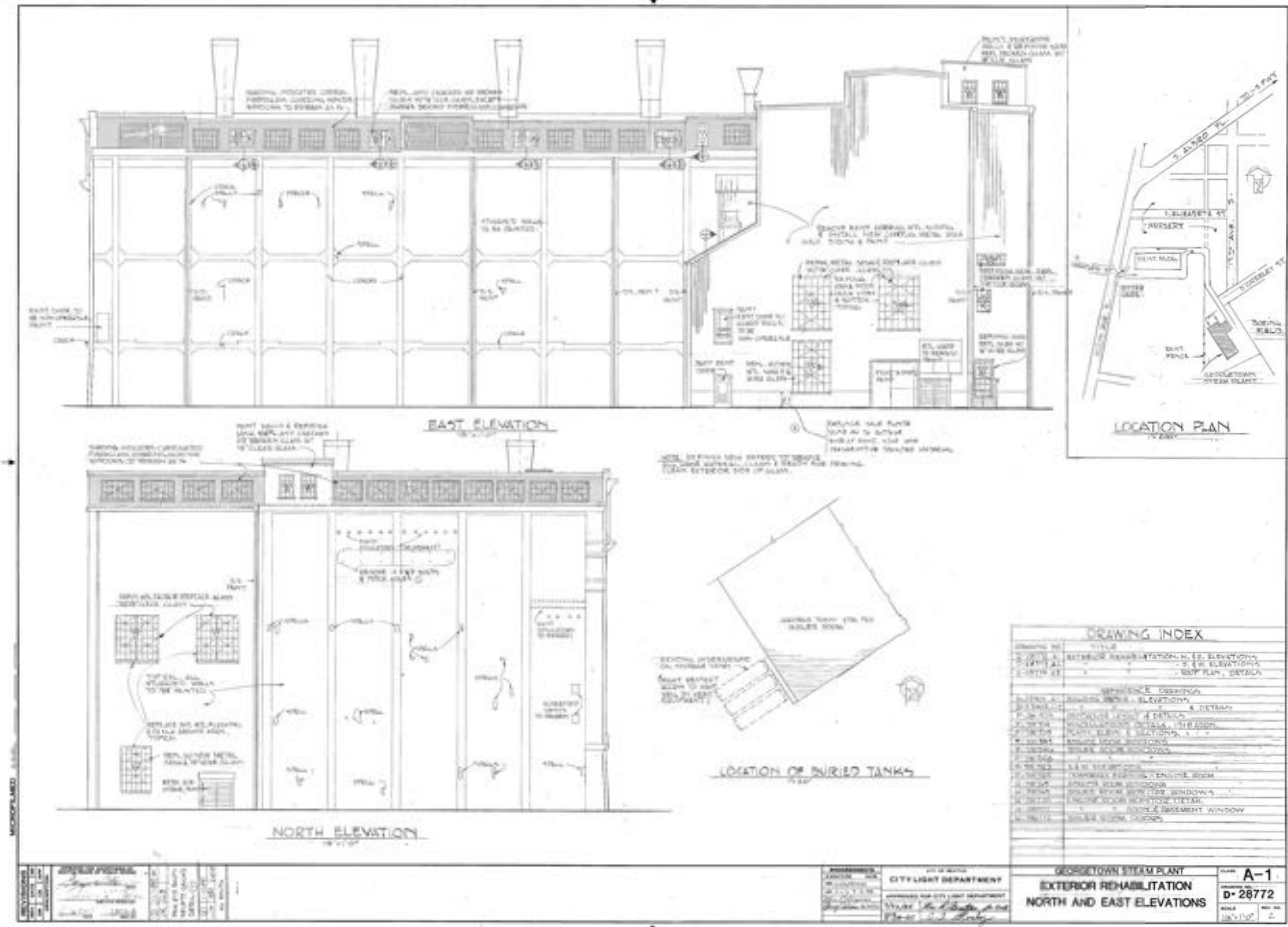
BUILDING REPAIR

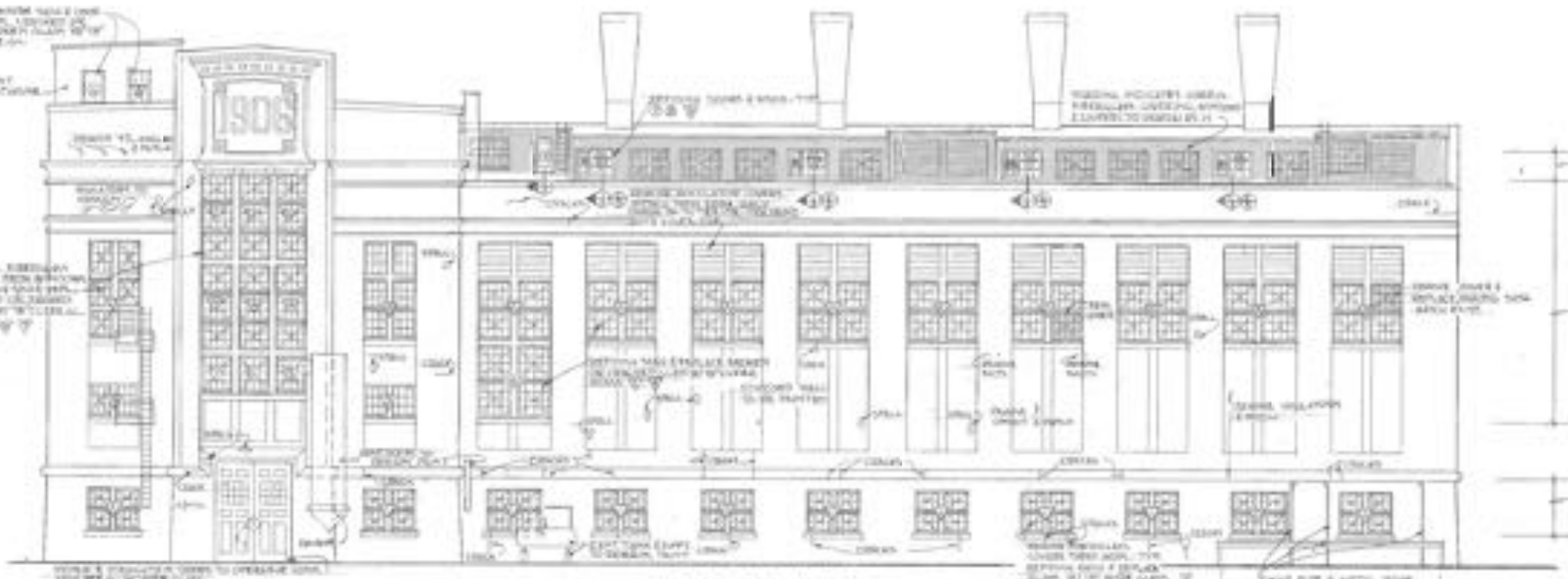
ELEVATIONS & DETAILS

C 2

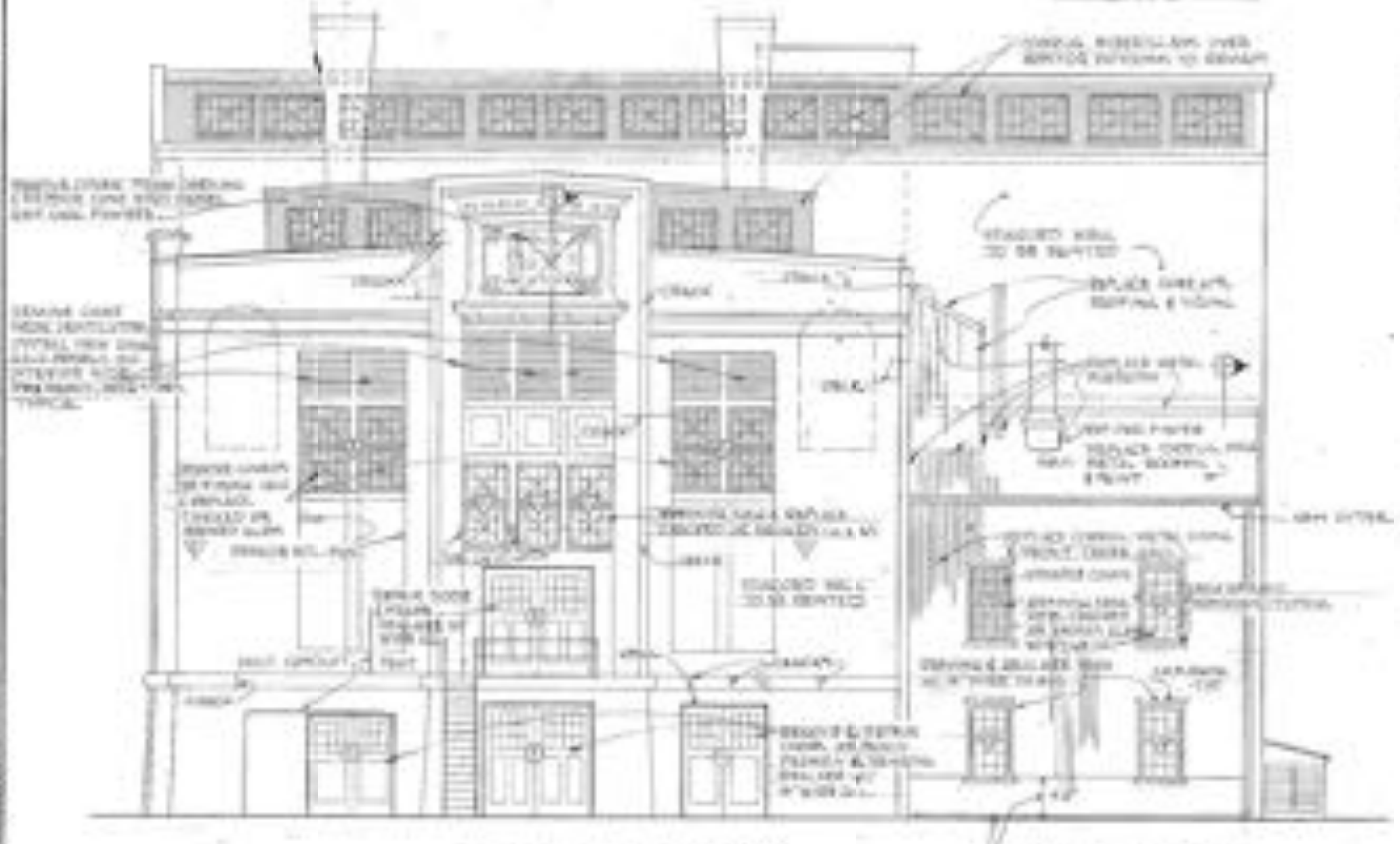
D-25402

1


EAST ELEVATION
NORTH ELEVATION
LOCATION PLAN
LOCATION OF BURIED TANKS
GEORGETOWN STEAM PLANT
BOEING FIELD
DRAWING INDEX
CITY LIGHT DEPARTMENT
GEORGETOWN STEAM PLANT
EXTERIOR REHABILITATION
NORTH AND EAST ELEVATIONS
A-1
D-28772



WEST ELEVATION



SOUTH ELEVATION

SIDE WALL FLASHING

END WALL FLASHING

WINDOW SCHEDULE

MARK	TYPE	MATERIAL	[illegible]	[illegible]	[illegible]	[illegible]	GLASS TYPE	SASH	REF. DRAWING
1	PIVOTED	WOOD	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2			4	[illegible]	[illegible]		[illegible]	[illegible]	F-SW 548
3			[illegible]	[illegible]	[illegible]			*	F-SW 543
4			[illegible]	[illegible]	[illegible]			*	F-SW 548
5			[illegible]	[illegible]	[illegible]			*	F-SW 543
6			[illegible]	[illegible]	[illegible]			*	
7			[illegible]	[illegible]	48			*	
8	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]		*	F-SW 606
9	FIXED		[illegible]	[illegible]	[illegible]	[illegible]		*	H-SW 195
10	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]		*	
11	PIVOTED		[illegible]	[illegible]	[illegible]	[illegible]		*	F-SW 546
12	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	*	H-SW 195
13	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	*	
14	[illegible]	STEEL	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
15	[illegible]	STEEL	[illegible]	24	[illegible]	[illegible]	[illegible]	[illegible]	F-SW 515
16	[illegible]	STEEL	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
17	[illegible]	WOOD	[illegible]	[illegible]	[illegible]	[illegible]			

* REPLACE CRACKED OR BROKEN GLASS

DOOR SCHEDULE (ALL DOORS BELOW TO BE OPERABLE)

MARK	TYPE	MATERIAL	[illegible]	[illegible]	[illegible]	REMARKS	REF. DRAWING
1	SINGLE	WOOD	[illegible]	[illegible]	[illegible]	[illegible] GLASS	[illegible]-SW 171
2	DOUBLE	WOOD	[illegible]	[illegible]	[illegible]	[illegible] GLASS	H-SW 172
3	DOUBLE	WOOD	[illegible]	[illegible]	[illegible]	[illegible] GLASS	H-SW 172
4	DOUBLE	WOOD	[illegible]	[illegible]	[illegible]	[illegible] GLASS	H-SW 172
5	DOUBLE	WOOD	[illegible]	[illegible]	[illegible]	[illegible] GLASS	H-SW 172
6	SINGLE	WOOD	[illegible]	[illegible]	NONE		F-SW 595
7	SINGLE	WOOD	[illegible]	[illegible]	NONE		D-28774
8	SINGLE	WOOD	[illegible]	[illegible]	NONE		D-28774

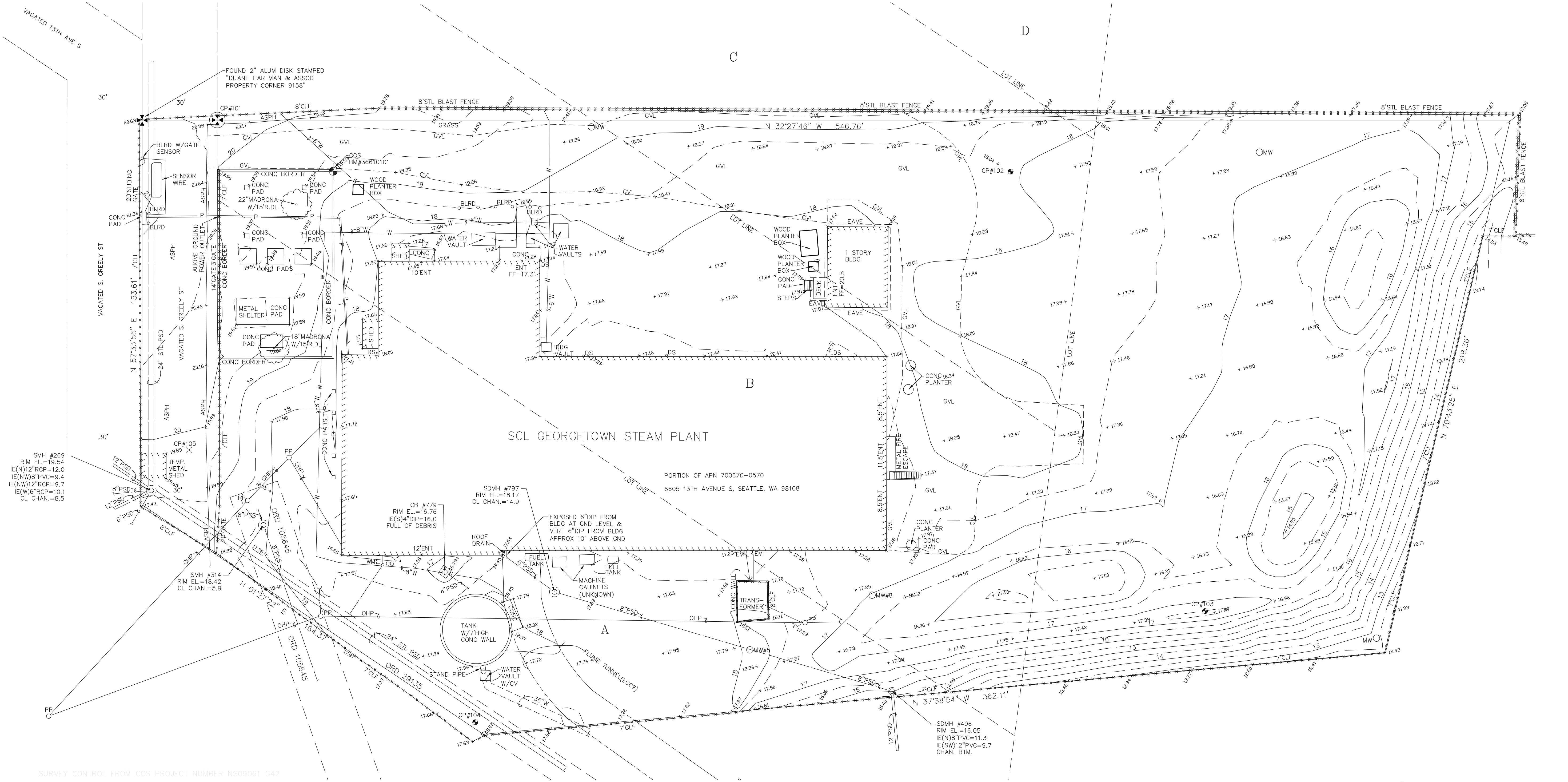
CITY LIGHT DEPARTMENT

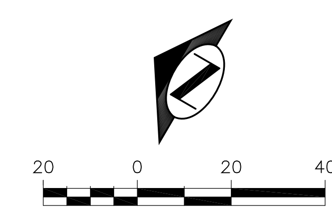
GEORGETOWN STEAM PLANT

EXTERIOR REHABILITATION
SOUTH AND WEST ELEVATIONS

A-2

D-28773





811
Know what's **below.**
Call before you dig.

SURVEY CONTROL FROM COS PROJECT NUMBER NS09061 G42

Survey Control Point Table				
Point #	Northing	Easting	Elevation	Description
101	201737.82	1274198.64	19.48	MIC
102	201459.28	1274351.43	18.18	RC
103	201299.47	1274245.00	17.49	RC
104	201521.75	1274051.00	17.93	RC
105	201676.53	1274081.43	19.92	MAG

REVISIONS

EILEEN M. FORRESTER — STATE OF WASHINGTON — 31453 REGISTERED — PROFESSIONAL LAND SURVEYOR

ENDORSEMENTS	
SIGNATURE	DATE
DRAWN: EF	3/18/13
CHECK: TI	3/18/13
DESIGN:	
CHECK:	

Seattle City Light

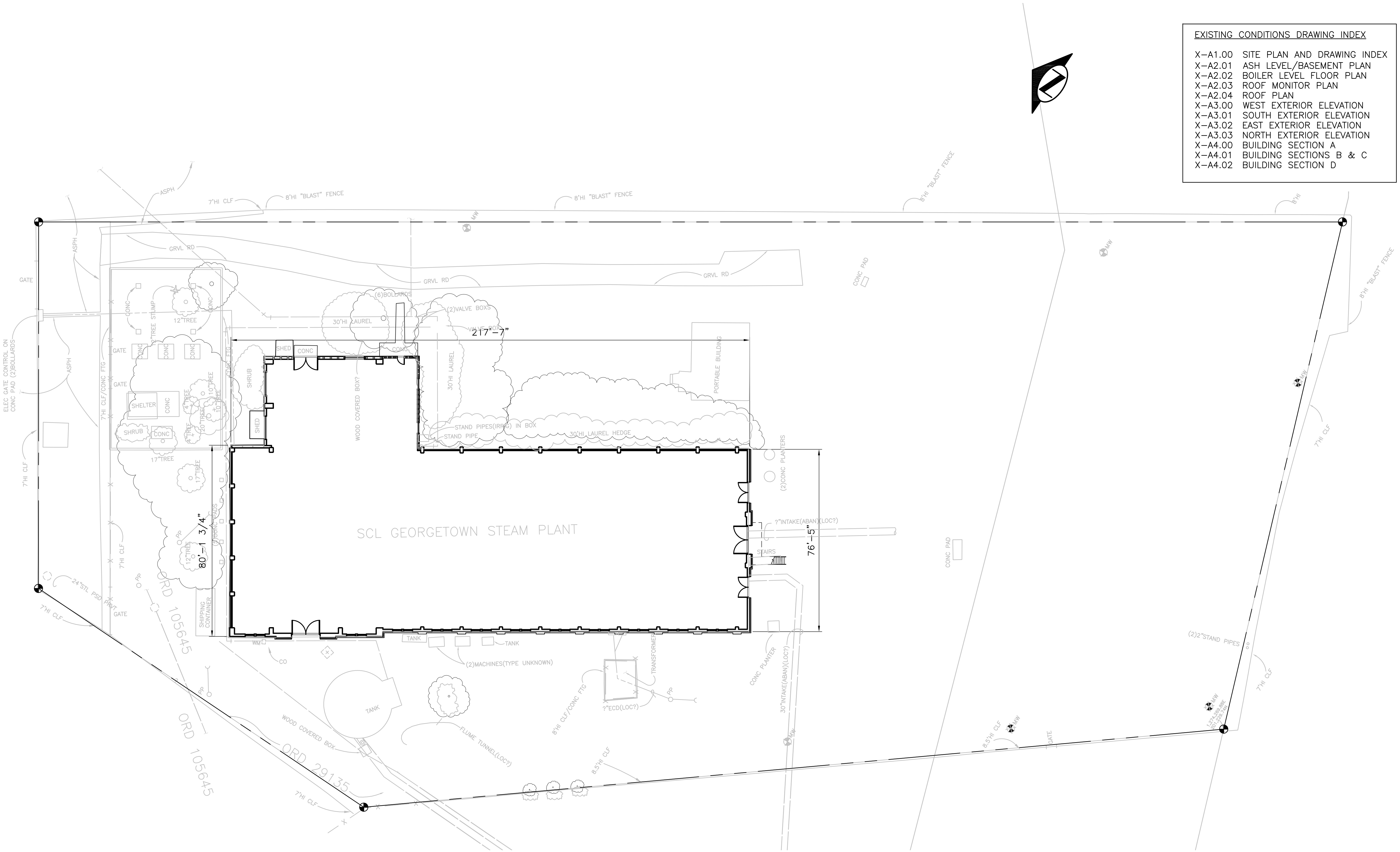
APPROVED FOR SEATTLE CITY LIGHT

DATE

SUBJECT	MAPPING
LOCATION	GEORGETOWN STEAM PLANT
TITLE	BOUNDARY & TOPOGRAPHICAL SURVEY PORTION OF SECTION 29, T 24, R 4 E, W.M.
SHEET	16 OF 74
CLASS \ SHEET	L-3
DRAWING NO.	D-47716
SCALE	1"=20'-0"
REV. NO.	0

C:_Current (PC-7 Suzie)\ACAD files\11-515_SCL Georgetown Steamplant\11-515_SCL GTSP_SHEETS\11-515_X-A1.00.dwg, ANSI-D: 22x34, BOLA, August 7, 2012 12:31 PM

EXISTING CONDITIONS DRAWING INDEX



ARCHITECTURAL SITE PLAN 1
1" = 20'-0"

ONE INCH AT FULL SIZE	REVISIONS
REV	DATE	IMAGE
DRAWN BY:	CHECKED BY:	APPROVED BY:
WORK ORDER #:	DESCRIPTION	
WORK ORDER #:		

BOLA
ARCHITECTURE + PLANNING
159 WESTERN AVE. W. SUITE 486
SEATTLE WA 98119

ENDORSEMENTS	
SIGNATURE	DATE
DRAWN:	08/03/2012
CHECK:	
DESIGN:	
CHECK:	

Seattle City Light
Power Production & Substations

APPROVED FOR SEATTLE CITY LIGHT

DATE

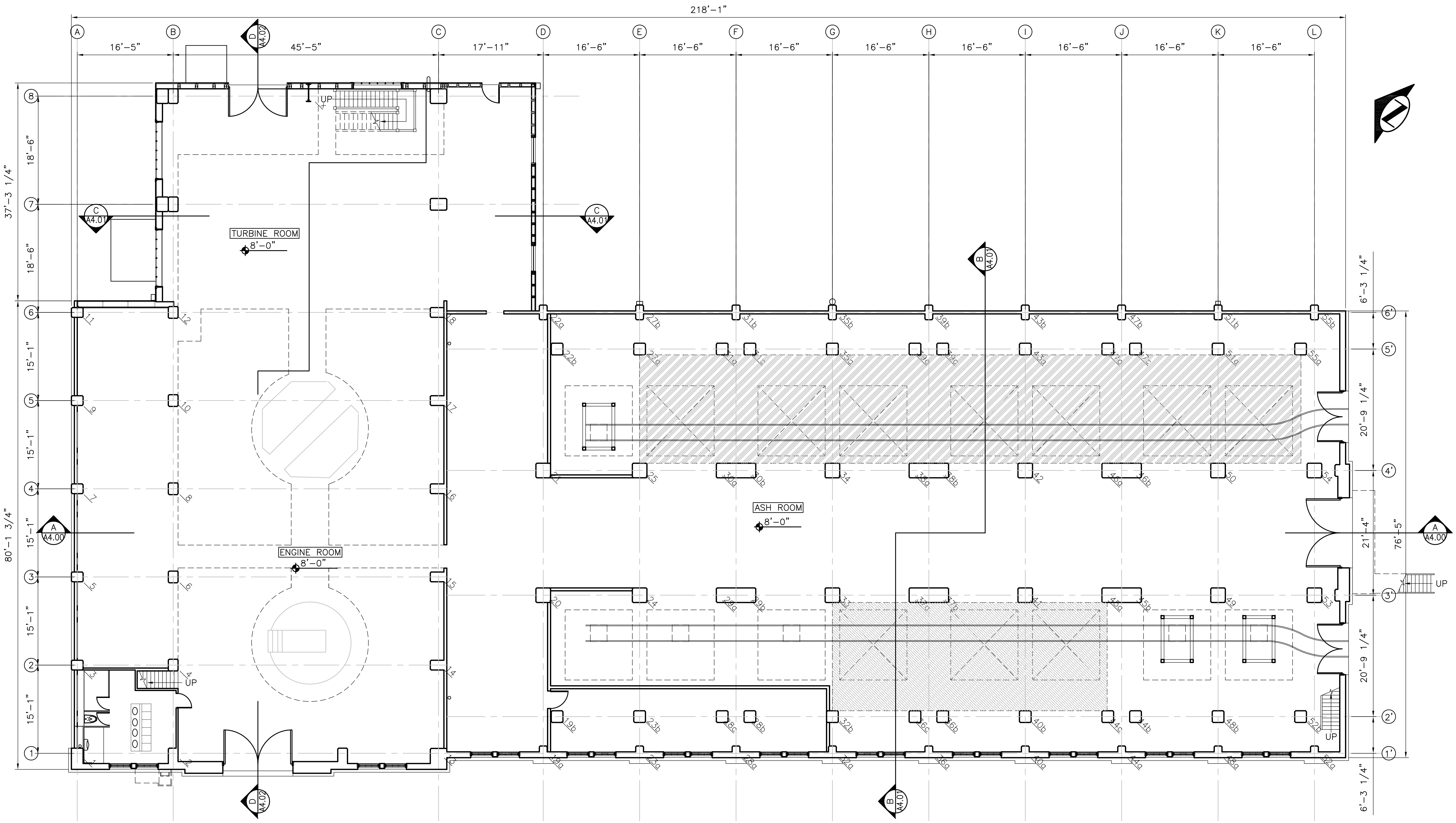
SUBJECT

LOCATION GEORGETOWN STEAM PLANT RENOVATION

TITLE EXISTING CONDITIONS

SITE PLAN & DRAWING INDEX

SHEET	OF
CLASS \ SHEET	X-A1.00
DRAWING NO.	
SCALE 1"=20'-0"	REV. NO. 0



ASH LEVEL/BASEMENT PLAN
1/8" = 1'-0"
1 —

ONE INCH AT FULL SIZE	REVISIONS	REV / DATE / IMAGE	DRAWN BY: / CHECKED BY: / APPROVED BY: / WORK ORDER #: / DESCRIPTION / WORK ORDER #:

BOLA
ARCHITECTURE + PLANNING
159 WESTERN AVE. W. SUITE 486
SEATTLE WA 98119

ENDORSEMENTS	
SIGNATURE	DATE
DRAWN:	08/03/2012
CHECK:	
DESIGN:	
CHECK:	

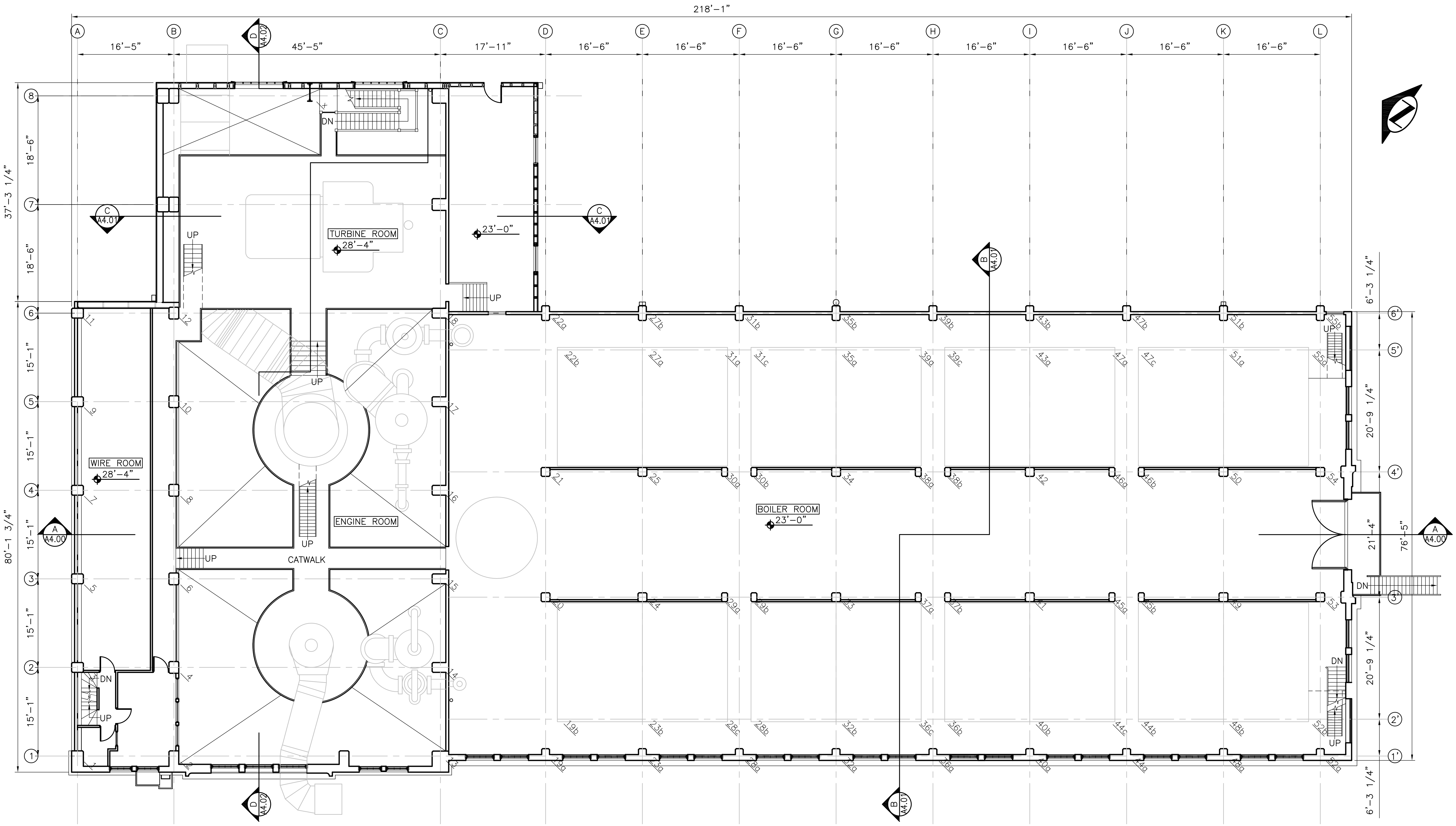
Seattle City Light
Power Production & Substations

APPROVED FOR SEATTLE CITY LIGHT

DATE

SUBJECT	SHEET OF
LOCATION GEORGETOWN STEAMPLANT RENOVATION	CLASS \ SHEET X-A2.01
TITLE EXISTING CONDITIONS	DRAWING NO.
ASH LEVEL/BASEMENT PLAN	SCALE 1/8"=1'-0" / REV. NO. 0

C:_Current (PC-7 Suze)\ACAD files\11-515_SCL Georgetown Steamplant\11-515_SCL GTSP_SHEETS\11-515_X-A2.01.dwg, ANSI-D: 22x34, BOLA, August 7, 2012 12:36 PM



BOILER LEVEL FLOOR PLAN

1/8" = 1'-0"

C:_Current (PC-7 Suzie)\ACAD files\11-515_SCL Georgetown Steamplant\11-515_SCL GTSP_SHEETS\11-515_X-A2.02.dwg, ANSI-D: 22x34, BOLA, August 7, 2012 12:38 PM

ONE INCH AT FULL SIZE

REVISIONS

REV	DATE	IMAGE
DRAWN BY:	CHECKED BY:	APPROVED BY:
WORK ORDER #:		
DESCRIPTION		

WORK ORDER #:

BOLA
ARCHITECTURE + PLANNING
159 WESTERN AVE. W. SUITE 486
SEATTLE WA 98119

ENDORSEMENTS

SIGNATURE	DATE
DRAWN:	08/03/2012
CHECK:	
DESIGN:	
CHECK:	

Seattle City Light
Power Production & Substations

APPROVED FOR SEATTLE CITY LIGHT

DATE

SUBJECT

LOCATION GEORGETOWN STEAM PLANT RENOVATION

TITLE EXISTING CONDITIONS

BOILER LEVEL FLOOR PLAN

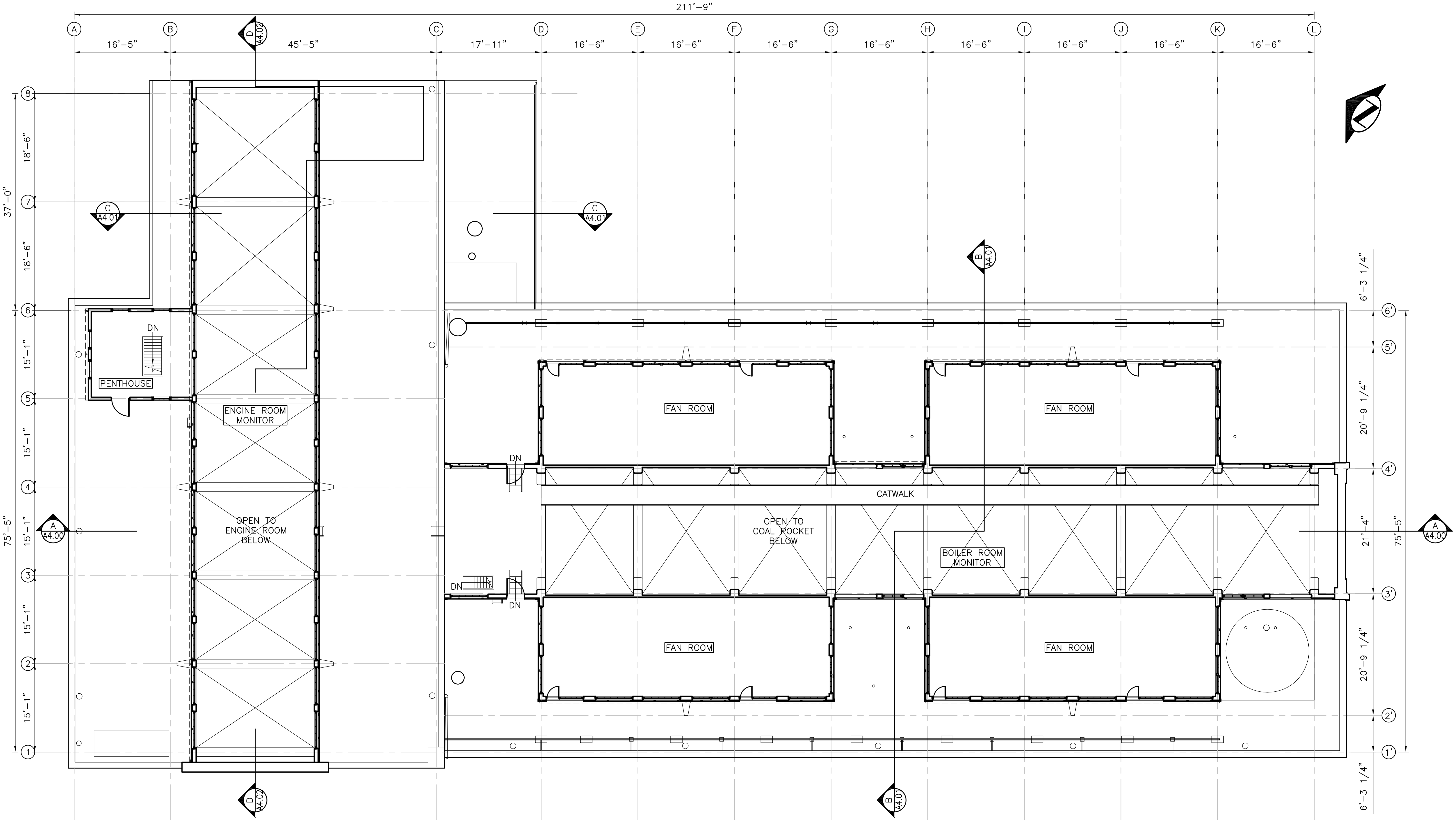
SHEET OF

CLASS \ SHEET X-A2.02

DRAWING NO.

SCALE 1/8"=1'-0"

REV. NO. 0



ROOF MONITOR PLAN
1/8" = 1'-0"

C:_Current (PC-7 Suze)\ACAD files\11-515_SCL Georgetown Steamplant\11-515_SCL GTSP_SHEETS\11-515_X-A2.03.dwg, ANSI-D: 22x34, BOLA, August 7, 2012 12:39 PM

ONE INCH AT FULL SIZE

REVISIONS

REV	DATE	IMAGE
DRAWN BY:	CHECKED BY:	APPROVED BY:
WORK ORDER #:		
DESCRIPTION		

WORK ORDER #:

BOLA
ARCHITECTURE + PLANNING
159 WESTERN AVE. W. SUITE 486
SEATTLE WA 98119

ENDORSEMENTS

SIGNATURE	DATE
DRAWN:	08/03/2012
CHECK:	
DESIGN:	
CHECK:	

Seattle City Light
Power Production & Substations

APPROVED FOR SEATTLE CITY LIGHT

DATE

SUBJECT

LOCATION GEORGETOWN STEAM PLANT RENOVATION

TITLE EXISTING CONDITIONS

ROOF MONITOR PLAN

SHEET OF

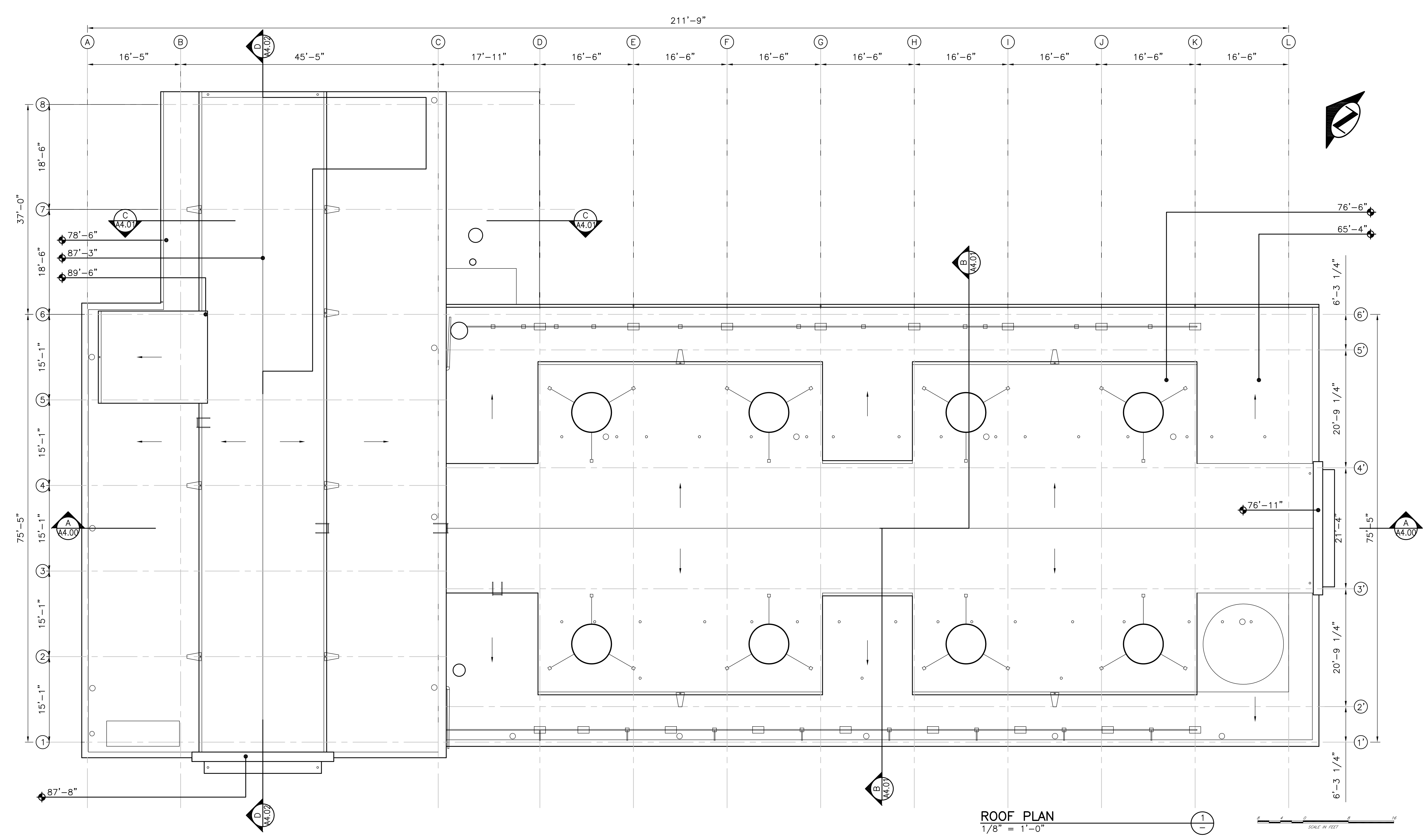
CLASS \ SHEET X-A2.03

DRAWING NO.

SCALE 1/8"=1'-0"

REV. NO. 0

C:_Current (PC-7 Suze)\ACAD files\11-515_SCL Georgetown Steamplant\11-515_SCL GTSP_SHEETS\11-515_X-A2.04.dwg, ANSI-D: 22x34, BOLA, August 7, 2012 12:41 PM



REV	DATE	IMAGE	DRAWN BY:	CHECKED BY:	APPROVED BY:
WORK ORDER #:	DESCRIPTION				

ONE INCH AT FULL SIZE

REVISIONS

WORK ORDER #:

BOLA
ARCHITECTURE + PLANNING
159 WESTERN AVE. W. SUITE 486
SEATTLE WA 98119

ENDORSEMENTS	
SIGNATURE	DATE
DRAWN:	08/03/2012
CHECK:	
DESIGN:	
CHECK:	

Seattle City Light
Power Production & Substations

APPROVED FOR SEATTLE CITY LIGHT

DATE

SUBJECT

LOCATION GEORGETOWN STEAM PLANT RENOVATION

TITLE EXISTING CONDITIONS

ROOF PLAN

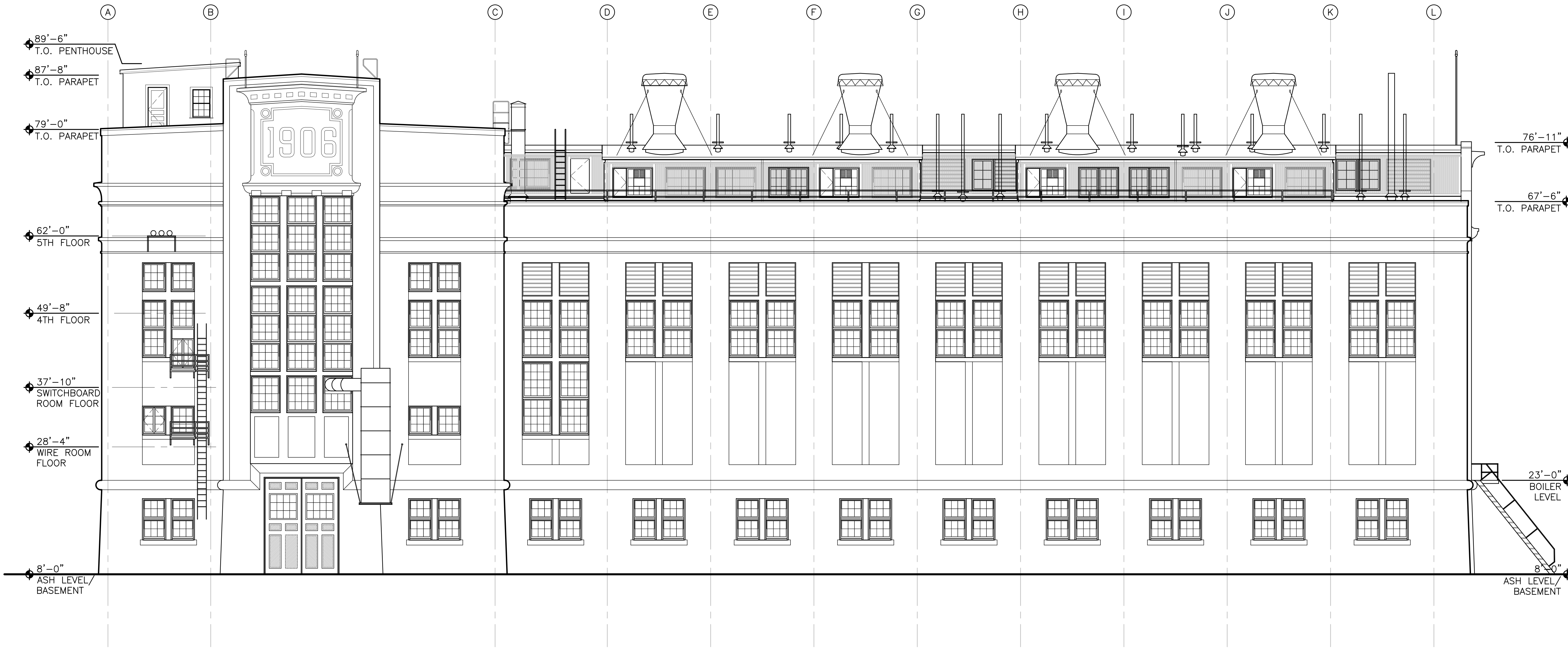
SHEET OF

CLASS \ SHEET X-A2.04

DRAWING NO.

SCALE 1/8"=1'-0"

REV. NO. 0



WEST EXTERIOR ELEVATION
1/8" = 1'-0"
1

C:_Current (PC-7 Suzie)\ACAD files\11-515_SCL Georgetown Steamplant\11-515_SCL GTSP_SHEETS\11-515_X-A3.00.dwg, ANSI-D: 22x34, BOLA, August 7, 2012 12:42 PM

ONE INCH AT FULL SIZE

REVISIONS

REV	DATE	IMAGE	DRAWN BY:	CHECKED BY:	APPROVED BY:	WORK ORDER #:	DESCRIPTION

WORK ORDER #:

BOLA
ARCHITECTURE + PLANNING
159 WESTERN AVE. W. SUITE 486
SEATTLE WA 98119

ENDORSEMENTS

SIGNATURE	DATE
DRAWN:	08/03/2012
CHECK:	
DESIGN:	
CHECK:	

Seattle City Light
Power Production & Substations

APPROVED FOR SEATTLE CITY LIGHT

DATE

SUBJECT

LOCATION GEORGETOWN STEAM PLANT RENOVATION

TITLE EXISTING CONDITIONS

WEST EXTERIOR ELEVATION

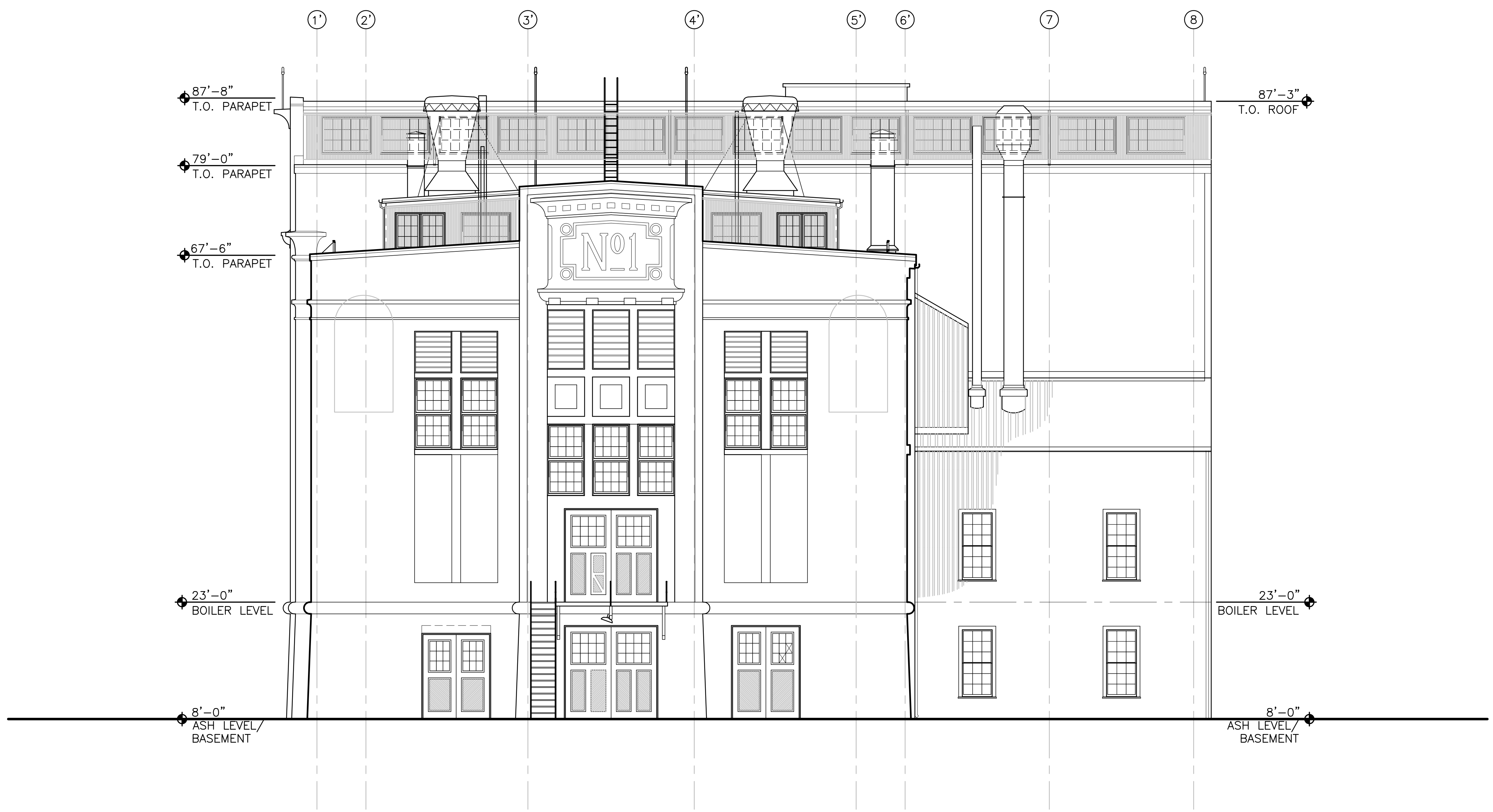
SHEET OF

CLASS \ SHEET X-A3.00

DRAWING NO.

SCALE 1/8"=1'-0"

REV. NO. 0



SOUTH EXTERIOR ELEVATION (1)

1/8" = 1'-0"

SCALE IN FEET

C:_Current (PC-7 Suzie)\ACAD files\11-515_SCL Georgetown Steamplant\11-515_SCL GTSP_SHEETS\11-515_X-A3.01.dwg, ANSI-D: 22x34, BOLA, August 7, 2012 12:43 PM

ONE INCH AT FULL SIZE	REVISIONS
REV	DATE	IMAGE	DRAWN BY:	CHECKED BY:	APPROVED BY:	WORK ORDER #:	DESCRIPTION	WORK ORDER #:

BOLA
ARCHITECTURE + PLANNING
159 WESTERN AVE. W. SUITE 486
SEATTLE WA 98119

ENDORSEMENTS	
SIGNATURE	DATE
DRAWN:	08/03/2012
CHECK:	
DESIGN:	
CHECK:	

Seattle City Light
Power Production & Substations

APPROVED FOR SEATTLE CITY LIGHT

DATE

SUBJECT

LOCATION GEORGETOWN STEAM PLANT RENOVATION

TITLE EXISTING CONDITIONS

SOUTH EXTERIOR ELEVATION

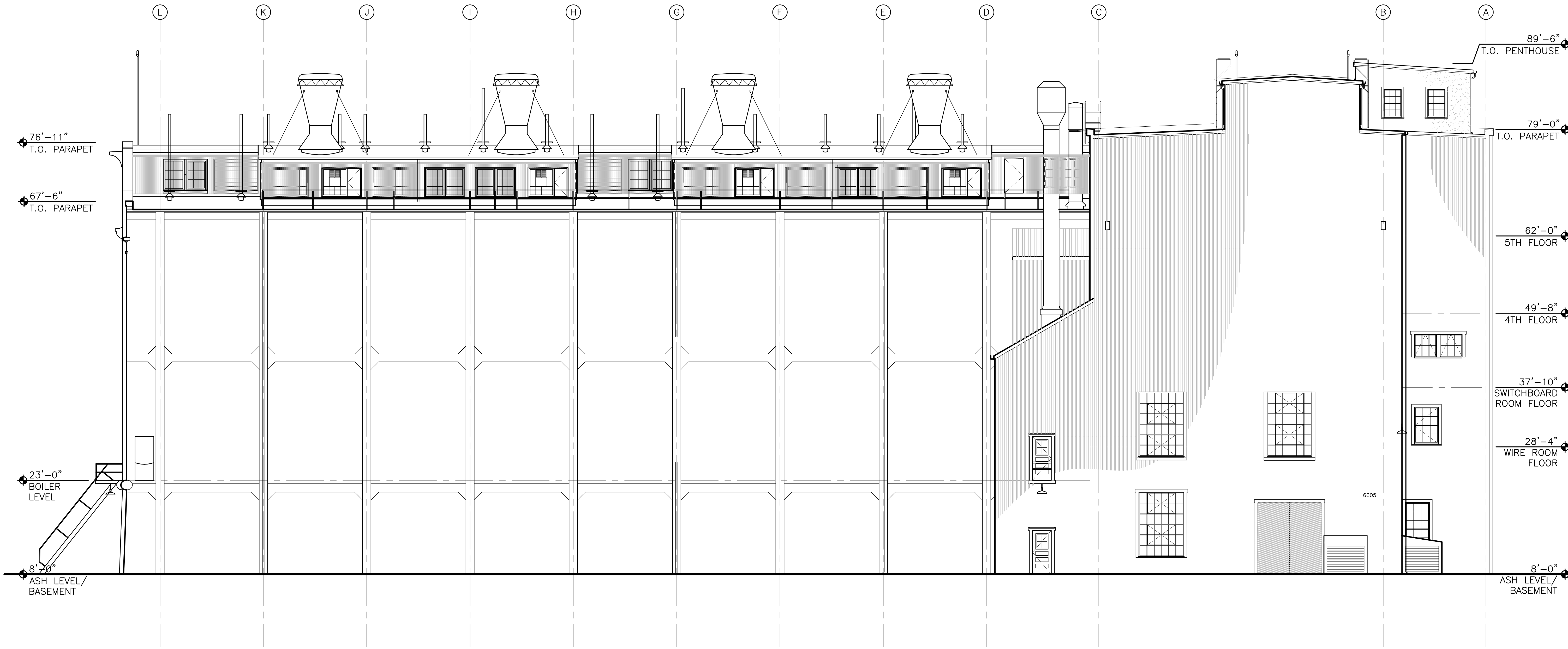
SHEET OF

CLASS \ SHEET X-A3.01

DRAWING NO.

SCALE 1/8"=1'-0"

REV. NO. 0



EAST EXTERIOR ELEVATION 1

1/8" = 1'-0"

SCALE IN FEET

C:_Current (PC-7 Suzie)\ACAD files\11-515_SCL Georgetown Steamplant\11-515_SCL GTSP_SHEETS\11-515_X-A3.02.dwg, ANSI-D: 22x34, BOLA, August 7, 2012 12:44 PM

ONE INCH AT FULL SIZE

REVISIONS

REV	DATE	DRAWN BY:	CHECKED BY:	APPROVED BY:	IMAGE	WORK ORDER #:	DESCRIPTION	WORK ORDER #:

BOLA
ARCHITECTURE + PLANNING
159 WESTERN AVE. W. SUITE 486
SEATTLE WA 98119

ENDORSEMENTS

SIGNATURE	DATE
DRAWN:	08/03/2012
CHECK:	
DESIGN:	
CHECK:	

Seattle City Light
Power Production & Substations

APPROVED FOR SEATTLE CITY LIGHT

DATE

SUBJECT

LOCATION GEORGETOWN STEAM PLANT RENOVATION

TITLE EXISTING CONDITIONS

EAST EXTERIOR ELEVATION

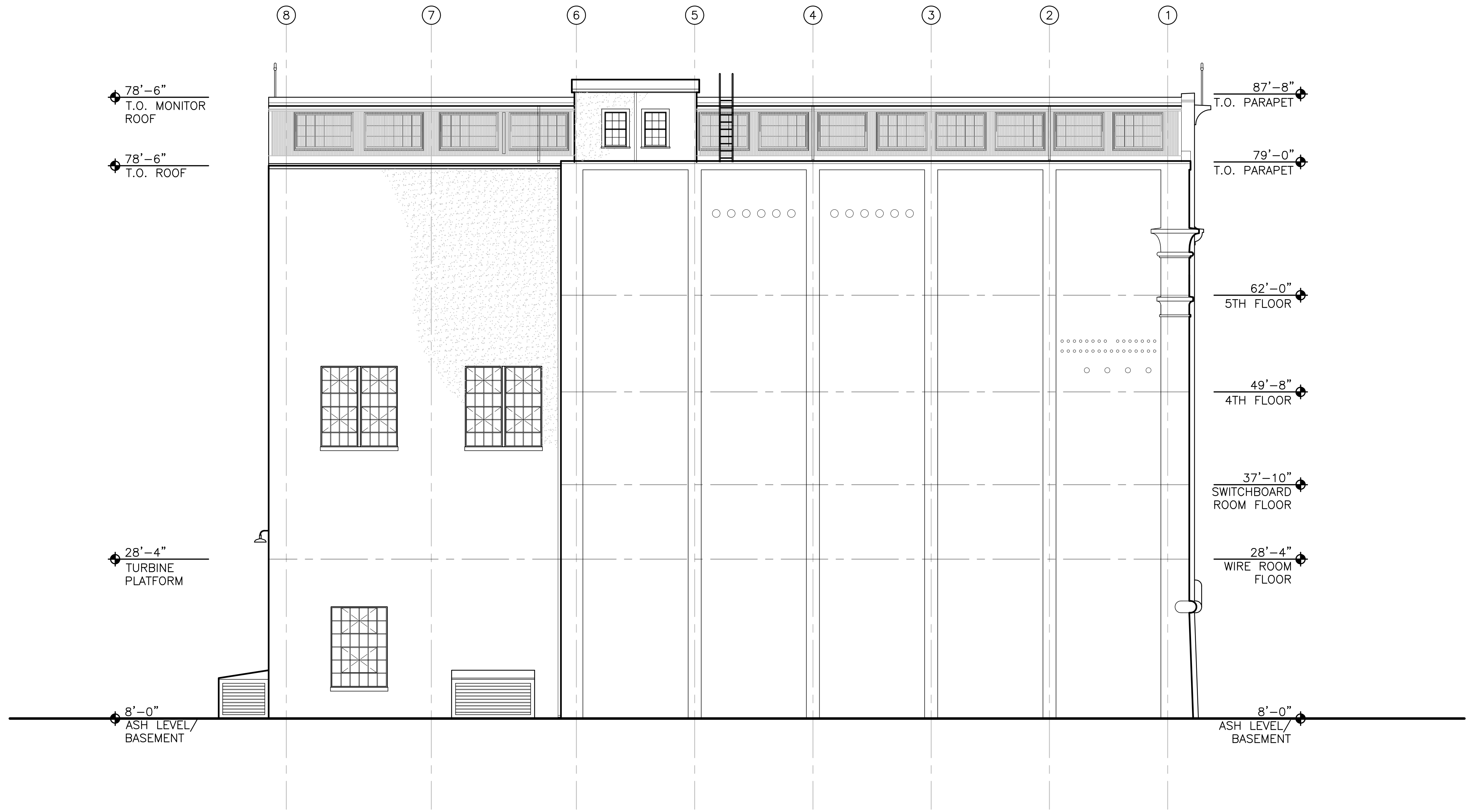
SHEET OF

CLASS \ SHEET X-A3.02

DRAWING NO.

SCALE 1/8"=1'-0"

REV. NO. 0



NORTH EXTERIOR ELEVATION (1)
1/8" = 1'-0"

SCALE IN FEET

C:_Current (PC-7 Suzie)\ACAD files\11-515_SCL Georgetown Steamplant\11-515_SCL GTSP_SHEETS\11-515_X-A3.03.dwg, ANSI-D: 22x34, BOLA, August 7, 2012 12:45 PM

ONE INCH AT FULL SIZE

REVISIONS

REV	DATE	IMAGE
DRAWN BY:	CHECKED BY:	APPROVED BY:
WORK ORDER #:		
DESCRIPTION		

WORK ORDER #:

BOLA
ARCHITECTURE + PLANNING
159 WESTERN AVE. W. SUITE 486
SEATTLE WA 98119

ENDORSEMENTS	
SIGNATURE	DATE
DRAWN:	08/03/2012
CHECK:	
DESIGN:	
CHECK:	

Seattle City Light
Power Production & Substations

APPROVED FOR SEATTLE CITY LIGHT

DATE

SUBJECT

LOCATION GEORGETOWN STEAM PLANT RENOVATION

TITLE EXISTING CONDITIONS

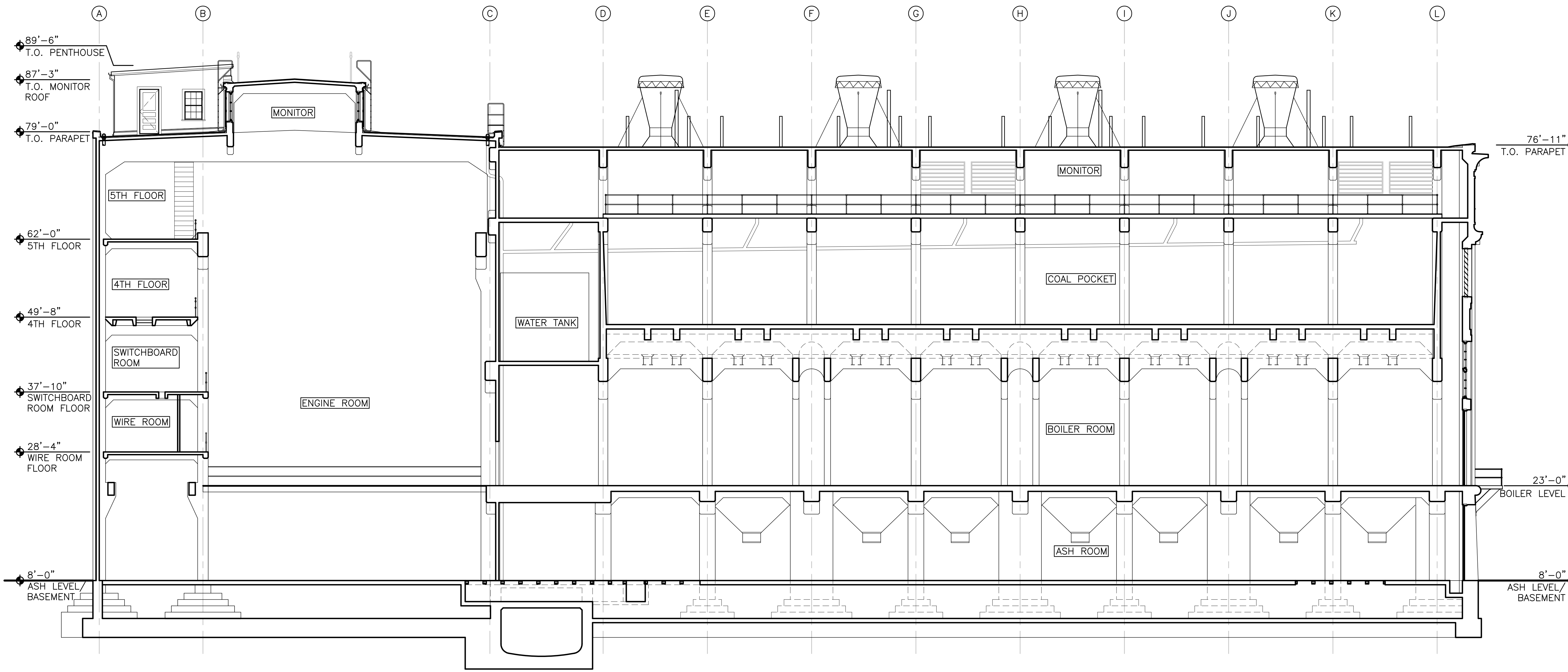
NORTH EXTERIOR ELEVATION

SHEET OF

CLASS \ SHEET X-A3.03

DRAWING NO.

SCALE	REV. NO.
1/8"=1'-0"	0



BUILDING SECTION A (A)
1/8" = 1'-0"

SCALE IN FEET

C:_Current (PC-7 Suzie)\ACAD files\11-515_SCL Georgetown Steamplant\11-515_SCL GTSP_SHEETS\11-515_X-A4.00.dwg, ANSI-D: 22x34, BOLA, August 7, 2012 12:46 PM

ONE INCH AT FULL SIZE

REVISIONS

REV	DATE	IMAGE
DRAWN BY:	CHECKED BY:	APPROVED BY:
WORK ORDER #:	DESCRIPTION	

WORK ORDER #:

BOLA
ARCHITECTURE + PLANNING
159 WESTERN AVE. W. SUITE 486
SEATTLE WA 98119

ENDORSEMENTS	
SIGNATURE	DATE
DRAWN:	08/03/2012
CHECK:	
DESIGN:	
CHECK:	

Seattle City Light
Power Production & Substations

APPROVED FOR SEATTLE CITY LIGHT

DATE

SUBJECT

LOCATION GEORGETOWN STEAM PLANT RENOVATION

TITLE EXISTING CONDITIONS

BUILDING SECTION A

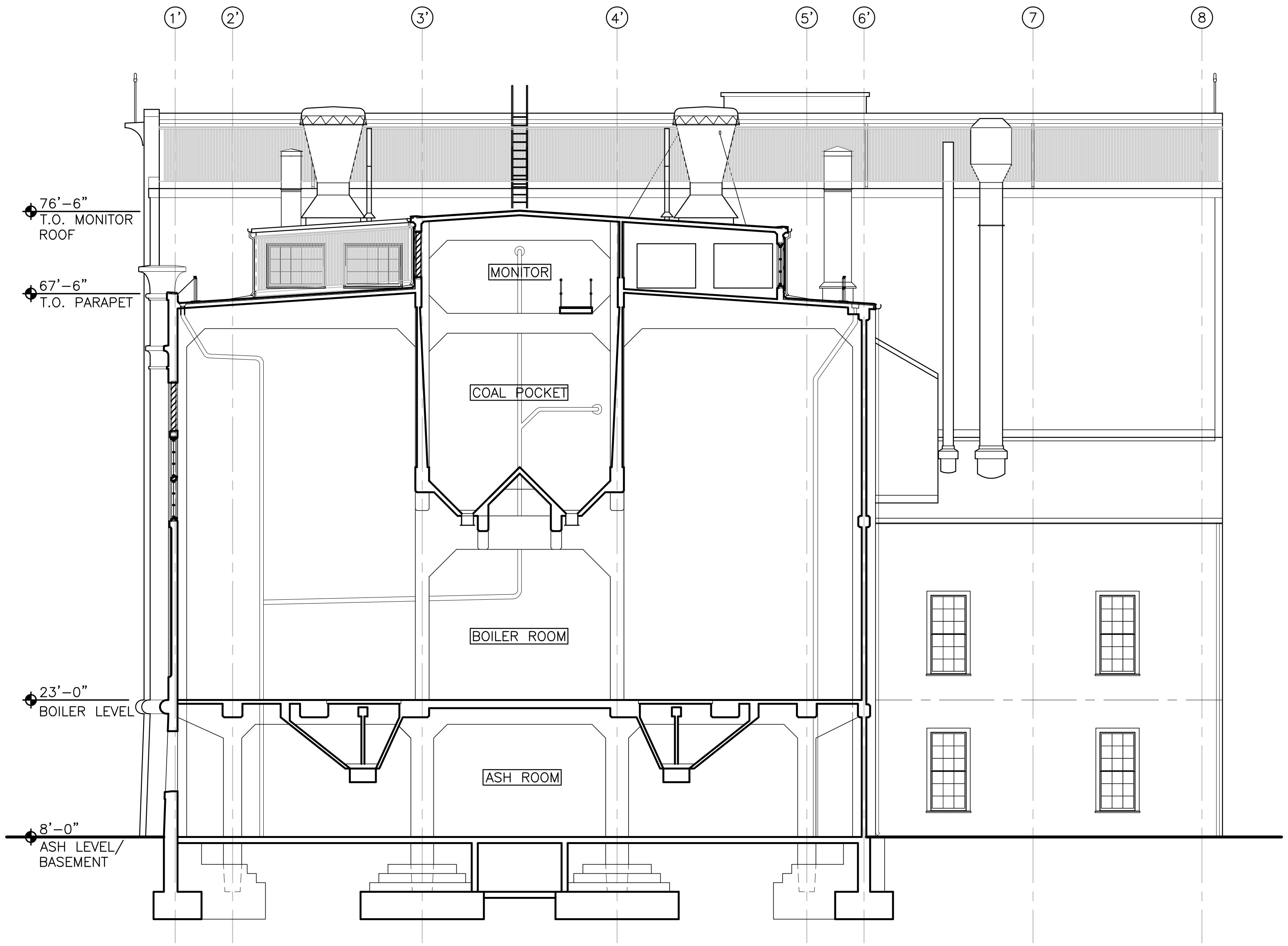
SHEET OF

CLASS \ SHEET X-A4.00

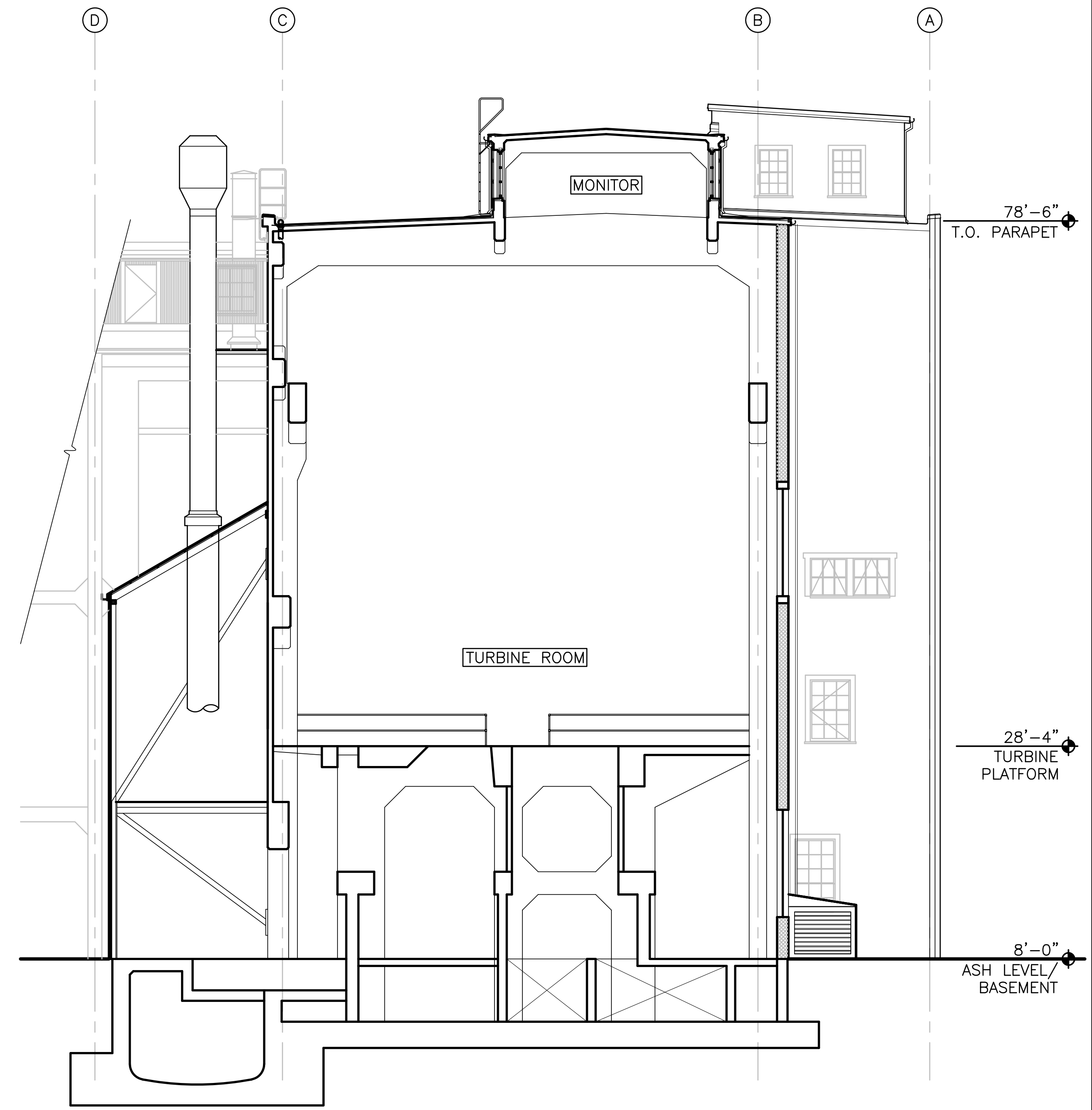
DRAWING NO.

SCALE	REV. NO.
1/8"=1'-0"	0

C:_Current (PC-7 Suzie)\ACAD files\11-515_SCL Georgetown Steamplant\11-515_SCL GTSP_SHEETS\11-515_X-A4.01.dwg, ANSI-D: 22x34, BOLA, August 7, 2012 12:46 PM



BUILDING SECTION B
1/8" = 1'-0"
B



BUILDING SECTION C
1/8" = 1'-0"
C

SCALE IN FEET

ONE INCH AT FULL SIZE	REVISIONS
REV	DATE	DRAWN BY:	CHECKED BY:	APPROVED BY:	IMAGE	WORK ORDER #:	DESCRIPTION	WORK ORDER #:

BOLA
ARCHITECTURE + PLANNING
159 WESTERN AVE. W. SUITE 486
SEATTLE WA 98119

ENDORSEMENTS	
SIGNATURE	DATE
DRAWN:	08/03/2012
CHECK:	
DESIGN:	
CHECK:	

Seattle City Light
Power Production & Substations

APPROVED FOR SEATTLE CITY LIGHT

DATE

SUBJECT

LOCATION GEORGETOWN STEAM PLANT RENOVATION

TITLE EXISTING CONDITIONS

BUILDING SECTIONS B & C

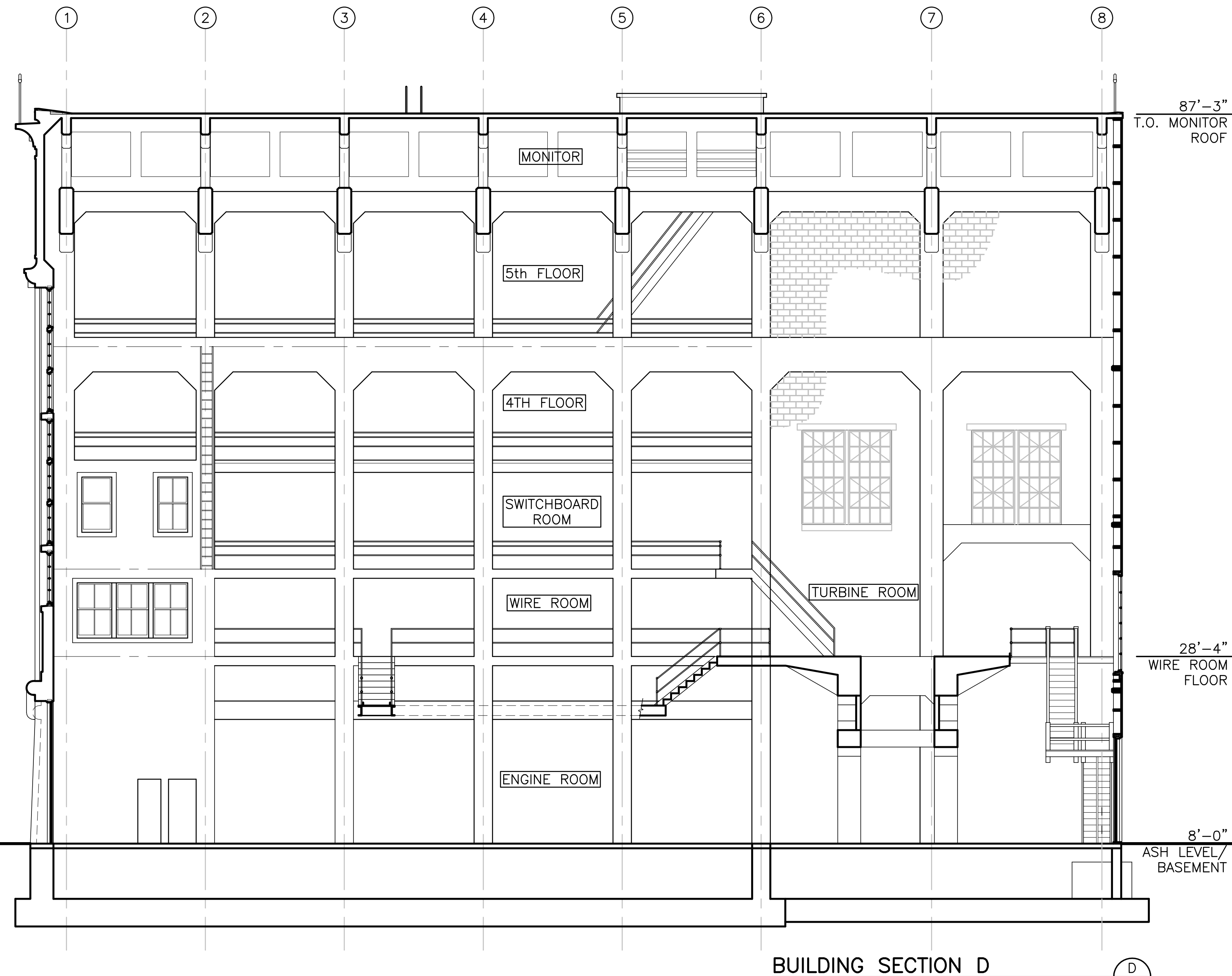
SHEET OF

CLASS \ SHEET X-A4.01

DRAWING NO.

SCALE 1/8"=1'-0"

REV. NO. 0



BUILDING SECTION D

1/8" = 1'-0"

D

C:_Current (PC-7 Suzie)\ACAD files\11-515_SCL Georgetown Steamplant\11-515_SCL GTSP_SHEETS\11-515_X-A4.02.dwg, ANSI-D: 22x34, BOLA, August 7, 2012 12:47 PM

ONE INCH AT FULL SIZE

REVISIONS

REV	DATE	IMAGE	DRAWN BY:	CHECKED BY:	APPROVED BY:	WORK ORDER #:	DESCRIPTION

WORK ORDER #:

BOLA
ARCHITECTURE + PLANNING
159 WESTERN AVE. W. SUITE 486
SEATTLE WA 98119

ENDORSEMENTS

SIGNATURE	DATE
DRAWN:	08/03/2012
CHECK:	
DESIGN:	
CHECK:	

Seattle City Light
Power Production & Substations

APPROVED FOR SEATTLE CITY LIGHT

DATE

SUBJECT

LOCATION GEORGETOWN STEAM PLANT RENOVATION

TITLE EXISTING CONDITIONS

BUILDING SECTION D

SHEET OF

CLASS \ SHEET X-A4.02

DRAWING NO.

SCALE 1/8"=1'-0"

REV. NO. 0

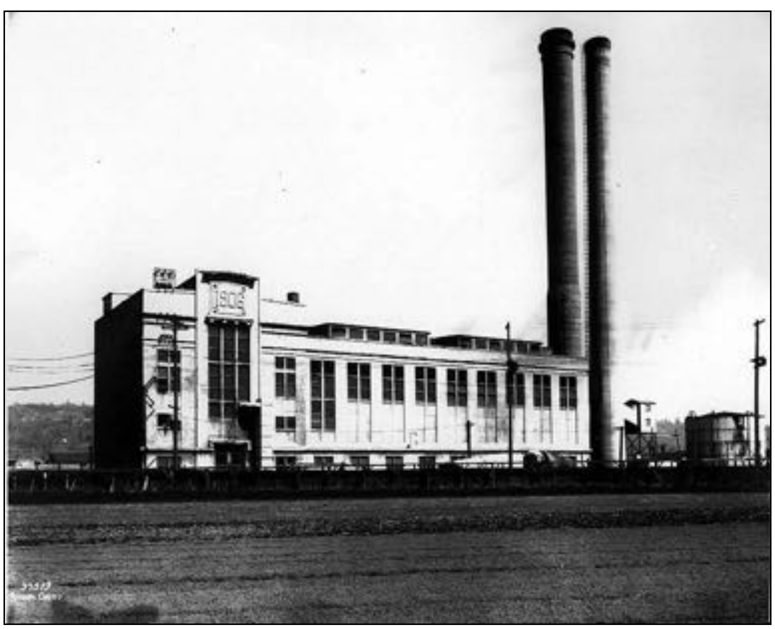
APPENDIX B
HISTORIC PHOTOGRAPHS

Top left: Looking southwest with the Georgetown Steam Plant visible in the distance,, showing the context in 1907. (MOHAI, image no. 1974.5868.233)

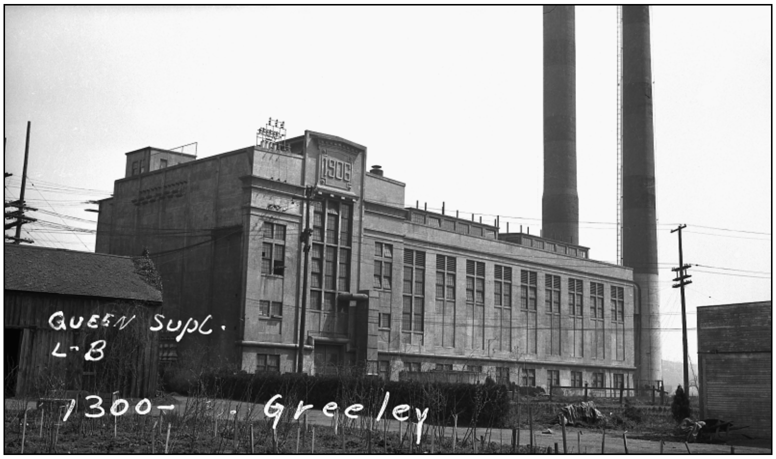
Middle: View looking northeast toward the Georgetown Steam Plant, April 24, 1916. (Seattle Municipal Archives, image no. 990)

Bottom: View in the vicinity of the Georgetown Steam Plant, April 24, 1916. (Seattle Municipal Archives, image no. 993)

Undated photo, view looking northeast showing west façade and the coal conveyor and stacks south of the building. (UW Libraries Special Collections)



View of the west façade, ca. 1920. (UW Libraries Special Collections)



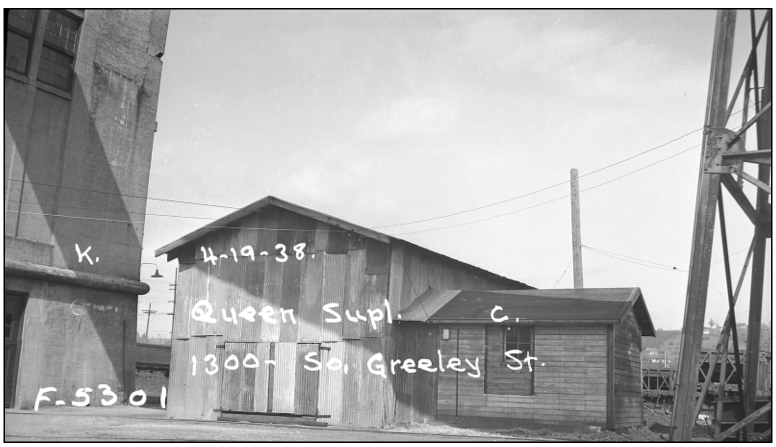
Archival tax record photos of the Georgetown Steam Plant and associated structures (Puget Sound Regional Archives):

Top: View of the north and west façades, 1937.

Middle: View looking southwest, showing the north and east sides of the building, April 19, 1938.

Bottom: View of the coal conveyor and a portion of the south façade of the plant, April 19, 1938.

Archival tax record photos of associated structures, all date from April 19, 1938. (Puget Sound Regional Archives)



View looking north, showing an oblique view of the west façade and the western end of the south façade. August 28, 1950. (Seattle Municipal Archives, item no. 22425)

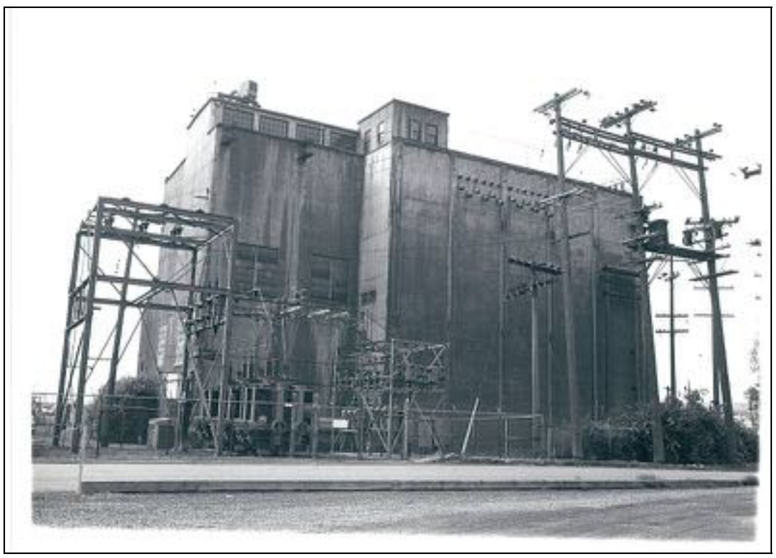
View looking northwest, showing the east façade and an oblique view of the south façade, August 28, 1950. (Seattle Municipal Archives, item no. 22426)

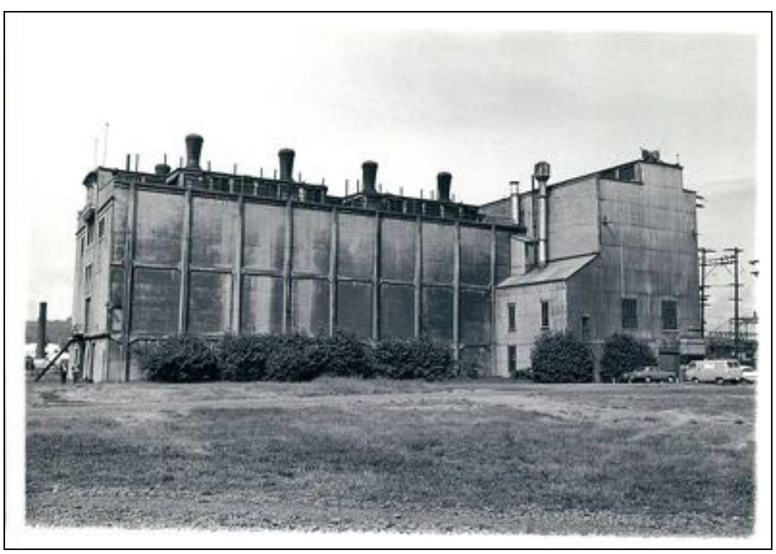
Series of undated photos from Seattle City Light Archives:

Above left: View looking southeast, showing west façade of Engine Room and west end of north façade.

Above right: View looking northwest, showing south façade.

Left: View looking southeast, showing west façade of Engine Room and Boiler Room.





Series of undated photos from Seattle City Light Archives (cont'd):

Left: View looking northeast, showing south façade and oblique view of west façade of Boiler Room.

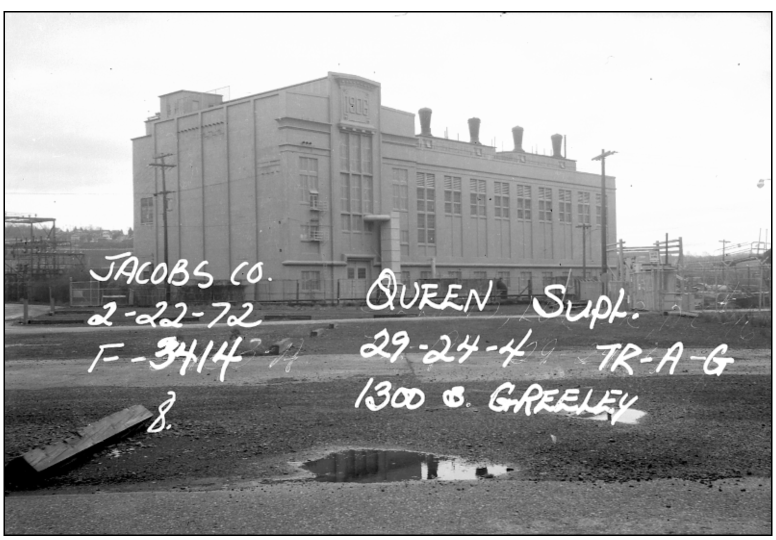
Middle: View looking south, showing north façade.

Bottom: View looking northwest, showing east façade.

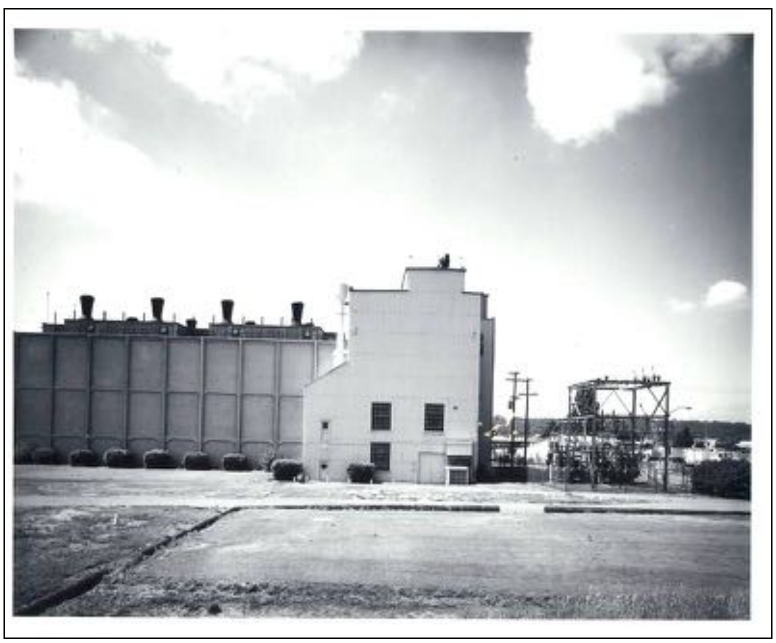
Series of undated photos from Seattle City Light Archives (cont'd):

Left: View looking southwest, showing oblique views of north and east façades.

Middle: View looking southwest, showing Boiler Room roof monitors and vent stacks.



Left: Archival tax record photo with view looking southeast, showing north and west façades. (Puget Sound Regional Archives)

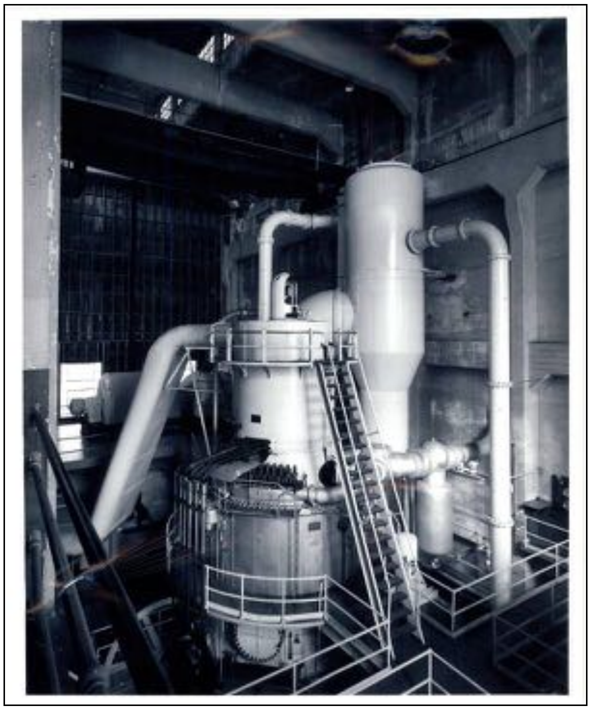


Selected photos from the Georgetown Steam Plant HAER Documentation, 1984:

Above left: West façade of Engine Room.

Above right: South façade.

Left: View looking west, showing east façade and context.



Selected photos from the Georgetown Steam Plant HAER Documentation, 1984 (cont'd):

Interior views in the Boiler Room.

View looking north toward the Boiler Room galleries. (HAER, 1984)

APPENDIX C
CONSULTANT REPORTS

Georgetown Steam Plant

Seattle City Light

Addendum to 2010 Condition Assessment

August 2012 | Final Report

kpff Consulting Engineers

Addendum to 2010 Condition Assessment

August 2012

Prepared for:
BOLA Architecture + Planning
159 Western Avenue W Suite 486
Seattle, WA 98119

Prepared by:
John M. Hochwalt, PE, SE, Associate
Gregory L. Varney, PE, SE, Principal
KPFF Consulting Engineers
1601 Fifth Avenue, Suite 1600
Seattle, WA 98101
Phone: (206) 622-5822
Fax: (206) 622-8130
KPFF Job No. 112202.20

This Page Intentionally Left Blank

Table of Contents

List of Figures

Appendices

This Page Intentionally Left Blank

Executive Summary

KPFF Consulting Engineers was retained by BOLA Architecture + Planning to update our 2010 condition assessment of Seattle City Light's Georgetown Steam Plant facility located in Seattle, Washington. The purpose of our assessment was to identify any variations between observed conditions at this time and our 2010 condition assessment, and to reconsider our condition assessment in the light of our seismic evaluation and the proposed restoration of the exterior envelope.

This Executive Summary addresses the combined findings of the 2010 condition assessment and this 2012 addendum to the condition assessment.

Access to the following areas should be restricted until the life safety hazards identified in this report are addressed:

- Within five feet of the intact or partially demolished ash hoppers
- The stair at the southwest corner of the building from the ground floor to the second floor
- The fire escape at the northwest corner of the building.
- The exterior stair and landing at the south side of the building.

We also recommend that following actions be taken to slow the deterioration of the building structure:

- Repair and maintain the building envelope to prevent water intrusion into the building.
- Repair water leaks from internal systems.
- Remove loose concrete and replace damaged or corroded pipe hangers with corrosion-resistant attachments.

As work on the building envelope is planned, we recommend giving priority to the south wall. This wall should be the first wall addressed because it is in the worst condition, and is a key component of the seismic force resisting system. The importance of this is further discussed in our seismic evaluation report.

Lastly, the planning and budgeting for any work being done on the building should anticipate that additional areas requiring repair will be identified in the course of the work. The findings in this report are based only on what we visually observed in areas to which we had access.

1. Field Observations

John Hochwalt, PE, SE, and Charlie Misner of KPFF Consulting Engineers visited the Georgetown Steam Plant on July 9, 2012, to update the structural condition assessment of the existing building that KPFF had performed in 2010. John Hochwalt performed a follow-up field visit on September 25, 2012, to observe the condition of the engine room clerestory columns, following removal of the fiberglass wall panels.

The objectives of our field observations were as follows:

- Evaluate whether there have been any significant changes to the condition of the building with respect to our 2010 condition assessment, specifically with respect to our findings about:
  - Potential life safety hazards:

    As structural engineers, we look for life-safety hazards where conditions could result in structural materials becoming dislodged and falling or that could lead to a local or general structural collapse. We do not look for non-structural conditions that could create risk of injury. Examples of these non-structural conditions would include slip-and-fall hazards, inadequate provisions for fall protection, non-structural items that could become dislodged and fall, exposure to live electrical circuits or toxic substances, or confined spaces.

    It should also be noted that our assessment of potential life safety hazards is based on the current usage of the structure, which permits only limited public access and where the structure is essentially unoccupied. We have not attempted to assess whether the structure complies with the life safety provisions of the current building code.

    Finally, our identification of potential life safety issues was limited by what we could see in the areas that we had access to during our limited time on site. Areas not viewed are identified later in the report. A more exhaustive study could identify additional life safety hazards.
  - Current condition of the structure:

    Based on our visual observations, we developed an opinion of the condition of the structure.
    - Good condition means that the structural element described has very few signs of deterioration or distress, and probably could remain in service for many years to come. There may be some minor deficiencies requiring repair prior to allowing reuse.
    - Fair condition means that the structural element described is starting to show signs of deterioration or distress, and its service life may already be limited due to the deterioration or distress. There are deficiencies requiring repair prior to allowing reuse.
    - Poor condition means that the structural element described has extensive signs of deterioration or distress. It has reached the end of its service life and major repairs are required to use the impacted portions of the structure in the future.

- Maintenance recommendations.
  - Reconsider the maintenance recommendations of the 2010 condition assessment in the context of the overall project, specifically:
    - The effect of the building condition on the reroofing, and restoration or replacement of exterior windows.
    - The effect of building condition on the seismic performance of the building.

1.1 DESCRIPTION OF FIELD WORK

Access to the building was provided by Seattle City Light personnel. Our assessment is based on visual observations, supplemented by soundings of the concrete surface, in accessible areas in the interior and exterior of the building, to identify areas of concrete delamination. No finishes were removed by KPFF and no destructive testing was performed. Building locations that were not accessed during the visit were the eastern boiler catwalk, the coal pocket above the boiler room, and any accessible below grade areas. Our ability to observe existing conditions was also limited by poor lighting on the interior, especially on the eastern side of the second floor of the south wing, and by trees and bushes around the exterior of the building, especially near the north and east elevations.

On a second field visit, we were able to observe the condition of selected clerestory columns at the boiler house roof where fiberglass wall panels had been removed by Seattle City Light.

1.2 BUILDING CONSTRUCTION

Please see our 2010 Condition Assessment for a description of building structure.

Figure 1-1: Possible Delaminated Concrete Slab Soffit over Stair

1.3 LIFE SAFETY ISSUES

As discussed in our 2010 condition assessment, 10 of 16 of the ash hoppers have been partially demolished. This partial demolition has created a life safety condition due to the potential for falling debris that has only been partially mitigated by the construction of platforms to contain falling debris. The six remaining ash hoppers also create potential life safety conditions due to the potential for concrete spalling that has only been partially mitigated by the shoring of these hoppers.

Our 2012 observations resulted in the identification of three additional potential life safety issues.

The first is in the southwest corner of the building where reinforcing in the second floor slab is badly corroded due to water penetrating the south exterior wall, as shown in Figure 1-1. It appears that there may be a large section of concrete that has delaminated from the slab soffit directly above the stair that provides access from the first level to the boiler level. This condition likely did not change dramatically since our 2010 observation, rather the stronger daylight this time enabled us to better perceive the probable extent of delamination. This represents a potential life safety issue due to the size of the concrete section that appears to be delaminated and its presence above a stair.

The second potential life safety issue is the exterior fire escape near the northwest corner of the building as shown in Figure 1-2. It is unknown whether this is a required means of egress. If it is a required means of egress, it will need to be certified as required by the City of Seattle. We recently became aware of the City of Seattle certification requirements and felt the need to identify potential deficiencies in this condition assessment. If it is not a required means of egress, access to it should be restricted due to its age, exterior exposure, unknown anchorage, and potential brittle failure modes.

The third potential life safety issue is the exterior fire escape on the south side of the building as shown in Figure 1-3. If it is a required means of egress, it will need to be repaired and certified as required by the City of Seattle. If it is not a required means of egress, access to it should be restricted due to given its poor condition as discussed under "Other Observations," below.


Figure 1-2: Northwest Fire Escape


Figure 1-3: South Fire Escape

1.4 CONDITION ASSESSMENT

General Comments

Please see the 2010 condition assessment for a general discussion of concrete deterioration and observed conditions. The reinforced concrete structure overall still appears to be in generally good condition with limited visible damage and without significant change with respect to our previous observations. We expect that the corrosion of reinforcing steel has continued since our 2010 observations, and that this has continued to cause deterioration of the surrounding concrete. The change over the 30 month period, however, was not dramatic enough to be apparent through our visual observations.

There are, however, areas in poorer condition that are more important considering the other parts of this project, such as those pertaining to life-safety and the seismic deficiencies in the building.

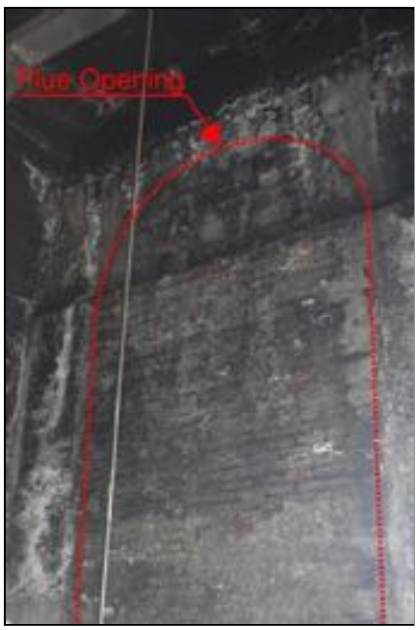


Figure 1-4: Masonry Infilled Flue Opening

Seismic Evaluation

The seismic evaluation established that the south wall of the building is a critical element for the seismic performance of the building. (See Draft "Georgetown Steam Plant Seismic Assessment," dated July 18, 2012, for a discussion on the importance of this wall to building performance.)

The condition of this wall is assessed as fair to poor.

The major areas of concerns with the wall are the masonry infill sections in the upper part of the wall (where the horizontal flues used to exit the building) shown in Figure 1-4, and the areas adjacent to the windows. In both cases, the issue is that water is entering the building through and around these elements. Since the brick infill is expected to be unreinforced, there is no steel to corrode at the point where water enters the building. However, the water continues down the inside face of the wall and onto the second floor and has resulted in the corrosion of reinforcing steel in the wall and floor below. The resulting deterioration of the wall is of particular concern with respect to the seismic performance of the building. An example of this can be seen in Figure 1-5.

At the windows, reinforcing in the sills, heads, and jambs is corroding, leading to spalling and delamination in these areas. Similar to the masonry infill areas, the water continues down the face of the wall resulting in corrosion of reinforcing steel and deterioration of the wall below the window. This would be expected to negatively affect the seismic performance of the wall.

Figure 1-5: Concrete Deterioration below Window Sill

The concrete deterioration is most severe above the second floor, where sections of the wall are considered to be poor condition. The wall below the second floor appears to have been largely protected from water by the second floor; it is generally characterized as being in fair condition. As is discussed in the seismic evaluation, this lower section of wall is subject to large seismic demands.

Another wall that is important to the seismic performance of the building is the west wall, which is perforated by a series of windows. Deterioration of this wall appears to be limited to localized deterioration adjacent to windows or where cracking of the wall has allowed water to enter the building. Due to the localized nature of the deterioration, it would not be expected to affect the strength of the wall.

Envelope Restoration

As we understand it, the envelope restoration that is being undertaken as a result of this assessment, includes reroofing of the building and refurbishment of the windows. We understand that window refurbishment may be done in situ, or may be done by removing, repairing, and then reinstalling the windows.

The condition of the roof could only be observed from the underside as the upper surface is covered with roofing. Our ability to observe the underside of the roof was also limited by the distance of the roof above the floor (partially compensated for by the use of binoculars and a telephoto lens), poor lighting, and inaccessibility.

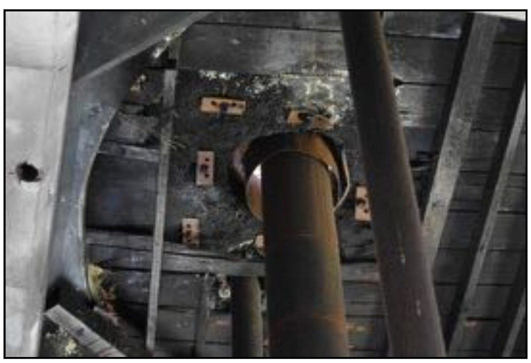


Figure 1-6: Wood infilled stack opening

The area of roof that appears to be the in worst condition is the southwest corner of the roof, extending to, and including the original stack opening. The original stack opening is infilled with wood framing which is in poor condition and has allowed water to enter the building as can be seen in Figure 1-6. This has resulted in corrosion of the reinforcing steel surrounding the opening and deterioration of the supporting structure.

The condition of the structure surrounding the window openings varies from good to poor. Corroded reinforcing and spalled concrete were visible on both the interior and exterior of the building. As discussed under the seismic evaluation above, the window openings on the south side of the building are in the worst condition. There are locations of deterioration around the west windows, but those are much more isolated.

We were able to observe the condition of some of the clerestory columns at the engine room roof for the first time in the course of this work. At the time of our 2010 assessment, these columns were completely covered by fiberglass wall panels, which were partially removed by Seattle City Light during this assessment.

The visible north clerestory columns were in fair condition with cracks and delaminations, apparently due to corrosion of the vertical reinforcing steel. These conditions had been addressed previously, likely as part of the 1985 repair work, by filling the crack area with a black mastic. The combination of the repair and the protection provided by the fiberglass wall panels appears to have been successful in stabilizing the condition of the structure, as the crack locations observed are consistent with the 1985 drawings and there was no sign of crack growth or rusting of the reinforcing steel.

The visible south clerestory columns appear to be in good condition. There was some dusting of the column surface, but this appears to be dusting of a parging layer; the underlying concrete appears to be sound.

Other Observations

There are two exterior fire escapes on the building: on the center of the south façade – providing access from top of the boiler level to grade – and near the northwest corner of the building – providing access from the second and third floors part ways towards the ground. The fire escape at the northwest corner was in fair condition, however the capacity of this fire escape should still be considered as unreliable, given its age, exterior exposure, and low redundancy. The fire escape on the south side was in poor condition with rotting of the wood landing and corrosion of the steel structure. The corrosion has progressed to the point where the corrosion products appear to be forcing the fire escape away from the building structure, as seen on the bracket on the right hand side of Figure 1-7.

Figure 1-7: South Fire Escape, Detail

1.5 RECOMMENDATIONS

The scope of work for the current project – mitigation of the hazards created by the deteriorating/dismantled ash hoppers, spalled concrete and corroded hangers – as well as restoration of the building envelope address the primary recommendations included in our 2010 Condition Assessment.

At a minimum, the three new potential life safety issues should be, at a minimum, addressed by restricting access to the areas in question: the two exterior fire escapes and the stair at the southwest corner of the building between the ground floor and the second floor. If any of these are a required means of egress, that could further restrict use of the building.

It will be necessary to perform structural restoration in selected areas. We expect that this will include:

- Removal and replacement of the wood infill framing of the stack opening near the southwest corner of the building. If this framing is historically significant, it may be possible to selectively replace this material. If the latter course is undertaken, a more detailed assessment of the condition of this framing would be required. Since this framing is located above the boilers, access from the bottom side would be problematic. Most likely, the assessment would need to be performed from the roof level after removal of the existing roofing.

- Concrete removal and replacement around the window openings. Concrete that has delaminated or spalled around the window openings should be removed and replaced as part of the window refurbishment. This work should consider the recommendations of the National Park Service's *Preservation Brief 15: Preservation of Historic Concrete,* and will need to find the right balance between the durability of the repair, which would suggest removal of larger areas of deteriorated concrete, and the historical preservation goals, which would suggest retaining as much of the original concrete and reinforcing as possible. Part of the solution could involve using cathodic protection or a surface applied migrating corrosion inhibitor to slow the on-going corrosion, allowing more of the existing materials to stay in place.
- The construction safety plan, which is part of the Contractor's "Means and Methods," should recognize that there may be some dislodgment of concrete due to construction activities. For example, it is possible that reroofing activities could cause delaminated concrete to spall, creating a hazard to those inside the building. This hazard can be mitigated by restricting access to areas where work is taking place overhead.
- Contracts for work on the building should anticipate that additional structural repair or restoration will likely occur in the course of the work. This may involve including unit prices in bids and carrying an appropriate contingency.

2. Conclusions

This report only addresses the structural condition of the building at the time of our visit, and is limited to what we were able to visually observe. Hazards from non-structural issues such as slip and fall hazards, inadequate provisions for fall protection, non-structural items that could become dislodged and fall, exposure to live electrical circuits or toxic substances, or confined spaces are outside the scope of this report. The ability of the building to perform during the code level seismic event for the site has been addressed in a separate report.

The following conclusions are based upon both our original condition assessment performed in 2010 and the supplemental condition assessment discussed in this document.

The items posing an immediate risk to personnel and public occupants are the most important findings. Access to these areas or items should be restricted until the conditions are addressed through repair or mitigation. These areas are as follows:

- Intact Ash Hoppers: Due to the poor condition of the three remaining hoppers, there is potential for loose pieces of concrete to become dislodged. No access should be permitted within 5 feet of the hoppers until the hazard is mitigated.
- Partially Demolished Ash Hoppers: No hazard mitigation has been performed for three of the existing ash hoppers that have been partially demolished. No access should be permitted within

5 feet of these demolished areas until proper shoring has been provided or the remaining loose materials sufficiently removed and the opening closed to mitigate the hazard from falling objects.

- Southwest Stair: Due to the poor condition of the second floor structure above this stair, no access should be permitted to this stair.
- Northwest Fire Escape: Due to the poor condition of the fire escape and its attachment to structure, no access should be permitted to the fire escape.
- South Exterior Stair: Due to the poor condition of this stair and the associated landing, no access should be permitted to this stair or the landing.

We have used our field observations to determine the overall existing condition of the building, as well as to identify issues regarding structural maintenance. The findings of this report are based on the condition of the structure as we observed on January 5, 2010, July 9, 2012, and September 25, 2012. The overall condition of the building is rated as in good condition. The structural related maintenance issues are as follows:

- Repair and maintain the building envelope to prevent water intrusion into the building.
- Repair water leaks from internal systems.
- Remove loose concrete and replace damaged or corroded pipe hangers with corrosion-resistant attachments.

The fair to poor condition of the south wall of the building takes on added importance due to this wall being identified as a critical element in our seismic evaluation. Repairs of this wall to enhance the seismic performance are discussed in our seismic evaluation report.

Lastly, we understand that some repairs to the building envelope are planned for 2013. It should be anticipated that some structure restoration or repairs will be necessary as part of the work envelope work. This may include addressing wood infill framing of a former stack opening in the roof and concrete repairs around window openings. Because of the limited nature of observations, it should be expected that additional locations requiring repair will be identified in the course of construction.

3. References

Gaudette, Paul and Slaton, Deborah. *Preservation Brief 15: Preservation of Historic Concrete.* National Park Service.

Appendix A

Photo Log

Indicates Photo of Interior

Indicates Photo of Exterior

Photo 1

Photo 2

Photo 3

Photo 4

Photo 5

Photo 6

Photo 7

Photo 8

Photo 9

Photo 10

Photo 11

Photo 12

Photo 13

Photo 14

Photo 15

Photo 16

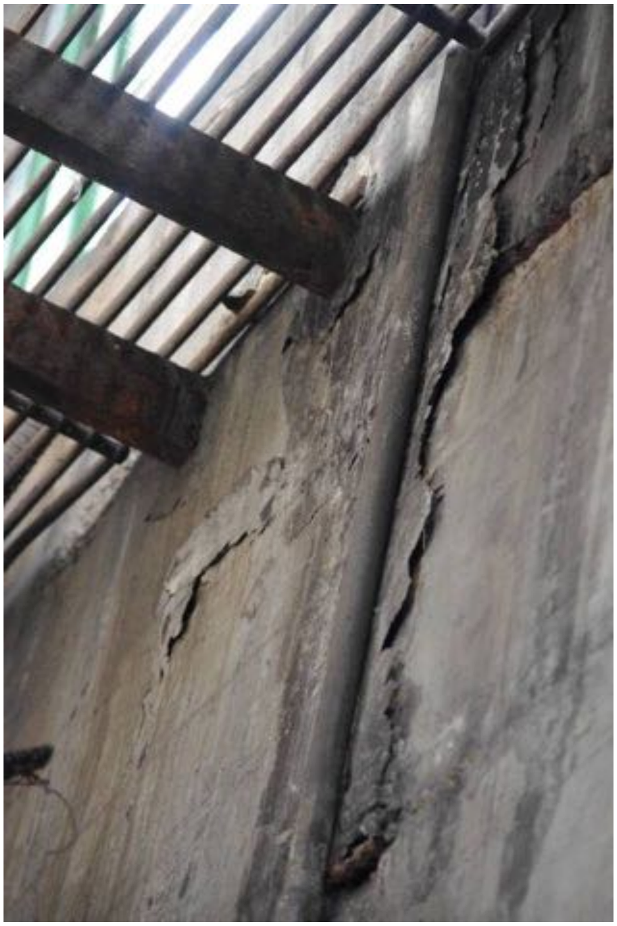


Photo 17

Photo 18

Photo 19

Photo 20

Photo 21

Photo 22

Photo 23

Photo 24

Photo 25

Photo 26

Photo 27

Georgetown Steam Plant

Seattle City Light

ASCE 31-03 Tier 1 and Seismic Evaluation Report

August 2012 | Final Report

kpff Consulting Engineers

ASCE 31-03 Tier 1 and Seismic Evaluation Report

August 2012

Prepared for:
BOLA Architecture + Planning
159 Western Avenue West, Suite 486
Seattle, WA 98119

Prepared by:
Scott L. Neuman, PE, SE, Associate
John M. Hochwalt, PE, SE, Associate
Gregory L. Varney, PE, SE, Principal
KPFF Consulting Engineers
1601 Fifth Avenue, Suite 1600
Seattle, WA 98101
Phone: (206) 622-5822
Fax: (206) 622-8130
KPFF Job No. 112202.10

This Page Intentionally Left Blank

Table of Contents

List of Figures

List of Tables

Appendices

ES. Executive Summary

KPFF was hired to perform a seismic evaluation of the Georgetown Steam Plant.

The Georgetown Steam Plant building was built in 1906.

The building has both concrete frames (beams and columns) and concrete shear walls that resist the lateral seismic forces.

A complete set of original structural drawings for the building were not available for our use. With the exception of the 1917 addition, rebar details were missing for the entire structure, so it is not possible to calculate the structural capacity and compare them to the seismic demands, though the demands were calculated.

ASCE 31 checklists were used to develop an initial understanding of the seismic performance of the building. An analytical model was constructed to observe the seismic behavior in more detail.

Seismic forces resisted by the concrete frames are identified as the behavior with the most risk of seismic damage leading to building collapse. Recommendations for retrofitting the structure are focused on ensuring that the seismic forces are resisted by the concrete walls, and not the frames.

Concrete stresses that were calculated from the seismic analysis were used to determine the locations where the building is most likely seismically deficient, although this cannot be known for certain without a complete set of structural drawings from which structural capacities can be determined.

KPFF recommends the following work listed in order of importance to improve the seismic performance of the building. These recommendations are not intended to bring the building up to the target ASCE 31 performance level, but are intended to address the most critical deficiencies in the building.

- Attach the concrete floor and roof diaphragms to the concrete walls at locations identified in the report, or verify existing attachments through radar or x-ray imaging.
- Strengthen the columns along the wall that separates the engine room from the boiler room at the roof using steel, concrete, or composite covers.
- Repair and strengthen the southern concrete wall by demolishing masonry infill of horizontal flues and replacing with reinforced concrete.
- Add a line of lateral force resisting elements (shear walls or braced frames) in the eastern portion of the engine room.
- Add braces at the clerestory windows where no concrete walls are present.
- Brace the clay tile wall on the north side of the building.

None of the currently planned maintenance will require a seismic renovation per the requirements of the Seattle Building Code, so seismic improvements of the building will be considered a voluntary effort by Seattle City Light.

1. Introduction

KPFF has been hired as a sub-consultant to BOLA Architecture + Planning to perform a seismic evaluation for the Georgetown Steam Plant which will be incorporated into a Historic Structure Report.

This assessment by KPFF is intended to summarize the findings of the following scope of work:

- Review of the existing building documentation.
- Perform a site visit to observe the condition of the building, the accuracy of the existing documentation, and the support of nonstructural elements.
- Perform ASCE 31 Tier 1 and seismic analysis for the structure to determine the seismic behavior of the building and to identify a viable load path for seismic forces.
- Propose mitigation measures for the most critical seismic deficiencies.
- Prepare this report.

Once Seattle City Light has had the opportunity to review this report, we expect to receive direction as to which mitigation measures they may be interested in pursuing. Once we receive that direction, we will prepare conceptual designs for those measures, suitable for budgeting and evaluation.

This report summarizes the findings from a seismic evaluation of the Georgetown Steam Plant performed using the American Society of Civil Engineers Standard ASCE/SEI 31 (ASCE 31). A Tier 1 seismic evaluation of the building was first performed using this standard, and then a more detailed seismic analysis was performed that used this standard as a guideline, but did not follow the standard in its entirety because of the limited drawings available. The Tier 1 evaluation was performed as an initial screening of potential seismic deficiencies if the facility was subjected to a major earthquake, such as those described later in this report. The seismic analysis was conducted to perform a more detailed evaluation of the building's seismic behavior, as well as to develop conceptual approaches for mitigating seismic hazards.

2. Building Description and Seismic Load Path

The Georgetown Steam Plant is largely constructed of reinforced concrete and consists of a northern high bay structure called the "Engine Room" and a southern three-story structure called the "Boiler Room." The Engine Room is approximately 64 feet by 117 feet. The Boiler Room is approximately 150 feet by 80 feet. These different spaces share a common wall at the south and north ends, respectively. See Figure 2-1, below, for a plan view of the building.

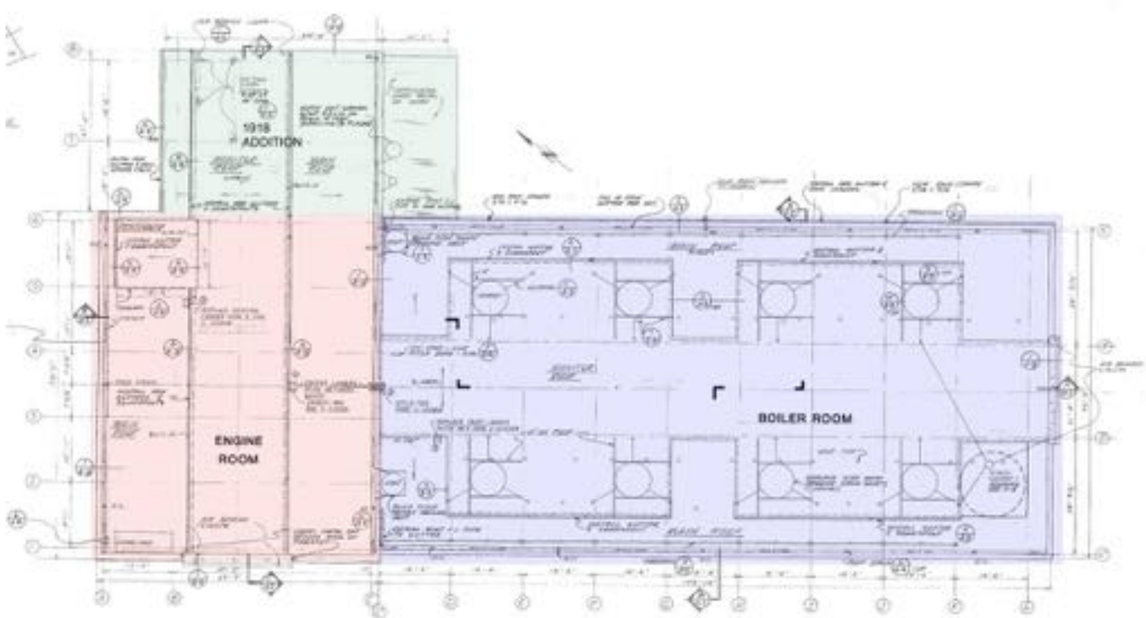


Figure 2-1: Plan view of Georgetown Steam Plant. Plan north is to the left.

The lowest floor of the structure is a reinforced structural slab at grade. Reinforced concrete walls for the generator enclosures can be observed at this level, which carry down to the timber pile foundations below.

The second floor of the Boiler Room supports large boilers and ash hoppers on the exterior bays. It is composed of one-way slabs spanning to perpendicular rectangular beams between columns. The columns at this level are typically square with some columns being larger rectangular shapes.

The third floor of the Boiler Room occurs in the middle bay only and was previously used as coal storage to feed the boilers below; the exterior bays are open for the tops of the boilers and their associated piping to the roof. The coal storage is a series of pyramidal shaped depressions on each side with beams framing the openings. Above the coal storage is a series of concrete beams supporting a continuous catwalk along the length of the Boiler Room. The roof of the exterior bays is a one-way flat slab spanning to perpendicular haunched beams aligned with the interior columns. This is located at approximately the same elevation as the interior bay beams supporting the catwalk. The roof of the center bay is similarly framed and located approximately 10 feet higher.

The Engine Room is a clear height space with 65-foot long span roof beams and no interior columns. The roof steps up for a clerestory to provide additional natural light. One-way slabs span between the deep roof beams. A narrow north bay consisting of five bays along its length has four levels of concrete composed of one-way slabs spanning east-to-west to perpendicular beams framing to columns.

An addition to the plant, approximately 65 feet by 27 feet, was constructed in 1918 on the northeast corner of the building adding two bays to the north portion of the building to house the horizontal generator. This consists of a floor and a roof constructed of reinforced concrete, which appears to mimic the original construction. This addition includes an independent support platform for the horizontal generator, which is isolated from the building structure with a visible gap.

Perimeter reinforced concrete walls are present with punched windows occurring primarily on the south and west faces. Concrete infill walls, identified by the distinct crack pattern at the beams and columns, appear to be present on the south face of the 1918 addition. Un-reinforced masonry infill walls were present on the entire north face of the addition. The east façade of the 1918 addition and south façade of a later addition are corrugated metal panels over timber and limited steel framing. We understand that this construction is original and the east face was intended to be removable to accommodate the removal and replacement of large pieces of equipment.

The seismic forces have multiple load paths which they can follow from the building diaphragms at each floor level to the building foundation. In both portions of the building, the seismic forces can transfer through the building via the concrete walls at the perimeter of the buildings, or the concrete frames at the building interior. Both the Engine Room and the Boiler Room have concrete shear walls in the long direction. These walls are likely to resist the majority of the seismic forces in the direction of the walls. For seismic forces perpendicular to the walls, the concrete frames are likely to participate to a greater degree in the seismic resistance of the building, due to the decreased stiffness of the walls and the building diaphragm in this direction.

3. Puget Sound Seismic Hazards

There are three kinds of earthquake sources in the Puget Sound region:

- Deep earthquakes, which occur within the Juan de Fuca plate as it descends beneath the North America plate (called Benioff zone or intraplate earthquakes).
- Colliding of the Juan de Fuca and North American plates (subduction zone or interplate earthquakes).
- Shallow earthquakes that occur within the crust of the North America plate (crustal earthquakes)

Figure 3-1 illustrates these different earthquake types.

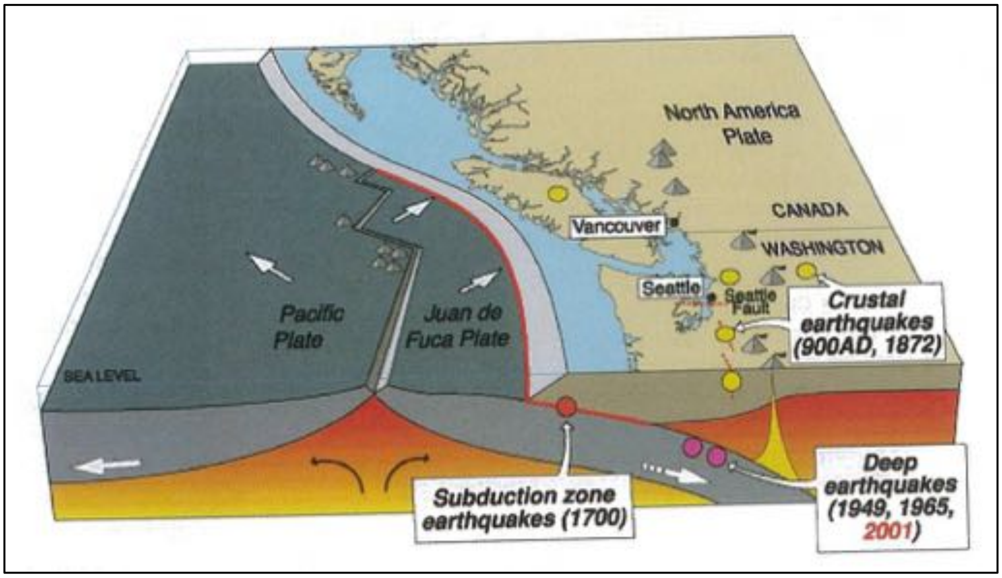


Figure 3-1: Puget Sound Earthquake Types (Source: USGS/CREW)

The characteristics of these earthquakes are different, including the expected magnitudes, durations, and recurrence intervals. These earthquake characteristics, in combination with the location of the earthquake source relative to a particular site and the geology at that site, are the major factors determining the intensity of ground shaking anticipated at the site.

Table 3-1 lists potential magnitudes, estimated return intervals, and prior examples for these different earthquake types.

Table 3-1: Probabilities for Earthquakes from Various Sources

Earthquake Source	Example Events	Potential Magnitude	Estimated Return Interval
Deep/Benioff Zone	Nisqually, 2001, M6.8 Seattle-Tacoma, 1965, M6.5 Olympia, 1949, M6.8	M7.5	35 – 50 years
Subduction Zone	1700	M9.0	500 – 600 years
Shallow/Crustal	Random Seattle Fault	M7.5 M7.5	333 years 1,000 years

Source: Scenario for a Magnitude 6.7 Earthquake on the Seattle Fault [Reference 4]

4. Probabilistic Earthquake Hazard Levels

Because of the age of the building, the Steam Plant has withstood several earthquakes that occurred over the building lifetime, including the 1949 quake, the 1965 quake, and the 2001 Nisqually quake listed in Table 3-1 above. All of these quakes are smaller than the design level earthquakes that are currently used for building construction and evaluation.

Various probabilistic earthquake hazard levels are employed by seismic codes and evaluation standards. An earthquake with a 10 percent chance of occurrence in a 50-year interval is similar to the magnitude of earthquake that is used to design new buildings. Figure 4-1 indicates the estimated relationship between earthquake peak ground accelerations and earthquake return intervals at the Georgetown Steam Plant site for the following return intervals:

- Ten percent probability of being exceeded in 50 years (475 year return interval)
- Fifty percent probability of being exceeded in 10 years (72 year return interval)

The peak ground acceleration recorded for the King County Emergency Operations Center (EOC) located near the Georgetown Steam Plant site for the 2001 Nisqually Earthquake is also shown on the graph for comparison. The approximate average return interval associated with this event is 67 years, but this return period may be shorter depending on the local soil conditions beneath the building.

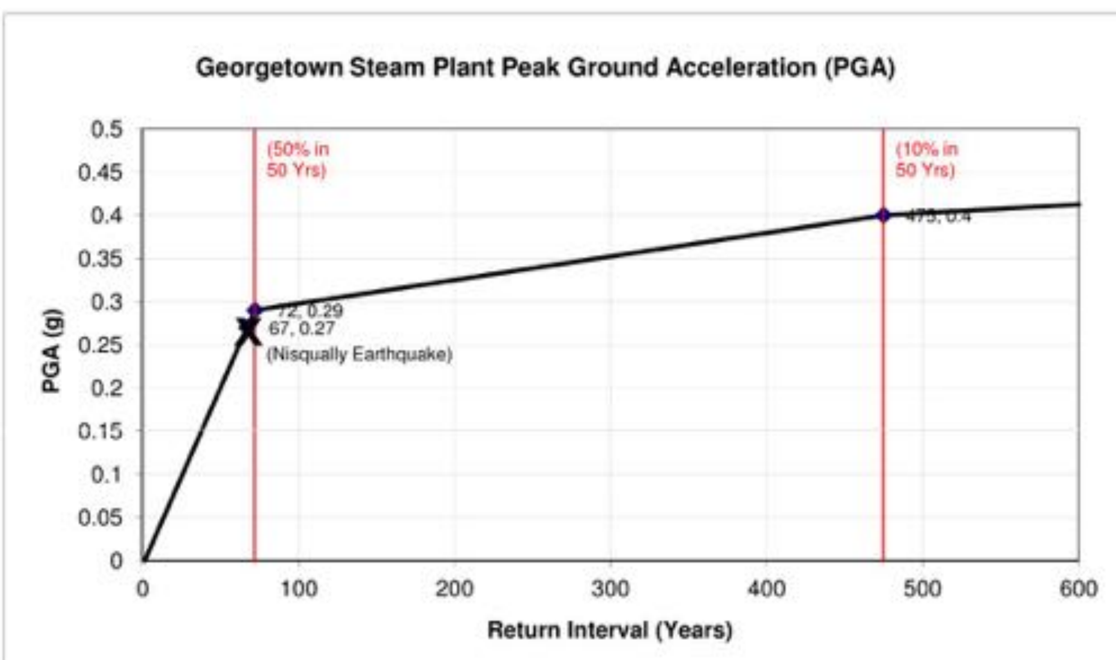


Figure 4-1: Estimated Peak Ground Accelerations at Steam Plant Site (based on 2002 USGS maps, Nisqually Earthquake records)

5. ASCE 31 Tier 1 Seismic Evaluation

5.1 ASCE 31

The document Seismic Evaluation of Existing Buildings, ASCE 31-03 (ASCE 31) was written by the American Society of Civil Engineers (ASCE) to provide a consensus standard for the seismic evaluation and rehabilitation of buildings throughout the United States. ASCE 31 provides a three-tiered process for the seismic evaluation of existing buildings in any region of seismicity. These three tiers are a Screening Phase (Tier 1), an Evaluation Phase (Tier 2), and a Detailed Evaluation Phase (Tier 3). Buildings are typically evaluated for either a Life Safety or Immediate Occupancy performance level. Use of ASCE 31 for evaluation and mitigation of seismic deficiencies is either voluntary or required by the building authority having jurisdiction.

The Screening Phase (Tier 1) consists of checklists that allow a rapid evaluation of the structural, nonstructural, and foundation/geologic hazard elements of the building and site conditions. The purpose of a Tier 1 evaluation is to screen out buildings that comply with the provisions of ASCE 31 or to quickly identify potential deficiencies. If potential deficiencies are identified for a building using the checklists, the engineer may proceed to Tier 2 and conduct a more detailed evaluation of the building, or conclude the evaluation and state that potential deficiencies were identified.

For a Tier 2 evaluation, a more detailed analysis of the building is performed that addresses the non-compliant items identified in Tier 1. If non-compliant items are identified during a Tier 2 evaluation, the engineer may choose to report deficiencies and recommend mitigation, or proceed to Tier 3 and conduct an even more detailed seismic analysis.

For the Georgetown Steam Plant, a Tier 1 evaluation was performed. A Tier 2 evaluation would require complete knowledge of the reinforcing layout within the concrete beams and columns of the building. Unfortunately, drawings showing these details for the original structure built in 1906 were not available for KPFF's use, although these drawings do exist for the 1918 addition. KPFF has constructed an analytical model of the building to compute seismic forces and to evaluate concrete stresses similar to a Tier 2 evaluation, and our recommendations will be based on these results. Because of the missing drawings, calculation of demand to capacity ratios as would be typical in a Tier 2 analysis is not possible. KPFF does not recommend a Tier 3 evaluation for further evaluation of the building.

5.2 LEVEL OF SEISMICITY

Level of seismicity is determined according to ASCE 31, Section 2.5, as follows:

From the 2002 United States Geological Survey (USGS) National Seismic Hazard Maps, the short period spectral response acceleration (S_S) and 1-second period spectral response acceleration (S_1) parameters for this site, based on the maximum considered earthquake (MCE) ground motion, are:

$S_S = 1.55$ g

$S_1 = 0.54$ g

KPFF has assumed that if classified by the current system, the soil at the site would be identified as a site class E or F as shown on the 2004 Site Class Map of King County Washington by the USGS. Based on this classification, Site Coefficients F_a and F_v were found to be:

$F_a = 1.0$

$F_v = 1.5$

Spectral response acceleration parameters S_{DS} and S_{D1} define the seismicity of a site as “low,” “moderate,” or “high.” The acceleration parameters are determined as shown below. The resulting products of spectral response accelerations and site coefficients classify the level of seismicity:

$S_{DS} = 2/3\ F_a S_S = 1.04\ g \geq 0.500g$ High Seismicity

$S_{D1} = 2/3\ F_v S_1 = 0.54\ g \geq 0.200g$ High Seismicity

Both S_{DS} and S_{D1} indicate that this building is located in an area with a level of high seismicity. This is typical for buildings located in the greater Seattle area.

5.3 BUILDING TYPE AND CHECKLISTS

Tier 1 screening is conducted with hazard checklists that are specific to the building type. With the combination of concrete shear walls and concrete frames in the building, two building type classifications are applicable:

Concrete Moment Frames (Type C1)

Concrete Shear Walls with Stiff Diaphragms (Type C2)

For this building, five checklists were applicable, as listed in Table 5-1. Refer to Appendix B for the completed checklists.

Table 5-1: Checklists for Tier 1 Evaluation

Tier 1 Checklist	ASCE 31 Reference
Basic Structural	Section 3.7
Supplemental Structural	Section 3.7
Geologic Site Hazard and Foundation	Section 3.8
Basic Nonstructural	Section 3.9.1
Intermediate Nonstructural	Section 3.9.2

5.4 INFORMATION COLLECTED

An incomplete set of the original 1906 architectural and structural drawings are available for review. In addition, the structural drawings for the 1918 engine room addition are available. Other recent drawings for mechanical revisions are available as well.

KPFF performed field surveys on June 15, 2012 and on July 9, 2012. This purpose of these surveys was to compare the visible structural systems to the existing structural drawings, observe the condition of the structural systems, and observe visible typical locations of support of nonstructural systems. The condition of the visible structural is detailed in the report titled "Georgetown Steam Plant: Condition Assessment" dated December 2010 and in the report titled "Georgetown Steam Plant: Addendum to 2010 Condition Assessment" dated July 2012.

Due to a lack of documentation of the original construction materials for the building, material strengths used for calculations were assumed as allowed by ASCE 31. Concrete strength was assumed to be 2,000 psi. Steel reinforcing yield strength was assumed to be 33 ksi.

The reinforcing ratio of the beams and columns was calculated based on the drawings for the 1918 building expansion shown in Figure 2-1. The reinforcing ratio for the beams varies between 0.0025 and 0.012. The reinforcing ratio for the columns varied between 0.02 and 0.033. The actual reinforcing ratio of the 1906 construction may vary from these values depending on the specific design of each element.

5.5 POTENTIAL SEISMIC DEFICIENCIES

The ASCE 31 Tier 1 evaluation procedure is based on a series of questions from checklists. If an item on the checklist complies with the ASCE 31 criterion, then no further investigation is required for that item. If an item on the checklist does not comply with the ASCE 31 criterion, then the item is flagged as potentially deficient. Upon further investigation (Tier 2 and possibly Tier 3 evaluations), the flagged item may or may not prove to be deficient. Items which are ultimately shown to be deficient would require structural upgrades in order for the building to meet the established seismic performance goal for the design-level earthquake.

The Tier 1 evaluation identified potential deficiencies, both structural and nonstructural, that may need to be mitigated to reduce seismic hazards. Structural deficiencies indicate that a seismic event is likely to damage the building and reduce its ability to support gravity (vertical) and lateral loads. Nonstructural deficiencies are typically occupant hazards, which indicate potential damage to the building contents or potential injury to the building occupants.

The completed Tier 1 checklists are included in Appendix B. A list and brief description of the nonconforming items follows:

Geologic Site Hazards

Liquefaction – The building is located on loose, saturated soils that have the potential to liquefy or laterally spread during an earthquake. The fill material and river deposits may extend beneath the bottom of the wooden piles, creating the potential for down-drag or loss of support if liquefaction occurs. Because the fill may extend beneath the bottom of the piles, the piles possess little resistance to the lateral spread of the supporting soil should this occur.

Structural Checklist – Concrete Moment Frames

Weak Story – The varying layout of the concrete frames results in a strength difference between floors, resulting in a weak story deficiency globally in the building.

Soft Story – The significant difference in story height above the first floor results in a soft story deficiency at first story.

Mass – The seismic mass varies more than 50 percent between floors, largely as a result of the mass of the boilers, resulting in a mass deficiency.

Torsion – The calculated center of rigidity is more than 20 percent of the building width from the calculated center of mass, resulting in a torsion deficiency.

Deterioration of Concrete – The concrete and reinforcing steel has visibly deteriorated. The concrete walls are cracked and spalled in places, particularly at interior and exterior of the southwest corner of the building. Concrete spalling has exposed the steel reinforcing in places at the beams and columns.

Interfering Walls – The 1918 addition to the Engine Room includes a concrete frame system that is infilled with masonry placed directly against the concrete frame. The original 1906 construction includes frames in the boiler room that are infilled with concrete walls.

Shear Stress Check – The calculated columns shears of 103 psi are greater than the 100 psi limit of ASCE 31.

Axial Stress Check – The calculated axial forces of 700 psi are greater than the 600 psi limit.

Concrete Columns – Drawings are not available of this portion of the building so it is unknown if the concrete columns are doweled into the foundations.

Supplemental Structural Checklist – Concrete Moment Frames

No Shear Failures – KPFF calculations based on the reinforcing used in the 1918 expansion of the building show that beams and columns may not be able to develop the full moment capacity, and may be limited by the shear capacity of the member. The result would be a shear failure controlling the strength of the member, which is the basis for this deficiency.

Strong Column/Weak Beam – KPFF calculations based on the reinforcing used in the 1918 expansion show that moment frame joints may not comply with the strong column/weak beam criteria.

Column-Bar Splices – Longitudinal column bars have splice lengths greater than 35 d_b where shown on the 1918 drawings, but are not enclosed with ties spaced less than 8 d_b.

Beam-Bar Splices – 1918 drawings show that top and bottom beam bars are lap spliced within the column joints.

Column Tie Spacing – Based on the 1918 drawings, column tie spacing is typically 12 inches on center (o.c.) along the entire column length, which is greater than d/4 or 8 d_b.

Stirrup Spacing – Based on the 1918 drawings, beam tie spacing is greater than d/2 along the beam length and is greater than $8\ d_b$ at potential plastic hinge locations.

Joint Reinforcing – 1918 drawings do not show that ties are used within the beam-column joints.

Deflection Compatibility – Secondary components are not expected to have shear capacity large enough to develop the flexural strength of the member based on the findings of the primary components.

Diaphragm Continuity – Diaphragms in the Boiler Room and Engine Room are at different elevations.

Uplift at Pile Caps – Details for the pile connections to the pile caps have not been located. Typical construction methods in the 1900's would not have included a connection between the pile and the pile caps that is able to resist uplift forces.

Structural Checklist – Concrete Shear Walls (duplicate deficiencies not listed)

Shear Stress Check – The concrete shear stresses of 275 psi are greater than the 100 psi limit of ASCE 31.

Reinforcing Steel – Drawings are not available for this portion of the building so it is unknown if the concrete walls meet the minimum reinforcing steel requirements.

Foundation Dowels – Drawings showing the connection between the shear walls and the foundations are not available for review so it is unknown if these dowels are present.

Supplemental Structural Checklist – Concrete Shear Walls (duplicate deficiencies not listed)

Deflection Compatibility – KPFF calculations based on the reinforcing used in the 1918 expansion of the building show that beams and columns may not be able to develop the full moment capacity, and may be limited by the shear capacity of the member

Coupling Beams – Drawings are not available for this portion of the building so it is unknown if the concrete walls meet the reinforcing steel requirements for coupling beams over building exits.

Basic Nonstructural Checklist

Unreinforced Masonry – Unreinforced masonry walls are present in the 1918 engine room addition and are unbraced.

Stair Details – The connections between the steel stairs and the structure relies on shallow concrete anchors.

Deterioration – Significant deterioration is observed in the anchorage of nonstructural components.

Attached Equipment – This building contains many items over 20 pounds attached to the ceiling and walls that are unbraced against lateral forces.

Intermediate Nonstructural Checklist

Glazing – The type of glass in the windows is unknown. If the windows are not tempered or are not laminated, when broken, these windows could break into jagged shards, or could fall from the window frames.

5.6 FURTHER DISCUSSION REGARDING TIER 1 RESULTS

Many nonconforming items were identified in the Tier 1 evaluation. Several of the deficiencies, such as Weak Story, Soft Story, Mass, and Torsion pertain to the general layout of the lateral force resisting system. Other deficiencies such as No Shear Failure, Strong Column/Weak Beam, and Column Bar Splices concern the layout of reinforcing within the structural elements. These deficiencies will be investigated further in the seismic evaluation of the structure. Because the interior of the building is largely unfinished, the number of deficient non-structural items is low. The liquefaction geologic site hazard (an unstable soil condition experienced during seismic events) will need to be investigated further by a licensed geotechnical engineer if more insight into this potential hazard is desired by the owner.

The largest question that the Tier 1 evaluation is not able to answer is when an earthquake occurs, how much of the seismic force is resisted by the concrete walls, and how much is resisted by the concrete frames. An analytical model of the building will be necessary to answer this question due to the unusual layout of the lateral force resisting elements and mass distribution within this building. This question is answered by our seismic evaluation and is discussed in the next section of this report.

6. Modified Tier 2 Seismic Evaluation

6.1 SEISMIC EVALUATION PROCEDURE

The ASCE 31 Tier 1 Seismic Evaluation section of this report describes the ASCE 31 tiers and their use. For this portion of the project, methods similar to those described in the ASCE 31 Tier 2 procedure are used to:

- Observe building seismic behavior and calculate seismic stresses in concrete elements.
- Quantify the effect of the shear walls on the building stiffness and compare the forces in the moment frames if the shear walls become detached from the building diaphragms.
- Develop conceptual approaches for upgrading the seismic force-resisting systems.

During the Tier 1 evaluation of the building, the concrete moment frames had both Shear Failures and Strong Column/Weak Beam deficiencies identified. If the columns are not stronger than the beams in the concrete frame, the initial yielding of the system will be forced into the columns. Because of the large tie spacing, the columns can fail in shear before a flexural hinge can form. FEMA 547, Techniques for the Seismic Rehabilitation of Existing Buildings states that, “buildings with these characteristics are among the most hazardous in the U.S. inventory and are in danger of collapse in ground motion strong enough to initiate shear failures in the columns.”

Due to the risks associated with the concrete frame action in this building KPFF’s seismic evaluation was focused on identifying frame action within the building and our recommendations are developed to reduce the magnitude of load that is resisted by frame action.

6.2 SEISMIC SPECTRAL RESPONSE ACCELERATION PARAMETERS

The level of seismicity for the Tier 2 procedure is the same as the level of seismicity for the Tier 1 procedure described in section 5.3.

6.3 ANALYSIS PROCEDURE

For the evaluations performed using the ASCE 31 Tier 2 approach, a three-dimensional computer model was constructed for the building. The Linear Dynamic Procedure in ASCE 31 was employed for the analyses, using modal response spectrum analysis. Figure 6-1 shows the analytical model of the building.

The building model includes all of the members that participate in the lateral force resistance of the building, including the concrete diaphragms, the concrete walls, and the concrete beams and columns. The building foundations are modeled as rigid elements.

This model was used to determine the expected seismic forces in the structural elements, and to quantify the percentage of seismic load that is resisted by the concrete shear walls and the concrete frames.

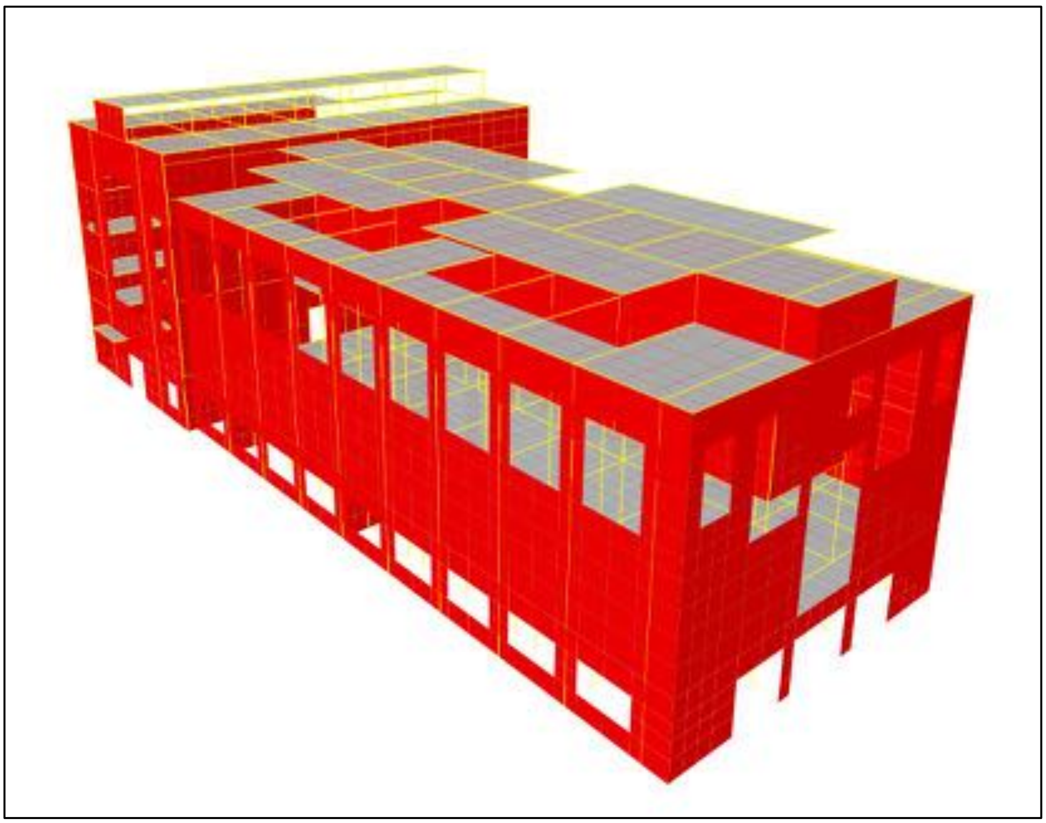


Figure 6-1: Analytical Model of Building

6.4 EVALUATION OF EXISTING SEISMIC FORCE RESISTING SYSTEMS

The structural issues identified in the Tier 1 evaluation are investigated further in the seismic analysis. In particular, the interaction between the concrete frames and the concrete shear walls are quantified, and the forces in the connections between the concrete walls and diaphragms are calculated. Additionally, the forces in the concrete frames at the East end of the engine room are calculated and compared to frame forces in frames closer to concrete walls. Finally, the forces near the discontinuity between the boiler room and the engine room are quantified.

In general, the shear walls were found to contribute significant seismic stiffness and strength to the building. The shear walls resist the majority of the seismic force in the building. In some locations, such as in the 1918 addition, the concrete frames are located on the opposite end of the building from the shear walls and so the frames resist most of the inertial seismic forces from this region of the building. Specific demand to capacity ratios are not provided for the seismic forces on the building because the reinforcing of the existing structure is not known. The linear seismic analysis shows that the concrete walls were found to resist over 90 percent of the seismic load in the north-to-south direction, and over 90 percent of the seismic load in the east-to-west direction.

To determine the importance of the shear walls to the lateral force resisting behavior of the building, the analytical model was run twice, the first time representing the existing condition of the building, and the second time representing a disconnection of the diaphragms from the concrete walls. For concrete frames in the engine room, a disconnection of the concrete walls typically resulted in a doubling of the forces in the concrete frame members. For concrete frames in the boiler room, a disconnection of the concrete walls typically resulted in frame forces that are 4 to 10 times larger in the concrete frames. Because the concrete frames are likely to be the source of the most severe seismic damage to the structure, maintaining the connection between the concrete walls and the concrete diaphragms could result in a building that is able to resist up to twice the magnitude of seismic forces before experiencing seismic damage associated with the concrete frames.

The concrete shear stresses were recorded in a number of locations within the building. Because the reinforcing in the majority of the structure is unknown, it is not possible to know if these locations are seismically deficient or not. Due to the particular behavior of the concrete frame elements, we are not able to provide a likely shear capacity for the walls, diaphragms, beams, or columns. Structural elements that were found to have significantly higher stresses than similar elements in the building are:

- The north and south portions of the high roof diaphragm above the boiler room. These stresses were found to be between 4 and 5 root f'c.
- Portions of the concrete walls at the South wall of the boiler room have stresses between 5 and 6 root f'c. These stresses occur because the number of openings in this wall concentrate the seismic shears into just a few piers of continuous concrete. The stresses in this wall are significantly higher than the stresses in the other concrete walls in the building. The capacity of this wall is questionable due to the observed damage that is documented in the Condition Assessment.

- The shear forces in the columns along the wall that separates the engine room from the boiler room are as high as 11 root f'c. These columns transfer forces between the roof diaphragms at two different elevations.

A concrete wall exists on the west end of the engine room, but the east end only has concrete frames. The predicted seismic deflections at the east end of this portion of the building are up to 8 times the deflections of the west side. The concrete frames resist a large portion of the seismic forces in this portion of the building and we expect that earthquake damage will appear first in this portion of the building.

Also, the high roof created by the clerestory has no mechanism to transfer seismic forces to the perimeter concrete walls besides the concrete frames. The use of these frames to transfer these forces will increase the likelihood of frame related seismic deficiencies. The clerestory in the boiler room has concrete walls that resist forces in the north-south direction which are expected to be adequate to transfer these forces.

7. Proposed Mitigation Measures

The type and extent of mitigation required will depend on Seattle City Light's objectives in performing mitigation. In preparing this report, we have been asked by Seattle City Light to consider three possible objectives, listed in order of increasing cost and improving performance:

- Targeted Investment – Target the mitigation measures at those deficiencies which offer the biggest improvement in seismic performance for the investment made. Due to the very limited information available on the reinforcing of the existing structure, the resulting improvement in performance cannot be quantified. The structure will, however, perform better than if no action is taken.
- Collapse Prevention – This performance level is defined by ASCE 41 as one where the building is "on the verge of partial or total collapse" following the design level earthquake. While the structure has not collapsed, there could be loss of life due to component failures and repair may not be possible.
- Life Safety – This performance level is defined by ASCE 41 as one where the building is one "in which significant damage has occurred" but "the overall risk of life threatening injury as a result of structural damage is low." The building should be repairable, but repair may not be economically practical. This is the performance level that the City of Seattle requires for buildings that undergo a substantial alteration, although there is a willingness by the City to negotiate the performance level if meeting the life safety performance level is too onerous to meet. The City of Seattle's Client Assistance Memo 314 provides guidelines for when a building is considered to be a substantial alteration. Of particular note for this building is that the intent is that "buildings with low or minimal usage are properly retrofitted when they become more fully occupied."

Whatever work is done should consider the recommendations of Preservation Brief 41: The Seismic Retrofit of Historic Buildings Keeping Preservation in the Forefront. In general, this means the mitigation measures should endeavor to keep the existing historic structure intact and to be removable, should better retrofit techniques become available in the future. This suggests, for example, that steel braced frames would be preferred over concrete shear walls, as the braced frames would be more easily removed in the future, and would not obscure the existing, historic, materials.

The following sections address each of these performance levels, and provide a rough order of magnitude cost for the associated work.

7.1 TARGETED INVESTMENT

This approach to mitigation is based on the findings of this report. Because of the very limited information available on the reinforcing of the structure, the suggested mitigation measures are based on the stress levels in our model, our understanding of structural behavior, and our engineering judgment. Our recommendation is to target the mitigation measures on minimizing the frame behavior of the building, and reinforcing elements with particularly high seismic stresses. In order of priority, this work includes:

- The attachment of the concrete diaphragms to the shear walls at all locations. The current method of attachment is unknown, and it is possible that there is little connection between the diaphragms and the walls. Alternately, it may be worthwhile to verify existing attachments through radar or x-ray imaging. If this investigation shows that adequate attachments exist, attachment may not be needed. For a rough order of magnitude cost, we anticipate that a cost of $100 to $200 per lineal foot. This could be selectively applied to the most highly stressed diaphragm to shear wall joints.
- Strengthen the columns along the wall that separates the engine room from the boiler room at the roof bolting on steel reinforcement. There are five columns affected and the cost of strengthening each column will be $2,500 to $5,000, resulting in a total cost between $12,500 and $50,000.
- Brace the clay tile wall on the north side of the building by adding light gage framing back-up. The cost is anticipated to be between $5,000 to $10,000.
- Repairing and strengthening the southern concrete wall. The cost is anticipated to be between $50,000 to $10,0000.
- Add concrete shear walls or steel braced frames in the eastern portion of the engine room. The cost is anticipated to be between $30,000 to $60,0000.
- Add steel braces behind the clerestory windows where no concrete walls are present. We anticipate that this would be done at four locations, and that the cost of each frame will be $5,000 to $10,000, resulting in a total cost between $20,000 and $40,000.

The work included in these recommendations is not intended to improve the seismic performance of the building to current building code standards, or even compliance with the target ASCE 31 performance level. These recommendations are expected to mitigate the most critical deficiencies in the building with a focus on the behaviors that can be addressed in an efficient, cost-effective manner. If it is necessary to improve the seismic performance of the building beyond the recommendations of this report, additional, more costly work could be performed such as strengthening the existing concrete columns in shear and flexure and strengthening the existing concrete beams in shear, or adding new concrete shear walls

7.2 COLLAPSE PREVENTION

There are two basic approaches that could be adopted to achieving a collapse prevention performance level – upgrading the existing structural components to achieve the required strength and ductility or inserting a new lateral force resisting system into the building. We believe that inserting a new structural system consisting of steel braced frames will be the most cost effective and historically respectful solution. The reasons for this are:

- Upgrading the existing structural components would require an extensive program of exploration and testing to determine what reinforcing is present in the existing concrete members and the material strengths.
- A new structural system will require less engineering effort.
- A new structural system will use more conventional materials and be simpler to construct.
- Upgrading the existing structural components will require wrapping, encasing, or overlaying the existing structure. This will obscure and damage the existing historical structural materials. In contrast, the steel braced frames would be largely independent of the existing structure and could be more easily removed if improved seismic retrofit systems become available in the future.

At the collapse performance level, it is not necessary to prevent damage to the existing structure in the design seismic event. As a result, the new structural system need only be designed to be strong enough to resist the full seismic load. For a rough order of magnitude cost, we anticipate that a total of eight frames will be required, and that the cost of each frame will be $50,000 to $100,000, resulting in a total cost between $400,000 and $800,000.

7.3 LIFE SAFETY

The same two basic approaches are available to achieve a life safety performance level as are available to achieve a collapse prevention performance level. The difference between the performance levels is that the life safety performance level requires control of the structural damage so that life-threatening injuries are avoided. This means that upgrades to existing structural components need to achieve greater strength and ductility than those at the collapse prevention level. A new lateral force resisting system would need to be significantly stiffer – stiff enough to protect the existing brittle structural components against excessive damage. Neither of these options will result in a particularly historically respectful solution, as the new lateral force resisting systems would likely need to consist of new cast-in-place concrete shear walls placed against the existing walls. Even so, new concrete shear walls would likely be the most appropriate solution.

For a rough order of magnitude cost, we anticipate that a total of eight walls will be required, and that the cost of each wall will be $75,000 to $150,000, resulting in a total cost between $600,000 and $1,200,000.

7.4 VOLUNTARY SEISMIC RETROFITTING

As discussed above, the City of Seattle Department of Planning and Development does not require the strengthening of any building unless a substantial alteration as defined by the Seattle Building Code is planned, or unless the building is dangerous to life, health, or the safety of the occupants (see Seattle

Building Code 2009 3401.4.1). KPFF has not identified any immediate threats to the occupants of the building due to seismic performance and the seismic deficiencies identified in this report are similar to seismic deficiencies that exist in other occupied facilities in the Seattle area. Additionally, the limited occupancy of the building reduces the probability of loss of life in the event of an earthquake. Seismic deficiencies are typically not classified as immediate threats to building occupants because the deficiencies will only pose a threat to the occupants during the relatively rare occurrence of an earthquake.

8. Conclusions

KPFF has performed a seismic evaluation of the Georgetown Steam Plant using ASCE 31 for a Tier 1 screening of the facility followed by a detailed seismic evaluation. The Tier 1 screening identified potential seismic deficiencies if the facility was subjected to a major earthquake. The seismic evaluation was conducted to both perform a more detailed evaluation of the building's performance with consideration of different earthquake demands, as well as to develop conceptual approaches for upgrading the seismic force-resisting systems.

A complete seismic evaluation of the building is not possible, because the original structural drawings for the building are not available. Without these drawings, the reinforcing in each structural element, and thus the strength of each element, is unknown. KPFF was able to create an analytical model of the building based on the information that was available, and our conclusions come from the results of this model.

Our evaluations determined that there are potential structural and nonstructural deficiencies in the Georgetown steam plant, with the majority of identified deficiencies being structural. Two different lateral force load resisting paths are identified in the building, the concrete shear walls, and the concrete frames, which could resist the seismic forces in the building. The concrete shear walls are the desired mechanism to resist the seismic forces due to the potential for damage to the building associated with the concrete frame behavior.

KPFF has identified the attachment of the building diaphragms to the concrete shear walls as the highest priority seismic upgrade, because this attachment will enable the seismic forces to be resisted by the perimeter concrete walls, instead of the interior concrete frames. The connection between the diaphragms and walls is unknown. KPFF recommends creating new connections that have the capacity to resist all of the seismic forces.

Additional seismic deficiencies exist within the building, and it is not likely to be feasible to fix each deficiency. A complete list of the seismic deficiencies and proposed methods to fix each deficiency is not possible because of the lack of structural drawings for the building. Besides strengthening the diaphragm to wall connection, the highest priority work should be to strengthen the south wall of the building, and add a line of lateral resistance to the east end of the engine room.

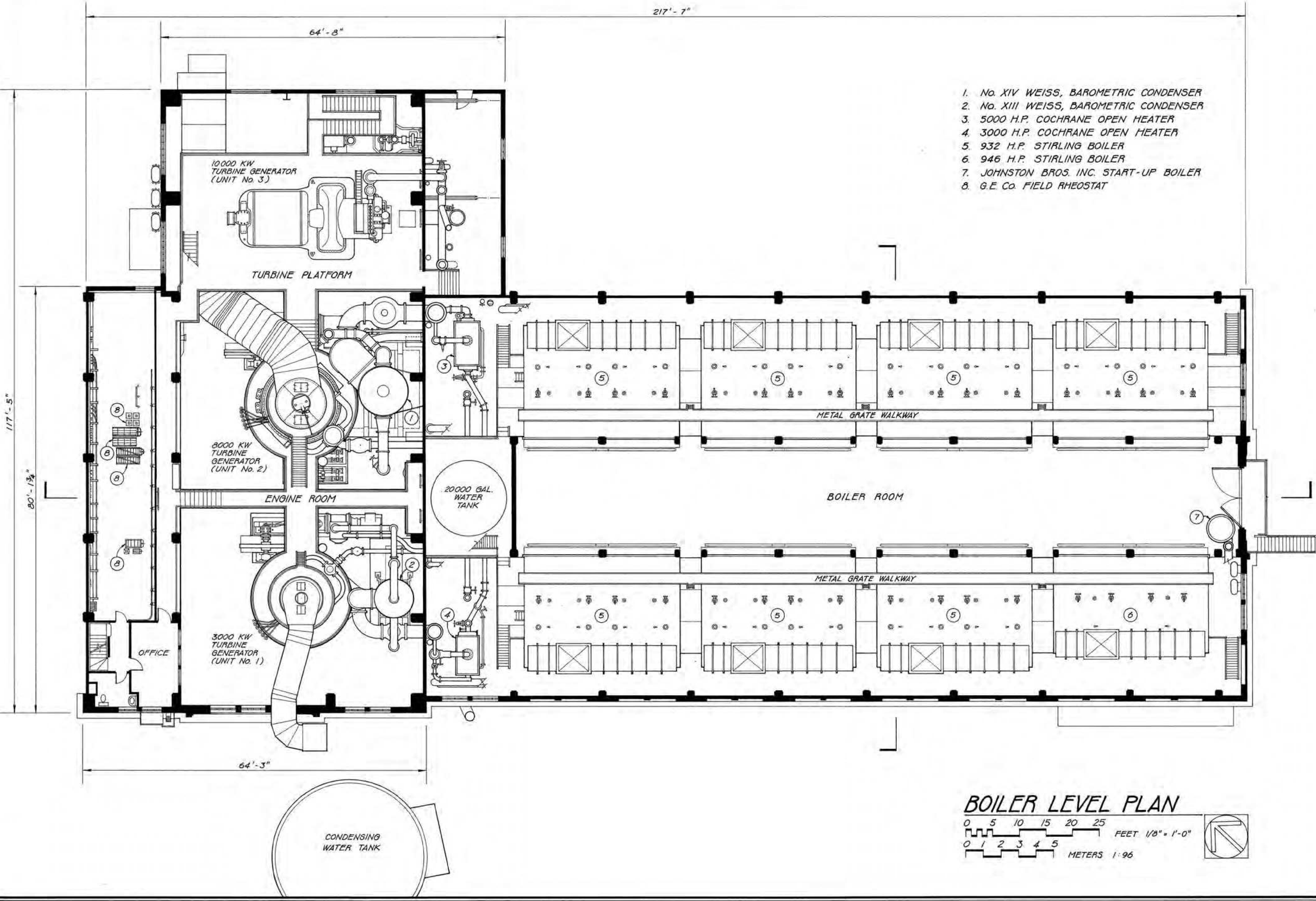
The City of Seattle Department of Planning and Development does not require the strengthening of any building unless a substantial alteration as defined by the Seattle Building Code is planned, or unless the building is dangerous to life, health, or the safety of the occupants (see Seattle Building Code 2009 3401.4.1). KPFF has not identified any immediate threats to the occupants of the building due to seismic performance and the deficiencies identified in this report are similar to deficiencies that exist in other occupied facilities in the Seattle area. Because of this, any seismic retrofitting that occurs as a result of this study will occur by the voluntary actions of Seattle City Light.

9. References

1. American Society of Civil Engineers/Structural Engineering Institute, *Minimum Design Loads for Buildings and Other Structures*, ASCE/SEI 7, 2005.
2. American Society of Civil Engineers/Structural Engineering Institute, *Seismic Evaluation of Existing Buildings*, ASCE/SEI 31, 2003.
3. American Society of Civil Engineers/Structural Engineering Institute, *Seismic Rehabilitation of Existing Buildings*, ASCE/SEI 41, 2006.
4. Federal Emergency Management Agency (FEMA), *NEHRP Recommended Provisions for Seismic Regulations for New Buildings and Other Structures: Provisions and Commentary*, FEMA 450, 2003.
5. Federal Emergency Management Agency (FEMA), *Techniques for the Seismic Rehabilitation of Existing Buildings*, FEMA 547, 2006.
6. International Code Council, *International Building Code*, 2009.
7. Pacific Northwest Seismic Network, http://www.pnsn.org/welcome.html.
8. United States Geological Survey (USGS), http://www.usgs.gov.
9. National Parks Service, *Preservation Brief 41: The Seismic Retrofit of Historic Buildings Keeping Preservation in the Forefront*, 1997

Appendix A

Select Existing Drawings



DELINEATED BY: BARRY A. RICHARDS & YOSHIKADO KOYAMA, 1982

GEORGETOWN STEAM PLANT PROJECT
OFFICE OF ARCHEOLOGY AND HISTORIC PRESERVATION
HERITAGE CONSERVATION AND RECREATION SERVICE
UNITED STATES DEPARTMENT OF THE INTERIOR

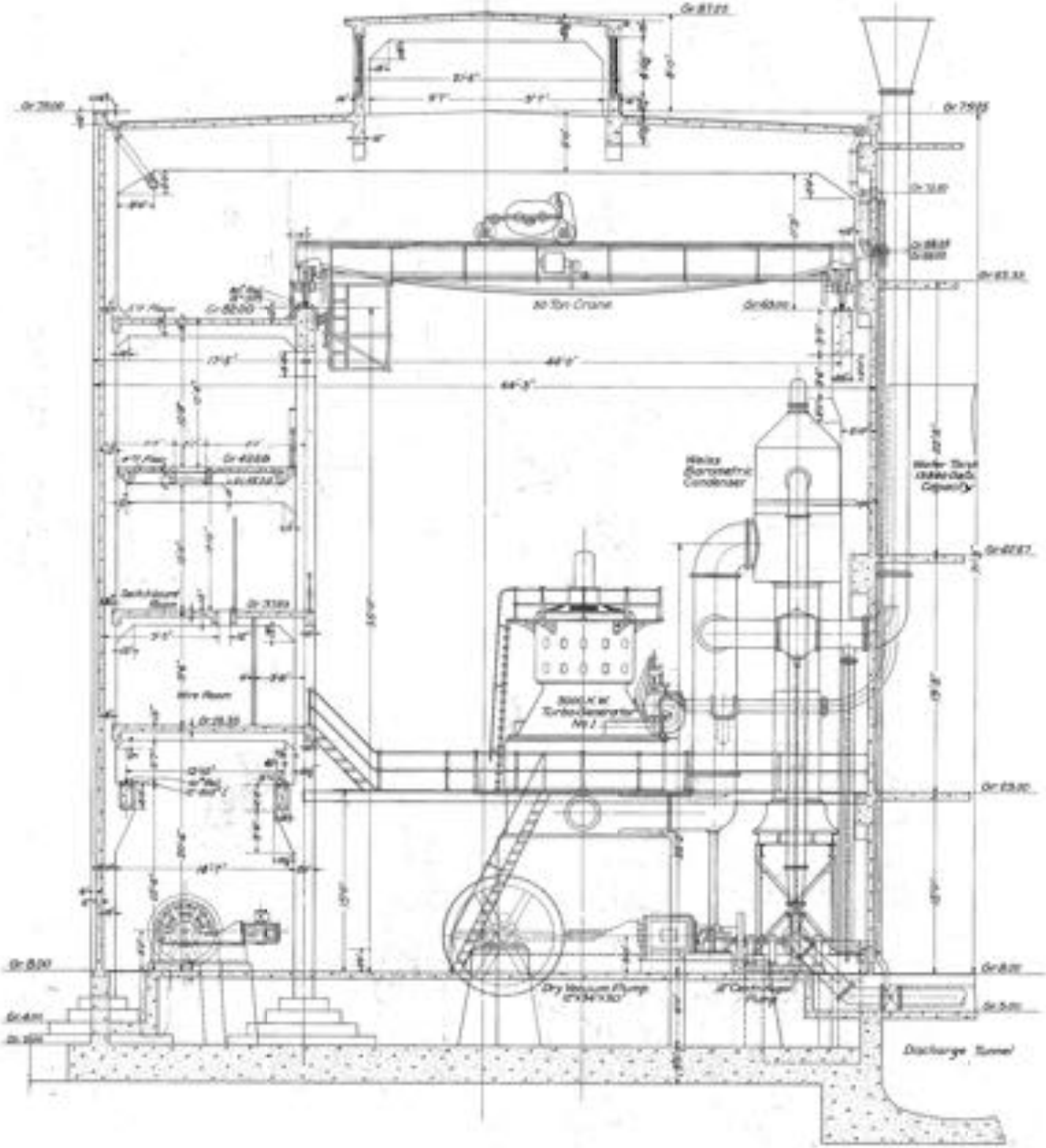
GEORGETOWN STEAM PLANT · 1906
1300 SOUTH GREELY STREET
KING COUNTY
SEATTLE WASHINGTON

SHEET 4 OF 8

HISTORIC AMERICAN ENGINEERING RECORD
WA-1

IF REPRODUCED, PLEASE CREDIT: HISTORIC AMERICAN ENGINEERING RECORD, HERITAGE CONSERVATION & RECREATION SERVICE, NAME OF DELINEATOR, DATE OF THE DRAWING


Coal Pocket.
Heater
Feed
Pump
Stirling
Battery
600 H.P.
Discharge Tunnel
Ash Car
LOOKING EAST.
LONG. SECTION BOILER ROOM
THE SEATTLE ELECTRIC CO.
STONE & WEBSTER ENGINEERING CORP.
BOSTON
F10742
F-in-531

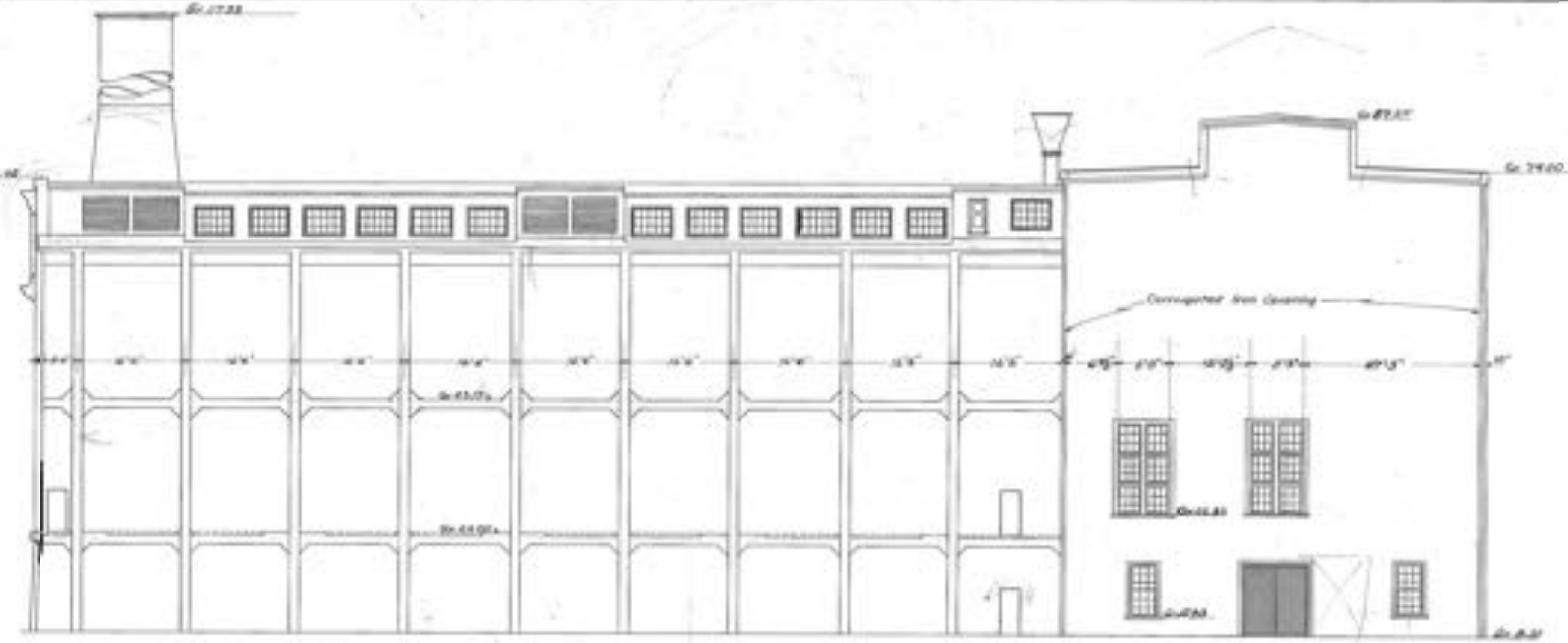


CROSS SECTION-ENGINE RM.
GEORGETOWN POWER STATION
THE SEATTLE ELECTRIC CO.
STONE & WEBSTER ENGINEERING CORP.
BOSTON

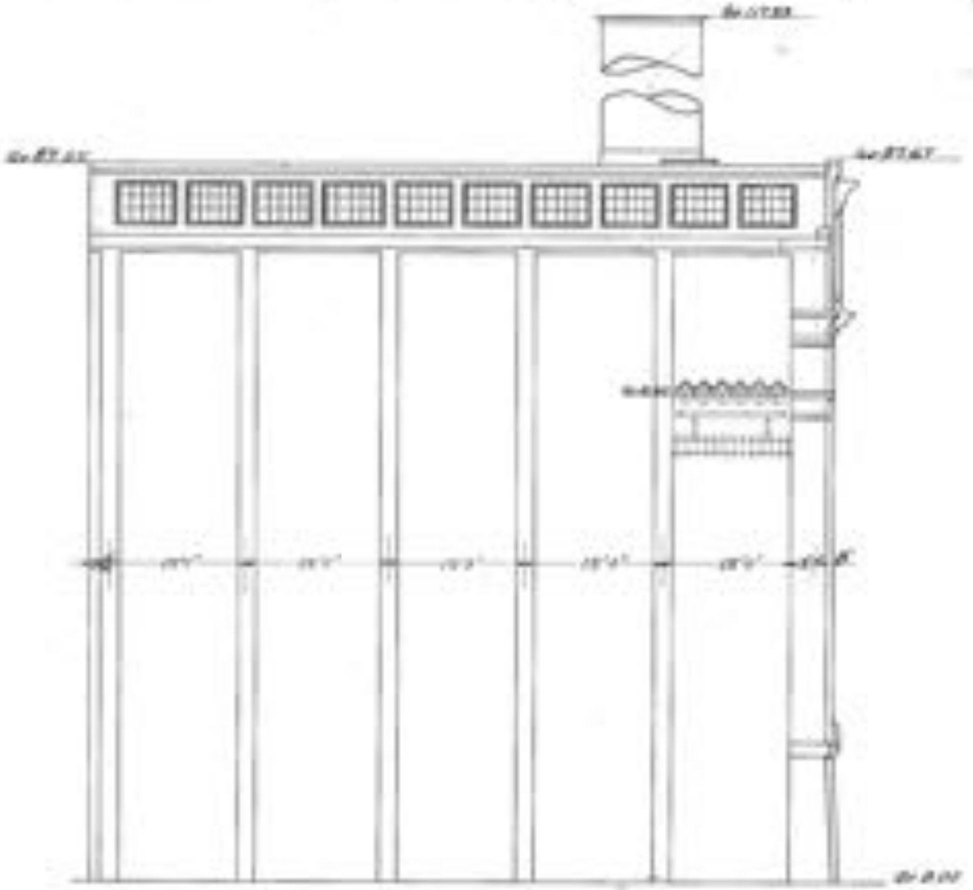
F8266

F-537

MICRO FILMED NOV 1



EAST ELEVATION

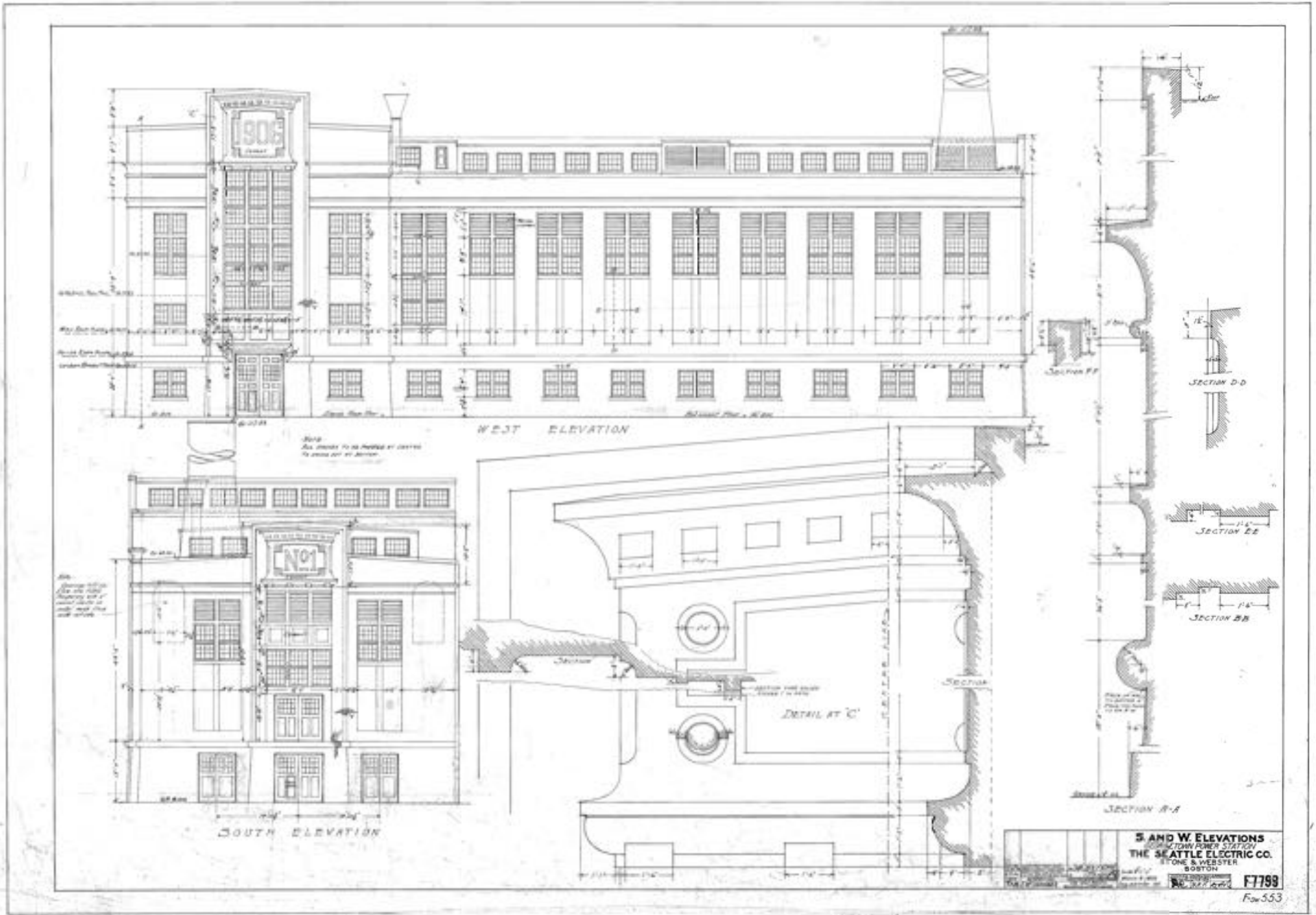


NORTH ELEVATION

N. & E. ELEVATION
GEORGETOWN POWER STATION
THE SEATTLE ELECTRIC CO.
STONE & WEBSTER ENGINEERING CORP.
BOSTON

F9044

F-SW 539


1906
No 1
WEST ELEVATION
SOUTH ELEVATION
DETAIL AT "C"
SECTION
SECTION F-F
SECTION D-D
SECTION E-E
SECTION B-B
SECTION A-A
S. AND W. ELEVATIONS
THE SEATTLE ELECTRIC CO.
STONE & WEBSTER
BOSTON
F7799
F-5w 553

Appendix B

ASCE 31 Tier 1 Checklists

Basic Structural Checklist for Buildings with Concrete Moment Frames (Building Type C1)

Building Name: Georgetown Steam Plant

Building System

C LOAD PATH: The structure shall contain a minimum of one complete load path for *Life Safety* and *Immediate Occupancy* for seismic force effects from any horizontal direction that serves to transfer the inertial forces from the mass to the foundation. (Tier 2: Sec. 4.3.1.1)

C ADJACENT BUILDINGS: The clear distance between the building being evaluated and any adjacent building shall be greater than 4 percent of the height of the shorter building for *Life Safety* and *Immediate Occupancy*. (Tier 2: Sec. 4.3.1.2)

C MEZZANINES: Interior mezzanine levels shall be braced independently from the main structure, or shall be anchored to the lateral-force-resisting elements of the main structure. (Tier 2: Sec. 4.3.1.3)

NC WEAK STORY: The strength of the lateral-force-resisting system in any story shall not be less than 80% of the strength in an adjacent story, above or below, for *Life Safety* and *Immediate Occupancy*. (Tier 2: Sec. 4.3.2.1)

NC SOFT STORY: The stiffness of the lateral-force-resisting system in any story shall not be less than 70% of the lateral-force-resisting system stiffness in an adjacent story above or below, or less than 80% of the average lateral-force-resisting system stiffness of the three stories above or below for *Life Safety* and *Immediate Occupancy*. (Tier 2: Sec. 4.3.2.2)

C GEOMETRY: There shall be no changes in horizontal dimension of the lateral-force-resisting system of more than 30% in a story relative to adjacent stories for *Life Safety* and *Immediate Occupancy*, excluding one-story penthouses and mezzanines. (Tier 2: Sec. 4.3.2.3)

C VERTICAL DISCONTINUITIES: All vertical elements in the lateral-force-resisting system shall be continuous to the foundation. (Tier 2: Sec. 4.3.2.4)

NC MASS: There shall be no change in effective mass more than 50% from one story to the next for *Life Safety* and *Immediate Occupancy*. Light roofs, penthouses, and mezzanines need not be considered. (Tier 2: Sec. 4.3.2.5)

NC TORSION: The estimated distance between the story center of mass and the story center of rigidity shall be less than 20% of the building width in either plan dimension for *Life Safety* and *Immediate Occupancy*. (Tier 2: Sec. 4.3.2.6)

NC DETERIORATION OF CONCRETE: There shall be no visible deterioration of concrete or reinforcing steel in any of the vertical- or lateral-force-resisting elements. (Tier 2: Sec. 4.3.3.4)

N/A POST-TENSIONING ANCHORS: There shall be no evidence of corrosion or spalling in the vicinity of post-tensioning or end fittings. Coil anchors shall not have been used. (Tier 2: Sec. 4.3.3.5)

Lateral Force Resisting System

C REDUNDANCY: The number of lines of moment frames in each principal direction shall be greater than or equal to 2 for *Life Safety* and *Immediate Occupancy*. The number of bays of moment frames in each line shall be greater than or equal to 2 for *Life Safety* and 3 for *Immediate Occupancy*. (Tier 2: Sec. 4.4.1.1.1)

NC INTERFERING WALLS: All concrete and masonry infill walls placed in moment frames shall be isolated from structural elements. (Tier 2: Sec. 4.4.1.2.1)

NC SHEAR STRESS CHECK: The shear stress in the concrete columns, calculated using the Quick Check procedure of Section 3.5.3.2, shall be less than the greater of 100 psi or $2\sqrt{f'c}$ for *Life Safety* and *Immediate Occupancy*. (Tier 2: Sec. 4.4.1.4.1)

NC AXIAL STRESS CHECK: The axial stress due to gravity loads in columns subjected to overturning forces shall be less than $0.10f'_c$ for *Life Safety* and *Immediate Occupancy*. Alternatively, the axial stresses due to overturning forces alone, calculated using the Quick Check Procedure of Section 3.5.3.6, shall be less than $0.30f'_c$ for *Life Safety* and *Immediate Occupancy*. (Tier 2: Sec. 4.4.1.4.2)

<u>Key</u>:
C = Compliant NC = Non-Compliant N/A = Not Applicable

Connections

NC CONCRETE COLUMNS: All concrete columns shall be doweled into the foundation for *Life Safety,* and the dowels shall be able to develop the tensile capacity of the reinforcement in columns of lateral-force-resisting system for *Immediate Occupancy*. (Tier 2: Sec. 4.6.3.2)

Supplemental Structural Checklist for Buildings with Concrete Moment Frames (Building Type C1)

Building Name: Georgetown Steam Plant

Lateral Force Resisting System

C FLAT SLAB FRAMES: The lateral-force-resisting system shall not be a frame consisting of columns and a flat slab/plate without beams. (Tier 2: Sec. 4.4.1.4.3)

N/A PRESTRESSED FRAME ELEMENTS: The lateral-load-resisting frames shall not include any prestressed or post-tensioned elements where the average prestress exceeds the lesser of 700 psi or $f'_c/6$ at potential hinge locations. The average prestress shall be calculated in accordance with the Quick Check procedure of Section 3.5.3.8. (Tier 2: Sec. 4.4.1.4.4)

C CAPTIVE COLUMNS: There shall be no columns at a level with height/depth ratios less than 50% of the nominal height/depth ratio of the typical columns at that level for *Life Safety* and 75% for *Immediate Occupancy*. (Tier 2: Sec. 4.4.1.4.5)

NC NO SHEAR FAILURES: The shear capacity of frame members shall be able to develop the moment capacity at ends of the members . (Tier 2: Sec. 4.4.1.4.6)

NC STRONG COLUMN/WEAK BEAM: The sum of the moment capacity of the columns shall be 20% greater than that of the beams at frame joints. (Tier 2: Sec. 4.4.1.4.7)

C BEAM BARS: At least two longitudinal top and two longitudinal bottom bars shall extend continuously throughout the length of each frame beam. At least 25% of the longitudinal bars provided at the joints for either positive or negative moment shall be continuous throughout the length of the members for *Life Safety* and *Immediate Occupancy*. (Tier 2: Sec. 4.4.1.4.8)

NC COLUMN-BAR SPLICES: All column bar lap splice lengths shall be greater than $35d_b$ for *Life Safety* and $50d_b$ for *Immediate Occupancy* and shall be enclosed by ties spaced at or less than $8d_b$ for *Life Safety* and *Immediate Occupancy*. Alternatively, the column bars shall be spliced with mechanical couplers with a capacity of at least 1.25 times the nominal yield strength of the spliced bar. (Tier 2: Sec. 4.4.1.4.9)

NC BEAM-BAR SPLICES: The lap splices or mechanical couplers for longitudinal beam reinforcing shall not be located within $l_b/4$ of the joints and shall not be located within the vicinity of potential plastic hinge locations. (Tier 2: Sec. 4.4.1.4.10)

NC COLUMN-TIE SPACING: Frame columns shall have ties spaced at or less than d/4 for *Life Safety* and *Immediate Occupancy* throughout their length and at or less than $8d_b$ for *Life Safety* and *Immediate Occupancy* at all potential plastic hinge locations. (Tier 2: Sec. 4.4.1.4.11)

NC STIRRUP SPACING: All beams shall have stirrups spaced at or less than d/2 for *Life Safety* and *Immediate Occupancy* throughout their length. At potential plastic hinge locations, stirrups shall be spaced at or less than the minimum of $8d_b$ or d/4 for *Life Safety* and *Immediate Occupancy*. (Tier 2: Sec. 4.4.1.4.12)

NC JOINT REINFORCING: Beam-column joints shall have ties spaced at or less than $8d_b$ for *Life Safety* and *Immediate Occupancy*. (Tier 2: Sec. 4.4.1.4.13)

N/A JOINT ECCENTRICITY: There shall be no eccentricities larger than 20% of the smallest column plan dimension between girder and column centerlines. **This statement shall apply to the *Immediate Occupancy* Performance Level only.** (Tier 2: Sec. 4.4.1.4.14)

N/A STIRRUP AND TIE HOOKS: The beam stirrups and column ties shall be anchored into the member cores with hooks of 135° or more. **This statement shall apply to the *Immediate Occupancy* Performance Level only.** (Tier 2: Sec. 4.4.1.4.15)

NC DEFLECTION COMPATIBILITY: Secondary components shall have the shear capacity to develop the flexural strength of the components for *Life Safety* and shall meet the requirements of Sections 4.4.1.4.9, 4.4.1.4.10, 4.4.1.4.11, 4.4.1.4.12, 4.4.1.4.15 for *Immediate Occupancy*. (Tier 2: Sec. 4.4.1.6.2)

N/A FLAT SLABS: Flat slabs/plates not part of lateral-force-resisting system shall have continuous bottom steel through the column joints for *Life Safety* and *Immediate Occupancy*. (Tier 2: Sec. 4.4.1.6.3)

Key:

C = Compliant NC = Non-Compliant N/A = Not Applicable

Supplemental Structural Checklist for Buildings with Concrete Moment Frames (Building Type C1)

Building Name: Georgetown Steam Plant

Diaphragms

NC DIAPHRAGM CONTINUITY: The diaphragms shall not be composed of split-level floors and shall not have expansion joints. (Tier 2: Sec. 4.5.1.1)

N/A PLAN IRREGULARITIES: There shall be tensile capacity to develop the strength of the diaphragm at re-entrant corners or other locations of plan irregularities. **This statement shall apply to the *Immediate Occupancy* Performance Level only.** (Tier 2: Sec. 4.5.1.7)

N/A DIAPHRAGM REINFORCEMENT AT OPENINGS: There shall be reinforcing around all diaphragms openings larger than 50% of the building width in either major plan dimension . **This statement shall apply to the *Immediate Occupancy* Performance Level only.** (Tier 2: Sec. 4.5.1.8)

Connections

NC UPLIFT AT PILE CAPS: Pile caps shall have top reinforcement and piles shall be anchored to the pile caps for *Life Safety*, and the pile cap reinforcement and pile anchorage shall be able to develop the tensile capacity of the piles for *Immediate Occupancy* . (Tier 2: Sec. 4.6.3.10)

Basic Structural Checklist for Buildings with Concrete Shear Walls and Stiff Diaphragms (Building Type C2)

Building Name: Georgetown Steam Plant

Building System

C LOAD PATH: The structure shall contain a minimum of one complete load path for *Life Safety* and *Immediate Occupancy* for seismic force effects from any horizontal direction that serves to transfer the inertial forces from the mass to the foundation. (Tier 2: Sec. 4.3.1.1)

C MEZZANINES: Interior mezzanine levels shall be braced independently from the main structure, or shall be anchored to the lateral-force-resisting elements of the main structure. (Tier 2: Sec. 4.3.1.3)

NC WEAK STORY: The strength of the lateral-force-resisting system in any story shall not be less than 80% of the strength in an adjacent story, above or below, for *Life Safety* and *Immediate Occupancy*. (Tier 2: Sec. 4.3.2.1)

NC SOFT STORY: The stiffness of the lateral-force-resisting system in any story shall not be less than 70% of the lateral-force-resisting system stiffness in an adjacent story above or below, or less than 80% of the average lateral-force-resisting system stiffness of the three stories above or below for *Life Safety* and *Immediate Occupancy*. (Tier 2: Sec. 4.3.2.2)

C GEOMETRY: There shall be no changes in horizontal dimension of the lateral-force-resisting system of more than 30% in a story relative to adjacent stories for *Life Safety* and *Immediate Occupancy*, excluding one-story penthouses and mezzanines. (Tier 2: Sec. 4.3.2.3)

C VERTICAL DISCONTINUITIES: All vertical elements in the lateral-force-resisting system shall be continuous to the foundation. (Tier 2: Sec. 4.3.2.4)

NC MASS: There shall be no change in effective mass more than 50% from one story to the next for *Life Safety* and *Immediate Occupancy*. Light roofs, penthouses, and mezzanines need not be considered. (Tier 2: Sec. 4.3.2.5)

NC TORSION: The estimated distance between the story center of mass and the story center of rigidity shall be less than 20% of the building width in either plan dimension for *Life Safety* and *Immediate Occupancy*. (Tier 2: Sec. 4.3.2.6)

NC DETERIORATION OF CONCRETE: There shall be no visible deterioration of concrete or reinforcing steel in any of the vertical- or lateral-force-resisting elements. (Tier 2: Sec. 4.3.3.4)

N/A POST-TENSIONING ANCHORS: There shall be no evidence of corrosion or spalling in the vicinity of post-tensioning or end fittings. Coil anchors shall not have been used. (Tier 2: Sec. 4.3.3.5)

C CONCRETE WALL CRACKS: All existing diagonal cracks in wall elements shall be less than 1/8" for *Life Safety* and 1/16" for *Immediate Occupancy*, shall not be concentrated in one location, and shall not form an X pattern. (Tier 2: Sec. 4.3.3.9)

Lateral Force Resisting System

C COMPLETE FRAMES: Steel or concrete frames classified as secondary components shall form a complete vertical-load-carrying system. (Tier 2: Sec. 4.4.1.6.1)

C REDUNDANCY: The number of lines of shear walls in each principal direction shall be greater than or equal to 2 for *Life Safety* and *Immediate Occupancy*. (Tier 2: Sec. 4.4.2.1.1)

NC SHEAR STRESS CHECK: The shear stress in the concrete shear walls, calculated using the Quick Check procedure of Section 3.5.3.3, shall be less than the greater of 100 psi or $2\sqrt{f'c}$ for *Life Safety* and *Immediate Occupancy*. (Tier 2: Sec. 4.4.2.2.1)

NC REINFORCING STEEL: The ratio of reinforcing steel area to gross concrete area shall be not less than 0.0015 in the vertical direction and 0.0025 in the horizontal direction for *Life Safety* and *Immediate Occupancy*. The spacing of reinforcing steel shall be equal to or less than 18" for *Life Safety* and *Immediate Occupancy*. (Tier 2: Sec. 4.4.2.2.2)

Key:

C = Compliant NC = Non-Compliant N/A = Not Applicable

Connections

C TRANSFER TO SHEAR WALLS: Diaphragms shall be connected for transfer of loads to the shear walls for *Life Safety* and the connections shall be able to develop the lesser of the shear strength of the walls or diaphragm for ***Immediate Occupancy***. (Tier 2: Sec. 4.6.2.1)

NC FOUNDATION DOWELS: Wall reinforcement shall be doweled into the foundation for *Life Safety*, and the dowels shall be able to develop the lesser of the strength of the walls or the uplift capacity of the foundation for *Immediate Occupancy*. (Tier 2: Sec. 4.6.3.5)

Suppemental Structural Checklist for Buildings with Concrete Shear Walls and Stiff Diaphragms (Building Type C2)

Building Name: Georgetown Steam Plant

Lateral Force Resisting System

NC DEFLECTION COMPATIBILITY: Secondary components shall have the shear capacity to develop the flexural strength of the components for *Life Safety* and shall meet the requirements of Sections 4.4.1.4.9, 4.4.1.4.10, 4.4.1.4.11, 4.4.1.4.12, 4.4.1.4.15 for *Immediate Occupancy*. (Tier 2: Sec. 4.4.1.6.2)

N/A FLAT SLABS: Flat slabs/plates not part of lateral-force-resisting system shall have continuous bottom steel through the column joints for *Life Safety* and *Immediate Occupancy*. (Tier 2 : Sec. 4.4.1.6.3

NC COUPLING BEAMS: The stirrups in coupling beams over means of egress shall be spaced at or less than *d*/2 and shall be anchored into the confined core of the beam with hooks of 135° or more for *Life Safety*. All coupling bema shall comply with the requirements above and shall have the capacity in shear to develop the uplift capacity of the adjacent wall for *Immediate Occupancy*. (Tier 2: sec. 4.4.2.2.3)

C OVERTURNING: All shear walls shall have aspect ratios less than 4-to-1. Wall piers need not be considered. **This statement shall apply to the *Immediate Occupancy* Performance Level only.** (Tier 2: Sec. 4.4.2.2.4)

N/A CONFINEMENT REINFORCING: For shear walls with aspect ratios greater than 2-to-1, the boundary elements shall be confined with spirals or ties with spacing less than $8d_b$. **This statement shall apply to the *Immediate Occupancy* Performance Level only.** (Tier 2: Sec. 4.4.2.2.5)

N/A REINFORCING AT OPENINGS: There shall be added trim reinforcement around all wall openings with a dimension greater than three times the thickness of the wall. **This statement shall apply to the *Immediate Occupancy* Performance Level only.** (Tier 2: Sec. 4.4.2.2.6)

N/A WALL THICKNESS: Thickness of bearing walls shall not be less than 1/25 the unsupported height or length, whichever is shorter, nor less than 4 inches. **This statement shall apply to the *Immediate Occupancy* Performance Level only.** (Tier 2: Sec. 4.4.2.2.7)

Diaphragms

NC DIAPHRAGM CONTINUITY: The diaphragms shall not be composed of split-level floors and shall not have expansion joints. (Tier 2: Sec. 4.5.1.1)

C OPENINGS AT SHEAR WALLS: Diaphragm openings immediately adjacent to the shear walls shall be less than 25% of the wall length for *Life Safety* and 15% of the wall length for *Immediate Occupancy*. (Tier 2: Sec. 4.5.1.4)

N/A PLAN IRREGULARITIES: There shall be tensile capacity to develop the strength of the diaphragm at re-entrant corners or other locations of plan irregularities. **This statement shall apply to the *Immediate Occupancy* Performance Level only.** (Tier 2: Sec. 4.5.1.7)

N/A DIAPHRAGM REINFORCEMENT AT OPENINGS: There shall be reinforcing around all diaphragms openings larger than 50% of the building width in either major plan dimension. **This statement shall apply to the *Immediate Occupancy* Performance Level only.** (Tier 2: Sec. 4.5.1.8)

Connections

NC UPLIFT AT PILE CAPS: Pile caps shall have top reinforcement and piles shall be anchored to the pile caps for *Life Safety*, and the pile cap reinforcement and pile anchorage shall be able to develop the tensile capacity of the piles for *Immediate Occupancy*. (Tier 2: Sec. 4.6.3.10)

Key:

C = Compliant NC = Non-Compliant N/A = Not Applicable

Geologic Site Hazards

The following statements shall be completed for buildings in levels of high or moderate seismicity.

NC LIQUEFACTION: Liquefaction-susceptible, saturated, loose granular soils that could jeopardize the building's seismic performance shall not exist in the foundation soils at depths within 50 feet under the building for *Life-Safety* and *Immediate-Occupancy*. (Tier 2: Sec. 4.7.1.1)

C SLOPE FAILURE: The building site shall be sufficiently remote from potential earthquake-induced slope failures or rockfalls to be unaffected by such failures or shall be capable of accommodating any predicted movements without failure. (Tier 2: Sec. 4.7.1.2)

C SURFACE FAULT RUPTURE: Surface fault rupture and surface displacement at the building site is not anticipated. (Tier 2: Sec. 4.7.1.3)

Condition of Foundations

The following statement shall be completed for all Tier 1 building evaluations.

C FOUNDATION PERFORMANCE: There shall be no evidence of excessive foundation movement such as settlement or heave that would affect the integrity or strength of the structure. (Tier 2: Sec. 4.7.2.1)

The following statement shall be completed for buildings in levels of high or moderate seismicity being evaluated to the *Immediate-Occupancy* Performance Level.

N/A DETERIORATION: There shall not be evidence that foundation elements have deteriorated due to corrosion, sulfate attack, material breakdown, or other reasons in a manner that would affect the integrity or strength of the structure. (Tier 2: Sec. 4.7.2.2)

Capacity of Foundations

The following statement shall be completed for all Tier 1 building evaluations.

N/A POLE FOUNDATIONS: Pole foundations shall have a minimum embedment depth of 4 ft. for *Life-Safety* and *Immediate-Occupancy*. (Tier 2: Sec. 4.7.3.1)

The following statements shall be completed for buildings in levels of moderate seismicity being evaluated to the *Immediate-Occupancy* Performance Level, and for buildings in levels of high seismicity.

N/A OVERTURNING: The ratio of the horizontal dimension of the lateral-force-resisting system at the foundation level to the building height (base/height) shall be greater than $0.6S_a$. (Tier 2: Sec. 4.7.3.2)

N/A TIES BETWEEN FOUNDATION ELEMENTS: The foundation shall have ties adequate to resist seismic forces where footings, piles, and piers are not restrained by beams, slabs, or soils classified as Class A, B, or C. (Sec. 3.5.2.3.1, Tier 2: Sec. 4.7.3.3)

N/A DEEP FOUNDATIONS: Piles and piers shall be capable of transferring the lateral forces between the structure and the soil. **This statement shall apply to the *Immediate-Occupancy* Performance Level only.** (Tier 2: Sec. 4.7.3.4)

N/A SLOPING SITES: The difference in foundation embedment depth from one side of the building to another shall not exceed one story in height. **This statement shall apply to the *Immediate-Occupancy* Performance Level only.** (Tier 2: Sec. 4.7.3.5)

Partitions

NC UNREINFORCED MASONRY: Unreinforced masonry or hollow clay tile partitions shall be braced at a spacing of equal to or less than 10 feet in regions of low and moderate seismicity and 6 feet in regions of high seismicity. (Tier 2: Sec. 4.8.1.1)

Ceiling Systems

N/A SUPPORT: The integrated suspended ceiling system shall not be used to laterally support the tops of gypsum board, masonry, or hollow clay tile partitions. Gypsum board partitions need not be evaluated where only the Basic Nonstructural Component Checklist is required by Table 3-2. (Tier 2: Sec. 4.8.2.1)

Light Fixtures

N/A EMERGENCY LIGHTING: Emergency lighting shall be anchored or braced to prevent falling or swaying during an earthquake. (Tier 2: Sec. 4.8.3.1)

Cladding and Glazing

N/A CLADDING ANCHORS: Cladding components weighing more than 10 psf shall be mechanically anchored to the exterior wall framing at a spacing equal to or less than 4 feet. A spacing of up to 6 feet is permitted where only the Basic Nonstructural Component Checklist is required by Table 3-2. (Tier 2: Sec. 4.8.4.1)

N/A DETERIORATION: There shall be no evidence of deterioration, damage or corrosion in any of the connection elements. (Tier 2: Sec. 4.8.4.2)

N/A CLADDING ISOLATION: For moment frame buildings of steel or concrete, panel connections shall be detailed to accommodate a drift ratio of 0.02. Panel connection detailing for a story drift ratio of 0.01 is permitted where only Basic Nonstructural Component Checklist is required by Table 3-2. (Tier 2: Sec. 4.8.4.3)

N/A MULITSTORY PANELS: For multistory panels attached at each floor level, the panels and connections shall be able to accommodate a drift ratio of 0.02. Panel connection detailing for a story drift ratio of 0.01 is permitted where only the Basic Nonstructural Component Checklist is required by Table 3-2. (Tier 2: Sec. 4.8.4.4)

N/A BEARING CONNECTIONS: Where bearing connections are required, there shall be a minimum of two bearing connections for each wall panel. (Tier 2: Sec. 4.8.4.5)

N/A INSERTS: Where inserts are used in concrete connections, the inserts shall be anchored to reinforcing steel or other positive anchorage. (Tier 2: Sec. 4.8.4.6)

N/A PANEL CONNECTIONS: Exterior cladding panels shall be anchored out-of-plane with a minimum of 4 connections for each wall panel. Two connections per wall panel are permitted where only the Basic Nonstructural Component Checklist is required by Table 3-2. (Tier 2: Sec. 4.8.4.7)

Masonry Veneer

N/A SHELF ANGLES: Masonry veneer shall be supported by shelf angles or other elements at each floor 30 feet or more above ground for *Life-Safety* and at each floor above the first floor for ***Immediate-Occupancy***. (Tier 2: Sec. 4.8.5.1)

N/A TIES: Masonry veneer shall be connected to the back-up with corrosion-resistant ties. The ties shall have a spacing of equal to or less than 24" with a minimum of one tie for every 2-2/3 square feet. A spacing of up to 36 inches is permitted where only the Basic Nonstructural Component Checklist is required by Table 3-2. (Tier 2: Sec. 4.8.5.2)

N/A WEAKENED PLANES: Masonry veneer shall be anchored to the back-up adjacent to weakened planes, such as at the locations of flashing. (Tier 2: Sec. 4.8.5.3)

N/A DETERIORATION: There shall be no evidence of deterioration, damage or corrosion in any of the connection elements. (Tier 2: Sec. 4.8.5.4)

Parapets, Cornices, Ornamentation and Appendages

N/A URM PARAPETS: There shall be no laterally unsupported unreinforced masonry parapets or cornices with height-to-thickness ratios greater than 1.5. A height-to-thickness ratio of up to 2.5 is permitted where only the Basic Nonstructural Component Checklist is required by Table 3-2. (Tier 2: Sec. 4.8.8.1)

N/A CANOPIES: Canopies located at building exits shall be anchored at a spacing 6 feet or less. An anchorage spacing of up to 10 feet is permitted where only the Basic Nonstructural Component Checklist is required by Table 3-2. (Tier 2: Sec. 4.8.8.2)

Masonry Chimneys

N/A URM CHIMNEYS: No unreinforced masonry chimney shall extend above the roof surface more than twice the least dimension of the chimney. A height above the roof surface of up to three times the least dimension of the chimney is permitted where only the Basic Nonstructural Component Checklist is required by Table 3-2. (Tier 2: Sec. 4.8.9.1)

Stairs

N/A URM WALLS: Walls around stair enclosures shall not consist of unbraced hollow clay tile or unreinforced masonry with a height-to-thickness ratio greater than 12-to-1. A height-thickness ratio of up to 15-to-1 is permitted where only the Basic Nonstructural Component Checklist is required by Table 3-2. (Tier 2: Sec. 4.8.10.1)

NC STAIR DETAILS: In moment frame structures, the connection between the stairs and the structure shall not rely on shallow anchors in concrete. Alternatively, the stair details shall be capable of accommodating the drift calculated using the Quick Check Procedure of Section 3.5.3.1 without inducing tension in the anchors. (Tier 2: Sec. 4.8.10.2)

Building Contents and Furnishing

NC TALL NARROW CONTENTS: Contents over 4 feet in height with a height-to-depth ratio greater than 3-to-1 shall be anchored to the floor slab or adjacent structural walls. A height-to-depth or height-to-width ratio of up to 4-to-1 is permitted where only the Basic Nonstructural Component Checklist is required by Table 3-2. (Tier 2: Sec. 4.8.11.1)

Mechanical and Electrical Equipment

N/A EMERGENCY POWER: Equipment used as part of an emergency power system shall be mounted to maintain continued operation after an earthquake. (Tier 2: Sec. 4.8.12.1)

N/A HAZARDOUS MATERIAL EQUIPMENT: HVAC or other equipment containing hazardous material shall not have damaged supply lines or unbraced isolation supports. (Tier 2: Sec. 4.8.12.2)

NC DETERIORATION: There shall be no evidence of deterioration, damage, or corrosion in any of the anchorage or supports of mechanical or electrical equipment. (Tier 2: Sec. 4.8.12.3)

NC ATTACHED EQUIPMENT: Equipment weighing over 20 lb that is attached to ceilings, walls, or other supports 4 ft. above the floor level shall be braced. (Tier 2: Sec. 4.8.12.4)

Piping

N/A FIRE SUPPRESSION PIPING: Fire suppression piping shall be anchored and braced in accordance with *NFPA-13* (NFPA, 1996). (Tier 2: Sec. 4.8.13.1)

N/A FLEXIBLE COUPLINGS: Fluid, gas and fire suppression piping shall have flexible couplings. (Tier 2: Sec. 4.8.13.2)

Hazardous Materials Storage and Distribution

N/A TOXIC SUBSTANCES: Toxic and hazardous substances stored in breakable containers shall be restrained from falling by latched doors, shelf lips, wires, or other methods. (Tier 2: Sec. 4.8.15.1)

Ceiling Systems

N/A LAY-IN TILES: Lay-in tiles used in ceiling panels located at exits and corridors shall be secured with clips. (Tier 2: Sec. 4.8.2.2)

N/A INTEGRATED CEILINGS: Integrated suspended ceilings at exits and corridors or weighing more than 2 pounds per square foot shall be laterally restrained with a minimum of 4 diagonal wires or rigid members attached to the structure above at a spacing of equal to or less than 12 ft. (Tier 2: Sec. 4.8.2.3)

N/A SUSPENDED LATH AND PLASTER: Ceilings consisting of suspended lath and plaster or gypsum board shall be attached to resist seismic forces for every 12 square feet of area. (Tier 2: Sec. 4.8.2.4)

Light Fixtures

N/A INDEPENDENT SUPPORT: Light fixtures in suspended grid ceilings shall be supported independently of the ceiling suspension system by a minimum of two wires at diagonally opposite corners of the fixtures. (Tier 2: Sec. 4.8.3.2)

Cladding and Glazing

NC GLAZING: Glazing in curtain walls and individual panes over 16 square feet in area, located up to a height of 10 feet above an exterior walking surface, shall have safety glazing. Such glazing located over 10 feet above an exterior walking surface shall be laminated annealed or laminated heat-strengthened safety glass or other glazing system that will remain in the frame when glass is cracked. (Tier 2: Sec. 4.8.4.8)

Parapets, Cornices, Ornamentation and Appendages

N/A CONCRETE PARAPETS: Concrete parapets with height-to-thickness ratios greater than 2.5 shall have vertical reinforcement. (Tier 2: Sec. 4.8.8.3)

N/A APPENDAGES: Cornices, parapets, signs, and other appendages that extend above the highest point of anchorage to the structure or cantilever from exterior wall faces and other exterior wall ornamentation shall be reinforced and anchored to the structural system at a spacing equal to or less than 10 feet for *Life-Safety* and 6 feet for ***Immediate-Occupancy***. This requirement need not apply to parapets or cornices compliant with Section 4.8.8.1 or 4.8.8.3. (Tier 2: Sec. 4.8.8.4)

Masonry Chimneys

N/A ANCHORAGE: Masonry chimneys shall be anchored at each floor level and the roof. (Tier 2: Sec. 4.8.9.2)

Mechanical and Electrical Equipment

N/A VIBRATION ISOLATORS: Equipment mounted on vibration isolators shall be equipped with restraints or snubbers. (Tier 2: Sec. 4.8.12.5)

Ducts

N/A FIRE AND SMOKE DUCTS: Stair pressurization and smoke control ducts shall be braced and shall have flexible connections at seismic joints. (Tier 2: Sec. 4.8.14.1)

Appendix C

Conceptual Retrofit Details

These details will be developed for the final version of this report after SCL has had a chance to review the draft report and provide the design team with performance expectations for the building.

GEORGETOWN STEAM PLANT CONDITIONS ASSESSMENT

CONTAINS CONFIDENTIAL INFORMATION – NOT FOR GENERAL DISTRIBUTION

December 31, 2010

NWAA Report Number WA09-053

NORTHWEST ARCHAEOLOGICAL ASSOCIATES, INC.
SEATTLE, WASHINGTON

GEORGETOWN STEAM PLANT CONDITIONS ASSESSMENT
SEATTLE, WASHINGTON

Report Prepared for:

Seattle City Light Department

By
Eileen Heideman

December 31, 2010

NWAA Report Number WA09-053

CONTAINS CONFIDENTIAL INFORMATION – NOT FOR GENERAL DISTRIBUTION

Northwest Archaeological Associates, Inc.
5418 - 20th Avenue NW, Suite 200
Seattle, Washington 98107

TABLE OF CONTENTS

LIST OF FIGURES

INTRODUCTION

Seattle City Light (SCL) contracted with Northwest Archaeological Associates (NWAA) to perform archaeological monitoring and mitigation measures as part of the Georgetown Steam Plant Flume Demolition, Removal and Drainage Project. The US Environmental Protection Agency (EPA) is the lead agency on the project, which is subject to Section 106 of the National Historic Preservation Act of 1966 (NHPA), as amended. Among these tasks is a Building Conditions Assessment of the Georgetown Steam Plant, which is a property listed in the National Register of Historic Places, is a National Historic Landmark, and a City of Seattle Landmark.

This report addresses concerns regarding the condition of structural and historic architectural features of the Georgetown Steam Plant and provides a prioritized list of issues that should be addressed in order to preserve the structural integrity of the historic building and its character-defining elements. Structural engineering concerns are summarized in this report and addressed in more detail in the Structural Condition Assessment included in Appendix A. The focus of this report is on the condition of the building's architectural elements, and it does not address seismic or code concerns or non-structural safety hazards.

Eileen Heideman of NWAA was the lead architectural historian on the project and the primary author of this report. She was assisted by Robert Weaver, a historical architect and principal of the Environmental History Company (EHC), in viewing and assessing the existing conditions of the building. KPFF Consulting Engineers conducted the structural conditions assessment. John Hochwall, Structural Engineer (SE) and Professional Engineer (PE) and Travis Williams, PE evaluated the building and provided the Condition Assessment.

The Georgetown Steam Plant is a reinforced concrete building housing the country's last operable examples of the first large-scale vertical steam turbine electric generators. It is also significant as an example of fast-track concrete construction pioneered by Frank B. Gilbreth. This Landmark is located in the northeast quarter of Section 29, Township 24 North, Range 4 East, Willamette Meridian in the Georgetown neighborhood of South Seattle (Figure 1). The property is adjacent to the King County International Airport.

CONDITIONS OVERVIEW

The structural engineering conditions assessment identified the ash hoppers as the primary area of concern, which should be addressed immediately due to life safety issues. There is a risk of falling concrete due to deterioration of the intact hoppers, and lack of hazard mitigation. Another concern that should be addressed in the near future is the lack of drainage from the condenser pit. Water continues to be channeled into the pit from roof drains, and no outlet currently exists following the recent demolition of the flume and filling of the discharge tunnel. Most of the other issues identified in the study can be traced to deferred maintenance.

METHODOLOGY

Eileen Heideman, architectural historian at Northwest Archaeological Associates, Inc., and Robert Weaver, historical architect and principal of Environmental History Company conducted a site visit on January 5, 2010 to view and assess existing conditions of the building. They were accompanied by John Hochwalt, PE, SE, and Travis Williams, PE of KPFF Consulting Engineers, who conducted a structural conditions assessment, and whose report is attached in

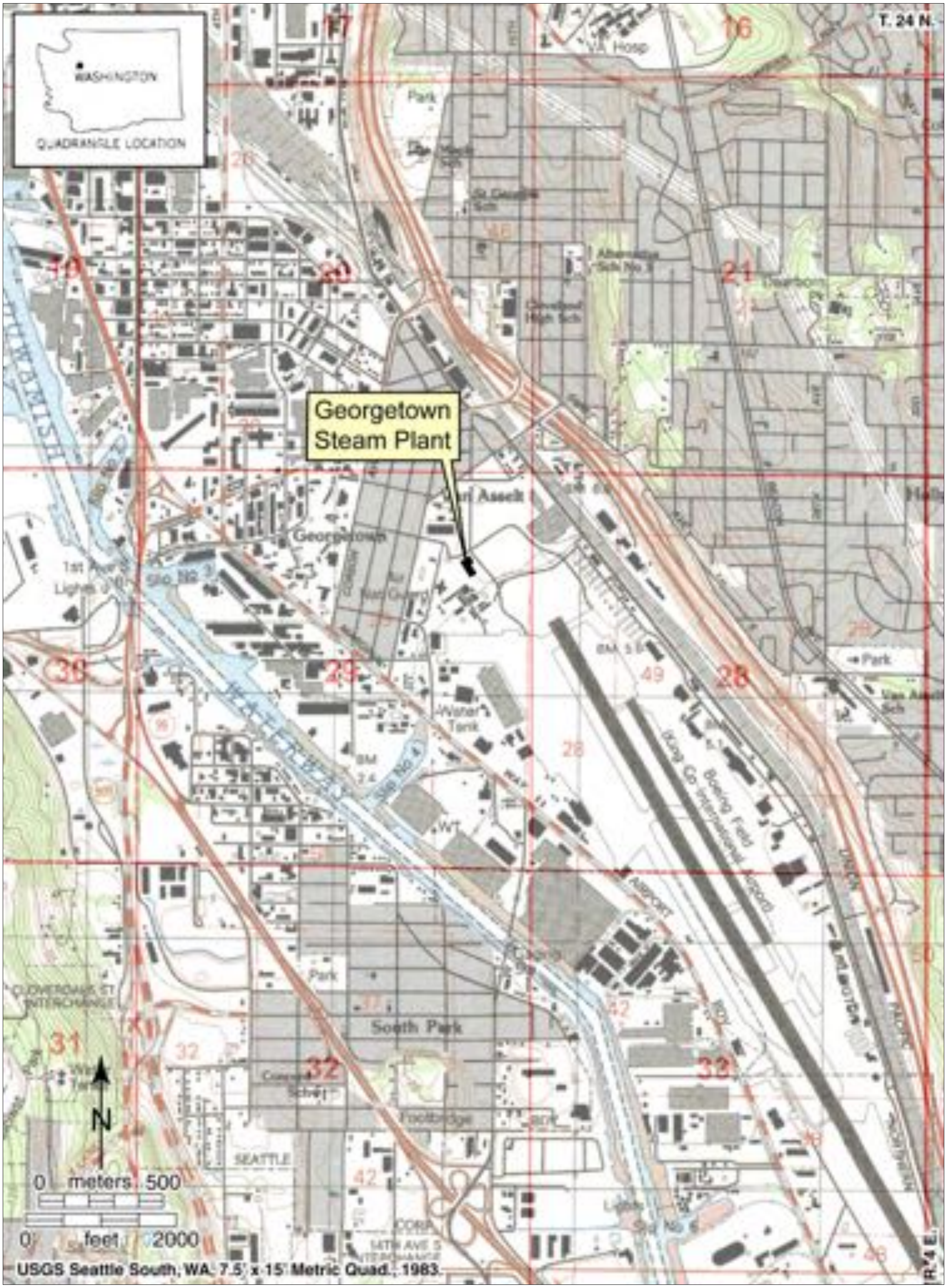


Figure 1. Location of Georgetown Steam Plant.

Appendix A. NWAA and EHC representatives spoke with Lily Tellefson, Director of the Georgetown Powerplant Museum, about known conditions problems and other concerns regarding the condition of the building. On-site work was limited to visual inspection of easily accessible areas and included noting problems and photographing conditions on the interior and exterior of the building. Portions of the building that could be seen without the use of special equipment were inspected (e.g., areas that could be seen without the use of ladders, extra lighting, computer equipment, or video cameras). A follow-up visit was conducted by Eileen Heideman on January 12, 2010.

CONSTRUCTION HISTORY

The Georgetown Steam Plant was originally constructed in 1906 and helped provide electricity to power the Seattle Electric Company's streetcar system. The building was designed with the intention of expanding the facility in the future, but its primary use was as a supplemental power generating facility. The steam plant became part of the Puget Sound Traction, Power and Light company, a subsidiary of Stone and Webster. An addition to house a third turbine was made to the northeast side in 1919, during the World War I era. A two-story shed addition was constructed shortly thereafter on the southeast side of the 1919 addition. The City of Seattle purchased the power plant in 1951 for use as a secondary facility, and it was last used for electricity production in 1953. The final test run of the facility occurred in 1974, and the building was decommissioned as an electricity-producing facility in 1977.

BUILDING DESCRIPTION

The Georgetown Steam Plant is a massive, reinforced concrete building that stands adjacent to the northeast edge of King County International Airport/Boeing Field in the Georgetown neighborhood, south of downtown Seattle, Washington (Figure 1). The building was designed with two distinct sections: a long, three and one-half story wing with a monitor roof and a northwest-southeast oriented ridge, and a slightly taller ell at the northwest end that is capped with a monitor roof with a southwest-northeast oriented ridge (Figure 2).

The taller, northwest segment houses the turbines and steam generators and the condenser, circulating pump, and exciters. This portion of the building is divided into two segments: a ground-level floor and a second clear-height floor with three levels of galleries on the northwest end. A full-height addition was constructed in 1919 on the northeast end of the building. The southeast wall of this building is a reinforced concrete frame with concrete infill, and the northwest wall consists of unreinforced concrete block. The northeast end wall was designed to allow further additions to be easily constructed: unlike the rest of the building, this wall is framed with dimensional lumber and is clad with corrugated metal siding. A second, shed-roofed addition is located on the southeast side of the 1919 addition. This area contains additional bracing for the reinforced concrete pillars in the earlier addition wall.

The southeast portion of the building is three bays wide and is divided into four levels. The majority of the equipment in this portion of the building is located in the two outer bays, leaving the center bay open. The ground level contains ash hoppers suspended from the ceiling beneath boilers on the second floor. The third level contains the upper levels of the boilers and coal storage bins, and the fourth level consists of a catwalk around a dismantled conveyor

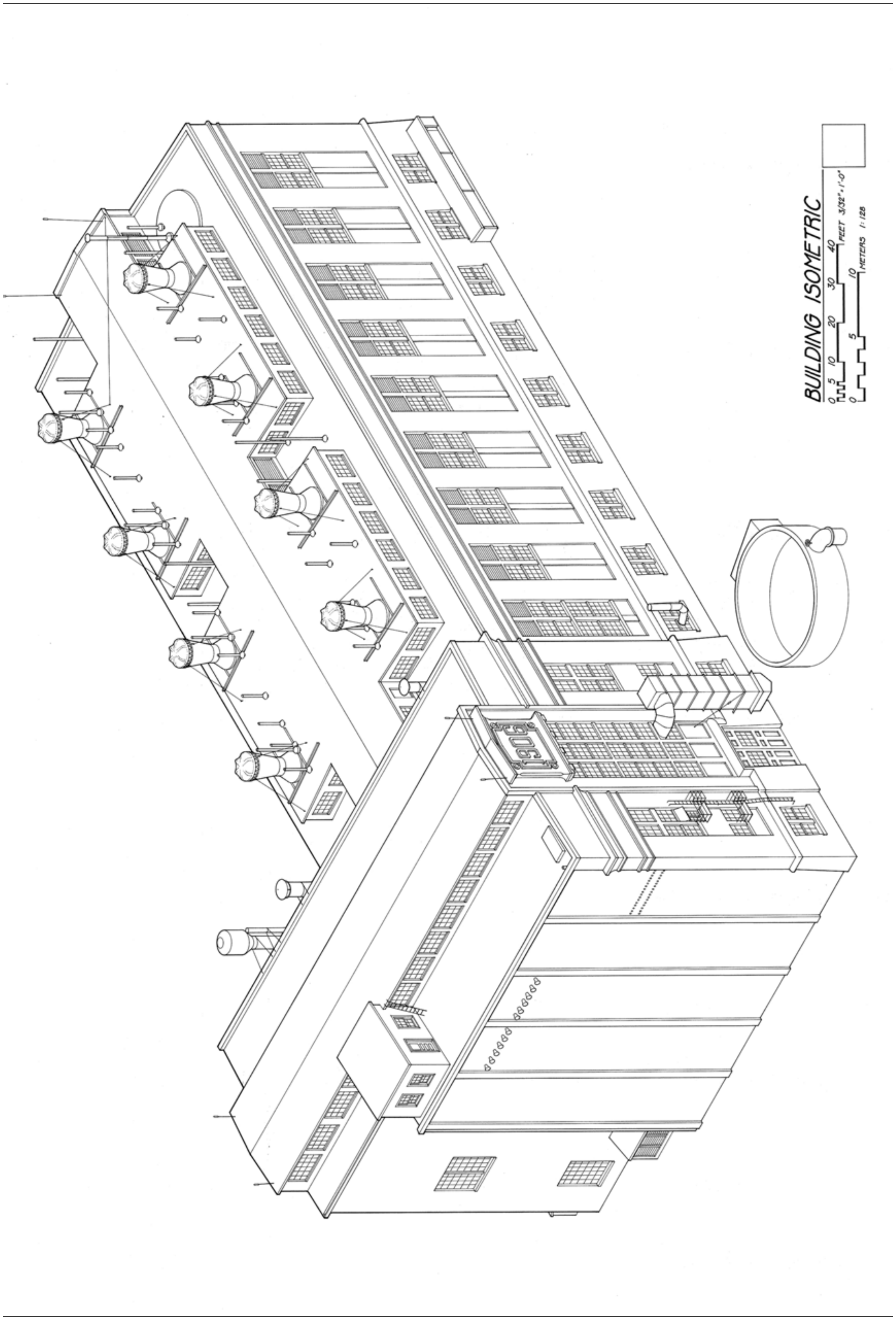


Figure 2. Isometric drawing of steam plant from HAER documentation (Jackson and Murphy 1984).

system over the coal storage bins. A poured concrete condenser pit beneath the northwest end of this ell was designed to collect and drain water through a discharge tunnel and flume which were recently demolished.

CONCERNS AND RECOMMENDATIONS

Prior to the site visit, city staff and museum personnel provided information on known problems. These include damage related to the removal of the majority of the ash hoppers several years ago (Figure 3). Some construction has been undertaken to mitigate safety concerns, but some areas remain unprotected. There is also an ongoing problem with cracked window glazing on the southeast and northeast sides of the building which may be linked to close proximity to aircraft operations due to a runway extension at the airport. Other known problems relate to water leaks and infiltration at various points in the building. Foundation-level seepage on the northeast side of the 1919 addition may be related to regrading during construction of the runway extension. Interior drains leading from the roof have significant leaks in more than one location, which has led to water pooling in the building on the second and ground levels (Figure 4).

The results and recommendations are divided into two categories. Priority 1 concerns should be addressed immediately or as soon as possible, as they may present a life-safety hazard. Priority 2 concerns are for the most part problems that can be addressed through standard building maintenance.

Figure 3. Damage resulting from demolition of ash hopper.

Figure 4. Water pooling at northwest end of boiler room due to roof drain leaks.

Priority 1 Concerns

These issues should be addressed immediately or as soon as possible, as they may present a life-safety hazard.

Ash Hoppers

Most of the ash hoppers were demolished several years ago, leaving ragged holes in the ceiling of the ground-level floor. The structural engineering report identified a need to mitigate the hazard of falling objects from this area. A similar need for mitigation was identified with the intact ash hoppers, which are deteriorating as a result of reactions of the concrete with sulfuric acid (Appendix A, page 7). Recommendations in the engineering report include restricting access to the area (no access should be permitted within five feet of the structures), shoring the remaining hoppers to prevent concrete from falling, and closing the holes created by the removed hoppers to mitigate the hazard from falling objects.

Condenser Pit Outlet

Much of the water draining from the roof is conducted through a series of cast-iron pipes that are located along the interior walls of the steam plant. These pipes feed into the condenser pit under the building. The outlet for this pit, a concrete tunnel and flume leading to Slip 4 of the Duwamish River, was recently demolished in the Georgetown Flume Removal and Demolition project. It is assumed that there is currently no outlet for the condenser pit. There is therefore a risk that water emptying into the pit could overflow into the building. In addition to flood damage, this creates the potential for life-safety concerns such as flood water coming into contact with electrical systems in the building.

The preferred option for mitigating this problem is to connect the condenser pit to the storm sewer system. If this is not possible, water from the roof should be directed into the storm sewer by a different route. The interior drain system should be retained, as it is part of the original design of the building. A study should be conducted to determine the effect of the blocked outlet on water drainage from the condenser pit, as water may enter the pit from other sources.

Water Leaks and Infiltration

A variety of water leaks and infiltration problems were noted throughout the building. One major source of leaks is the aging drainage system carrying water from the roof inside the building to the condenser pit underneath the foundation. Many areas of these cast iron pipes have corroded or seals have deteriorated, and large amounts of water leak into the building from these points (Figure 5). The water then pools and drains to lower areas of the building, causing extensive portions of the building interior to be in near constant contact with water. Some of these leaks are located very close to live electrical lines and panels, adding the risk of electrocution for individuals in the building. The interior drainage system should be repaired and, where necessary, replaced in kind.

The second major point of water infiltration is located on the northeast side of the 1919 addition, where water seeps into the building at ground level. Museum personnel indicate that this problem began after the regrading of land north of a runway extension on adjacent airport property. A study should be conducted to determine the source of the water entering the

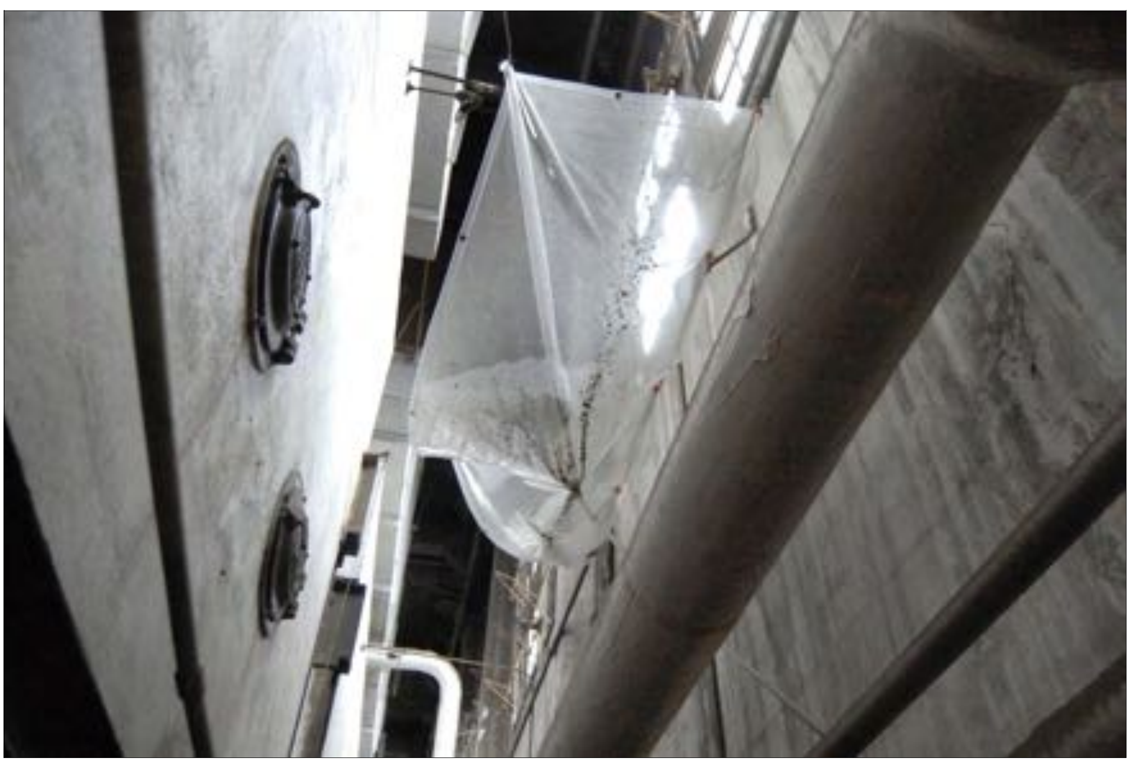


Figure 5. Plastic sheet and pipes used to redirect drain leaks.

building in this location. If the source is surface run-off, possible solutions include constructing a birm or ditch to redirect the water, or installation of perimeter drains around the steam plant foundation.

Water infiltration is also occurring at various points in the building envelope, including windows and doors. Efflorescence was noted in several locations throughout the building, but was particularly noticeable on the southeast end wall. The source of this appears to be direct infiltration from precipitation on the exterior walls, particularly those facing the prevailing wind. The bricked-in arches where the stacks formerly attached to the building are particularly susceptible to moisture wicking due to numerous exterior mortar joints and the porous quality of the brick. Maintaining an effective moisture barrier is necessary to prevent precipitation from seeping into the building through the concrete walls. Exterior walls should be painted and inspected annually. Windows and doors should be inspected for weathering and deterioration and repaired and painted where necessary.

Concrete Spalling

Concrete spalling was noted throughout the building, and appears to be due to oxidation of reinforcing bars and electrical conduits embedded in the concrete, as well as damage from other expanding materials such as salts. The source of the oxidation and efflorescence is probably due to contact with moisture. Exterior and interior walls should be inspected and loose spalls should be removed. If reinforcing bar or other ferrous metal is visible on the exterior, than any noticeable rust should be removed, the exposed metal should be treated with an anti-rusting agent, and the area should be covered with a concrete patch. More spalling will almost definitely develop throughout the building due to prolonged moisture contact, but the process may be slowed by preventing further moisture infiltration.

Some of the decorative concrete molding on the southeast side of the building is spalling. Special care should be taken with this area and any other decorative moldings, so that the appearance of the building is not altered. Any molding that needs to be removed due to damage should be returned to its original appearance.

Pipe Hangers

Numerous pipe hangers in the building are deteriorating, and some may be near the point of failure, creating a risk for injury from falling objects. These should be reinforced with additional supports and severely deteriorated hangers should be replaced in kind, if possible.

Southeast Exterior Stairs and Balcony

A set of steel and concrete stairs and a wooden balcony on the southeast side of the building are severely deteriorated (Figure 6). The wood floor of the balcony exhibits severe moisture damage, but the full extent is unknown. Several concrete steps are severely deteriorated, and the metal frame is damaged by extensive rusting. At a minimum, interior and exterior access to the balcony and stair should be immediately blocked off. The metal frame should be inspected for damage and repaired where necessary. Damaged concrete should be removed and re-poured, and the wood balcony platform should be repaired and/or replaced in kind.

Figure 6. Detail of weathering and deterioration of exterior stair and second level door on southeast side, view to the southwest.

Priority 2 Concerns

These concerns do not necessarily present an immediate life-safety hazard, and are typically addressed through standard maintenance.

Building Envelope

As mentioned earlier, this building has extensive problems with moisture infiltration, including wicking through exterior walls and leaks around deteriorated portions of windows and doors (Figure 7). This kind of moisture problem is typically due to deferred maintenance of the building envelope, and can be extremely damaging in the long term. The building exterior should be repainted to create an effective moisture barrier, and weathered and damaged wood elements such as doors and windows should be repaired and painted. Standing water was noted in several locations on the roof, indicating that the surface does not slope properly toward drains. At the moment, there appear to be few active leaks in the roof, but this issue should be addressed when the roof is next repaired. In the meantime, the roof should be inspected at least twice a year to locate problem areas. The retrofitted gutter and downspout system is disconnected in some areas, channeling water down the side of the building or causing it to puddle next to the foundation. Disconnected sections should be reattached and downspouts added to all gutter outlets. A few vent caps on the roof are corroded and need to be patched or replaced.

Figure 7. Detail of weathering and deterioration of southwest-facing window, view to the northeast.

Window Cracking

Windows on the southeast and northeast sides of the building have an ongoing problem with cracked glazing. Museum personnel indicated that this problem began when the adjacent runway at the airport was extended. This placed airplanes in much closer proximity to the steam plant, with the engines facing these facades, creating the possibility that vibrations from the engines are causing windows to crack (Figure 8). Although a study was conducted to identify the source of this problem and mitigation measures were undertaken, window damage has continued to occur (Georgetown Steamplant Window Vibration Impact Study. Stickney Murphy Romine Architects, December 13, 2005). The city should coordinate with King County to find a solution to the problem that does not adversely affect the integrity of the steam plant.

CONCLUSIONS

Phased repairs should occur based on the priorities listed above, and all work should follow the Secretary of the Interior's Standards for the Treatment of Historic Properties (Appendix B), in particular the Standards and Guidelines for Preservation. These may also be accessed at http://www.nps.gov/hps/tps/standards/index.htm. Looking through the National Park Service's Technical Preservation Service (TPS) publications is also highly recommended. The TPS Preservation Briefs provide specific guidelines for how to repair and maintain various types of historic architectural features. These are available online at no cost: http://www.nps.gov/hps/tps/briefs/presbhom.htm.

Figure 8. Proximity of airport to steam plant, showing problem areas on northeast and southeast sides of building.

A maintenance plan should be created for the building. This should include an annual inspection of the building envelope, including looking for and addressing additional concrete spalling and checking for window and door damage and deterioration. Known problems such as water leaks and moisture infiltration should be checked on a regular basis (at least quarterly, if not more often). The annual inspection should include a checklist to be dated and initialed after each area is checked. The maintenance plan may include other information, such as guidelines for machinery and heating and cooling system maintenance, among other topics.

APPENDIX A: Georgetown Steam Plant Condition Assessment, KPFF Consulting Engineers

Georgetown Steam Plant
Seattle City Light

Condition Assessment

December 2010 | Final Report

kpff Consulting Engineers

Georgetown Steam Plant Condition Assessment

December 2010

Prepared for:
Northwest Archeological Associates, Inc
5418 20th Avenue Northwest, Suite 200
Seattle, WA 98107
(206) 781-1909

Prepared by:
John M. Hochwalt, PE, SE
KPFF Consulting Engineers
1601 Fifth Avenue, Suite 1600
Seattle, WA 98101
(206) 622-5822
KPFF Job No. 110018.10

kpff

This Page Intentionally Left Blank.

Table of Contents

List of Figures

Appendices

This Page Intentionally Left Blank.

Executive Summary

KPFF Consulting Engineers was retained by Northwest Archeological Associates, Inc., (NAA) to assess the existing condition of Seattle City Light's Georgetown Steam Plant facility located in Seattle, Washington. The purpose of our assessment was to assist in identifying apparent structural deficiencies, provide recommendations for future studies, and recommend concept level treatments for structural maintenance.

We identified several conditions that pose an immediate threat to life safety. Access to the areas where these conditions occur should be restricted immediately and remain restricted until the conditions are addressed through repair or demolition. These areas are as follows:

- Intact Ash Hoppers: Due to the poor condition of the three remaining existing hoppers, there is potential for loose pieces of concrete to become dislodged.
- Removed Ash Hoppers: No hazard mitigation has been performed for three of the existing ash hoppers that have been partially demolished. Unrestricted access should not be permitted within 5 feet of these hoppers until proper shoring has been provided or the remaining loose materials sufficiently removed and the opening closed to mitigate the hazard from falling objects.

KPFF also identified conditions that require long-term maintenance issues needing to be addressed. We recommend that measures be taken to protect the structure from further damage and to repair degraded structural elements. Our specific recommendations are as follows:

- Repair and maintain the building envelope to prevent water intrusion into the building.
- Repair water leaks from internal systems.
- Should pooling water occur and observed by building personnel, manually direct water to drain to prevent long-standing water.
- Remove loose concrete and replace damaged or corroded pipe hangers with corrosion resistant attachments.

1. Field Observations

John Hochwalt, PE, SE, and Travis Williams, PE, of KPFF Consulting Engineers visited the Georgetown Steam Plant on January 5, 2010, to perform a structural condition assessment of the existing building.

The structure is a reinforced concrete structure built between 1906 and 1907 with an addition constructed in 1917. The building was one of the first reinforced concrete structures built on the West Coast (NPS 2009).

The site is located in the Duwamish River area; the facility was originally constructed on the east bank of the river. The river was later straightened for navigation and diverted from its original location. This area generally has poor soils overlying the bedrock as a result of marine sediments, alluvial deposits, and fill material being deposited (SAIC 2009).

The objectives of our field observations were as follows:

- Identify potential life safety hazards:

  As structural engineers, we look for life-safety hazards where conditions could result in structural materials becoming dislodged and falling or that could lead to a local or general structural collapse. We do not look for non-structural conditions that could create risk of injury. Examples of these non-structural conditions would include slip-and-fall hazards, inadequate provisions for fall protection, non-structural items that could become dislodged and fall, exposure to live electrical circuits or toxic substances, or confined spaces.

  It should also be noted that our assessment of potential life safety hazards is based on the current usage of these structures, which permits only limited public access and where the structures are essentially unoccupied. We have not attempted to assess whether these structures comply with the life safety provisions of the current building code.

  Finally, our identification of potential life safety issues was limited by what we could see in the areas that we had access to during our limited time on site. Areas not viewed are identified later in the report. A more exhaustive study could identify additional life safety hazards.

- Assess the current condition of the structure:

  Based on our visual observations, we developed an opinion of the condition of the structure.

  - Good condition means that the structural element described has very few signs of deterioration or distress, and probably could remain in service for many years to come. There may be some minor deficiencies requiring repair prior to allowing reuse.

- Fair condition means that the structural element described is starting to show signs of deterioration or distress, and its service life may already be limited due to the deterioration or distress. There are deficiencies requiring repair prior to allowing reuse.
- Poor condition means that the structural element described has extensive signs of deterioration or distress. It has reached the end of its service life and major repairs are required to use the structure in the future.

- Advise where additional studies or investigations may be appropriate to clarify our findings.
- Recommend maintenance that should be undertaken to prevent further deterioration of the building structure.

GEORGETOWN STEAM PLANT

Access to the building was provided by Lilly Tellefson of the Georgetown Powerplant Museum. Only visual observations were performed; no finishes were removed and no destructive testing was performed. Building locations that were not accessed during the visit were the eastern boiler catwalk, the coal pocket above the boiler room, and any accessible below grade areas.

BUILDING CONSTRUCTION

The Georgetown Steam Plant is largely constructed of reinforced concrete and consists of a northern high bay structure and a southern three-story structure. The northern portion is approximately 64 feet by 117 feet in the east – west direction. The southern portion is approximately 150 feet by 80 feet in the east – west direction. These different spaces share a common wall at the south and north ends, respectively. See Figure 1-1 below for a plan view of the building.

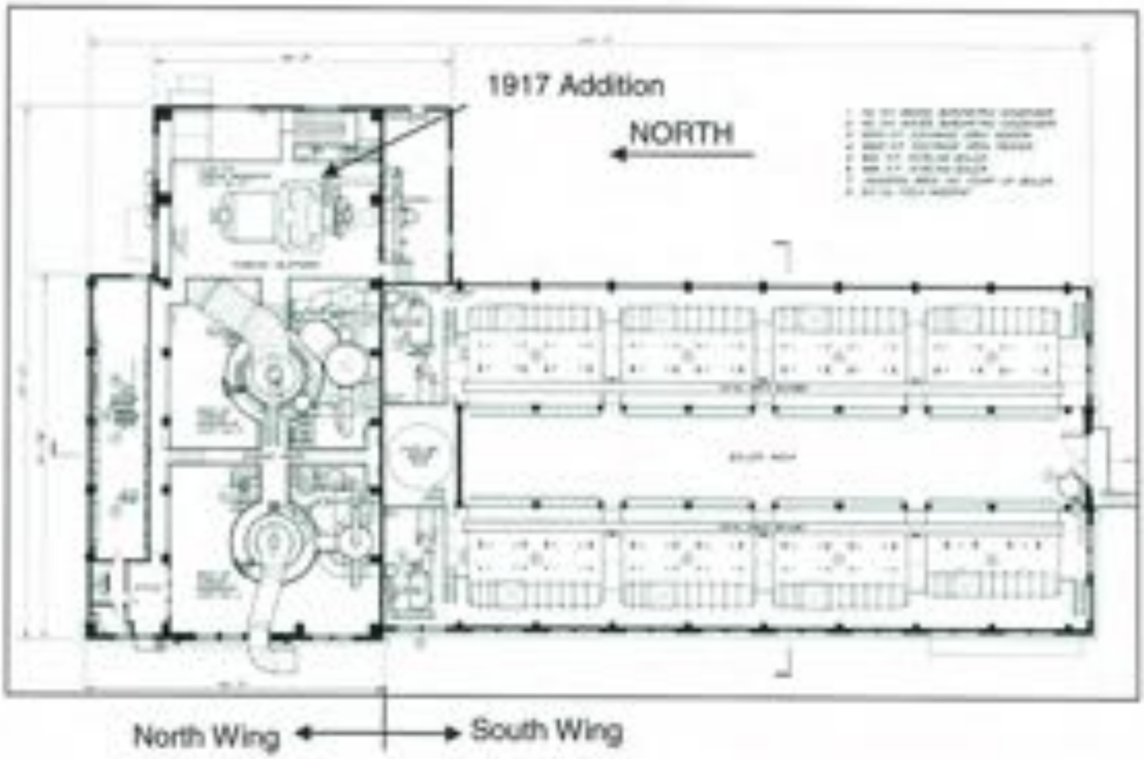


Figure 1-1: Second Floor Plan of Building (Per Historical American Engineering Record, Heritage Conservation & Recreation Service, Barry A. Richards & Yoshikado Koyama, 1982)

The lowest floor structure is a reinforced structural slab at grade. Reinforced concrete walls for the generators can be observed at this level, which carry down to the foundation below.

The second floor of the southern structure supports large boilers and ash hoppers on the exterior bays. It is composed of one-way slabs spanning approximately 16 feet to perpendicular rectangular beams between columns. The columns at this level are typically square with some columns being larger rectangular shapes. The exterior bays are approximately 6 feet wide with three internal bays of approximately 20 feet in width. A building section through the southern portion of the structure may be seen in Figure 1-2 below.

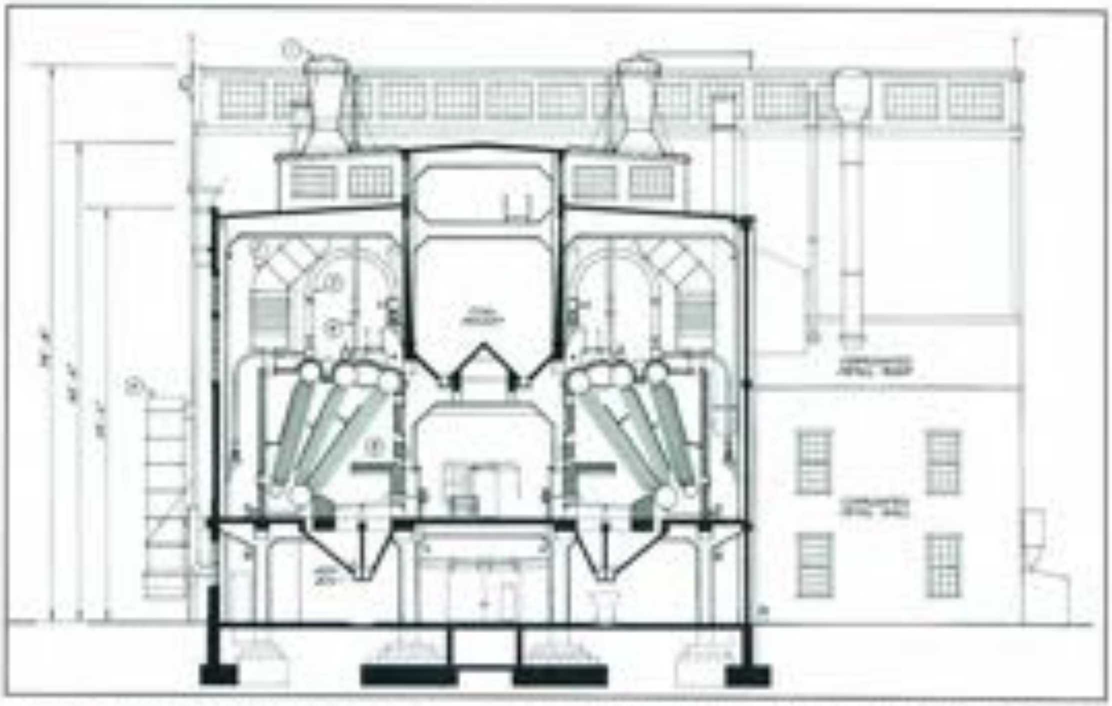


Figure 1-2: Building Section (Per Historical American Engineering Record, Heritage Conservation & Recreation Service, Barry A. Richards & Yoshikado Koyama, 1982)

The third floor of the southern structure is limited to the middle bay only and was previously used as coal storage to feed the boilers below; the exterior bays are open for the tops of the boilers and their associated piping to the roof. The coal storage is a series of pyramidal shaped depressions on each side with beams framing the openings. Above the coal storage is a series of concrete beams supporting a continuous catwalk along the length of southern building. The roof of the exterior bays is a one-way flat slab spanning to perpendicular haunched beams aligned with the interior and exterior columns. This is located at approximately the same elevation as the interior bays beams supporting the catwalk. The roof of the center bay is similarly framed and located approximately 10 feet higher.

The northern portion of the building is a clear height space with 65-foot long span roof beams and no interior columns. The roof steps up for an interior clerestory to provide additional natural light. One-way slabs span between the deep roof beams. A narrow north bay consisting of five bays along its length has four levels of concrete composed of one-way slabs spanning east – west 15 feet to perpendicular beams framing to columns.

An addition to the plant, approximately 65 feet by 37 feet, was constructed on the northeast corner of the building adding two bays to the north portion of the building to house the horizontal generator. This consists of a floor and a roof constructed of reinforced concrete, which appears to mimic the original construction. This addition included an independent support platform for the horizontal generator, which is isolated from the building structure with a visible gap.

The two-bay addition on the south side of the 1917 addition's concrete wall is constructed of structural steel girders with floor timber framing wall framing. A steel ledger angle bolted to the adjoining concrete wall provides additional support for the timber framing. Double channel braces bolted to the wall tie the addition to the concrete walls of the earlier addition.

Perimeter reinforced concrete walls are present with punched windows occurring primarily on the south and west faces. Concrete infill walls, assumed from the distinct crack pattern at the beams and columns, appear to be present on the south face of the 1917 addition. Un-reinforced masonry infill walls were present on the entire north face of the addition. The east façade of the 1917 addition and south façade of the later addition are corrugated metal panels over timber and limited steel framing. We understand that this construction is original and the east face was intended to be removable to accommodate the removal and replacement of large pieces of equipment. Concrete infill walls are present at the second from the north, center bay of the south portion.

Existing foundations could not be observed, but records from the Historic American Engineering Record (HAER 2009) indicate that the building has pile foundations driven to resistance. While the condition and capacity of these systems are unknown, we observed no indication of structural distress due to settling or deterioration of the piles.

LIFE SAFETY ISSUES

We understand that in the 1990s, the ash hoppers were partially demolished, see Figure 1-3. This partial demolition has created a potential life safety condition due to the potential for falling debris that has only been partially mitigated. Of the eight ash hoppers on the east side, the southern seven were partially demolished. We could not observe the condition of the structure in this area as it was hidden by a steel platform; see Figure 1-4, that was added in the 1990s to mitigate this hazard. We were unable to find documentation for the construction, but the platform appeared to be in good condition. Six of the eight ash hoppers on the east side were partially demolished. The third, fourth, and fifth ash hoppers from the south have been partially mitigated by constructing a wood platform, see Figure 1-5, to protect against falling debris. Like the steel platform on the east side, we were unable to find documentation for the construction, but the platform appeared to be in good condition. The north most ash hoppers remaining on the west side have had no mitigation performed and present an imminent hazard due to falling debris.

Figure 1-3: Partially demolished ash hopper viewed from below.

Figure 1-4: Steel platform on east bay.

Figure 1-5: Wood platform on west bay.

The existing intact ash hoppers (the northern ash hopper on the east side and the southern two ash hoppers on the west side) are also visibly distressed with extensive cracking, spalled concrete, and exposed reinforcement. A brief literature search indicates that a possible cause of this severe deterioration could be sulfuric acid leaching from the coal ash. When exposed to sulfuric acid, the chemistry of the concrete changes and expansive products such as gypsum and ettringite can be formed. The distress observed is consistent with the formation of expansive products. These remaining ash hoppers are currently shored with timber posts, but the shoring only supports the overall hopper, not the discrete patches of damaged concrete. The current shoring, Figure 1-6, of these intact hoppers does not appear to be engineered, but likely partially mitigates the risk of collapse of the hoppers, but does not adequately prevent spalled pieces of concrete from dislodging and falling.

Figure 1-6: Timber shoring of intact ash hopper

CONDITION ASSESSMENT

General Comments

The reinforced concrete structure appears to be in generally good condition with limited visible damage.

The most visible signs of concrete deterioration are where corrosion of reinforcement or embedded electrical conduit has progressed to the point where concrete spalling has occurred, which then exposes the corroded element; see Figure 1-7. This deterioration is likely caused by the steel being exposed to moisture while having limited concrete cover. The corrosion of steel creates expansive products that first cause the concrete to split. The splitting creates a delamination, or void, in the concrete that cannot be identified visually, but can be identified by sounding the concrete surface and listening for a hollow sound. As the corrosion continues, the splitting of the concrete progresses until it propagates all the way to the concrete surface, and the concrete covers falls off leaving behind a spalled concrete surface and an exposed corroded element. In the case of concrete reinforcing, the corrosion can become severe enough that the amount of steel effective to resist loads is reduced, resulting in a reduction in the load carrying capacity of the building structure.

Figure 1-7: Concrete spalling and carrion of embedded conduit or reinforcement.

Figure 1-8: Top slab reinforcement corrosion at the second floor on the west inner bay.

Concrete deterioration was typically observed at areas with visible exposure to water as observed by the presence of existing water or from concrete staining. This was observed as occurring around, but not limited to, the windows of the west wall at the north structure; the underside of the second floor of the south structure near pipe penetrations that are present, or in close proximity, to the hoppers; the walls and underside of the floor system at southwest corner of the south structure; around the windows of the clerestory of the central roof above the ash storage; the top of the second floor slab at the west face mid-length of the building (see Figure 1-8); and the underside of the roof at various locations. This was most prevalent in exterior elements with limited deterioration occurring at interior elements with exposure to moisture sources.

At the locations where corroded reinforcement was visible, the corrosion did not appear to be significant enough or the area affected extensive enough to be concerned that the original structural capacity has been reduced. It should be noted, however, that the corrosion will continue to cause further delaminations and spalls with the attendant hazards from falling concrete.

The corrosion of steel is accelerated by the presence of stray electrical currents and the presence of water. While stray electrical currents are certainly a potential in a facility like this, assessing them was beyond the scope of this report, and the state of the deterioration was not such that it could not be explained by the more likely cause of a moist environment. In that respect, we observed water inside the building at several locations, originating from multiple sources. One example would be at the second level on the south side of the concrete wall between the southern and northern portions of the structure. At that location, water was seen dripping from a leaky roof drainpipe. The water from this one source was able to run through penetrations in the floor to the ground floor landing on various other pipes and machinery below. Another example would be that the west side second floor near the middle of the building had water intrusion from the roof causing water ponding and corrosion of embedded reinforcement at the top surface of the floor slab.

Southern Structure

Pipe and utility hangers were observed as having corrosion on their attachments and where they are attached to structure. This was particularly noticeable in the northwest corner, where the pipes are suspended from the high roof. The roof at this location was too far overhead to allow close observation of the condition of the hangers or their attachments. Should the corrosion of these elements progress to where the support for the pipe detaches, the pipe may damage other nearby utilities or historical artifacts, or could be a fall hazard.

We were informed, by building personnel, that the underground/under-slab condenser pit that runs under the north end of the southern wing was filled with soil in a recent maintenance project, and that this may be negatively affecting the building's below-slab drainage system and in some instances may be resulting in standing water. At the time of our site visit, standing water was observed at the floor drain, but this appeared to be due to inadequate sloping of the floor not from blockage of the drain below.

Northern Wing

The east wall of the 1917 addition to the north wing is constructed of corrugated metal panel over timber and steel framing and was reported to require recurring window replacements. The cause of this damage could not be determined by our visual observation.

On the south side of the 1917 addition to the north wing, there is a wood framed addition. Within the wood framed addition, there are two braced frames. The frames are oriented in the north-south direction and are attached to the easternmost two columns on the south face of the 1917 addition. As shown in Figure 1-9, the braced frames consist of a braced bay between the ground and second floor, and of a single diagonal brace extending from the south wall at the second floor of the wood framed addition to a point on the concrete column on the 1917 addition that is approximately 15 feet above the second floor. The function of these braced frames is not obvious.

The upper diagonal of the braced frames consists of two double channel diagonal steel braces. These steel channels were observed to be bowed out of plane approximately 4 inches, as shown in Figure 1-10. It was unclear as to whether these were installed in with a bow in them or if some other issue has caused the braces to bow. Based on what we currently know, these braces do not appear to be performing a critical structural function and their current condition does not appear to represent a threat to life safety.

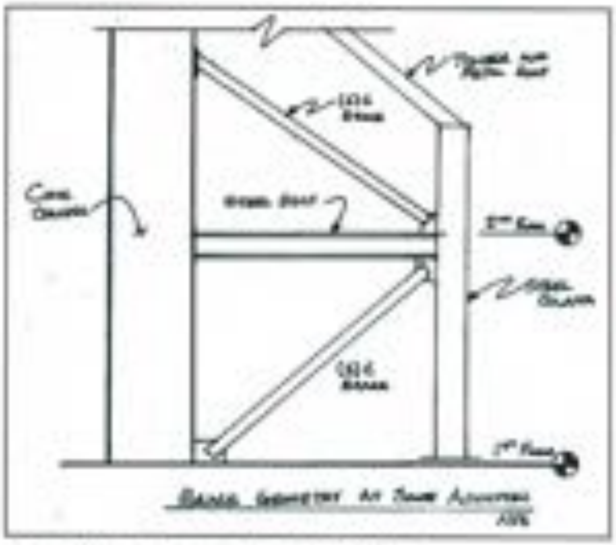


Figure 1-9: Brace geometry at south addition.

The un-reinforced masonry on the north wall of the 1917 addition appears to be in good condition with limited visible deterioration or damage. Historically, these types of walls have exhibited poor performance during seismic events due to limited out-of-plane ductility or strength. Although not a maintenance issue, and while a seismic assessment was beyond the scope of this study, this unreinforced masonry may pose a life safety hazard during a seismic event.

Figure 1-10: Double channel braces at the second floor.

Other Observations

During our visit around the building, we were exposed to many elevated levels with railings and catwalks. The majority of the locations within the buildings had railings and these appeared to be in good condition. While some of the roofs had railings at the edges, many locations did not. Assessing the code compliance of the railings that are present is outside the scope of this study.

RECOMMENDATIONS

The most important recommendation is to complete the mitigation of the hazards presented by the remaining and partially demolished ash hoppers. At a minimum, the mitigation should consist of restricting access to no closer than 5 feet to these hoppers. The current platforms supporting the intact and partially demolished ash hoppers should be investigated to ensure they are engineered, and if not, calculations should be made to verify their adequacy. For areas where no such platforms exist, steps shall be taken to provide an adequately designed overhead protective system or to remove all loose materials that pose a falling debris hazard.

The next important recommendation would to provide such repairs as are necessary to restore the integrity of the building envelope to provide a watertight and dry interior environment for the structure. This includes preventing water intrusion from the exterior, repairing all leaking drain lines, repainting the building exterior, and providing adequate storm water removal from the building if the system is no longer functioning properly. The current extent of the existing damage from water intrusion and resulting corrosion does not appear to significantly impact the strength of the structure, but if the envelope is allowed to continue to degrade, the deterioration of the structure will accelerate.

Our next recommendation would be to remove any concrete that has spalled but not fallen yet, and to replace any severely corroded hanger supports. Due to tall floor-to floor heights, it may be difficult to see the condition of the concrete surface or hanger supports in some areas. We have found that observation using binoculars and good lighting can be an effective way to make observations in these conditions if the operation of a lift in this area is practically or financially difficult.

The east wall of the 1917 addition could be stiffened or re-framed if the window failures are due to the flexibility of the wall structure. More analysis or investigation would need to be performed to provide a clearer understanding of the causes.

Without a change of use or substantial investment in the building, there is no code-based requirement for the owner to address seismic hazards. If it was desired to better understand what hazards may be present, we would recommend a seismic safety study be performed using a Tier 1 evaluation in accordance with ASCE 31-03: Seismic Evaluation of Existing Buildings. The Tier 1 approach identifies whether the building has any potential deficiencies in its ability to resist seismic loads. One deficiency that would be identified by the Tier 1 study would be the unreinforced masonry wall on the north side of the building. This hazard could be mitigated at any time by installing supplemental bracing for un-reinforced masonry.

2. Conclusions

The items posing an immediate risk to personnel and public occupants are the most important findings. Access to these areas or items should be restricted to authorized personnel until the conditions are addressed through repair or mitigation. These areas are as follows:

- Intact Ash Hoppers: Due to the poor condition of the three remaining hoppers, there is potential for loose pieces of concrete to become dislodged. No access should be permitted within 5 feet of the hoppers until the hazard is mitigated.
- Partially Demolished Ash Hoppers: No hazard mitigation has been performed for three of the existing ash hoppers that have been partially demolished. Unrestricted access should not be permitted within 5 feet of these hoppers until proper shoring has been provided or the remaining loose materials sufficiently removed and the opening closed to mitigate the hazard from falling objects.

We have used our field observations to determine the overall existing condition of the building, as well as issues regarding structural maintenance. The findings of this report are based on the condition of the structure as we observed on January 5, 2010. The condition of the building is rated as in good condition. The structural related maintenance issues are as follows:

- Repair and maintain the building envelope to prevent water intrusion into the building.
- Repair water leaks from internal systems.
- Should pooling water occur and observed by building personnel, provide removal and manually direct water to drain to prevent long-standing water.
- Remove loose concrete and replace damaged or corroded pipe hangers with corrosion resistant attachments.

The ability of the building to perform during the code level seismic event for the site was beyond the scope of this report, as are hazards from non-structural issues such as slip and fall hazards, inadequate provisions for fall protection, non-structural items that could become dislodged and fall, exposure to live electrical circuits or toxic substances, or confined spaces.

3. References

Science Applications International Corporation. North Boeing Field and Georgetown Steam Plant Supplemental Report: Summary of Existing information and Identification of Data Gaps (August 2009) Bothell, WA

Historic American Engineering Record. *Historical American Buildings Survey/Historic American Engineering Record: Georgetown Steam Plant, King County Airport, Seattle, King County, WA.* Retrieved January 4, 2010, from http://hdl.loc.gov/loc.pnp/hhh.wa0169.

National Park Service. *Seattle Electric Company Georgetown Steam Plant.* Retrieved January 4, 2010 from http://www.nps.gov/nr/travel/seattle/s35.htm.

Appendix A

Photo Log

LIST OF PHOTOGRAPHS

Photo 1

Photo 2

Photo 1 – Overall southeast elevation view of Georgetown Steam Plant.
Photo 2 – Top of south façade with cracks and exposure of concrete.

Photo 3

Photo 4

Photo 3 – Top of south façade with cracks and exposure of concrete.
Photo 4 – Top of south façade at west ledge.


Photo 5


Photo 6

Photo 5 – Top of south façade at the third floor, east side.
Photo 6 – Elevation of the vertical stacks at the east side of the building.

Photo 7

Photo 8

Photo 7 – Existing condition of the damaged ash hoppers.
Photo 8 – Existing condition of the damaged ash hoppers.


Photo 9


Photo 10

Photo 9 – Exposed beam reinforcement at the damaged ash hoppers.
Photo 10 – Existing condition of the damaged ash hoppers.


Photo 11


Photo 12

Photo 11 – Exposed beam reinforcement at the damaged ash hoppers.
Photo 12 – Added overhead shoring below damaged ash hoppers in the east bay.

Photo 13

Photo 14

Photo 13 – Added timber shoring of the intact ash hoppers.
Photo 14 – Added timber shoring of the intact ash hoppers.

Photo 15

Photo 16

Photo 15 – Concrete damage of the intact ash hoppers.
Photo 16 – Concrete damage and concrete staining of the intact ash hoppers.

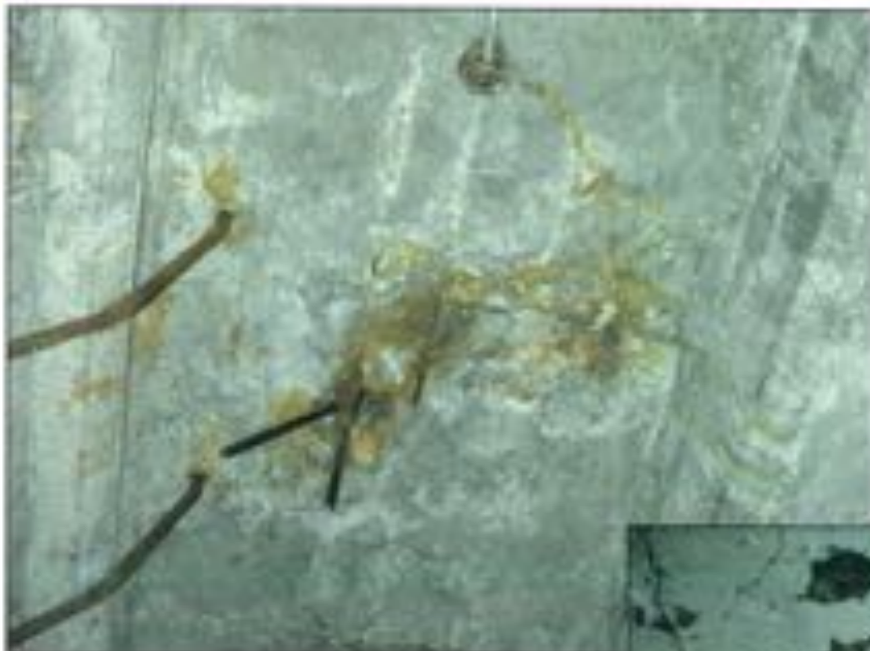


Photo 17


Photo 18

Photo 17 – Corrosion of original supports and concrete damage of the intact ash hoppers.
Photo 18 – Overhead concrete spalling at the second vertical generator foundation.

Photo 19

Photo 20

Photo 19 – Cracks along infill walls at the first floor.
Photo 20 – Exposed wall reinforcement at the southwest corner.

Photo 21

Photo 22

Photo 21 – Water staining and concrete spalling at the southwest corner of the second floor.
Photo 22 – Steel corrosion at the top of slab on the second floor below observed exterior leak.

Photo 23

Photo 24

Photo 23 – Water staining, concrete spalling, and reinforcement corrosion at the southwest corner of the second floor

Photo 24 – Concrete spalling at roof in middle bay of south portion.

Photo 25

Photo 26

Photo 25 – Concrete cracking in exterior east wall middle pay of south portion.
Photo 26 – Water staining of concrete below the window.


Photo 27

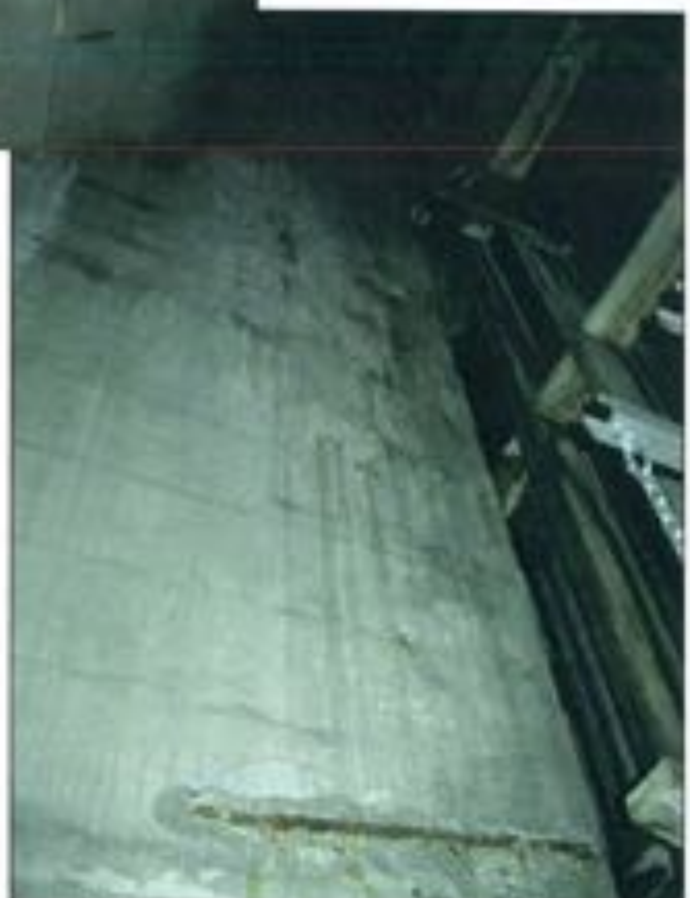


Photo 28

Photo 27 – Steel corrosion at underside of roof slab.
Photo 28 – Concrete staining and reinforcement corrosion at the east addition at the second floor.

Photo 29

Photo 30

Photo 29 – Concrete staining and reinforcement corrosion at the east addition at the second floor.
Photo 30 – Out of plane buckling of double channel braces at the east addition at the second floor.


Photo 31

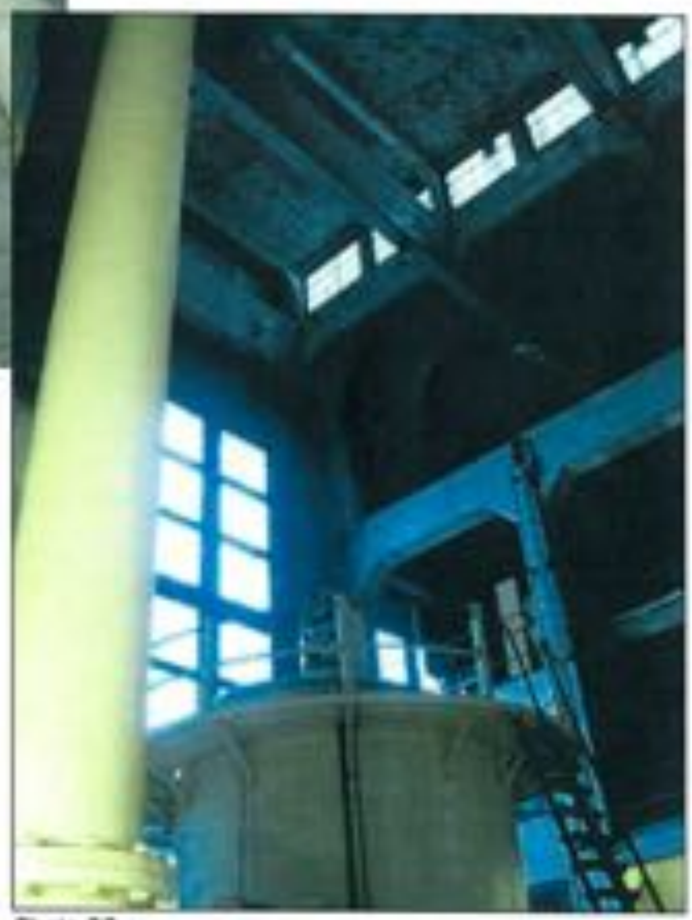


Photo 32

Photo 31 – Out of plane buckling of double channel braces at the east addition at the second floor.
Photo 32 – Typical construction of the north-most bays and crane support of the north portion of the building.


Photo 33


Photo 34

Photo 33 – Typical construction for the roof and the north portion of the building.
Photo 34 – Water staining of the roof of the north portion of the building.

Photo 35

Photo 36

Photo 35 – Water staining of the roof of the north portion of the building.
Photo 36 – Water staining of the southeast wall of the north portion of the building.

Photo 37

Photo 38

Photo 37 – Water staining of the roof at the southwest corner of the north portion of the building.
Photo 38 – Water staining and corrosion at the windowsill on the west side.

Photo 39

Photo 40

Photo 39 – Water staining and corrosion at the windowsill on the west side.
Photo 40 – Overall elevation of the interior of the east wall of the north addition.

Photo 41

Photo 42

Photo 41 – Base condition and framing of the east wall of the north addition
Photo 42 – Overall framing of the interior of the east wall of the north addition.

APPENDIX B: Secretary of the Interior’s Standards and Guidelines for the Treatment of Historic Properties

Secretary of the Interior's Standards and Guidelines for the Treatment of Historic Properties

The Standards for Preservation are the most appropriate guidelines to follow for the Georgetown Steam Plant. The others may be useful if the decision is made to alter the use of the building for other purposes. All of the following information is directly quoted from National Park Service guidelines and can be accessed at: http://www.nps.gov/history/hps/tps/standguide/

PRESERVATION

Preservation is defined as the act or process of applying measures necessary to sustain the existing form, integrity, and materials of an historic property. Work, including preliminary measures to protect and stabilize the property, generally focuses upon the ongoing maintenance and repair of historic materials and features rather than extensive replacement and new construction. New exterior additions are not within the scope of this treatment; however, the limited and sensitive upgrading of mechanical, electrical, and plumbing systems and other code-required work to make properties functional is appropriate within a preservation project.

Standards for Preservation

1. A property will be used as it was historically, or be given a new use that maximizes the retention of distinctive materials, features, spaces, and spatial relationships. Where a treatment and use have not been identified, a property will be protected and, if necessary, stabilized until additional work may be undertaken.

2. The historic character of a property will be retained and preserved. The replacement of intact or repairable historic materials or alteration of features, spaces, and spatial relationships that characterize a property will be avoided.

3. Each property will be recognized as a physical record of its time, place, and use. Work needed to stabilize, consolidate, and conserve existing historic materials and features will be physically and visually compatible, identifiable upon close inspection, and properly documented for future research.

4. Changes to a property that have acquired historic significance in their own right will be retained and preserved.

5. Distinctive materials, features, finishes, and construction techniques or examples of craftsmanship that characterize a property will be preserved.

6. The existing condition of historic features will be evaluated to determine the appropriate level of intervention needed. Where the severity of deterioration requires repair or limited replacement of a distinctive feature, the new material will match the old in composition, design, color, and texture.

7. Chemical or physical treatments, if appropriate, will be undertaken using the gentlest means possible. Treatments that cause damage to historic materials will not be used.

8. Archeological resources will be protected and preserved in place. If such resources must be disturbed, mitigation measures will be undertaken.

Guidelines for Preservation

When the property's distinctive materials, features, and spaces are essentially intact and thus convey the historic significance without extensive repair or replacement; when depiction at a particular period of time is not appropriate; and when a continuing or new use does not require additions or extensive alterations, Preservation may be considered as a treatment. Prior to undertaking work, a documentation plan for Preservation should be developed.

Choosing Preservation as a Treatment

In Preservation, the options for replacement are less extensive than in the treatment, Rehabilitation. This is because it is assumed at the outset that building materials and character-defining features are essentially intact, i.e, that more historic fabric has survived, unchanged over time. The expressed goal of the Standards for Preservation and Guidelines for Preserving Historic Buildings is retention of the building's existing form, features and detailing. This may be as simple as basic maintenance of existing materials and features or may involve preparing a historic structure report, undertaking laboratory testing such as paint and mortar analysis, and hiring conservators to perform sensitive work such as reconstituting interior finishes. Protection, maintenance, and repair are emphasized while replacement is minimized.

Identify, Retain, and Preserve Historic Materials and Features

The guidance for the treatment Preservation begins with recommendations to identify the form and detailing of those architectural materials and features that are important in defining the building's historic character and which must be retained in order to preserve that character. Therefore, guidance on identifying, retaining, and preserving character-defining features is always given first. The character of a historic building may be defined by the form and detailing of exterior materials, such as masonry, wood, and metal; exterior features, such as roofs, porches, and windows; interior materials, such as plaster and paint; and interior features, such as moldings and stairways, room configuration and spatial relationships, as well as structural and mechanical systems; and the building's site and setting.

Stabilize Deteriorated Historic Materials and Features as a Preliminary Measure

Deteriorated portions of a historic building may need to be protected thorough preliminary stabilization measures until additional work can be undertaken. Stabilizing may include structural reinforcement, weatherization, or correcting unsafe conditions. Temporary stabilization should always be carried out in such a manner that it detracts as little as possible from the historic building's appearance. Although it may not be necessary in every preservation project, stabilization is nonetheless an integral part of the treatment Preservation; it is equally applicable, if circumstances warrant, for the other treatments.

Protect and Maintain Historic Materials and Features

After identifying those materials and features that are important and must be retained in the process of Preservation work, then protecting and maintaining them are addressed. Protection generally involves the least degree of intervention and is preparatory to other work. For example, protection includes the maintenance of historic materials through treatments such as rust removal, caulking, limited paint removal, and re-application of protective coatings; the cyclical cleaning of roof gutter systems; or installation of fencing, alarm systems and other temporary protective measures. Although a historic building will usually require more extensive work, an overall evaluation of its physical condition should always begin at this level.

Repair (Stabilize, Consolidate, and Conserve) Historic Materials and Features

Next, when the physical condition of character-defining materials and features requires additional work, repairing by stabilizing, consolidating, and conserving is recommended. Preservation strives to retain existing materials and features while employing as little new material as possible. Consequently, guidance for repairing a historic material, such as masonry, again begins with the least degree of intervention possible such as strengthening fragile materials through consolidation, when appropriate, and repointing with mortar of an appropriate strength. Repairing masonry as well as wood and architectural metal features may also include patching, splicing, or otherwise reinforcing them using recognized preservation methods. Similarly, within the treatment Preservation, portions of a historic structural system could be reinforced using contemporary materials such as steel rods. All work should be physically and visually compatible, identifiable upon close inspection and documented for future research.

Limited Replacement In Kind of Extensively Deteriorated Portions of Historic Features

If repair by stabilization, consolidation, and conservation proves inadequate, the next level of intervention involves the limited replacement in kind of extensively deteriorated or missing parts of features when there are surviving prototypes (for example, brackets, dentils, steps, plaster, or portions of slate or tile roofing). The replacement material needs to match the old both physically and visually, i.e., wood with wood, etc. Thus, with the exception of hidden structural reinforcement and new mechanical system components, substitute materials are not appropriate in the treatment Preservation. Again, it is important that all new material be identified and properly documented for future research. If prominent features are missing, such as an interior staircase, exterior cornice, or a roof dormer, then a Rehabilitation or Restoration treatment may be more appropriate.

Energy Efficiency/Accessibility Considerations/Health and Safety Code Considerations

These sections of the Preservation guidance address work done to meet accessibility requirements and health and safety code requirements; or limited retrofitting measures to improve energy efficiency. Although this work is quite often an important aspect of preservation projects, it is usually not part of the overall process of protecting, stabilizing, conserving, or repairing character-defining features; rather, such work is assessed for its potential negative impact on the building's historic character. For this reason, particular care must be taken not to obscure, damage, or destroy character-defining materials or features in the process of undertaking work to meet code and energy requirements.

REHABILITATION

Rehabilitation is defined as the act or process of making possible a compatible use for a property through repair, alterations, and additions while preserving those portions or features which convey its historical, cultural, or architectural values.

Standards for Rehabilitation

1. A property will be used as it was historically or be given a new use that requires minimal change to its distinctive materials, features, spaces, and spatial relationships.

2. The historic character of a property will be retained and preserved. The removal of distinctive materials or alteration of features, spaces, and spatial relationships that characterize a property will be avoided.

3. Each property will be recognized as a physical record of its time, place, and use. Changes that create a false sense of historical development, such as adding conjectural features or elements from other historic properties, will not be undertaken.

4. Changes to a property that have acquired historic significance in their own right will be retained and preserved.

5. Distinctive materials, features, finishes, and construction techniques or examples of craftsmanship that characterize a property will be preserved.

6. Deteriorated historic features will be repaired rather than replaced. Where the severity of deterioration requires replacement of a distinctive feature, the new feature will match the old in design, color, texture, and, where possible, materials. Replacement of missing features will be substantiated by documentary and physical evidence.

7. Chemical or physical treatments, if appropriate, will be undertaken using the gentlest means possible. Treatments that cause damage to historic materials will not be used.

8. Archeological resources will be protected and preserved in place. If such resources must be disturbed, mitigation measures will be undertaken.

9. New additions, exterior alterations, or related new construction will not destroy historic materials, features, and spatial relationships that characterize the property. The new work shall be differentiated from the old and will be compatible with the historic materials, features, size, scale and proportion, and massing to protect the integrity of the property and its environment.

10. New additions and adjacent or related new construction will be undertaken in a such a manner that, if removed in the future, the essential form and integrity of the historic property and its environment would be unimpaired.

Guidelines for Rehabilitation

When repair and replacement of deteriorated features are necessary; when alterations or additions to the property are planned for a new or continued use; and when its depiction at a particular period of time is not appropriate, Rehabilitation may be considered as a treatment. Prior to undertaking work, a documentation plan for Rehabilitation should be developed.

Choosing Rehabilitation as a Treatment

In Rehabilitation, historic building materials and character-defining features are protected and maintained as they are in the treatment Preservation; however, an assumption is made prior to work that existing historic fabric has become damaged or deteriorated over time and, as a result, more repair and replacement will be required. Thus, latitude is given in the Standards for Rehabilitation and Guidelines for Rehabilitation to replace extensively deteriorated, damaged, or missing features using either traditional or substitute materials. Of the four treatments, only Rehabilitation includes an opportunity to make possible an efficient contemporary use through alterations and additions.

Identify, Retain, and Preserve Historic Materials and Features

Like Preservation, guidance for the treatment Rehabilitation begins with recommendations to identify the form and detailing of those architectural materials and features that are important in defining the building's historic character and which must be retained in order to preserve that character. Therefore, guidance on identifying, retaining, and preserving character-defining features is always given first. The character of a historic building may be defined by the form and detailing of exterior materials, such as masonry, wood, and metal; exterior features, such as roofs, porches, and windows; interior materials, such as plaster and paint; and interior features, such as moldings and stairways, room configuration and spatial relationships, as well as structural and mechanical systems.

Protect and Maintain Historic Materials and Features

After identifying those materials and features that are important and must be retained in the process of Rehabilitation work, then protecting and maintaining them are addressed. Protection generally involves the least degree of intervention and is preparatory to other work. For example, protection includes the maintenance of historic material through treatments such as rust removal, caulking, limited paint removal, and re-application of protective coatings; the cyclical cleaning of roof gutter systems; or installation of fencing, alarm systems and other temporary protective measures. Although a historic building will usually require more extensive work, an overall evaluation of its physical condition should always begin at this level.

Repair Historic Materials and Features

Next, when the physical condition of character-defining materials and features warrants additional work repairing is recommended. Rehabilitation guidance for the repair of historic materials such as masonry, wood, and architectural metals again begins with the least degree of intervention possible such as patching, piecing-in, splicing, consolidating, or otherwise reinforcing or upgrading them according to recognized preservation methods. Repairing also includes the limited replacement in kind--or with compatible substitute material--of extensively deteriorated or missing parts of features when there are surviving prototypes (for example, brackets, dentils, steps, plaster, or portions of slate or tile roofing). Although using the same kind of material is always the preferred option, substitute material is acceptable if the form and design as well as the substitute material itself convey the visual appearance of the remaining parts of the feature and finish.

Replace Deteriorated Historic Materials and Features

Following repair in the hierarchy, Rehabilitation guidance is provided for replacing an entire character-defining feature with new material because the level of deterioration or damage of materials precludes repair (for example, an exterior cornice; an interior staircase; or a complete porch or storefront). If the essential form and detailing are still evident so that the physical evidence can be used to re-establish the feature as an integral part of the rehabilitation, then its replacement is appropriate. Like the guidance for repair, the preferred option is always replacement of the entire feature in kind, that is, with the same material. Because this approach may not always be technically or economically feasible, provisions are made to consider the use of a compatible substitute material. It should be noted that, while the National Park Service guidelines recommend the replacement of an entire character-defining feature that is extensively deteriorated, they never recommend removal and replacement with new material of a feature that--although damaged or deteriorated--could reasonably be repaired and thus preserved.

Design for the Replacement of Missing Historic Features

When an entire interior or exterior feature is missing (for example, an entrance, or cast iron facade; or a principal staircase), it no longer plays a role in physically defining the historic character of the building unless it can be accurately recovered in form and detailing through the process of carefully documenting the historical appearance. Although accepting the loss is one possibility, where an important architectural feature is missing, its replacement is always recommended in the Rehabilitation guidelines as the first or preferred, course of action. Thus, if adequate historical, pictorial, and physical documentation exists so that the feature may be accurately reproduced, and if it is desirable to re-establish the feature as part of the building's historical appearance, then designing and constructing a new feature based on such information is appropriate. However, a second acceptable option for the replacement feature is a new design that is compatible with the remaining character-defining features of the historic building. The new design should always take into account the size, scale, and material of the historic building itself and, most importantly, should be clearly differentiated so that a false historical appearance is not created.

Alterations/Additions for the New Use

Some exterior and interior alterations to a historic building are generally needed to assure its continued use, but it is most important that such alterations do not radically change, obscure, or destroy character-defining spaces, materials, features, or finishes. Alterations may include providing additional parking space on an existing historic building site; cutting new entrances or windows on secondary elevations; inserting an additional floor; installing an entirely new mechanical system; or creating an atrium or light well. Alteration may also include the selective removal of buildings or other features of the environment or building site that are intrusive and therefore detract from the overall historic character. The construction of an exterior addition to a historic building may seem to be essential for the new use, but it is emphasized in the Rehabilitation guidelines that such new additions should be avoided, if possible, and considered only after it is determined that those needs cannot be met by altering secondary, i.e., non character-defining interior spaces. If, after a thorough evaluation of interior solutions, an exterior addition is still judged to be the only viable alterative, it should be designed and constructed to be clearly differentiated from the historic building and so that the character-defining features are not radically changed, obscured, damaged, or destroyed. Additions and alterations to historic buildings are referenced within specific sections of the Rehabilitation guidelines such as Site, Roofs, Structural Systems, etc., but are addressed in detail in New Additions to Historic Buildings.

Energy Efficiency/Accessibility Considerations/Health and Safety Code Considerations

These sections of the guidance address work done to meet accessibility requirements and health and safety code requirements; or retrofitting measures to improve energy efficiency. Although this work is quite often an important aspect of Rehabilitation projects, it is usually not a part of the overall process of protecting or repairing character-defining features; rather, such work is assessed for its potential negative impact on the building's historic character. For this reason, particular care must be taken not to radically change, obscure, damage, or destroy character-defining materials or features in the process of meeting code and energy requirements.

RESTORATION

Restoration is defined as the act or process of accurately depicting the form, features, and character of a property as it appeared at a particular period of time by means of the removal of features from other periods in its history and reconstruction of missing features from the restoration period. The limited and sensitive upgrading of mechanical, electrical, and plumbing systems and other code-required work to make properties functional is appropriate within a restoration project.

Standards for Restoration

1. A property will be used as it was historically or be given a new use which reflects the property's restoration period.

2. Materials and features from the restoration period will be retained and preserved. The removal of materials or alteration of features, spaces, and spatial relationships that characterize the period will not be undertaken.

3. Each property will be recognized as a physical record of its time, place, and use. Work needed to stabilize, consolidate and conserve materials and features from the restoration period will be physically and visually compatible, identifiable upon close inspection, and properly documented for future research.

4. Materials, features, spaces, and finishes that characterize other historical periods will be documented prior to their alteration or removal.

5. Distinctive materials, features, finishes, and construction techniques or examples of craftsmanship that characterize the restoration period will be preserved.

6. Deteriorated features from the restoration period will be repaired rather than replaced. Where the severity of deterioration requires replacement of a distinctive feature, the new feature will match the old in design, color, texture, and, where possible, materials.

7. Replacement of missing features from the restoration period will be substantiated by documentary and physical evidence. A false sense of history will not be created by adding conjectural features, features from other properties, or by combining features that never existed together historically.

8. Chemical or physical treatments, if appropriate, will be undertaken using the gentlest means possible. Treatments that cause damage to historic materials will not be used.

9. Archeological resources affected by a project will be protected and preserved in place. If such resources must be disturbed, mitigation measures will be undertaken.

10. Designs that were never executed historically will not be constructed.

Guidelines for Restoration

When the property's design, architectural, or historical significance during a particular period of time outweighs the potential loss of extant materials, features, spaces, and finishes that characterize other historical periods; when there is substantial physical and documentary evidence for the work; and when contemporary alterations and additions are not planned, Restoration may be considered as a treatment. Prior to undertaking work, a particular period of time, i.e., the restoration period, should be selected and justified, and a documentation plan for Restoration developed.

Choosing Restoration as a Treatment

Rather than maintaining and preserving a building as it has evolved over time, the expressed goal of the Standards for Restoration and Guidelines for Restoring Historic Buildings is to make the building appear as it did at a particular--and most significant--time in its history. First, those materials and features from the "restoration period" are identified, based on thorough historical research. Next, features from the restoration period are maintained, protected, repaired (i.e., stabilized, consolidated, and conserved), and replaced, if necessary. As opposed to other treatments, the scope of work in Restoration can include removal of features from other periods; missing features from the restoration period may be replaced, based on documentary and physical evidence, using traditional materials or compatible substitute materials. The final guidance emphasizes that only those designs that can be documented as having been built should be re-created in a restoration project.

Identify, Retain, and Preserve Materials and Features from the Restoration Period

The guidance for the treatment Restoration begins with recommendations to identify the form and detailing of those existing architectural materials and features that are significant to the restoration period as established by historical research and documentation. Thus, guidance on identifying, retaining, and preserving features from the restoration period is always given first. The historic building's appearance may be defined by the form and detailing of its exterior materials, such as masonry, wood, and metal; exterior features, such as roofs, porches, and windows; interior materials, such as plaster and paint; and interior features, such as moldings and stairways, room configuration and spatial relationships, as well as structural and mechanical systems; and the building's site and setting.

Protect and Maintain Materials and Features from the Restoration Period

After identifying those existing materials and features from the restoration period that must be retained in the process of Restoration work, then protecting and maintaining them is addressed. Protection generally involves the least degree of intervention and is preparatory to other work. For example, protection includes the maintenance of historic material through treatments such as rust removal, caulking, limited paint removal, and re-application of protective coatings; the cyclical cleaning of roof gutter systems; or installation of fencing, alarm systems and other temporary protective measures. Although a historic building will usually require more extensive work, an overall evaluation of its physical condition should always begin at this level.

Repair (Stabilize, Consolidate, and Conserve) Materials and Features from the Restoration Period

Next, when the physical condition of restoration period features requires additional work, repairing by stabilizing, consolidating, and conserving is recommended. Restoration guidance focuses upon the preservation of those materials and features that are significant to the period. Consequently, guidance for repairing a historic material, such as masonry, again begins with the least degree of intervention possible, such as strengthening fragile materials through consolidation, when appropriate, and repointing with mortar of an appropriate strength. Repairing masonry as well as wood and architectural metals includes patching, splicing, or otherwise reinforcing them using recognized preservation methods. Similarly, portions of a historic structural system could be reinforced using contemporary material such as steel rods. In Restoration, repair may also include the limited replacement in kind--or with compatible substitute material--of extensively deteriorated or missing parts of existing features when there are surviving prototypes to use as a model. Examples could include terra-cotta brackets, wood balusters, or cast iron fencing.

Replace Extensively Deteriorated Features from the Restoration Period

In Restoration, replacing an entire feature from the restoration period (i.e., a cornice, balustrade, column, or stairway) that is too deteriorated to repair may be appropriate. Together with documentary evidence, the form and detailing of the historic feature should be used as a model for the replacement. Using the same kind of material is preferred; however, compatible substitute material may be considered. All new work should be unobtrusively dated to guide future research and treatment. If documentary and physical evidence are not available to provide an accurate re-creation of missing features, the treatment Rehabilitation might be a better overall approach to project work.

Remove Existing Features from Other Historic Periods

Most buildings represent continuing occupancies and change over time, but in Restoration, the goal is to depict the building as it appeared at the most significant time in its history. Thus, work is included to remove or alter existing historic features that do not represent the restoration period. This could include features such as windows, entrances and doors, roof dormers, or landscape features. Prior to altering or removing materials, features, spaces, and finishes that characterize other historical periods, they should be documented to guide future research and treatment.

Re-Create Missing Features from the Restoration Period

Most Restoration projects involve re-creating features that were significant to the building at a particular time, but are now missing. Examples could include a stone balustrade, a porch, or cast iron storefront. Each missing feature should be substantiated by documentary and physical evidence. Without sufficient documentation for these "re-creations," an accurate depiction cannot be achieved. Combining features that never existed together historically can also create a false sense of history. Using traditional materials to depict lost features is always the preferred approach; however, using compatible substitute material is an acceptable alternative in Restoration because, as emphasized, the goal of this treatment is to replicate the "appearance" of the historic building at a particular time, not to retain and preserve all historic materials as they have evolved over time. If documentary and physical evidence are not available to provide an accurate re-creation of missing features, the treatment Rehabilitation might be a better overall approach to project work.

Energy Efficiency/Accessibility Considerations/Health and Safety Code Considerations

These sections of the Restoration guidance address work done to meet accessibility requirements and health and safety code requirements; or limited retrofitting measures to improve energy efficiency. Although this work is quite often an important aspect of restoration projects, it is usually not part of the overall process of protecting, stabilizing, conserving, or repairing features from the restoration period; rather, such work is assessed for its potential negative impact on the building's historic appearance. For this reason, particular care must be taken not to obscure, damage, or destroy historic materials or features from the restoration period in the process of undertaking work to meet code and energy requirements.

RECONSTRUCTION

Reconstruction is defined as the act or process of depicting, by means of new construction, the form, features, and detailing of a non-surviving site, landscape, building, structure, or object for the purpose of replicating its appearance at a specific period of time and in its historic location.

Standards for Reconstruction

1. Reconstruction will be used to depict vanished or non-surviving portions of a property when documentary and physical evidence is available to permit accurate reconstruction with minimal conjecture, and such reconstruction is essential to the public understanding of the property.

2. Reconstruction of a landscape, building, structure, or object in its historic location will be preceded by a thorough archeological investigation to identify and evaluate those features and artifacts which are essential to an accurate reconstruction. If such resources must be disturbed, mitigation measures will be undertaken.

3. Reconstruction will include measures to preserve any remaining historic materials, features, and spatial relationships.

4. Reconstruction will be based on the accurate duplication of historic features and elements substantiated by documentary or physical evidence rather than on conjectural designs or the availability of different features from other historic properties. A reconstructed property will re-create the appearance of the non-surviving historic property in materials, design, color, and texture.

5. A reconstruction will be clearly identified as a contemporary re-creation.

6. Designs that were never executed historically will not be constructed.

Guidelines for Reconstruction

When a contemporary depiction is required to understand and interpret a property's historic value (including the re-creation of missing components in a historic district or site); when no other property with the same associative value has survived; and when sufficient historical documentation exists to ensure an accurate reproduction, Reconstruction may be considered as a treatment. Prior to undertaking work, a documentation plan for Reconstruction should be developed.

Choosing Reconstruction as a Treatment

Whereas the treatment Restoration provides guidance on restoring--or re-creating--building features, the Standards for Reconstruction and Guidelines for Reconstructing Historic Buildings address those aspects of treatment necessary to re-create an entire non-surviving building with new material. Much like restoration, the goal is to make the building appear as it did at a particular--and most significant--time in its history. The difference is, in Reconstruction, there is far less extant historic material prior to treatment and, in some cases, nothing visible. Because of the potential for historical error in the absence of sound physical evidence, this treatment can be justified only rarely and, thus, is the least frequently undertaken. Documentation requirements prior to and following work are very stringent. Measures should be taken to preserve extant historic surface and subsurface material. Finally, the reconstructed building must be clearly identified as a contemporary re-creation.

Research and Document Historical Significance

Guidance for the treatment Reconstruction begins with researching and documenting the building's historical significance to ascertain that its re-creation is essential to the public understanding of the property. Often, another extant historic building on the site or in a setting can adequately explain the property, together with other interpretive aids. Justifying a reconstruction requires detailed physical and documentary evidence to minimize or eliminate conjecture and ensure that the reconstruction is as accurate as possible. Only one period of significance is generally identified; a building, as it evolved, is rarely re-created. During this important fact-finding stage, if research does not provide adequate documentation for an accurate reconstruction, other interpretive methods should be considered, such as an explanatory marker.

Investigate Archeological Resources

Investigating archeological resources is the next area of guidance in the treatment Reconstruction. The goal of physical research is to identify features of the building and site which are essential to an accurate re-creation and must be reconstructed, while leaving those archeological resources that are not essential, undisturbed. Information that is not relevant to the project should be preserved in place for future research. The archeological findings, together with archival documentation, are then used to replicate the plan of the building, together with the relationship and size of rooms, corridors, and other spaces, and spatial relationships.

Identify, Protect and Preserve Extant Historic Features

Closely aligned with archeological research, recommendations are given for identifying, protecting, and preserving extant features of the historic building. It is never appropriate to base a Reconstruction upon conjectural designs or the availability of different features from other buildings. Thus, any remaining historic materials and features, such as remnants of a foundation or chimney and site features such as a walkway or path, should be retained, when practicable, and incorporated into the reconstruction. The historic as well as new material should be carefully documented to guide future research and treatment.

Reconstruct Non-Surviving Building and Site

After the research and documentation phases, guidance is given for Reconstruction work itself. Exterior and interior features are addressed in general, always emphasizing the need for an accurate depiction, i.e., careful duplication of the appearance of historic interior paints, and finishes such as stenciling, marbling, and graining. In the absence of extant historic materials, the objective in reconstruction is to re-create the appearance of the historic building for interpretive purposes. Thus, while the use of traditional materials and finishes is always preferred, in some instances, substitute materials may be used if they are able to convey the same visual appearance. Where non-visible features of the building are concerned--such as interior structural systems or mechanical systems--it is expected that contemporary materials and technology will be employed. Re-creating the building site should be an integral aspect of project work. The initial archeological inventory of subsurface and aboveground remains is used as documentation to reconstruct landscape features such as walks and roads, fences, benches, and fountains.

Energy Efficiency/Accessibility/Health and Safety Code Considerations

Code requirements must also be met in Reconstruction projects. For code purposes, a reconstructed building may be considered as essentially new construction. Guidance for these sections is thus abbreviated, and focuses on achieving design solutions that do not destroy extant historic features and materials or obscure reconstructed features.

APPENDIX C: Memorandum of Agreement

**MEMORANDUM OF AGREEMENT
AMONG FEDERAL AVIATION ADMINISTRATION, KING COUNTY,
WASHINGTON STATE HISTORIC PRESERVATION OFFICER, CITY OF SEATTLE,
AND THE NATIONAL PARK SERVICE REGARDING THE RUNWAY SAFEY AREA
PROJECT AT KING COUNTY INTERNATIONAL AIRPORT/BOEING FIELD**

WHEREAS, King County International Airport (KCIA) has prepared a Master Plan for the County International Airport/Boeing Field ("the Airport") that identified that the existing runway safety areas ("RSAs") do not meet the Federal Aviation Administration's (FAA) current standards;

WHEREAS, KCIA and the FAA have reviewed all prudent and feasible alternatives and determined that only two primary alternatives exist: shift the runway about 880 feet to the north to achieve the standards or shorten the runway by about 880 feet to meet the standards;

WHEREAS, the shortening of the runway will create significant effects on the operational capability of the Airport and adversely affect the ability of The Boeing Company to service critical aircraft such as the AWACs and to test and deliver commercial aircraft;

WHEREAS, KCIA and the FAA have agreed upon a Preferred Alternative that restricts use of the new section of runway to those operations that require 10,000 feet for takeoff including AWACs and commercial aircraft testing and delivery;

WHEREAS, the Georgetown Steam Plant ("the Steam Plant"), a National Historic Landmark and a City of Seattle Landmark is located adjacent to the Airport. It is the last working example of vertical Curtis turbines and is an example of the innovative fast-track design and construction method pioneered by Frank Gilbreth, a nationally recognized efficiency engineer;

WHEREAS, Seattle City Light owns the Steam Plant and leases the facility to a museum foundation whose purpose is to preserve the historical integrity of the Georgetown Steam Plant;

WHEREAS, the Georgetown Steam Plant is located approximately 1,200 feet from the existing runway end and taxiway and would be about 500 feet from the shifted runway and taxiway;

WHEREAS, a noise analysis was conducted for the National Environmental Policy Act (NEPA) Environmental Assessment (EA) and a State Environmental Policy Act (SEPA) Environmental Impact Statement (EIS) for the Master Plan. The analysis found that the runway shift would not create a significant noise impact, as defined by FAA Order 5050.4A.

WHEREAS, a special vibration analysis conducted at the Georgetown Steam Plant to evaluate the effects of the runway shift on the physical structure found that with conservative mitigation assumptions, the glass window panels could be vibrated loose constituting an adverse impact, under Section 106 of the National Historic Preservation Act (NHPA);

WHEREAS, KCIA has proposed to conduct a window mitigation project on behalf of Seattle City Light;

WHEREAS, KCIA and FAA have consulted with the Washington State Department of Community, Trade and Economic Development - Office of Archaeology and Historic Preservation (otherwise commonly known as the State Historic Preservation Officer – SHPO), the National Park Service, Pacific West Region, Seattle City Light and City of Seattle Department of Neighborhoods, representing the City of Seattle, and the King County Historic Preservation Program as signatories to this agreement, pursuant to 36 CFR 800, regulations implementing Section 106 of the NHPA, concerning the Georgetown Steam Plant;

WHEREAS, there are no other feasible alternatives to the runway shift and the anticipated impacts of the Preferred Alternative can be mitigated;

WHEREAS, the Advisory Council on Historic Preservation (ACHP) was invited to participate in this consultation and declined. The final version of this MOA will be filed with their office;

NOW, THEREFORE, the parties agree that prior to operation of the shifted runway at the Airport, all reasonable attempts will be made to address vibration impacts to the facility.

STIPULATIONS

The FAA will ensure the following:

I. Prior to mitigating the vibration effects on any windows, KCIA or its agents, with oversight by the City of Seattle, will contact the NPS Pacific West Region, Seattle, to determine Historic American Engineering Record (HAER) project photographic documentation requirements. Copies of the documentation will be provided to the NPS, City of Seattle, SHPO, and the Library of Congress.

II. KCIA will conduct a supplemental analysis (and associated coordination) of the effect of the project on the Georgetown Steam Plant to facilitate the design of the window mitigation. The existing study, based on an 800–foot shift, and using conservative criteria showed the need for replacing the windows. The additional study will be based on an 880 feet-shift. In addition to final quantification of vibration effect, the study will include a window conditions evaluation, which will identify the possible means of addressing vibration mitigation, such as re-caulking the glass, storm windows and window replacement. KCIA will continue to coordinate the results of this study with the signators of this agreement. The mitigation options will be evaluated to comply with the Secretary of Interior's *Standards for the Treatment of Historic Buildings* (U.S. Department of Interior, National Park Service, 1995). KCIA will propose to the signators a recommended window vibration mitigation project that ensures the windows are protective of the anticipated vibration levels for all types of aircraft using the airport.

III. KCIA will ensure that the window mitigation project complies with the Secretary of Interior's *Standards for the Treatment of Historic Buildings* (U.S. Department of Interior, National Park Service, 1995). KCIA, will hire a qualified window restoration consultant, approved by the consulting parties, to ensure that the design and specifications for the undertaking are developed in compliance with the *Secretary of the Interior's Standards for Treatment of Historic Buildings*. No construction, alteration, remodeling or any other physical action to the Steam Plant subject to the window mitigation project will be undertaken which would affect the appearance or structural integrity of the plant without the express written permission of the signatories to this agreement.

IV. KCIA shall ensure that any change order to the project design required subsequent to the approval of the project will be developed in consultation with the signatories of this agreement.

V. Should the SHPO object within 30 calendar days to any construction documents provided for review pursuant to the terms of this Agreement, KCIA shall consult with the signatories to this agreement to resolve the objection. If KCIA determines that the objections cannot be resolved, KCIA shall request the further comments of the SHPO. Any SHPO comment provided in response to such a request shall be taken into account by the KCIA with reference only to the subject of the dispute under this agreement. Should the Landmarks Preservation Board not approve the proposed changes, KCIA may appeal the Board's decision pursuant to SMC 25.12. In the event that SHPO comments are not resolved, KCIA will refer the issue to the ACHP for resolution.

VI. Should any signatory to this Agreement determine that the terms of this Agreement cannot be met or believes that a change is necessary, that signatory is responsible for immediately requesting that other signatories consider voiding, amending, or affecting an amendment to this Agreement. Such an agreement or addendum shall be executed in the same manner as the original agreement.

VII. **DURATION.** Thirty days after execution of this agreement, KCIA shall initiate the process for window mitigation outlined herein and proceed diligently and expeditiously to complete the window mitigation project. If KCIA has not completed its obligation within five (5) years from the date of its execution, the City may declare this agreement null and void and KCIA shall pay the Seattle City Light just and complete compensation for Seattle City Light's performing the window mitigation project itself, plus any damages incurred by Seattle City Light due to KCIA's delay.

VIII. **AMENDMENTS.** If any signatory to this MOA determines that its terms will not or cannot be carried out or that amendment to its terms must be made, that party shall immediately consult with the other parties to develop an amendment to this MOA pursuant to 36 CFR §800.6(c) (7)). The amendment will be effective on the date a copy signed by all of the original signatories is filed with the ACHP. If the signatories cannot agree to appropriate terms to amend the MOA, any signatory may terminate the agreement for reason in accordance with Stipulation X below pursuant to 36 CFR §800.6 (c)(8).

IX. **UNEXPECTED DISCOVERIES.** KCIA will notify the FAA as soon as practicable if it appears that an undertaking will affect a previously unidentified property that may be historic, or affect a known historic property in an unanticipated manner. The county will stop construction activities in the vicinity of the discovery, and take all reasonable measures to avoid or minimize harm to the property until the FAA concludes consultation with the SHPO, the consulting parties, and any Native American Tribe that might attach religious and cultural resource significance to the affected property. In the case of human remains, KCIA will also immediately notify the local law enforcement office and the county coroner/medical examiner.

X. **TERMINATION.** If the MOA is not amended following the consultation set out in Stipulation VIII, it may be terminated due to conditions found in Stipulations VIII and IX by any signatory. Within 30 days following termination, the FAA shall notify the signatories if it will initiate consultation to execute an MOA with the signatories under 36 CFR

§800.6(c)(1) or request the comments of the ACHP under 36 CFR §800.7(a) and proceed accordingly.

EXECUTION OF THIS MEMORANDUM OF AGREEMENT and implementation of its terms evidences that the FAA and KCIA have afforded the SHPO, National Park Service, Seattle Landmarks Board, and the City of Seattle an opportunity to comment on the proposed window mitigation project and its effect on the Plant, and that KCIA has taken into account the effect of the runway shift and window mitigation on this historic property.

Federal Aviation Administration	6/3/04 Date
Washington Office of Archaeology and Historic Preservation	6/3/04 Date
King County International Airport	6.4.04 Date
City of Seattle	June 17, 2004 Date
King County Historic Preservation Program	6/3/04 Date
National Park Service	6/4/04 Date

W E T H E R H O L T   A N D   A S S O C I A T E S ,   I N C .

Roofing and Exterior Wall Condition Report
Georgetown Steam Plant - Renovation 2012
Seattle, Washington

BOLA Architecture & Planning
159 Western Ave West, Ste 486
Seattle, WA 98119

Attn: Matt Hamel & Rhoda Lawrence

August 2, 2012
1206-13A

13104 N.E. 85th Street • P.O. Box 816 • Kirkland, WA 98083-0816
Phone: 425-822-8397 • Fax: 425-822-7595

W E T H E R H O L T A N D A S S O C I A T E S , I N C .

August 2, 2012
1206-13A

BOLA Architecture & Planning
159 Western Ave West, Ste 486
Seattle, WA 98119

Tel: 206-447-4749 Fax: 206-447-6462

Attn: Matt Hamel — Email: mhamel@bolarch.com
Rhoda Lawrence — Email: rlawrence@bolaarch.com

Ref: Roofing and Exterior Wall Condition Report
Georgetown Steam Plant - Renovation 2012
Seattle, Washington

Greetings,

At the request of Matt Hamel and Rhoda Lawrence, Jose Laurean and Don Davis were on site June 15, 2012 to visually evaluate the condition of the roof, windows and exterior walls of the historic Georgetown Steam Plant in Seattle, Washington. The purpose of the evaluation was to help identify issues with the roofing and exterior wall assemblies that could be corrected when restoration occurs; currently scheduled for 2013.

Observations/Discussion

Low Slope Roofing

From review of documents provided by BOLA, it appears the last roof replacement occurred in approximately 1983, according to reroofing specifications dated as such. Slope appears to be incorporated into the roof deck with drainage into gutters and downspouts, or drop drains into pipes located just inboard of the north and west parapet perimeters.

Test cuts where performed on each of the roof areas, six (6) total, to confirm the composition. Each roof was found to have gravel surfacing over a four-ply coal tar pitch built-up membrane adhered directly to the concrete deck. No insulation is currently present and we understand that the building is considered non-heated and will not be retrofitted as a heated space in the future.

Baseflashing membrane includes Koppers Aluminum KMM, Koppers Multipurpose Membrane with embossed aluminum surfacing. The KMM membrane is installed over plysheets.

Perimeter edges on the roofs include both raised (approximately 12 inches) perimeter edges with coping metal and low perimeter edges with embedded edge metal. The raised perimeter edges appear to be good condition except for some delaminating aluminum surfacing on the baseflasing membrane in some locations.

13104 N.E. 85th Street • P.O. Box 816 • Kirkland, WA 98083-0816
Phone: 425-822-8397 • Fax: 425-822-7595

Baseflashing at the low perimeter edges has separated from the embedded edge metal, especially at lap seams in the edge metal. A sealant knife could easily be inserted under the membrane and between the lap in the metal edge flashing. These conditions are considered entry points for water to wick to the wood nailers and/or into the building. If possible, all perimeter edges should be raised to accommodate scuppers and insulation crickets for drainage.

The height of the perimeter curb depends upon the distance between scuppers. Additional scuppers may need to be added to reduce the distance. For example: at a maximum of 50 feet between scuppers the tapered insulation to form crickets would be approximately 6 inches at the thickest location. The perimeter curb would need to extend a minimum of 3 inches above the thickest location, which would equal a 9 inch minimum curb.

There are multiple pitch pockets installed on the roof to seal hand railing penetrations, large vent stacks, and soil stack penetrations. Pitch pockets are maintenance items and can become leak prone. Pitch pockets should not be utilized on a roof requiring long term life and low maintenance. Liquid resin membrane with reinforcing fabric should be installed in place of the pitch pockets and/or the penetrations modified to allow lead flashing.

Sheet metal coping and surface mounted metal flashings are poorly flashed at the ends. Coping metal butts to exterior walls with minimal turn up and no soldered transition or saddle flashing to provide termination. Embedded edge metal terminates at the edge of the roof and has no soldered end flashing and counterflashing that extends beyond the edge of the roof, as appropriate.

Drop drains appear to be inserted into existing pipes and not connected, as indicated on the 1969 drawings. The drains should be tightlined where they extend into the building. The existing drop drains should be removed and cast iron drains grouted in the concrete and plumbing connections made to existing drain lines at the interior. Each primary drain should have an overflow, such as an adjacent scupper that extends through the parapet wall. Overflow scuppers are typically installed 2 inches above drains.

Options for reroofing or repairing the low slope roof areas would include the following:

1. Reroof: Remove the existing roof assembly and install a new SBS (styrene butadiene styrene) or APP (atactic polypropylene) modified bitumen system consisting of (from bottom to top): Two plies of glass reinforced basesheet in hot asphalt over a primed and prepared concrete substrate, a six-sided wood fiber board in hot asphalt (to provide sumps at drains), a base sheet, inner ply and white or light grey mineral surfaced capsheet with plies set in hot asphalt except for the finish capsheet ply which could be adhered in cold adhesive or torch-applied.

2. Baseflashing Repair: A more economical approach would be to leave the existing field roofing in-place, remove existing baseflashing membrane at perimeters and penetrations, and install new membrane baseflashings, penetration flashings and sheet metal counterflashings. If the latter approach is taken, installation of fluid-applied membrane flashings would be beneficial at drains, roof-to-wall transitions, embedded edge metal and penetrations as needed to promote a weather-tight assembly.

With both options the following issues should be dealt with:

1. The existing drains should be removed and replaced with conventional cast iron drain and clamping ring assemblies.

2. Delete low perimeter edges and gutters and replace with raised parapets with scuppers, utilizing crickets between the scuppers for drainage. Coping metal will replace the embedded edge metal, providing a functional long-term roofing application. We understand this modified condition does adjust the aesthetics of the building a small amount, but realize there are short parapets on the west and north elevations, as well as the south side of the lower engine room roof.

3. Asbestos testing results should be provided to bidders prior to any roof removal.

<u>Steep Slope Metal Roofing</u>

The southeast corner of the engine room at the north end of the building has a corrugated metal roof with exposed fasteners. It was not confirmed but we assume there is no insulation below this sheet metal roof. Slope appears to be approximately 10:12, but was not measured. There is no transition flashing installed where the roof meets the wall at the rake edge. The metal roofing appears to be butted and sealed with a black mastic or sealant. Where the metal roofing butts the wall at the top of the slope there is a sheet metal flashing with a termination bar against the plaster. Sealant along the top edge of the flashing is only partially sealed to the plaster. The roofing is rusted through around a vent stack.

The corrugated metal roofs should be removed and replaced with standing seam metal roof panels using concealed fasteners, which has a longer life than corrugated metal with exposed fasteners. Surface mounted or inset roof-to-wall flashings should be installed where the current detailing provides minimal protection from water intrusion by simply butting the exterior walls. A fabricated sheet metal diverter flashing should be incorporated into the new roofing assembly at typical eave-to-rising wall interface with the column bump-out on the east elevation.

<u>Exterior Walls</u>

Exterior walls were visually evaluated with the use of a mechanical lift. Due to safety precautions and/or restricted access, the majority of the west elevation and the northern-most part of the north elevation where not included in our evaluation from the lift but were viewed from the ground.

The exterior walls are steel reinforced cast-in-place board-formed concrete, with the exception of the north elevation addition which is hollow clay tile with a cementitious parge coat, and the east wall of the 1918 addition, or Turbine Room, which is wood and steel framed with metal panels. We understand that the east wall of the Turbine Room was built to allow easy access for removal and replacement of the equipment.

The reinforced concrete walls show numerous instances of cracking and spalled concrete which appear to have been overlaid with cementitious patches. Most of the repair patches made were found to have voids behind them. In some locations, the patch or concrete surface has delaminated exposing the reinforcing steel which has become severely oxidized to the point of becoming easily broken.

It is likely that the patching was performed with conventional concrete which created a corrosion mechanism between the old chloride-contaminated concrete and new chloride-free concrete, or that the reinforcing steel was placed too close to the concrete face, allowing rusting due to exposure to moisture and oxygen. It is interesting to note that the majority of the spalls and cracks we observed were identified on the 1985 Exterior Rehabilitation drawings, which indicates the repairs performed were unsuccessful and problems have reoccurred in the same locations.

A method for repair of these spalled concrete areas which employs cathodic[1] protection is recommended. This would entail removing the concrete around the reinforcing steel, removing the deteriorated sections of rebar, installing new rebar and connecting a galvanic anode[2] such as zinc prior to patching the area with a low resistivity mortar. In general, a direct current would be generated by the potential difference between the zinc and reinforcing steel when connected making the rebar cathodic. Over time, the sacrificial anode will be consumed rather than the reinforcing steel. Several parameters must be met before electing to use the cathodic protection method which would include, but not be limited to, appropriate levels of chloride content in the existing concrete, whether or not the structure is structurally sound and the majority of the rebar should be electrically continuous. A structural and/or metallurgical engineer should be consulted to ensure that the criteria are met.

At areas where the structural concrete is not delaminated but cracked, and rebar does not appear to be exposed, epoxy or urethane grout injection into the cracks should be considered.

There is an elastomeric coating on the exterior walls. The coating should be further reviewed and/or tested to confirm adhesion and necessary surface preparation prior to installing a new coating. It is likely the existing coating would need to be removed. New coatings to consider should be breathable, such as Tnemec Series 156 or 157 Enviro-Crete, and would be applied over all concrete and cementitious wall surfaces.

Corrugated metal wall panels with exposed fasteners are present at the 1918 addition. We understand the metal panels were new from the 1985 Exterior Rehabilitation project.

There are two steel channels (crane tracks) that extend through the metal panels and turn up that have copious amounts of sealant around the point of penetration. These are prone to leakage as the sealant does not appear adhered.

---

[1] Cathode: Site where no corrosion occurs and current flows to.
[2] Anode: Site where corrosion occurs and current flow from.

The metal panels extend below grade, or have been covered by soil and vegetation over the years. The grade should be reworked to provide positive slope away from the walls and space below the panels to reduce the potential of water penetration into the building and rusting of the panels.

Windows

The windows on the original structure are present on the south and west elevations and roof clerestories and are wood framed with panes set into the sash with glazing putty. Steel sash windows are present on the addition at the north end. Wood framed windows at the roof clerestories are covered with corrugated fiberglass.

Wood frames are severely deteriorated on many of the windows. We understand the clerestory windows were covered with corrugated fiberglass due to the level of deterioration and to help prevent water entry. The fiberglass is attached to wood framing. In many locations, wood windowsills were notched to fit the wood framing tight against the concrete walls around the windows.

Steel frames are in need of replacement at the north elevation of the 1918 addition where they are deflected inward and rusted. The cause of the deflection was not clear, but may be due to the hollow clay tile and/or lack of support. The structural engineer should review these windows.

Wood window repair could include repair in place or replacement of the wood frames. In-place repair may not provide complete repair of the hidden deterioration. We also observed back-sloping concrete sills in upper windows at the south elevation. Back-sloping sills tend to feed water under the wood window frames, causing deterioration and/or leakage into the building.

Options for windowsill repair would include removal of the frames, reworking concrete sills to slope towards the exterior, and installation of steel angle backstops at the sills with liquid flashing membrane in the rough opening and under the wood frame. Another option would include similar work but using soldered sill flashing pans set in sealant under the wood frames.

Since this building is registered as historical, all replacement/repairs will need to be reviewed with the historic preservation authority and verified as acceptable.

We trust the above discussion has been of assistance. If you have any questions, or if we may be of further service, please do not hesitate to call.

Photographs taken during the site visit are included below. Note that photographs have notations with additional information recorded that may be helpful as part of this evaluation report.

Respectfully,

Don Davis, RRC/RWC/REWC/RBEC
Senior Field Engineer
Wetherholt and Associates, Inc.

Reviewed by,

Mike Caniglia, RRC/RWC/REWC/RBEC
Field Engineer
Wetherholt and Associates, Inc.

Please note that this investigation report is provided at the request of Rhoda Lawrence, whom we understand represents BOLA Architecture. No liability, warranty of merchantability, or guarantee of building service life is accepted or implied. Wetherholt and Associates, Inc. is a neutral building envelope consulting firm specializing in resolving building and roof related problems.

Photo 1: Overview of roof areas and exterior walls from the south.

Photograph 2:
SW roof. Test cut in foreground.

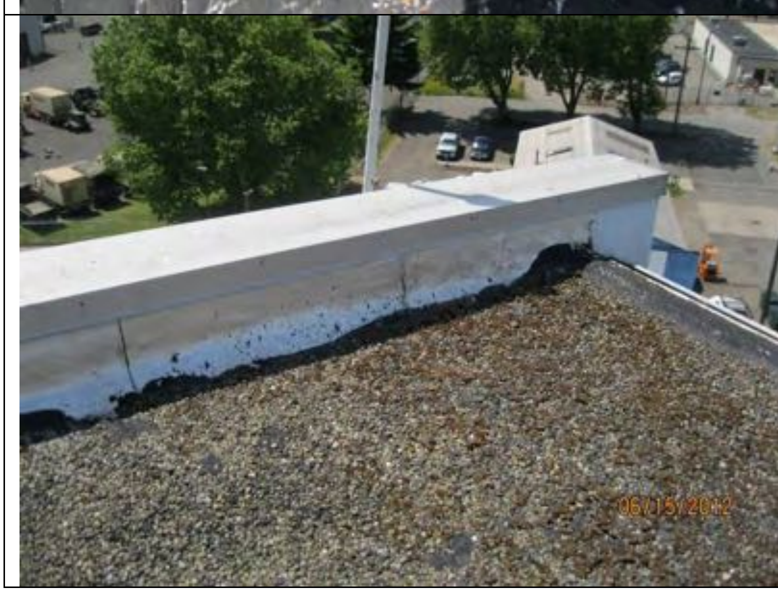
<table>
<tr><td>
</td><td>Photograph 3:
NW roof with two pipe penetrations in a pitch pocket at the corner. Pitch pockets should not be utilized if possible as they require maintenance.</td></tr>
<tr><td>
</td><td>Photograph 4:
Typical drop drain adjacent raised perimeter edges.</td></tr>
<tr><td>
</td><td>Photograph 5:
Coping to wall at the NW roof. The coping is not sufficiently counterflashed.</td></tr>
</table>

	Photograph 6: NW roof parapet is approximately 11 inches off the finished roof height.
	Photograph 7: East end of NW roof with access door. Note parge coat over hollow clay tile is cracked and spalling around the window.

	Photograph 8: Upper north roof looking east over the 1918 addition. Test cut in foreground.
	Photograph 9: Overview of north stairwell roof and roof areas below that wrap around the stairwell roof.
	Photograph 10: Note foil facing peeling from baseflashing and blister in baseflashing at same location (arrow).

Photograph 11:
Membrane unadhered and peeling from edge metal at lap joint in edge metal. Note sealant knife is inserted under the edge metal, which does not appear to be sealed in the lap joint.

Photograph 12:
Test cut at the perimeter edge of the stairwell roof confirms that the 1967 drawings appear to be accurate at the embedded metal edges.

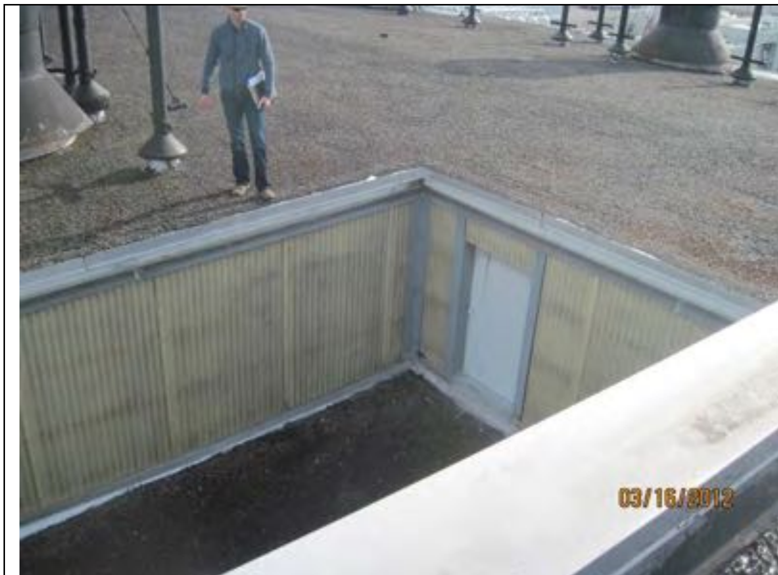


Photograph 13:
West end of upper roof with raised parapet.

Photograph 14:
Looking south from the upper north roof.

Photograph 15:
Overview of roof to the south of the upper north roof, looking east.

Photograph 16:
Ladder to south roofs bolted to interior side of parapet.



Photograph 17:
Door at east side to access low south and east roof areas.

Photograph 18:
Circular roof with KMM membrane at SW corner. We understand from 1983 drawings this is the original stack through the roof and the raised portion is a wood framed cover that has been roofed and flashed into the gravel surfaced roof.

Photograph 19:
Turn buckle penetration and south roof area. Guy wires are used to support stacks. Turn buckle and eyebolt penetrations need to be revised to provide a long term flashable detail.

	Photograph 20: Low SE roof.
	Photograph 21: Looking south along west edge of southern roof area.
	Photograph 22: Drain line penetration from upper roof to low southwest roof is routed over west parapet.

Photograph 23:
Handrails on east and west sides of the roof are apparently welded to steel angles bolted to the roof substrate. Pitch pockets are placed around the angles. These penetrations need to be revised to round pipe penetrations that can be properly flashed.

Photograph 24:
Typical transition where embedded edge metal meets rising wall is improperly detailed. There needs to be a soldered flashing to receive the cant strip and the counterflashing needs to extend beyond the edge of the roof.

Photograph 25:
Test cut at south end of south roof, west side. Similar to previous test cuts.

	Photo 26: Gutter on east side of south roof area.
	Photo 27: Gutter is full of debris indicating maintenance is not performed, at least to clean gutters.
	Photo 28: Membrane unadhered at sheet metal lap joint; typical condition.

	Photo 29: South facing wall at engine room addition. Corrugated metal roofing below.
	Photo 30: Corner of corrugated metal roof is not well flashed. Flashing should extend beyond corner. Sealant joint needs to be replaced or covered with sheet metal..
	Photo 31: Stack penetrations through corrugated metal roof need to be reflashed and sealed, as the metal flashing is rusted through in locations.

	Photo 32: Pointing out where flashing is rusted through.
	Photo 33: Upper corrugated metal roof drains to lower metal roof. There is no counterflashing along the rake edge of the upper roof. It appears the roofing butts to the wall.
	Photo 34: Lower corrugated metal roof with roofing material butting to concrete wall. Mastic has been applied at the joint.

Photo 35:
Close-up of previous photo at bottom edge (SW corner of roof). This is a built in leak where the roofing runs into a concrete column. There needs to be a custom soldered cricket/diverter installed with counterflashing on the wall.

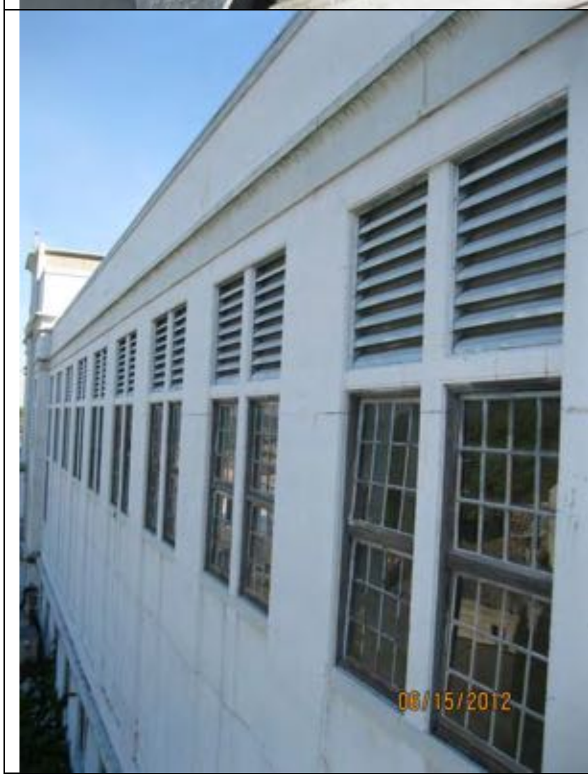


Photo 36: Overview of the west elevation looking north.

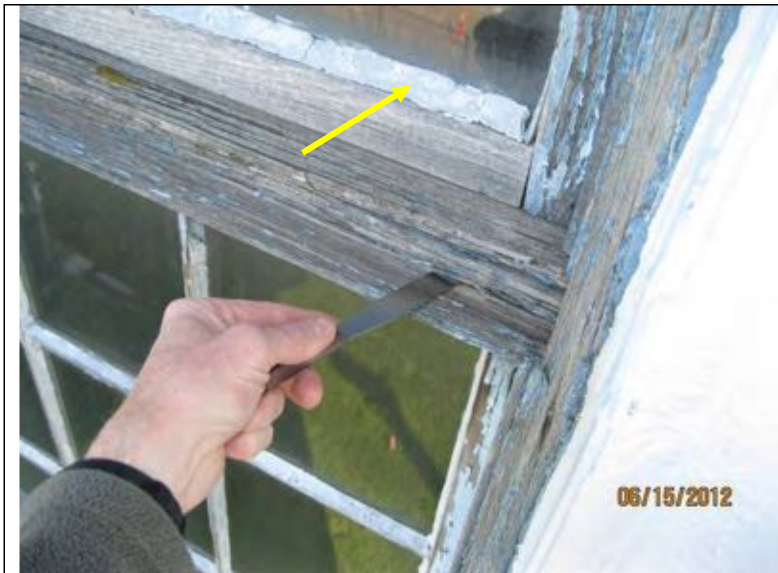


Photo 37:
Wood window frames are deteriorated to varying degrees, worst at west and south elevations. Note glazing putty holding the glazing in place where the arrow points.

Photo 38:
Horizontal crack in what appears to be a cold joint in the concrete at the west elevation.

Photo 38:
Spalled concrete on west wall, towards the south end, with rusted reinforcing steel in hand.

	Photo 39: ½ round cornice at west elevation with cracks and spalls at underside.
	Photo 40: Moss growth at top of ½ round cornice. It appears the top holds moisture.
	Photo 41: Steel louvers at top of west elevation appear to be in serviceable condition, other than surface preparation and paint.

Photo 42:
South elevation with station label. Note inaccurate patching at wall and cracks/spalls where water has caused plant growth at drip edge.

Photo 43:
Spalled and delaminated concrete at corner of cornice, south elevation top of wall.

Photo 44:
Sealant knife inserted into what appears to be an open cold joint in the concrete between windows, south elevation.

	Photo 45: Spalled concrete at jamb of window, south elevation.
	Photo 46: East wall; sealant knife inserted behind delaminated patch material.
	Photo 47: Overview of a portion of the east elevation south of the Engine Room.

Photo 48:
Overview of south facing wall at 1918 addition. This wall includes parge coat over board formed concrete.

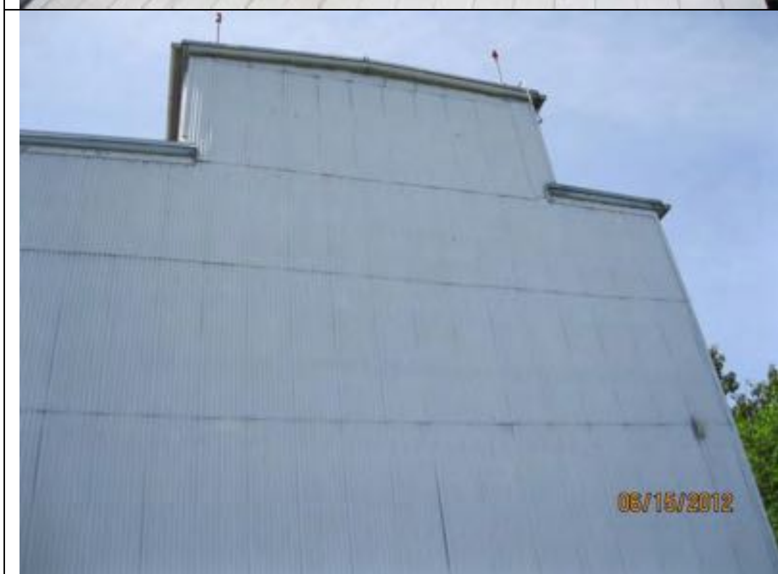


Photo 49:
East wall of 1918 addition with exposed fastener corrugated metal panels.

Photo 50:
Rail tracks extend through siding and are bent up. Sealant applied around penetrations is not watertight.

Photo 51:
Edge of low slope roof without closure where embedded edge metal meets parapet wall. Wood nailer below metal flashing is exposed. Photo taken at east end of south engine room roof.

Photo 52:
Sheet metal wall panels appear to butt to underside of concrete at east end of engine room roof. Sealant knife is inserted in open joint.

Photo 53:
Overview of east wall of engine room, 1918 addition. Steel framed windows are present.

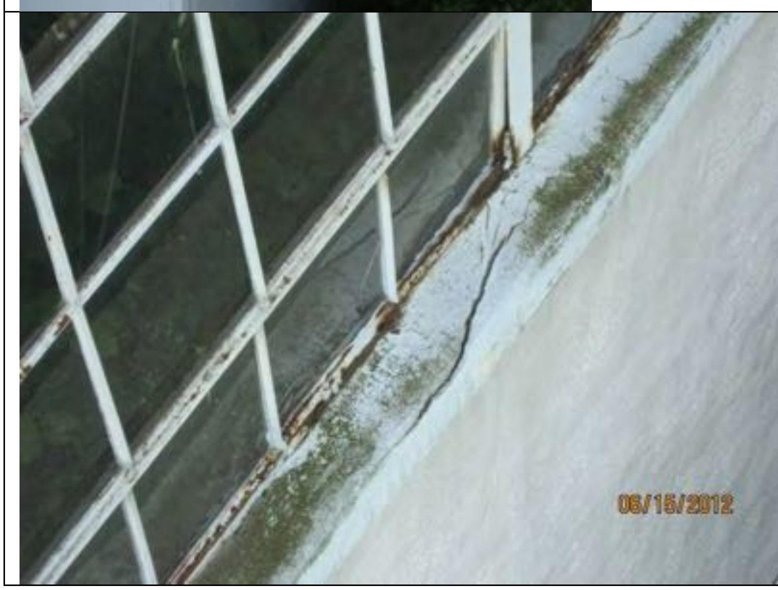
	Photo 54: Overview of north wall of east engine room, 1918 addition. Plaster installed over hollow clay tile.
	Photo 55: Rusted steel framed window and spalled concrete sill material.

	Photo 56: Steel windows are deflected inward at north wall of 1918 addition.
	Photo 57: Rusted steel window at north elevation of 1918 addition.

Photo 58:
Window deflecting inward at north elevation of addition. Note hollow clay tile at interior wall.

Photo 59:
Steel siding below grade at east elevation of addition.

	Photo 60: Overview of west elevation at north end. Note spalls and cracks in concrete walls.
	Photo 61: Overview of north wall at NW corner.

Photo 62:
Clerestory wood framed windows at roof. Uncovered for condition evaluation. Note wood framing to support corrugated fiberglass is bolted to concrete. Wood sills notched in order to fit framing overlay. Wood window frames are deteriorated.

Photo 63:
Severely spalled concrete and exposed/rusted reinforcing steel.

Photo 64:
Notched windowsill at clerestory windows for wood framing fit.

Photo 65:
Typical deteriorated wood window frame.

MECHANICAL AND ELECTRICAL SYSTEMS PREDESIGN CONDITION REPORT

GEORGETOWN STEAM PLANT
SEATTLE, WASHINGTON

AUGUST 2012

Prepared For:

BOLA ARCHITECTURE + PLANNING
159 Western Avenue West, Suite 486
Seattle, Washington 98119

Prepared By:

Coffman Engineers, Inc.
1601 Fifth Avenue, Suite 900
Seattle, Washington 98101
206-623-0717

CEI Project #12412

COFFMAN ENGINEERS

I. INTRODUCTION

A. General: This narrative provides a summary description of the mechanical roof drainage, electric steam boiler, electrical and low-voltage systems impacted by the proposed upgrades to the facility. In addition to establishing a baseline understanding of the anticipated work, issues that require further investigation and consideration by the design team may be identified. This narrative is based on several site visits that took place in June and July of 2012, as well as discussions on-site with facility personnel.

B. Codes and Guidelines: The electrical installation shall comply with the following codes guidelines and standards as adopted and amended by the City of Seattle, Washington:

1. 2009 UPC (Uniform Plumbing Code)
2. 2009 IBC (International Building Code; Note: Chapter 34 has provisions to control alteration, repair, maintenance, and change of occupancy of existing buildings and structures. The building official is authorized to modify specific requirements of the code for historic buildings.)
3. 2008 NFPA 70 (National Electrical Code)

II. MECHANICAL ASSESSMENT

A. Roof Drainage System: The existing roof drainage system is a combination of interior roof drainage piping and exterior down spouts. Following is a list of existing conditions and deficiencies:

1. General: Existing roof drains vary in style from bare pipes open to atmosphere to original building wire cage strainers to more modern styles (Images 1 through 4). According to a previous roof drain assessment from 2007, the original roof drains on the southeast side of the Boiler Room have been disconnected and roof drainage is handled by a roof gutter and down spouts along the face of the building. Many of the roof drain locations are clogged with debris.
2. The existing horizontal roof drainage pipe in the southeast corner of the building is reported as being blocked and not in use. There is also a section on the west side of the Boiler Room that leaks and has a large sheet of plastic suspended below it that connects to a ¾" garden hose to collect storm water from the leak (Image 5). We were unable to determine if the pipe itself leaks or just the joints.
3. East Wall of the Engine Room: There is a galvanized roof drain pipe that drops at the interior wall and penetrates the exterior wall at floor level. It then routes below grade outside (Images 6 and 7). The connection at floor level is

misconnected and there is a gap outside at the connection to the piping that continues to below grade. Below grade piping cannot be confirmed.

4. Southeast Corner of the Engine Room: There is an exterior galvanized down spout that connects to a concrete pipe then routes to below grade. The end of the concrete pipe is open to atmosphere and can be an entry point for debris into the pipe (see Image 8).

B. Electric Steam Boiler and Unit Heater System: There is an existing electric steam boiler that serves steam unit heaters in both the Boiler Room and the Engine Room. We were unable to locate a nameplate for the boiler. Condensate is piped back to a receiver and flash tank before being returned to the boiler. A permit was applied for on November 19, 2001, to install this system. This would make the system approximately 10 years old. Many of the access panels were removed from the boiler (Images 9 and 10). Some corrosion is visible on the boiler exterior and the connection piping and fittings (Images 11 and 12). The existing steam unit heaters, distribution piping and condensate pumps appear to be in good condition (Images 13 through 16).

III. MECHANICAL RECOMMENDATIONS

A. Recommendations to Improve Drainage System:

1. Clean out all of the existing roof drainage piping. When the building is reroofed, replace all existing roof drains that are in service with new roof drains with Zurn Model Z100 or equal by J.R. Smith, Wade or Josam.

2. Replace the leaking horizontal pipe on the west side of the Boiler Room. Perform a hydrostatic test on all of the roof drainage piping to identify and repair any other leaks.

3. Replace the galvanized roof drain piping at the east side of the Engine Room with cast iron pipe, seal the exterior wall penetration and connect to the existing storm pipe below grade.

4. Clean out the existing exposed, open concrete storm drain pipe and provide a plug at the open end.

B. Recommendations for Boiler and Unit Heater System:

1. Since the boiler is approximately 10 years old and corrosion appears to be surface only, we do not recommend replacement of the boiler at this time.

2. Corrosion on the boiler exterior and accessible areas inside the boiler should be wire brushed and primed to minimize further corrosion.

3. A qualified Boiler Contractor or the original manufacturer's representative should examine the boiler to confirm that there is no hidden interior problem.

Boiler should be serviced to optimize operation. The missing access panels should be reinstalled.

IV. ELECTRICAL ASSESSMENT (see location drawings, end of report)

A. Distribution: The existing electrical system consists of the following three services:

1. Service 1: An 800A 480Y/277V Main Distribution Panel; (refer to Image 1) with three electrical panels A, B and C. This service contains five switches; three serve Panels A (225A), B (70A breaker to 45kVA 480V:208Y/120V transformer), and C (125A breaker to 25kVA 480V:208Y/120V transformer); one serves an air compressor unit, 60A; and one spare 250A switch.
2. Service 2: An 800A 480Y/277V Main Service Panel consisting of one 800A service disconnect to serve the 500kW Boiler unit (Image 2).
3. Service 3: An existing 120/240V single phase service has been derived from the north via the 2400V, 2-phase service. This 120/240V single phase service feeds a panel located in a north end office, which serves the rooftop aircraft lights.

B. Lighting Controls: Most of the existing building lighting controls use the existing knife switches located in various fuse panels (see "Fused Panels" discussion).

C. Fuse Panels: There are at least four fused branch circuit panels located throughout the facility. These do not appear to have been upgraded within the past 70-years and some parts of the panels date back to the original construction over 100 years ago. Some of the knife switches within these panels are still used on a daily basis to control lighting. Wiring within these panels is a mixture of very old and some newer conductors. It was apparent that many circuits have been removed and/or disconnected over the years. The panels have a wood framed hinged cover with a glass panel. The condition of the different panels varies.

D. 500kW Electric Heating Boiler System: The boiler is powered at 480V, 3 phase from a dedicated electrical service identified as Service 2 in this report. Approximately nine unit heaters are distributed throughout the facility. These unit heaters are powered at 120V with most of the circuits derived from the fuse panels. We saw no deficiencies associated with the electric boiler system.

E. Electrical Loads: For the purpose of our assessment we have not assessed the loading and capacity of the services. We saw nothing that implied a capacity problem and we know that the proposed upgrades will not increase electrical loads.

F. 2400V Service Concerns: For reasons that are unclear, the 120/240V service is still derived internal to the building by a transformer that is connected to the original 2400V 2-phase bus of the distribution system. This requires that the busing for the old marble faced switchboard stay in-use and live. This represents a significant hazard, requiring staff and sometimes visitors to be in close proximity to exposed bussing at these elevated voltages. Due to the age and custom nature of the installation clear labeling and indication of which bussing is live and which bussing is not, does not exist.

V. ELECTRICAL RECCOMMENDATIONS

A. Aircraft Obstruction Light Power Source: The existing aircraft obstruction light support structures are rusted over and will need to be replaced with new Aircraft Obstruction lights. The existing branch circuit to the 120/240V panel will be adequate for the new obstruction lights. The new obstruction lights will be dual lamp type.

B. Fused Panels: The fused panels appear to date back to the 1920's and because of their glass cabinet doors and exposed live-front bussing have some historic appeal and value. Due to the glass doors, the age of the equipment and associated wiring, and because some of the knife switch must be operated manually in order to turn the lights on, these panels present some hazards. We recommend the following two options:

- Option A: Replace glass doors with nonbreakable acrylic covers or laminated glass. This option would require prior approval by building official under WAC 51-50-481101.
- Option B: Provide new panelboard adjacent to fuse panel and cut over existing circuits to new panelboard. The fuse panel could remain for historic preservation but would be de-energized.

C. Light Switching: The existing lighting controls are switched by knife switches in the fuse panels. This switching method poses a hazard of shock and arc flash from regular operation. We recommend providing contactors or relays mounted near the fuse panels with an adjacent light switch to operate lights and prevent regular exposure to live parts (see Images 3 & 5, red and black handles).

D. Boiler Electrical System: The current boiler electrical system is adequate for continued electrical service to the boiler system.

E. 2400V Hazards: We see no reason to leave the old 2400V 2-phase switchgear and bussing live. The purpose appears to be to serve power to the 120/240V service transformer that derives power for general lighting and equipment. SCL should consider re-feeding the existing 120/240V equipment from a direct feed from outside the building, thus allowing the old equipment to be de-energized. Leaving the old 2400V equipment energized presents numerous hazards due to personnel exposure to live parts as well as the risk of a damaging fault due simply to the age of the equipment and conductors.

VI. LIGHTING ASSESSMENT

A. Capacity: The existing Panel A, on Service 1, contains adequate space to serve any future lighting loads that would be added per future design projects.

B. Controls: The current edition of the Washington State NonResidential Energy Code requires daylight sensing in all areas that have vertical fenestration, as well as automatic shutoff controls. However, Section 101.3.2.2 of the 2009 Seattle Energy Code exempts Historic Buildings from this requirement with approval from code officials.

C. The current exterior lighting is not adequately protected from weather damage and the fixtures are nearing the end of their useful life. We recommend replacing the fixtures (see Image 10).

D. Emergency Exit Lighting: This building is not currently provided with code compliant emergency or exit lighting. It is our recommendation that battery backup exit signs with emergency lights be provided in the event of an emergency. These battery fixtures will have minimal impact on electrical load and may be fed from existing Panel A.

END OF REPORT

APPENDIX

Mechanical and Plumbing


Image 1: Existing roof drain


Image 2: Existing roof drain


Image 3: Existing roof drain


Image 4: Existing roof drain


Image 5: West side Boiler Room leak


Image 6: East side Boiler Rm drain pipe


Image 7: East side Boiler Rm drain pipe


Image 8: SE corner Engine Room


Image 9: Boiler access panel removed


Image 10: Boiler access panel removed


Image 11: Corrosion on boiler, piping

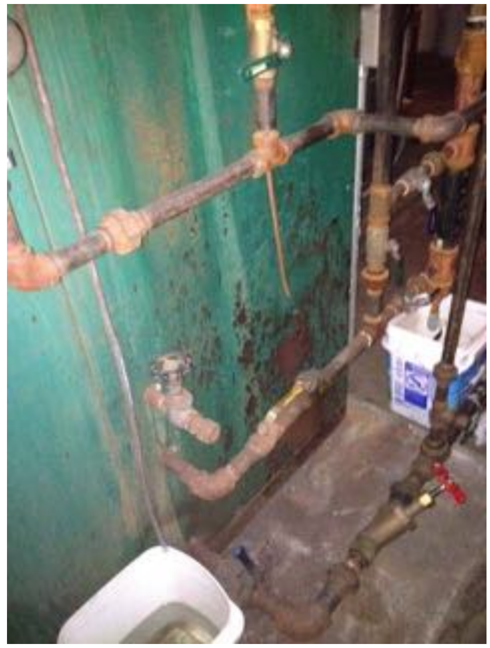


Image 12: Corrosion on boiler, piping

Images 13-16: Existing steam unit heaters, distribution piping and condensate pumps


Image 13


Image 14


Image 15


Image 16

Electrical

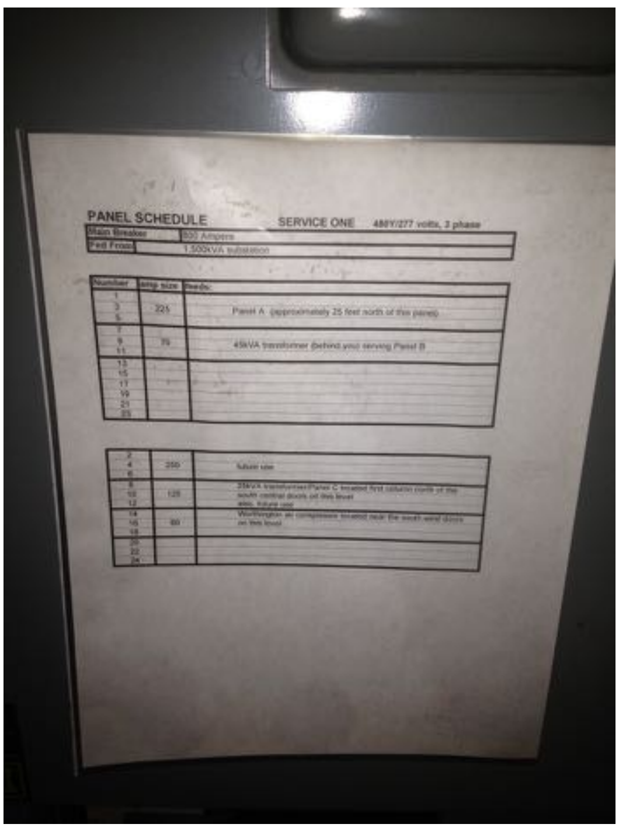


Image 1: MDP 1 Panel Schedule

Image 2: 500kW Boiler Disconnect

Image 3: Fuse Panel

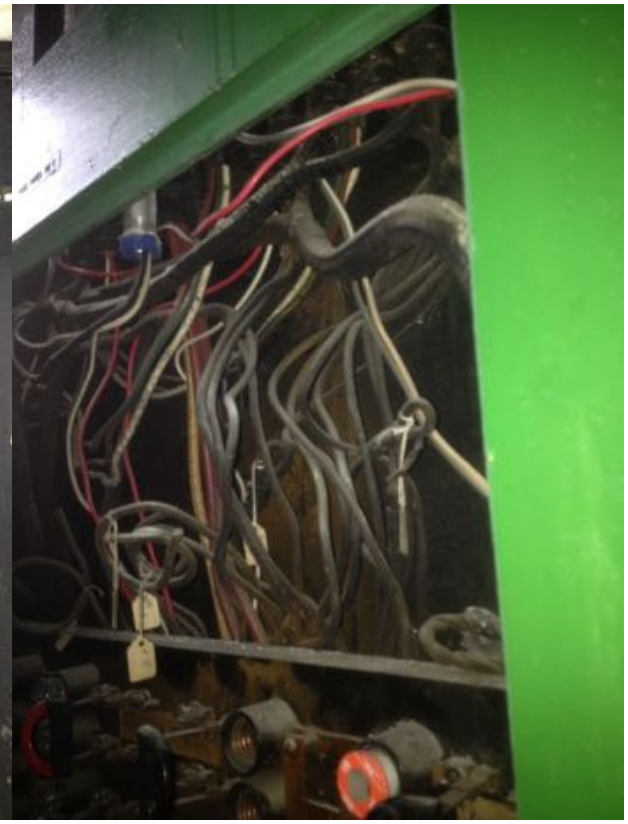


Image 4: Fuse Panel


Image 5: Fuse Panel

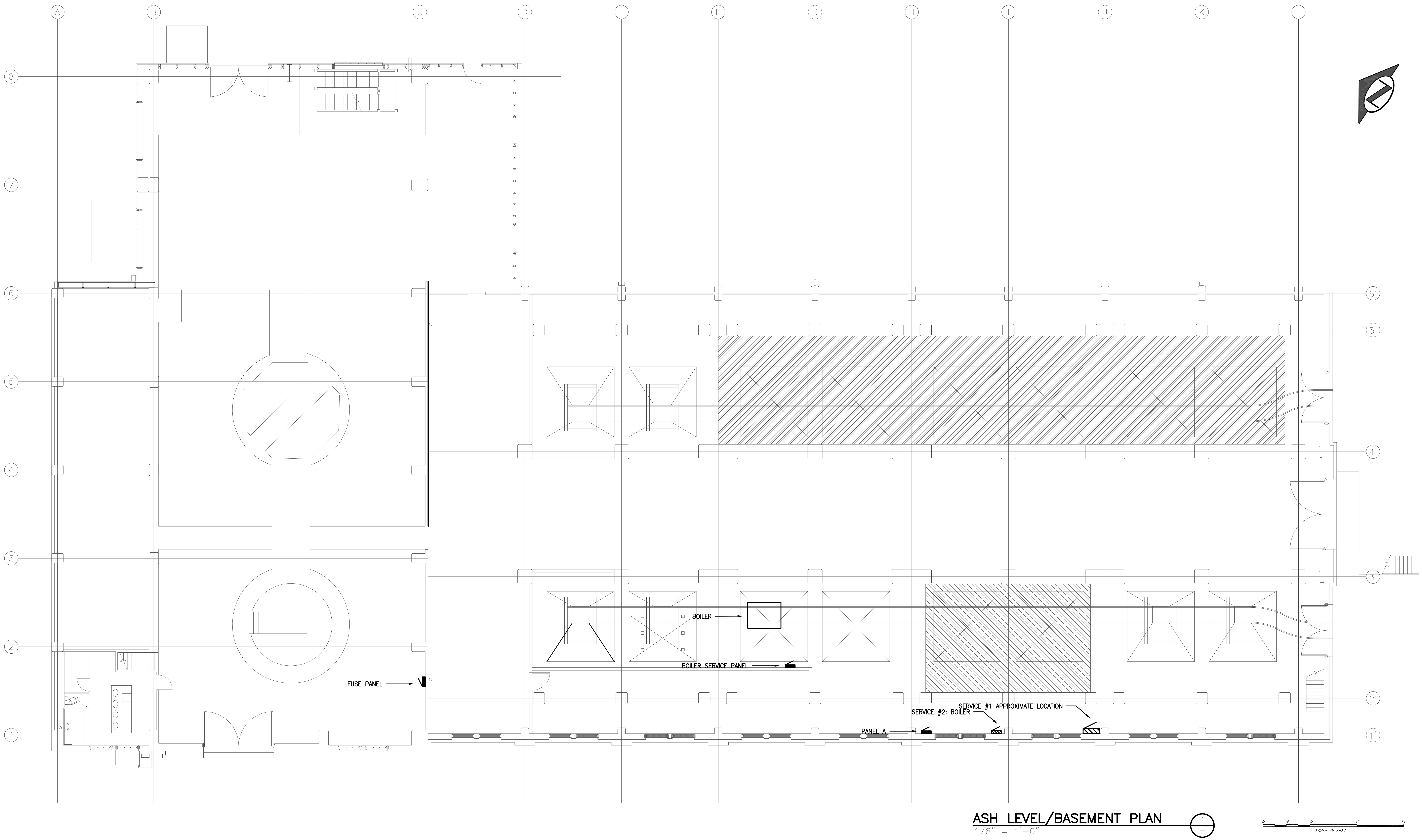

Image 6: Fuse Panel Door


Image 7: Aircraft Obstruction Light Base


Image 8: Fuse Panel


Image 9: Boiler Controller

Image 10: Exterior Light Fixture



ASH LEVEL/BASEMENT PLAN

1/8" = 1'-0"

J:\12Jobs\12412 Georgetown Steam Plant Renovation\0.0 DWGS\E\12412E1.01.dwg, ANSI-D: 22x34, MAXWELLJ, October 5, 2012 8:18 AM

ONE INCH AT FULL SIZE

REVISIONS

REV	DATE	IMAGE
DRAWN BY:	CHECKED BY:	APPROVED BY:
WORK ORDER #:		
DESCRIPTION		

WORK ORDER #:

BOLA ARCHITECTURE + PLANNING
159 WESTERN AVE. W. SUITE 486
SEATTLE WA 98119

ENDORSEMENTS

SIGNATURE	DATE
DRAWN:	09/25/2012
CHECK:	
DESIGN:	
CHECK:	

Seattle City Light
Power Production & Substations

APPROVED FOR SEATTLE CITY LIGHT

DATE

SUBJECT

LOCATION GEORGETOWN STEAM PLANT RENOVATION

TITLE ASH LEVEL/BASEMENT PLAN

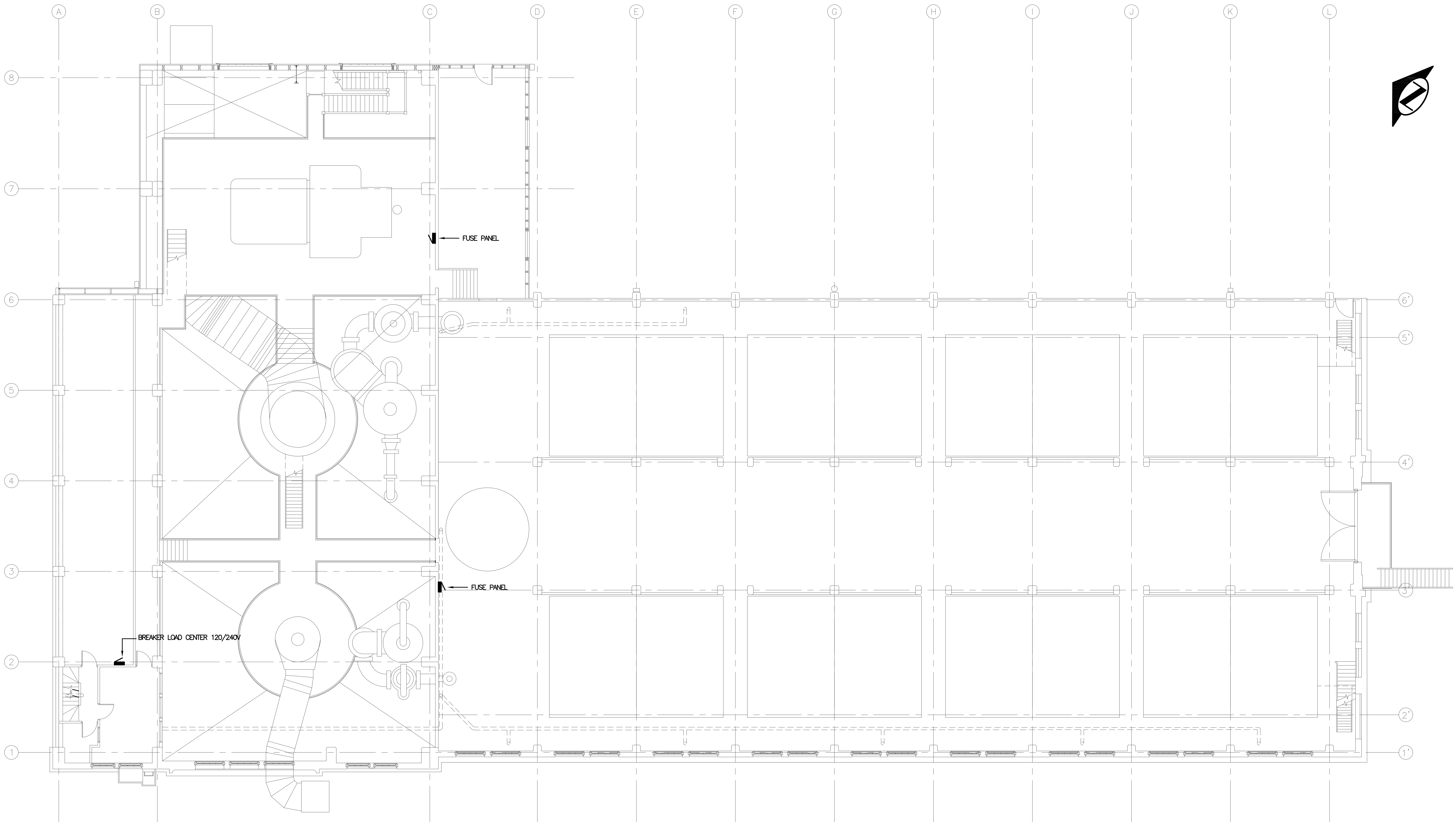
SHEET OF

CLASS \ SHEET E1.01

DRAWING NO.

SCALE 1/8"=1'-0"

REV. NO. 0



BOILER LEVEL FLOOR PLAN 1
1/8" = 1'-0"

8 4 0 8 16
SCALE IN FEET

J:\12Jobs\12412 Georgetown Steam Plant Renovation\0.0 DWGS\E\12412E1.02.dwg, ANSI-D: 22x34, MAXWELLJ, October 5, 2012 8:26 AM

ONE INCH
AT FULL SIZE

REVISIONS

REV	DATE	DRAWN BY:	CHECKED BY:	APPROVED BY:	IMAGE	WORK ORDER #:	DESCRIPTION

WORK ORDER #:

BOLA
ARCHITECTURE + PLANNING
159 WESTERN AVE. W. SUITE 486
SEATTLE WA 98119

ENDORSEMENTS	
SIGNATURE	DATE
DRAWN:	09/25/2012
CHECK:	
DESIGN:	
CHECK:	

Seattle City Light
Power Production &
Substations

APPROVED FOR SEATTLE CITY LIGHT

DATE

SUBJECT

LOCATION GEORGETOWN STEAM PLANT RENOVATION

TITLE BOILER LEVEL FLOOR PLAN

SHEET OF

CLASS \ SHEET E1.02

DRAWING NO.

SCALE 1/8"=1'-0"

REV. NO. 0

ARGUS PACIFIC
TRAINING • CONSULTING

Targeted Asbestos and Lead Assessment
- Exterior Renovation Report
Georgetown Steam Plant
BOLA Architecture + Planning
Seattle, Washington
Revised Version 3, December 10, 2012

July 17, 2012
Revision R.1, August 2, 2012
Revision R.2, November 6, 2012

PROVIDING
ORGANIZATIONS
WITH
HEALTH
AND
SAFETY
SOLUTIONS

ARGUS PACIFIC
TRAINING • CONSULTING

Project Title:	Targeted Asbestos and Lead Assessment - Exterior Renovation Georgetown Steam Plant BOLA Architecture + Planning 6605 13th Avenue South Seattle, Washington
Prepared for:	Ms. Rhoda Lawrence BOLA Architecture + Planning 159 Western Avenue West, Suite 486 Seattle, Washington 98119
Assessment Conducted by:	Argus Pacific, Inc. 1900 W. Nickerson Street, Suite 315 Seattle, Washington 98119
Argus Pacific Project Number:	640238R
Assessment Personnel:	Mr. Conor Foley AHERA-Accredited Building Inspector Number 135923 (exp. 3/21/2013) Peter Snider AHERA-Accredited Building Inspector Number 112750 (exp. 7/19/2013)
Assessment Date:	June 14 and July 9, 2012
Report Prepared by:	Conor Foley Industrial Hygienist Argus Pacific, Inc.
Report Reviewed by:	Scott R. Parker, Principal Senior Consultant Argus Pacific, Inc.
Report Issue Date:	July 17, 2012
Report Revision Date R.1:	August 2, 2012
Report Revision Date R.2:	November 5, 2012
Report Revision Date R.3:	December 10, 2012

TABLE OF CONTENTS

EXECUTIVE SUMMARY

BOLA Architecture + Planning retained Argus Pacific, Inc. (Argus Pacific) to conduct a targeted asbestos and lead assessment of the exterior of the Seattle City Light Georgetown Steam Plant located at 6605 13th Avenue South in Seattle, Washington. The scope of this targeted assessment included the exterior of the building and the vertical surfaces of the roof penthouse and monitor roofs. Argus Pacific's representative, Mr. Conor Foley, conducted the assessment on June 14 and July 9, 2012. Mr. Peter Snider assisted Mr. Foley on July 9, 2012. Additional paint chip samples were collected by Mr. Scott Parker on November 15, 2012. The scope of the services provided is described in Argus Pacific Proposal Number P640238 dated May 11, 2012.

Argus Pacific assessed the building for the following regulated building materials:

- Asbestos-containing materials (ACM);
- Assumed asbestos-containing materials; and
- Lead-containing coatings (paints).

Forty-four bulk samples of suspect asbestos-containing materials were collected and analyzed using Polarized Light Microscopy (PLM). Ten materials were found to contain greater than one percent asbestos and no materials were assumed to contain asbestos.

Eighteen paint chip samples were collected and analyzed for total lead content. Fifteen of the paint chip samples were found to contain detectable levels of lead.

1.0 INTRODUCTION

BOLA Architecture + Planning retained Argus Pacific, Inc. (Argus Pacific) to conduct a targeted asbestos and lead assessment of the exterior of the Seattle City Light Georgetown Steam Plant located at 6605 13th Avenue South in Seattle, Washington. The scope of this targeted assessment included the exterior of the building and the vertical surfaces of the roof penthouse and monitor roofs. Argus Pacific's representative, Mr. Conor Foley, conducted the assessment on June 14 and July 9, 2012. Mr. Peter Snider assisted Mr. Foley on July 9, 2012. The scope of the services provided is described in Argus Pacific Proposal Number P640238 dated May 11, 2012.

Argus Pacific assessed the building for the following regulated building materials:

- Asbestos-containing materials (ACM);
- Assumed asbestos-containing materials; and
- Lead-containing coatings (paints).

2.0 PROJECT BACKGROUND

This report presents the results of our targeted asbestos and lead assessment conducted of the Seattle City Light Georgetown Steam Plant in Seattle, Washington. The purpose of the assessment was to identify potential asbestos-containing material and lead-containing coatings prior to renovation and for purposes of hazard communication and on-going management. This assessment included the exterior and vertical surfaces of the rooftop penthouses and monitor roofs.

This assessment will assist BOLA Architecture + Planning with communicating the presence of lead-containing coatings and the presence, location, and quantity of ACM to employees, vendors, and contractors working in the building and to meet the requirements for an asbestos survey for the Puget Sound Clean Air Agency (PSCAA) and a good faith inspection as required by Washington State Department of Labor and Industries' Division of Occupational Safety and Health (DOSH) regulations prior to building renovation. Regulations require that a complete copy of this assessment be kept in a conspicuous location on-site at all times during activities that may impact known and suspect ACM.

2.1 Sources of Information

During the course of the assessment, the following personnel and drawings provided assistance to the Argus Pacific inspector:

- Ms. Rhoda Lawrence and Mr. Matt Hamel, BOLA Architecture + Planning
- *Georgetown Steam Plant Runway Extension Window Impacts,* Building Elevations – Window Survey, Stickney Murphy Romine Architects, dated October 21, 2005
- *Georgetown Steam Plant,* Building Repair Elevations and Details – City of Seattle Department of Lighting, dated march 26, 1969

2.2 Building Description

The Georgetown Steam Plant is located at 6605 13th Avenue South in Seattle, Washington and was constructed in 1906 and contains approximately 20,000 square feet of interior floor space. The museum has high ceilings and multiple mezzanine levels throughout the facility. The exterior walls of the museum are concrete with a textured cementious layer. The building contains approximately 163 windows. Exterior windows are mostly wood, with some metal windows on the east exterior. The raised penthouse and monitor roofs of the museum have concrete walls and wood windows.

3.0 ASBESTOS ASSESSMENT

3.1 Building Assessment

Mr. Foley and Mr. Snider, both Asbestos Hazard Emergency Response Act (AHERA)-accredited building inspectors (Certification 135923, expiration date: 3/21/2013 and Certification 112750, expiration date: 7/19/2013, respectively) from Argus Pacific, performed the sampling on June 14 and July 9, 2012. Argus Pacific's inspector collected fourty-four samples of materials identified as suspect ACM.

This assessment was conducted using a modified protocol adapted from AHERA. The protocol is as follows:

- Identify suspect asbestos-containing materials.
- Group materials into homogeneous sampling areas/materials.
- Quantify each homogeneous material and collect representative samples. The number of samples collected of miscellaneous materials was determined by the inspector.
- Samples of each material were taken to the substrate, ensuring that all components and layers of the material were included.
- Sample locations are referenced on the field data forms according to sample number.
- Sampling was performed by an AHERA-accredited building inspector, and the use of proper protective equipment and procedures was followed.

3.2 Sampling Procedures

This sampling was conducted using the following procedures:

1. Spread the plastic drop cloth (if needed) and set up other equipment, e.g., ladder.
2. Don protective equipment (respirator and protective clothing if needed).
3. Label sample container with its identification number and record number. Record sample location and type of material sampled on a sampling data form.
4. Moisten area where sample is to be extracted (spray the immediate area with water).
5. Extract sample using a clean knife, drill capsule, or cork boring tool to cut out or scrape off approximately one tablespoon of the material. Penetrate all layers of material.
6. Place sample in a container and tightly seal it.

7. Wipe the exterior of the container with a wet wipe to remove any material that may have adhered to it during sampling.
8. Clean tools with wet wipes and wet mop; or vacuum area with HEPA vacuum to clean all debris.
9. Discard protective clothing, wet wipes and rags, cartridge filters, and drop cloth in a labeled plastic waste bag.

3.3 Analytical Methodology

Suspect ACMs were sampled in general accordance with 40 CFR 763.86 by an Environmental Protection Agency (EPA) AHERA-accredited building inspector. Each sample was collected and stored in a heavy-duty, self-sealing plastic bag, and delivered to Seattle Asbestos Test, LLC in Bellevue, Washington. Samples were analyzed via polarized light microscopy (PLM) in accordance with EPA/600/R-93/116.

Table 3.3-1 provides a list of suspect homogeneous sampling area (HSA) material descriptions, material locations, and results for this sampling. Asbestos-containing materials and assumed asbestos-containing materials are presented in bold text. Refer to the attached Figures for sample locations and material extents (as applicable). Refer to the attached photographs for HSA pictures. If asbestos was not identified in the material the results are considered non-detect for asbestos (ND).

Table 3.3-1. Results of Bulk Sample Analyses

HSA ID, Material Description, and AHERA Classification	Material Location	HSA Results
1: Grey texture material with white paint (S)	On vertical surfaces throughout exterior of building	ND
1A: Grey/tan window putty glazing with black asphaltic patching material (M)	**On wood windows at muntin and glass seam for 72” x48” windows on monitor roofs**	**ND to 2%chrysotile**
1AA: Off-white window putty glazing and black asphaltic patching material (M)	On wood windows at muntin and glass seam for 72” x 48” windows with vents and plywood on monitor roofs	ND
1B: Black asphaltic patching material and beige window putty glazing (M)	**On wood windows at muntin and glass seam for 88” x 54” windows on monitor roofs**	**Paint/patching: <1% to 2% chrysotile Glazing: ND**
2: Grey/white window putty glazing (M)	On wood windows at muntin and glass seam for 60” x 52” windows on south exterior	ND
3: White window putty glazing with paint (M)	On wood windows at muntin and glass seam for 48” x 84” windows on east end of south exterior	ND
4: Grey window putty glazing and black brittle material (M)	On metal windows at muntin and glass seam for 52” x 72” windows on north end of east exterior	Glazing: ND Brittle material: ND

ARGUS PACIFIC
TRAINING • CONSULTING

Table 3.3-1. Results of Bulk Sample Analyses

HSA ID, Material Description, and AHERA Classification	Material Location	HSA Results
4A: Black sealant with paint (M)	On metal HSA 4 windows at some metal muntin and glass seams	2% chrysotile
5: Off-white window putty glazing with paint (M)	On windows for wood doors on south exterior	ND to 2% chrysotile
6: Grey cementious material and black asphaltic material (S) (NOTE: same HSA as #17 in Roofing Assessment report)	Patching for cracks on vertical surfaces of north west wall of engine room monitor roof	Cementious material: ND Asphaltic material: 4% chrysotile
7: White/grey window putty glazing (M)	On wood windows at muntin and glass seam for 33.5” x 54” windows on penthouse on north, east, and west sides	ND to 2% chrysotile
8: Beige/grey window putty glazing (M)	On wood windows at muntin and glass seam for 33.5” x 54” lower windows on west exterior	ND to 2%chrysotile
9: Window putty glazing with 4 by 3 window pane pattern (M)	On wood windows at muntin and glass seam for upper windows on west exterior	Assumed (inaccessible)
10: Window putty glazing with 4 by 3 window pane pattern (M)	On wood windows at muntin and glass seam for windows under “1906” sign on west exterior	Assumed (inaccessible)
11: Window putty glazing with 3 by 3 window pane pattern (M)	On wood windows at muntin and glass seam for windows directly to the north and directly to the south of HSA 10 windows	ND to 2% chrysotile
12: Window putty glazing with 4 by 4 window pane pattern (M)	On wood windows at muntin and glass seam for row of windows (3 EA) under HSA 10 windows	Assumed (inaccessible)
13: Window putty glazing (M)	On windows at muntin and glass seam for north exterior windows	Assumed (inaccessible)
14: Window putty glazing with 4 by 4 window pane pattern (M)	On wood windows at muntin and glass seam for 2 windows under HSA 9 windows on north end of west exterior	Assumed (inaccessible)
15: White and grey window putty glazing (M)	On windows at muntin and glass seam for windows at far north end of east exterior	ND to 2% chrysotile
16: Beige window putty glazing with paint (M)	On windows for wood doors at north end of west exterior	2% chrysotile

ND: none detected, HSA: material that is uniform in color, texture, general appearance, and construction and application date
S: Surfacing material per AHERA, T: Thermal system insulation per AHERA, M: Miscellaneous material per AHERA

Additional ACMs may be present in inaccessible or concealed spaces. These spaces include, but are not limited to, materials inside the building, fire doors, electrical systems, interior of mechanical components, beneath foundation pads, etc. If future maintenance, renovation, and/or demolition activities make these areas accessible, Argus Pacific recommends that a thorough assessment of these spaces be conducted at that time to identify and confirm the presence or absence of additional ACMs. Until then, all such unidentified materials must be treated as assumed ACMs in accordance with applicable federal, state, and local regulations.

If the analytical results indicate that all the samples collected per HSA do not contain asbestos, then the HSA (material) is considered a non-ACM. However, if the analytical results of one or more of the samples collected per HSA indicate that asbestos is present in quantities of greater than one percent asbestos as defined by the EPA, all of the HSA (material) is considered to be an ACM regardless of any other analytical.

Any material that contains greater than one percent asbestos is considered an ACM and must be handled according to Occupational Safety and Health Administration (OSHA), EPA, and applicable state and local regulations.

4.0 LEAD ASSESSMENT

Homogeneous areas of suspected lead-containing coatings (paints) were identified and sampled in accessible areas throughout the exterior of BOLA Architecture + Planning's Georgetown Steam Plant located at 6605 13th Avenue South in Seattle, Washington. Homogeneous painted surfaces were defined by substrate, application, and color.

4.1 Sampling Methodology

Paint chip samples were collected to the substrate to ensure that all layers present on the substrate were included in the laboratory analysis. Each sample was collected and stored in a heavy-duty, self-sealing plastic bag and delivered to NVL Laboratories in Seattle, Washington. Samples were analyzed via Atomic Absorption Spectrophotometry in accordance with Method EPA 7000B. NVL Laboratories in Seattle, Washington is accredited by the American Industrial Hygiene Association (AIHA) for lead analysis.

4.2 Lead Sampling Results

Eighteen paint chip samples were collected and analyzed and fifteen of the samples had reportable levels of lead. One piece of lead metal fascia was identified on the exterior of the building. The results of the analyses are presented in Table 4.2-1.

Table 4.2-1. Paint Chip Sample Results

Sample Number and Description	Paint Location	Sample Result in parts per million (ppm)
Pb1: White paint on concrete	Throughout building exterior	<48
Pb2: White/grey paint on wood	Wood doors on south exterior	40,000

Sample Number and Description	Paint Location	Sample Result in parts per million (ppm)
Pb3: Black paint on wood	On HSA 1A and 1B wood window sashes and muntins	31,000
Pb4: White paint on wood	On HSA 1AA wood window sashes and muntins	50,000
Pb5: Blue paint on wood	On HSA 7 wood window sashes, muntins and sills	32,000
Pb6: Blue paint on metal	On HSA 4 metal window sashes and muntins	590
Pb7: Blue paint on wood	On HSA 2 wood window sashes and muntins	71,000
Pb8: Light blue paint on metal	On metal louvers on south exterior	3,300
Pb9: Pliable metal fascia	Above east entry doorway	Assumed
PB-ST1: Black paint on large metal stacks	Monitor roof of boiler room	730 to 2,200
PB-ST2: Black paint on small metal stacks	Monitor roof and main roof of boiler room	1,000
PB-ST3: White paint on large stacks	Main roof of boiler room, north end	280,000
PB-EXTCT: Light grey paint on exterior concrete	All four sides of building	<39 to 2,300
PB-EXCM: Light grey paint on exterior corrugated metal	Exterior east face of engine room	<170

<: below the reporting limit

5.0 CONCLUSIONS AND RECOMMENDATIONS

On June 14 and July 9, 2012, Argus Pacific conducted a renovation-level regulated building materials assessment of the Georgetown Steam Plant located at 6605 13th Avenue South in Seattle, Washington.

5.1 Asbestos

Some materials were assumed to contain asbestos because they were not accessible at the time of the assessment. This applies primarily to materials at elevations that could not be reached by the boom lift because the boom lift could only access the east and south sides of the building due to the ground conditions. The following table identifies the confirmed ACM and assumed ACM.

ARGUS PACIFIC
TRAINING • CONSULTING

Table 5.1-1. ACM and Assumed ACM

HSA ID, Material Description, and AHERA Classification	Material Location	HSA Quantity (approximate)
1A: Grey/tan window putty glazing (M)	On wood windows at muntin and glass seam for 72" x48" windows on monitor roofs	18 EA
1B: Black paint/patching and beige window putty glazing (M)	On wood windows at muntin and glass seam for 88" x 54" windows on monitor roofs	4 EA
4A: Black sealant with paint (M)	On metal HSA 4 windows (52" x 72") at some metal muntin and glass seams	3 EA
5: Off-white window putty glazing with paint (M)	On windows for wood doors on south exterior	8 EA
6: Grey cementious material and black asphaltic material (S)	Patching for cracks on vertical surfaces of north west wall of engine room monitor roof	300 SF (NOTE: same HSA as #17 in Roofing Assessment report)
7: White/grey window putty glazing (M)	On wood windows at muntin and glass seam for 33.5" x 54" windows on penthouse on north, east, and west sides	5 EA
8: Beige/grey window putty glazing (M)	On wood windows at muntin and glass seam for 33.5" x 54" lower windows on west exterior	22 EA
9: Window putty glazing with 4 by 3 window pane pattern (M)	On wood windows at muntin and glass seam for upper windows on west exterior	18 EA
10: Window putty glazing with 4 by 3 window pane pattern (M)	On wood windows at muntin and glass seam for windows under "1906" sign on west exterior	18 EA
11: Window putty glazing with 3 by 3 window pane pattern (M)	On wood windows at muntin and glass seam for windows directly to the north and directly to the south of HSA 10 windows	16 EA
12: Window putty glazing with 4 by 4 window pane pattern (M)	On wood windows at muntin and glass seam for row of windows (3 EA) under HSA 10 windows	3 EA
13: Window putty glazing (M)	On windows at muntin and glass seam for north exterior windows	3 EA

HSA ID, Material Description, and AHERA Classification	Material Location	HSA Quantity (approximate)
14: Window putty glazing with 4 by 4 window pane pattern (M)	**On wood windows at muntin and glass seam for 2 windows under HSA 9 windows on north end of west exterior**	**2 EA**
15: White and grey window putty glazing (M)	**On windows at muntin and glass seam for 51" x 47" windows at far north end of east exterior**	**5 EA**
16: Beige window putty glazing with paint (M)	**On windows for wood doors at north end of west exterior**	**16 EA**

HSA: material that is uniform in color, texture, general appearance, and construction and application date
S: Surfacing material per AHERA, T: Thermal system insulation per AHERA, M: Miscellaneous material per AHERA

Asbestos-related work must be performed in compliance with Washington State worker protection and environmental protection regulations. See WAC 296-62, WAC 296-65, and PSCAA Regulation III, Article 4 for additional information.

5.2 Lead

Seven of the eight paints sampled and analyzed contained detectable levels of lead. The Washington State Department of Labor and Industries requires an exposure assessment be conducted during operations that may disturb the lead paint in such a way that the airborne exposure may reach or exceed the Action level of 30 micrograms per cubic meter ($\mu g/m^3$) or the Permissible Exposure Limit of 50 $\mu g/m^3$. The worker protection requirements of WAC 296-62-155-176 "Lead in Construction" may apply.

Some of the coatings contained detectable levels of lead. If this building or portions of it will be demolished and disposed of, a toxicity characteristic leachate procedure (TCLP) sample that is representative of the waste stream must be collected and analyzed per the requirements of WAC 173-303. If the results of the TCLP analysis determine the waste to be a "dangerous waste" as defined by WAC 173-303, it must be disposed of accordingly.

One piece of pliable lead fascia metal was identified above the east entrance to the steam plant.

The Georgetown Steam Plant is not defined as "target housing" or a "child-occupied facility" as defined by the Washington State Department of Commerce Lead Renovation, Repair, and Painting (RRP) regulation WAC 365-230. Therefore the lead paint chip sampling and reporting conducted as a part of this assessment does not meet the RRP requirements.

6.0 LIMITATIONS

This report presents the results of the asbestos and lead coatings sampling conducted of the Georgetown Steam Plant located at 6605 13th Avenue South in Seattle, Washington. The assessment was for the purposes of identifying ACM and lead-containing paint prior to renovation.

Regulated building material assessments are non-comprehensive and subject to many limitations, including those presented below. Our assessment has considered risks pertaining to asbestos and lead in coatings on the exterior of the building; however, this assessment is limited to only those locations and materials assessed. This assessment was not designed to identify all potential concerns or to eliminate all risks associated with renovation, demolition, material removal, construction, or transferring of property title. Evaluation of other risks not specifically described in the Scope of Work have not been included; for example: structural integrity; engineering loads; electrical; mechanical; radon gas; slope stability; building settlement; and evaluation of toxic and hazardous substances in, or in contact with, soil and groundwater. No warranty, expressed or implied, is made.

Argus Pacific has performed the services set forth in the Scope of Work in accordance with generally accepted industrial hygiene practices in the same or similar localities, related to the nature of the work accomplished, at the time the services were performed.

The regulated building materials and conditions presented in this report represent those observed on the dates we conducted the sampling. This sampling is intended for the exclusive use of BOLA Architecture + Planning for specific application to the referenced property. This assessment does not replace nor can be used as professionally developed construction or demolition plans, specifications, or bidding documents. This report is not a legal opinion.

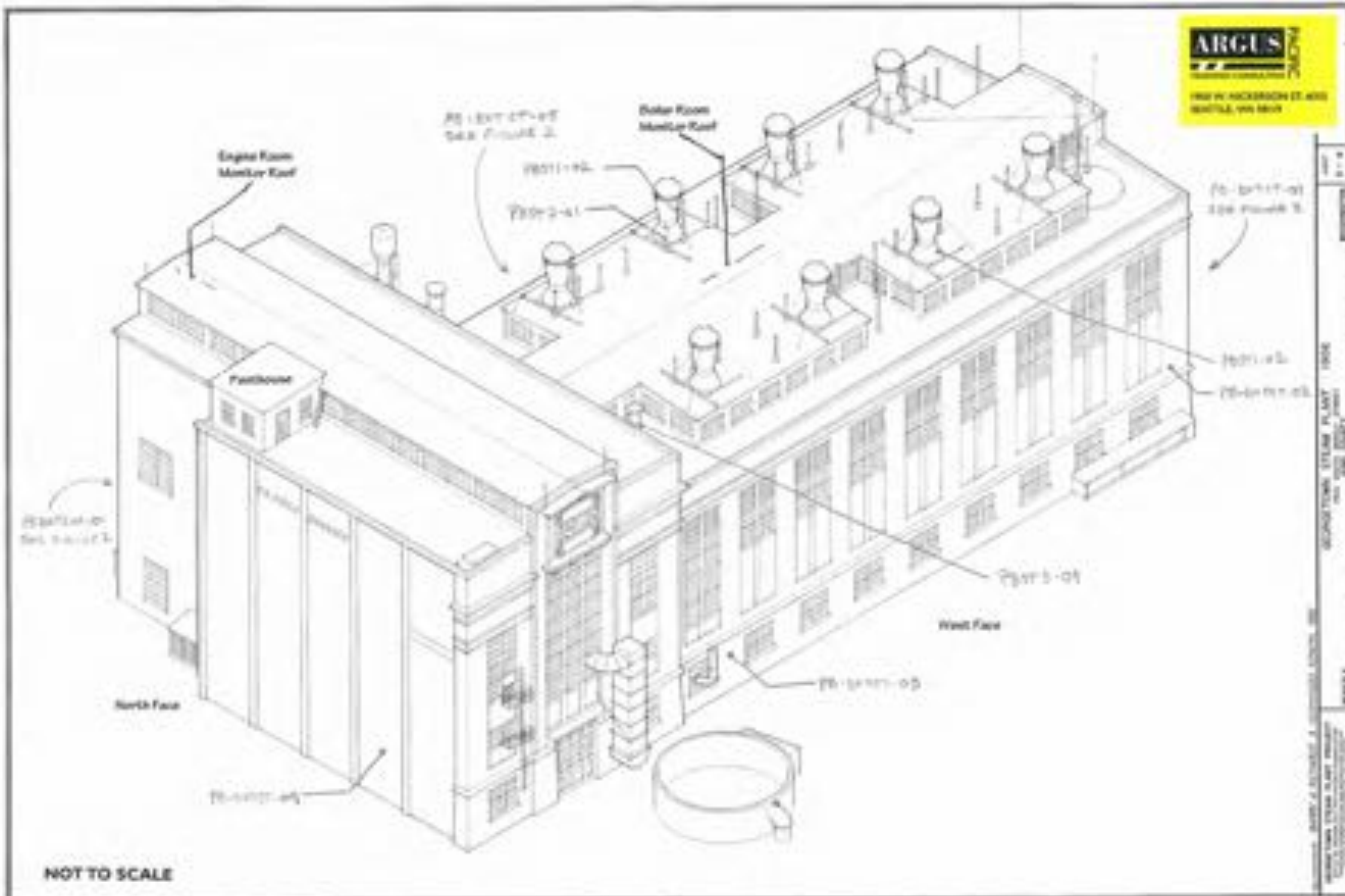
Prepared by:

Conor Foley
Industrial Hygienist
Argus Pacific, Inc.

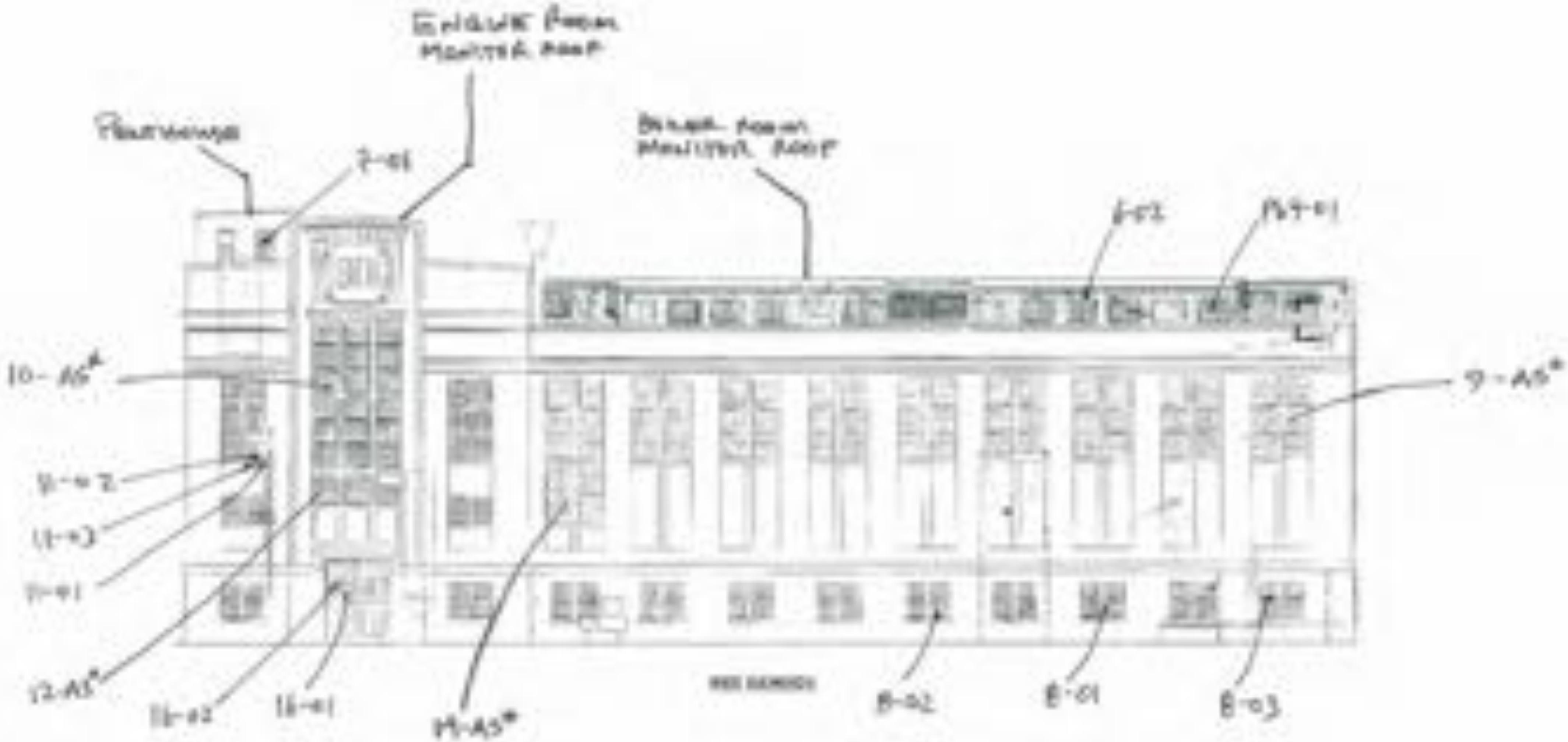
Reviewed by:

Scott R. Parker, Principal
Senior Consultant
Argus Pacific, Inc.

Figures


ARGUS
Engine Room Monitor Roof
Boiler Room Monitor Roof
Penthouse
West Face
North Face
NOT TO SCALE

ARGUS

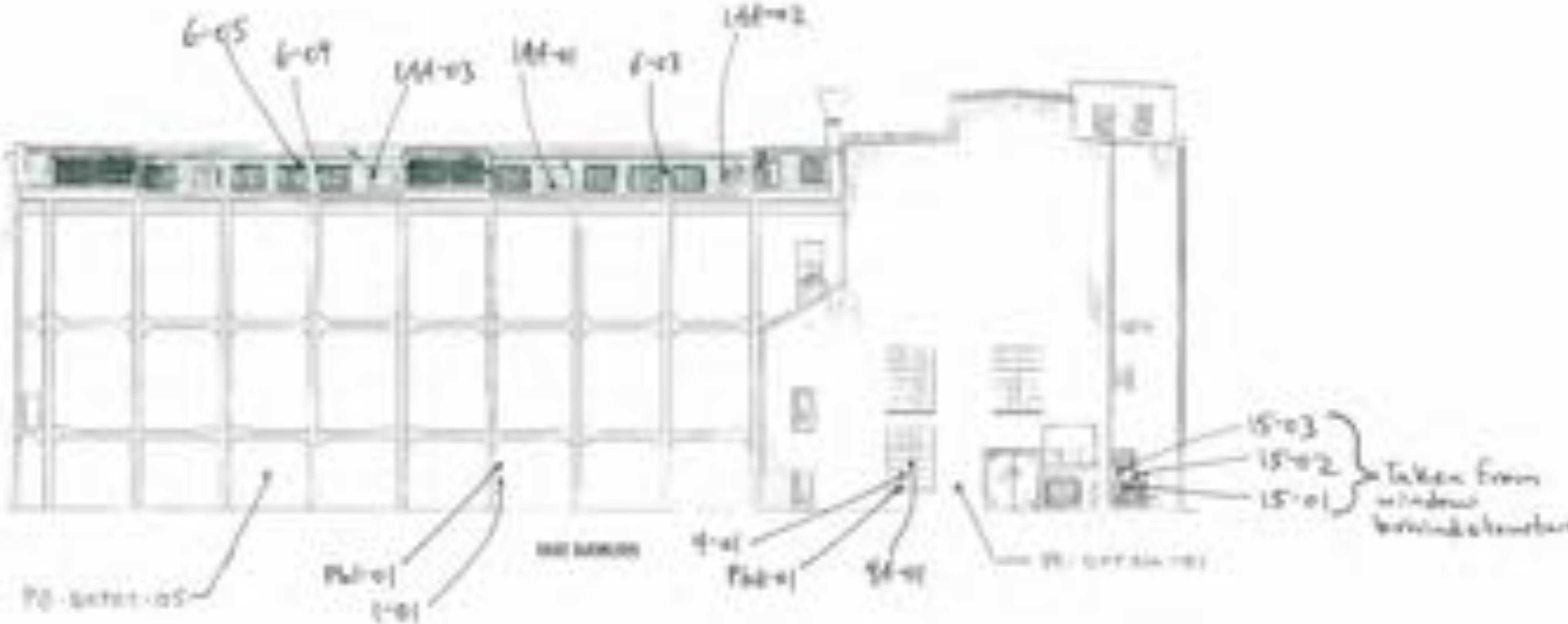


*A5= ASSUMED TO BE ASBESTOS-CONTAINING MATERIAL INACCESSIBLE

NOT TO SCALE

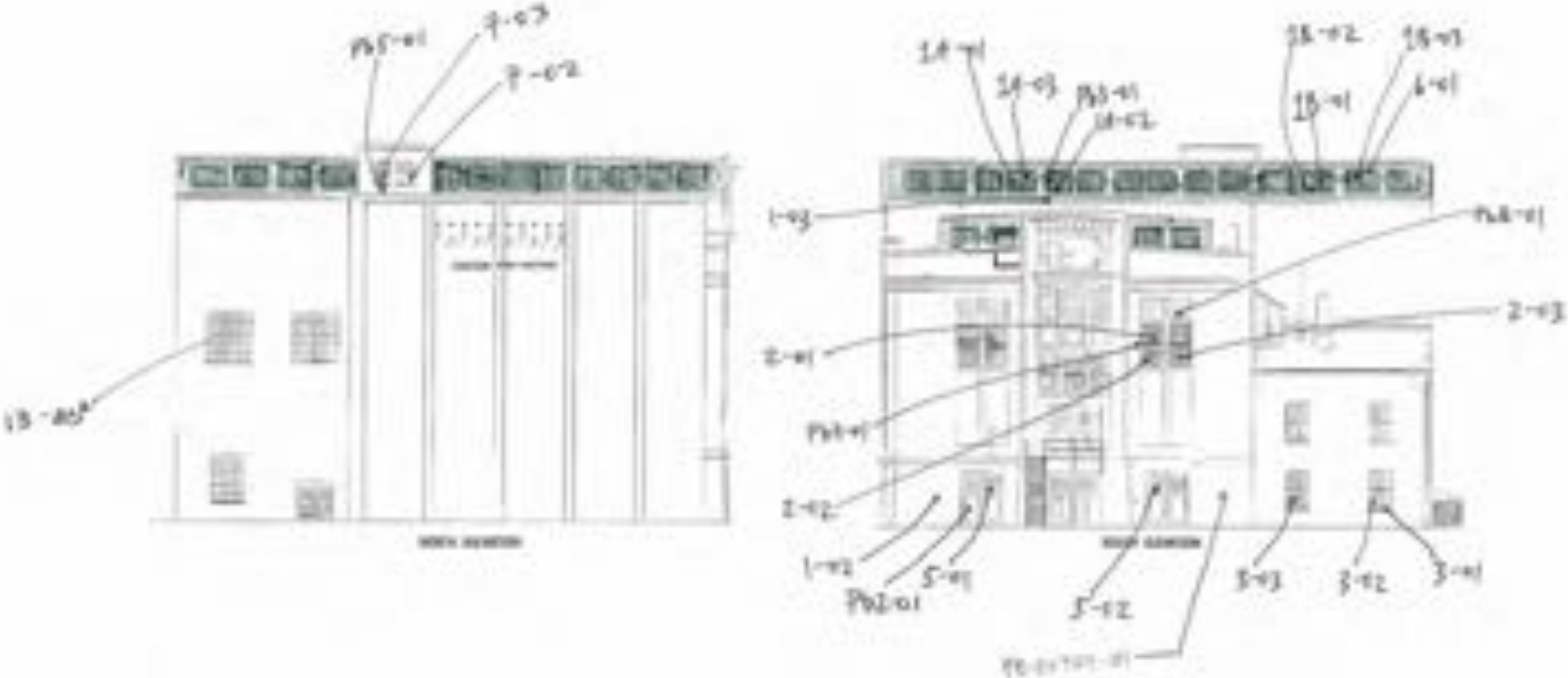
Figure 1
Bulk Sample Locations
West Exterior

ARGUS



NOT TO SCALE

Figure 2
Bulk Sample Locations
East Exterior



*AS = ASSUMED TO BE ASBESTOS-CONTAINING MATERIAL [illegible]

Figure 3
Bulk Sample Locations
North and South Exteriors

NOT TO SCALE

ARGUS

LEGEND – WEST ELEVATION

Asbestos-containing gray/tan window putty glazing with black asphaltic patching material
HSA ID: 16

Asbestos-containing white/gray window putty glazing
HSA ID: 7

Asbestos-containing beige/gray window putty glazing
HSA ID: 8

Assumed asbestos-containing window putty putty glazing with 4 by 3 window pane pattern for upper windows along west exterior
HSA ID: 9

Assumed asbestos-containing Window putty glazing with 4 by 8 window pane pattern for windows under "HSA" sign
HSA ID: 10

Asbestos-containing window putty glazing with 3 by 3 window pane pattern
HSA ID: 11

Assumed asbestos-containing window putty glazing under HSA 10 windows
HSA ID: 12

Assumed asbestos-containing window putty glazing with 4 by 4 window pane pattern
HSA ID: 14

Asbestos-containing beige window putty glazing with paint
HSA ID: 18

NOT TO SCALE

Figure 4
Approximate ACM Locations
West Exterior

ARGUS PACIFIC

LEGEND – EAST ELEVATION

- Asbestos-containing grey/tan window putty glazing with black asphaltic patching material HSA ID: 1A
- Asbestos-containing black sealant with paint HSA ID: 4A
- Asbestos-containing white/grey window putty glazing HSA ID: 7
- Asbestos-containing white and grey window putty glazing HSA ID: 15

NOT TO SCALE

Figure 5
Approximate ACM Locations
East Exterior

LEGEND – NORTH AND SOUTH ELEVATIONS

- Asbestos-containing gray/tan window putty glazing with black asphaltic patching material HSA ID: 1A
- Asbestos-containing black asphaltic patching material and beige window putty glazing HSA ID: 1B
- Asbestos-containing off white window putty glazing for windows on south exterior doors HSA ID: 6
- Asbestos-containing White/gray window putty glazing HSA ID: 7
- Assumed asbestos-containing window putty glazing HSA ID: 13

NOT TO SCALE

Figure 6
Approximate ACM Locations
North and South Exteriors

Photographs

Photograph 1. HSA 1: Grey texture material with white paint (S)

Photograph 2. HSA 1A: Grey/tan window putty glazing with black asphaltic patching material (M)

Photograph 3. HSA 1AA: Off-white window putty glazing and black asphaltic patching material (M)

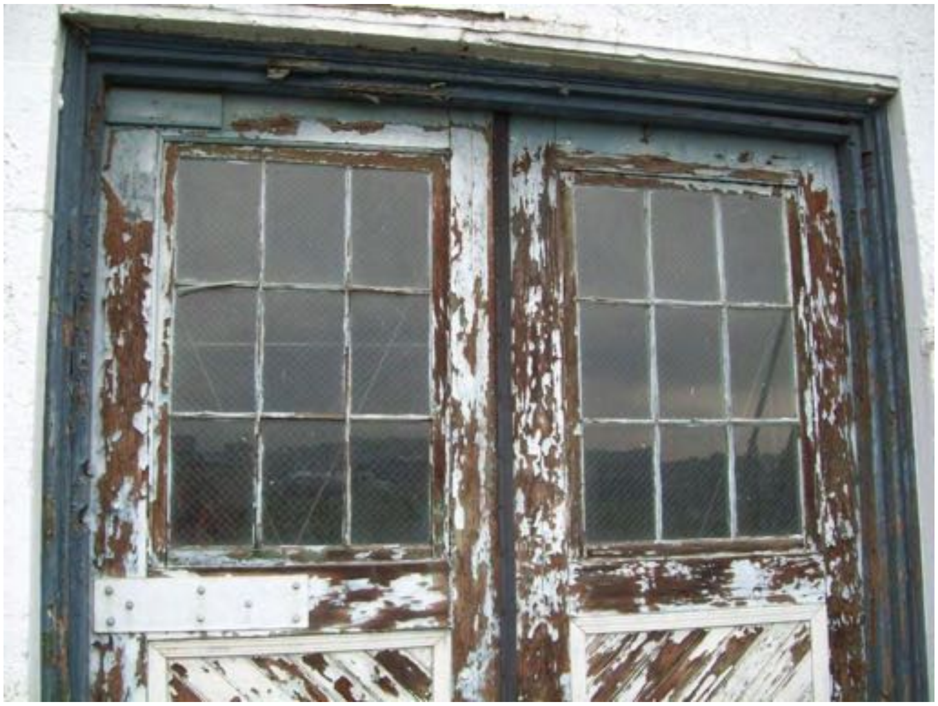
Photograph 4. HSA 1B: Black asphaltic patching material and beige window putty glazing (M)

Photograph 5. HSA 2: Grey/white window putty glazing (M)

Photograph 6. HSA 3: White window putty glazing with paint (M)

Photograph 7. HSA 4: Grey window putty glazing and black brittle material (M)

Photograph 8. HSA 4A: Black sealant with paint (M)

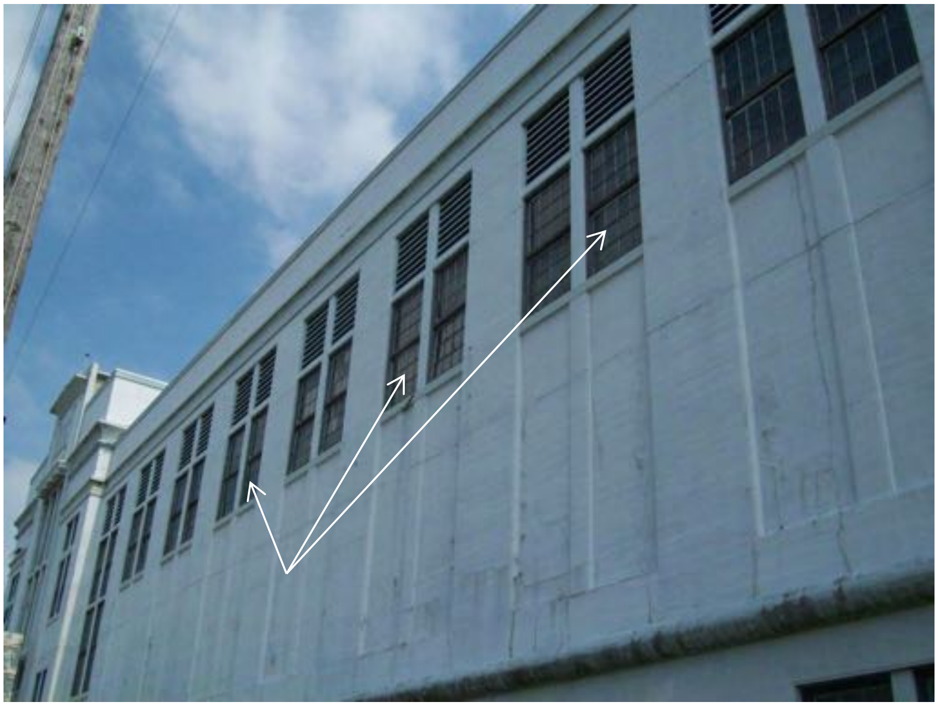


Photograph 9. HSA 5: Off-white window putty glazing with paint (M)

Photograph 10. HSA 6: Grey cementious material and black asphaltic material (S)

Photograph 11. HSA 7: White/grey window putty glazing (M)

Photograph 12. HSA 8: Beige/grey window putty glazing (M)

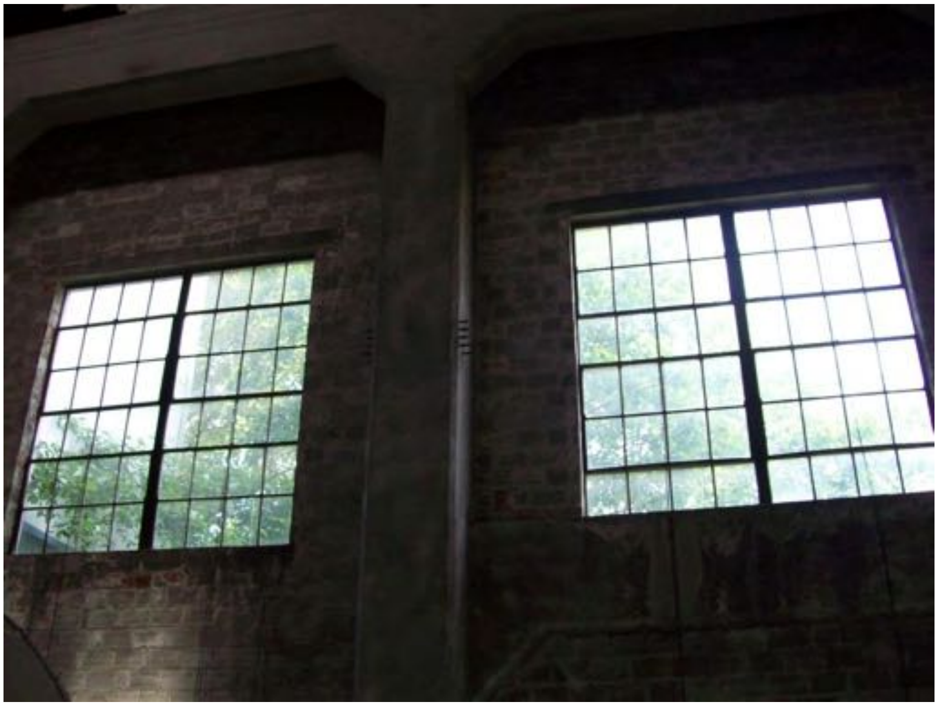


Photograph 13. HSA 9: Window putty glazing with 4 by 3 window pane pattern (M)

Photograph 14. HSA 10: Window putty glazing with 4 by 3 window pane pattern (M)

Photograph 15. HSA 11: Window putty glazing with 3 by 3 window pane pattern (M)

Photograph 16. HSA 12: Window putty glazing with 4 by 4 window pane pattern (M)



Photograph 17. HSA 13: Window putty glazing (M)

Photograph 18. HSA 14: Window putty glazing with 4 by 4 window pane pattern (M)

Photograph 19. HSA 15: White and grey window putty glazing for windows at far north end of east exterior (M)

Photograph 20. HSA 16: Beige window putty glazing with paint on windows for wood doors at north end of west exterior (M)

Appendix A
Asbestos Laboratory Analytical Results

SEATTLE ASBESTOS TEST, LLC

NVLAP Accreditation Lab Codes:
LYNNWOOD LAB: 200768-0, BELLEVUE LAB: 200876-0

19711 Scriber Lake Road, Suite D, Lynnwood, WA 98036, Tel:425.673.9850
12727 Northup Way, Suite 1, Bellevue, WA 98005, Tel:425.861.1111
www.seattleasbestostest.com, admin@seattleasbestostest.com

Date Analyzed: 6/26/2012

Client Job #: 640238R.000 4

Project Loc.: Georgetown Steam Plant

Laboratory Batch#: 201212038

Samples Received: 35

Mr. Scott Parker / Mr. Conor Foley
Argus Pacific
1900 W Nickerson St # 315, Seattle, WA 98119

Enclosed please find the test results for the bulk samples submitted to our laboratory for asbestos analysis. Analysis was performed using polarized light microscopy (PLM) in accordance with Test Method US EPA/600/R-93/116.

Percentages for this report are done by visual estimate. Since variation in data increases as the quantity of asbestos decreases toward the limit of detection, the EPA recommends point counting for samples containing between <1% and 10% asbestos (NESHAP, 40 CFR Part 61). Statistically, point counting is a more accurate method. If you feel a point count might be beneficial, please feel free to call and request one.

The test results refer only to the samples or items submitted and tested. The accuracy with which these samples represent the actual materials is totally dependent on the acuity of the person who took the samples. This report must not be used by the client to claim product certification, approval, or endorsement by Seattle Asbestos Test, LLC, NVLAP, NIST, or any agency of the Federal government.

This report is highly confidential and will not be released without your consent. Samples are archived for two weeks after the analysis, and disposed of as hazardous waste thereafter.

Thank you for using our service and let us know if we can further assist you.

Sincerely

Steve (Fanyao) Zhang
President

#201212038

SEATTLE ASBESTOSTEST, LLC — *Analyzing Quality*

Lynnwood Lab: 19711 Scriber Lake Road, Suite D, WA 98036, Tel:425.673.9850, Fax:425.673.9810
Bellevue Lab: 12737 Northup Way, Suite 1, Bellevue, WA 98005, Tel:425.861.1111, Fax:425.861.1118
Email: admin@seattleasbestostest.com, Website: www.seattleasbestostest.com

CHAIN OF CUSTODY

☐ Bulk Asbestos ☐ Point Count 400 ☐ Point Count 1000 ☐ Point Count Gravimetric ☐ Other (Specify) ____
☐ 1 Hour ☐ 2 Hours ☐ Same day (4 to 6 Hrs.) ☐ 1 Day ☒ 5 Days

Argus Pacific

1900 W Nickerson St # 315, Seattle, WA 98119 Tel: (206) 285-3373 Fax: (206) 285-3927

Number of Samples 35 PO# 6110238E.0004 Project Location Georgetown Steam Plant

Project Manager (Check one or more):

☐	Christopher Selders	206.462.9355	chris@arguspacific.com	☒	Conor Foley	650.743.4363	conor@arguspacific.com
☐	Meagan Yoshimoto	206.714.7152	meagan@arguspacific.com	☐	Nicole Gladu	206.518.6094	nicole@arguspacific.com
☒	Scott Parker	206.714.7152	sparker@arguspacific.com	☐	Scott Rinear	206.571.5891	srinear@arguspacific.com
☐	Tim Nickell		tim@arguspacific.com	☐			

SEQ#	CLIENT SAMPLE #	SAMPLE DESCRIPTION	LOCATION	NOTES
61	1-01			
62	1-02			
63	1-03			
64	1-04			
65	1-05			
66	1-06			
67	1-07			
68	1A-01			
69	1A-02			
70	1A-03			
71	1AA-01			
72	1AA-02			
73	1AA-03			
74	1B-01			
75	1B-02			
76	1B-03			
77	2-01			
78	2-02			
79	2-03			
80	3-01			

	Print Name	Signature	Company	Date	Time
Sampled	Conor Foley	[signature]	Argus Pacific	6/15/12	4:00pm
Relinquished	Conor Foley	[signature]	Argus Pacific	6/21/12	9:05am
Delivered	Conor Foley	[signature]	Argus Pacific	6/21/12	9:05am
Received	E. Dutton	[signature]	Seattle Asbestos Test - B	6/21/2012	0905
Analyzed	E. Dutton	[signature]	Seattle Asbestos Test - B	6/26/2012	1405
Reported	[signature]		Seattle Asbestos Test	6/26/12	

Results reporting method: ☐ Phone ☐ Fax ☒ Email ☐ Pick-up

☐ Composite all wallboard samples ☐ Text result to phone ☐ Point count samples with ___ % or less asbestos

#201212038

SEATTLE ASBESTOSTEST, LLC

Analyzing Quality

Lynnwood Lab: 19711 Scriber Lake Road, Suite D, WA 98036, Tel 425.673.9850, Fax 425.673.9810
Bellevue Lab: 12727 Northup Way, Suite 1, Bellevue, WA 98005, Tel 425.861.1111, Fax 425.861.1118
Email: admin@seattleasbestostest.com, Website: www.seattleasbestostest.com

CHAIN OF CUSTODY

☐ Bulk Asbestos ☐ Point Count 400 ☐ Point Count 1000 ☐ Point Count Gravimetric ☐ Other (Specify) ______

☐ 1 Hour ☐ 2 Hours ☐ Same day (4 to 8 Hrs.) ☐ 1 Day ☒ 5 Days

Argus Pacific

1900 W Nickerson St # 315, Seattle, WA 98119 Tel: (206) 285-3373 Fax: (206) 285-3927

Number of Samples 35 PO# 0902380.0004 Project Location Georgetown Steam Plant

Project Manager (Check one or more):

☐	Christopher Selders	206.462.9355	chris@arguspacific.com	☒	Conor Foley	650.743.4363	conor@arguspacific.com
☐	Meagan Yoshimoto	206.714.7152	meagan@arguspacific.com	☐	Nicole Gladu	206.518.6094	nicole@arguspacific.com
☑	Scott Parker	206.714.7152	sparker@arguspacific.com	☐	Scott Rinear	206.571.5991	srinear@arguspacific.com
☐	Tim Nickell		tim@arguspacific.com	☐			

SEQ#	CLIENT SAMPLE #	SAMPLE DESCRIPTION	LOCATION	NOTES
61	3-02			
62	3-03			
63	4-01			
64	4A-01			
65	5-01			
66	6-01			
67	6-02			
68	6-03			
69	6-04			
70	6-05			
71	7-01			
72	7-02			
73	7-03			
74	8-01			
75	8-02			
76				
77				
78				
79				
80				

	Print Name	Signature	Company	Date	Time
Sampled	Conor Foley	[signature]	Argus Pacific	6/15/12	4:00pm
Relinquished	Conor Foley	[signature]	Argus Pacific	6/21/12	9:05am
Delivered	Conor Foley	[signature]	Argus Pacific	6/21/12	9:05am
Received	E.Dutton	[signature]	Seattle Asbestos Test	6/21/2012	0905
Analyzed	E.Dutton	[signature]	Seattle Asbestos Test	6/21/2012	1405
Reported	Steve Zhy	[signature]	Seattle Asbestos Test	6/26/12	

Results reporting method: ☐ Phone ☐ Fax ☑ Email ☐ Pick-up

☐ Composite all wallboard samples ☐ Text result to phone ☐ Point count samples with ___ % or less asbestos

SEATTLE ASBESTOS TEST, LLC

NVLAP Accredited Lab Code - Bellevue:200876, Lynnwood:200768

Lynnwood Laboratory: 19711 Scriber Lake Rd, Suite D, Lynnwood, WA 98036; Tel: 425.673.9850, Fax:425.673.9810

Bellevue Laboratory: 12727 Northup Way, Suite 1, Bellevue, WA 98005; Tel: 425.861.1111, Fax: 425.861.1118

Website: http://www.seattleasbestostest.com, E-mail: admin@seattleasbestostest.com

ANALYTICAL LABORATORY REPORT

PLM by Method EPA/600/R-93/116

Attn.: Mr. Scott Parker / Mr. Conor Foley
Client: Argus Pacific
Address: 1900 W Nickerson St # 315, Seattle, WA 98119

Client Job #: 640238R.0004
Laboratory Batch #: 201212038
Date Received: 6/20/2012
Samples Received: 35
Date Analyzed: 6/26/2012
Samples Analyzed: 35

Project: Georgetown Steam Plant

Lab ID	Client Sample ID	Layer	Description	%	Asbestos Fibers	Non-Fibrous Components	%	Non-asbestos Fibers
1	1-01	1	Gray brittle material with paint		None detected	Paint, Filler, Binder	2	Cellulose
2	1-02	1	Gray brittle material with paint		None detected	Paint, Filler, Binder	3	Cellulose
3	1-03	1	Gray sandy/brittle material with paint		None detected	Sands, Filler, Binder, Paint	5	Cellulose
4	1-04	1	Gray brittle material with paint and sand		None detected	Paint, Filler, Binder, Sands	4	Cellulose
5	1-05	1	Gray brittle material with paint and sand		None detected	Paint, Filler, Binder, Sands	2	Cellulose
6	1-06	1	Gray brittle material with paint and sand		None detected	Paint, Filler, Binder, Sands	3	Cellulose
7	1-07	1	Gray hard brittle material with paint and sand		None detected	Paint, Filler, Binder, Sands	2	Cellulose
8	1A-01	1	Tan brittle material with paint		None detected	Paint, Filler, Binder	3	Cellulose
9	1A-02	1	Gray brittle material	2	Chrysotile	Filler, Binder, Fine particles	3	Cellulose
10	1A-03	1	Tan brittle material with paint		None detected	Paint, Filler, Binder	2	Cellulose
11	1AA-01	1	Off-white brittle material with paint		None detected	Paint, Filler, Binder	4	Cellulose
12	1AA-02	1	Off-white brittle material with paint		None detected	Paint, Filler, Binder	4	Cellulose
13	1AA-03	1	Off-white brittle material with paint		None detected	Paint, Filler, Binder	2	Cellulose
14	1B-01	1	Black/dark gray brittle material with paint	2	Chrysotile	Paint, Filler, Asphalt/Binder	2	Cellulose
		2	Beige brittle material with paint		None detected	Paint, Filler, Binder	2	Cellulose
15	1B-02	1	Black brittle material	<1	Chrysotile	Filler, Asphalt/Binder	3	Cellulose
		2	Tan brittle material with paint		None detected	Paint, Filler, Binder	2	Cellulose
16	1B-03	1	Black brittle material	<1	Chrysotile	Filler, Asphalt/Binder	3	Cellulose
		2	Beige brittle material with paint		None detected	Paint, Filler, Binder	2	Cellulose
17	2-01	1	Gray brittle material		None detected	Binder, Filler	4	Cellulose

Analyzed by: Liz Dutton

Report reviewed by: Steve (Fanyao) Zhang, President

SEATTLE ASBESTOS TEST, LLC

NVLAP Accredited Lab Code - Bellevue:200676; Lynnwood:200768

Lynnwood Laboratory: 19711 Scriber Lake Rd, Suite D, Lynnwood, WA 98036; Tel: 425.673.9850, Fax:425.673.9810

Bellevue Laboratory: 12727 Northup Way, Suite 1, Bellevue, WA 98005; Tel: 425.861.1111, Fax: 425.861.1118

Website: http://www.seattleasbestostest.com, E-mail: admin@seattleasbestostest.com

ANALYTICAL LABORATORY REPORT

PLM by Method EPA/600/R-93/116

Attn.: Mr. Scott Parker / Mr. Conor Foley
Client: Argus Pacific
Address: 1900 W Nickerson St # 315, Seattle, WA 98119

Client Job #: 640238R.0004
Laboratory Batch #: 201212038
Date Received: 6/20/2012
Samples Received: 35
Date Analyzed: 6/26/2012
Samples Analyzed: 35

Project: Georgetown Steam Plant

Lab ID	Client Sample ID	Layer	Description	%	Asbestos Fibers	Non-Fibrous Components	%	Non-asbestos Fibers
18	2-02	1	Gray/white brittle material		None detected	Binder, Filler	5	Cellulose
19	2-03	1	Gray/white brittle material		None detected	Binder, Filler	4	Cellulose
20	3-01	1	White brittle material with paint		None detected	Paint, Filler, Binder	2	Cellulose
21	3-02	1	White brittle material with paint and debris		None detected	Paint, Filler, Binder, Debris, Fine particles	3	Cellulose
22	3-03	1	White brittle material with paint		None detected	Paint, Filler, Binder	3	Cellulose
23	4-01	1	Gray loose brittle material		None detected	Filler, Binder	2	Cellulose
		2	Trace black hard/brittle material		None detected	Filler, Binder		None detected
24	4A-01	1	Black soft/elastic material with paint	2	Chrysotile	Binder, Filler, Paint	4	Cellulose
25	5-01	1	Off-white brittle material with paint		None detected	Paint, Filler, Binder	2	Cellulose
26	6-01	1	Gray hard sandy/brittle material		None detected	Sands, Filler, Binder	3	Cellulose
27	6-02	1	Gray sandy/brittle material		None detected	Sands, Filler, Binder	2	Cellulose
28	6-03	1	Gray sandy/brittle material		None detected	Sands, Filler, Binder	3	Cellulose
29	6-04	1	Gray sandy/brittle material		None detected	Sands, Filler, Binder	4	Cellulose
30	6-05	1	Gray sandy/brittle material		None detected	Sands, Filler, Binder	5	Cellulose
		2	Black asphaltic material	4	Chrysotile	Filler, Asphalt, Binder	2	Cellulose
31	7-01	1	White brittle material with paint		None detected	Paint, Filler, Binder	2	Cellulose
32	7-02	1	White/gray brittle material with paint		None detected	Paint, Filler, Binder	3	Cellulose
33	7-03	1	Gray brittle material with paint	2	Chrysotile	Paint, Filler, Binder	4	Cellulose
34	8-01	1	Beige/tan brittle material with paint		None detected	Paint, Filler, Binder	2	Cellulose
35	8-02	1	Gray brittle material with paint	2	Chrysotile	Paint, Filler, Binder	3	Cellulose

Analyzed by: Liz Dutton

Report reviewed by: Steve (Fanyao) Zhang, President

SEATTLE ASBESTOS TEST, LLC

19711 Scriber Lake Road, Suite D, Lynnwood, WA 98036, Tel:425.673.9850
12727 Northup Way, Suite 1, Bellevue, WA 98005, Tel:425.861.1111
www.seattleasbestostest.com, admin@seattleasbestostest.com

NVLAP Accreditation Lab Codes:
LYNNWOOD LAB: 200768-0, BELLEVUE LAB: 200876-0

Date Analyzed: 7/10/2012

Client Job #: 640238.00004
Project Loc.: Georgetown Steam Plant - Ext
Laboratory Batch#: 201212446
Samples Received: 9

Mr. Scott Parker / Mr. Conor Foley
Argus Pacific
1900 W Nickerson St # 315, Seattle, WA 98119

Enclosed please find the test results for the bulk samples submitted to our laboratory for asbestos analysis. Analysis was performed using polarized light microscopy (PLM) in accordance with Test Method US EPA/600/R-93/116.

Percentages for this report are done by visual estimate. Since variation in data increases as the quantity of asbestos decreases toward the limit of detection, the EPA recommends point counting for samples containing between <1% and 10% asbestos (NESHAP, 40 CFR Part 61). Statistically, point counting is a more accurate method. If you feel a point count might be beneficial, please feel free to call and request one.

The test results refer only to the samples or items submitted and tested. The accuracy with which these samples represent the actual materials is totally dependent on the acuity of the person who took the samples. This report must not be used by the client to claim product certification, approval, or endorsement by Seattle Asbestos Test, LLC, NVLAP, NIST, or any agency of the Federal government.

This report is highly confidential and will not be released without your consent. Samples are archived for two weeks after the analysis, and disposed of as hazardous waste thereafter.

Thank you for using our service and let us know if we can further assist you.

Sincerely

Steve (Fanyao) Zhang
President

SEATTLE ASBESTOSTEST, LLC

Analyzing Quality

Lynnwood Lab: 19711 Scriber Lake Road, Suite D, WA 98036, Tel:425.673.9850, Fax:425.673.9810
Bellevue Lab: 12727 Northup Way, Suite 1, Bellevue, WA 98005, Tel:425.861.1111, Fax:425.861.1118
Email: admin@seattleasbestostest.com, Website: www.seattleasbestostest.com

#201212446

CHAIN OF CUSTODY

☐ Bulk Asbestos ☐ Point Count 400 ☐ Point Count 1000 ☐ Point Count Gravimetric ☐ Other (Specify) ________

☐ 1 Hour ☐ 2 Hours ☒ Same day (4 to 8 Hrs.) ☐ 1 Day ☐ ______ Days

Argus Pacific

1900 W Nickerson St # 315, Seattle, WA 98119 Tel: (206) 285-3373 Fax: (206) 285-3927

Number of Samples 9 PO# 640128.0004 Project Location Georgetown Steam Plant - Ext.

Project Manager (Check one or more):

☐	Christopher Selders	206.462.9355	chris@arguspacific.com	☒	Conor Foley	650.743.4363	conor@arguspacific.com
☐	Meagan Yoshimoto	206.714.7152	meagan@arguspacific.com	☐	Nicole Gladu	206.518.6094	nicole@arguspacific.com
☒	Scott Parker	206.714.7152	sparker@arguspacific.com	☐	Scott Rinear	206.571.5991	srinear@arguspacific.com
☐	Tim Nickell		tim@arguspacific.com	☐			

SEQ#	CLIENT SAMPLE #	SAMPLE DESCRIPTION	LOCATION	NOTES
21	5-02			
22	11-01			
23	11-02			
24	11-03			
25	15-01			
26	15-02			
27	15-03			
28	16-01			
29	16-02			
30				
31				
32				
33				
34				
35				
36				
37				
38				
39				
40				

	Print Name	Signature	Company	Date	Time
Sampled:	Conor Foley	[signature]	Argus Pacific	3/9/12	12:30 pm
Relinquished:	Conor Foley	[signature]	Argus Pacific	3/9/12	4:47 pm
Delivered:	Conor Foley	[signature]	Argus Pacific	3/9/12	4:47 pm
Received:	[illegible]	[signature]	Seattle Asbestos Test - B	3/9/12	1104
Analyzed:	E. Dutton	[signature]	Seattle Asbestos Test - B	3/10/12	1145
Reported:	[illegible]	[signature]	Seattle Asbestos Test	3/12/12	

Results reporting method: ☐ Phone ☐ Fax ☒ Email ☐ Pick-up

☐ Composite all wallboard samples ☐ Text result to phone ☐ Point count samples with ..... % or less asbestos

SEATTLE ASBESTOS TEST, LLC

NVLAP Accredited Lab Code - Bellevue:200876; Lynnwood:200768

Lynnwood Laboratory: 19711 Scriber Lake Rd, Suite D, Lynnwood, WA 98036; Tel: 425.673.9850, Fax:425.673.9810

Bellevue Laboratory: 12727 Northup Way, Suite 1, Bellevue, WA 98005; Tel: 425.861.1111, Fax: 425.861.1118

Website: http://www.seattleasbestostest.com, E-mail: admin@seattleasbestostest.com

ANALYTICAL LABORATORY REPORT

PLM by Method EPA/600/R-93/116

Attn.: Mr. Scott Parker / Mr. Conor Foley
Client: Argus Pacific
Address: 1900 W Nickerson St # 315, Seattle, WA 98119

Client Job #: 640238.00004
Laboratory Batch #: 201212446
Date Received: 7/9/2012
Samples Received: 9
Date Analyzed: 7/10/2012
Samples Analyzed: 9

Project: Georgetown Steam Plant - Ext

Lab ID	Client Sample ID	Layer	Description	%	Asbestos Fibers	Non-Fibrous Components	%	Non-asbestos Fibers
1	5-02	1	Gray brittle material with paint	2	**Chrysotile**	Paint, Filler, Binder	2	Cellulose
2	11-01	1	Gray brittle material with paint	2	**Chrysotile**	Paint, Filler, Binder	3	Cellulose
3	11-02	1	Gray soft material		**None detected**	Filler, Binder	2	Cellulose
		2	Brown wood debris with paint		**None detected**	Wood debris, Paint	7	Cellulose
4	11-03	1	White brittle material		**None detected**	Filler, Binder	4	Cellulose
5	15-01	1	Beige brittle material with paint	2	**Chrysotile**	Paint, Filler, Binder	2	Cellulose
6	15-02	1	Off-white brittle material with paint		**None detected**	Paint, Filler, Binder	3	Cellulose
7	15-03	1	Off-white brittle material with paint		**None detected**	Paint, Filler, Binder	4	Cellulose
8	16-01	1	Beige brittle material with paint	2	**Chrysotile**	Paint, Filler, Binder	2	Cellulose
9	16-02	1	Beige brittle material with paint	2	**Chrysotile**	Paint, Filler, Binder	2	Cellulose

Analyzed by: Liz Dutton

Report reviewed by: Steve (Fanyao) Zhang, President

Appendix B
Lead Laboratory Analytical Results

June 25, 2012

Scott Parker
Argus Pacific, Inc.
1900 W. Nickerson St., Suite 315
Seattle, WA 98119

RE: Metals Analysis; NVL Batch # 1209410.00

Dear Mr. Parker,

Enclosed please find the test results for samples submitted to our laboratory for analysis. Preparation of these samples was conducted following protocol outlined in EPA Method SW 846-3051 unless stated otherwise. Analysis of these samples was performed using analytical instruments in accordance with U.S. EPA, NIOSH, OSHA and other ASTM methods.

For matrix materials submitted as paint, dust wipe, soil or TCLP samples, analysis for the presence of total metals is conducted using published U.S. EPA Methods. Paint and soil results are usually expressed in mg/Kg which is equivalent to parts per million (ppm). Lead (Pb) in paint is usually expressed in mg/Kg (ppm) , Percent (%) or mg/cm^2 by area. Dust wipe sample results are usually expressed in ug/wipe and ug/ft^2. TCLP samples are reported in mg/L (ppm). For air filter samples, analyses are conducted using NIOSH and OSHA Methods. Results are expressed in ug/filter and ug/m^3. Other matrix materials are analyzed accordingly using published methods or specified by client. The reported test results pertain only to items tested. Lead test results are not blank corrected.

For recent regulation updates pertaining to current regulatory levels or permissible exposure levels, please call your local regulatory agencies for more details.

This report is considered highly confidential and will not be released without your approval. Samples are archived for two weeks following analysis. Samples that are not retrieved by the client are discarded after two weeks.

Thank you for using our laboratory services. if you need further assistance please feel free to call us at 206-547-0100 or 1-888-NVLLABS.

Sincerely,

Nick Ly, Technical Director

Enclosure:

NVL Laboratories, Inc.
4708 Aurora Ave. N., Seattle, WA 98103
Tel: 206.547.0100, Fax: 206.634.1936
www.nvllabs.com

Analysis Report

AIHA - IH # 101861
WA - DOE # C1765

AIHA Environmental Lead and Industrial Hygiene ACCREDITED LABORATORY

Total Lead (Pb)

Client: Argus Pacific, Inc.
Address: 1900 W. Nickerson St., Suite 315
Seattle, WA 98119

Attention: Mr. Scott Parker
Project Location: Seattle, WA

Batch #: 1209410.00
Matrix: Paint Chips
Method: EPA 7000B
Client Project #: 640238R.0004
Date Received: 06/20/2012
Samples Received: 8
Samples Analyzed: 8

Lab ID	Client Sample #	Sample Weight (g)	RL in mg/Kg	Results in mg/Kg	Results in percent
12055632	Pb1-01	0.1940	48.0	< 48.0	< 0.0048
12055633	Pb2-01	0.2084	45.0	40000.0	4.0000
12055634	Pb3-01	0.1992	47.0	31000.0	3.1000
12055635	Pb4-01	0.1985	47.0	50000.0	5.0000
12055636	Pb5-01	0.2071	45.0	32000.0	3.2000
12055637	Pb6-01	0.1998	47.0	590.0	0.0590
12055638	Pb7-01	0.2068	45.0	71000.0	7.1000
12055639	Pb8-01	0.2025	46.0	3300.0	0.3300

Sampled by: Client
Analyzed by: Aaron Brown
Reviewed by: Nick Ly

Date Analyzed: 06/25/2012
Date Issued: 06/25/2012

Nick Ly, Technical Director

mg/ Kg =Milligrams per kilogram
Percent = Milligrams per kilogram / 10000
Note : Method QC results are acceptable unless stated otherwise.
Unless otherwise indicated, the condition of all samples was acceptable at time of receipt.

RL = Reporting Limit
'<' = Below the reporting Limit

Bench Run No: 32-0622-03

NVL Laboratories, Inc.
4708 Aurora Ave N, Seattle, WA 98103
Tel: 206.547.0100 Emerg.Cell: 206.914.4646
Fax: 206.634.1936 1.888.NVL.LABS (685.5227)

CHAIN of CUSTODY SAMPLE LOG

BATCH ID
1209410.00

Client: Argus Pacific, Inc.
Street: 1900 W. Nickerson St., Suite 315, Seattle, WA 98119
Project Manager: ~~Ms. Nicole Gladu~~ Scott Parker
Project Location: Seattle, WA

Phone: (206) 285-3373 Fax: (206) 285-3927

NVL Batch Number:
Client Job Number: 610238R.0004
Total Samples: 8
Turn Around Time: ☐ 1-Hr ☐ 8-Hrs ☐ 2 Days ☒ 5 Days ☐ 2-Hrs ☐ 12-Hrs ☐ 3 Days ☐ 6-10 Day ☐ 4-Hrs ☐ 24-Hrs ☐ 4 Days
Please call for TAT less than 24 Hrs
Email address: ~~nicole@arguspacific.com~~ cfoley@arguspacific.com
Cell (206) 280-1708

☐ Asbestos Air: ☐ PCM (NIOSH 7400) ☐ TEM (NIOSH 7402) ☐ TEM (AHERA) ☐ TEM (EPA Level II) ☐ Other

☐ Asbestos Bulk: ☐ PLM (EPA/600/R-93/116) ☐ PLM (EPA Point Count) ☐ PLM (EPA Gravimetry) ☐ TEM BULK

☐ Mold/Fungus: ☐ Mold Air ☐ Mold Bulk ☐ **Rotometer Calibration**

METALS	Det. Limit	Matrix		RCRA Metals		Other Metals
☒ Total Metals	☒ FAA (ppm)	☐ Air Filter	☐ Soil	☐ Arsenic (As)	☐ All 8	☐ All 3
☐ TCLP	☐ ICP (ppm)	☐ Drinking water	☒ Paint Chips in %	☐ Barium (Ba)	☐ Chromium (Cr)	☐ Copper (Cu)
☐ Cr 6	☐ GFAA (ppb)	☐ Dust/wipe (Area)	☐ Paint Chips in cm	☐ Cadmium (Cd)	☒ Lead (Pb)	☐ Nickel (Ni)
					☐ Mercury (Hg)	☐ Zinc (Zn)

☐ Other Types of Analysis: ☐ Fiberglass ☐ Silica ☐ Nuisance Dust ☐ Respirable Dust ☐ Other (Specify) ____

Condition of Package: ☐ Good ☐ Damaged (no spillage) ☐ Severe damage (spillage)

Seq. #	Lab ID	Client Sample Number	Comments (e.g Sample are, Sample Volume, etc)	A/R
1		Pb1-01		
2		Pb2-01		
3		Pb3-01		
4		Pb4-01		
5		Pb5-01		
6		Pb6-01		
7		Pb7-01		
8		Pb8-01		
9				
10				
11				
12				
13				
14				
15				

	Print Below	Sign Below	Company	Date	Time
Sampled by	Conor Foley	[signature]	Argus Pacific	6/15/12	4:00pm
Relinquished by	Conor Foley	[signature]	Argus Pacific	6/20/12	4:20pm
Received by	Midori Koike	[signature]	NVL	6/20/12	1620
Analyzed by	Aaron Brown	[signature]	NVL	6/25/12	10:05
Results Called by					
Results Faxed by					

Special Instructions: Unless requested in writing, all samples will be disposed of two (2) weeks after analysis.

NVL
LABS
INDUSTRIAL HYGIENE SERVICES
Laboratory | Management | Training

November 23, 2012

Scott Parker
Argus Pacific, Inc.
1900 W. Nickerson St., Suite 315
Seattle, WA 98119

RE: Metals Analysis; NVL Batch # 1218348.00

Dear Mr. Parker,

Enclosed please find the test results for samples submitted to our laboratory for analysis. Preparation of these samples was conducted following protocol outlined in EPA Method SW 846-3051 unless stated otherwise. Analysis of these samples was performed using analytical instruments in accordance with U.S. EPA, NIOSH, OSHA and other ASTM methods.

For matrix materials submitted as paint, dust wipe, soil or TCLP samples, analysis for the presence of total metals is conducted using published U.S. EPA Methods. Paint and soil results are usually expressed in mg/Kg which is equivalent to parts per million (ppm). Lead (Pb) in paint is usually expressed in mg/Kg (ppm) , Percent (%) or mg/cm^2 by area. Dust wipe sample results are usually expressed in ug/wipe and ug/ft^2. TCLP samples are reported in mg/L (ppm). For air filter samples, analyses are conducted using NIOSH and OSHA Methods. Results are expressed in ug/filter and ug/m^3. Other matrix materials are analyzed accordingly using published methods or specified by client. The reported test results pertain only to items tested. Lead test results are not blank corrected.

For recent regulation updates pertaining to current regulatory levels or permissible exposure levels, please call your local regulatory agencies for more details.

This report is considered highly confidential and will not be released without your approval. Samples are archived for two weeks following analysis. Samples that are not retrieved by the client are discarded after two weeks.

Thank you for using our laboratory services. if you need further assistance please feel free to call us at 206-547-0100 or 1-888-NVLLABS.

Sincerely,

Nick Ly, Technical Director

Enclosure:

NVL Laboratories, Inc.
4708 Aurora Ave. N., Seattle, WA 98103
Tel: 206.547.0100, Fax: 206.634.1936
www.nvllabs.com

Analysis Report

AIHA - IH # 101861
WA - DOE # C1765

AIHA Environmental Lead and Industrial Hygiene ACCREDITED LABORATORY

Total Lead (Pb)

Client: Argus Pacific, Inc.
Address: 1900 W. Nickerson St., Suite 315
Seattle, WA 98119

Attention: Mr. Scott Parker
Project Location: GTSP

Batch #: 1218348.00
Matrix: Paint Chips
Method: EPA 7000B
Client Project #: 640238R
Date Received: 11/15/2012
Samples Received: 10
Samples Analyzed: 10

Lab ID	Client Sample #	Sample Weight (g)	RL in mg/Kg	Results in mg/Kg	Results in percent
12104312	PB-ST1-01	0.2075	44.0	730.0	0.0730
12104313	PB-ST1-02	0.1921	47.0	2200.0	0.2200
12104314	PB-ST2-01	0.1926	47.0	1000.0	0.1000
12104315	PB-ST3-01	0.2285	40.0	280000.0	28.0000
12104316	PB-EXTCT-01	0.1995	46.0	89.0	0.0089
12104317	PB-EXTCT-02	0.2209	41.0	100.0	0.0100
12104318	PB-EXTCT-03	0.2203	41.0	91.0	0.0091
12104319	PB-EXTCT-04	0.2095	43.0	2300.0	0.2300
12104320	PB-EXTCT-05	0.2337	39.0	< 39.0	< 0.0039
12104321	PB-EXTCM-01	0.0536	170.0	< 170.0	< 0.0170

Sampled by: Client
Analyzed by: Jacob Blair
Reviewed by: Nick Ly

Date Analyzed: 11/23/2012
Date Issued: 11/23/2012

Nick Ly, Technical Director

mg/ Kg =Milligrams per kilogram
Percent = Milligrams per kilogram / 10000
RL = Reporting Limit
'<' = Below the reporting Limit
Note : Method QC results are acceptable unless stated otherwise.
Unless otherwise indicated, the condition of all samples was acceptable at time of receipt.

Bench Run No: 32-1121-06

BATCH ID
1218348.00

LABS
HAZARDOUS MATERIALS SERVICES

NVL Laboratories, Inc.

4708 Aurora Ave N, Seattle, WA 98103
Tel: 206.547.0100 Emerg.Pager: 206.344.1878
Fax: 206.634.1936 1.888.NVL.LABS (685.5227)

CHAIN of CUSTODY SAMPLE LOG

Client: Argus Pacific
Street: 1900 W. Nickerson, St 315
Seattle WA

Project Manager: Scott Parker
Project Location: GTSP

NVL Batch Number:
Client Job Number: 640238R
Total Samples: 10
Turn Around Time: ☐ 1-Hr ☐ 24-Hrs ☐ 4 Days ☐ 2-Hrs ☐ 2 Days ☑ 5 Days ☐ 4-Hrs ☐ 3 Days ☐ 6 to 10 Days
Please call for TAT less than 24 Hrs
Email address: SParker@ArgusPacific.com

Phone: Fax:

☐ Asbestos Air: ☐ PCM (NIOSH 7400) ☐ TEM (NIOSH 7402) ☐ TEM (AHERA) ☐ TEM (EPA Level II) ☐ Other

☐ Asbestos Bulk: ☐ PLM (EPA/600/R-93/116) ☐ PLM (EPA Point Count) ☐ PLM (EPA Gravimetry) ☐ TEM Bulk

☐ Mold/Fungus: ☐ Mold Air ☐ Mold Bulk ☐ Rotometer Calibration

METALS	Inst./Det Limit	Matrix		RCRA Metals ☐ All 8		Other Metals
☑ Total Metals	☑ FAA (ppm)	☐ Air Filter	☐ Paint Chips in cm	☐ Arsenic (As)	☐ Mercury (Hg)	☐ All 3
☐ TCLP	☐ ICP (ppm)	☐ Drinking water	☐ Waste Water	☐ Barium (Ba)	☐ Selenium (Se)	☐ Copper (Cu)
	☐ GFAA (ppb)	☐ Dust/wipe (Area)	☐ Other	☐ Cadmium (Cd)	☐ Silver (Ag)	☐ Nickel (Ni)
		☐ Soil		☐ Chromium (Cr)		☐ Zinc (Zn)
		☑ Paint Chips in %		☑ Lead (Pb)		

☐ Other Types of Analysis: ☐ Fiberglass ☐ Nuisance Dust ☐ Other (Specify) ☐ Silica ☐ Respirable Dust

Condition of Package: ☐ Good ☐ Damaged (no spillage) ☐ Severe damage (spillage)

Seq. #	Lab ID	Client Sample Number	Comments (e.g Sample area, Sample Volume, etc)	A/R
1		PB-ST1-01		
2		PB-ST1-02		
3		PB-ST2-01		
4		PB-ST3-01		
5		PB-EXTCT-01		
6		PB-EXTCT-02		
7		PB-EXTCT-03		
8		PB-EXTCT-04		
9		PB-EXTCT-05		
10		PB-EXTCM-01		
11				
12				
13				
14				
15				

	Print Below	Sign Below	Company	Date	Time
Sampled by	S. Parker	[signature]	Argus Pacific	11/14/12	15:00
Relinquished by	S. Parker	[signature]	Argus Pacific	11/15/12	4:50
Received by	Nathan	[signature]	NVL Labs	11/16/12	4:53pm
Analyzed by	Jacob Blair	[signature]	NVL	11/23/12	09:4?
Results Called by					
Results Faxed by					

Special Instructions: Unless requested in writing, all samples will be disposed of two (2) weeks after analysis.

Appendix C
Personnel and Laboratory Accreditations

Certificate of Completion

This is to certify that

Conor V. Foley

has satisfactorily completed
4 hours of refresher training as an

Asbestos Building Inspector

to comply with the training requirements of
TSCA Title II / 40 CFR 763 (AHERA)

135923
Certificate Number

EPA Provider Cert. Number: 1085

ARGUS PACIFIC
TRAINING • CONSULTING

Mar 21, 2012
Date(s) of Training

Exam Score: NA

Expiration Date: Mar 21, 2013

Argus Pacific, Inc. • 1900 W. Nickerson, Suite 315 • Seattle, Washington • 98119 • 206.285.3373 • fax 206.285.3927

Certificate of Completion

This is to certify that

Peter T. Snider

has satisfactorily completed
4 hours of refresher training as an

Asbestos Building Inspector

to comply with the training requirements of
TSCA Title II / 40 CFR 763 (AHERA)

137618
Certificate Number

Susan N. Moss
Instructor

EPA Provider Cert. Number: 1085

ARGUS PACIFIC
TRAINING • CONSULTING

Jun 27, 2012
Date(s) of Training

Exam Score: NA

Expiration Date: Jun 27, 2013

Argus Pacific, Inc. • 1900 W. Nickerson, Suite 315 • Seattle, Washington • 98119 • 206.285.3373 • fax 206.285.3927

United States Department of Commerce
National Institute of Standards and Technology

NVLAP®

Certificate of Accreditation to ISO/IEC 17025:2005

NVLAP LAB CODE: 200876-0

Seattle Asbestos Test Bellevue
Bellevue, WA

is accredited by the National Voluntary Laboratory Accreditation Program for specific services, listed on the Scope of Accreditation, for:

BULK ASBESTOS FIBER ANALYSIS

This laboratory is accredited in accordance with the recognized International Standard ISO/IEC 17025:2005. This accreditation demonstrates technical competence for a defined scope and the operation of a laboratory quality management system (refer to joint ISO-ILAC-IAF Communique dated January 2009).

2012-07-01 through 2013-06-30
Effective dates

For the National Institute of Standards and Technology

NVLAP-01C (REV. 2009-01-28)

ilac-MRA

AIHA
Laboratory Accreditation Programs, LLC

AIHA Laboratory Accreditation Programs, LLC

acknowledges that

NVL Laboratories, Inc.

4708 Aurora Avenue North, Seattle, WA 98103
Laboratory ID: 101861

along with all premises from which key activities are performed, as listed above, has fulfilled the requirements of the AIHA Laboratory Accreditation Programs (AIHA-LAP), LLC accreditation to the ISO/IEC 17025:2005 international standard, *General Requirements for the Competence of Testing and Calibration Laboratories in* the following:

LABORATORY ACCREDITATION PROGRAMS

✓	**INDUSTRIAL HYGIENE**	Accreditation Expires: 05/01/2013
✓	**ENVIRONMENTAL LEAD**	Accreditation Expires: 05/01/2013
✓	**ENVIRONMENTAL MICROBIOLOGY**	Accreditation Expires: 05/01/2013
☐	**FOOD**	Accreditation Expires:

Specific Field(s) of Testing (FoT)/Method(s) within each Accreditation Program for which the above named laboratory maintains accreditation is outlined on the attached **Scope of Accreditation**. Continued accreditation is contingent upon successful on-going compliance with ISO/IEC 17025:2005 and AIHA-LAP, LLC requirements. This certificate is not valid without the attached **Scope of Accreditation**. Please review the AIHA-LAP, LLC website (www.aihaaccreditedlabs.org) for the most current Scope.

Christine Powell

Christine Powell

Chairperson, Analytical Accreditation Board

Cheryl O. Morton

Cheryl O. Morton

Director, AIHA Laboratory Accreditation Programs, LLC

Revision 10: 01/13/2011

Date Issued: 05/01/2011

AIHA Laboratory Accreditation Programs, LLC

SCOPE OF ACCREDITATION

NVL Laboratories, Inc. Laboratory ID: **101861**
4708 Aurora Avenue North, Seattle, WA 98103 Issue Date: 05/01/2011

The laboratory is approved for those specific field(s) of testing/methods listed in the table below. Clients are urged to verify the laboratory's current accreditation status for the particular field(s) of testing/Methods, since these can change due to proficiency status, suspension and/or revocation. A complete listing of currently accredited Industrial Hygiene laboratories is available on the AIHA-LAP, LLC website at: http://www.aihaaccreditedlabs.org

Industrial Hygiene Laboratory Accreditation Program (IHLAP)

Initial Accreditation Date: 04/01/1997

IHLAP Scope Category	Field of Testing (FoT)	Technology sub-type/ Detector	Published Reference Method/Title of In-house Method	Method Description or Analyte (*for internal methods only*)
Spectrometry Core	Atomic Absorption	FAA	NIOSH 7024	
			NIOSH 7030	
			NIOSH 7048	
			NIOSH 7082	
	Inductively-Coupled Plasma	ICP/AES	EPA SW-846 3051	
			NIOSH 7300	
Asbestos/Fiber Microscopy Core	Phase Contrast Microscopy (PCM)		NIOSH 7400	
Miscellaneous Core	Gravimetric		NIOSH 0500	
			NIOSH 0600	

AIHA
Laboratory Accreditation Programs, LLC

The laboratory participates in the following AIHA-LAP, LLC-approved proficiency testing programs:

- √ AIHA-PAT Programs, LLC IHPAT Metals
- ☐ AIHA-PAT Programs, LLC IHPAT Organic Solvents
- √ AIHA-PAT Programs, LLC IHPAT Silica
- ☐ AIHA-PAT Programs, LLC IHPAT Diffusive Sampler (3M)
- ☐ AIHA-PAT Programs, LLC IHPAT Diffusive Sampler (SKC)
- ☐ AIHA-PAT Programs, LLC IHPAT Diffusive Sampler (AT)
- √ AIHA-PAT Programs, LLC IHPAT Asbestos
- ☐ AIHA-PAT Programs, LLC Bulk Asbestos (BAPAT)
- ☐ AIHA-PAT Programs, LLC Beryllium (BePAT)
- ☐ HSE Workplace Analytical Scheme for Proficiency (WASP) (Formaldehyde)
- ☐ HSE Workplace Analytical Scheme for Proficiency (WASP) (Thermal Desorption Tubes)
- ☐ Pharmaceutical Round Robin
- ☐ Compressed/Breathing Air Round Robin
- ☐ National Voluntary Laboratory Accreditation Program (NVLAP - determined at the time of site assessment)
- ☐ New York State Department of Health (NYS DOH – PCM and TEM)
- ☐ ERA Air and Emissions standards for indoor air quality
- ☐ Institut für Arbeitsschutz der Deutschen Gesetzlichen Unfallversicherung (IFA, formerly BGIA)
- ☐ Institut de Recherche Robert-Sauvé en Santé et en Sécurité du Travail (IRSST)

AIHA Laboratory Accreditation Programs, LLC
SCOPE OF ACCREDITATION

NVL Laboratories, Inc. — Laboratory ID: **101861**
4708 Aurora Avenue North, Seattle, WA 98103 — Issue Date: 05/01/2011

The laboratory is approved for those specific field(s) of testing/methods listed in the table below. Clients are urged to verify the laboratory's current accreditation status for the particular field(s) of testing/Methods, since these can change due to proficiency status, suspension and/or revocation. A complete listing of currently accredited Environmental Lead laboratories is available on the AIHA-LAP, LLC website at: http://www.aihaaccreditedlabs.org

The EPA recognizes the AIHA-LAP, LLC ELLAP program as meeting the requirements of the National Lead Laboratory Accreditation Program (NLLAP) established under Title X of the Residential Lead-Based Paint Hazard Reduction Act of 1992 and includes paint, soil and dust wipe analysis. Air analysis is not included as part of the NLLAP.

Environmental Lead Laboratory Accreditation Program (ELLAP)

Initial Accreditation Date: 02/07/1997

Field of Testing (FoT)	Method	Method Description (*for internal methods only*)
Airborne Dust	EPA SW-846 3051	
	NIOSH 7082	
Paint	CPSC-CH-E1003-09	
	EPA SW-846 3051	
	EPA SW-846 7000B	
Settled Dust by Wipe	EPA SW-846 3051	
	EPA SW-846 7000B	
Soil	EPA SW-846 3051	
	EPA SW-846 7000B	

The laboratory participates in the following AIHA-LAP, LLC-approved proficiency testing programs:

- √ Paint
- √ Soil
- √ Settled Dust by Wipe
- √ Airborne Dust

AIHA Laboratory Accreditation Programs, LLC

SCOPE OF ACCREDITATION

NVL Laboratories, Inc. Laboratory ID: **101861**
4708 Aurora Avenue North, Seattle, WA 98103 Issue Date: 05/01/2011

The laboratory is approved for those specific field(s) of testing/methods listed in the table below. Clients are urged to verify the laboratory's current accreditation status for the particular field(s) of testing/Methods, since these can change due to proficiency status, suspension and/or revocation. A complete listing of currently accredited Environmental Microbiology laboratories is available on the AIHA-LAP, LLC website at: http://www.aihaaccreditedlabs.org

Environmental Microbiology Laboratory Accreditation Program (EMLAP)

Initial Accreditation Date: 02/01/2007

EMLAP Category	Field of Testing (FoT)	Method	Method Description *(for internal methods only)*
Fungal	**Bulk - Direct Examination**	SOP 12.130	In-House: Analysis of Bulk and Surface for Fungi
	Surface - Direct Examination	SOP 12.130	In-House: Analysis of Bulk and Surface for Fungi

The laboratory participates in the following AIHA-LAP, LLC-approved proficiency testing programs**:**

- √ Fungal Culturable
- ❑ Bacterial Culturable
- ❑ Fungal Direct Examination

ARGUS PACIFIC
TRAINING • CONSULTING

Targeted Asbestos Assessment -
Roof Renovation Report
Georgetown Steam Plant
BOLA Architecture + Planning
Seattle, Washington
Revised Version 2 November 6, 2012

July 17, 2012
Revision R.1, August 2, 2012

PROVIDING ORGANIZATIONS WITH HEALTH AND SAFETY SOLUTIONS

Project Title:	Targeted Asbestos Assessment - Roof Renovation Georgetown Steam Plant BOLA Architecture + Planning 6605 13th Avenue South Seattle, Washington
Prepared for:	Ms. Rhoda Lawrence BOLA Architecture + Planning 159 Western Avenue West, Suite 486 Seattle, Washington 98119
Assessment Conducted by:	Argus Pacific, Inc. 1900 W. Nickerson Street, Suite 315 Seattle, Washington 98119
Argus Pacific Project Number:	640238R
Assessment Personnel:	Mr. Scott Rinear AHERA-Accredited Building Inspector Number 134900 (exp. 1/10/2013) Mr. Peter Snider AHERA-Accredited Building Inspector Number 112750 (exp. 7/19/2013) Mr. Conor Foley AHERA-Accredited Building Inspector Number 135923 (exp. 3/21/2013)
Assessment Date:	June 26 and July 9, 2012
Report Prepared by:	Conor Foley Industrial Hygienist Argus Pacific, Inc.
Report Reviewed by:	Scott R. Parker, Principal Senior Consultant Argus Pacific, Inc.
Report Issue Date:	July 17, 2012
Report Revision Date R.1:	August 2, 2012
Report Revision Date R.2:	November 6, 2012

ARGUS PACIFIC
TRAINING • CONSULTING

TABLE OF CONTENTS

EXECUTIVE SUMMARY

BOLA Architecture + Planning retained Argus Pacific, Inc. (Argus Pacific) to conduct a targeted asbestos assessment of the Seattle City Light Georgetown Steam Plant located at 6605 13th Avenue South in Seattle, Washington. The scope of this targeted assessment was limited to the roof of the Georgetown Steam Plant. Argus Pacific's representatives, Mr. Scott Rinear and Mr. Peter Snider conducted the initial assessment on June 26 and July 9, 2012. Mr. Snider assisted Mr. Foley during the follow-up assessment on July 9, 2012. The scope of the services provided is described in Argus Pacific Proposal Number P640238 dated May 11, 2012.

Argus Pacific assessed the building for the following regulated building materials:

- Asbestos-containing materials (ACM); and
- Assumed asbestos-containing materials.

Forty-six bulk samples of suspect asbestos-containing materials were collected and analyzed using Polarized Light Microscopy (PLM). Ten materials were found to contain greater than one percent asbestos and no materials were assumed to contain asbestos.

ARGUS PACIFIC
TRAINING • CONSULTING

1.0 INTRODUCTION

BOLA Architecture + Planning retained Argus Pacific, Inc. (Argus Pacific) to conduct a targeted asbestos assessment of the Seattle City Light Georgetown Steam Plant located at 6605 13th Avenue South in Seattle, Washington. The scope of this targeted assessment was limited to the roof of the Georgetown Steam Plant. Argus Pacific's representatives, Mr. Scott Rinear and Mr. Peter Snider conducted the initial assessment on June 26 and July 9, 2012. Mr. Snider assisted Mr. Conor Foley during the follow-up assessment on July 9, 2012. The scope of the services provided is described in Argus Pacific Proposal Number P640238 dated May 11, 2012.

Argus Pacific assessed the building for the following regulated building materials:

- Asbestos-containing materials (ACM); and
- Assumed asbestos-containing materials.

2.0 PROJECT BACKGROUND

This report presents the results of our targeted asbestos assessment conducted at the Seattle City Light Georgetown Steam Plant in Seattle, Washington. The purpose of the assessment was to identify potential asbestos-containing materials prior to renovation and for purposes of hazard communication and on-going management. This assessment was limited to the roof of the Georgetown Steam Plant.

This assessment will assist BOLA Architecture + Planning with communicating the presence, location, and quantity of ACM to employees, vendors, and contractors working on the roof and to meet the requirements for an asbestos survey for the Puget Sound Clean Air Agency (PSCAA) and a good faith inspection as required by Washington State Department of Labor and Industries' Division of Occupational Safety and Health (DOSH) regulations prior to roof replacement and renovation. Regulations require that a complete copy of this assessment be kept in a conspicuous location on-site at all times during activities that may impact known and suspect ACM.

2.1 Sources of Information

During the course of the assessment, the following personnel and drawings provided assistance to the Argus Pacific inspector:

- Ms. Rhoda Lawrence and Mr. Matt Hamel, BOLA Architecture + Planning
- *Georgetown Steam Plant Runway Extension Window Impacts,* Building Elevations – Window Survey, Stickney Murphy Romine Architects, dated October 21, 2005
- *Georgetown Steam Plant,* Building Repair Elevations and Details – City of Seattle Department of Lighting, dated march 26, 1969

2.2 Building Description

The Georgetown Steam Plant is located at 6605 13th Avenue South in Seattle, Washington and was constructed in 1906 and contains approximately 20,000 square feet of interior floor space. The building consists of a Boiler Room and an Engine Room, both with associated roofs. The Boiler Room extends to the south and has a main roof and monitor (upper) roof with boiler stacks and other penetrations. The Engine Room extends off the north end of the building and has a main roof and monitor (upper) roof. The Engine Room roof also has a penthouse located in the northeast corner of the main roof. The penthouse provides access to the roof from the interior of the building.

3.0 ASBESTOS ASSESSMENT

3.1 Building Assessment

Mr. Rinear, Mr. Snider and Mr. Foley, all Asbestos Hazard Emergency Response Act (AHERA)-accredited building inspectors (Certification 134900, expiration date: 1/10/2013, Certification 112750, expiration date: 7/19/2013, and Certification 135923 expiration date: 3/21/2013, respectively) from Argus Pacific, performed the sampling on June 26 and July 9, 2012. Argus Pacific's inspectors collected fourty-six samples of materials identified as suspect ACM.

This assessment was conducted using a modified protocol adapted from AHERA. The protocol is as follows:

- Identify suspect asbestos-containing materials.
- Group materials into homogeneous sampling areas/materials.
- Quantify each homogeneous material and collect representative samples. The number of samples collected of miscellaneous materials was determined by the inspector.
- Samples of each material were taken to the substrate, ensuring that all components and layers of the material were included.
- Sample locations are referenced on the field data forms according to sample number.
- Sampling was performed by an AHERA-accredited building inspector, and the use of proper protective equipment and procedures was followed.

3.2 Sampling Procedures

This sampling was conducted using the following procedures:

1. Spread the plastic drop cloth (if needed) and set up other equipment, e.g., ladder.
2. Don protective equipment (respirator and protective clothing if needed).
3. Label sample container with its identification number and record number. Record sample location and type of material sampled on a sampling data form.
4. Moisten area where sample is to be extracted (spray the immediate area with water).
5. Extract sample using a clean knife, drill capsule, or cork boring tool to cut out or scrape off approximately one tablespoon of the material. Penetrate all layers of material.
6. Place sample in a container and tightly seal it.

7. Wipe the exterior of the container with a wet wipe to remove any material that may have adhered to it during sampling.
8. Clean tools with wet wipes and wet mop; or vacuum area with HEPA vacuum to clean all debris.
9. Discard protective clothing, wet wipes and rags, cartridge filters, and drop cloth in a labeled plastic waste bag.

3.3 Analytical Methodology

Suspect ACMs were sampled in general accordance with 40 CFR 763.86 by an Environmental Protection Agency (EPA) AHERA-accredited building inspector. Each sample was collected and stored in a heavy-duty, self-sealing plastic bag, and delivered to Seattle Asbestos Test, LLC in Bellevue, Washington. Samples were analyzed via polarized light microscopy (PLM) in accordance with EPA/600/R-93/116.

3.4 Asbestos Results

Table 3.4-1 provides a list of suspect homogeneous sampling areas (HSA) material descriptions, material locations, and results for this sampling. The inspectors who conducted the assessment assumed all roofs (Boiler Room, Engine Room, and penthouse) to be homogeneous (HSA RF-1) and these roofs are represented in the sampling. Asbestos-containing materials and assumed asbestos-containing materials are presented in bold text. Refer to the attached Figures for sample locations and roof name designations (as applicable). Refer to the attached photographs for HSA pictures.

Table 3.4-1. Results of Bulk Sample Analyses

HSA ID, Material Description, and AHERA Classification	Material Location	HSA Results
RF-1: Multi-layer black built-up roofing with pebbles, black asphaltic sealant and black fibrous material (M)	Throughout flat or near flat portions of Boiler room, Engine room and penthouse roofs.	Built-up roofing: ND Black fibrous material: ND Black asphaltic sealant: ND to 4% chrysotile (ACM layer is HSA RF-5)
RF-2: Black roll-down roofing over silver foil over black asphaltic sealant over multi-layered black felt, and residual sealant (HSA RF-5) (M)	Throughout roof parapet walls	Black roll-down: ND Silver foil: ND Black felt: ND Black sealant: ND to 4% chrysotile (ACM layer is HSA RF-5)
RF-3: Grey soft caulking with paint (M)	**Around seam base of penthouse exterior walls and seam where Boiler Room roof meets south portion of main roof on Engine Room**	**2% chrysotile**

Table 3.4-1. Results of Bulk Sample Analyses

HSA ID, Material Description, and AHERA Classification	Material Location	HSA Results
RF-4: Black roll-down roofing over silver foil over black asphaltic sealant over multi-layered black felt (M)	On non-parapet roof edges	Black roll-down: ND Foil: ND Black sealant: ND Black felt: ND
RF-5: Black asphaltic sealant (M)	**Associated with cable-stay anchors for roof stacks, base of handrails of Boiler Room main roof, and base of light poles**	**5% to 6% chrysotile**
RF-6: Black asphaltic sealant/coating and silver paint (M)	**Coating on small cylindrical pipe stacks throughout both Boiler Room roofs and on main exhaust stacks on Boiler Room monitor roof**	**Sealant: ND to 4% chrysotile** **Paint: ND**
RF-7: Grey caulking, brown brittle material, silver brittle material and black asphaltic sealant (M)	Associated with small cylindrical pipe penetrations	Grey caulking: ND Brown material: ND Silver material: ND Black sealant: ND
RF-8: Multiple layers of silver foil over black roll-down roofing material over black asphaltic sealant (M)	**At base of all roof penetrations**	**Foil: ND** **Roll-down roofing: ND** **Sealant: 4% chrysotile**
RF-9: Black asphaltic sealant/coating, silver paint and brown brittle material (M)	**Coating on main exhaust stacks on Boiler Room monitor roof**	**Sealant: ND** **Paint: ND** **Brown brittle material: ND** **(assumed positive based on homogeneity with HSA RF-6)**
RF-10: Multi-layer black built-up roofing with pebbles over multi-layered black fibrous material (M)	**Roof on south end of Boiler Room monitor roof (upper roof on south structure)**	**Built-up roofing: ND** **Fibrous material: ND to 25% chrysotile**
RF-11: Grey caulking with paint, silver material with paint, silver paint, black asphaltic sealant and brown brittle material (M)	**At bottom seam on white-painted stacks on roof**	**Grey caulking: ND** **Silver material: ND** **Silver paint: ND** **Black sealant: 5% chrysotile** **Brown brittle material: ND**
RF-12: Silver paint and white/orange paint (M)	On main roof stacks	Silver paint: ND White/orange paint: ND

Table 3.4-1. Results of Bulk Sample Analyses

HSA ID, Material Description, and AHERA Classification	Material Location	HSA Results
RF-13: Grey rubber caulking (M)	At metal flashing on main roof	ND
RF-14: Multiple layers of silver foil over black built-up roofing and brown/pink sandy material (M)	At circular roof penetration at southwest end of roof	Foil: ND Built-up roofing: ND Brown/pink material: ND
RF-15: Black/grey sealant (M)	**At seams where base of Boiler Room monitor roof structure meets Boiler Room main roof and at base of parapet wall along the west side of Boiler Room main roof**	**6% chrysotile**
RF-16: Silver foil over black built-up roofing over black asphaltic sealant over black felt (M)	**West parapet on Boiler Room main roof**	**Foil: ND** **Built-up roofing: ND** **Sealant: 4% chrysotile** **Felt: ND**
RF-17: Black asphaltic sealant and grey concrete (M)	**Patching for cracks on vertical surfaces of north west wall of Engine Room monitor roof**	**Sealant: 8% chrysotile** **Concrete: ND**
RF-18: Silver foil over black built-up roofing over black felt (M)	Parapets for monitor roof structure on main roof	Foil: ND Built-up roofing: ND Felt: ND

ND: none detected, HSA: material that is uniform in color, texture, general appearance, and construction and application date
S: Surfacing material per AHERA, T: Thermal system insulation per AHERA, M: Miscellaneous material per AHERA

Additional ACMs may be present in inaccessible or concealed spaces. These spaces include, but are not limited to materials inside the building, asbestos-containing patches below multiple layers of roofing, interior of mechanical components, etc. If future maintenance, renovation, and/or demolition activities make these areas accessible, Argus Pacific recommends that a thorough assessment of these spaces be conducted at that time to identify and confirm the presence or absence of additional ACMs. Until then, all such unidentified materials must be treated as assumed ACMs in accordance with applicable federal, state, and local regulations.

If the analytical results indicate that all the samples collected per HSA do not contain asbestos, then the HSA (material) is considered a non-ACM. However, if the analytical results of one or more of the samples collected per HSA indicate that asbestos is present in quantities of greater than one percent asbestos as defined by the EPA, all of the HSA (material) is considered to be an ACM regardless of any other analytical results.

Any material that contains greater than one percent asbestos is considered an ACM and must be handled according to Occupational Safety and Health Administration (OSHA), EPA, and applicable state and local regulations.

4.0 CONCLUSIONS AND RECOMMENDATIONS

On June 26 and July 9, 2012, Argus Pacific conducted a renovation-level regulated building materials assessment of the Georgetown Steam Plant located at 6605 13th Avenue South in Seattle, Washington.

4.1 Asbestos

The following table identifies the confirmed ACM and assumed ACM.

Table 4.1-1. ACM and Assumed ACM

HSA ID, Material Description, and AHERA Classification	Material Location	HSA Quantity (approximate)
RF-3: Grey soft caulking (M)	Around seam base of penthouse exterior walls and seam where Boiler Room roof meets south portion of main roof on Engine Room	150 LF
RF-5: Black asphaltic sealant (M)	Associated with cable-stay anchors for roof stacks, base of handrails of Boiler Room main roof, and base of light poles	At cable-stay anchors for roof stacks: 32 SF at 32 locations Handrail bases at east side of main roof: 35 SF at 18 locations Handrail bases at west side of main roof: 33 SF at 15 locations At base of light poles: 5 SF at 3 locations
RF-6: Black asphaltic sealant/coating and silver paint (M)	Coating on small cylindrical pipe stacks throughout both Boiler Room roofs and on main exhaust stacks on Boiler Room monitor roof	Smaller cylindrical vents: 38 EA Height: 3-4.5 ft. Circumference: ~ 1 ft. Larger main exhaust stacks: 800 SF, 8 EA
RF-8: Black asphaltic sealant associated with multiple layers of silver foil over black roll-down roofing material (M)	At base of all roof penetrations	350 SF, 46 EA
RF-9: Black asphaltic sealant/coating, silver paint and brown brittle material (M)	Coating on main exhaust stacks on Boiler Room monitor roof	Quantity included in material RF-6
RF-10: Multi-layer black built-up roofing with pebbles over multi-layered black fibrous material (M)	Roof on south end of Boiler Room monitor roof (upper roof on south structure)	500 SF

HSA ID, Material Description, and AHERA Classification	Material Location	HSA Quantity (approximate)
RF-11: Black sealant associated with non-ACM grey caulking, silver material with paint, silver paint (M)	At bottom seam on white-painted stacks on roof	20 LF, 2 EA
RF-15: Black/grey sealant (M)	At seams where base of Boiler Room monitor roof structure meets Boiler Room main roof and at base of parapet wall along the west side of Boiler Room main roof	650 SF
RF-16: Black asphaltic sealant associated with non-ACM silver foil over black built-up roofing over black felt (M)	West parapet on Boiler Room main roof	160 SF
RF-17: Black asphaltic sealant (M)	Patching for cracks on vertical surfaces of north west wall of Engine Room monitor roof	300 SF

HSA: material that is uniform in color, texture, general appearance, and construction and application date
S: Surfacing material per AHERA, T: Thermal system insulation per AHERA, M: Miscellaneous material per AHERA

Asbestos-related work must be performed in compliance with Washington State worker protection and environmental protection regulations. See WAC 296-62, WAC 296-65, and PSCAA Regulation III, Article 4 for additional information.

5.0 LIMITATIONS

This report presents the results of the asbestos roof sampling conducted of the Georgetown Steam Plant located at 6605 13th Avenue South in Seattle, Washington. The assessment was for the purposes of identifying ACM on the roof prior to renovation.

Regulated building material assessments are non-comprehensive and subject to many limitations, including those presented below. Our assessment has considered risks pertaining to asbestos; however, this assessment is limited to only those locations and materials assessed. This assessment was not designed to identify all potential concerns or to eliminate all risks associated with renovation, demolition, material removal, construction, or transferring of property title. Evaluation of other risks not specifically described in the Scope of Work have not been included; for example: lead paint assessment, structural integrity; engineering loads; electrical; mechanical; radon gas; slope stability; building settlement; and evaluation of toxic and hazardous substances in, or in contact with, soil and groundwater. No warranty, expressed or implied, is made.

Argus Pacific has performed the services set forth in the Scope of Work in accordance with generally accepted industrial hygiene practices in the same or similar localities, related to the nature of the work accomplished, at the time the services were performed.

The regulated building materials and conditions presented in this report represent those observed on the dates we conducted the sampling. This sampling is intended for the exclusive use of BOLA Architecture + Planning for specific application to the referenced property. This assessment does not replace nor can be used as professionally developed construction or demolition plans, specifications, or bidding documents. This report is not a legal opinion.

Prepared by:

Conor Foley
Industrial Hygienist
Argus Pacific, Inc.

Reviewed by:

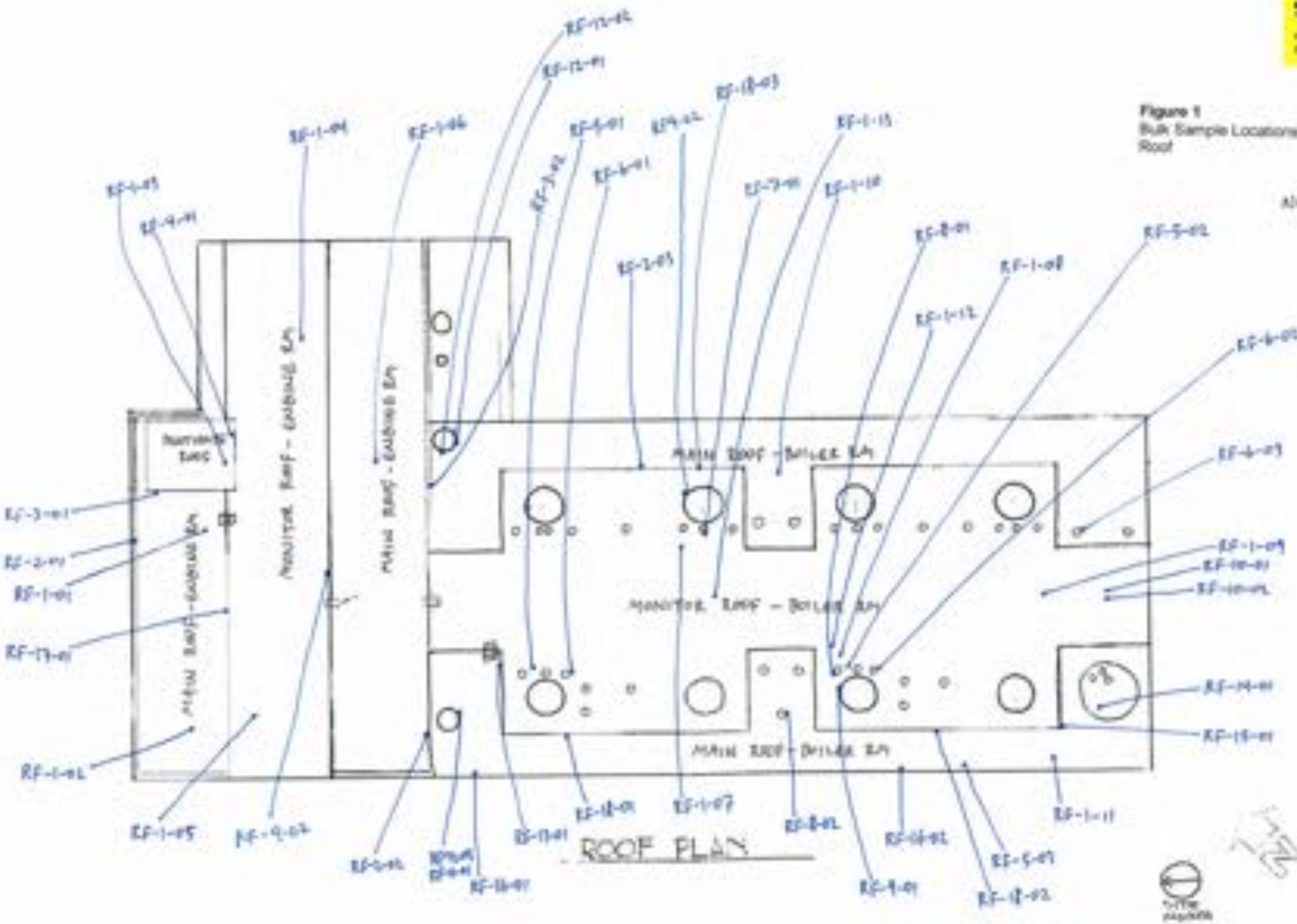
Scott R. Parker, Principal
Senior Consultant
Argus Pacific, Inc.

Figures

ARGUS PACIFIC

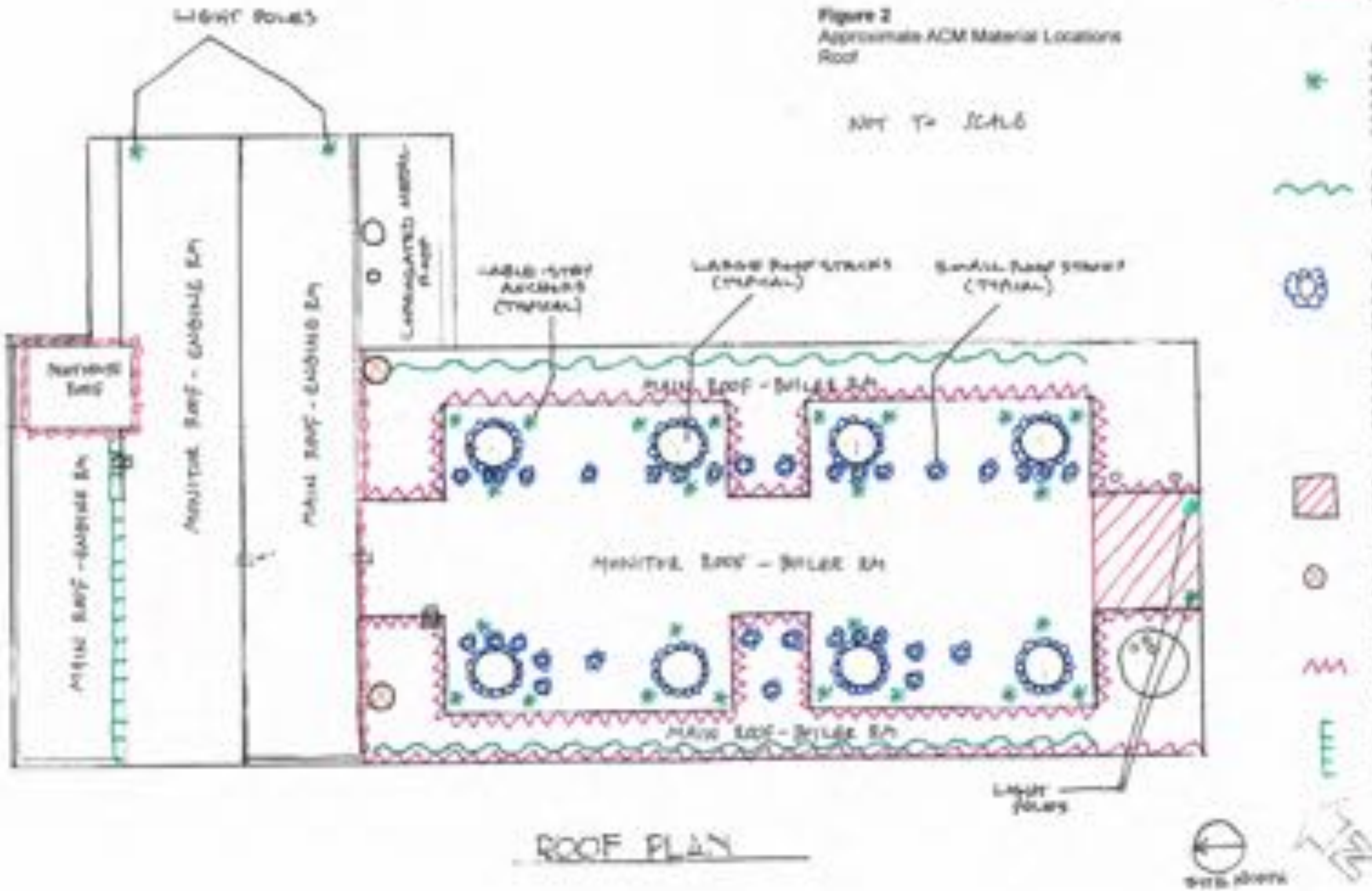
Figure 1
Bulk Sample Locations
Roof

NOT TO SCALE



ARGUS PACIFIC

Figure 2
Approximate ACM Material Locations
Roof



LEGEND

ARGUS PACIFIC
TRAINING • CONSULTING

Photographs

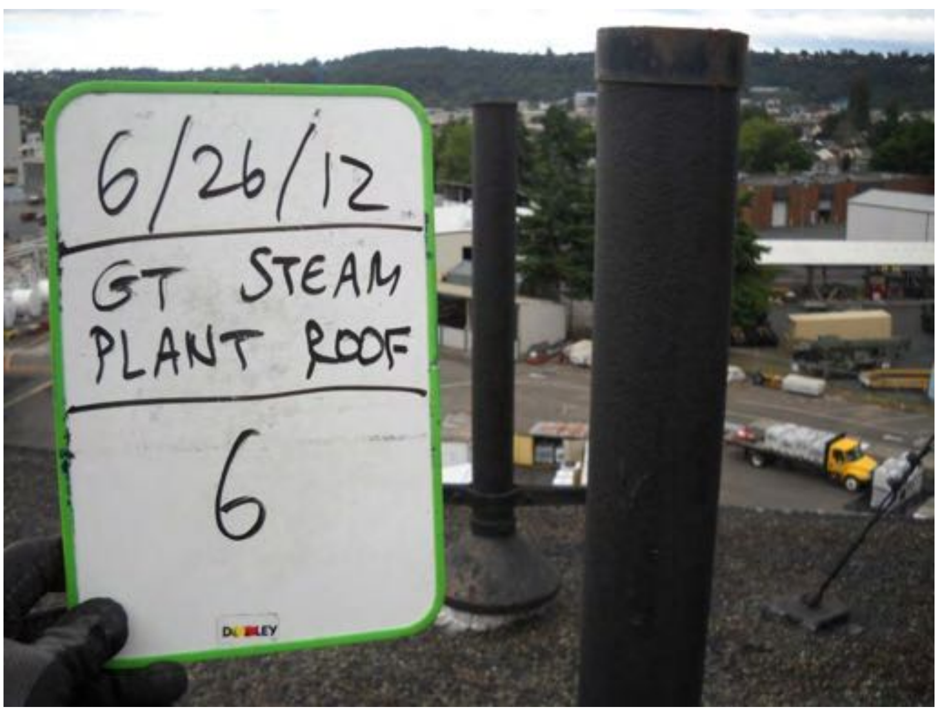
Photograph 1. RF-1: Multi-layer black built-up roofing with pebbles, black asphaltic sealant and black fibrous material (M)

Photograph 2. RF-2: Black roll-down roofing over silver foil over black asphaltic sealant over multi-layered black felt (M)

Photograph 3. RF-3: Grey soft caulking with paint (M)

Photograph 4. RF-4: Black roll-down roofing over silver foil over black asphaltic sealant over multi-layered black felt (M)

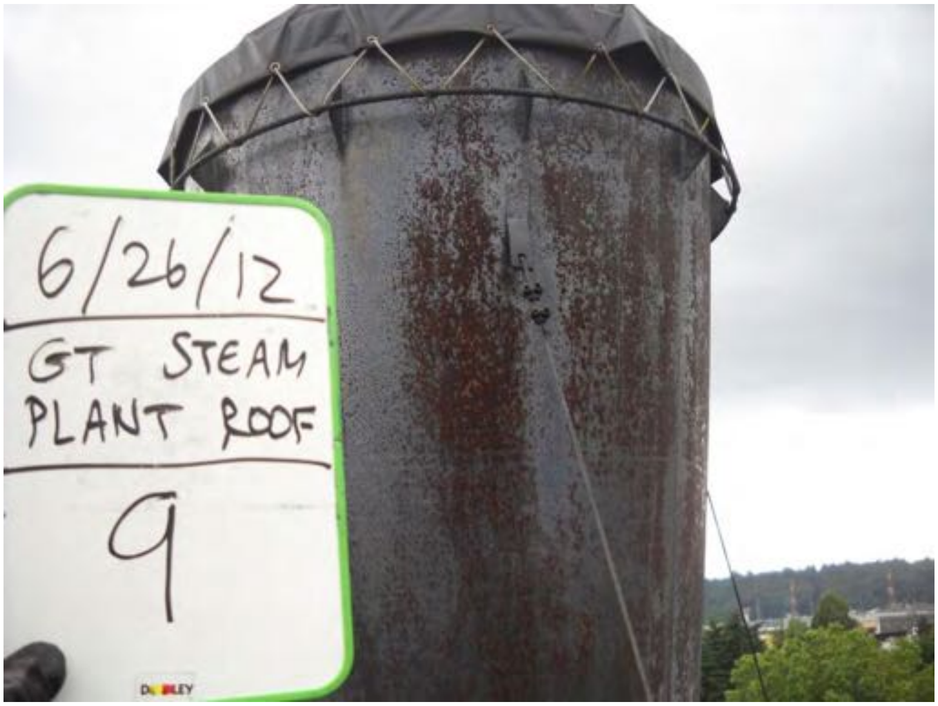
Photograph 5. RF-5: Black asphaltic sealant (M)



Photograph 6. RF-6: Black asphaltic sealant and silver paint (M)

Photograph 7.

Photograph 8. RF-8: Multiple layers of silver foil over black roll-down roofing material over black asphaltic sealant (M)



Photograph 9. RF-9: Black asphaltic sealant, silver paint and brown brittle material (M)

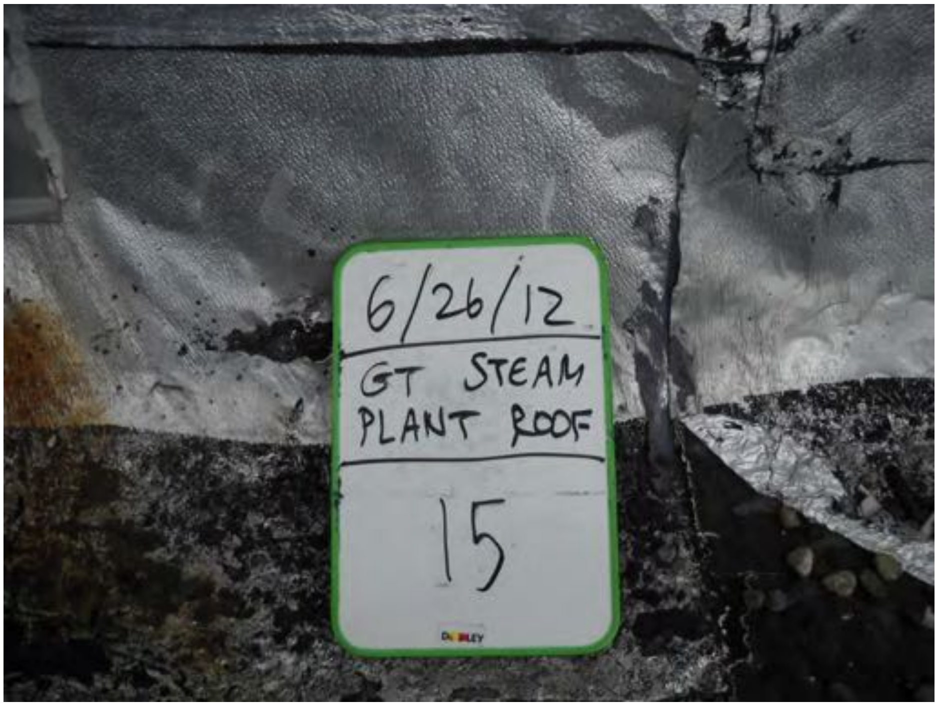
Photograph 10. RF-10: Multi-layer black built-up roofing with pebbles over multi-layered black fibrous material (M)

Photograph 11. RF-11: Grey caulking with paint, silver material with paint, silver paint, black asphaltic sealant and brown brittle material (M)

Photograph 12. RF-12: Silver paint and white/orange paint (M)

Photograph 13. RF-13: Grey rubber caulking (M)

Photograph 14. RF-14: Multiple layers of silver foil over black built-up roofing and brown/pink sandy material (M)



Photograph 15. RF-15: Black/grey sealant (M)

Photograph 16. RF-16: Silver foil over black built-up roofing over black asphaltic sealant over black felt (M)

Photograph 17. RF-17: Black asphaltic sealant and grey concrete (M)

Photograph 18. RF-18: Silver foil over black built-up roofing over black felt (M)

Appendix A
Asbestos Laboratory Analytical Results

SEATTLE ASBESTOS TEST, LLC

19711 Scriber Lake Road, Suite D, Lynnwood, WA 98036, Tel:425.673.9850
12727 Northup Way, Suite 1, Bellevue, WA 98005, Tel:425.861.1111
www.seattleasbestostest.com, admin@seattleasbestostest.com

NVLAP Accreditation Lab Codes:
LYNNWOOD LAB: 200768-0, BELLEVUE LAB: 200876-0

Date Analyzed: 6/29/2012

Client Job #: 640238
Project Loc.: Georgetown Steam Plant - Roof
Laboratory Batch#: 201212176
Samples Received: 40

Mr. Scott Rinear
Argus Pacific
1900 W Nickerson St # 315, Seattle, WA 98119

Enclosed please find the test results for the bulk samples submitted to our laboratory for asbestos analysis. Analysis was performed using polarized light microscopy (PLM) in accordance with Test Method US EPA/600/R-93/116.

Percentages for this report are done by visual estimate. Since variation in data increases as the quantity of asbestos decreases toward the limit of detection, the EPA recommends point counting for samples containing between <1% and 10% asbestos (NESHAP, 40 CFR Part 61). Statistically, point counting is a more accurate method. If you feel a point count might be beneficial, please feel free to call and request one.

The test results refer only to the samples or items submitted and tested. The accuracy with which these samples represent the actual materials is totally dependent on the acuity of the person who took the samples. This report must not be used by the client to claim product certification, approval, or endorsement by Seattle Asbestos Test, LLC, NVLAP, NIST, or any agency of the Federal government.

This report is highly confidential and will not be released without your consent. Samples are archived for two weeks after the analysis, and disposed of as hazardous waste thereafter.

Thank you for using our service and let us know if we can further assist you.

Sincerely

Steve (Fanyao) Zhang
President

SEATTLE ASBESTOS TEST, LLC **Analyzing Quality**

Lynnwood Lab: [illegible] Lynnwood, WA [illegible]
Bellevue Lab: [illegible] Bellevue, WA [illegible]
Email: [illegible] website: [illegible]
NVLAP Lab Code: Lynnwood: [illegible], Bellevue: [illegible]

Batch# 201212176

CHAIN OF CUSTODY

CLIENT INFORMATON

Company: Argus Pacific, Inc Address: 1900 W Nickerson Street, #315, Seattle, WA 98119
Phone: (206) 285-3373 Fax: (206) 285-3927 Email:

METHOD (SELECT ONE)

(◉) Bulk Asbestos (PLM) ( ) PointCount400 ( ) PointCount1000 ( ) Pt. Count Gravimetric ( ) Other (Specify)

PROJECT INFORMATION

\# of Samples: 40 Job#: 640238 Project Location: Georgetown Steam Plant-Roof

PROJECT MANAGERS (SELECT ONE OR MORE)

	Name	Phone	Email		Name	Phone	Email
☐	Elizabeth Black			☐	Nicole Gladu		nicole@arguspacific.com
☐	Melodie McNab			☐	Tim Nickell		
☐	Scott Parker		sparker@arguspacific.com	☑	Scott Rinear		srinear@arguspacific.com
☐	Christopher Selders		chris@arguspacific.com	☐	John Terrill		john@arguspacific.com
☐	Joe White			☐	Megan Yoshimoto		

TURNAROUND TIME

( ) 1 Hour ( ) 2 Hours ( ) Same Day (4 to 6 hrs) ( ) 1 Day (◉) Number of Days: 3-5

SEQ#	CLIENT SAMPLE #	SAMPLE DESCRIPTION	GROUP	COMPOSITE	PT. COUNT
1	RF-1-01	Pebble is top-side of sample layers			
2	RF-1-02	Pebble is top-side of sample layers			
3	RF-1-03	Pebble is top-side of sample layers			
4	RF-1-04	Pebble is top-side of sample layers			
5	RF-1-05	Pebble is top-side of sample layers			
6	RF-1-06	Pebble is top-side of sample layers			
7	RF-1-07	Pebble is top-side of sample layers			
8	RF-1-08	Pebble is top-side of sample layers			
9	RF-1-09	Pebble is top-side of sample layers			
10	RF-1-10	Pebble is top-side of sample layers			
11	RF-1-11	Pebble is top-side of sample layers			
12	RF-2-01	Silver foil is top-side of sample layers			
13	RF-2-02	Silver is top-side of sample layers			
14	RF-2-03	Silver is top-side of sample layers			
15	RF-3-01				
16	RF-3-02				
17	RF-4-01	Silver foil is top-side of sample layers			
18	RF-4-02	Silver foil is top-side of sample layers			
19	RF-5-01				
20	RF-5-02				

	Print Name	Signature	Company Name	Date	Time
Sampled by	Scott Rinear	[signature]	Argus Pacific	06/26/12	1300
Relinquished by	Peter Snider	[signature]	Argus Pacific	06/27/12	1048
Delivered by	Peter Snider	[signature]	Argus Pacific	06/27/12	1048
Received by	EDUtton	[signature]	Seattle Asbestos Test, LLC-B	6/27/12	1048
Analyzed by	EDUtton	[signature]	Seattle Asbestos Test, LLC-B	6/28/12	1745
Reported by	[signature]	[signature]	Seattle Asbestos Test, LLC	6/29/12	

PREFERRED REPORTING METHOD ☐ Phone ☐ Fax ☑ Email ☐ Postal Mail

SEATTLE ASBESTOS TEST, LLC **Analyzing Quality**

Lynnwood Lab: 19711 Scriber Lake Road, Suite D, Lynnwood, WA 98036, T 425.673.9850, F 425.673.9810
Bellevue Lab: 12727 Northup Way, Suite 24, Bellevue, WA 98005, T 425.861.1111, F 425.861.1118
Email: admin@seattleasbestostest.com, website: www.seattleasbestostest.com
NVLAP Lab Code: Lynnwood: 200768-0, Bellevue: 200876-0

Batch# 201212176

CHAIN OF CUSTODY

CLIENT INFORMATON

Company: Argus Pacific, Inc. Address: 1900 W Nickerson Street, #315, Seattle, WA 98119
Phone: (206) 285-3373 Fax: (206) 285-3927 Email:

METHOD (SELECT ONE)

(●) Bulk Asbestos (PLM) ( ) PointCount400 ( ) PointCount1000 ( ) Pt. Count Gravimetric ( ) Other (Specify)

PROJECT INFORMATION

\# of Samples: 40 Job#: 840238 Project Location: Georgetown Steam Plant-Roof

PROJECT MANAGERS (SELECT ONE OR MORE)

	Name	Phone	Email
☐	Elizabeth Black		
☐	Melodie McNab		
☐	Scott Parker		sparker@arguspacific.com
☐	Christopher Selders		chris@arguspacific.com
☐	Joe White		

	Name	Phone	Email
☐	Nicole Gladu		nicole@arguspacific.com
☐	Tim Nickell		
☑	Scott Rinear		srinear@arguspacific.com
☐	John Terrill		john@arguspacific.com
☐	Megan Yoshimoto		

TURNAROUND TIME

( ) 1 Hour ( ) 2 Hours ( ) Same Day (4 to 8 hrs) ( ) 1 Day (●) Number of Days: 3-5

SEQ#	CLIENT SAMPLE #	SAMPLE DESCRIPTION	GROUP	COMPOSITE	PT. COUNT
21	RF-5-03				
22	RF-6-01				
23	RF-6-02				
24	RF-6-03				
25	RF-7-01				
26	RF-8-01	Silver foil is top-side of sample layers			
27	RF-8-02	Silver foil is top-side of sample layers			
28	RF-9-01				
29	RF-9-02				
30	RF-10-01				
31	RF-10-02				
32	RF-11-01				
33	RF-12-01				
34	RF-12-02				
35	RF-12-03				
36	RF-13-01				
37	RF-14-01	Silver foil is top-side of sample layers			
38	RF-15-01				
39	RF-16-01	Silver foil is top-side of sample layers			
40	RF-17-01				

	Print Name	Signature	Company Name	Date	Time
Sampled by	Scott Rinear		Argus Pacific	06/26/12	1300
Relinquished by	Peter Snider		Argus Pacific	06/27/12	
Delivered by	Peter Snider		Argus Pacific	06/27/12	
Received by	E.Dutton	[signature]	Seattle Asbestos Test, LLC -B	6/27/12	1048
Analyzed by	E.Dutton	[signature]	Seattle Asbestos Test, LLC -B	6/28/12	1745
Reported by	[signature]	[signature]	Seattle Asbestos Test, LLC	6/29/12	

PREFERRED REPORTING METHOD ☐ Phone ☐ Fax ☑ Email ☐ Postal Mail

Version [illegible]

SEATTLE ASBESTOS TEST, LLC

NVLAP Accreditation Lab Codes - Bellevue:200878; Lynnwood:200768

Lynnwood Laboratory: 19711 Scriber Lake Rd, Suite D, Lynnwood, WA 98036; Tel: 425.673.9850, Fax:425.673.9810
Bellevue Laboratory: 12727 Northup Way, Suite 1, Bellevue, WA 98005; Tel: 425.861.1111, Fax: 425.861.1118
Website: http://www.seattleasbestostest.com, E-mail: admin@seattleasbestostest.com

ANALYTICAL LABORATORY REPORT

PLM by Method EPA/600/R-93/116

Attn: Mr. Scott Rinear
Client: Argus Pacific
Address: 1900 W Nickerson St # 315, Seattle, WA 98119

Project: Georgetown Steam Plant - Roof

Client Job#: 640238
Laboratory Batch #: 201212176
Date Received: 6/27/2012
Samples Received: 40
Date Analyzed: 6/29/2012
Samples Analyzed: 40

Lab ID	Client Sample ID	Layer	Description	%	Asbestos Fibers	Non-Fibrous Components	%	Non-asbestos Fibers
1	RF-1-01	1	Black asphaltic material with fibrous material and gravel		**None detected**	Filler, Asphalt, Binder, Gravel	16	Cellulose
		2	Black asphaltic material		**None detected**	Filler, Asphalt, Binder	2	Cellulose
2	RF-1-02	1	Black asphaltic material with fibrous material and gravel		**None detected**	Filler, Asphalt, Binder, Gravel	17	Cellulose
		2	Black asphaltic material		**None detected**	Filler, Asphalt, Binder	3	Cellulose
3	RF-1-03	1	Black asphaltic material with fibrous material and gravel		**None detected**	Filler, Asphalt, Binder, Gravel	15	Cellulose
		2	Black asphaltic material		**None detected**	Filler, Asphalt, Binder	2	Cellulose
4	RF-1-04	1	Black asphaltic material with fibrous material and gravel		**None detected**	Filler, Asphalt, Binder, Gravel	19	Cellulose
		2	Black asphaltic material		**None detected**	Filler, Asphalt, Binder	4	Cellulose
5	RF-1-05	1	Black asphaltic material with fibrous material and gravel		**None detected**	Filler, Asphalt, Binder, Gravel	18	Cellulose
6	RF-1-06	1	Black asphaltic material with fibrous material and gravel		**None detected**	Filler, Asphalt, Binder, Gravel	21	Cellulose
		2	Black asphaltic material		**None detected**	Filler, Asphalt, Binder	4	Cellulose
		3	Gray hard sandy/brittle material		**None detected**	Sands, Filler, Binder	2	Cellulose
7	RF-1-07	1	Black asphaltic material with fibrous material		**None detected**	Filler, Asphalt, Binder	36	Cellulose
8	RF-1-08	1	Black asphaltic material with sand and gravel	4	**Chrysotile**	Filler, Asphalt, Binder, Sands, Gravel	2	Cellulose
		2	Black asphaltic material with fibrous material		**None detected**	Filler, Asphalt, Binder	34	Cellulose
		3	Black asphaltic material		**None detected**	Filler, Asphalt, Binder	3	Cellulose
9	RF-1-09	1	Black asphaltic material with fibrous material and gravel		**None detected**	Filler, Asphalt, Binder, Gravel	31	Cellulose
10	RF-1-10	1	Black asphaltic material with fibrous material and gravel		**None detected**	Filler, Asphalt, Binder, Gravel	30	Cellulose
11	RF-1-11	1	Black asphaltic material with gravel		**None detected**	Filler, Asphalt, Binder	2	Cellulose
		2	Black asphaltic material with fibrous material		**None detected**	Filler, Asphalt, Binder	30	Cellulose
		3	Multi-layered black asphaltic fibrous material		**None detected**	Filler, Asphalt, Binder	67	Cellulose
12	RF-2-01	1	Silver foil		**None detected**	Foil/binder		None detected
		2	Black asphaltic material		**None detected**	Filler, Asphalt, Binder	2	Cellulose
		3	Multi-layered black asphaltic fibrous material		**None detected**	Filler, Asphalt, Binder	63	Cellulose
13	RF-2-02	1	Black asphaltic material		**None detected**	Filler, Asphalt, Binder	2	Cellulose
		2	Silver foil		**None detected**	Foil/binder		None detected
		3	Black soft material		**None detected**	Filler, Asphalt, Binder	3	Cellulose
		4	Multi-layered black asphaltic fibrous material		**None detected**	Filler, Asphalt, Binder	64	Cellulose
14	RF-2-03	1	Black asphaltic material		**None detected**	Filler, Asphalt, Binder	2	Cellulose

Analyzed by: Liz Dutton

Report reviewed by: Steve (Fanyao) Zhang, President

SEATTLE ASBESTOS TEST, LLC

NVLAP Accreditation Lab Codes - Bellevue:200876; Lynnwood:200768

Lynnwood Laboratory: 19711 Scriber Lake Rd, Suite D, Lynnwood, WA 98036; Tel: 425.673.9850, Fax:425.673.9810
Bellevue Laboratory: 12727 Northup Way, Suite 1, Bellevue, WA 98005, Tel: 425.861.1111, Fax: 425.861.1118
Website: http://www.seattleasbestostest.com, E-mail: admin@seattleasbestostest.com

ANALYTICAL LABORATORY REPORT

PLM by Method EPA/600/R-93/116

Attn.: Mr. Scott Rinear
Client: Argus Pacific
Address: 1900 W Nickerson St # 315, Seattle, WA 98119

Client Job#: 640238
Laboratory Batch #: 201212176
Date Received: 6/27/2012
Samples Received: 40
Date Analyzed: 6/29/2012
Samples Analyzed: 40

Project: Georgetown Steam Plant - Roof

Lab ID	Client Sample ID	Layer	Description	%	Asbestos Fibers	Non-Fibrous Components	%	Non-asbestos Fibers
		2	Silver foil		**None detected**	Foil/binder		None detected
		3	Black asphaltic material		**None detected**	Filler, Asphalt, Binder	2	Cellulose
		4	Black asphaltic material	**4**	**Chrysotile**	Filler, Asphalt, Binder	5	Cellulose
		5	Multi-layered black asphaltic fibrous material		**None detected**	Filler, Asphalt, Binder	58	Cellulose
15	RF-3-01	1	Gray soft material with paint	**2**	**Chrysotile**	Binder, Filler, Paint	4	Cellulose
16	RF-3-02	1	Gray soft material	**2**	**Chrysotile**	Binder, Filler	3	Cellulose
17	RF-4-01	1	Black asphaltic material		**None detected**	Filler, Asphalt, Binder	2	Cellulose
		2	Silver foil		**None detected**	Foil/binder		None detected
		3	Black asphaltic material		**None detected**	Filler, Asphalt, Binder	9	Cellulose
		4	Multi-layered black asphaltic fibrous material		**None detected**	Filler, Asphalt, Binder	63	Cellulose
18	RF-4-02	1	Black asphaltic material		**None detected**	Filler, Asphalt, Binder	2	Cellulose
		2	Silver foil		**None detected**	Foil/binder		None detected
		3	Black/brown asphaltic material with soft material		**None detected**	Filler, Asphalt, Binder	6	Cellulose
		4	Black asphaltic material with fibrous material		**None detected**	Filler, Asphalt, Binder	26	Cellulose
		5	Multi-layered black asphaltic fibrous material		**None detected**	Filler, Asphalt, Binder	59	Cellulose
19	RF-5-01	1	Black asphaltic material	**6**	**Chrysotile**	Filler, Asphalt, Binder	5	Cellulose
20	RF-5-02	1	Black asphaltic material	**6**	**Chrysotile**	Filler, Asphalt, Binder	8	Cellulose
21	RF-5-03	1	Black asphaltic material	**5**	**Chrysotile**	Filler, Asphalt, Binder	6	Cellulose
22	RF-6-01	1	Black loose asphaltic material		**None detected**	Filler, Asphalt, Binder	3	Glass fibers
23	RF-6-02	1	Black loose asphaltic material		**None detected**	Filler, Asphalt, Binder	4	Cellulose
		2	Trace silver paint		**None detected**	Paint, Binder	2	Cellulose
24	RF-6-03	1	Black loose asphaltic material	**4**	**Chrysotile**	Filler, Asphalt, Binder	3	Cellulose
25	RF-7-01	1	Brown brittle material		**None detected**	Filler, Binder		None detected
		2	Gray soft/elastic material		**None detected**	Binder, Filler	4	Cellulose
		3	Silver brittle material		**None detected**	Filler, Binder		None detected
		4	Black asphaltic material		**None detected**	Filler, Asphalt, Binder	5	Cellulose
26	RF-8-01	1	Silver foil		**None detected**	Foil/binder		None detected
		2	Black asphaltic material		**None detected**	Filler, Asphalt, Binder	6	Cellulose
		3	Silver foil		**None detected**	Foil/binder		None detected
		4	Black asphaltic material		**None detected**	Filler, Asphalt, Binder	2	Cellulose
		5	Silver foil		**None detected**	Foil/binder		None detected
		6	Black asphaltic material		**None detected**	Filler, Asphalt, Binder	3	Cellulose
		7	Silver foil		**None detected**	Foil/binder		None detected
		8	Black asphaltic material		**None detected**	Filler, Asphalt, Binder	2	Cellulose
		9	Black asphaltic material	**4**	**Chrysotile**	Filler, Asphalt, Binder	5	Cellulose
27	RF-8-02	1	Black asphaltic material		**None detected**	Filler, Asphalt, Binder	6	Cellulose

Analyzed by: Liz Dutton

Report reviewed by: Steve (Fanyao) Zhang, President

SEATTLE ASBESTOS TEST, LLC
NVLAP Accreditation Lab Codes - Bellevue:200879; Lynnwood:200768
Lynnwood Laboratory: 19711 Scriber Lake Rd, Suite D, Lynnwood, WA 98036; Tel: 425.673.9850, Fax:425.673.9810
Bellevue Laboratory: 12727 Northup Way, Suite 1, Bellevue, WA 98005; Tel: 425.861.1111, Fax: 425.861.1118
Website: http://www.seattleasbestostest.com, E-mail: admin@seattleasbestostest.com

ANALYTICAL LABORATORY REPORT
PLM by Method EPA/600/R-93/116

Attn.: Mr. Scott Rinear
Client: Argus Pacific
Address: 1900 W Nickerson St # 315, Seattle, WA 98119

Project: Georgetown Steam Plant - Roof

Client Job#: 640238
Laboratory Batch #: 201212176
Date Received: 6/27/2012
Samples Received: 40
Date Analyzed: 6/29/2012
Samples Analyzed: 40

Lab ID	Client Sample ID	Layer	Description	%	Asbestos Fibers	Non-Fibrous Components	%	Non-asbestos Fibers
		2	Silver foil		**None detected**	Foil/binder		None detected
		3	Black asphaltic material		**None detected**	Filler, Asphalt, Binder	6	Cellulose
		4	Silver foil		**None detected**	Foil/binder		None detected
		5	Black asphaltic material		**None detected**	Filler, Asphalt, Binder	2	Cellulose
		6	Silver foil		**None detected**	Foil/binder		None detected
		7	Black asphaltic material		**None detected**	Filler, Asphalt, Binder	3	Cellulose
		8	Silver foil		**None detected**	Foil/binder		None detected
		9	Black asphaltic material		**None detected**	Filler, Asphalt, Binder	2	Cellulose
28	RF-9-01	1	Black asphaltic material		**None detected**	Filler, Asphalt, Binder	2	Cellulose
		2	Silver paint		**None detected**	Paint, Filler	4	Cellulose
		3	Brown brittle material		**None detected**	Filler, Binder		None detected
29	RF-9-02	1	Black asphaltic material		**None detected**	Filler, Asphalt, Binder	3	Cellulose
		2	Trace silver paint		**None detected**	Paint, Filler	2	Cellulose
		3	Trace brown brittle material		**None detected**	Filler, Binder		None detected
30	RF-10-01	1	Black asphaltic material with fibrous material		**None detected**	Filler, Asphalt, Binder	12	Cellulose
		2	Multi-layered black asphaltic fibrous material		**None detected**	Filler, Asphalt, Binder	57	Cellulose
		3	Black asphaltic fibrous material	**25**	**Chrysotile**	Filler, Asphalt, Binder	35	Cellulose
31	RF-10-02	1	Black asphaltic material with fibrous material		**None detected**	Filler, Asphalt, Binder	18	Cellulose
		2	Multi-layered black asphaltic fibrous material		**None detected**	Filler, Asphalt, Binder	58	Cellulose
32	RF-11-01	1	Gray soft/elastic material with paint		**None detected**	Binder, Filler, Paint	2	Cellulose
		2	Silver soft/elastic material with paint		**None detected**	Binder, Filler, Paint	3	Cellulose
		3	Trace silver paint		**None detected**	Paint, Filler	4	Cellulose
		4	Black asphaltic material with paint	**5**	**Chrysotile**	Filler, Asphalt, Binder	2	Cellulose
		5	Brown brittle material		**None detected**	Filler, Binder		None detected
33	RF-12-01	1	White/orange paint		**None detected**	Paint, Filler	4	Cellulose
		2	Silver paint		**None detected**	Paint, Filler	2	Cellulose
34	RF-12-02	1	White/orange paint		**None detected**	Paint, Filler	2	Cellulose
		2	Silver paint		**None detected**	Paint, Filler	3	Cellulose
35	RF-12-03	1	White/orange paint		**None detected**	Paint, Filler	4	Cellulose
		2	Silver paint		**None detected**	Paint, Filler	2	Cellulose
36	RF-13-01	1	Silver soft/elastic material		**None detected**	Binder, Filler	4	Cellulose
37	RF-14-01	1	Silver foil		**None detected**	Foil/binder		None detected
		2	Black asphaltic material		**None detected**	Filler, Asphalt, Binder	5	Cellulose
		3	Silver foil		**None detected**	Foil/binder,		None detected
		4	Black asphaltic material		**None detected**	Filler, Asphalt, Binder	3	Cellulose
		5	Silver foil		**None detected**	Foil/binder		None detected

Analyzed by: Liz Dutton

Report reviewed by: Steve (Fanyao) Zhang, President

SEATTLE ASBESTOS TEST, LLC

NVLAP Accreditation Lab Codes - Bellevue 200876; Lynnwood 200768

Lynnwood Laboratory: 19711 Scriber Lake Rd, Suite D, Lynnwood, WA 98036; Tel: 425.673.9850, Fax:425.673.9810
Bellevue Laboratory: 12727 Northup Way, Suite 1, Bellevue, WA 98005; Tel: 425.861.1111, Fax: 425.861.1118
Website: http://www.seattleasbestostest.com, E-mail: admin@seattleasbestostest.com

ANALYTICAL LABORATORY REPORT
PLM by Method EPA/600/R-93/116

Attn.: Mr. Scott Rinear
Client: Argus Pacific
Address: 1900 W Nickerson St # 315, Seattle, WA 98119

Client Job# 640238
Laboratory Batch # 201212176
Date Received: 6/27/2012
Samples Received: 40
Date Analyzed: 6/29/2012
Samples Analyzed: 40

Project: Georgetown Steam Plant - Roof

Lab ID	Client Sample ID	Layer	Description	%	Asbestos Fibers	Non-Fibrous Components	%	Non-asbestos Fibers
		6	Brown/pink hard sandy/brittle material		**None detected**	Sands, Filler, Binder	3	Cellulose
38	RF-15-01	1	Black asphaltic material	**6**	**Chrysotile**	Filler, Asphalt, Binder	2	Cellulose
39	RF-16-01	1	Silver foil		**None detected**	Foil/binder		None detected
		2	Black asphaltic material		**None detected**	Filler, Asphalt, Binder	8	Glass fibers, Cellulose
		3	Silver foil		**None detected**	Foil/binder		None detected
		4	Black asphaltic material		**None detected**	Filler, Asphalt, Binder	6	Cellulose
		5	Black asphaltic material	**4**	**Chrysotile**	Filler, Asphalt, Binder	6	Cellulose
		6	Black asphaltic fibrous material		**None detected**	Filler, Asphalt, Binder	63	Cellulose
40	RF-17-01	1	Black asphaltic material	**8**	**Chrysotile**	Filler, Asphalt, Binder	2	Cellulose
		2	Gray hard sandy/brittle material		**None detected**	Sands, Filler, Binder	3	Cellulose

Analyzed by: Liz Dutton

Report reviewed by: Steve (Fanyao) Zhang, President

SEATTLE ASBESTOS TEST, LLC

19711 Scriber Lake Road, Suite D, Lynnwood, WA 98036, Tel:425.673.9850
12727 Northup Way, Suite 1, Bellevue, WA 98005, Tel:425.861.1111
www.seattleasbestostest.com, admin@seattleasbestostest.com

NVLAP Accreditation Lab Codes:
LYNNWOOD LAB: 200768-0, BELLEVUE LAB: 200876-0

Date Analyzed: 7/10/2012

Client Job #: 640238.00001

Project Loc.: Georgetown Steam Plant Roof

Laboratory Batch#: 201212445

Samples Received: 6

Mr. Scott Parker / Mr. Conor Foley
Argus Pacific
1900 W Nickerson St # 315, Seattle, WA 98119

Enclosed please find the test results for the bulk samples submitted to our laboratory for asbestos analysis. Analysis was performed using polarized light microscopy (PLM) in accordance with Test Method US EPA/600/R-93/116.

Percentages for this report are done by visual estimate. Since variation in data increases as the quantity of asbestos decreases toward the limit of detection, the EPA recommends point counting for samples containing between <1% and 10% asbestos (NESHAP, 40 CFR Part 61). Statistically, point counting is a more accurate method. If you feel a point count might be beneficial, please feel free to call and request one.

The test results refer only to the samples or items submitted and tested. The accuracy with which these samples represent the actual materials is totally dependent on the acuity of the person who took the samples. This report must not be used by the client to claim product certification, approval, or endorsement by Seattle Asbestos Test, LLC, NVLAP, NIST, or any agency of the Federal government.

This report is highly confidential and will not be released without your consent. Samples are archived for two weeks after the analysis, and disposed of as hazardous waste thereafter.

Thank you for using our service and let us know if we can further assist you.

Sincerely

Steve (Fanyao) Zhang
President

SEATTLE ASBESTOSTEST, LLC

Analyzing Quality

Lynnwood Lab: 19711 Scriber Lake Road, Suite D, WA 98036, Tel 425.673.9850, Fax 425.673.9810
Bellevue Lab: 12727 Northup Way, Suite 1, Bellevue, WA 98005, Tel 425.861.1111, Fax 425.861.1118
Email: admin@seattleasbestostest.com, Website: www.seattleasbestostest.com

#201212445

CHAIN OF CUSTODY

☐ Bulk Asbestos ☐ Point Count 400 ☐ Point Count 1000 ☐ Point Count Gravimetric ☐ Other (Specify) ______
☐ 1 Hour ☐ 2 Hours ☒ Same-day (4 to 6 Hrs.) ☐ 1 Day ☐ ______ Days

Argus Pacific

1900 W Nickerson St # 315, Seattle, WA 98119 Tel: (206) 285-3373 Fax: (206) 285-3927

Number of Samples: 6 PO# 610238.0001 Project Location: Georgetown steam plant Roof

Project Manager (Check one or more):

☐	Christopher Selders	206.462.9355	chris@arguspacific.com	☒	Conor Foley	650.743.4363	conor@arguspacific.com
☐	Meagan Yoshimoto	206.714.7152	meagan@arguspacific.com	☐	Nicole Gladu	206.518.6094	nicole@arguspacific.com
☒	Scott Parker	206.714.7152	sparker@arguspacific.com	☐	Scott Rinear	206.571.5991	srinear@arguspacific.com
☐	Tim Nickell		tim@arguspacific.com	☐			

SEQ#	CLIENT SAMPLE #	SAMPLE DESCRIPTION	LOCATION	NOTES
21	RF-1-12			
22	RF-1-13			
23	RF-16-02			
24	RF-18-01			
25	RF-18-02			
26	RF-18-03			
27				
28				
29				
30				
31				
32				
33				
34				
35				
36				
37				
38				
39				
40				

	Print Name	Signature	Company	Date	Time
Sampled	Conor Foley	[signature]	Argus Pacific	7/9/12	12:00 pm
Relinquished	Conor Foley	[signature]	Argus Pacific	7/9/12	4:55 pm
Delivered	Conor Foley	[signature]	Argus Pacific	7/9/12	4:57 pm
Received	Christina Bule	[signature]	Seattle Asbestos Test-B	7/9/12	16:55
Analyzed	Christina Bule	[signature]	Seattle Asbestos Test-B	7/10/12	1045
Reported	[illegible]		Seattle Asbestos Test	7/10/12	

Results reporting method: ☐ Phone ☐ Fax ☒ Email ☐ Pick-up

☐ Composite all wallboard samples ☐ Text result to phone ☐ Point count samples with ___ % or less asbestos

SEATTLE ASBESTOS TEST, LLC

NVLAP Accredited Lab Code - Bellevue:200870, Lynnwood:200768

Lynnwood Laboratory: 19711 Scriber Lake Rd, Suite D, Lynnwood, WA 98036; Tel: 425.673.9850, Fax:425.673.9810

Bellevue Laboratory: 12727 Northup Way, Suite 1, Bellevue, WA 98005; Tel: 425.861.1111, Fax: 425.861.1118

Website: http://www.seattleasbestostest.com, E-mail: admin@seattleasbestostest.com

ANALYTICAL LABORATORY REPORT

PLM by Method EPA/600/R-93/116

Attn.: Mr. Scott Parker / Mr. Conor Foley
Client: Argus Pacific
Address: 1900 W Nickerson St # 315, Seattle, WA 98119

Client Job #: 640238.00001
Laboratory Batch #: 201212445
Date Received: 7/9/2012
Samples Received: 6
Date Analyzed: 7/10/2012
Samples Analyzed: 6

Project: Georgetown Steam Plant Roof

Lab ID	Client Sample ID	Layer	Description	%	Asbestos Fibers	Non-Fibrous Components	%	Non-asbestos Fibers
1	RF-1-12	1	Black asphaltic material with fibrous material		None detected	Asphalt/binder, Binder/filler	37	Cellulose
2	RF-1-13	1	Black asphaltic material with fibrous material		None detected	Asphalt/binder, Binder/filler	32	Cellulose
3	RF-16-02	1	Silver foil		None detected	Foil/binder		None detected
		2	Black asphaltic material		None detected	Asphalt/binder	21	Cellulose, Glass fibers
		3	Silver foil		None detected	Foil/binder		None detected
		4	Black asphaltic material		None detected	Asphalt/binder	7	Cellulose
		5	Multi-layered black asphaltic fibrous material		None detected	Asphalt/binder, Binder/filler	64	Cellulose
		6	Brown fibrous material		None detected	Binder/filler	69	Cellulose
4	RF-18-01	1	Silver foil		None detected	Foil/binder		None detected
		2	Black asphaltic material		None detected	Asphalt/binder	6	Cellulose
		3	Black asphaltic material with fibrous material		None detected	Asphalt/binder, Binder/filler	29	Cellulose
		4	Black asphaltic fibrous material		None detected	Filler, Asphalt, Binder	61	Cellulose
5	RF-18-02	1	Silver foil		None detected	Foil/binder		None detected
		2	Black asphaltic material		None detected	Asphalt/binder	8	Cellulose
		3	Multi-layered black asphaltic material with fibrous material		None detected	Asphalt/binder, Binder/filler	33	Cellulose
		4	Brown fibrous material		None detected	Binder/filler	64	Cellulose
6	RF-18-03	1	Silver foil		None detected	Foil/binder		None detected
		2	Black asphaltic material		None detected	Asphalt/binder	6	Cellulose

Analyzed by: Christina Buce

Report reviewed by: Steve (Fanyao) Zhang, President

SEATTLE ASBESTOS TEST, LLC

NVLAP Accredited Lab Code - Bellevue:200876; Lynnwood:200768

Lynnwood Laboratory: 19711 Scriber Lake Rd, Suite D, Lynnwood, WA 98036; Tel: 425.673.9850, Fax:425.673.9810

Bellevue Laboratory: 12727 Northup Way, Suite 1, Bellevue, WA 98005; Tel: 425.861.1111, Fax: 425.861.1118

Website: http://www.seattleasbestostest.com, E-mail: admin@seattleasbestostest.com

ANALYTICAL LABORATORY REPORT

PLM by Method EPA/600/R-93/116

Attn.: Mr. Scott Parker / Mr. Conor Foley
Client: Argus Pacific
Address: 1900 W Nickerson St # 315, Seattle, WA 98119

Client Job #: 640238.00001
Laboratory Batch #: 201212445
Date Received: 7/9/2012
Samples Received: 6
Date Analyzed: 7/10/2012
Samples Analyzed: 6

Project: Georgetown Steam Plant Roof

Lab ID	Client Sample ID	Layer	Description	%	Asbestos Fibers	Non-Fibrous Components	%	Non-asbestos Fibers
		3	Multi-layered black asphaltic material with fibrous material		**None detected**	Asphalt/binder, Binder/filler	35	Cellulose
		4	Brown fibrous material		**None detected**	Binder/filler	68	Cellulose

Analyzed by: Christina Buce

Report reviewed by: Steve (Fanyao) Zhang, President

Appendix B
Personnel and Laboratory Accreditations

Certificate of Completion

This is to certify that

Scott Rinear

has satisfactorily completed
4 hours of refresher training as an

Asbestos Building Inspector

to comply with the training requirements of
TSCA Title II / 40 CFR 763 (AHERA)

134900
Certificate Number

Instructor
EPA Provider Cert. Number: 1085

ARGUS PACIFIC
TRAINING•CONSULTING

Jan 11, 2012
Date(s) of Training
Exam Score: NA
Expiration Date: Jan 10, 2013

Argus Pacific, Inc. • 1900 W. Nickerson, Suite 315 • Seattle, Washington • 98119 • 206.285.3373 • fax 206.285.3927

Certificate of Completion

This is to certify that

Conor V. Foley

has satisfactorily completed
4 hours of refresher training as an

Asbestos Building Inspector

to comply with the training requirements of
TSCA Title II / 40 CFR 763 (AHERA)

135923
Certificate Number

EPA Provider Cert. Number: 1085

ARGUS PACIFIC
TRAINING • CONSULTING

Mar 21, 2012
Date(s) of Training

Exam Score: NA

Expiration Date: Mar 21, 2013

Argus Pacific, Inc. • 1900 W. Nickerson, Suite 315 • Seattle, Washington • 98119 • 206.285.3373 • fax 206.285.3927

United States Department of Commerce
National Institute of Standards and Technology

NVLAP®

Certificate of Accreditation to ISO/IEC 17025:2005

NVLAP LAB CODE: 200876-0

Seattle Asbestos Test Bellevue
Bellevue, WA

is accredited by the National Voluntary Laboratory Accreditation Program for specific services, listed on the Scope of Accreditation, for:

BULK ASBESTOS FIBER ANALYSIS

This laboratory is accredited in accordance with the recognized International Standard ISO/IEC 17025:2005. This accreditation demonstrates technical competence for a defined scope and the operation of a laboratory quality management system (refer to joint ISO-ILAC-IAF Communique dated January 2009).

2012-07-01 through 2013-06-30
Effective dates

For the National Institute of Standards and Technology

NVLAP-01C (REV. 2009-01-28)

APPENDIX D
NATIONAL REGISTER NOMINATION & HAER REPORT

NPS Form 10-900
(7-81)

24N 4E 29

OMB NO. 1024-0018
EXP. 12/31/84

United States Department of the Interior
National Park Service

For NPS use only
received
date entered

National Register of Historic Places Inventory—Nomination Form

See instructions in *How to Complete National Register Forms*
Type all entries—complete applicable sections

KI 138

1. Name

historic Seattle Electric Company Georgetown Steam Plant

and/or common Georgetown Steam Plant

2. Location

street & number King County Airport, N.E. Corner ___ not for publication

city, town Seattle ___ vicinity of [redacted]

state WA code 53 county King code 033

3. Classification

Category	Ownership	Status	Present Use	
___ district	X public	X occupied	___ agriculture	___ museum
X building(s)	___ private	___ unoccupied	___ commercial	___ park
___ structure	___ both	___ work in progress	___ educational	___ private residence
___ site	**Public Acquisition**	**Accessible**	___ entertainment	___ religious
___ object	___ in process	X yes: restricted	___ government	___ scientific
	___ being considered	___ yes: unrestricted	X industrial	___ transportation
		___ no	___ military	___ other:

4. Owner of Property

name Seattle City Light

street & number City Light Building, Third Avenue

city, town Seattle, ___ vicinity of state WA

5. Location of Legal Description

courthouse, registry of deeds, etc. King County Courthouse

street & number

city, town Seattle state WA

6. Representation in Existing Surveys

title National Register of Historic Places has this property been determined eligible? X yes ___ no

date August 1, 1978 X federal ___ state ___ county ___ local

depository for survey records 1100 L Street N.W.

city, town Washington, D.C. state

7. Description

Condition		Check one	Check one
X excellent	___ deteriorated	X unaltered	X original site
___ good	___ ruins	___ altered	___ moved date ___
___ fair	___ unexposed		

Describe the present and original (if known) physical appearance

The Georgetown Steam Plant is a substantial reinforced concrete frame structure located in an industrial area in the Georgetown district of Seattle. It contains three steam turbine/generators rated at capacities of 3,000 kw, 8,000 kw, and 10,000 kw. These generators were installed individually in 1907, 1908, and 1917 respectively.

The two smaller machines are vertical Curtis turbine generators with the generator unit positioned directly above the turbine drive and connected by a single upright shaft. The 10,000 kw machine is a Curtis turbine of the later horizontal type in which the turbine is mounted alongside the generator and the single shaft is horizontal. All three turbo-generators are operational and most of the original ancillary equipment is still in place.

The plant is roughly T-shaped in plan, one wing measuring 76 feet by 153 feet and the other measuring 79 feet by 64 feet with a 36 foot extension at one end. The exterior architectural treatment is a simplified adaptation of the New-Classic Revival style. Such characteristic details as cornice, belt course, and water table are incorporated in the design. Masonry areas delineating the bays of the building are proportioned to suggest pilasters.

The front (west) facade of the smaller Engine House is divided into three bays, the central predominating in architectural detail and scale. Sash windows three over three are separated by cast concrete masonry grids. Crowning the upper sash is a cast concrete triangular pediment with a lower dentil motif and chamfered sides, terminating in a plinth. Underneath the plinth are four masonry modillions. In the center is cast the construction date "1906" framed by cast concrete in a linear design with four corner boses. The two side bays of the front façade are comprised of sash windows four over two, interrupted by masonry slabs. A bolectian belt course separates the first two stories and spans the entire length of the structure. The top of the west facade is capped by an entablature, excluding frieze relief decoration. The north elevation of the Engine House is divided into five bays by vertical cast concrete members, proportioned to simulate pilasters. Crowning the top is a cornice. On the roof is a clerestory, comprised of casement windows, spanning the entire length of the north elevation, interrupted by a single stairwell monitor. The back end of the north elevation projects out, with two casement windows. The end corner is framed by cast concrete in a vertical pattern.

The Boiler House consists of nine bays spanning the front (west) elevation consisting of sash windows two over two and separated by masonry grids. The tops of the windows are finished off with recessed shutters which provide ventilation to the interior. Across the top spans an entablature excluding frieze relief, and a second cornice directly above the entablature. The wing is four stories in height with a slerestory spanning the full length of the roof, interrupted by four recesses. The conical symmetry of the later-added stacks is the only interruption of the overall liner design of this building. At the south elevation, the triangular cast periment of the west facade is repeated. A bolectian belt course also spans the full length of the engine room exterior. Below the belt course are sash windows, defining the first floor, with masonry sills.

(see continuation sheets, Item 7 Sheets 1 - 17)

GEORGETOWN STEAMPLANT: ARCHITECTURAL DESCRIPTION

The Georgetown Steamplant, constructed in 1906, is a significant example of Neo-Classical Revival architecture. This particular style, introduced in the United States in the 1890s, served as a model for numerous federal, municipal and industrial structures across the country. Many of these period structures are standing today, and share the distinction with the Georgetown Steamplant of being on the National Register of Historic Places. The Neo-Classical Revival style derives inspiration from Greek and Roman architecture both in plan and exterior design. Although boasting elements of applied surface ornamentation, the Neo-Classical style emphasizes monumentality, scale and structural expression.

The Georgetown Steam plant has a T-shaped plan and is constructed of reinforced concrete. Overall, the Neo-Classical Revival elements are simplified on the exterior, with linear as opposed to symmetrical design. The building is divided into two main wings, the Engine House and the Boiler House.

The front facade (west facade) of the Engine House is divided into three bays, the central predominating in architectural detail and scale. Sash windows three over three are separated by cast concrete masonry grids. Crowning the upper casement is a cast concrete triangular pediment with a lower dentil motif and chamfered sides, terminating in a plinth. Underneath the plinth are four masonry modillions. In the center is cast the construction date of the building "1906", framed by cast masonry in a linear design with four corner boscs. The two side bays of the front facade are comprised of sash windows four over two, interrupted by masonry slabs. A bolectian belt course separates the first two stories and spans the entire length of the structure. The top of the west facade is capped by an entablature, excluding frieze relief decoration. The north elevation of the Engine House is divided into five bays by vertical masonry members, proportioned to simulate pilasters. Crowning the top is a masonry cornice. The simplicity of design here suggests the mass and weight element, characteristic of Neo-Classical Revival architecture. On the roof is a clerestory, comprised of casement windows, spanning the entire length of the north elevation, interrupted by a single monitor wing or outbuilding. The back end of the north elevation projects out, with two sash windows. The end corner is framed by cast masonry in a vertical pattern.

The Boiler House consists of nine bays spanning the front, (west elevation) comprised of sash windows two over two, and separated by masonry grids. The top of the windows are finished off with recessed shutters, which provide ventilation to the interior. Across the top spans an entablature excluding frieze relief, and a second cornice

NPS Form 10-900a
(7-81)

OMB NO. 1024-0018
EXP. 12/31/84

United States Department of the Interior
National Park Service

[redacted]

National Register of Historic Places Inventory—Nomination Form

Continuation sheet | Item number | Page

directly above the entablature. The wing is four stories in height with a clerestory spanning the full length of the roof, interrupted by four recesses. The conical symmetry of the later-added stacks is the only interruption of the overall linear design of this building. At the south elevation, the triangular masonry pediment of the west facade is repeated. A bolectian belt course also spans the full length of the engine room exterior. Below the belt course are casement windows, defining the first floor level, with masonry sills.

In terms of operating efficiency, the plant is very precisely organized. Its longest wing is devoted almost entirely to the production of steam. Before conversion to oil fired boilers, this wing consisted of four levels, each with a separate function. At the top level was the conveyor floor for bringing coal into the building. There the coal was dumped from a continuous moving belt into eight funnel-shaped bunkers on the floor below. Each bunker stoked a pair of immense 932 H.P. Sterling water tube boilers. Smoke flues extended along both sides of the coal bunkers directly above the boilers for carrying smoke to a fan-assisted rooftop stack.

On the second floor, the sixteen boilers were separated into two banks facing each other across a corridor that ran the full length of the wing. From the corridor each boil could be inspected and maintained. On the ground level, below both rows of boilers, there was an ash car that rolled on rails set in the floor. Each car consisted of a dumping hopper that could be moved from boiler to boiler where it would collect ash waste for removal from the building.

The entire coal and ash handling system within the building was arranged to allow the fuel and waste material to be simply dumped as necessary from one floor to the next without relying upon further mechanical distribution.

Oriented on a perpendicular axis across one end of the boiler wing, the second, shorter wing is devoted to generating electricity. The engine room, as it is called, includes the three turbo-generators each with a circulating pump, a vacuum pump, and a barometric or jet condenser. The vertical generators are interconnected by a system of catwalks and ladders, and the condenser and steam piping are arranged between the generators and the wall. A raised platform at the second floor level is provided for the horizontal generator, and the condenser for this machine is located in the space directly below it.

Above the generators the engine room is open to the roof. A 50-ton crane runs on a track overhead to assist with disassembling the equipment for maintenance. Across fro the generators on the opposite wall, the room is divided into a gallery with five levels. The lower floor is occupied by a bank of transformers and two exciters (small generators necessary to energize field windings in the turbo-generators to produce the basic electromagnetic force). Above this section at various levels are the plant offi the switchboard room, and other control equipment.

The 10,000 KW horizontal generator and its condenser are simpler and more compact than the two older vertical machines. It is smaller even than the 3,000 KW unit which has less than one-third its generating capacity. The vertical configuration requires the use of a step bearing to carry the tremendous weight of the revolving mass. This bearing actually floats the shaft on a thin layer of oil that is constantly injected by high pressure pumps.

The Georgetown Steam Plant has undergone very little modernization since the installat of its third generator in 1917. The boilers were converted to steam atomized oil fire furnaces beginning in 1918 and the process of conversion continued until 1946. This modification was accomplished without requiring any substantial alterations to the building, although the coal conveyor and ash cars were removed.

When the King County Airport was constructed on adjoining property in the mid-1930's, it became necessary to replace the tall exhaust stack with roof mounted induced draft fans to prevent the stack from interfering with the flight path. Both original smoke flues were dismantled, and new ducts were installed to connect into the system of fans

The plant was originally built on the east bank of the Duwamish River to take advantage of the river as a source of cooling water for the condensers and for convenience in discharging wastewater. At roughly the same time the stack was removed the Duwamish was diverted to accommodate construction of the county airport, leaving the plant some distance from the river's new channel. A pumping station was therefore built to insure a continued supply of river water, and the discharge tunnel was also lengthened.

Finally, the original barometric condensers for the two vertical generators were rebui in 1965 and 1969. Both new condensers are in general duplications of the earlier installation as is apparent from the engineer's drawings on file.

A complete inventory of equipment currently at the Georgetown Steam Plant is included on the following pages of this section.

NATIONAL REGISTER OF HISTORIC PLACES INVENTORY -- NOMINATION FORM

EQUIPMENT INVENTORY (Preliminary)

EQUIPMENT	REMARKS	DATE OF MANUFACTURE OR INSTALLATION
Steam Boilers		
7 Boilers, each rated 369 boiler horsepower, equipped with superheater.	The boilers were originally coal fired, then converted to burn oil starting in 1918. Final conversion to oil was completed in 1946.	1906 & 1918
2 Boilers, each rated 473 boiler horsepower, equipped with superheater.	Babcock & Wilcox manufactured 14 of the boilers for the Seattle Electric Co. in 1906. In 1918 two more boilers were added.	
7 Boilers each rated 519 boiler horsepower. Boilers are not equipped with superheater.	Each Sterling type boiler has lettered cast manhole inspection covers, 12 per boiler. The boilers also have the name "The Seattle Electric Company" across the top.	
Boiler Steam Pressure Gauges		
0-300 psi. (Total of 16)	Manufactured by J. Marsh Co., Chicago, Illinois. These are fancy brass gauges approximately 15 inches in diameter.	1906 & 1918
Boiler Room Panel		
See remarks	Mounted on the panel is an antique brass pressure gauge (1898) manufactured by Wm. H. Birch Co., San Francisco, Calif. Range 0 to 250 psi., 10 inch. The panel also contains: an old Bristol Recorder manufactured by the Bristol Company, Waterbury,	

EQUIPMENT (Continued)	REMARKS	DATE OF MANUFACTURE OR INSTALLATION
	Conn., a small gauge manufactured by North Coast Engineering Company, Seattle, Wash., and a larger gauge manufactured by J. P. March Co., Chicago, Ill.	
Donkey Boiler		
Boiler Number 3535 Operating pressure 0-160 psig. Oil Fired.	Built for Bucyrus Company, by Johnston Bros., Inc. Ferrysburg, Michigan. The boiler is used for start up.	1924
Induced Draft Fans		
Size 998 Design 2 Fans number 1 & 2, 9 & 10, 13 & 14, 15 & 16 are Model Number 13741. Fans number 3 & 4, 5 & 6, 7 & 8, 11 & 12 are Model Number 13740.	Manufactured by B. F. Sturtevant Company.	ca. 1935
Fuel Oil Storage Tank		
Storage capacity 20,328 barrels.	The storage tank is buried underground.	ca. 1917
Turbo-Generator Number 1		
Curtis Steam Turbine (No. 3007) (4 stage vertical shaft steam turbine).	Manufactured by General Electric Co. Steam Pressure 175 psi.	1907
Alternating Current Generator 3,000 KW Vertical Type ATB No. 148684 Class 10, Volts 13,200, Amps 131.5	Manufactured by General Electric Co. Schenectady, N.Y.	1907

FOR NPS USE ONLY
RECEIVED
DATE ENTERED

NATIONAL REGISTER OF HISTORIC PLACES INVENTORY -- NOMINATION FORM

EQUIPMENT (Continued)	REMARKS	DATE OF MANUFACTURE OR INSTALLATION
Turbo-Generator Number 2		
Curtis Steam Turbine (No. 4137) (5 stage vertical shaft steam turbine).	Manufactured by General Electric Co. Steam Pressure 175 psi.	1908
Alternating Current Generator 8,000 KW Vertical Type ATB No. 119566 Class 10, Volts 13,800, Amps 334	Manufactured by General Electric Co., Schenectady, N.Y.	1908
Turbo-Generator Number 3		
Curtis Steam Turbine (No. 13401) (9 stage horizontal shaft steam turbine).	Manufactured by General Electric Co. Steam Pressure 175 psi.	1917
Alternating Current Generator 10,000 KW Horizontal Type ATB-4 Volts 13,800, Amps 524 No. 1181396	Manufactured by General Electric Co., Schenectady, N.Y.	1917
Barometric Condenser No. 1	Manufactured by City Light Used with Unit No. 1.	1969
Barometric Condenser No. 2	Manufactured by Hydraulic Supply Manufacturing Co., Seattle, Wash., Used with Unit No. 2.	1965
Jet Condenser	Manufactured by C. H. Wheeler, This condenser is used with Unit No. 3.	1917

FOR NPS USE ONLY
RECEIVED
DATE ENTERED

NATIONAL REGISTER OF HISTORIC PLACES INVENTORY -- NOMINATION FORM

EQUIPMENT (Continued)	REMARKS	DATE OF MANUFACTURE OR INSTALLATION
Weiss Air Pump (Vacuum)		
Number 149 Used with vertical Turbo-Generator Unit No. .	Built by Southwark Foundry and Machine Co. Patented April 28, 1896 Philadelphia, PA	1907
Weiss Air Pump (Vacuum)		
Number 174 Used with vertical Turbo-Generator Unit No. 2.	Built by Southwark Foundry and Machine Co. Patented April 28, 1896 Philadelphia, PA	1908
Electrical Panels		
Panels are Grey Marble approximately 2 inches thick. There are 27, two piece sections.		ca. 1907 & 1917
The following equipment is panel mounted on these panels.		
1 Western Stanton Volt Meter Number 5746 Range 0-600 Volts	Manufactured by Western Electric Instrument Co., Newark, New Jersey	
Thompson Recording Watthour Range 2000 amp, 600 volt (Total of 4)	The meters appear to be in good condition. All were manufactured by General Electric Company.	
Thompson Astatic Ammeter 1 - Range 0 - 500 amp 1 - Range 0 - 800 amp 1 - Range 0 - 1000 amp 1 - Range 0 - 1300 amp 4 - Range 0 - 1500 amp 1 - Range 0 - 2000 amp	All meters were manufactured by General Electric Company	

EQUIPMENT	REMARKS	DATE OF MANUFACTURE OR INSTALLATION
Electric Panels (Continued)		
Miscellaneous Meters Volt meters, Ammeters Watthour meters, Temperature indicators (Total of 50 meters)	The majority of these meters are ammeters, 34 of these. All meters were manufactured by General Electric Company	
Power Factor Meter (Antique) 1 meter	Manufactured by Westinghouse Electric Company.	
Voltage Regulator (Antique) 1 regulator Number 1661	Manufactured by General Electric Company, Schenectady, N.Y., USA.	
Synchronous Meter 1 Meter	Manufactured by Genernal Electric Company.	
Reverse Power Relays 2 Relays (small) 8 Relays (large)	Manufactured by General Electric Company	
Frequency Indicator Frahm System	Manufactured by James G. Biddle Company	
Large Solid Copper Knife Switch 8 total, miscellaneous sizes, multiple blade type.	Manufacturer unknown.	
Two Blade Knife Switch Solid Copper 13 total, misc. sizes	Manufacturer unknown.	
Single Blade Knife Switch Solid Copper 15 total, misc. sizes	Manufacturer unknown.	

Form No. 10-300a
(Rev. 10-74)
UNITED STATES DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE

NATIONAL REGISTER OF HISTORIC PLACES INVENTORY -- NOMINATION FORM

FOR NPS USE ONLY
RECEIVED
DATE ENTERED

EQUIPMENT (Continued)	REMARKS	DATE OF MANUFACTURE OR INSTALLATION
Framed Switch and Fuse Panels		
4 Panels, the panels have two blade knife type switches and use screw-in type fuses.	The panels are for lighting and miscellaneous circuits. Manufacturer unknown.	ca. 1907
Oil Circuit Breakers		
7 Breakers - small 36 Breakers - large	Manufactured by General Electric Company	1907 & 1917
Knife Switches		
More than 50 solid Copper multi blade type switches.	Manufacturer unknown.	1907 & 1917
Transformers		
Bank No. 1 Type WC, 500 KW 13,800 volt (2 transformers in bank)	Manufactured by General Electric Company	ca. 1907
Transformers		
Bank No. 2 13,800 1000 KVA (2 transformers in bank)	Manufactured by Westinghouse Electric Company	1907
Automatic Circuit Breakers (Antique)		
4 Circuit Breakers	Manufactured by General Electric Company	ca. 1907
Lube Oil Pump (Duplex Type)		
Steam Driven, 2 cylinder Size 9 x 3-1/8 x 10 Number 189-977	Manufactured by Worthington	ca. 1907

EQUIPMENT (Continued)	REMARKS	DATE OF MANUFACTURE OR INSTALLATION
Lube Oil Pump (Duplex Type)		
Steam Driven, 2 cylinder Size 9 x 3-18 x 10 Number 190-208	Manufactured by Worthington	ca. 1907
Lube Oil Transfer Pump (Duplex Type)		
Steam Driven, 2 cylinder Size 4-1/2 x 2-3/4 x 4 Number 164828X9	Manufactured by Knowles Pump Works New York, New York.	ca. 1917
Fuel Oil Pump (Duplex Type)		
Steam Driven, 2 cylinder Reciprocating Type Size (Data not available) 2 identical pumps	Manufactured by - (Name plate data missing) Hallidie Machinery Company, Seattle, WA Sales agent.	ca. 1918
Fuel Oil Pump		
Screw Type, Electric Motor Driven Size 4, 250 Head, 80 gal/min Number 867	Manufactured by William E. Quemby, Inc., New York, New York	ca. 1930
Feed Water Pump East)		
DeLaval Centrifugal Type 140-TC-3P5 650 gal/min 520 Head Number 56980	Manufactured by Ingersoll Rand Co. New York, New York.	ca. 1917
Steam Turbine (for feed pump) 2300 RPM Number 56980	Manufactured by DeLaval Steam Turbine Company, Trenton, New Jersey	ca. 1917

FOR NPS USE ONLY
RECEIVED
DATE ENTERED

NATIONAL REGISTER OF HISTORIC PLACES INVENTORY -- NOMINATION FORM

EQUIPMENT (Continued)	REMARKS	DATE OF MANUFACTURE OR INSTALLATION
Feed Water Pump (West)		
Ingersoll Rand Centrifugal 900 gal/min, Size 4GT900 552 Ft. Head Number 06493050	Manufactured by Ingersoll Rand Company, New York, New York.	1949
Steam Turbine (for feed pump) 3600 RPM Serial Number 79336 Model Number 7TDP1117AEK 180 Horsepower	Manufactured by General Electric Company, Schenectady, New York.	1949
Air Compressor		
Size 8 x 8 Electric Motor Driven Number 36175	Manufactured by Curtis St. Louis, Mo.	1950
Centrifugal Water Pump		
Spare Pump Small Electric Motor Driven (Name plate date missing.)	Name plate data missing. The Spare pump is not connected into system	ca. 1917
Hot Well Tank		
14 ft. diameter x 12 ft. deep Steel plate construction.	Manufacturer unknown	1917
Fuel Oil Strainer System	Manufactured by Bethlehem Steel	ca. 1930
Step Bearing Lube Oil Tank	Manufactured by Turner Oil Filter Co. Niles, Michigan.	1907
Mid Bearing Lube Oil Tank	"	" 1907
Spare Lube Oil Tank	"	" 1907
Air Pump Lube Oil Tank	"	" 1908

Form No. 10-300a
(Rev. 10-74)

UNITED STATES DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE

FOR NPS USE ONLY

RECEIVED

DATE ENTERED

NATIONAL REGISTER OF HISTORIC PLACES INVENTORY -- NOMINATION FORM

EQUIPMENT (Continued)	REMARKS	DATE OF MANUFACTURE OR INSTALLATION
Ingersoll Rand Air Compressor		
Large unit similar to the unit installed in Lake Union Steam Plant	This unit is dismantled. It will be used for parts for the Lake Union Compressor. In addition there is an Allis Chalmers 125 horsepower induction motor to run this compressor.	
Step Bearing Oil Pump (Duplex)		
Steam driven 2 cylinder Recriprocating Type Size 12 x 2-3/4 x 18 Number 192035 Used on Unit No. 1	Manufactured by Worthington.	1907
Step Bearing Oil Pump (Duplex)		
Steam driven 2 cylinder Recriprocating Type Size 12 x 2-3/4 x 18 Number 192036 Used on Unit No. 2	Manufactured by Worthington	1908
Centrifugal Pump		
Steam driven Size 4 400 gal/minute 560 ft head 2750 RPM	This is a spare pump not connected to plant system. Manufactured by Platt Iron Works Dayton, Ohio	
Turbine Drive Terry Turbine Number 1759 2750 RPM	Manufactured by Terry Steam Turbine Company Hartford, Connecticut	

EQUIPMENT (Continued)	REMARKS	DATE OF MANUFACTURE OR INSTALLATION
Condenser Pump (Unit No. 3)		
Pump Size 18 D.V.S. Number 06280	The pump may be operated by either electric motor or by steam turbine. Manufactured by Wheeler Condenser Engineering Company	1917
Pump Reduction Gear Drive Number 548	Manufactured by Moore Steam Turbine Corporation.	1917
Turbine Drive Number 3555	Manufactured by Terry Turbine Company.	1917
Pump Electric Motor Drive Number 1648315	Manufacturer General Electric Company	1917
Wheeler Turbo Air Pump (Vacuum)		
Pump Size T-A-100 Number 04968	Manufactured by Wheeler Condenser & Engineering Co., New York, N.Y. The pump is used with condenser number 3 and is steam driven.	1917
Steam Turbine Drive Number 4635	Manufactured by Westinghouse Machine Co., Designers & Builders, East Pittsburgh, Pa.	1917
Overhead Bridge Crane		
Capacity 50 ton Number 715	Manufactured by Northern Engineering Works, Detroit, Mich. This is the main powerhouse crane.	1907
Overhead Bridge Crane		
Capacity 20 ton	Manufactured by Reading Crane & Hoist Works, Reading, Pa. The crane is located in the area over the Motor Generator sets	1907

NATIONAL REGISTER OF HISTORIC PLACES INVENTORY -- NOMINATION FORM

EQUIPMENT (Continued)	REMARKS	DATE OF MANUFACTURE OR INSTALLATION
Small Electric Crane		
Capacity 1 ton M 1210 Frame 25	Manufacturer Budget	1955
Step Bearing Oil Pressure Balance Weight Alarm		
Set at 950 psi.	Manufacturer unknown.	1907
Simplex Water Meter		
Meter Scale measures in 100,000 lbs per hour at 70 F.	Manufactured by Simplex Valve and Meter Company, Philadelphia, Pa. This meter is a valuable antique.	1907
Per Cent Carbon Dioxide (CO_2) Wall Mounted Meter		
0 to 20% Scale Multi Point type	Used to monitor Boiler Combustion, Manufactured by Leeds & Northrup Company, Philadelphia, Pa.	1907
Panels		
The two panels (one for Turbo Generator Number 1 and the other for Turbo Generator Number 2), have solid brass gauges. One gauge for 1st stage pressure, one gauge for Steam Supply pressure, one gauge for step bearing oil pressure, one gauge for vacuum. The panel for Unit Number 1 has a frequency indicator mounted at the top. It may be used to monitor either unit's frequency.	4 Gauges were manufactured by General Electric Company. The frequency indicator was manufactured by James G. Biddle, Philadelphia, Pa.	1907 & 1908

EQUIPMENT (Continued)	REMARKS	DATE OF MANUFACTURE OR INSTALLATION
Panel		
Turbo-generator Unit Number 3 2 brass hydraulic pressure gauges, 0-2000 psi.	Ashcraft	1917
1 Brass steam gauge, 0-260 psi.. .	Syracuse Gauge	1917
1 Aston Brass Gauge	Aston	1917
Telephones (Antique)		
Hand crank type.	There are 4 or more units, one located in the pump house and at least 3 located in the plant. Manufacturer unknown	
Fuel Oil Transfer Pump (Duplex)		
2 Cylinder reciprocating type Electric Motor Driven	Manufactured by Fairbanks Morse Company. (ca. 1910) Brought in from Lake Union Plant	1953
Motor Generator Set No. 2		
Continuous current Generator No. 159471 Type MP Class 8-500-514 Form H Amperes - 833 Speed - 514 RPM Volts 600	Manufactured by General Electric Company, Schenectady, N.Y.	1907?
Snychronous Motor Number 161143 Type ATI Class 14-530-514 Form C H Power - 700	Manufactured by General Electric Company, Schenectady, N.Y. Approx. Mfg. 1906	1907

FOR NPS USE ONLY
RECEIVED
DATE ENTERED

NATIONAL REGISTER OF HISTORIC PLACES INVENTORY -- NOMINATION FORM

EQUIPMENT	REMARKS	DATE OF MANUFACTURE OR INSTALLATION
Motor Generator Set No. 2 (Continued)		
Speed 514 Volts 13,200 Amp 28.8 Cycles 60		
Exciter No. 2		
Motor Generator Set Continuous Current Generator Number 140447 Form B KW-120 Amperes 960 Speed 600 Volts 125	Manufactured by General Electric Company, Schenectady, N.Y. Approx. Manufacture 1906	1907
Induction Motor Model No. 14070 Type 10-17-12-175-600 Form K Volts 280 Amps 40 Number 161679 HP 75 Speed 580 2 Phase	Manufactured by General Electric Company, Schenectady, N.Y. Approx. Manufacture 1906	1907
Direct Current Generator		
No. 1201823 Type MPC - 6-200-1200 Form L Amps 1600 Volts 125 Speed 1200 RPM 200 KW Nominal	Manufactured by General Electric Co., Schenectady, N.Y.	1917

Form No. 10-300a
(Rev. 10-74)

UNITED STATES DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE

NATIONAL REGISTER OF HISTORIC PLACES INVENTORY -- NOMINATION FORM

FOR NPS USE ONLY

RECEIVED

DATE ENTERED

EQUIPMENT	REMARKS	DATE OF MANUFACTURE OR INSTALLATION
Direct Current Generator (Continued)		
Steam Turbine Drive Number 56684 Speed 3600 RPM Steam Pressure 200 psig With DeLaval Speed Reducer	Manufactured by DeLaval Steam Turbine Co., Trenton, N.Y.	1917
Exciter No. 1		
Generator No. 78345 Volts 120 Amperes 125 RPM 1130	Manufactured by Allis Chalmers Company, Milwaukee, Wis.	1907
Electric Motor Number 78346 HP 22.5 Volts 220 Amps 55 3 Phase Frequency 60 H_z RPM 11,300	Manufactured by Allis Chalmers Company, Milwaukee, Wis.	1907
River Pumps		
20" Size 13,500 Gallons per Minute 85 Feet Head 690 RPM Type 5 Pump #1, Style A, Serial No. 1498 Pump #2, Style B, Serial No. 1497	The two pumps are in the pumphouse located on the Duwamish River. The pumps were manufactured by Allis Chalmers. The pumps are each driven by a 400 HP electric motor. The motors are type IQ, Form K, 2200 volt, 2 phase, manufactured by General Electric Company.	ca. 1935
Floor Mounted Drill Press		
Antique, Belt Driven Type	Manufactured by Champion Company.	ca. 1907

EQUIPMENT (Continued)	REMARKS	DATE OF MANUFACTURE OR INSTALLATION
Bristol Recorders		
Panel mounted Antique type (vacuum gauge)	Manufactured by Bristol Company, Waterbury, Conn.	ca. 1907 & 1918
Large Master Gauge		
Approx. 2 feet in diameter Range 150 to 210 psi. Brass construction	Manufactured by Ashton. This is an antique	1906
Air Raid Siren		
World War II model Roof Mounted Engine Driven	Engine manufactured by Chrysler. Siren manufactured by American Blower Co.	ca. 1941

8. Significance

Period

- ___ prehistoric
- ___ 1400–1499
- ___ 1500–1599
- ___ 1600–1699
- ___ 1700–1799
- ___ 1800–1899
- X 1900–

Areas of Significance—Check and justify below

- ___ archeology-prehistoric
- ___ archeology-historic
- ___ agriculture
- ___ architecture
- ___ art
- ___ commerce
- ___ communications
- ___ community planning
- ___ conservation
- ___ economics
- ___ education
- X engineering
- ___ exploration/settlement
- ___ industry
- ___ invention
- ___ landscape architecture
- ___ law
- ___ literature
- ___ military
- ___ music
- ___ philosophy
- ___ politics/government
- ___ religion
- ___ science
- ___ sculpture
- ___ social/humanitarian
- ___ theater
- ___ transportation
- ___ other (specify)

Specific dates 1906–1908, 1917 **Builder/Architect** Stone and Webster Engineering, Boston with Frank B. Gilbreth, Consultant

Statement of Significance (in one paragraph)

The Georgetown Steam Plant is a 1906 reinforced concrete building housing the last operational examples of the world's first large-scale steam turbine. Patented by Curtis and built by General Electric, the success of these vertical steam turbine generators marked the end of an era of reciprocating steam engine driven generators, the beginning of a steam turbine technology still in use today, and the survival of General Electric as a manufacturer of large-scale steam-driven prime movers. The structure, built using a "fast-track" construction process, was designed and supervised by Frank B. Gilbreth, later a nationally famous proponent of efficiency engineering.

Its history as a standby or "peaking" facility demonstrates the changing demands for, and development of, electrical power in Seattle, while its survival and its integrity of equipment, building, and site assure a national level of significance in electrical, mechanical and civil engineering. There are, therefore, three national streams of historical development: one, the history of the Curtis turbine, General Electric and the electrical industry; a second, the development of reinforced concrete fast-track construction and the erection of the Georgetown plant; and a third, the history of urban power development and use, that merge in a single surviving representative, the Georgetown Steam Plant.

(see continuation sheets for full historical report)

STATEMENT OF SIGNIFICANCE

The Georgetown Steamplant is a 1906 reinforced concrete building housing the last operating examples of the world's first large scale steam turbine. Patented by Curtis and built by General Electric, the success of these vertical steam turbine generators marked the end of an era of reciprocating steam engine driven generators, the beginning of a steam turbine technology still in use today, and the survival of General Electric as a manufacturer of large-scale steam-driven prime movers. The structure, built using a "fast-track" construction process, was designed and supervised by Frank B. Gilbreth, later a nationally famous proponent of efficiency engineering.

Its history as a standby or "peaking" facility demonstrates the changing demands for and development of electrical power in Seattle, while its survival and its integrity of equipment, building and site assure a national level of significance in electrical, mechanical and civil engineering. There are, therefore, three national streams of historical development: one, the history of the Curtis turbine, General Electric and the electrical industry; a second, the development of reinforced concrete fast-track construction and the erection of the Georgetown plant; and a third, the history of urban power development and use, that merge in a single surviving representative, the Georgetown Steamplant, in Seattle, Washington.

GEORGETOWN STEAMPLANT HISTORY AND SIGNIFICANCE

I. General Electric, Westinghouse and Urban Electrification

In 1882, Thomas Edison opened his Pearl Street Plant in New York City to initiate the Electrical Age in urban America. While advocates debated the relative merits of direct and alternating current, eventually settling on the latter, reciprocating steam engines driving a separate electrical generator appeared from coast to coast. As demand for electricity increased, companies tried to increase both the size and number of generating units, but were beginning to encounter limits on engine/generator size as well as station size. In an early attempt to alleviate this threat, the Westinghouse Company secured the patents to the Parsons steam turbine (patented 1884), the first successful industrial turbine, much smaller than equal engine/generator units, even if no more efficient. For nearly a decade, Westinghouse clearly had the upper hand. The growth of central generating stations required increases in capacity and the massive engine/generator units with their vibration limits and size requirements could not meet that demand. Westinghouse had the only operating turbine on the market.

Charles G. Curtis (1860-1953) received patents 566,967, 566,968, and 566,969, protecting the basic principles of the Curtis turbine, in September, 1896. These patents cover, respectively, the expansion nozzles and their regulation, the concept of velocity compounding, and the concept of pressure compounding. Curtis assigned all three patents to his own company, the Curtis Company, which one year later entered into a liscensing agreement with the General Electric Company. For $1,500,000, General Electric received rights to all uses of the Curtis turbine except aerial and marine propulsion.[1]

General Electric formed a new division to undertake the development and manufacture of the Curtis turbine. From 1897 to 1902, General Electric built and tested a variety of designs based on the Curtis patents. Until 1900, Charles Curtis himself directed this research.[2] In 1901, William Le Roy Emmet took charge of the development of the Curtis turbine. Emmet (1858-1941), a central figure in General Electric's development of prime movers, trained at the U.S. Naval Academy and worked at various jobs in the electrical industry before he joined the new General Electric in 1892. General Electric, concerned by the lack of progress with the Curtis turbine project offered Emmet charge of the turbine project at a point when it was considering dropping it. Emmet realized the difficulties but thought the work extremely important and urged that it be allowed to proceed. In his autobiography he noted his overall impression of the work: "I think it is safe to say that there have not been many jobs more extensive and strenuous in the art of engineering." (Emmet 1931, p. 142)

Emmet directed the Curtis turbine project for twelve years, until 1913. Many of the features of the machine were incorporated as a result of his guidance, including the vertical orientation of the larger sizes. Emmet invented the oil-supported step bearing used to test the generators installed at Niagara Falls and made use of them in the Curtis turbine. He was also responsible for the selection of the sizes of the turbine, and for meeting the deadline for the delivery of the first machines. (Emmet 1931, p. 147)

Between 1897 and 1902, General Electric made a number of small turbines based on Curtis's principles. These were used for tests. The first placed in operation was a 500 KW unit installed at the General Electric plant in Schenectady in November, 1901. (Robinson 1937, pp. 239-240) The first vertical turbine to be placed in commercial service, a 500 KW machine, was shipped in February 1903 to the Newport and Fall River Company of Newport, Rhode Island. The first large Curtis turbine, and the machine which demonstrated the working feasibility of the design, was the 5,000 KW turbogenerator installed in the Fisk Street Generating Station of the Commonwealth Electric Company of Chicago in 1903. This turbine, removed to the Turbo-Generator Development Laboratory of General Electric's Schenectady plant, was designated a National Historic Mechanical Engineering Landmark by the American Society of Mechanical Engineers in 1975. The Fisk Street Station was the first power house designed specifically for vertical turbogenerators; room was allowed, though, should the unit have to be replaced by the more traditional reciprocating engine. (A.S.M.E. 1975, p. 4)

The Curtis turbogenerator was quickly successful. In the first fifteen months of sales, ending in 1903, General Electric sold 225,000 H.P. of Curtis turbines. (Westinghouse, by comparison, had sold some 300,000 H.P. of Parsons turbines for land use, and 83,000 H.P. for marine use, in the previous twelve years.) By June 1905, there were 224 units of the "larger sizes" in operation, totaling 350,000 H.P., including ten 5,000 KW machines. (Robinson 1937, pp. 241-242; G.E. Pamphlet 1907, p. 5) By September of 1906, Charles B. Burleigh reported to the National Association of Cotton Manufacturers "more than twice as many Curtis turbines in commercial operation in this country as there are of any other manufacture and more than the number of horse power of vertical shaft turbines in this country than there are of horizontal shaft turbines of all other manufacture . . ." (Burleigh 1906, p. 40) In three years of manufacture, the Curtis machine demonstrated its capacity as a cheap, compact, powerful, and efficient prime mover for electrical generation.[3] The design won the only grand prize for steam turbines at the St. Louis Exposition of 1904 and a gold medal at the Lewis and Clark Exposition in Oregon in 1905. (Burleigh 1906, p. 28)

Reasons for the superiority of the Curtis vertical steam turbine were often cited in long lists published by General Electric. Most often, these and other commentators focused on four major points: efficiency at all loads, simplicity, low maintenance, and economy in space. (G.E. Pamphlet 1907, p. 5) To this should be added the dramatic improvements achieved by General Electric during the decade of the 1900s. The Curtis units were significantly more efficient because they used both velocity and pressure compounding, because they did not require converting reciprocating motion to rotary motion, and because of a unique method of governing or maintaining speed under varying loads.[4] The most important reason for its efficiency, explained an article in the General Electric Review, was the combination of pressure and velocity compounding to deal with the difference between the velocity of the steam some 3,600 feet per second, and the desired speed of the turbine, much slower than that. Two pressure stages, each of three wheels, give a peripheral velocity of 425 feet per second in the Curtis turbine. To use steam at an equal efficiency in other turbines would require, according to the article, eighteen steps of pressure-compounded De Laval wheels, or 72 expansion stages (36 fixed and 36 movable) in a Parsons turbine. (Burleigh 1910, p. 510)

The simplicity of the Curtis units derived from several features. They mounted both prime mover and generator on a single shaft and required far fewer moving parts. Because there were none of the lateral strains and thrusts of the reciprocating engines, foundations were "a matter of less importance than with any other steam prime mover." (Burleigh 1906, p. 51) Maintenance was easier because the vertical configuration left all parts of the turbine and generator accessible and because the single turbogenerator shaft rested on a single thrust bearing that was easily replaced. (Burleigh 1906, p. 40) In May 1904, General Electric published a pamphlet including four pages of scale drawings comparing the floor space and height required by engines and Curtis turbines in 100 KW, 500 KW, 1,500 KW and 5,000 KW sizes clearly demonstrating the space savings of the turbines. (pp. 25-28) Given the pressures on central-city generating facilities, it seemed clear the vertical "compact design results in marked savings in land, buildings, foundations, and equipment." (Burleigh 1906, p. 70)

Finally, General Electric achieved significant improvement in the design of the units. As one example of the results of this effort, the four original 5,000 KW units installed in the Fisk Street Station in Chicago in 1904, were replaced by 12,000 KW units in 1909. "These occupy no greater space than the original machines and no increase in the capacity of the boilers supplying them was necessary." The report went on to claim the "kilowatt per square feet of station has been more than doubled" while also achieving a 25 percent increase in steam economy. (Parker 1910, p. 64-65) The message to those needing to expand electrical generating capacity but unable to expand existing stations was clear. By 1909, 1,200 Curtis units were installed across the United States and another 200 were on order. (Kirkland 1909, p. 101)

The vertical arrangement of the Curtis turbine was successful for the early middle-sized, slowly rotating machines. Between 1908 and 1913, however, General Electric gradually abandoned this form. Customers demanded larger machines, which meant more stages and a longer shaft; this was more easily accomodated in a horizontal configuration. New materials made possible faster speeds, up to 3,600 rpm, which required a stiffer structure than could be provided to a vertical machine. (A.S.M.E. 1975, p. 6) These new materials also proved the demise of the Curtis velocity-compounded multiple-row wheels. An engineer, reviewing the history of the Curtis turbine, wrote:

> . . . the reasons why the multi-row Curtis wheel was so successful are not . . . self-evident.
>
> The facts of the case seem to be that the time was not yet ripe for an expensive multi-stage single-row construction such as characterizes a modern high-efficiency machine. The Curtis multi-row wheels proved far mor efficient than the single-stage De Laval machine and far cheaper, more compact, and rugged than the many-stage reaction Parsons machines of that day. The De Laval machine was decidedly limited in capacity. With only low-grade materials available, the Curtis arrangement was ideally adapted to effect the required energy conversion with a minimum of wheel speed; whereas, neither a single-wheel design nor a reaction design could do this. Some such considerations surely explain the general preference for the Curtis turbine at the time and its great success. (Robinson 1937, p. 242)

For this brief period, 1903-1913 (the Georgetown units were installed in 1906 and 1907), the vertical steam turbine generator units manufactured by General Electric swept the market. General Electric established its significance as a manufacturer of steam turbines, and in fact, rapidly developed the technology they pioneered with the Curtis machine. Requiring one-tenth the space of a corresponding engine-generator unit and one-third to one-half the steam, the General Electric units made possible the large central-station generating plants that characterized urban electrification for at least a quarter of a century. Yet the success of these units was short-lived: General Electric itself saw the limits on the vertical configuration and began as early as 1908 to move toward a horizontal Curtis unit for units of the largest size (20,000 KW was apparently the upper range for the vertical units). The tremendous expansion in demand for electricity forced the rapid replacement of smaller and less efficient units leaving only two solitary surviving examples of what was once a development of overwhelming significance. Even at Georgetown, a third horizontal unit, installed in a small addition to the original plant in 1919, is remarkably smaller than either of the first two vertical units and yet produces power roughly equal the two older units combined, thus repeating the very process that once established the hegemony of the

General Electricity/Curtis vertical steam turbine generator over the engine/generator units in use in 1900.

II. Stone and Webster, Seattle Electric and the Georgetown Steamplant: Structure and Equipment

The early lead of Seattle in electric streetlighting and electric railways, as well as its large number of small, often under-financed, generating companies proved an excellent expansion area for the Boston-based firm of Stone and Webster. In 1899, Stone and Webster purchased the Union Electric Company, created their own Seattle Electric Company as a Stone and Webster subsidiary, and within one year acquired an additional sixteen local steam generating companies. (Phelps and Blanchard, p. 151; Dick, p. 3) Seattle Electric petitioned the city for exclusive operation of the street railway system and received the franchise amidst much public debate over the Stone and Webster "syndicate." (Dick, pp. 47-50) The company proceeded to improve, unify, and extend the system, creating the Puget Sound Power Company to construct a major hydroelectric facility at Electron on the Puyallup River in 1904. (The Argus, 17 Dec. 1904, p. 32) Between 1905 and 1910, the Seattle Electric Company's load increased from 10,000 KW to 30,000 KW largely in response to the growing railway system and increased domestic and industrial use.

Electricity was fast becoming a way of life. Customers were less willing to accept power failures -- peak load capacity became crucial. Because the Seattle Electric Company faced the competition of both the municipal utility and the Seattle-Tacoma (Snoqualmie Falls) Power Company, additional back-up or peaking power appeared essential. The Georgetown Plant, Seattle Electric Company's second major new steamplant after construction of the Post Street plant in 1902, gave the company an additional edge on competition and further bolstered the system's stability. (Dick 1965, pp. 52-82)

The Board of Directors of the Seattle Electric Company voted to approve the construction of a steamplant in Georgetown at their August 26, 1906, meeting. No records of the site selection process have been uncovered, but there were a number of reasons why the Georgetown site was clearly a wise choice. Land in Georgetown on the Duwamish River was readily available at a good price. The site was situated on the route of the transmission line from Stone and Webster's hydroelectric facility at Electron. The company's own electric car barns and maintenance shops were already located in Georgetown, the interurban line ran in close proximity, and the area was ripe for industrial development.

Building the Georgetown Steamplant

The decision to build the plant was apparently made before the meeting; the earliest blueprints for the plant date from May, 1906, and the Stone and Webster Unit Cost Record gives a start date of 1 April 1906. The Stone and Webster Construction Company, a branch of the Stone and Webster Company which managed the Seattle Electric Company, was to design and build the Georgetown plant for cost plus a fixed fee of $30,000. The contract included the provision that Frank B. Gilbreth, a contracting engineer and specialist in the construction of reinforced concrete power plants, be hired to design and erect the building for cost plus a fixed fee of $20,000. (Puget Sound Power and Light, Box 116)

Frank B. Gilbreth (1868-1924) was a self-taught mechanical engineer and a major contributor to the field of scientific managment. From his first apprenticeship in bricklaying at the age of 17, Gilbreth rose quickly to become head of one of the largest contracting and building firms in the nation. His invention of a portable gravity concrete mixer, patented in 1899, was an overwhelming financial success that allowed him to expand his Boston-based construction business at a rapid rate. A strong believer in the value of advertising, his promotional materials emphasized his expertise in the new field of concrete construction. By his mid-thirties, Gilbreth's contracts spanned the continent from Boston to Seattle. By staying abreast of technological advances in reinforced concrete construction, and by remaining ever interested in the value of speed and efficiency in any job, Gilbreth established a solid national reputation as a top expert in the construction of power stations, dams, and other types of industrial structures. His work in this area culminated in his book <u>Concrete Construction</u> published in 1906. (Yost, Chapter I-VIII)

Gilbreth's theories on the value and efficiency of reinforced concrete and efficient construction techniques were put into full effect at the Georgetown Steamplant. Gilbreth himself wrote about the project in an article published in a California technical journal in 1908. Noting "the structure is a unit which it is intended to duplicate from time to time as necessity demands." (Gilbreth 1908, p. 23) Gilbreth explained the original plans for the plant had called for a steel frame with brick curtain walls. The waiting time for structural steel was some five months and the scarcity and high wages of mechanics to construct such a structure in Seattle were prohibitive. Reinforced concrete, which first came into wide use in the early years of the twentieth century, was selected instead. Power plants like Georgetown especially benefited from the special characteristics of reinforced concrete: it is fireproof, stands up well under vibration, and requires little maintenance. (Gilbreth, pp. 23-25)

With characteristic assertiveness, Gilbreth wrote: "Like most of the work undertaken by Frank B. Gilbreth, speed was of utmost importance, and it was desirable to begin driving piles directly after the contract was signed." (Gilbreth, p. 24) Just before pile driving was completed, working drawings for the foundation were completed. While the foundation was in progress, working drawings for the superstructure were finalized. For cost effectiveness, washed gravel instead of broken stone was used in most places. Reinforcing rods, generally round rods, were cut to schedule and shipped by rail from Pittsburgh directly to Seattle. Gilbreth even hired a man to oversee loading of these rods and to travel with them to insure timely delivery. While the final working drawings were being completed and the rods on their way from Pittsburgh, workers erected scaffolding to the full intended height of the entire structure just outside the outer walls. From this staging, all forms could be constructed, concrete poured, forms removed and the completed building washed down. (Gilbreth, pp. 24-25)

Construction planning apparently started as early as April 1906, but actual work on the building began after August 1906. (Stone and Webster, Unit Cost Record, Sheet 1) By December, The Argus reported: "Undoubtedly one of the most important of the improvements now being made by the Seattle Electric Company is the new power generating plant and machine shops located at Georgetown. The building . . . is of reinforced concrete, built in the most approved style and on a solid foundation made of piles and masonry which will last for ages. (Dec. 15, 1906, pp. 63-64) Materials used in construction included 1,712 piles in the foundation, 3,480 cubic yards of concrete in the superstructure and another 2,700 in the machinery foundations. A Weber concrete chimney 268 feet high and seventeen feet in diameter served the boilers. (Gilbreth, p. 24; Stone and Webster, Unit Cost Record, Sheet 1 and 2) In March 1907, before the plant was complete, Seattle Electric voted to order and install a second turbogenerator. The building was designed for such expansion, so space was available for the new unit, its boilers and auxiliary equipment. This second unit of 8,000 KW more than doubled the generating capacity of the plant and extended the completion date to January 1908. (Puget Sound Power and Light, Box 116, 14) Total cost for the complete generating plant: 921,031 dollars. (Stone and Webster, Unit Cost Record, Sheet 5)

The Georgetown Steamplant was a state-of-the-art example of reinforced concrete powerplant construction. The Engineering Record of June 1908 (pp. 721-724) included a standard technical report on the new facility.

> The station building is a reinforced-concrete structure, 80 x 218 feet in plan, and with a height of 68.25 feet from the ground line to the top of the roof. The reinforced-concrete frame, and the side and end walls of the building, stand on spread footings of concrete carried by piles driven to refusal. 1,800 piles being

used to secure and stable foundation for the building and equipment. The side walls of the building are 10 inch reinforced-concrete slabs carried by columns spaced 16 feet apart on centers; the end walls are 6 inches thick and are carried by columns spaced 15 feet 1 inch apart on centers. The roof consists of 5 inch reinforced-concrete slabs carried by beams and girders resting on the wall columns and on rows of columns in the interior of the building.

> The building is divided by a transverse 6 inch reinforced-concrete wall into a boiler room and a generator room, the former being 153 feet 10 inches long, and the latter occupying the remainder of the building. A basement, with its floor at the ground level, extends under the entire boiler room. The boilers are on a reinforced-concrete floor over this basement, which floor is carried by reinforced-concrete columns on spread footings on piles.
>
> . . . The floor of the generator room is carried by 65 foot span reinforced-concrete girders, exiting from the transverse partition wall to the end wall of the building, so this room is entirely free of columns. The switchboard, wiring connections, switches, transformers and electric auxiliaries are at the opposite side of the generator room from the boilers, in a reinforced-concrete gallery having four floors above the generator room floor.

Gilbreth discussed other features in his 1908 article including calculations of the economy and safety of reinforced concrete beams and the very long beams transversing the engine room. These sixty-five foot long girders were to his knowledge "The longest span of any ever constructed whose section, at the point where maximum bending moment occurs, is rectangular." (Gilbreth, p. 26) Permanent in character, free from vibration, and fireproof, the Georgetown Steamplant building stood ready to receive its complex assortment of electrical generating equipment.

The Machinery and Operation of the Georgetown Steamplant

The basic concept behind a steam turbine electrical generating plant is straightforward. A source of heat, in this case coal or oil, is used to turn water to steam. The steam, under pressure, is directed against the blades of a turbine, causing it to turn. A generator is turned by the turbine, producing electricity. The actual operation, of course, is not nearly as simple as this much abbreviated description. Every step in the process is made as efficient as possible Though in some ways primitive compared to modern plants, the Georgetown Steamplant was the product of an advanced science and engineering.

What follows is a description of the machinery at the Georgetown plant and its mode of operation when it was new, in 1907; changes will be mentioned later.

The Boilers

The Georgetown plant was built to burn both coal and oil. Complete facilities to handle either fuel were designed into the plant. In its early days and in recent years the plant has been powered by bunker oil which was stored in a 150,000 gallon steel tank near the plant, pumped into the plant, heated and delivered to the boilers. Oil was transferred to the front of the boilers by 2-1/2 inch steam pipes. At the burner, the oil was steam-atomized in special nozzles to ignite more easily. (In startup, when there is no steam, the oil was atomized with compressed air.) The atomized oil enters from the burners in the front of the boilers into the combustion chamber.

Though not used at first, a complete coal delivery system was also built into the plant. Coal arrived over the Seattle Electric Company's street railways. At the rear of the plant (the southeast side) a conveyor belt lifted the coal to the top floor Another conveyor near the ceiling of the boiler room carried the coal to eight funnel-shaped bunkers from which coal dropped to the boiler room and moved into the burners by mechanical chain-grate stokers built by the Green Engineering Company. After burning, the ashes could be dumped from the bottom of the boiler into an ash car which ran on rails in the basement beneath the boilers.

The six boilers producing steam for the 3,000 KW turbogenerator were served in turn by a 125-foot steel stack eleven feet in diameter. The row of boilers on the other side of the room connected to a 268-foot high, 17-foot in diameter reinforced concrete stack 55 feet from the building. This stack had the capacity to serve a planned expansion of ten additional boilers.

Feed water for the Georgetown boilers came from the Duwamish River, on which the plant was located. A 10-inch pipe ran underground in a concrete-lined 6 x 10 foot-trench. Two Blake steam-driven reciprocating pumps brought water to a 13,280-gallon steel tank. This large overhead tank furnished water to six boilers serving the 3,000 KW turbogenerator as well as the six serving the larger turbogenerator. This water supply or "feed water" had to be heated, a step accomplished by using the exhaust steam of the turbogenerator's auxiliary equipment.

There were originally fourteen water tube boilers at the Georgetown plant. Six on the southwest side of the boiler room provided steam for the 3,000 KW unit; the eight on the northeast side of the room serviced the 8,000 KW unit. The boilers, built by the Stirling Consolidated Boiler Company, were rated at 466 H.P. each. Seven of the fourteen boilers at Georgetown -- every other one -- provided superheated steam, raising steam temperature from about 390 to 520 degrees. There are several advantages to superheated steam. The boiler is made more efficient because the added energy in the steam is in part gained from heat which would otherwise be wasted. Superheated steam has a lower thermal conductivity than saturated steam and therefore loses less heat to the pipes. Most important, however, are the advantages of superheated steam in the turbines. Superheated steam is used more efficienty by the turbines than is saturated steam. The Georgetown plant probably gained an increase in efficiency of between 10 and 15 percent through the use of supersaturated steam. The boilers and their fuel delivery system take up the large wing of the Georgetown Steamplant. They deliver steam to the smaller wing where the turbines, their auxiliary equipment, and the electrical equipment is located.

Turbines

There are two vertical Curtis steam turbogenerators at the Georgetown Steamplant, apparently the last of their type still in operating condition. Turbogenerator Number 1, the smaller unit -- the turbine produced 4,000 H.P., the generator 3,000 KW -- is a four-stage machine, each stage having two movable and one stationary wheel. Turbogenerator Number 2, a 10,700 H.P., 8,000 KW machine, has five stages and is larger, but otherwise similar to Number 1. Both were "run condensing," that is, they were operated so that spent steam discharged into a condenser held at a vacuum.

The turbines were fed with superheated steam from the boilers. It entered the turbine through two sets of nozzles located 180 degrees apart. (One of these was for regular use and admitted steam to the first stage; the other, opened when the turbogenerator was running on overload, above its rated capacity, admitted steam to the second stage.) The nozzles were regulated by a governor which opened or closed one or several of the first or second stage nozzles. The governor kept the turbine at a constant speed of 720 revolutions per minute; more nozzles were opened when a heavier load was placed on the generator. When all of the first stage nozzles were opened, the band of steam covered about one-sixth the circumference of that stage; at the last stage the steam covered the complete circumference of the machine. A nozzle was either completely open or completely closed; only the amount of steam, and not its velocity, was regulated.

The steam entered the turbine at a pressure of about 175 pounds per square inch. It hit the first, movable, row of blades, pushed it and was deflected to the fixed row and then to the second movable row, through that row and then to the nozzles of the second stage. The steam passed through each of the stages in a similar fashion, each at a lower pressure. In the 3,000 KW turbogenerator for example, the pressure is reduced from 175 psi at the first stage to about 50 psi on entering the second stage, 5 psi on entering the third stage, to a partial vacuum on entering the fourth stage. It exited the fourth stage at the condenser vacuum of about 28 inches of mercury (1 psi absolute). The steam gave up about one quarter of its energy to each stage.

From the last stage of the turbine the steam is directed to the condenser. Both turbines at the Georgetown plant make use of Weiss counter-current barometric condensers, tall metal towers behind each of the machines. The condenser for Turbogenerator Number 2 rises to 54-1/2 feet above the floor; its shell is 9 feet in diameter. Some 130,000 pounds of steam per hour was delivered to it by a pipe 78 inches in diameter, entering the condenser 41 feet above the floor. Water entered near the top, was forced up the tube a small way, and then plummeted down the tube past a cone which broke it into a fine spray. Steam entered below the water, and was combined with the water and cooled by it as it plummets down the tube. It was discharged into a "hot well" measuring 14 x 14 x 7 feet at the bottom of the main barometric tube. Inside the tube a column of water was held at a height of about 15 feet by the vacuum generated by the horizontal tandem Weiss crank and fly-wheel air pump located next to each turbine.

Water for the condensers was drawn from the Duwamish River, pulled through a 16 inch pipe by a centrifugal pump direct-connected to a 10 x 12 inch high-speed Porter-Allen engine (for the 3,000 KW unit) and an 18 inch horizontal centrifugal pump driven by an 11 x 14 inch high-speed Porter-Allen engine (for the 8,000 KW unit). This latter pump provided 7,500 gallons of cooling water per minute, and the smaller pump proportionately less After passing through the condenser, the water, heated to about 115 degrees, was discharged back into the river via a tunnel 8 x 12-1/2 feet in cross section. This concrete-lined tunnel was 300 feet long, extending some 200 feet downstream of the intake pipes.

Electrical Equipment

The generators at the Georgetown Steamplant are mounted on the same shaft as the turbines which turn them. Both units are 3-phase, 60-cycle, 10-pole separately excited revolving field generators designed to deliver current at 13,800 volts, and to operate at a speed of 720 revolutions per minute. Unit Number 1 produced 3,000 kilowatts, Unit Number 2, 8,000 kilowatts.

The auxiliary electrical equipment at the Georgetown Steamplant is located in the galleries on the far wall of the engine room from the boilers. Three exciters on the first floor powered the magnetic field of the large generators. The 3,000 KW generator had two exciters, a 40 KW electric motor driven, direct current generator and a 75 KW steam driven, direct current generator. The 8,000 KW generator had a single 120 KW motor driven exciter. The steam exciter was powered by a 130 H.P. Porter-Allen engine.

The Georgetown Steamplant was used as a substation as well as a generating station. In the first floor gallery are the transformers and motor-generators which converted some of the high voltage alternating current produced by the large generators and by other plants in the system to lower voltage current for specific uses. Two 500 KW motor generators provided 600 volt direct current to the Seattle Elecric Company's street car system and to the Seattle-Tacoma interurban railroad.

All of the electrical equipment in the station is controlled from the third floor gallery. The reporter for the Engineering Record described it in some detail:

> The main units are arranged for remote control from panels in the third gallery floor. A cable from each phase of both main generators is carried from the latter in brass pipes leading to conduits under the floor of the generator room. These conduits extend to the end wall of the building at the rear of the galleries, and the cables are carried up a 12 inch space between this wall and the gallery floors to motor-operated oil switches on the fourth floor of the gallery. On the third floor of the galleries are also located panels controlling the railway motor generator and the railway feeder circuits; also panels for local light and power service. All panels of this switchboard are of blue Vermont marble mounted with standard General Electric switches and recording and measuring apparatus. The gallery floors are entirely of reinforced-concrete and are reached by stairways of concrete, so the gallery structure is fully fireproof. (June 1908, p. 724)

The fourth floor contains the motor-operated oil switches used on the high-tension lines leading from the plant. The connections to the outside are made on the fifth floor of the gallery, which also contains lightning arresters and static dischargers.

Changes in the Georgetown Steamplant

The machinery in the Georgetown plant has been altered only slightly over the years of its operation. The plant remains close to its original condition, but a succession of minor alterations and a few major additions reflect the plant's changing use as well as the changes in the technology of steam generating plants.

A few days after it was put into operation on August 3, 1907, the 3,000 KW turbogenerator burned out. It was repaired but continued to cause problems, burning out three more times in the next three months. The second turbogenerator was put into service December 17, 1907, but burned out on January 7, 1908 and was not operational again until March. The troubles with the new steamplant were topped off by the explosion of a steam pipe in May, 1908, which killed G.W. Tucker, the chief engineer. Problems continued and in October F.N. Bushell was sent to Georgetown from Stone and Webster's head office to "look into the steam turbine question." His specific recommendations are unknown, but the measures taken were apparently successful.[5] In 1911, the smaller generator was rewound from 3,000 KW to 5,000 KW. (Puget Sound Power and Light, Box 119) This was a common procedure; as generator technology changed, more electric power could be produced with the same amount of mechanical energy.

In the first years after the Georgetown Steamplant was built, the Seattle Electric Company was distributing about ten million kilowatt-hours per month. (The total rose from six million KWH in 1907 to eleven and one-half million KWH in 1910.) Most of this power was bought from other companies. Puget Sound Power Company's Electron plant produced about 70 percent of this power, Seattle Tacoma Power Company's Snoqualmie Falls plant about 15 percent, and the Tacoma Company about 10 percent. The rest was provided by the Seattle Electric Company's steamplants, mostly the Post Street Steamplant, which operated continuously to provide steam for heating. The Georgetown plant, used as a peaking facility, operated mostly between six o'clock and ten o'clock in the morning and three o'clock and eight o'clock in the evening, when demand was heaviest. Most of the Seattle Electric Company's power, up to 90 percent of it at peak times, was used to operate its street cars. The Georgetown plant was run more in the fall and the winter, when water for the hydroelectric plants was low, and also more toward the end of the first five years, reflecting increased demand. (Puget Sound Power and Light, Box 119)

In 1912, the Massachusetts-incorporated firm of Puget Sound Traction, Power and Light purchased and consolidated the Seattle Electric Company along with the Seattle-Tacoma Power Company (Snoqualmie Falls), the Pacific Coast Power Company, the Puget Sound Power Company, and the Whatcom County Railroad and Light Company. The new corporation was another Stone and Webster enterprise. The merger combined four major hydroelectric plants as well as four steamplants in Seattle and Tacoma, and it established electrical service on a regional basis for the first time in western Washington. The effect of the consolidation was increased dependability of the system and reduced rates.

This 1912 consolidation of all major electric companies made the Georgetown Steamplant a part of a larger network. Cheaper power from hydroelectric plants, including the new 14,000 KW White River facility, supplied the bulk of the demand. For a short time, the Georgetown plant was used only to supply steam heat to the company's nearby car barns. A company brochure of 1912 mentions the Georgetown plant as being "used only in cases of emergency." (Electric Journal 1912, pp. 50-51) A 1915 history of Seattle notes that "not one percent of the current for the city is generated by steamplants," but adds that they are kept ready for emergencies. (Bagley 1915, p. 442)

The American entry into World War I spurred the growing demand for electrical power in the Puget Sound region. Puget Sound Traction, Power and Light did not have the capital to build an additional hydroelectric plant to meet the new demand, but instead expanded its White River hydroelectric plant and its steamplant at Georgetown, adding to the latter, a 10,000 KW horizontal Curtis steam turbogenerator. (Lubar, pp. 24-25) The new equipment was installed and ready for use on May 18, 1919. (Puget Sound Power and Light 1921, p. 7) The new unit required an addition to the building, a small structure added to the north corner of the building. Two new boilers and alterations to increase the power of seven of the old boilers from 460 to 552 H.P. were added to provide power to drive the new turbine. These were serviced by a new smokestack. Several new transformers were added to deal with the additional power. Cooling water for the horizontal turbine was held in a concrete overflow tank on the southwest side of the plant. Water was piped to this tank and then to the condenser. At the same time the new turbogenerator was added, ducts were installed to supply cooling air to the old turbogenerators in order to increase their overload capacity.

Two other major changes to the Georgetown plant were made in the 1917 to 1919 period. In 1917, the course of the Duwamish River was changed and the Duwamish Waterway created by the Army Corps of Engineers necessitated a number of alterations in the means by which the plant drew its boiler and condenser water. A new pump house was built on the bank of the waterway, and the old connections replaced with a wood-stave pipe for intake condenser water and an open wood-lined trench for its exhaust.

As early as 1909, the Seattle Electric Company had had trouble getting enough oil for its plants, and in 1917, the fuel used by the boilers at

Georgetown was changed from oil to coal. This switch had been foreseen, and the plans for the plant had provided for most of the coal handling equipment already. All that was needed were a system of conveyors, a coal pile outside the plant, and ash removal facilities.

In the 1920s, demand for power increased greatly. Puget Sound Power and Light (they dropped their traction service in 1919) increased the size of several of their hydroelectric plants to meet the need. There was still need for a steam peaking facility, but by the end of the 1920s, the Georgetown plant was outdated and too small to be of much use. In 1930, Puget Sound Power and Light built a new steamplant, the Shuffleton plant at Renton, Washington. This facility with a capacity of 113,000 H.P., largely took over the Georgetown plant's role of standby steamplant. The 1930s and 1940s were times of increased interconnection among power companies, and also of the great federal hydroelectric projects in the Pacific Northwest. More power was available, and the need for the Georgetown plant decreased. A 1948 Puget Sound Power and Light Company Report mentions that in years of average stream flow the plant was used only one hundred hours per year, but that about every four years, because of reduced water flow, the plant saw more use. (Ford, p. 28) In the late 1940s and early 1950s, the plant was occasionally operated in the winter, when there was not enough water to allow the hydroelectric plants to supply peak demand.

Another major change came to the plant in 1937 with the construction of Boeing Field just south of the steamplant. Both stacks were razed to clear the ends of the runway, and a new induced-draft ventilation system installed in their stead. The openings where the ducts to the stacks exited the plant are still visible, bricked over, on the southeast side of the building.

The last major change in the building was made in the late 1940s, when the plant switched from coal back to oil. For a while, the plant was set up to burn either fuel, but when the price of oil fell after World War Two, the facilities for coal handling were removed and the plant switched permanently to oil.

In 1951, the Georgetown Steamplant was purchased by the City of Seattle Department of Lighting, now Seattle City Light. Very little changed. Most of the employees at the Georgetown plant were simply transferred from the old company to the new, and the machinery kept in its former condition. Seattle City Light already had a steamplant, the Lake Union facility, which meant that the need for power from the Georgetown facility was further reduced. The Georgetown Steamplant's last production run was from November, 1952, to January, 1953, during a major water shortage.

In recent years the place has been run only for tests. The Bonneville Power Authority gave credit to Seattle City Light for having the plant as a standby facility. In order to receive this credit it was necessary for City Light to operate the plant occasionally. Turbine Number 1 was last run on November 28, 1972. Turbine Numbers 2 and 3 on November 14, 1974. On June 20, 1977, the plant was taken off the Bonneville roles. It could not meet environmental standards, and was thought to be unreliable. It has not operated since.

III. Urban Electric Power Development and Use in Seattle

The Georgetown Steamplant played neither a dominant nor crucial role in the electrical history of Seattle. It was, instead, a part of a growing complexity of electrical power generation facilities designed to supply consumers with ever-increasing quantities of power. In streetlighting, transportation, and in industrial and domestic use, the ability to provide increasing quantities and stable supplies of electricity proved crucial to corporate success. Seattle, Stone and Webster, and Georgetown all reflect this national trend toward corporate consolidation, technological improvement, and ever-increasing consumption.

Electricity in Seattle: 1886-1928

In the mid 1880s, Seattle was a city of horse-drawn trolleys and gas lighting. By the close of that decade, the city had moved to the forefront of communities across the nation in the manufacture and application of electrical power. A Seattle company established the first Edison incandescent central station lighting plant west of the Rocky Mountains in 1886. (Dick 1965, pp. 1-2; Hanford 1924, p. 265; Beaton 1914, pp. 106, 120-121) The Seattle Electric Light Company obtained a contract for streetlighting in the same year. Shortly thereafter in 1889, Seattle electrified its horse-drawn trolleys and became the fourth city in the world to establish an electrical railway system. (Bagley, pp. 429-438)

At first Seattle reacted skeptically to the new power source. One observer of the electric railway construction warned the president of the company, "Don't you see that you can never operate in winter? The rains will wash the current off the wires and you will not be able to turn a wheel." (Beaton, p. 107) One pillar of the community remarked in reference to the streetlighting company's steamplant "How foolish of these young men to build the generating station on the waterfront. If they had put it at the top of the hill the electricity would run down the wires by gravity. Now they'll have to pump it." (Dick, p. 2)

National Register of Historic Places Inventory—Nomination Form

Since its beginning in 1873, the Seattle Gas Company held a monopoly on the streetlighting of Seattle. Alarmed by the upstart electrical industry, the company changed its name to Seattle Gas and Electric in 1886, determined to survive the competition. They built a steamplant at Fourth and Main and provided the city's first carbon arc lighting, a far more efficient method of illuminating large open spaces. (Phelps and Blanchard 1978, pp. 49-50)

The next company formed in response to the growing demand for electricity was Dr. E.C. Kilbourne's Pacific Electric Company. Kilbourne's experience came from his early involvement in the electric railway system of the previous few years. Pacific Electric leased the old powerhouse and equipment from the railway company and hired Baker and Balch, Seattle's first electrical engineering contractors, to put up the pole line. (Beaton 1914, pp. 122-123)

Both of these early firms were reorganized under new names, and by 1892 had merged to become the Union Electric Company -- this became the major (but by no means the only) generating and distributing firm serving Seattle in the next decade. A multitude of small companies with steamplants in the basements of downtown buildings sprang up, and there were many mergers and reorganizations. Competition was fierce and rates remained uniformly high. (Beaton, pp. 124-125)

In 1899, the Boston-based engineering firm of Stone and Webster took over Union Electric. By 1900, a total of some seventeen small locally-based utility companies had been absorbed by Stone and Webster's Seattle Electric Company. (Beaton, p. 112a) When the near-monopoly petitioned the city for a consolidation franchise for exclusive operation of the local street railway system, much public debate arose. Anti-corporation, pro-municipal ownership coalitions formed the basis of the opposition. The Stone and Webster "syndicate" was viewed by many as a foreign monopoly, an "octopus" out to sap and plunder the resources of the burgeoning city. Nevertheless, the street-railway franchise was granted, and the Seattle Electric Company proceeded to greatly improve, unify, and extend the system throughout the city for the next decade. (Dick, pp. 47-50)

In December of 1906, <u>The Argus</u> reported a projected expenditure of $1,800,000 for 1907 for "improvements, betterments, and new equipment" in Seattle. Population growth and increased demand for system extension were cited as reasons for the largest annual appropriation ever made by Stone and Webster to its Seattle holdings. This same article goes on to tout the construction of a new steamplant to augment its existing power generation facilities:

> Undoubtedly one of the most important of the improvements now being made by the Seattle Electric Company is the new power generating plant and machine shops located at Georgetown. The

> building . . . is of reinforced concrete, built in the most approved style and on a solid foundation made of piles and masonry, which will last for ages. (The Argus, Dec. 15, 1906, pp. 63-64)

The year 1912 signaled the end of the era of local power supply. Stone and Webster purchased and consolidated utility holdings in Bellingham, Everett, Seattle, and Tacoma including four major power companies and three major hydroelectric plants, under the umbrella of the Puget Sound Traction, Power and Light Company. Territorial power supply in Pacific Northwest had begun. (Chronological History, pp. 6-7)

Competition

During the heyday of Stone and Webster, the Snoqualmie Falls Power Company provided a measure of competition for the Seattle Electric Company. The Snoqualmie Falls project was Washington's first major hydroelectric project, and was built and operated by Charles Baker in 1898. By mid 1899, Snoqualmie Falls supplied power to portions of Seattle's street railway system and to various stationary motors and flour mill operations around the city. But by arrangement with Stone and Webster, the Snoqualmie Falls Power Company only sold power wholesale to Seattle Electric, and the latter handled all retail distribution within the city. (Dick, pp. 51, 83-84)

The turn-of-the-century movement toward a municipal utility system produced serious competition for the Seattle Electric Company by 1905. The momentum began with a public vote in 1896 to consider the Cedar River as a power source after the completion of the city water works there. This populist sentiment grew in strength until the election of 1902 which authorized construction of a hydroelectric project on the Cedar. City Engineer R.H. Thompson hired J.D. Ross as electrical engineer on the project The Cedar River plant first supplied current to the city in January of 1905. Its distribution station was built on Yesler Way at Seventh Avenue The city's top priority was to service its eleven street lighting circuits, and was soon competing with the Seattle Electric Company in private domestic lighting. At the end of the first year of operation The Argus wrote:

> The municipal electric lighting and power plant is now in successful operation, and is supplying the city with four hundred and fifty arc lamps, an increase of two hundred and fifty, and nineteen hundred incandescent lights . . . It is also supplying power for manufacturing purposes, and has installed lights in a considerable number of private homes. (The Argus, Dec. 23, 1905, p. 21)

The absolute superiority of hydro-generated electricity was realized in the first decade of the new century. Hydroelectricity meant more current for less work with a resulting radical decrease in consumer rates. The Seattle Electric Company originally relied on small steam-generating plants, as had its predecessor companies. But in 1904, Stone and Webster, under the name of the Puget Sound Power Company followed the lead of Charles Baker's Snoqualmie Falls project and constructed a major hydroelectric plant at Electron on the Puyallup River. Electron meant substantial rate reductions for the people of Seattle. (The Argus, Dec. 17, 1904, p. 32)

By 1905, the Snoqualmie Falls, Electron, and Cedar River municipal plant supplied Seattle with the bulk of the electrical power needed to meet its transportation, street lighting, private domestic, and industrial needs. These major sources were amplified in 1912 by the Puget Sound Traction Power and Light Company's White River hydroelectric project. Through the first decade of the century, steamplants continued to be built as auxiliary power sources. Steamplants such as the Seattle Electric Company's Georgetown plant, provided power companies with back-up and peak load capability. They meant stability and the guarantee of uninterrupted service. This peak hour capability was what small utility companies lacked and was the ultimate reason for their failure.

In 1912, Puget Sound Traction, Power and Light purchased and consolidated the Seattle Electric Company along with the Seattle-Tacoma Power Company (Snoqualmie Falls), the Pacific Coast Power Company, the Puget Sound Power Company, and the Whatcom County Railway and Light Company. The new corporation was another Stone and Webster enterprise. The merger combined four major hydroelectric plants as well as four steamplants in Seattle and Tacoma, and it established electrical service on a regional basis for the first time in western Washington. The effect of the consolidation was the increased dependability of the system and reduced rates. Gradually, the corporation bought up small utilities in outlying towns where peak demands were too difficult to meet without a steam power backup system. (The Argus, "Preparedness for Industrial Development," p. 61)

From 1910 through 1920, the demand for electric transportation in Seattle decreased. The electric streetcar system was sold to the city in 1919, and Puget Sound Traction Power and Light dropped the "Traction" from its name. By 1924, the company provided service from "tide water on the west to the Columbia River on the east and from the international border on the north to points in Oregon on south." (Hawford, p. 267) In 1928, Stone and Webster sold out of the company. Puget Sound Power and Light remains in operation today, still the predominant private regional power supplier in the Puget Sound country.

IV. Urban Electricity from Luxury to Necessity

The early twentieth century, the time when the Georgetown Steamplant saw its most intensive use, was one that transformed electricity from a novelty to a necessity. In streetlighting, transportation, and in domestic and industrial use, electricty became a necessity, a power source that had to be supplied in ever-increasing yet dependable quantities every day. As a rare surviving "peaking" facility, the Georgetown plant supplied back-up power for all these uses. It was an era initiated by small urban steamplants, later dominated by more remote hydro-electric facilities and their standby peaking facilities, and eventually replaced by even larger hydroplants and a new generation of massive steamplants.

The yellow glow of gas lamps first illuminated the streets of Seattle on New Year's Eve in 1873. During the 1880s the coal gas plant and the service it provided were considerably expanded, and by the end of the decade gas lighting in the home was a clear symbol of status. (Phelps and Blanchard, p. 148)

With the availability of electricity, street gas luminaires began to be gradually replaced, first with incandescent (carbon filament) and soon afterward with carbon arc lights. The latter were suspended on cables over intersections or from outriggers on utility poles. Arc lighting was the most effective means of illuminating large open spaces, although incandescents remained in use in suburban areas requiring less intense lighting. In 1893, the enclosed arc was introduced, and eliminated the need for the daily replacement of carbons. (Phelps and Blanchard, pp. 149-152) Until 1909-1910, Seattle's streetlighting system as a whole was haphazard and non-uniform in design. The City Engineer's Annual Report of 1891 noted that the city was using a total of 89 arc lights, 282 30 c.p. incandescent lights, and 303 15 c.p. incandescents to light its streets. (Phelps and Blanchard, pp. 151-152)

The cost of electric lighting in the home remained relatively high until the tremendous reduction in cost made possible by hydroelectric power developments. In the early 1890s, however, the flat rate cost of a single 16 c.p. lamp in the home ranged from around $1.50 to $3.00 depending upon the hours of use. (Pacific Electric Company rates, Beaton, p. 123) Gas lighting continued to provide competition in home illumination into the twentieth century. (ads in The Argus, Dec. 1899, 1901)

The City of Seattle gained control of all streetlighting in 1905 with the opening of the Cedar River power plant. As the city assumed metropolitan proportions and character, the haphazard mixture of street lighting types and designs became more and more unacceptable. In 1909-1910, replacement of the entire system with a uniform cluster light design took place for a total cost of $51,279. The project instigated by the downtown businessmen who petitioned on the basis of a local Improvement District, and the lights themselves were designed by J.D. Ross. The new arrangement used five or three ball clusters of 80 c.p. tungsten lamps with lightly-sandblasted globes on ornamental iron poles. The system was an understandable source of city pride, as the City Lighting Department's Annual Report of 1911 indicates:

> Seattle's cluster lighting system is one of the finest in existence and is generally admired by tourists and visitors from all parts of the country . . . . This design gives a beautiful effect of festoons of decorative lights along the sidewalks, and at the same time secures a uniform illumination on all parts of the street. (Phelps and Blanchard, p. 152)

Electric lighting effects played an increasingly important role in public ornamentation in the first decade of the century. Promotional materials for the Alaska-Yukon-Pacific Exposition in 1909 extolled not only the virtues of lighting at the exposition grounds, but also on the main commercial thoroughfares of the city itself:

> By night the Exposition is a spectacle that has never been surpassed. The grounds and buildings are a blaze of light and the Cascades -- pouring down the central court -- a plunging rainbow, showing every color of the solar prism. The Geyser Basin at the foot, is a lake of liquid fire in which trout and bass sport among sunken gardens. Every building on the grounds is thrown into brilliant silhouette by incandescent lights dotting their outlines at six-inch intervals, and the Alaska Shaft, which marks the center of the Exposition grounds, is a tower of brilliancy.

And downtown:

> At night First, Second, and Third Avenues are dazzingly illuminated by eight lamp posts in every block, each post supporting a pyramid of five electric lights, and they present a scene that is not paralleled in either Chicago or New York -- despite their size and wealth. In a word, Seattle is the modern marvel of magical city possibilities. (Seattle and the Pacific Northwest . . . A-Y-P Hotel and Commercial Guide, pp. 2 and 6)

The Georgetown Steamplant, as a facility of the Seattle Electric Company and later the Puget Sound Power and Light Company, was never a direct supplier of power to the city's lighting system. By 1905, the City Lighting Department had assumed full responsibility for streetlighting in Seattle. The ornamental one-, three-, and five-globe cluster lighting system, restored today in the vicinity of Pike Place Market and Pioneer Square, was installed in 1909 and 1910. By 1925, increased automotive traffic challenged the adequacy of that system. While it was apparent that new lighting was sorely needed, controversies over design among downtown property owners prevented installation of a new system until 1929. All cluster lighting was removed in the business district and replaced by luminaires designed by Carl Gould of the architectural firm of Bebb and Gould. By the end of 1931, this system extended into the city's residential neighborhoods.

The last major replacement of the city's streetlighting system occurred in 1948-1954 in the business district and in 1964-1968 in the residential districts. Mercury vapor lamps were installed, but in many cases the ornamental iron bases designed by Carl Gould were retained. (Phelps and Blanchard, pp. 153-161)

Transportation

Young Frank Osgood from Boston came west to Seattle in 1883 with a desire to contribute to the development of the city. At the suggestion of Thomas Burke, Osgood developed a horse-drawn streetcar system along Second Avenue with branches to Lake Union and to Belltown. Osgood's system, begun in the Fall of 1884, was the first in Washington Territory and was a feather in Seattle's cap in the bitter rivalry with Tacoma. Osgood kept abreast of developments in electricity, and in 1888 joined forces and funds with L.H. Griffith, Morgan Carkeek, Dr. E.C. Kilbourne, Judge Thomas Burke and others to form the Seattle Electric Railway and Power Company. The purpose of the company was to electrify the existing trolley line, open new territory for development, and beat the competition of the cable-car company. (Beaton, pp. 100-105)

Osgood and Kilbourne contracted with the Thomson-Houston Electric Company for equipment. A plant was built at the foot of Pike Street with an 80-h.p. generator and a 100-h.p. engine. The rolling stock included five double-reduction Thomson-Houston 15-h.p. motor equipments, four Jones car bodies with Brill trucks. Electric trolley service began at midnight on March 30, 1889, and the horse cars were retired to car barns never to run again on Seattle streets. Citizens turned out in droves along Second Avenue the following day. When the trolleys made the grade, Seattlelites cheered and the cable car company began to worry. (Beaton, p. 106)

Seattle's electric streetcar system was a tremendous success as an advertisment for the city, as a money-making venture, and as a stimulus to real-estate development. New "streetcar" suburbs were opened up for subdivision, and thus electricity became a prime factor in the rapid growth of the city. By 1891, there were 13 separate cable and electric railway companies and 48 miles of electric trackage. (The Argus, Dec.

11, 1911) Among others, the Grant Street Electric Railway built tracks on piles around the tideflats to Georgetown in 1893. A brick powerhouse with three generators supplied power for the car system with enough left over to provide electric lighting to several establishments in Georgetown. (Blanchard, pp. 37-38)

The Panic of 1893 had a disasterous impact on Seattle's electric trolley companies. All but the Madison Street Cable Company and the Seattle Traction Company went into receivership. Many trolley enterprises revived with the business recovery brought on by the Alaska gold discoveries, but the tracks and rolling stock had begun to deteriorate Talk of consolidation of the myriad systems became a reality when the giant eastern firm of Stone and Webster entered the field. (Phelps and Blanchard, pp. 164-165)

Stone and Webster's consolidation of Seattle's myriad streetcar lines led to immediate improvements in the system. In December of 1900, G.W. Dickinson, manager of the Seattle Electric Company, reported on these improvements in The Argus, and asked the citizen's indulgence for the torn-up condition of the streets. Dickinson also noted that it was now possible for the working public to live on the outskirts of the city within a radius of five miles, and be within twenty minutes of Pioneer Square by street railway. The following year The Argus reported that:

> . . . during the past two years the lines have been nearly all rebuilt and equipped with latest improvements, both in rolling stock and other appliances, and when improvements under construction are completed, no city in the country will have better service. (The Argus, Dec. 21, 1901)

The improvement and extension of the street railway system had a direct effect on the expansion of the city. "Streetcar suburbs" grew up overnight, and the general prosperity of the times allowed working people to purchase their own homes on the installment plan. Seattle became a city of single-family-homes and well-defined neighborhoods because of this direct access by streetcar to and from the commercial center. (Seattle of Today, p. 39)

In 1902 an interurban electric railroad line was completed between Seattle and Tacoma. This efficient, rapid means of transportation opened up still more suburban areas to settlement, and brought into existence a number of new towns and villages along its route. A branch line to the coal-mining town of Renton was soon added to the system and by 1907 a line to Everett was under construction. With the operation of these roads, electrical transportation in Seattle reached its zenith. (The Argus, Dec. 20, 1902, and Seattle of Today, p. 39)

Tourism and recreation in and around Seattle were encouraged and enhanced by the Seattle Electric Company's transportation system. "Trolley parks" at scenic locations at the end of the streetcar lines at Leschi and Madison Park on Lake Washington, were developed by the Company into popular resort facilities. During the summer months as many as eight "Seeing Seattle" tourist cars were operated on tour routes throughout the city. These proved immensely popular during the Alaska-Yukon-Pacific Exposition of 1909. ("Trolley Trips About Seattle") The AYP itself spurred construction of several new streetcar lines and the upgrading of rolling stock and terminals. Outside of the city the interurbans were tourist attractions in themselves, with miles of scenic vistas of farmlands, forests, water, and mountains. (The Argus, Dec. 20, 1902, and Dec. 16, 1911)

By 1911, Stone and Webster's rate of investment in the Seattle street railway system had slowed to the extent that criticism was being raised by municipal ownership advocates. "A Short History of Seattle's Street Railway System," an article published by The Argus on December 16, 1911 was an obvious attempt to praise and defend the Seattle Electric Company's many accomplishments over the previous decade. Nevertheless, service continued to deteriorate, and the Seattle Municipal Railway came into existence in 1911 with the construction of a new line of its own. It was a taste of things to come in the next decade when the City would incrementally enter the public transportation field, and Stone and Webster interests would subside. (Phelps and Blanchard, pp. 165-167)

When the Georgetown Steamplant was constructed in 1906-07, the city's electric car service and the region's interurban service was at its peak. The Seattle Electric Company's streetcar system was the major consumer of the company's power, and it provided service to 246,000 people over 155 miles of track. By 1912, however, the operation of the system had become less profitable, and Stone and Webster's investment in its maintenance declined. Local sentiment toward municipal ownership of the system revived once again. The city had proved its interest and ability to operate such a system with its construction of the "Division A" line in 1911 and its take-over of the Highland Park-Lake Burien line in 1913. Tension and disputes between the city and Stone and Webster (by then consolidated as Puget Sound Power and Light) continued to mount during World War I.

In 1919, the city purchased the entire street railway system at the asking price of Stone and Webster. Under the contract, the city was also to take over the substations supplying street railway current. Municipal operation of the street railway system was plagued with problems. Ineligibility for state subsidies, rigorous payment terms, management changes, increased wartime traffic followed by a business slump, and finally depression led to bankruptcy of the system in 1938.

During the twenty-year life of the Seattle Municipal Street Railway, the city had purchased absolutely no new equipment. The entire system was eventually replaced by rubber tire gasoline engine vehicles -- the last electric car ran on April 13, 1941. (Blanchard, pp. 91-94, "Chronological History," n.p.)

Industrial and Domestic Use

From the first instance of industrial use of electricity in Seattle at the Lowman-Hanford presses in 1890, the application of the new power source to industry grew rapidly. In an advertisement in The Argus, of December 23, 1899, the Northwest Fixture Company offered electric fixtures, motors, dynamos, and electrical machinery and elevators for sale. In the same issue of that magazine, the Seattle Cataract Company offered cheap power from Snoqualmie Falls to grind flour, mine coal, or smelt ores.

Local articles published throughout the first decade of the century promoted Seattle as a good place to establish manufacturing concerns, precisely because of the abundance of cheap power made available through its hydroelectric and steam plant facilities. The local utility companies advertised extensively for industrial customers, even to the extent of gathering data for prospective manufacturers. W.E. Herring, Industrial Agent for the Puget Sound Traction Power and Light Company, published two such informative articles in The Argus, (Dec. 13, 1913 and Dec. 18, 1915), describing the natural resources of the Puget Sound Region, the untapped opportunities in manufacturing, and the availability of electrical power at low cost in both urban and rural areas.

New Domestic Uses

In the first decade of the new century, the application of electricity to domestic use revolutionized the operation of Seattle households. Wider application was made possible by the lower rates associated with hydroelectric generation, and by a growing understanding of the new technology. The Municipal Lighting Department's Annual Report of 1912 reported on city-wide experiments with electric heating systems, both radiant and hot water. Cooking with electricity, the report noted, was well established in many homes.

The Seattle Electric Company's headquarters in the Electric Building on Seventh and Olive featured for a number of years a unique display of domestic electrical devices known as "The House Without a Chimney." This five room model "flat" exhibited a range of available appliances appropriate for use in each room, and clearly portrayed the ultimate in domestic luxury of the period. A 1912 Souvenir Edition of The Electric Journal described the electrical contents of the rooms as follows:

-- drawing room -- fireplace with luminous radiator, ceiling fixtures, and "artistic applications of electric light to decorations."
-- kitchen -- range, hot plate, percolator, water heater, tea kettle, combination cooker, frying pan, griddle, toaster oven, broiler, disc stove, egg boiler, and sterilizer.
-- bathroom -- electric water heater attached to tub, portable luminous radiator, shaving mirror and mug, and vibrator.
-- bedroom -- reading lamp, sewing machine, warming pad, curling iron, hair dryer, cigar lighter and water heater.

In contrast to electric transportation, domestic and industrial consumption of electricity continued to expand decade after decade. The Seattle Electric Company, followed by Puget Sound Power and Light, competed with the Municipal City Light Department in supplying users. Electric heating remained expensive and experimental until the 1950s. In 1925, for example, only 700 homes in Seattle were using electric heat exclusively. The price was double that of coal, and the average yearly cost for heating a five-room house with electricity was $175/year.

By 1910, electric ranges were on display at the Electric Building in downtown Seattle. The Seattle Lighting Department promoted their use through sales, and by providing maintenance. In 1914, Puget Sound Traction, Power and Light offered free demonstrations in "Electric Cookery -- Practical, Simple, Cheap and Economical." Seattle City Light served approximately 2,500 ranges by 1922. By the end of 1926, that number had increased to 10,556.

Refrigeration by electricity was still in its infancy in Seattle in 1926, and cost was still a major problem. The electric water heater, however, had gained widespread acceptance by 1912. (Seattle City Light Annual Reports, 1912-13, 1922, 1926) A local 1914 advertisement for an "Electric Christmas" featured small appliances from heating pads, to Christmas tree lights, to waffle irons. A 1939 ad demonstrates the growth of major appliances including "water heaters, vacuum cleaners, and other modern household electrical servants." By 1950, Seattle City Light boasted that Seattle used over three times as much electricity as the national average.

Georgetown: The Community

As a community, one of many "streetcar suburbs," Georgetown reflected the increased availability and application of electricity. In 1906, Georgetown was a separate incorporation, known for its political independence, its industrial potential and its "wide open" roadhouses. The settlement was originally the agricultural community of Duwamish, first homesteaded by the familiar names of Holgate, Van Asselt, and Horton. Italian truck gardeners were also among the earliest inhabitants. The town was platted by Julius and Ann Horton, and the name changed to Georgetown after their son George in 1901. Georgetown was incorporated in 1904 and stubbornly held out against annexation by Seattle until 1910, largely owing to the partnership of its leaders with the local brewery and saloon interests. (Peterson, pp. 1-4, 22, 71-77)

Industry was the driving force of Georgetown from an early date. The town grew from a population of 2,500 in 1901 to 7,000 in 1910, largely because of increasing industrial activity. The Denny Clay Company, a major brick manufacturing firm which supplied brick and terra cotta to build much of Seattle, was the first to locate in Georgetown. The Seattle Brewing and Malting Company was established in 1893 and soon became the community's largest and most influential employer. The census of 1900 listed a number of Seattle Electric Company employees -- conductors, brakemen, and switchmen -- as residents of Georgetown where the company car barns and an interurban station were located. The Olympic and the Union iron foundries, furniture manufacturing, and river-related industries were also situated in Georgetown by 1900. (Peterson, pp. 25-27) By 1906, the dredging and straightening of the Duwamish River was planned and its future as a major shipping center already envisioned. Streetcars first arrived in Georgetown in 1882 on the Grant Street line, running open cars over trestles above the tideflats. The Seattle Electric Company extended that line to South Park and brought its car barns to Georgetown at the turn-of-the-century. In 1906, larger car barns were built employing over 200 men, in conjunction with construction of the Georgetown Steamplant. (Pacific Building and Engineering Record, January 13, 1906 and Peterson, pp. 40-41)

In spite of its industrial economic base, Georgetown was also a community of residences, businesses, parks, and institutions. Georgetown was the site of the King County Hospital and Poor Farm. With a large German population, Oktoberfest was a major community festivity. There were many boarding and rooming houses for single male workers, including off-season carnival employees and gypsies. Entertainment in Georgetown was never puritanical. Meadows Race Track was two miles out of town, and roadhouses along the way contributed to a steady stream of joy-riders from Seattle on summer afternoons. Georgetown was a colorful, liveable place to its residents, but the community was under frequent attack by the Seattle press for its liquor laws. On November 3, 1909, the Seattle Times wrote that:

> It is one of the few places in the state where the sale of liquor has been abused and where the whole community has become a by-word

and a reproach for all that is vile and depraved in the liquor business. (Peterson, pp. 56, 63, 77)

Although the electric car barns were eventually closed, Georgetown remains an industrial community, comfortably mixing a small residential section with much larger industrial plants. It is, like its namesake steamplant, a survivor from a past era of smaller scale and more restricted patterns of transportation. Today, both electricity and electrical users operate on much larger scales, commuting from distant suburbs, and transporting electricity on regional grids. In their heyday, Georgetown and the Georgetown Steamplant were considered leaders in a new electrical way of life. Their survival in the last decades of the twentieth century, remind us all of a national movement into the Electric Age. As an ironic comment on how quickly what seemed paramount so soon became mundane and on how much our dependence on electricity continues to accelerate. The mosaic mural in the central offices of Seattle City Light proclaims its determination to supply electricity "that man may use freely as the air he breathes . . . ."

NPS Form 10-900-a

OMB No. 1024-0018
EXP. 12/31/84

United States Department of the Interior
National Park Service

National Register of Historic Places Inventory—Nomination Form

Continuation sheet | Item number | Page

MAJOR BIBLIOGRAPHICAL REFERENCES

Emmet, William LeRoy
The Autobiography of an Engineer. The American Society of Mechanical Engineers: 1940.

Gilbreth, Frank B.
"Reinforced Concrete Power Station," California Journal of Technology. February, 1908, pp. 23-28.

Pacific
Pacific Building and Engineering Record, "Story of Georgetown's Prosperity," January 13, 1906.

Passer, Harold
The Electrical Manufacturers, 1975-1900, A Study in Competition, Entrepreneurship, Technical Change and Economic Growth. Harvard University Press, 1953.

Peterson, June
The Georgetown Story - That Was a Town, 1904-1910. Georgetown Designs: Seattle, 1979.

Phelps, Myra and Leslie Blanchard
Public Works in Seattle: A Narrative History, The Engineering Department 1875-1975. Seattle Engineering Department: 1978.

Seattle
The Seattle Daily Times, "Georgetown is Growing Fast: Many Industries Moving In," January 3, 1926.

Yost, Edna
Frank and Lillian Gilbreth: Partners for Life. Rutgers University Press: 1949.

Journals and Newspapers

Electrical World
Engineering News-Record
General Electric Review
Mechanical Engineering
Seattle Post-Intelligencer
Seattle Times
Stone and Webster Public Service Journal

FOOTNOTES

1. The general history of General Electric's development of the Curtis turbine is discussed in J.W. Hammond, Men and Volts: The Story of General Electric (New York: Lippincott, 1941), pp. 283 ff; E.L. Robinson, "The Steam Turbine in the United States; III--Developments by the General Electric Company," Mechanical Engineering, Volume 59 (1937) pp. 239-256; and most usefully, William Le Roy Emmet, The Autobiography of an Engineer (Albany: Fort Orange Press, 1931), Chapter 8.

2. Curtis was a patent lawyer and entrepreneur in addition to being an engineer. He studied civil engineering at Columbia College, graduating in 1881, and law at the New York Law School, graduating in 1883. After eight years as a patent lawyer, he became involved with the manufacture of electric motors. His first important patents were those for the steam turbines. He went on to obtain the first American patent on a gas turbine, in 1899, and an important patent on diesel engines, in 1930. (A.S.M.E. 1975, pp. 1-3)

3. General Electric did not keep the records of the early sales of Curtis turbines (personal communication, George Wise, Historian, General Electric Company, August 3, 1979) so it is impossible to say who bought them. The figures of the 1907 U.S. Census Special Report on Street and Electric Railways, p. 518, suggest that electric railway companies (who generally also sold electric power to the public) bought most of them:

size	number	power
all	252	535,404 H.P.
less than 500 H.P.	23	3,788
500-1000	70	49,491
1000-2000	51	69,787
over 2000	108	412,338
over 500	23	179,200

Individual manufacturing companies, producing power for their own factories, were probably the second largest group of purchasers.

4. Unlike early steam engines that varied the pressure of steam to control speed under load, the Curtis turbine used a series or belt of steam nozzles at one or two points around the turbine wheel. The governor directly controlled the number of nozzles open at any one time, thus assuring full pressure at the inlet point, no matter how many or how few nozzles were open. Greater loads on the generator would cause the governor to open more nozzles to maintain

a constant speed. "With such a machine it is possible to operate over at least half the range of the machine with maximum and minimum economy varying not more than five percent from the average." (Parker 1910, p. 78)

5. Stone and Webster Public Service Journal, Volume 1, August 1907, p. 118; September, p. 206; October, p. 272; November, p. 354; Volume 2, January, 1908, p. 535; March, p. 685-6; April, p. 773; and June, p. 950.

Form 10-300 (Rev. 10-74)

UNITED STATES DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE

NATIONAL REGISTER OF HISTORIC PLACES INVENTORY -- NOMINATION FORM

FOR NPS USE ONLY
RECEIVED
DATE ENTERED

SEE INSTRUCTIONS IN *HOW TO COMPLETE NATIONAL REGISTER FORMS*
TYPE ALL ENTRIES -- COMPLETE APPLICABLE SECTIONS

1 NAME

HISTORIC: Seattle Electric Company Georgetown Steam Plant

AND/OR COMMON: Georgetown Steam Plant

2 LOCATION

STREET & NUMBER: King County Airport, N.E. corner — __NOT FOR PUBLICATION

CITY, TOWN: Seattle — __ VICINITY OF — CONGRESSIONAL DISTRICT: 7th - Hon. Brock Adams

STATE: Washington — CODE: 53 — COUNTY: King — CODE: 033

3 CLASSIFICATION

CATEGORY	OWNERSHIP	STATUS	PRESENT USE	
__DISTRICT	X PUBLIC	X OCCUPIED	__AGRICULTURE	__MUSEUM
X BUILDING(S)	__PRIVATE	__UNOCCUPIED	__COMMERCIAL	__PARK
__STRUCTURE	__BOTH	__WORK IN PROGRESS	__EDUCATIONAL	__PRIVATE RESIDENCE
__SITE	**PUBLIC ACQUISITION**	**ACCESSIBLE**	__ENTERTAINMENT	__RELIGIOUS
__OBJECT	__IN PROCESS	__YES: RESTRICTED	__GOVERNMENT	__SCIENTIFIC
	__BEING CONSIDERED	__YES: UNRESTRICTED	X INDUSTRIAL	__TRANSPORTATION
		X NO	__MILITARY	__OTHER:

4 OWNER OF PROPERTY

NAME: Seattle City Light

STREET & NUMBER: City Light Building - Third Avenue

CITY, TOWN: Seattle — __ VICINITY OF — STATE: Washington

5 LOCATION OF LEGAL DESCRIPTION

COURTHOUSE, REGISTRY OF DEEDS, ETC.: King County Courthouse

STREET & NUMBER:

CITY, TOWN: Seattle — STATE: Washington

6 REPRESENTATION IN EXISTING SURVEYS

TITLE: None

DATE: __FEDERAL __STATE __COUNTY __LOCAL

DEPOSITORY FOR SURVEY RECORDS:

CITY, TOWN: — STATE:

7 DESCRIPTION

CONDITION		CHECK ONE	CHECK ONE
X EXCELLENT	__DETERIORATED	__UNALTERED	X ORIGINAL SITE
__GOOD	__RUINS	X ALTERED	__MOVED DATE______
__FAIR	__UNEXPOSED		

DESCRIBE THE PRESENT AND ORIGINAL (IF KNOWN) PHYSICAL APPEARANCE

The Georgetown Steam Plant is a substantial reinforced concrete frame structure located in an industrial area in the Georgetown district of south Seattle. It contains three steam turbine generators rated at capacities of 3,000 kw, 8,000 kw, and 10,000 kw. These generators were installed individually in 1907, 1908, and 1917 respectively.

The two smaller machines are vertical Curtis turbine generators with the generating unit positioned directly above the turbine drive and connected by an upright shaft. The 10,000 kw machine is a Curtis turbine of the later horizontal type where the turbine is mounted alongside the generator and the connecting shaft is horizontal. All three turbo-generators are operational and most of the original ancillary equipment is still in place.

The plant is roughly T-shaped in plan, one wing measuring 76 feet by 153 feet and the other measuring 79 feet by 64 feet with a 36 foot extension at one end.

The exterior architectural treatment is a simplified adaptation of the Neo-Classic Revival style. Such characteristic details as a cornice, belt course, and water table are incorporated in the design. Masonry areas delineating the bays of the building are proportioned to suggest pilasters.

The longer wing is four stories in height with a monitor or clerestory running the length of the roof. The shorter wing is five stories in height, also with a monitor.

In terms of operating efficiency, the plant is very precisely organized. Its longest wing is devoted almost entirely to the production of steam. Before conversion to oil fired boilers, this wing consisted of four levels, each with a separate function. At the top level was the conveyor floor for bringing coal into the building. There the coal was dumped from a continuous moving belt into eight funnel-shaped bunkers on the floor below. Each bunker stoked a pair of immense 932 hp. Sterling water tube boilers. Smoke flues extended along both sides of the coal bunkers directly above the boilers for carrying smoke to a fan assisted rooftop stack.

On the second floor, the sixteen boilers were separated into two banks facing each other across a corridor that ran the full length of the wing. From the corridor each boiler could be inspected and maintained. On the ground level, below both rows of boilers, there was an ash car that rolled on rails set in the floor. Each car consisted of a dumping hopper that could be moved from boiler to boiler where it would collect ash waste for removal from the building.

The entire coal and ash handling system within the building was arranged to allow the fuel and waste material to be simply dumped as necessary from one floor to the next without relying upon further mechanical distribution.

Oriented on a perpendicular axis across one end of the boiler wing, the second, shorter wing is devoted to generating electricity. The engine room, as it is called, includes the three turbo-generators each with a circulating pump, a vacuum pump and a barometric or jet condenser. The vertical generators are interconnected by a system of catwalks and ladders, and the condenser and steam piping are arranged between the generators and the wall. A raised platform at the second floor level is provided for the horizontal generator, and the condenser for this machine is located in the space directly below it.

Above the generators the engine room is open to the roof. A 50 ton crane runs on a track overhead to assist with disassembling the equipment for maintenance. Across from the generators on the opposite wall, the room is divided into a gallery with five levels. The lower floor is occupied by a bank of transformers and two exciters (small generators necessary to energize field windings in the turbo-generators to produce the basic electromagnetic force). Above this section at various levels are the plant office the switchboard room, and other control equipment.

The 10,000 kw horizontal generator and its condenser are simpler and more compact than the two older vertical machines. It is smaller even than the 3,000 kw unit which has less than one-third its generating capacity. The vertical configuration requires the use of a step bearing to carry the tremendous weight of the revolving mass. This bearing actually floats the shaft on a thin layer of oil that is constantly injected by high pressure pumps.

The Georgetown Steam Plant has undergone very little modernization since the installatio of its third generator in 1917. The boilers were converted to steam atomized oil fired furnaces beginning in 1918 and the process of conversion continued until 1946. This modification was accomplished without requiring any substantial alterations to the building, although the coal conveyor and ash cars were removed.

When the King County Airport was constructed on adjoining property in the mid-1930's, it became necessary to replace the tall exhaust stack with roof mounted induced draft fans to prevent the stack from interfering with the flight path. Both original smoke flues were dismantled, and new ducts were installed to connect into the system of fans.

The plant was originally built on the east bank of the Duwamish River to take advantage of the river as a source of cooling water for the condensers and for convenience in discharging wastewater. At roughly the same time the stack was removed the Duwamish was diverted to accommodate construction of the county airport, leaving the plant some distance from the river's new channel. A pumping station was therefore built to insure a continued supply of river water, and the discharge tunnel was also lengthened.

Finally, the original barometric condensers for the two vertical generators were rebuil in 1965 and 1969. Both new condensers are in general duplications of the earlier installation as is apparent from the engineer's drawings on file.

A complete inventory of equipment currently at the Georgetown Steam Plant is included on the following pages of this section.

EQUIPMENT INVENTORY (Preliminary)

EQUIPMENT	REMARKS	DATE OF MANUFACTURE OR INSTALLATION
Steam Boilers		
7 Boilers, each rated 369 boiler horsepower, equipped with superheater.	The boilers were originally coal fired, then converted to burn oil starting in 1918. Final conversion to oil was completed in 1946.	1906 & 1918
2 Boilers, each rated 473 boiler horsepower, equipped with superheater.	Babcock & Wilcox manufactured 14 of the boilers for the Seattle Electric Co. in 1906. In 1918 two more boilers were added.	
7 Boilers each rated 519 boiler horsepower. Boilers are not equipped with superheater.	Each Sterling type boiler has lettered cast manhole inspection covers, 12 per boiler. The boilers also have the name "The Seattle Electric Company" across the top.	
Boiler Steam Pressure Gauges		
0-300 psi. (Total of 16)	Manufactured by J. Marsh Co., Chicago, Illinois. These are fancy brass gauges approximately 15 inches in diameter.	1906 & 1918
Boiler Room Panel		
See remarks	Mounted on the panel is an antique brass pressure gauge (1898) manufactured by Wm. H. Birch Co., San Francisco, Calif. Range 0 to 250 psi., 10 inch. The panel also contains: an old Bristol Recorder manufactured by the Bristol Company, Waterbury,	

FOR NPS USE ONLY
RECEIVED
DATE ENTERED

NATIONAL REGISTER OF HISTORIC PLACES INVENTORY -- NOMINATION FORM

EQUIPMENT (Continued)	REMARKS	DATE OF MANUFACTURE OR INSTALLATION
	Conn., a small gauge manufactured by North Coast Engineering Company, Seattle, Wash. and a larger gauge manufactured by J. P. March Co., Chicago, Ill.	
Donkey Boiler		
Boiler Number 3535 Operating pressure 0-160 psig. Oil Fired.	Built for Bucyrus Company, by Johnston Bros., Inc. Ferrysburg, Michigan. The boiler is used for start up.	1924
Induced Draft Fans		
Size 998 Design 2 Fans number 1 & 2, 9 & 10, 13 & 14, 15 & 16 are Model Number 13741. Fans number 3 & 4, 5 & 6, 7 & 8, 11 & 12 are Model Number 13740.	Manufactured by B. F. Sturtevant Company.	ca. 1935
Fuel Oil Storage Tank		
Storage capacity 20,328 barrels.	The storage tank is buried underground.	ca. 1917
Turbo-Generator Number 1		
Curtis Steam Turbine (No. 3007) (4 stage vertical shaft steam turbine).	Manufactured by General Electric Co. Steam Pressure 175 psi.	1907
Alternating Current Generator 3,000 KW Vertical Type ATB No. 148684 Class 10, Volts 13,200, Amps 131.5	Manufactured by General Electric Co. Schenectady, N.Y.	1907

UNITED STATES DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE

NATIONAL REGISTER OF HISTORIC PLACES INVENTORY -- NOMINATION FORM

FOR NPS USE ONLY

RECEIVED

DATE ENTERED

EQUIPMENT (Continued)	REMARKS	DATE OF MANUFACTURE OR INSTALLATION
Turbo-Generator Number 2		
Curtis Steam Turbine (No. 4137) (5 stage vertical shaft steam turbine).	Manufactured by General Electric Co. Steam Pressure 175 psi.	1908
Alternating Current Generator 8,000 KW Vertical Type ATB No. 119566 Class 10, Volts 13,800, Amps 334	Manufactured by General Electric Co., Schenectady, N.Y.	1908
Turbo-Generator Number 3		
Curtis Steam Turbine (No. 13401) (9 stage horizontal shaft steam turbine).	Manufactured by General Electric Co. Steam Pressure 175 psi.	1917
Alternating Current Generator 10,000 KW Horizontal Type ATB-4 Volts 13,800, Amps 524 No. 1181396	Manufactured by General Electric Co., Schenectady, N.Y.	1917
Barometric Condenser No. 1	Manufactured by City Light Used with Unit No. 1.	1969
Barometric Condenser No. 2	Manufactured by Hydraulic Supply Manufacturing Co., Seattle, Wash., Used with Unit No. 2.	1965
Jet Condenser	Manufactured by C. H. Wheeler, This condenser is used with Unit No. 3.	1917

EQUIPMENT (Continued)	REMARKS	DATE OF MANUFACTURE OR INSTALLATION
Weiss Air Pump (Vacuum)		
Number 149 Used with vertical Turbo-Generator Unit No. .	Built by Southwark Foundry and Machine Co. Patented April 28, 1896 Philadelphia, PA	1907
Weiss Air Pump (Vacuum)		
Number 174 Used with vertical Turbo-Generator Unit No. 2.	Built by Southwark Foundry and Machine Co. Patented April 28, 1896 Philadelphia, PA	1908
Electrical Panels		
Panels are Grey Marble approximately 2 inches thick. There are 27, two piece sections.		ca. 1907 & 1917
The following equipment is panel mounted on these panels.		
1 Western Stanton Volt Meter Number 5746 Range 0-600 Volts	Manufactured by Western Electric Instrument Co., Newark, New Jersey	
Thompson Recording Watthour Range 2000 amp, 600 volt (Total of 4)	The meters appear to be in good condition. All were manufactured by General Electric Company.	
Thompson Astatic Ammeter 1 - Range 0 - 500 amp 1 - Range 0 - 800 amp 1 - Range 0 - 1000 amp 1 - Range 0 - 1300 amp 4 - Range 0 - 1500 amp 1 - Range 0 - 2000 amp	All meters were manufactured by General Electric Company	

FOR NPS USE ONLY
RECEIVED
DATE ENTERED

EQUIPMENT	REMARKS	DATE OF MANUFACTURE OR INSTALLATION
Electric Panels (Continued)		
Miscellaneous Meters Volt meters, Ammeters Watthour meters, Temperature indicators (Total of 50 meters)	The majority of these meters are ammeters, 34 of these. All meters were manufactured by General Electric Company	
Power Factor Meter (Antique) 1 meter	Manufactured by Westinghouse Electric Company.	
Voltage Regulator (Antique) 1 regulator Number 1661	Manufactured by General Electric Company, Schenectady, N.Y., USA.	
Synchronous Meter 1 Meter	Manufactured by Genernal Electric Company.	
Reverse Power Relays 2 Relays (small) 8 Relays (large)	Manufactured by General Electric Company	
Frequency Indicator Frahm System	Manufactured by James G. Biddle Company	
Large Solid Copper Knife Switch 8 total, miscellaneous sizes, multiple blade type.	Manufacturer unknown.	
Two Blade Knife Switch Solid Copper 13 total, misc. sizes	Manufacturer unknown.	
Single Blade Knife Switch Solid Copper 15 total, misc. sizes	Manufacturer unknown.	

EQUIPMENT (Continued)	REMARKS	DATE OF MANUFACTURE OR INSTALLATION
Framed Switch and Fuse Panels		
4 Panels, the panels have two blade knife type switches and use screw-in type fuses.	The panels are for lighting and miscellaneous circuits. Manufacturer unknown.	ca. 1907
Oil Circuit Breakers		
7 Breakers - small 36 Breakers - large	Manufactured by General Electric Company	1907 & 1917
Knife Switches		
More than 50 solid Copper multi blade type switches.	Manufacturer unknown.	1907 & 1917
Transformers		
Bank No. 1 Type WC, 500 KW 13,800 volt (2 transformers in bank)	Manufactured by General Electric Company	ca. 1907
Transformers		
Bank No. 2 13,800 1000 KVA (2 transformers in bank)	Manufactured by Westinghouse Electric Company	1907
Automatic Circuit Breakers (Antique)		
4 Circuit Breakers	Manufactured by General Electric Company	ca. 1907
Lube Oil Pump (Duplex Type)		
Steam Driven, 2 cylinder Size 9 x 3-1/8 x 10 Number 189-977	Manufactured by Worthington	ca. 1907

EQUIPMENT (Continued)	REMARKS	DATE OF MANUFACTURE OR INSTALLATION
Lube Oil Pump (Duplex Type)		
Steam Driven, 2 cylinder Size 9 x 3-18 x 10 Number 190-208	Manufactured by Worthington	ca. 1907
Lube Oil Transfer Pump (Duplex Type)		
Steam Driven, 2 cylinder Size 4-1/2 x 2-3/4 x 4 Number 164828X9	Manufactured by Knowles Pump Works New York, New York.	ca. 1917
Fuel Oil Pump (Duplex Type)		
Steam Driven, 2 cylinder Reciprocating Type Size (Data not available) 2 identical pumps	Manufactured by - (Name plate data missing) Hallidie Machinery Company, Seattle, WA Sales agent.	ca. 1918
Fuel Oil Pump		
Screw Type, Electric Motor Driven Size 4, 250 Head, 80 gal/min Number 867	Manufactured by William E. Quemby, Inc., New York, New York	ca. 1930
Feed Water Pump (East)		
DeLaval Centrifugal Type 140-TC-3P5 650 gal/min 520 Head Number 56980	Manufactured by Ingersoll Rand Co. New York, New York.	ca. 1917
Steam Turbine (for feed pump) 2300 RPM Number 56980	Manufactured by DeLaval Steam Turbine Company, Trenton, New Jersey	ca. 1917

Form No. 10-300a
(Rev. 10-74)

UNITED STATES DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE

NATIONAL REGISTER OF HISTORIC PLACES INVENTORY -- NOMINATION FORM

FOR NPS USE ONLY
RECEIVED
DATE ENTERED

CONTINUATION SHEET | ITEM NUMBER 7 | PAGE 10

EQUIPMENT (Continued)	REMARKS	DATE OF MANUFACTURE OR INSTALLATION
Feed Water Pump (West)		
Ingersoll Rand Centrifugal 900 gal/min, Size 4GT900 552 Ft. Head Number 06493050	Manufactured by Ingersoll Rand Company, New York, New York.	1949
Steam Turbine (for feed pump) 3600 RPM Serial Number 79336 Model Number 7TDP1117AEK 180 Horsepower	Manufactured by General Electric Company, Schenectady, New York.	1949
Air Compressor		
Size 8 x 8 Electric Motor Driven Number 36175	Manufactured by Curtis St. Louis, Mo.	1950
Centrifugal Water Pump		
Spare Pump Small Electric Motor Driven (Name plate date missing.)	Name plate data missing. The Spare pump is not connected into system	ca. 1917
Hot Well Tank		
14 ft. diameter x 12 ft. deep Steel plate construction.	Manufacturer unknown	1917
Fuel Oil Strainer System	Manufactured by Bethlehem Steel	ca. 1930
Step Bearing Lube Oil Tank	Manufactured by Turner Oil Filter Co. Niles, Michigan.	1907
Mid Bearing Lube Oil Tank	" "	1907
Spare Lube Oil Tank	" "	1907
Air Pump Lube Oil Tank	" "	1908

UNITED STATES DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE

NATIONAL REGISTER OF HISTORIC PLACES INVENTORY -- NOMINATION FORM

FOR NPS USE ONLY
RECEIVED
DATE ENTERED

EQUIPMENT (Continued)	REMARKS	DATE OF MANUFACTURE OR INSTALLATION
Ingersoll Rand Air Compressor		
Large unit similar to the unit installed in Lake Union Steam Plant	This unit is dismantled. It will be used for parts for the Lake Union Compressor. In addition there is an Allis Chalmers 125 horsepower induction motor to run this compressor.	
Step Bearing Oil Pump (Duplex)		
Steam driven 2 cylinder Reciprocating Type Size 12 x 2-3/4 x 18 Number 192035 Used on Unit No. 1	Manufactured by Worthington.	1907
Step Beraing Oil Pump (Duplex)		
Steam driven 2 cylinder Reciprocating Type Size 12 x 2-3/4 x 18 Number 192036 Used on Unit No. 2	Manufactured by Worthington	1908
Centrifugal Pump		
Steam driven Size 4 400 gal/minute 560 ft head 2750 RPM	This is a spare pump not connected to plant system. Manufactured by Platt Iron Works Dayton, Ohio	
Turbine Drive Terry Turbine Number 1759 2750 RPM	Manufactured by Terry Steam Turbine Company Hartford, Connecticut	

EQUIPMENT (Continued)	REMARKS	DATE OF MANUFACTURE OR INSTALLATION
Condenser Pump (Unit No. 3)		
Pump Size 18 D.V.S. Number 06280	The pump may be operated by either electric motor or by steam turbine. Manufactured by Wheeler Condenser Engineering Company	1917
Pump Reduction Gear Drive Number 548	Manufactured by Moore Steam Turbine Corporation.	1917
Turbine Drive Number 3555	Manufactured by Terry Turbine Company.	1917
Pump Electric Motor Drive Number 1648315	Manufacturer General Electric Company	1917
Wheeler Turbo Air Pump (Vacuum)		
Pump Size T-A-100 Number 04968	Manufactured by Wheeler Condenser & Engineering Co., New York, N.Y. The pump is used with condenser number 3 and is steam driven.	1917
Steam Turbine Drive Number 4635	Manufactured by Westinghouse Machine Co., Designers & Builders, East Pittsburgh, Pa.	1917
Overhead Bridge Crane		
Capacity 50 ton Number 715	Manufactured by Northern Engineering Works, Detroit, Mich. This is the main powerhouse crane.	1907
Overhead Bridge Crane		
Capacity 20 ton	Manufactured by Reading Crane & Hoist Works, Reading, Pa. The crane is located in the area over the Motor Generator sets	1907

EQUIPMENT (Continued)	REMARKS	DATE OF MANUFACTURE OR INSTALLATION
Small Electric Crane		
Capacity 1 ton M 1210 Frame 25	Manufacturer Budget	1955
Step Bearing Oil Pressure Balance Weight Alarm		
Set at 950 psi.	Manufacturer unknown. .	1907
Simplex Water Meter		
Meter Scale measures in 100,000 lbs per hour at 70 F.	Manufactured by Simplex Valve and Meter Company, Philadelphia, Pa. This meter is a valuable antique.	1907
Per Cent Carbon Dioxide (CO_2) Wall Mounted Meter		
0 to 20% Scale Multi Point type	Used to monitor Boiler Combustion. Manufactured by Leeds & Northrup Company, Philadelphia, Pa.	1907
Panels		
The two panels (one for Turbo Generator Number 1 and the other for Turbo Generator Number 2), have solid brass gauges. One gauge for 1st stage pressure, one gauge for Steam Supply pressure, one gauge for step bearing oil pressure, one gauge for vacuum. The panel for Unit Number 1 has a frequency indicator mounted at the top. It may be used to monitor either unit's frequency.	4 Gauges were manufactured by General Electric Company. The frequency indicator was manufactured by James G. Biddle, Philadelphia, Pa.	1907 & 1908

EQUIPMENT (Continued)	REMARKS	DATE OF MANUFACTURE OR INSTALLATION
Panel		
Turbo-generator Unit Number 3 2 brass hydraulic pressure gauges, 0-2000 psi.	Ashcraft	1917
1 Brass steam gauge, 0-260 psi.. .	Syracuse Gauge	1917
1 Aston Brass Gauge	Aston	1917
Telephones (Antique)		
Hand crank type.	There are 4 or more units, one located in the pump house and at least 3 located in the plant. Manufacturer unknown	
Fuel Oil Transfer Pump (Duplex)		
2 Cylinder reciprocating type Electric Motor Driven	Manufactured by Fairbanks Morse Company. (ca. 1910) Brought in from Lake Union Plant	1953
Motor Generator Set No. 2		
Continuous current Generator No. 159471 Type MP Class 8-500-514 Form H Amperes - 833 Speed - 514 RPM Volts 600	Manufactured by General Electric Company, Schenectady, N.Y.	1907
Snychronous Motor Number 161143 Type ATI Class 14-530-514 Form C H Power - 700	Manufactured by General Electric Company, Schenectady, N.Y. Approx. Mfg. 1906	1907

EQUIPMENT	REMARKS	DATE OF MANUFACTURE OR INSTALLATION
Motor Generator Set No. 2 (Continued)		
Speed 514 Volts 13,200 Amp 28.8 Cycles 60		
Exciter No. 2		
Motor Generator Set Continuous Current Generator Number 140447 Form B KW-120 Amperes 960 Speed 600 Volts 125	Manufactured by General Electric Company, Schenectady, N.Y. Approx. Manufacture 1906	1907
Induction Motor Model No. 14070 Type 10-17-12-175-600 Form K Volts 280 Amps 40 Number 161679 HP 75 Speed 580 2 Phase	Manufactured by General Electric Company, Schenectady, N.Y. Approx. Manufacture 1906	1907
Direct Current Generator		
No. 1201823 Type MPC - 6-200-1200 Form L Amps 1600 Volts 125 Speed 1200 RPM 200 KW Nominal	Manufactured by General Electric Co., Schenectady, N.Y.	1917

EQUIPMENT	REMARKS	DATE OF MANUFACTURE OR INSTALLATION
Direct Current Generator (Continued)		
Steam Turbine Drive Number 56684 Speed 3600 RPM Steam Pressure 200 psig With DeLaval Speed Reducer	Manufactured by DeLaval Steam Turbine Co., Trenton, N.Y.	1917
Exciter No. 1		
Generator No. 78345 Volts 120 Amperes 125 RPM 1130	Manufactured by Allis Chalmers Company, Milwaukee, Wis.	1907
Electric Motor Number 78346 HP 22.5 Volts 220 Amps 55 3 Phase Frequency 60 H_z RPM 11,300	Manufactured by Allis Chalmers Company, Milwaukee, Wis.	1907
River Pumps		
20" Size 13,500 Gallons per Minute 85 Feet Head 690 RPM Type S Pump #1, Style A, Serial No. 1498 Pump #2, Style B, Serial No. 1497	The two pumps are in the pumphouse located on the Duwamish River. The pumps were manufactured by Allis Chalmers. The pumps are each driven by a 400 HP electric motor. The motors are type IQ, Form K, 2200 volt, 2 phase, manufactured by General Electric Company.	ca. 1935
Floor Mounted Drill Press		
Antique, Belt Driven Type	Manufactured by Champion Company.	ca. 1907

UNITED STATES DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE

NATIONAL REGISTER OF HISTORIC PLACES INVENTORY -- NOMINATION FORM

FOR NPS USE ONLY
RECEIVED
DATE ENTERED

EQUIPMENT (Continued)	REMARKS	DATE OF MANUFACTURE OR INSTALLATION
Bristol Recorders		
Panel mounted Antique type (vacuum gauge)	Manufactured by Bristol Company, Waterbury, Conn.	ca. 1907 & 1918
Large Master Gauge		
Approx. 2 feet in diameter Range 150 to 210 psi. Brass construction	Manufactured by Ashton. This is an antique	1906
Air Raid Siren		
World War II model Roof Mounted Engine Driven	Engine manufactured by Chrysler. Siren manufactured by American Blower Co.	ca. 1941

8 SIGNIFICANCE

PERIOD	AREAS OF SIGNIFICANCE -- CHECK AND JUSTIFY BELOW			
__PREHISTORIC	__ARCHEOLOGY-PREHISTORIC	__COMMUNITY PLANNING	__LANDSCAPE ARCHITECTURE	__RELIGION
__1400-1499	__ARCHEOLOGY-HISTORIC	__CONSERVATION	__LAW	__SCIENCE
__1500-1599	__AGRICULTURE	__ECONOMICS	__LITERATURE	__SCULPTURE
__1600-1699	__ARCHITECTURE	__EDUCATION	__MILITARY	__SOCIAL/HUMANITARIAN
__1700-1799	__ART	X ENGINEERING	__MUSIC	__THEATER
__1800-1899	__COMMERCE	__EXPLORATION/SETTLEMENT	__PHILOSOPHY	__TRANSPORTATION
X 1900-	__COMMUNICATIONS	__INDUSTRY	__POLITICS/GOVERNMENT	__OTHER (SPECIFY)
		__INVENTION		

SPECIFIC DATES 1907, 1908 and 1917 BUILDER/ARCHITECT Stone & Webster Engineering, Boston

STATEMENT OF SIGNIFICANCE

At the time of its manufacture in 1903, the 5000 kw Curtis steam turbine generator was the world's most powerful steam driven turbine. It represented a significant achievement in electric power generation technology that has had an influence on the design of all major thermal power generation systems built since its introduction. The two vertical Curtis turbines at Seattle's Georgetown Steam Plant are understood to be the only turbines of this type that remain in an operating condition.

The Curtis turbine generator, when first manufactured by the General Electric Company, more than tripled the power capacity of turbine generators then in use. The Curtis turbine was smaller in size and lower in cost than reciprocating steam engines of the same power output, yet due to its continuous rotary motion, it was significantly smoother in operation. Severe vibrations were a factor that limited the potential size of reciprocating engines due to the impossibility of achieving perfect balance. The success of the Curtis design established that the steam turbine was a practical and compact prime mover capable of producing large amounts of power.

The historic significance of the vertical Curtis steam turbine generator is summarized by Professor E. F. C. Somerscales in a report prepared for the American Society of Mechanical Engineers:

> *The contributions of the steam turbine to the history of power production are . . . . quite as important as the more widely recognized roles of the water turbine and the reciprocating steam engine and consequently make the 5000 kw Curtis turbine-generator a very important landmark in the history of mechanical engineering.*

The turbine can run at inlet and exhaust conditions that achieve a greater degree of efficiency in the steampower cycle than is possible with a reciprocating piston driven engine. Turbines permit the use of superheated steam at a much higher pressure and temperature because in piston engines the lubricating oil necessary for valves and cylinders tends to carbonize above a certain threshold. Further, a turbine may be operated at exhaust pressures below atmospheric. This allows an additional improvement in the efficiency of the power cycle by extracting more heat energy from the steam before it condenses and is wasted. To successfully make use of steam at such low pressures in a piston engine would require larger cylinders of an impractical size.

One of the first three vertical Curtis turbines sold commercially was installed in 1903 on an experimental basis at the Fisk Street Generating Station of the Commonwealth Electric Company in Chicago. Fisk Street was probably the world's first generating plant designed and built for steam turbine equipment. However, sufficient additional room was provided when the plant was built so that the turbines could be replaced with reciprocating engine if they failed to perform as expected.

To accommodate a reciprocating engine of equivalent capacity it was necessary to allow 500 square feet of floor area and 60 feet of overhead clearance as opposed to the 250 square feet of floor space and 25 feet of headroom required for the 5000 kw Curtis turbines. At the time General Electric introduced these machines, the largest turbine generator in existence was a new 1500 kw Westinghouse unit supplied to the Hartford Electric Light company.

The successful development of a powerful steam turbine came during a very opportune perio in the history of electric utilities. The growing demand for electricity had already exceeded the production capability of conventional reciprocating steam engines where hydroelectric power was unavailable as an alternative source. The huge machines necessar to respond to increased demand produced violent vibrations that could be felt in the neighboring community. A judgement resulting from a lawsuit in England succeeded in preventing the local utility from further operating its generators.

Occurring when it did, the invention of a practical steam turbine enabled producers to respond to the need for additional generating capacity. This development was a major contribution toward the general availability of low cost electric power. It has led to the increasing modern reliance on large centralized generating stations.

Early Curtis turbine generators were arranged with the generator positioned directly above the turbine and connected by a vertical shaft. This vertical configuration was an adaptation to steam turbines of an arrangement commonly used with hydroelectric generators. Its use was first proposed by William LeRoy Emmet, an electrical engineer employed by General Electric.

The principal advantages were that stacking the components in this way required less floor space, and the connecting shaft was not subject to the stress of lateral distortion due to the force of gravity and the tremendous weight of the revolving parts.

Emmet is the project engineer who is actually credited with achieving the practical development of the Curtis Turbine for use in the generation of electricity. Curtis himself is said to have opposed the vertical configuration, although he licensed his basic patents to the General Electric Company.

General Electric abandoned its use of the vertical shaft as further refinements in the design of the turbine were adopted between 1908 and 1913. Operating speeds were increased from 500 rpm to 1800 rpm and eventually to 3600 rpm. At higher speeds it was necessar to restrain the top end of the shaft more effectively to prevent it from wobbling off center. The additional bracing required a much stiffer structure that could be more easily constructed if both ends of the shaft were supported directly on the floor of the building. Also, as more stages were added to increase the power output and efficiency of the turbine, the shaft had to be lengthened. This further complicated the problem of bracing and added to the amount of headroom required.

An immediate predecessor to the Curtis Turbine was the reaction turbine patented in 1884 by Parsons in England and licensed to the Westinghouse Machine Company for production in the United States. This was the first steam turbine that was competitive in a practical sense with the reciprocating steam engine as a source of power for generating large amounts of electricity.

In 1896 Charles Gordon Curtis patented two principles of turbine construction: pressure compounding and velocity compounding. Both concepts represented significant advancements in the state of the art and helped to overcome limitations inherent in the Parsons turbine. Pressure compounding involved the connection of two or more simple turbines in a series of stages where the inlet pressure of succeeding stages was the exhaust pressure of the previous stage. Velocity compounding recovered energy from the speed of the moving steam by adding several rows of fan-like blades in each stage separated by rows of stationery vanes that redirected the steam for optimum effect.

C. G. Curtis was a patent lawyer and civil engineer born April 20, 1860 in Boston, Massachusetts. After graduating from New York Law School in 1883 and practicing as an attorney for eight years, he became involved in manufacturing electric motors and fans. In addition to his contributions to steam turbine technology, Curtis is credited with other important inventions including the first American gas turbine patented in 1899, and certain improvements in the design of two-stroke diesel engines.

Further advancements in turbine technology have resulted in the general abandonment of velocity compounding in major electric power generating applications. Losses due to turbulence and fluid friction limited the efficiency of this principle. Also each succeeding row of blades was less effective because the steam loses speed as it passes from one row to the next.

The effectiveness of pressure compounding was greatly improved in 1898 by Rateau in France. Rateau changed the method of applying steam to the blades which increased the effectiveness of each stage and required fewer stages to recover the energy available in the steam. The result was a smaller, simpler machine that was less expensive to build and install. However, with this one basic modification, Curtis' original concept is still used in all high output steam turbine generators.

In 1910, C. G. Curtis was awarded the Rumford Prize of the American Society of Arts and Sciences for his development of the Curtis turbine.

The successful marketing of a large capacity turbine driven generator by the General Electric Company apparently convinced other manufacturers to produce other types of turbines of equivalent power. For this reason, the Curtis turbine can be said to have led to a general increase in the capacity of steam turbines and in turn to the widespread reliance on turbines throughout the thermal power industry. The steam turbine has since completely replaced the reciprocating piston engine as the preferred prime mover for large thermal powered generating stations.

The Georgetown Steam Plant was designed in 1906 by Stone and Webster Engineering Corporation of Boston, Massachusetts. It was originally built and operated by the Seattle Electric Company which was founded in the late 1890's when a number of Seattle's small, fiercely competitive electric utilities merged to form a single corporation.

In response to renewed competition, in 1912 most of the city's remaining suppliers of electricity were further consolidated under the name Puget Sound Light, Traction and Power Company, which acquired the Georgetown plant in the merger. This combined organization was owned by Stone and Websters holding company subsidiary. Under pressure from the federal government, Stone and Webster was forced to divest itself of certain properties. To comply with the order, Stone and Webster relinquished the traction portic of its operations in Seattle, reorganizing under the name Puget Sound Power and Light Company but still under the control of the parent corporation. Finally in 1951, Seattle City Light bought out Puget Power and Light's Seattle area facilities, and the Georgetown Steam Plant came under municipal ownership.

The plant was last operated on a regular basis during World War II to alleviate critical shortages in generating capacity. Since then it has only been run to meet brief power shortages in the early 1950's and 1960's.

Since that time, it has remained on stand-by status. The plant is only operated occasionally to check the condition of its equipment, but regular maintenance is performed to prevent deterioration. Heaters are used to stop moisture from condensing inside the machinery, and the shafts are rotated regularly to prevent them from permanent deforming or seizing the bearings.

A recent test run surprised the plant engineers and demonstrated that the generators are capable of producing considerably more power than City Light previously estimated. This has resulted in an update revision in the plant's rating for stand-by capacity.

A modern generating plant is approximately three times more efficient in its energy consumption for the production of an equivalent amount of electric power. The Georgetown facility no longer complies with air and water quality standards and this situation jeopardizes its continued preservation.

The Georgetown Steam Plant is significant not only because it contains the last operating examples of the vertical Curtis turbine, but also because it includes an improved horizontal Curtis turbine installed ten years later. The horizontal machine represents the second generation of Curtis turbines and it reflects design improvements significant in themselves that were the result of early experiments with this type of power source. The Georgetown Plant and its equipment are a unique working demonstration of this period in the history of electric power generation technology.

9 MAJOR BIBLIOGRAPHICAL REFERENCES

GEZ 6655, "A Legacy of Leadership," General Electric Pulication, December, 1976, Page 27, Schenectady, New York

Miller, J. A., "At the Touch of a Button - The Story of Electric Power," Schenectady, New York: Mohawk Development Service, Inc., 1962, Pages 35 - 37

Somerscales, E.F.C., The 5000 KW Vertical Steam-Turbine Generator at the Schenectady Plant of the General Electric Company, ASME, May 28, 1975

10 GEOGRAPHICAL DATA

ACREAGE OF NOMINATED PROPERTY three

UTM REFERENCES

	ZONE	EASTING	NORTHING
A	1,0	5,5,1,5,4,0	5,2,6,5,5,2,0
B	1,0	5,5,1,0,6,0	5,2,6,4,7,0,0
C			
D			

VERBAL BOUNDARY DESCRIPTION

Tracts A and B of the plat of the Queen Addition to Georgetown, Washington (now Seattle), and Tract 11 of the Duwamish Industrial Addition together with all existing easements and rights of way that pertain to the ducting of water to and from Seattle City Lights Georgetown generating facility. Rights of way are indicated by a red line connecting points A and B on the accompanying USGS map.

LIST ALL STATES AND COUNTIES FOR PROPERTIES OVERLAPPING STATE OR COUNTY BOUNDARIES

STATE	CODE	COUNTY	CODE

11 FORM PREPARED BY

NAME / TITLE

Jacob Thomas

ORGANIZATION

Office of Archaeology and Historic Preservation

DATE

October, 28, 1977

STREET & NUMBER

111 West 21st Street KL-11

TELEPHONE

(206) 753-4116

CITY OR TOWN

Olympia

STATE

Washington 98504

12 STATE HISTORIC PRESERVATION OFFICER CERTIFICATION

THE EVALUATED SIGNIFICANCE OF THIS PROPERTY WITHIN THE STATE IS:

NATIONAL X STATE ___ LOCAL ___

As the designated State Historic Preservation Officer for the National Historic Preservation Act of 1966 (Public Law 89-665), I hereby nominate this property for inclusion in the National Register and certify that it has been evaluated according to the criteria and procedures set forth by the National Park Service.

STATE HISTORIC PRESERVATION OFFICER SIGNATURE

TITLE DATE

FOR NPS USE ONLY

I HEREBY CERTIFY THAT THIS PROPERTY IS INCLUDED IN THE NATIONAL REGISTER

DATE

DIRECTOR, OFFICE OF ARCHEOLOGY AND HISTORIC PRESERVATION

DATE

ATTEST:

KEEPER OF THE NATIONAL REGISTER

Form No. 10-300a
(Rev. 10-74)

UNITED STATES DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE

FOR NPS USE ONLY
RECEIVED
DATE ENTERED

NATIONAL REGISTER OF HISTORIC PLACES INVENTORY -- NOMINATION FORM

CONTINUATION SHEET ITEM NUMBER 9 PAGE 2

"They Also Serve Who Only Stand and Wait," Seattle City Light News, February, 1968

Groner, Paul, "Preliminary Equipment Inventory - Georgetown Steam Plant," Seattle City Light, October 1977, unpublished

Form No. 10-300a
(Rev. 10-74)

UNITED STATES DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE

NATIONAL REGISTER OF HISTORIC PLACES
INVENTORY -- NOMINATION FORM

FOR NPS USE ONLY
RECEIVED
DATE ENTERED

CONTINUATION SHEET   ITEM NUMBER 10   PAGE

Revision

Change the verbal boundary description to read as follows:

Tracts A, B, C, and D of the Queen Addition to Georgetown, Washington (now Seattle), and the southern 100 feet of Tract II of the Duwamish Industrial Addition, together with all existing easements and rights-of-way that pertain to the ducting of water to and from Seattle City Lights Georgetown generating facility. Rights-of-way are indicated on the attached site map.

Revision

Change the acreage of nominated property to: four acres.

Form No. 10-300a
(Rev. 10-74)

UNITED STATES DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE

NATIONAL REGISTER OF HISTORIC PLACES INVENTORY -- NOMINATION FORM

FOR NPS USE ONLY
RECEIVED
DATE ENTERED

CONTINUATION SHEET   ITEM NUMBER 7   PAGE

Page 2
Correction

The nomination reads, "At rougly the same time the stack was removed, the Duwamish was diverted to accommodate construction of the county airport, leaving the plant some distance from the river's new channel. A pumping station was therefore built to insure a continued supply of river water, and the discharge tunnel was also lengthened."

The Duwamish River was actually diverted prior to 1920. No direct connection between th diversion and construction of the airport has been established. The pumping station was added ca. 1917 for the purpose stated.

Page 16
Correction

The nomination indicates that the river pumps were installed ca. 1935. These pumps were in fact added ca. 1917 when the pumping station was constructed.

Page 2
Revision

Insert prior to the penultimate paragragh:

The pumping station is a small reinforced concrete structure measuring approximately 16 by 40 feet in plan. It is situated directly on the east bank of the Duwamish Waterway resting on a short concrete bulkhead and a pair of screened inlet gates. The shoreline recedes away from the main waterway toward the building and the soil is retained by long wooden bulkheads that fan out from the corners of the pump house at an angle of about 110 degrees from one another.

The building itself has conventional classic revival details such as a simple entablature with parapet, strip pilasters and a water table. There are three bays on the long facades and one on the end walls. Centered in each bay there is a large window with four translucent lights, except for one bay at the back where there is a pair of pannelled doors with transom. A large steel stack stands at the rear of the building. Within the structure there are two Allis Chalmers river pumps each driven by a 400 horsepower electric motor manufactured by the General Electric Company.

There are two storage tanks located near the steam plant that are essential to its operation. One is an open 28 foot diameter concrete reservoir for holding a supply of river water. This is located adjacent to the power house at its Southwest

Form No. 10-300a
(Rev. 10-74)

UNITED STATES DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE

NATIONAL REGISTER OF HISTORIC PLACES INVENTORY -- NOMINATION FORM

FOR NPS USE ONLY
RECEIVED
DATE ENTERED

CONTINUATION SHEET | ITEM NUMBER 2 | PAGE

Typographical error

The correct address is: King County Airport, North West Corner

Revision

Change the ownership to include additionally:

King County
King County Administration Building
Seattle, Washington

Form No. 10-300a
(Rev. 10-74)

UNITED STATES DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE

NATIONAL REGISTER OF HISTORIC PLACES INVENTORY -- NOMINATION FORM

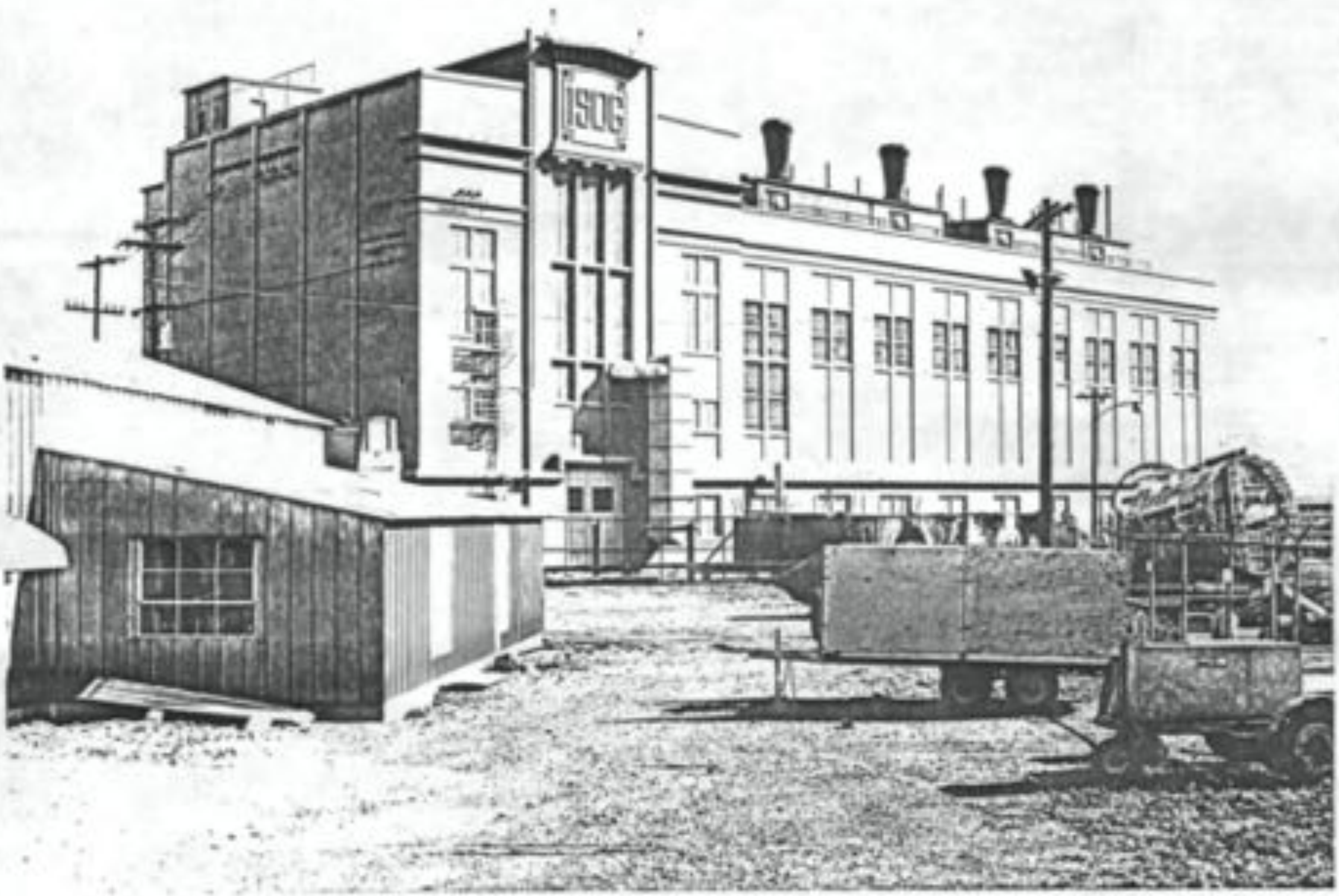
FOR NPS USE ONLY
RECEIVED
DATE ENTERED

CONTINUATION SHEET ITEM NUMBER 7 PAGE

Page 2
Revision Continued

end. The other is a partially buried 20,000 barrel cylindrical steel tank for the fuel oil supply. It is located 150 feet to the northeast of the building behind a berm of earth. Only the top of the tank is visible from above.

With the exception of a small corrugated metal shack used as an oil house, there are no extraneous buildings on the nominated property.

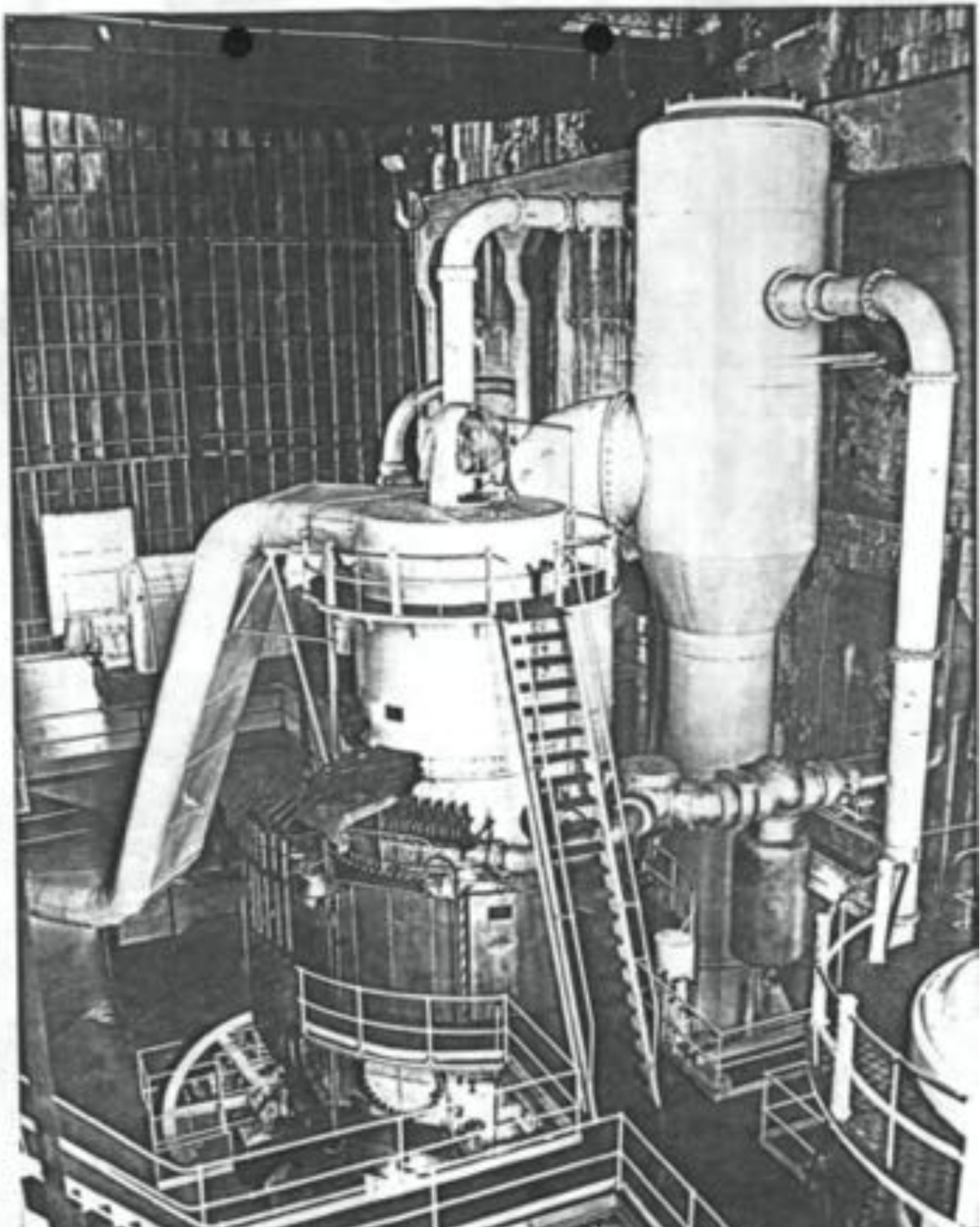


Georgetown Steam Plant

Seattle, Washington
Exterior view, northwest corner

Jacob Thomas
Office of Archaeology and Historic Preservation
September, 1977

1 of 7

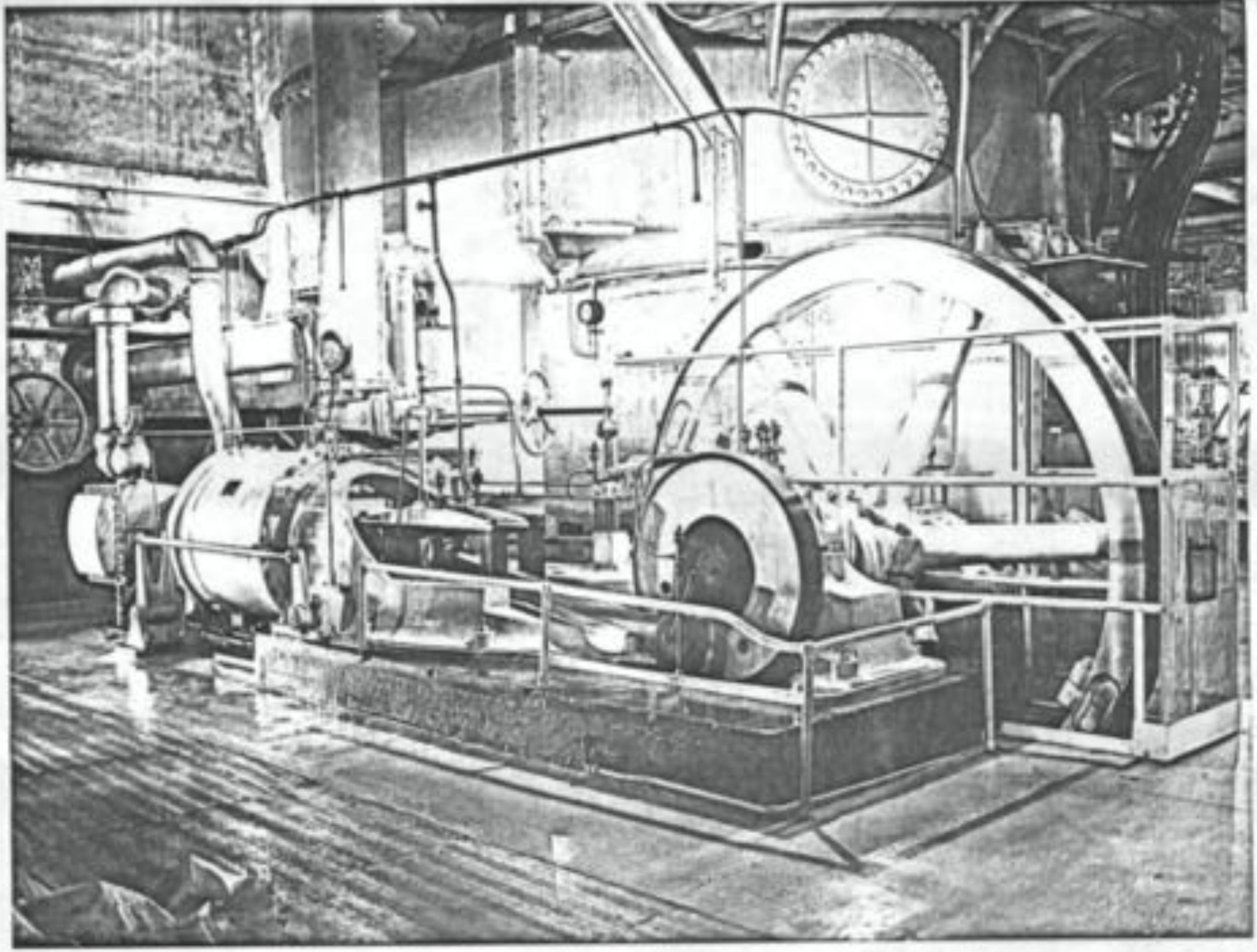


Georgetown Steam Plant

Seattle, Washington
Turbo-generator #2, 8000 KW capacity, installed 1908. For comparison the 10,000 KW generator is visible in the background on the left.

Jacob Thomas
Office of Archaeology and Historic Preservation
September, 1977

2 of 7

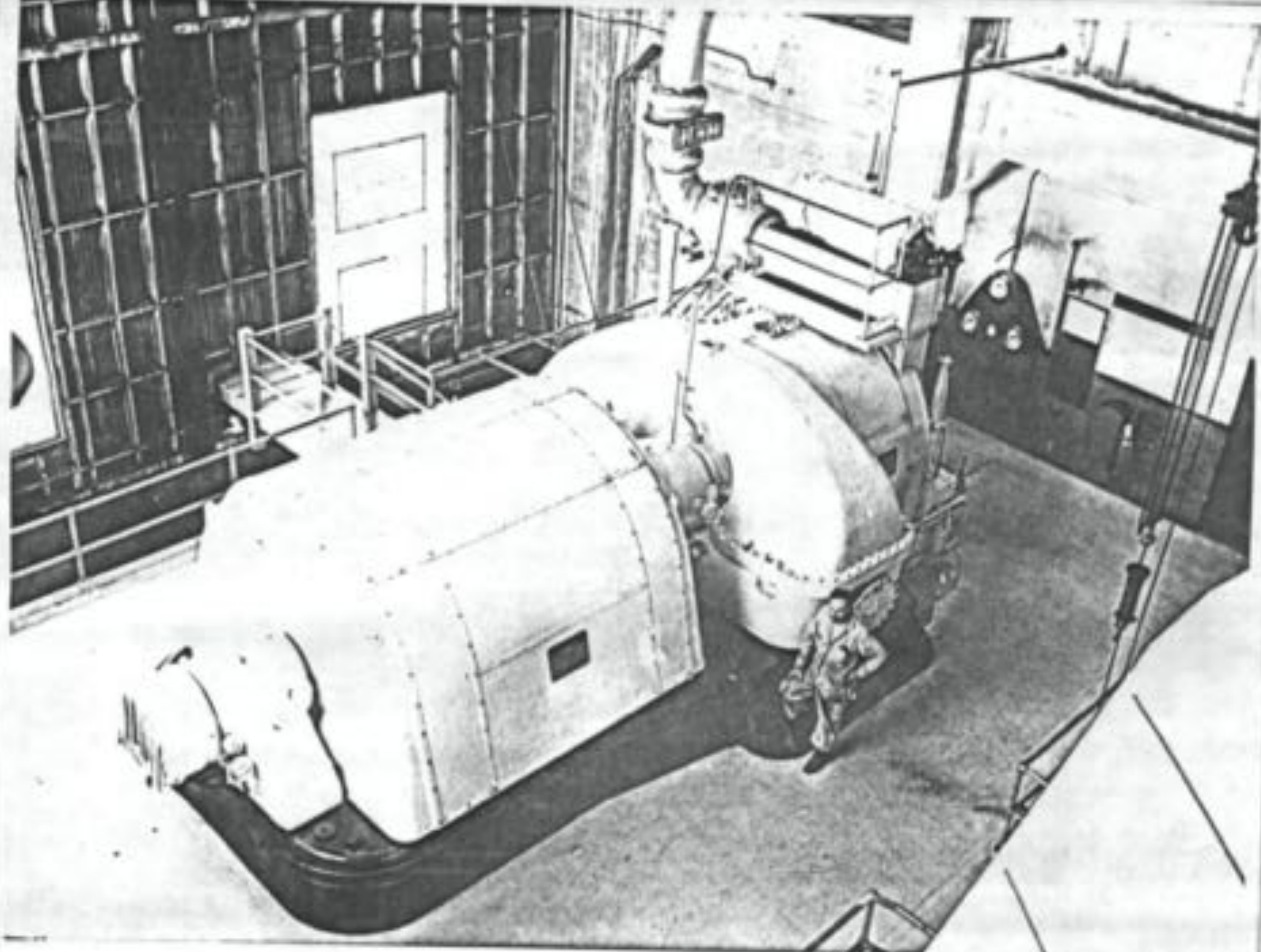


Georgetown Steam Plant

Seattle, Washington
Weiss vacuum pump at the base of generator #2

Jacob Thomas
Office of Archaeology and Historic Preservation
September, 1977

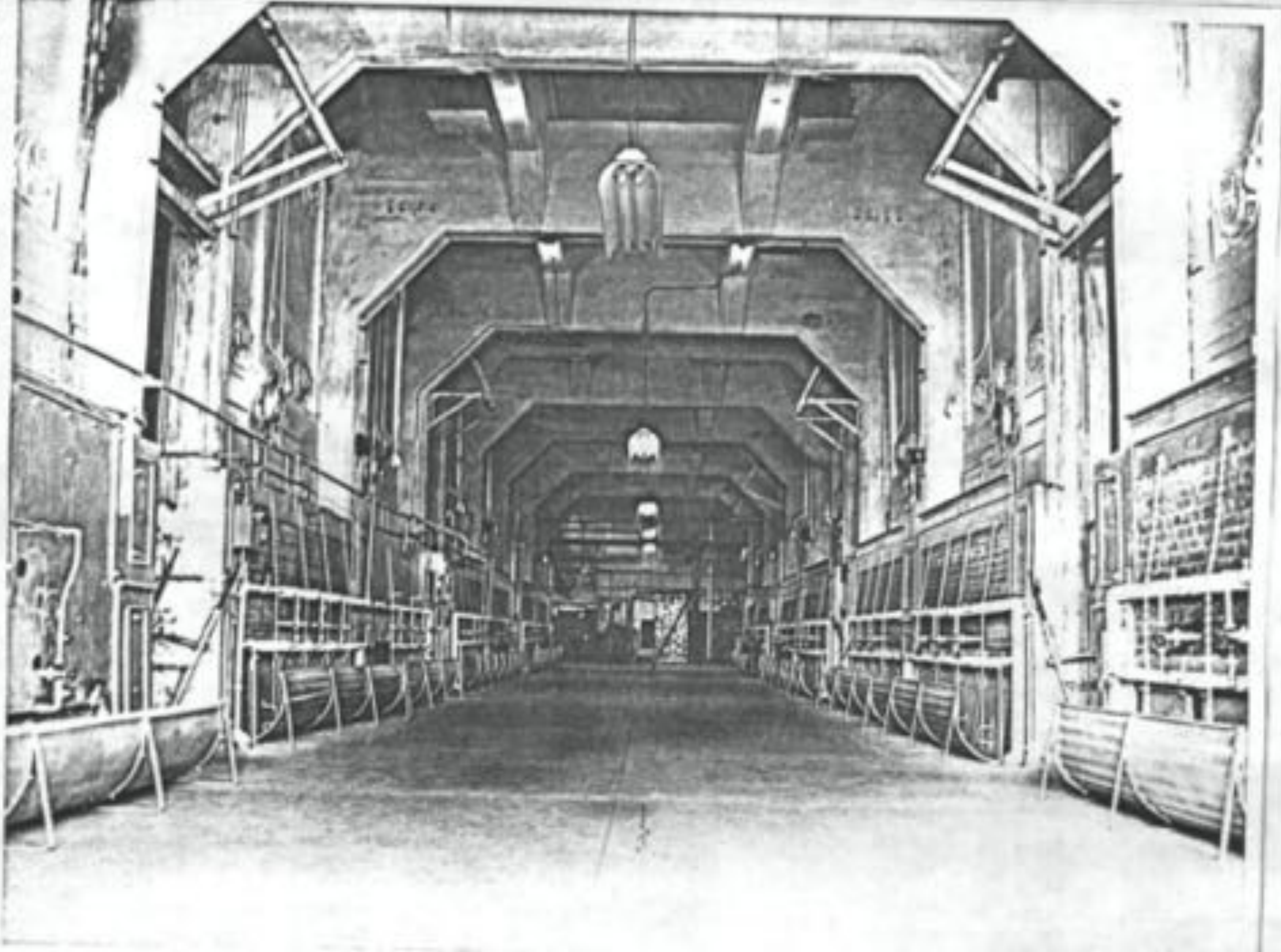
3 of 7



Georgetown Steam Plant

Seattle, Washington
Turbo-generator #3, 10,000 KW capacity, installed 1917. Note temporary corrugated iron end wall on the left provided to allow for future expansion.

Jacob Thomas
Office of Archaeology and Historic Preservation
September, 1977

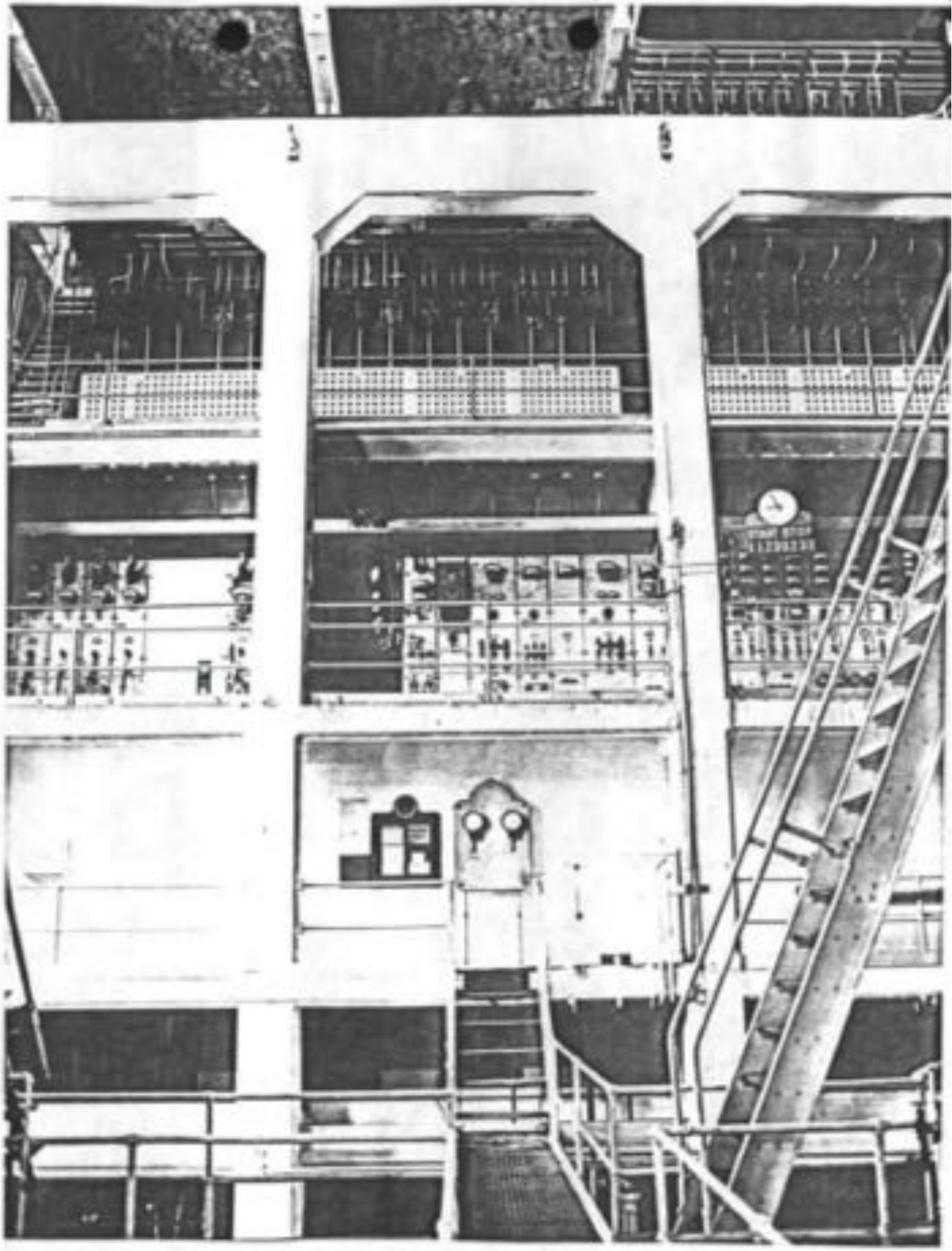


Georgetown Steam Plant

Seattle, Washington
Boiler room, view from the south end

Jacob Thomas
Office of Archaeology and Historic Preservation
September, 1977

5 of 7

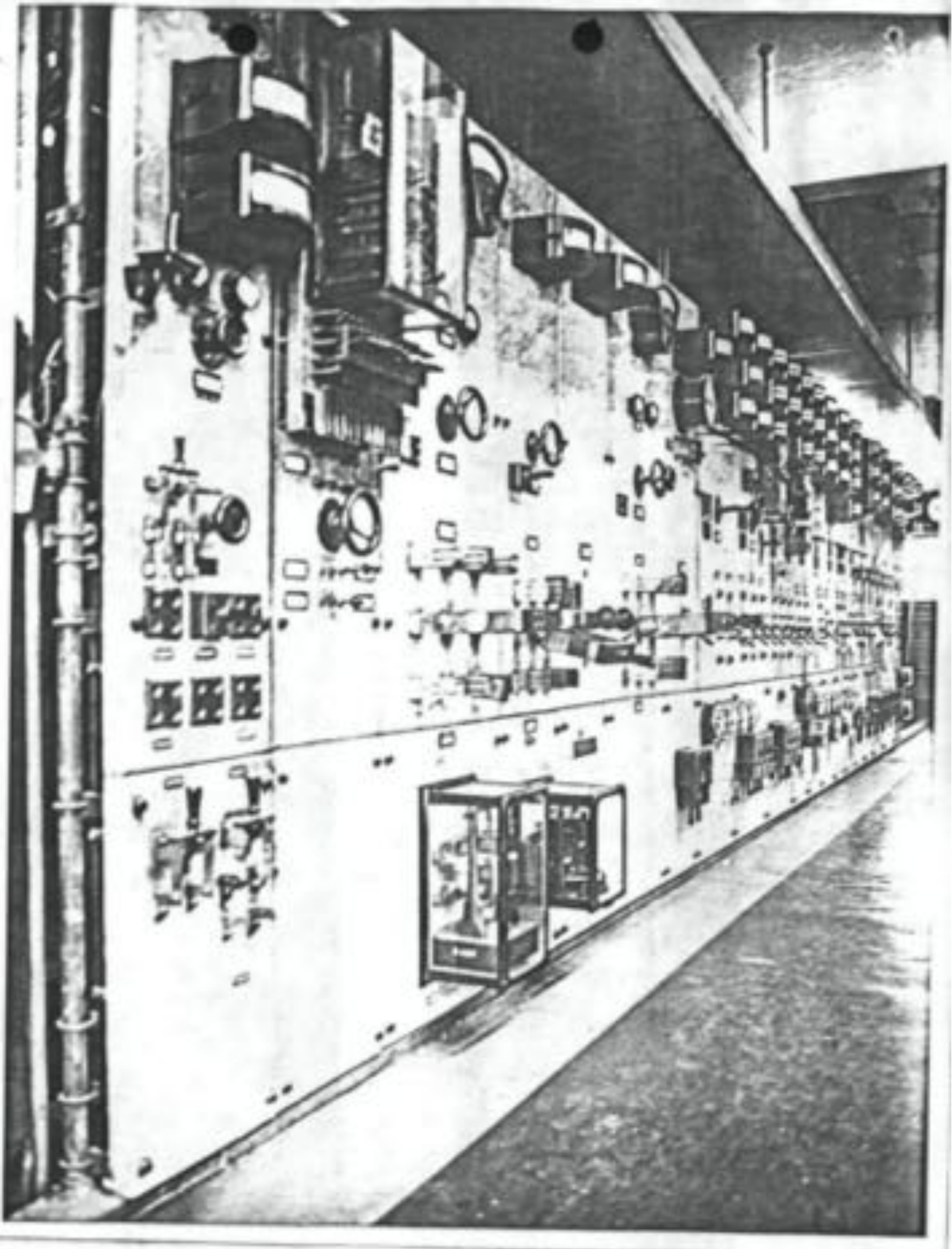


Georgetown Steam Plant

Seattle, Washington
Galleries at north end of engine room

Jacob Thomas
Office of Archaeology and Historic Preservation
September, 1977

6 of 7



Custom Photo Service

Georgetown Steam Plant

Seattle, Washington
Switching panel mounted on marble at third
gallery level

Jacob Thomas
Office of Archaeology and Historic Preservation
September, 1977

7 of 7

INTRODUCTION

The Georgetown Steam Plant stands today as a reminder of the era of electrification of America's cities -- the era when industry was first attracted by Seattle's cheap hydroelectric power and electric trolleys drove along Seattle streets.

The plant was built in 1906 by the Seattle Electric Company on 18 acres of land on the Duwamish River. Georgetown, its site, was the center of considerable manufacturing, of the state's largest brewery, and of a [illegible], wide-open entertainment district.

From the beginning, the plant was intended to provide Seattle Electric with peak-load capacity in periods of heavy use. The boilers were fired up to operate in the morning from six to ten o'clock and again in the afternoon from three to eight o'clock -- particularly in fall and winter when low water curtailed operation of the hydroelectric system. Much of its power went to operate the Seattle Electric Company streetcars.

In 1912, Puget Sound Power and Light purchased Seattle Electric Company and consolidated all of the electric companies in the Seattle area except for the municipal utility. In the process, the Georgetown Plant was relegated to a minor role in the system; for a time it was used only to supply steam heat to the company's nearby [illegible].

The City of Seattle Department of Lighting, now the City Light Department, purchased the properties of the Puget Sound Power and Light in 1951. The plant's last production run was in the winter of [illegible] during a major water shortage.

From 1971 to 1977, the plant was maintained on "cold standby" as part of a regional reserve for emergency situations, with the City of Seattle receiving credits from the regional Bonneville Power Administration for maintaining the plant in operating condition.

DESCRIPTION

The Georgetown Steam Plant is a reinforced concrete frame building located in the Georgetown district of south Seattle. It contains three steam turbine generators rated at capacities of 3,000 kw, 8,000 kw, and 10,000 kw which were installed in 1907, 1916, and 1917.

3000 kw Curtis vertical turbine generator located in foreground and 8000 kw Curtis in background.

The two smaller machines are vertical Curtis steam turbine generators with the generating unit positioned directly above the turbine drive and connected by an upright shaft. The 10,000 kw machine is a Curtis turbine of the later horizontal type in which the turbine is mounted beside the generator and the connecting shaft is horizontal. All three turbo-generators are operational and most of the original auxiliary equipment is still in place.

The building was designed in Neo-Classic Revival style with such characteristic details as a cornice, belt course, and water table. The steam plant was designed to operate with either oil or coal, and the plant layout reflected an attention to operating efficiency. The longest wing of the plant was devoted to the production of steam. On the top floor was a conveyor for bringing coal into the building. Sixteen boilers were arranged in two rows running the entire length of the second floor. On the ground level, an ash car rolled on rails below both rows of boilers. There was a coal and ash handling system that allowed the dumping of fuel and waste material from floor to floor without the need for mechanical distribution.

Oriented perpendicularly across one end of the boiler wing, is the second, shorter wing, devoted to generating electricity. The engine room includes the three turbo-generators, each with a circulating pump, a vacuum pump and a barometric or jet condenser. Above the generators, the

1917 vintage Westinghouse steam turbine drive for the horizontal Curtis steam turbine.

engine room is open to the roof. Across from the generators on the opposite wall, the room is divided into a gallery with five levels. The lower floor is occupied by a bank of transformers and by two exciters (small generators necessary to energize field windings in the turbo-generators to produce the basic electromagnetic force.) Above this section at various levels are the plant office, the switchboard room, and other control equipment.

The 10,000 kw horizontal generator and its condenser are simpler and more compact than the two older vertical machines. It is smaller even than the 3,000 kw unit which has less than one-third of its generating capacity.

The Georgetown Steam Plant has undergone little modernization since the installation of its third generator in 1917. The boilers were converted to steam-atomized oil-fired furnaces beginning in 1918, and the process of conversion continued until 1948. The plant was originally built on the east bank of the Duwamish River to take advantage of the river as a source of cooling water for the condensers and for convenience in discharging wastewater. In the mid-20s, the Duwamish was diverted to accommodate construction of the King County Airport, leaving the plant some distance from the river's new channel. So a pumping station was built to insure a continued supply of river water, and the discharge tunnel was lengthened at that time.

10,000 kw horizontal Curtis turbine generator.

DEVELOPMENT OF [illegible]

In 1907, the [illegible] generator was [illegible] [illegible] [illegible] significant [illegible] generation [illegible] the design of [illegible] generators [illegible]

When it was [illegible] Electric Company [illegible] generator had [illegible] power capacity [illegible] in use. It was [illegible] in [illegible] Seattle [illegible] design [illegible] practical and [illegible] of producing [illegible]

[illegible]

[illegible]

ACKNOWLEDGEMENTS

The Western Washington Section of The American Society of Mechanical Engineers gratefully acknowledges the efforts of all who cooperated on the landmark dedication of the Georgetown Steam Plant, Seattle, Washington.

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

Dr. Donald N. Zwiep, President
Dr. Charles E. Jones, President-Elect
[illegible], Vice President, ASME Region VIII
James D. [illegible], Chairman, History & Heritage, Region VIII
Dr. Rogers B. Finch, Executive Director and Secretary

THE ASME NATIONAL HISTORY AND HERITAGE COMMITTEE

Prof. J.J. Ermenc, Chairman
Dr. R. Carson Dalzell, Secretary
Prof. R.S. Hartenberg
Robert M. Vogel, Smithsonian Institution
Carron Garvin-Donohue, ASME Staff Director of Operations
Jill Birghenthal, Administrator

THE ASME WESTERN WASHINGTON SECTION

Thomas [illegible], Chairman
James [illegible], Vice Chairman
Eugene [illegible] Stephens, Secretary
William [illegible], Treasurer
[illegible]
[illegible]
[illegible]
Paul [illegible]
Donald J. [illegible]
Donald [illegible], Chairman, History & Heritage
[illegible], Publicity and Newsletter Chairman

We wish to express our gratitude to the City of Seattle, City Light Department, the General Electric Company, and the Westinghouse Company, whose kind cooperation made this dedication possible.

Material for this brochure was compiled and written by Donald [illegible] and John Thomas. Photos by Jet Lowe, Heritage Conservation & Recreation Service. Drawing: Historic American Engineering Record.

GEORGETOWN STEAM PLANT
Seattle, Washington

NATIONAL HISTORIC MECHANICAL ENGINEERING LANDMARK

Dedication Program
May 7, 1980

Welcome
[illegible], Vice President, Region VIII

Introduction
Thomas [illegible], Chairman, Western Washington Section

Mayor's Address
Robert J. [illegible], Deputy Mayor of Seattle

ASME Landmark Program
Prof. J.J. Ermenc, Chairman, National History & Heritage Committee

History of Georgetown Steam Plant
Joseph P. [illegible], Assistant Superintendent, The City of Seattle, City Light Department

Presentation of Plaque
Dr. Charles E. Jones, President-Elect, ASME

Acceptance of Plaque

Closing Remarks

PRELIMINARY

SEATTLE CITY LIGHT

GEORGETOWN STEAM PLANT

* * * * *

HISTORICAL INVENTORY

Mechanical Engineering Div. 823
C.P. Croner
October 1977

Item #7 continuation sheet
[omit page #1]

PRELIMINARY

Georgetown Steam Plant

Equipment Inventory
(Preliminary)

EQUIPMENT	REMARKS	Date of Manufacture or installation
Steam Boilers		
7 Boilers, each rated 369 boiler horsepower, equipped with superheater. 2 Boilers, each rated 473 boiler horsepower, equipped with superheater. 7 Boilers each rated 519 boiler horsepower. Boilers are not equipped with superheater.	The boilers were originally coal fired, then converted to burn oil starting in 1918. Final conversion to oil was completed in 1946. Babcock & Wilcox manufactured 14 of the boilers for the Seattle Electric Co. in 1906. In 1918 two more boilers were added. Each Sterling type boiler has antique-lettered cast manhole inspection covers, 12 per boiler. The boilers also have the name "The Seattle Electric Company" across the top.	1906 & 1918
Boiler Steam Pressure Gauges		
0-300 psi. (Total of 16)	Manufactured by J. Marsh Company, Chicago Illinois. These are fancy brass gauges approximately 15 inches in diameter.	1906 & 1918
Boiler Room Panel		
See remarks	Mounted on the panel is an antique brass pressure gauge (1898) manufactured by Wm. H. Birch Company, San Francisco Calif. Range 0 to 250 psi., 10 inch. The panel also contains: an old Bristol Recorder manufactured by the Bristol Company, Waterbury, Conn., a small gauge manufactured by North Coast Engineering Company, Seattle, Wash. and a larger gauge manufactured by J.P. March Co., Chicago, Ill.	

Mechanical Engineering Div. 831
C.P. Gremer
October 1977

Equipment Inventory (Contd.) PRELIMINARY

Georgetown Steam Plant

EQUIPMENT (Continued)	REMARKS	
Donkey Boiler		
Boiler Number 3535 Operating pressure 0-160 psig. Oil Fired.	Built for Bucyrus Company, ~~(1924)~~, by Johnston Bros., Inc. Ferrysburg, Michigan. The boiler is used for start up.	1924
Induced Draft Fans		
Size 998 Design 2 Fans number 1 & 2, 9 & 10, 13 & 14, 15 & 16 are Model Number 13741. Fans number 3 & 4, 5 & 6, 7 & 8, 11 & 12 are Model Number 13740.	Manufactured by B.F. Sturtevant Company.	c. 1935
Fuel Oil Storage Tank		
Storage capacity 20,328 barrels.	The storage tank is buried underground.	c.1917
Turbo-Generator Number 1		
Curtis Steam Turbine (No. 3007) (4 stage vertical shaft steam turbine).	Manufactured by General Electric Co. (1907). Steam Pressure 175 psi.	1907
Alternating Current Generator 3,000 KW Vertical Type ATB No. 148684 Class 10, Volts 13,200, Amps 131.5	Manufactured by General Electric Co. Schenectady, N.Y. (1907).	1907
Turbo-Generator Number 2		
Curtis Steam Turbine (No. 4137) (5 stage vertical shaft steam turbine).	Manufactured by General Electric Co. ~~(1908)~~. Steam Pressure 175 psi.	1908
Alternating Current Generator 8,000 KW Vertical Type ATB No. 119566 Class 10, Volts 13,800, Amps 334	Manufactured by General Electric Co. Schenectady, N.Y. (1908).	1908

 PRELIMINARY

EQUIPMENT (Continued)	REMARKS	
Turbo-Generator Number 3		
Curtis Steam Turbine (No. 13401) (9 stage horizontal shaft steam turbine).	Manufactured by General Electric Co. ~~(1917)~~. Steam Pressure 175 psi.	1917
Alternating Current Generator 10,000 KW Horizontal Type ATB-4 Volts 13,800, Amps 524 No. 1181396	Manufactured by General Electric Co., Schenectady, N.Y. ~~(1917)~~.	1917
Barometric Condenser No. 1	Manufactured by City Light (1969). Used with Unit No. 1.	1969
Barometric Condenser No. 2	Manufactured by Hydraulic Supply Manufacturing Co., Seattle Wash., 1965. Used with Unit No. 2	1965
Jet Condenser	Manufactured by C.H. Wheeler. This condenser is used with Unit No. 3.	1917
Weiss Air Pump (Vacuum) Number 149 Used with vertical Turbo-Generator Unit No. 1	Built by Southwark Foundry and Machine Co. Patented April 28, 1896 Philadelphia, PA	1907
Weiss Air Pump (Vacuum) Number 174 Used with vertical Turbo-Generator Unit No. 2	Built by Southwark Foundry and Machine Co. Patented April 28, 1896 Philadelphia, PA	1908
Electrical Panels Panels are Grey Marble approximately 2 inches thick. There are 27, two piece sections.	~~Data on manufacturer not available.~~	c.1907-1917
The following equipment is panel mounted on these panels.		
1 Weston Stanton Volt Meter Number 5746 Range 0-600 Volts	Manufactured by Weston Electric Instrument Co., Newark, New Jersey.	

Mechanical Engineering Div. 831
G.P. Groner
October 1977

Georgetown Steam Plant

EQUIPMENT	REMARKS
Electric Panels (Continued)	
Thompson Recording Watthour Range 2000 amp, 600 volt (Total of 4)	The meters appear to be in good condition ~~and would make good museum pieces~~. All meters were manufactured by General Electric Company.
Thompson Astatic Ammeter 1 - Range 0 - 500 amp 1 - Range 0 - 800 amp 1 - Range 0 - 1000 amp 1 - Range 0 - 1300 amp 4 - Range 0 - 1500 amp 1 - Range 0 - 2000 amp	All meters were manufactured by General Electric Company.
Miscellaneous Meters Volt meters, Ammeters Watthour meters, Temperature indicators (Total of 50 meters)	The majority of these meters are ammeters, 34 of these. All meters were manufactured by General Electric Company.
(Antique) Power Factor Meter 1 meter	Manufactured by Westinghouse Electric Company.
(Antique) Voltage Regulator 1 regulator Number 1661	Manufactured by General Electric Company Schenectady N.Y., USA.
Synchronous Meter 1 Meter	Manufactured by General Electric Company.
Reverse Power Relays 2 Relays (small)	Manufactured by General Electric Company.
8 Relays (large)	Manufactured by General Electric Company.
Frequency Indicator - Frahm System	Manufactured by James G. Biddle Co.
Large Solid Copper Knife Switch 8 total, miscellaneous sizes, multiple blade type.	Manufacturer unknown.
Two Blade Knife Switch Solid Copper 13 total, misc. sizes	Manufacturer unknown.

PRELIMINARY

Georgetown Steam Plant

EQUIPMENT	REMARKS	
Electric Panels (Continued)		
Single Blade Knife Switch Solid Copper 15 total, misc. sizes	Manufacturer unknown.	

NOTE: More detailed information on the equipment mounted on the main electrical panels may be obtained by contacting G.P. Groner - Div. 823.

~~Antique-Oak Framed~~ Switch & Fuse Panels		
4 Panels, the panels have two blade knife type switches and use screw-in type fuses.	The panels are for lighting and miscellaneous circuits. Manufacturer unknown.	c. 1917
Oil Circuit Breakers		
7 Breakers - small 36 Breakers - large	Manufactured by General Electric Company.	1907 & 1917
Knife Switches		
More than 30 solid Copper multi blade type switches.	Manufacturer unknown.	1907 & 1917
Transformers		
Bank No. 1 Type WC, 500 KW 13,800 volt (2 transformers in bank)	Manufactured by General Electric Company	c. 1907
Transformers		
Bank No. 2 13,800 volt 1000 KVA (2 transformers in bank)	Manufactured by Westinghouse Electric Co.	c. 1907
(Antique) Automatic Circuit Breakers		
4 Circuit Breakers	Manufactured by General Electric Company	c. 1907

EQUIPMENT (Continued)	REMARKS	
Lube Oil Pump (Duplex Type)		
Steam Driven, 2 cylinder Size 9 x 3-1/8 x 10 Number 189-977	Manufactured by Worthington	c. 1907
Lube Oil Pump (Duplex Type)		
Steam Driven, 2 cylinder Size 9 x 3-18 x 10 Number 190-208	Manufactured by Worthington	?
Lube Oil Transfer Pump (Duplex Type)		
Steam Driven, 2 cylinder Size 4-1/2 x 2-3/4 x 4 Number 16482BX9	Manufactured by Knowles Pump Works New York, New York.	c. 1917
Fuel Oil Pump (Duplex Type)		
Steam Driven, 2 cylinder Reciprocating Type Size (Data not available) 2 identical pumps	Manufactured by - (Name plate data missing) Hallidie Machinery Company, Seattle, WA Sales agent.	c. 1918?
Fuel Oil Pump		
Screw Type, Electric Motor Driven Size 4, 250 Head, 80 gal/min Number 867	Manufactured by William E. Quemby, Inc. New York, New York.	c. 1930?
Feed Water Pump (East)		
DeLaval Centrifugal Type 140-TC-3P5 650 gal/min 520 Head Number 56980	Manufactured by Ingersall Rand Co. New York, New York.	c. 1917?
Steam Turbine (for feed pump) 2300 RPM Number 56980	Manufactured by DeLaval Steam Turbine Company, Trenton, New Jersey.	c. 1917?
Feed Water Pump (West)		
Ingersall Rand Centrifugal 900 gal/min, Size 4GT900 552 Ft. Head Number 06493050	Manufactured by Ingersall Rand Company New York, New York.	1949
Steam Turbine (for feed pump) 3600 RPM Serial Number 79336 Model Number 7TDF1117AEK 180 Horsepower	Manufactured by General Electric Company, Schenectady, New York.	

 PRELIMINARY

EQUIPMENT	REMARKS	
Air Compressor		
Size 8 x 8 Electric Motor Driven Number 36175	Manufactured by Curtis St. Louis, Mo.	1950
Centrifugal Water Pump		
Spare Pump Small Electric Motor Driven (Name plate date missing.)	Name plate data missing. The Spare pump is not connected into system.	c. 1917 ?
Hot Well Tank		
14 ft. diameter x 12 ft. deep Steel plate construction.	Manufacturer unknown.	1917
Fuel Oil Strainer System	Manufactured by Bethlehem Steel	c. 1930 ?
Step Bearing Lube Oil Tank	Manufactured by Turner Oil Filter Co. Niles, Michigan.	1907
Mid Bearing Lube Oil Tank	" " " " " "	
Spare Lube Oil Tank	" " " " " "	
Air Pump Lube Oil Tank	" " " " " "	1908
Ingersall Rand Air Compressor		
Large unit similar to the unit installed in Lake Union Steam Plant.	This unit is dismantled. It will be used for parts for the Lake-Union Compressor. In addition there is an Allis Chalmers 125 horsepower induction motor to run this compressor.	
Step Bearing Oil Pump (Duplex)		
Steam driven 2 cylinder Reciprocating Type Size 12 x 2-3/4 x 18 Number 192035 Used on Unit No. 1	Manufactured by Worthington.	1907
Step Bearing Oil Pump (Duplex)		
Steam driven 2 cylinder Reciprocating Type Size 12 x 2-3/4 x 18 Number 192036 Used on Unit No. 2	Manufactured by Worthington.	1908
Centrifugal Pump		
Steam driven Size 4 400 gal/minute 360 ft head 2750 RPM	This is a spare pump not connected to plant system. Manufactured by Platt Iron Works Dayton, Ohio	

 PRELIMINARY

EQUIPMENT	REMARKS	
Centrifugal Pump (Continued)		
Turbine Drive Terry Turbine Number 1759 2750 RPM	Manufactured by Terry Steam Turbine Company Hartford, Connecticut	
Condenser Pump (Unit No. 3)		
Pump Size 18 D.V.S. Number 06280	The pump may be operated by either electric motor or by steam turbine. Manufactured by Wheeler Condenser Engineering Company.	1917
Pump Reduction Gear Drive Number 548	Manufactured by Moore Steam Turbine Corporation.	1917
Turbine Drive Number 3555	Manufactured by Terry Turbine Company.	1917
Pump Electric Motor Drive Number 1648315	Manufacturer General Electric Company.	1917
Wheeler Turbo Air Pump (Vacuum)		
Pump Size T-A-100 Number 04968	Manufactured by Wheeler Condenser & Engineering Co., New York, N.Y. The pump is used with condenser number 3 and is steam driven.	1917
Steam Turbine Drive Number 4635	Manufactured by Westinghouse Machine Co., Designers & Builders, East Pittsburgh, Pa.	1917
Overhead Bridge Crane		
Capacity 50 ton Number 715	Manufactured by Northern Engineering Works, Detroit, Mich. This is the main powerhouse crane.	1967
Overhead Bridge Crane		
Capacity 20 ton	Manufactured by Reading Crane & Hoist Works, Reading, Pa. The crane is located in the area over the Motor Generator sets.	1907

PRELIMINARY

EQUIPMENT (Continued)	REMARKS	
Small Electric Crane		
Capacity 1 ton M 1210 Frame 25	Manufacturer Budget	1955
Step Bearing Oil Pressure Balance Weight Alarm		
Set at 950 psi	Manufacturer unknown	1907
Simplex Water Meter		
Meter Scale measures in 100,000 lbs per hour at 70° F.	Manufactured by Simplex Valve and Meter Company, Philadelphia, Pa. This meter is a valuable antique.	1907
Per Cent Carbon Dioxide (CO_2) Wall Mounted Meter		
0 to 20% Scale Multi Point type	Used to monitor Boiler Combustion, Manufactured by Leeds & Northrup Company, Philadelphia, Pa.	1907
Panels		
The two panels (one for Turbo Generator Number 1 and the other for Turbo Generator Number 2), have solid brass gauges. One gauge for 1st stage pressure, one gauge for Steam Supply pressure, one gauge for step bearing oil pressure, one gauge for vacuum. The panel for Unit Number 1 has a frequency indicator mounted at the top. It may be used to monitor either units frequency.	4 Gauges were manufactured by General Electric Company. The frequency indicator was manufactured by James G. Biddle, Philadelphia, Pa.	1907
Panel		
Turbo-generator Unit Number 3 2 brass hydraulic pressure gauges, 0-2000 psi	Ashcraft	1917
1 Brass steam gauge, 0-260 psi	Syracuse Gauge	
1 Aston Brass Gauge	Aston	

PRELIMINARY

EQUIPMENT (Continued) — REMARKS

Antique Telephones

Hand crank type.

There are 4 or more units, one located in the pump house and at least 3 located in the plant. Manufacturer unknown.

Fuel Oil Transfer Pump (Duplex)

2 Cylinder reciprocating type
Electric Motor Driven

Manufactured by Fairbanks Morse Company. c. 1910 Brought in from Lake Union Plant 1953

Motor Generator Set No. 2

Continuous current
Generator No. 159471
Type MP Class 8-500-514
Form H
Amperes - 833
Speed - 514 RPM
Volts 600

Manufactured by General Electric Company, Schenectady, N.Y. 1907

Synchronous Motor
Number 161143
Type ATI
Class 14-530-514
Form C
H Power - 700
Speed 514
Volts 13,200
Amp 28.8
Cycles 60

Manufactured by General Electric Company, Schenectady, N.Y. Approx. Mfg. 1906 1907

Mechanical Engineering Div. 823
October 1977

PRELIMINARY

Georgetown Steam Plant

EQUIPMENT (Continued)	REMARKS	
Exciter No. 2		
Motor Generator Set Continuous Current Generator Number 140447 Form B KW-120 Amperes 960 Speed 600 Volts 125	Manufactured by General Electric Company, Schenectady, N.Y. Approx. Manufacture 1906	1917
Induction Motor Model No. 14070 Type 10-17-12-175-600 Form K Volts 280 Amps 40 Number 161679 HP 75 Speed 580 2 Phase	Manufactured by General Electric Company, Schenectady, N.Y. Approx. Manufacture 1906	[illegible]
Direct Current Generator		
No. 1201823 Type MPC - 6-200-1200 Form L Amps 1600 Volts 125 Speed 1200 RPM 200 KW Nominal	Manufactured by General Electric Co., Schenectady, N.Y.	1917 ?
Steam Turbine Drive Number 56684 Speed 3600 RPM Steam Pressure 200 psig With DeLaval Speed Reducer	Manufactured by DeLaval Steam Turbine Co., Trenton, N.Y.	1917 ?

Mechanical Engineering Div. 823
October 1977

PRELIMINARY

EQUIPMENT (Continued)	REMARKS	
Exciter No. 1		
Generator No. 78345 Volts 120 Amperes 125 RPM 1130	Manufactured by Allis Chalmers Company, Milwaukee, Wis.	1907
Electric Motor Number 78346 HP 22.5 Volts 220 Amps 55 3 Phase Frequency 60 H_z RPM 11,300	Manufactured by Allis Chalmers Company, Milwaukee, Wis.	1907
River Pumps		
20" Size 13,500 Gallons per Minute 85 Feet Head 690 RPM Type S Pump #1, Style A, Serial No. 1498 Pump #2, Style B, Serial No. 1497	The two pumps are in the pumphouse located on the Duwamish River. The pumps were manufactured by Allis Chalmers. The pumps are each driven by a 400 HP electric motor. The motors are type IQ, Form K, 2200 volt, 2 phase, manufactured by General Electric Company.	c. 1935
Floor Mounted Drill Press		
Antique, Belt Driven Type	Manufactured by Champion Company.	c. 1907
Bristol Recorders		
Panel mounted Antique type (vacuum gauge)	Manufactured by Bristol Company, Waterbury, Conn.	c. 1907 + 1918
Large Master Gauge		
Approx. 2 feet in diameter Range 150 to 210 psi Brass construction	Manufactured by Ashton. This is an antique.	1918
Air Raid Siren		
World War II model Roof Mounted Engine Driven	Engine manufactured by Chrysler. Siren manufactured by American Blower Co.	c. 1941


1909


1906


1906

Georgetown Steam Plant
King County Airport
Seattle
King County
Washington

HAER No. WA-1

HAER
WASH,
9-SEAT,
2-

PHOTOGRAPHS

REDUCED COPIES OF MEASURED DRAWINGS

WRITTEN HISTORICAL AND DESCRIPTIVE DATA

Historic American Engineering Record
National Park Service
Department of the Interior
Washington, D.C. 20240

HAER
WASH
17-SEAT,
2-

HISTORIC AMERICAN ENGINEERING RECORD

Georgetown Steam Plant

WA-1

Location:	Northeast corner of King County Airport Seattle King County Washington
Date of Construction:	1906-08, 1917
Engineers:	Stone and Webster Construction Co., with Frank B. Gilbreath, consultant
Owner:	Seattle City Light City Light Building Third Avenue Seattle, Washington
Significance:	The Georgetown Steam Plant is an early reinforced concrete structure housing America's last operable examples of the "first generation" of large scale, vertical steam turbine electric generators. It is also significant as an early example of "fast track" construction advocated by Frank B. Gilbreath.
Historians:	Steve Lubar, Flo Lenty and T. Allan Comp, 1979-84
Transmitted by:	Donald C. Jackson and Kevin Murphy, 1984

ARCHITECTURAL AND PHYSICAL DESCRIPTION:

The Georgetown Steamplant, constructed in 1906, is a significant example of Neo-Classical Revival architecture. This particular style, introduced in the United States in the 1890s, served as a model for numerous Federal, municipal and industrial structures across the country. The plant has a T-shaped plan and is constructed of reinforced concrete. The building is divided into two main wings, the Engine House and the Boiler House.

The front facade (west facade) of the Engine House is divided into three bays, the central predominating in architectural detail and scale. In the center is cast the construction date of the building "1906". The north elevation of the Engine House is divided into five bays by vertical masonry members, proportioned to simulate pilasters. Crowning the top is a masonry cornice. The simplicity of design here suggests the mass and weight element, characteristic of Neo-Classical Revival architecture. On the roof is a clerestory, comprised of casement windows, spanning the entire length of the north elevation, interrupted by a single monitor wing or outbuilding.

The Boiler House consists of nine bays spanning the front, (west elevation) comprised of sash windows and separated by masonry grids. The wing is four stories in height with a clerestory spanning the full length of the roof, interrupted by four recesses. The conical symmetry of the later-added stacks is the only interruption of the overall linear design of the building.

In terms of operating efficiency, the plant is very precisely organized. Its longest wing is devoted almost entirely to the production of steam. Before conversion to oil fired boilers, this wing consisted of four levels each with a separate function. At the top level was the conveyor floor for bringing coal into the building. There the coal was dumped form a continuous moving belt into eight funnel-shaped bunkers on the floor below. Each bunker stoked a pair of immense 932 H.P. Sterling water tube boiler Smoke flues extended along both sides of the coal bunkers directly above the boilers for carrying smoke to a fan-assisted rooftop stack.

On the second floor, the sixteen boilers were separated into two banks facing each other across a corridor that ran the full length of the wing. From the corridor each boiler could be inspected and maintained. On the ground level, below both rows of boilers, there was an ash car that rolled on rails set in the floor. Each car consisted of a dumping hopper that could be moved from boiler to boiler where it would collect ash waste for removal from the building. The entire coal and ash handling system within the building was arranged to allow the fuel and waste material to be simply dumped as necessary from one floor to the next without relying upon further mechanical distribution.

Oriented on a perpendicular axis across one end of the boiler wing, the second, shorter wing is devoted to generating electricity. The engine room, includes the three turbo-generators each with a circulating pump, a vacuum pump, and a barometric or jet condenser. The vertical generators are interconnected by a system of catwalks and ladders, and the condenser and steam piping are arranged between the generators and the wall. A raised platform at the second floor level is provided for the horizontal generator, and the condenser for this machine is located in the space directly below it.

Above the generators the engine room is open to the roof. A 50-ton crane runs on a track overhead to assist with disassembling the equipment for maintenance. Across from the generators on the opposite wall, the room is divided into a gallery with five levels. The lower floor is occupied by a bank of transformers and two exciters (small DC generators necessary to energize field windings in the turbo-generators to produce the basic electromagnetic force). Above this section at various levels are the plant office, the switchboard room, and other control equipment. The 10,000 KW horizontal generator and its condenser are simpler and more compact than the two older vertical machines. It is smaller even than the 3,000 KW unit which has less than one-third its generating capacity. The vertical configuration requires the use of a step bearing to carry the tremendous weight of the revolving mass. The bearing actually floats the shaft on a thin layer of oil that is constantly injected by high pressure pumps.

The Georgetown Steam Plant has undergone very little modernization since the installation of its third generator in 1917. The boilers were converted to steam atomized oil furnaces beginning in 1918 and the process of conversion continued until 1946. This modification was accomplished without requiring any substantial alterations to the building, although the coal conveyor and ash cars were removed. When the King County Airport was constructed on adjoining property in the mid-1930's, it became necessary to replace the tall exhaust stack with roof mounted induced draft fans to prevent the stack from interfering with the flight path. Both original smoke flues were dismantled, and new ducts were installed to connect into the system of fans.

The plant was originally built on the east bank of the Duwamish River to take advantage of the river as a source of cooling water for the condensers and for convenience in discharging wastewater. At roughly the same time the stack was removed the Duwamish was diverted to accommodate construction of the county airport, leaving the plant some distance from the river's new channel. A pumping station was therefore built to insure a continued supply of river water, and the discharge tunnel was also lengthened. Finally, the original barometric condensers for the two vertical generators were rebuilt in 1965 and 1969. Both new condensers are in general duplications of the earlier installation as is apparent from the engineer's drawings on file.

GEORGETOWN STEAMPLANT HISTORY AND SIGNIFICANCE

I. General Electric, Westinghouse and Urban Electrification

In 1882, Thomas Edison opened his Pearl Street Plant in New York City to initiate the Electrical Age in urban America. While advocates debated the relative merits of direct and alternating current, eventually settling on the latter, reciprocating steam engines driving a separate electrical generator appeared from coast to coast. As demand for electricity increased, companies tried to increase both the size and number of generating units, but were beginning to encounter limits on engine/generator size as well as station size. In an early attempt to alleviate this threat, the Westinghouse Company secured the patents to the Parsons steam turbine (patented 1884), the first successful industrial turbine, much smaller than equal engine/generator units, even if no more efficient. For nearly a decade, Westinghouse clearly had the upper hand. The growth of central generating stations required increases in capacity and the massive engine/generator units with their vibration limits and size requirements could not meet that demand. Westinghouse had the only operating turbine on the market.

Charles G. Curtis (1860-1953) received patents 566,967, 566,968, and 566,969, protecting the basic principles of the Curtis turbine, in September, 1896. These patents cover, respectively, the expansion nozzles and their regulation, the concept of velocity compounding, and the concept of pressure compounding. Curtis assigned all three patents to his own company, the Curtis Company, which one year later entered into a liscensing agreement with the General Electric Company. For $1,500,000, General Electric received rights to all uses of the Curtis turbine except aerial and marine propulsion.[1]

General Electric formed a new division to undertake the development and manufacture of the Curtis turbine. From 1897 to 1902, General Electric built and tested a variety of designs based on the Curtis patents. Until 1900, Charles Curtis himself directed this research.[2] In 1901, William Le Roy Emmet took charge of the development of the Curtis turbine. Emmet (1858-1941), a central figure in General Electric's development of prime movers, trained at the U.S. Naval Academy and worked at various jobs in the electrical industry before he joined the new General Electric in 1892. General Electric, concerned by the lack of progress with the Curtis turbine project offered Emmet charge of the turbine project at a point when it was considering dropping it. Emmet realized the difficulties but thought the work extremely important and urged that it be allowed to proceed. In his autobiography he noted his overall impression of the work: "I think it is safe to say that there have not been many jobs more extensive and strenuous in the art of engineering." (Emmet 1931, p. 142)

Emmet directed the Curtis turbine project for twelve years, until 1913. Many of the features of the machine were incorporated as a result of his guidance, including the vertical orientation of the larger sizes. Emmet invented the oil-supported step bearing used to test the generators installed at Niagara Falls and made use of them in the Curtis turbine. He was also responsible for the selection of the sizes of the turbine, and for meeting the deadline for the delivery of the first machines. (Emmet 1931, p. 147)

Between 1897 and 1902, General Electric made a number of small turbines based on Curtis's principles. These were used for tests. The first placed in operation was a 500 KW unit installed at the General Electric plant in Schenectady in November, 1901. (Robinson 1937, pp. 239-240) The first vertical turbine to be placed in commercial service, a 500 KW machine, was shipped in February 1903 to the Newport and Fall River Company of Newport, Rhode Island. The first large Curtis turbine, and the machine which demonstrated the working feasibility of the design, was the 5,000 KW turbogenerator installed in the Fisk Street Generating Station of the Commonwealth Electric Company of Chicago in 1903. This turbine, removed to the Turbo-Generator Development Laboratory of General Electric's Schenectady plant, was designated a National Historic Mechanical Engineering Landmark by the American Society of Mechanical Engineers in 1975. The Fisk Street Station was the first power house designed specifically for vertical turbogenerators; room was allowed, though, should the unit have to be replaced by the more traditional reciprocating engine. (A.S.M.E. 1975, p. 4)

The Curtis turbogenerator was quickly successful. In the first fifteen months of sales, ending in 1903, General Electric sold 225,000 H.P. of Curtis turbines. (Westinghouse, by comparison, had sold some 300,000 H.P. of Parsons turbines for land use, and 83,000 H.P. for marine use, in the previous twelve years.) By June 1905, there were 224 units of the "larger sizes" in operation, totaling 350,000 H.P., including ten 5,000 KW machines. (Robinson 1937, pp. 241-242; G.E. Pamphlet 1907, p. 5) By September of 1906, Charles B. Burleigh reported to the National Association of Cotton Manufacturers "more than twice as many Curtis turbines in commercial operation in this country as there are of any other manufacture and more than the number of horse power of vertical shaft turbines in this country than there are of horizontal shaft turbines of all other manufacture . . ." (Burleigh 1906, p. 40) In three years of manufacture, the Curtis machine demonstrated its capacity as a cheap, compact, powerful, and efficient prime mover for electrical generation.[3] The design won the only grand prize for steam turbines at the St. Louis Exposition of 1904 and a gold medal at the Lewis and Clark Exposition in Oregon in 1905. (Burleigh 1906, p. 28)

Reasons for the superiority of the Curtis vertical steam turbine were often cited in long lists published by General Electric. Most often, these and other commentators focused on four major points: efficiency at all loads, simplicity, low maintenance, and economy in space. (G.E. Pamphlet 1907, p. 5) To this should be added the dramatic improvements achieved by General Electric during the decade of the 1900s. The Curtis units were significantly more efficient because they used both velocity and pressure compounding, because they did not require converting reciprocating motion to rotary motion, and because of a unique method of governing or maintaining speed under varying loads.[4] The most important reason for its efficiency, explained an article in the General Electric Review, was the combination of pressure and velocity compounding to deal with the difference between the velocity of the steam some 3,600 feet per second, and the desired speed of the turbine, much slower than that. Two pressure stages, each of three wheels, give a peripheral velocity of 425 feet per second in the Curtis turbine. To use steam at an equal efficiency in other turbines would require, according to the article, eighteen steps of pressure-compounded De Laval wheels, or 72 expansion stages (36 fixed and 36 movable) in a Parsons turbine. (Burleigh 1910, p. 510)

The simplicity of the Curtis units derived from several features. They mounted both prime mover and generator on a single shaft and required far fewer moving parts. Because there were none of the lateral strains and thrusts of the reciprocating engines, foundations were "a matter of less importance than with any other steam prime mover." (Burleigh 1906, p. 51) Maintenance was easier because the vertical configuration left all parts of the turbine and generator accessible and because the single turbogenerator shaft rested on a single thrust bearing that was easily replaced. (Burleigh 1906, p. 40) In May 1904, General Electric published a pamphlet including four pages of scale drawings comparing the floor space and height required by engines and Curtis turbines in 100 KW, 500 KW, 1,500 KW and 5,000 KW sizes clearly demonstrating the space savings of the turbines. (pp. 25-28) Given the pressures on central-city generating facilities, it seemed clear the vertical "compact design results in marked savings in land, buildings, foundations, and equipment." (Burleigh 1906, p. 70)

Finally, General Electric achieved significant improvement in the design of the units. As one example of the results of this effort, the four original 5,000 KW units installed in the Fisk Street Station in Chicago in 1904, were replaced by 12,000 KW units in 1909. "These occupy no greater space than the original machines and no increase in the capacity of the boilers supplying them was necessary." The report went on to claim the "kilowatt per square feet of station has been more than doubled" while also achieving a 25 percent increase in steam economy. (Parker 1910, p. 64-65) The message to those needing to expand electrical generating capacity but unable to expand existing stations was clear. By 1909, 1,200 Curtis units were installed across the United States and another 200 were on order. (Kirkland 1909, p. 101)

The vertical arrangement of the Curtis turbine was successful for the early middle-sized, slowly rotating machines. Between 1908 and 1913, however, General Electric gradually abandoned this form. Customers demanded larger machines, which meant more stages and a longer shaft; this was more easily accomodated in a horizontal configuration. New materials made possible faster speeds, up to 3,600 rpm, which required a stiffer structure than could be provided to a vertical machine. (A.S.M.E. 1975, p. 6) These new materials also proved the demise of the Curtis velocity-compounded multiple-row wheels. An engineer, reviewing the history of the Curtis turbine, wrote:

> . . . the reasons why the multi-row Curtis wheel was so successful are not . . . self-evident.
>
> The facts of the case seem to be that the time was not yet ripe for an expensive multi-stage single-row construction such as characterizes a modern high-efficiency machine. The Curtis multi-row wheels proved far mor efficient than the single-stage De Laval machine and far cheaper, more compact, and rugged than the many-stage reaction Parsons machines of that day. The De Laval machine was decidedly limited in capacity. With only low-grade materials available, the Curtis arrangement was ideally adapted to effect the required energy conversion with a minimum of wheel speed; whereas, neither a single-wheel design nor a reaction design could do this. Some such considerations surely explain the general preference for the Curtis turbine at the time and its great success. (Robinson 1937, p. 242)

For this brief period, 1903-1913 (the Georgetown units were installed in 1906 and 1907), the vertical steam turbine generator units manufactured by General Electric swept the market. General Electric established its significance as a manufacturer of steam turbines, and in fact, rapidly developed the technology they pioneered with the Curtis machine. Requiring one-tenth the space of a corresponding engine-generator unit and one-third to one-half the steam, the General Electric units made possible the large central-station generating plants that characterized urban electrification for at least a quarter of a century. Yet the success of these units was short-lived: General Electric itself saw the limits on the vertical configuration and began as early as 1908 to move toward a horizontal Curtis unit for units of the largest size (20,000 KW was apparently the upper range for the vertical units). The tremendous expansion in demand for electricity forced the rapid replacement of smaller and less efficient units leaving only two solitary surviving examples of what was once a development of overwhelming significance. Even at Georgetown, a third horizontal unit, installed in a small addition to the original plant in 1919, is remarkably smaller than either of the first two vertical units and yet produces power roughly equal the two older units combined, thus repeating the very process that once established the hegemony of the

General Electricity/Curtis vertical steam turbine generator over the engine/generator units in use in 1900.

II. Stone and Webster, Seattle Electric and the Georgetown Steamplant: Structure and Equipment

The early lead of Seattle in electric streetlighting and electric railways, as well as its large number of small, often under-financed, generating companies proved an excellent expansion area for the Boston-based firm of Stone and Webster. In 1899, Stone and Webster purchased the Union Electric Company, created their own Seattle Electric Company as a Stone and Webster subsidiary, and within one year acquired an additional sixteen local steam generating companies. (Phelps and Blanchard, p. 151; Dick, p. 3) Seattle Electric petitioned the city for exclusive operation of the street railway system and received the franchise amidst much public debate over the Stone and Webster "syndicate." (Dick, pp. 47-50) The company proceeded to improve, unify, and extend the system, creating the Puget Sound Power Company to construct a major hydroelectric facility at Electron on the Puyallup River in 1904. (The Argus, 17 Dec. 1904, p. 32) Between 1905 and 1910, the Seattle Electric Company's load increased from 10,000 KW to 30,000 KW largely in response to the growing railway system and increased domestic and industrial use.

Electricity was fast becoming a way of life. Customers were less willing to accept power failures -- peak load capacity became crucial. Because the Seattle Electric Company faced the competition of both the municipal utility and the Seattle-Tacoma (Snoqualmie Falls) Power Company, additional back-up or peaking power appeared essential. The Georgetown Plant, Seattle Electric Company's second major new steamplant after construction of the Post Street plant in 1902, gave the company an additional edge on competition and further bolstered the system's stability. (Dick 1965, pp. 52-82)

The Board of Directors of the Seattle Electric Company voted to approve the construction of a steamplant in Georgetown at their August 26, 1906, meeting. No records of the site selection process have been uncovered, but there were a number of reasons why the Georgetown site was clearly a wise choice. Land in Georgetown on the Duwamish River was readily available at a good price. The site was situated on the route of the transmission line from Stone and Webster's hydroelectric facility at Electron. The company's own electric car barns and maintenance shops were already located in Georgetown, the interurban line ran in close proximity, and the area was ripe for industrial development.

Building the Georgetown Steamplant

The decision to build the plant was apparently made before the meeting; the earliest blueprints for the plant date from May, 1906, and the Stone and Webster Unit Cost Record gives a start date of 1 April 1906. The Stone and Webster Construction Company, a branch of the Stone and Webster Company which managed the Seattle Electric Company, was to design and build the Georgetown plant for cost plus a fixed fee of $30,000. The contract included the provision that Frank B. Gilbreth, a contracting engineer and specialist in the construction of reinforced concrete power plants, be hired to design and erect the building for cost plus a fixed fee of $20,000. (Puget Sound Power and Light, Box 116)

Frank B. Gilbreth (1868-1924) was a self-taught mechanical engineer and a major contributor to the field of scientific managment. From his first apprenticeship in bricklaying at the age of 17, Gilbreth rose quickly to become head of one of the largest contracting and building firms in the nation. His invention of a portable gravity concrete mixer, patented in 1899, was an overwhelming financial success that allowed him to expand his Boston-based construction business at a rapid rate. A strong believer in the value of advertising, his promotional materials emphasized his expertise in the new field of concrete construction. By his mid-thirties, Gilbreth's contracts spanned the continent from Boston to Seattle. By staying abreast of technological advances in reinforced concrete construction, and by remaining ever interested in the value of speed and efficiency in any job, Gilbreth established a solid national reputation as a top expert in the construction of power stations, dams, and other types of industrial structures. His work in this area culminated in his book Concrete Construction published in 1906. (Yost, Chapter I-VIII)

Gilbreth's theories on the value and efficiency of reinforced concrete and efficient construction techniques were put into full effect at the Georgetown Steamplant. Gilbreth himself wrote about the project in an article published in a California technical journal in 1908. Noting "the structure is a unit which it is intended to duplicate from time to time as necessity demands." (Gilbreth 1908, p. 23) Gilbreth explained the original plans for the plant had called for a steel frame with brick curtain walls. The waiting time for structural steel was some five months and the scarcity and high wages of mechanics to construct such a structure in Seattle were prohibitive. Reinforced concrete, which first came into wide use in the early years of the twentieth century, was selected instead. Power plants like Georgetown especially benefited from the special characteristics of reinforced concrete: it is fireproof, stands up well under vibration, and requires little maintenance. (Gilbreth, pp. 23-25)

With characteristic assertiveness, Gilbreth wrote: "Like most of the work undertaken by Frank B. Gilbreth, speed was of utmost importance, and it was desirable to begin driving piles directly after the contract was signed." (Gilbreth, p. 24) Just before pile driving was completed, working drawings for the foundation were completed. While the foundation was in progress, working drawings for the superstructure were finalized. For cost effectiveness, washed gravel instead of broken stone was used in most places. Reinforcing rods, generally round rods, were cut to schedule and shipped by rail from Pittsburgh directly to Seattle. Gilbreth even hired a man to oversee loading of these rods and to travel with them to insure timely delivery. While the final working drawings were being completed and the rods on their way from Pittsburgh, workers erected scaffolding to the full intended height of the entire structure just outside the outer walls. From this staging, all forms could be constructed, concrete poured, forms removed and the completed building washed down. (Gilbreth, pp. 24-25)

Construction planning apparently started as early as April 1906, but actual work on the building began after August 1906. (Stone and Webster, Unit Cost Record, Sheet 1) By December, The Argus reported: "Undoubtedly one of the most important of the improvements now being made by the Seattle Electric Company is the new power generating plant and machine shops located at Georgetown. The building . . . is of reinforced concrete, built in the most approved style and on a solid foundation made of piles and masonry which will last for ages. (Dec. 15, 1906, pp. 63-64) Materials used in construction included 1,712 piles in the foundation, 3,480 cubic yards of concrete in the superstructure and another 2,700 in the machinery foundations. A Weber concrete chimney 268 feet high and seventeen feet in diameter served the boilers. (Gilbreth, p. 24; Stone and Webster, Unit Cost Record, Sheet 1 and 2) In March 1907, before the plant was complete, Seattle Electric voted to order and install a second turbogenerator. The building was designed for such expansion, so space was available for the new unit, its boilers and auxiliary equipment. This second unit of 8,000 KW more than doubled the generating capacity of the plant and extended the completion date to January 1908. (Puget Sound Power and Light, Box 116, 14) Total cost for the complete generating plant: 921,031 dollars. (Stone and Webster, Unit Cost Record, Sheet 5)

The Georgetown Steamplant was a state-of-the-art example of reinforced concrete powerplant construction. The Engineering Record of June 1908 (pp. 721-724) included a standard technical report on the new facility.

> The station building is a reinforced-concrete structure, 80 x 218 feet in plan, and with a height of 68.25 feet from the ground line to the top of the roof. The reinforced-concrete frame, and the side and end walls of the building, stand on spread footings of concrete carried by piles driven to refusal. 1,800 piles being

> used to secure and stable foundation for the building and equipment. The side walls of the building are 10 inch reinforced-concrete slabs carried by columns spaced 16 feet apart on centers; the end walls are 6 inches thick and are carried by columns spaced 15 feet 1 inch apart on centers. The roof consists of 5 inch reinforced-concrete slabs carried by beams and girders resting on the wall columns and on rows of columns in the interior of the building.
>
> The building is divided by a transverse 6 inch reinforced-concrete wall into a boiler room and a generator room, the former being 153 feet 10 inches long, and the latter occupying the remainder of the building. A basement, with its floor at the ground level, extends under the entire boiler room. The boilers are on a reinforced-concrete floor over this basement, which floor is carried by reinforced-concrete columns on spread footings on piles.
>
> . . . The floor of the generator room is carried by 65 foot span reinforced-concrete girders, exiting from the transverse partition wall to the end wall of the building, so this room is entirely free of columns. The switchboard, wiring connections, switches, transformers and electric auxiliaries are at the opposite side of the generator room from the boilers, in a reinforced-concrete gallery having four floors above the generator room floor.

Gilbreth discussed other features in his 1908 article including calculations of the economy and safety of reinforced concrete beams and the very long beams transversing the engine room. These sixty-five foot long girders were to his knowledge "The longest span of any ever constructed whose section, at the point where maximum bending moment occurs, is rectangular." (Gilbreth, p. 26) Permanent in character, free from vibration, and fireproof, the Georgetown Steamplant building stood ready to receive its complex assortment of electrical generating equipment.

The Machinery and Operation of the Georgetown Steamplant

The basic concept behind a steam turbine electrical generating plant is straightforward. A source of heat, in this case coal or oil, is used to turn water to steam. The steam, under pressure, is directed against the blades of a turbine, causing it to turn. A generator is turned by the turbine, producing electricity. The actual operation, of course, is not nearly as simple as this much abbreviated description. Every step in the process is made as efficient as possible Though in some ways primitive compared to modern plants, the Georgetown Steamplant was the product of an advanced science and engineering.

What follows is a description of the machinery at the Georgetown plant and its mode of operation when it was new, in 1907; changes will be mentioned later.

The Boilers

The Georgetown plant was built to burn both coal and oil. Complete facilities to handle either fuel were designed into the plant. In its early days and in recent years the plant has been powered by bunker oil which was stored in a 150,000 gallon steel tank near the plant, pumped into the plant, heated and delivered to the boilers. Oil was transferred to the front of the boilers by 2-1/2 inch pipes. At the burner, the oil was steam-atomized in special nozzles to ignite more easily. (In startup, when there is no steam, the oil was atomized with compressed air.) The atomized oil enters from the burners in the front of the boilers into the combustion chamber.

Though not used at first, a complete coal delivery system was also built into the plant. Coal arrived over the Seattle Electric Company's street railways. At the rear of the plant (the southeast side) a conveyor belt lifted the coal to the top floor Another conveyor near the ceiling of the boiler room carried the coal to eight funnel-shaped bunkers from which coal dropped to the boiler room and moved into the burners by mechanical chain-grate stokers built by the Green Engineering Company. After burning, the ashes could be dumped from the bottom of the boiler into an ash car which ran on rails in the basement beneath the boilers.

The six boilers producing steam for the 3,000 KW turbogenerator were served in turn by a 125-foot steel stack eleven feet in diameter. The row of boilers on the other side of the room connected to a 268-foot high, 17-foot in diameter reinforced concrete stack 55 feet from the building. This stack had the capacity to serve a planned expansion of ten additional boilers.

Feed water for the Georgetown boilers came from the Duwamish River, on which the plant was located. A 10-inch pipe ran underground in a concrete-lined 6 x 10 foot-trench. Two Blake steam-driven reciprocating pumps brought water to a 13,280-gallon steel tank. This large overhead tank furnished water to six boilers serving the 3,000 KW turbogenerator as well as the six serving the larger turbogenerator. This water supply or "feed water" had to be heated, a step accomplished by using the exhaust steam of the turbogenerator's auxiliary equipment.

There were originally fourteen water tube boilers at the Georgetown plant. Six on the southwest side of the boiler room provided steam for the 3,000 KW unit; the eight on the northeast side of the room serviced the 8,000 KW unit. The boilers, built by the Stirling Consolidated Boiler Company, were rated at 466 H.P. each. Seven of the fourteen boilers at Georgetown -- every other one -- provided superheated steam, raising steam temperature from about 390 to 520 degrees. There are several advantages to superheated steam. The boiler is made more efficient because the added energy in the steam is in part gained from heat which would otherwise be wasted. Superheated steam has a lower thermal conductivity than saturated steam and therefore loses less heat to the pipes. Most important, however, are the advantages of superheated steam in the turbines. Superheated steam is used more efficienty by the turbines than is saturated steam. The Georgetown plant probably gained an increase in efficiency of between 10 and 15 percent through the use of superheated steam. The boilers and their fuel delivery system take up the large wing of the Georgetown Steamplant. They deliver steam to the smaller wing where the turbines, their auxiliary equipment, and the electrical equipment is located.

Turbines

There are two vertical Curtis steam turbogenerators at the Georgetown Steamplant, apparently the last of their type still in operating condition. Turbogenerator Number 1, the smaller unit -- the turbine produced 4,000 H.P., the generator 3,000 KW -- is a four-stage machine, each stage having two movable and one stationary wheel. Turbogenerator Number 2, a 10,700 H.P., 8,000 KW machine, has five stages and is larger, but otherwise similar to Number 1. Both were "run condensing," that is, they were operated so that spent steam discharged into a condenser held at a vacuum.

The turbines were fed with superheated steam from the boilers. It entered the turbine through two sets of nozzles located 180 degrees apart. (One of these was for regular use and admitted steam to the first stage; the other, opened when the turbogenerator was running on overload, above its rated capacity, admitted steam to the second stage.) The nozzles were regulated by a governor which opened or closed one or several of the first or second stage nozzles. The governor kept the turbine at a constant speed of 720 revolutions per minute; more nozzles were opened when a heavier load was placed on the generator. When all of the first stage nozzles were opened, the band of steam covered about one-sixth the circumference of that stage; at the last stage the steam covered the complete circumference of the machine. A nozzle was either completely open or completely closed; only the amount of steam, and not its velocity, was regulated.

The steam entered the turbine at a pressure of about 175 pounds per square inch. It hit the first, movable, row of blades, pushed it and was deflected to the fixed row and then to the second movable row, through that row and then to the nozzles of the second stage. The steam passed through each of the stages in a similar fashion, each at a lower pressure. In the 3,000 KW turbogenerator for example, the pressure is reduced from 175 psi at the first stage to about 50 psi on entering the second stage, 5 psi on entering the third stage, to a partial vacuum on entering the fourth stage. It exited the fourth stage at the condenser vacuum of about 2.8 inches of mercury (1.4 psi absolute). The steam gave up about one quarter of its energy to each stage.

From the last stage of the turbine the steam is directed to the condenser. Both turbines at the Georgetown plant make use of Weiss counter-current barometric condensers, tall metal towers behind each of the machines. The condenser for Turbogenerator Number 2 rises to 54-1/2 feet above the floor; its shell is 9 feet in diameter. Some 130,000 pounds of steam per hour was delivered to it by a pipe 78 inches in diameter, entering the condenser 41 feet above the floor. Water entered near the top, was forced up the tube a small way, and then plummeted down the tube past a cone which broke it into a fine spray. Steam entered below the water, and was combined with the water and cooled by it as it plummeted down the tube. It was discharged into a "hot well" measuring 14 x 14 x 7 feet at the bottom of the main barometric tube. Inside the tube a column of water was held at a height of about 30 feet by the vacuum generated by the horizontal tandem Weiss crank and fly-wheel air pump located next to each turbine.

Water for the condensers was drawn from the Duwamish River, pulled through a 16 inch pipe by a centrifugal pump direct-connected to a 10 x 12 inch high-speed Porter-Allen engine (for the 3,000 KW unit) and an 18 inch horizontal centrifugal pump driven by an 11 x 14 inch high-speed Porter-Allen engine (for the 8,000 KW unit). This latter pump provided 7,500 gallons of cooling water per minute, and the smaller pump proportionately less After passing through the condenser, the water, heated to about 115 degrees, was discharged back into the river via a tunnel 8 x 12-1/2 feet in cross section. This concrete-lined tunnel was 300 feet long, extending some 200 feet downstream of the intake pipes.

Electrical Equipment

The generators at the Georgetown Steamplant are mounted on the same shaft as the turbines which turn them. Both units are 3-phase, 60-cycle, 10-pole separately excited revolving field generators designed to deliver current at 13,800 volts, and to operate at a speed of 720 revolutions per minute. Unit Number 1 produced 3,000 kilowatts, Unit Number 2, 8,000 kilowatts.

The auxiliary electrical equipment at the Georgetown Steamplant is located in the galleries on the far wall of the engine room from the boilers. Three exciters on the first floor powered the magnetic field of the large generators. The 3,000 KW generator had two exciters, a 40 KW electric motor driven, direct current generator and a 75 KW steam driven, direct current generator. The 8,000 KW generator had a single 120 KW motor driven exciter. The steam excifer was powered by a 130 H.P. Porter-Allen engine.

The Georgetown Steamplant was used as a substation as well as a generating station. In the first floor gallery are the transformers and motor-generators which converted some of the high voltage alternating current produced by the large generators and by other plants in the system to lower voltage current for specific uses. Two 500 KW motor generators provided 600 volt direct current to the Seattle Elecric Company's street car system and to the Seattle-Tacoma interurban railroad.

All of the electrical equipment in the station is controlled from the third floor gallery. The reporter for the Engineering Record described it in some detail:

> The main units are arranged for remote control from panels in the third gallery floor. A cable from each phase of both main generators is carried from the latter in brass pipes leading to conduits under the floor of the generator room. These conduits extend to the end wall of the building at the rear of the galleries, and the cables are carried up a 12 inch space between this wall and the gallery floors to motor-operated oil switches on the fourth floor of the gallery. On the third floor of the galleries are also located panels controlling the railway motor generator and the railway feeder circuits; also panels for local light and power service. All panels of this switchboard are of blue Vermont marble mounted with standard General Electric switches and recording and measuring apparatus. The gallery floors are entirely of reinforced-concrete and are reached by stairways of concrete, so the gallery structure is fully fireproof. (June 1908, p. 724)

The fourth floor contains the motor-operated oil switches used on the high-tension lines leading from the plant. The connections to the outside are made on the fifth floor of the gallery, which also contains lightning arresters and static dischargers.

Changes in the Georgetown Steamplant

The machinery in the Georgetown plant has been altered only slightly over the years of its operation. The plant remains close to its original condition, but a succession of minor alterations and a few major additions reflect the plant's changing use as well as the changes in the technology of steam generating plants.

A few days after it was put into operation on August 3, 1907, the 3,000 KW turbogenerator burned out. It was repaired but continued to cause problems, burning out three more times in the next three months. The second turbogenerator was put into service December 17, 1907, but burned out on January 7, 1908 and was not operational again until March. The troubles with the new steamplant were topped off by the explosion of a steam pipe in May, 1908, which killed G.W. Tucker, the chief engineer. Problems continued and in October F.N. Bushell was sent to Georgetown from Stone and Webster's head office to "look into the steam turbine question." His specific recommendations are unknown, but the measures taken were apparently successful.[5] In 1911, the smaller generator was rewound from 3,000 KW to 5,000 KW. (Puget Sound Power and Light, Box 119) This was a common procedure; as generator technology changed, more electric power could be produced with the same amount of mechanical energy.

In the first years after the Georgetown Steamplant was built, the Seattle Electric Company was distributing about ten million kilowatt-hours per month. (The total rose from six million KWH in 1907 to eleven and one-half million KWH in 1910.) Most of this power was bought from other companies. Puget Sound Power Company's Electron plant produced about 70 percent of this power, Seattle Tacoma Power Company's Snoqualmie Falls plant about 15 percent, and the Tacoma Company about 10 percent. The rest was provided by the Seattle Electric Company's steamplants, mostly the Post Street Steamplant, which operated continuously to provide steam for heating. The Georgetown plant, used as a peaking facility, operated mostly between six o'clock and ten o'clock in the morning and three o'clock and eight o'clock in the evening, when demand was heaviest. Most of the Seattle Electric Company's power, up to 90 percent of it at peak times, was used to operate its street cars. The Georgetown plant was run more in the fall and the winter, when water for the hydroelectric plants was low, and also more toward the end of the first five years, reflecting increased demand. (Puget Sound Power and Light, Box 119)

In 1912, the Massachusetts-incorporated firm of Puget Sound Traction, Power and Light purchased and consolidated the Seattle Electric Company along with the Seattle-Tacoma Power Company (Snoqualmie Falls), the Pacific Coast Power Company, the Puget Sound Power Company, and the Whatcom County Railroad and Light Company. The new corporation was another Stone and Webster enterprise. The merger combined four major hydroelectric plants as well as four steamplants in Seattle and Tacoma, and it established electrical service on a regional basis for the first time in western Washington. The effect of the consolidation was increased dependability of the system and reduced rates.

This 1912 consolidation of all major electric companies made the Georgetown Steamplant a part of a larger network. Cheaper power from hydroelectric plants, including the new 14,000 KW White River facility, supplied the bulk of the demand. For a short time, the Georgetown plant was used only to supply steam heat to the company's nearby car barns. A company brochure of 1912 mentions the Georgetown plant as being "used only in cases of emergency." (Electric Journal 1912, pp. 50-51) A 1915 history of Seattle notes that "not one percent of the current for the city is generated by steamplants," but adds that they are kept ready for emergencies. (Bagley 1915, p. 442)

The American entry into World War I spurred the growing demand for electrical power in the Puget Sound region. Puget Sound Traction, Power and Light did not have the capital to build an additional hydroelectric plant to meet the new demand, but instead expanded its White River hydroelectric plant and its steamplant at Georgetown, adding to the latter, a 10,000 KW horizontal Curtis steam turbogenerator. (Lubar, pp. 24-25) The new equipment was installed and ready for use on May 18, 1919. (Puget Sound Power and Light 1921, p. 7) The new unit required an addition to the building, a small structure added to the north corner of the building. Two new boilers and alterations to increase the power of seven of the old boilers from 460 to 552 H.P. were added to provide power to drive the new turbine. These were serviced by a new smokestack. Several new transformers were added to deal with the additional power. Cooling water for the horizontal turbine was held in a concrete overflow tank on the southwest side of the plant. Water was piped to this tank and then to the condenser. At the same time the new turbogenerator was added, ducts were installed to supply cooling air to the old turbogenerators in order to increase their overload capacity.

Two other major changes to the Georgetown plant were made in the 1917 to 1919 period. In 1917, the course of the Duwamish River was changed and the Duwamish Waterway created by the Army Corps of Engineers necessitated a number of alterations in the means by which the plant drew its boiler and condenser water. A new pump house was built on the bank of the waterway, and the old connections replaced with a wood-stave pipe for intake condenser water and an open wood-lined trench for its exhaust.

As early as 1909, the Seattle Electric Company had had trouble getting enough oil for its plants, and in 1917, the fuel used by the boilers at

Georgetown was changed from oil to coal. This switch had been foreseen, and the plans for the plant had provided for most of the coal handling equipment already. All that was needed were a system of conveyors, a coal pile outside the plant, and ash removal facilities.

In the 1920s, demand for power increased greatly. Puget Sound Power and Light (they dropped their traction service in 1919) increased the size of several of their hydroelectric plants to meet the need. There was still need for a steam peaking facility, but by the end of the 1920s, the Georgetown plant was outdated and too small to be of much use. In 1930, Puget Sound Power and Light built a new steamplant, the Shuffleton plant at Renton, Washington. This facility with a capacity of 113,000 H.P., largely took over the Georgetown plant's role of standby steamplant. The 1930s and 1940s were times of increased interconnection among power companies, and also of the great federal hydroelectric projects in the Pacific Northwest. More power was available, and the need for the Georgetown plant decreased. A 1948 Puget Sound Power and Light Company Report mentions that in years of average stream flow the plant was used only one hundred hours per year, but that about every four years, because of reduced water flow, the plant saw more use. (Ford, p. 28) In the late 1940s and early 1950s, the plant was occasionally operated in the winter, when there was not enough water to allow the hydroelectric plants to supply peak demand.

Another major change came to the plant in 1937 with the construction of Boeing Field just south of the steamplant. Both stacks were razed to clear the ends of the runway, and a new induced-draft ventilation system installed in their stead. The openings where the ducts to the stacks exited the plant are still visible, bricked over, on the southeast side of the building.

The last major change in the building was made in the late 1940s, when the plant switched from coal back to oil. For a while, the plant was set up to burn either fuel, but when the price of oil fell after World War Two, the facilities for coal handling were removed and the plant switched permanently to oil.

In 1951, the Georgetown Steamplant was purchased by the City of Seattle Department of Lighting, now Seattle City Light. Very little changed. Most of the employees at the Georgetown plant were simply transferred from the old company to the new, and the machinery kept in its former condition. Seattle City Light already had a steamplant, the Lake Union facility, which meant that the need for power from the Georgetown facility was further reduced. The Georgetown Steamplant's last production run was from November, 1952, to January, 1953, during a major water shortage.

In recent years the place has been run only for tests. The Bonneville Power Authority gave credit to Seattle City Light for having the plant as a standby facility. In order to receive this credit it was necessary for City Light to operate the plant occasionally. Turbine Number 1 was last run on November 28, 1972. Turbine Numbers 2 and 3 on November 14, 1974. On June 20, 1977, the plant was taken off the Bonneville rolls. It could not meet environmental standards, and was thought to be unreliable. It has not operated since.

III. Urban Electric Power Development and Use in Seattle

The Georgetown Steamplant played neither a dominant nor crucial role in the electrical history of Seattle. It was, instead, a part of a growing complexity of electrical power generation facilities designed to supply consumers with ever-increasing quantities of power. In streetlighting, transportation, and in industrial and domestic use, the ability to provide increasing quantities and stable supplies of electricity proved crucial to corporate success. Seattle, Stone and Webster, and Georgetown all reflect this national trend toward corporate consolidation, technological improvement, and ever-increasing consumption.

Electricity in Seattle: 1886-1928

In the mid 1880s, Seattle was a city of horse-drawn trolleys and gas lighting. By the close of that decade, the city had moved to the forefront of communities across the nation in the manufacture and application of electrical power. A Seattle company established the first Edison incandescent central station lighting plant west of the Rocky Mountains in 1886. (Dick 1965, pp. 1-2; Hanford 1924, p. 265; Beaton 1914, pp. 105, 120-121) The Seattle Electric Light Company obtained a contract for streetlighting in the same year. Shortly thereafter in 1889, Seattle electrified its horse-drawn trolleys and became the fourth city in the world to establish an electrical railway system. (Bagley, pp. 429-438)

At first Seattle reacted skeptically to the new power source. One observer of the electric railway construction warned the president of the company, "Don't you see that you can never operate in winter? The rains will wash the current off the wires and you will not be able to turn a wheel." (Beaton, p. 107) One pillar of the community remarked in reference to the streetlighting company's steamplant "How foolish of these young men to build the generating station on the waterfront. If they had put it at the top of the hill the electricity would run down the wires by gravity. Now they'll have to pump it." (Dick, p. 2)

Since its beginning in 1873, the Seattle Gas Company held a monopoly on the streetlighting of Seattle. Alarmed by the upstart electrical industry, the company changed its name to Seattle Gas and Electric in 1886, determined to survive the competition. They built a steamplant at Fourth and Main and provided the city's first carbon arc lighting, a far more efficient method of illuminating large open spaces. (Phelps and Blanchard 1978, pp. 49-50)

The next company formed in response to the growing demand for electricity was Dr. E.C. Kilbourne's Pacific Electric Company. Kilbourne's experience came from his early involvement in the electric railway system of the previous few years. Pacific Electric leased the old powerhouse and equipment from the railway company and hired Baker and Balch, Seattle's first electrical engineering contractors, to put up the pole line. (Beaton 1914, pp. 122-123)

Both of these early firms were reorganized under new names, and by 1892 had merged to become the Union Electric Company -- this became the major (but by no means the only) generating and distributing firm serving Seattle in the next decade. A multitude of small companies with steamplants in the basements of downtown buildings sprang up, and there were many mergers and reorganizations. Competition was fierce and rates remained uniformly high. (Beaton, pp. 124-125)

In 1899, the Boston-based engineering firm of Stone and Webster took over Union Electric. By 1900, a total of some seventeen small locally-based utility companies had been absorbed by Stone and Webster's Seattle Electric Company. (Beaton, p. 112a) When the near-monopoly petitioned the city for a consolidation franchise for exclusive operation of the local street railway system, much public debate arose. Anti-corporation, pro-municipal ownership coalitions formed the basis of the opposition. The Stone and Webster "syndicate" was viewed by many as a foreign monopoly, an "octopus" out to sap and plunder the resources of the burgeoning city. Nevertheless, the street-railway franchise was granted, and the Seattle Electric Company proceeded to greatly improve, unify, and extend the system throughout the city for the next decade. (Dick, pp. 47-50)

In December of 1906, The Argus reported a projected expenditure of $1,800,000 for 1907 for "improvements, betterments, and new equipment" in Seattle. Population growth and increased demand for system extension were cited as reasons for the largest annual appropriation ever made by Stone and Webster to its Seattle holdings. This same article goes on to tout the construction of a new steamplant to augment its existing power generation facilities:

> Undoubtedly one of the most important of the improvements now being made by the Seattle Electric Company is the new power generating plant and machine shops located at Georgetown. The

> building . . . is of reinforced concrete, built in the most approved style and on a solid foundation made of piles and masonry, which will last for ages. (The Argus, Dec. 15, 1906, pp. 63-64)

The year 1912 signaled the end of the era of local power supply. Stone and Webster purchased and consolidated utility holdings in Bellingham, Everett, Seattle, and Tacoma including four major power companies and three major hydroelectric plants, under the umbrella of the Puget Sound Traction, Power and Light Company. Territorial power supply in Pacific Northwest had begun. (Chronological History, pp. 6-7)

Competition

During the heyday of Stone and Webster, the Snoqualmie Falls Power Company provided a measure of competition for the Seattle Electric Company. The Snoqualmie Falls project was Washington's first major hydroelectric project, and was built and operated by Charles Baker in 1898. By mid 1899, Snoqualmie Falls supplied power to portions of Seattle's street railway system and to various stationary motors and flour mill operations around the city. But by arrangement with Stone and Webster, the Snoqualmie Falls Power Company only sold power wholesale to Seattle Electric, and the latter handled all retail distribution within the city. (Dick, pp. 51, 83-84)

The turn-of-the-century movement toward a municipal utility system produced serious competition for the Seattle Electric Company by 1905. The momentum began with a public vote in 1896 to consider the Cedar River as a power source after the completion of the city water works there. This populist sentiment grew in strength until the election of 1902 which authorized construction of a hydroelectric project on the Cedar. City Engineer R.H. Thompson hired J.D. Ross as electrical engineer on the project The Cedar River plant first supplied current to the city in January of 1905. Its distribution station was built on Yesler Way at Seventh Avenue The city's top priority was to service its eleven street lighting circuits, and was soon competing with the Seattle Electric Company in private domestic lighting. At the end of the first year of operation The Argus wrote:

> The municipal electric lighting and power plant is now in successful operation, and is supplying the city with four hundred and fifty arc lamps, an increase of two hundred and fifty, and nineteen hundred incandescent lights . . . It is also supplying power for manufacturing purposes, and has installed lights in a considerable number of private homes. (The Argus, Dec. 23, 1905, p. 21)

The absolute superiority of hydro-generated electricity was realized in the first decade of the new century. Hydroelectricity meant more current for less work with a resulting radical decrease in consumer rates. The Seattle Electric Company originally relied on small steam-generating plants, as had its predecessor companies. But in 1904, Stone and Webster, under the name of the Puget Sound Power Company followed the lead of Charles Baker's Snoqualmie Falls project and constructed a major hydroelectric plant at Electron on the Puyallup River. Electron meant substantial rate reductions for the people of Seattle. (The Argus, Dec. 17, 1904, p. 32)

By 1905, the Snoqualmie Falls, Electron, and Cedar River municipal plant supplied Seattle with the bulk of the electrical power needed to meet its transportation, street lighting, private domestic, and industrial needs. These major sources were amplified in 1912 by the Puget Sound Traction Power and Light Company's White River hydroelectric project. Through the first decade of the century, steamplants continued to be built as auxiliary power sources. Steamplants such as the Seattle Electric Company's Georgetown plant, provided power companies with back-up and peak load capability. They meant stability and the guarantee of uninterrupted service. This peak hour capability was what small utility companies lacked and was the ultimate reason for their failure.

In 1912, Puget Sound Traction, Power and Light purchased and consolidated the Seattle Electric Company along with the Seattle-Tacoma Power Company (Snoqualmie Falls), the Pacific Coast Power Company, the Puget Sound Power Company, and the Whatcom County Railway and Light Company. The new corporation was another Stone and Webster enterprise. The merger combined four major hydroelectric plants as well as four steamplants in Seattle and Tacoma, and it established electrical service on a regional basis for the first time in western Washington. The effect of the consolidation was the increased dependability of the system and reduced rates. Gradually, the corporation bought up small utilities in outlying towns where peak demands were too difficult to meet without a steam power backup system. (The Argus, "Preparedness for Industrial Development," p. 61)

From 1910 through 1920, the demand for electric transportation in Seattle decreased. The electric streetcar system was sold to the city in 1919, and Puget Sound Traction Power and Light dropped the "Traction" from its name. By 1924, the company provided service from "tide water on the west to the Columbia River on the east and from the international border on the north to points in Oregon on south." (Hawford, p. 267) In 1928, Stone and Webster sold out of the company. Puget Sound Power and Light remains in operation today, still the predominant private regional power supplier in the Puget Sound country.

IV. Urban Electricity from Luxury to Necessity

The early twentieth century, the time when the Georgetown Steamplant saw its most intensive use, was one that transformed electricity from a novelty to a necessity. In streetlighting, transportation, and in domestic and industrial use, electricty became a necessity, a power source that had to be supplied in ever-increasing yet dependable quantities every day. As a rare surviving "peaking" facility, the Georgetown plant supplied back-up power for all these uses. It was an era initiated by small urban steamplants, later dominated by more remote hydro-electric facilities and their standby peaking facilities, and eventually replaced by even larger hydroplants and a new generation of massive steamplants.

The yellow glow of gas lamps first illuminated the streets of Seattle on New Year's Eve in 1873. During the 1880s the coal gas plant and the service it provided were considerably expanded, and by the end of the decade gas lighting in the home was a clear symbol of status. (Phelps and Blanchard, p. 148)

With the availability of electricity, street gas luminaires began to be gradually replaced, first with incandescent (carbon filament) and soon afterward with carbon arc lights. The latter were suspended on cables over intersections or from outriggers on utility poles. Arc lighting was the most effective means of illuminating large open spaces, although incandescents remained in use in suburban areas requiring less intense lighting. In 1893, the enclosed arc was introduced, and eliminated the need for the daily replacement of carbons. (Phelps and Blanchard, pp. 149-152) Until 1909-1910, Seattle's streetlighting system as a whole was haphazard and non-uniform in design. The City Engineer's Annual Report of 1891 noted that the city was using a total of 89 arc lights, 282 30 c.p. incandescent lights, and 303 15 c.p. incandescents to light its streets. (Phelps and Blanchard, pp. 151-152)

The cost of electric lighting in the home remained relatively high until the tremendous reduction in cost made possible by hydroelectric power developments. In the early 1890s, however, the flat rate cost of a single 16 c.p. lamp in the home ranged from around $1.50 to $3.00 per hour depending upon the hours of use. (Pacific Electric Company rates, Beaton, p. 123) Gas lighting continued to provide competition in home illumination into the twentieth century. (ads in The Argus, Dec. 1899, 1901)

The City of Seattle gained control of all streetlighting in 1905 with the opening of the Cedar River power plant. As the city assumed metropolitan proportions and character, the haphazard mixture of street lighting types and designs became more and more unacceptable. In 1909-1910, replacement of the entire system with a uniform cluster light design took place for a total cost of $51,279. The project instigated by the downtown businessmen who petitioned on the basis of a local Improvement District, and the lights themselves were designed by J.D. Ross. The new arrangement used five or three ball clusters of 80 c.p. tungsten lamps with lightly-sandblasted globes on ornamental iron poles. The system was an understandable source of city pride, as the City Lighting Department's Annual Report of 1911 indicates:

> Seattle's cluster lighting system is one of the finest in existence and is generally admired by tourists and visitors from all parts of the country . . . . This design gives a beautiful effect of festoons of decorative lights along the sidewalks, and at the same time secures a uniform illumination on all parts of the street. (Phelps and Blanchard, p. 152)

Electric lighting effects played an increasingly important role in public ornamentation in the first decade of the century. Promotional materials for the Alaska-Yukon-Pacific Exposition in 1909 extolled not only the virtues of lighting at the exposition grounds, but also on the main commercial thoroughfares of the city itself:

> By night the Exposition is a spectacle that has never been surpassed. The grounds and buildings are a blaze of light and the Cascades -- pouring down the central court -- a plunging rainbow, showing every color of the solar prism. The Geyser Basin at the foot, is a lake of liquid fire in which trout and bass sport among sunken gardens. Every building on the grounds is thrown into brilliant silhouette by incandescent lights dotting their outlines at six-inch intervals, and the Alaska Shaft, which marks the center of the Exposition grounds, is a tower of brilliancy.

And downtown:

> At night First, Second, and Third Avenues are dazzingly illuminated by eight lamp posts in every block, each post supporting a pyramid of five electric lights, and they present a scene that is not paralleled in either Chicago or New York -- despite their size and wealth. In a word, Seattle is the modern marvel of magical city possibilities. (Seattle and the Pacific Northwest . . . A-Y-P Hotel and Commercial Guide, pp. 2 and 6)

The Georgetown Steamplant, as a facility of the Seattle Electric Company and later the Puget Sound Power and Light Company, was never a direct supplier of power to the city's lighting system. By 1905, the City Lighting Department had assumed full responsibility for streetlighting in Seattle. The ornamental one-, three-, and five-globe cluster lighting system, restored today in the vicinity of Pike Place Market and Pioneer Square, was installed in 1909 and 1910. By 1925, increased automotive traffic challenged the adequacy of that system. While it was apparent that new lighting was sorely needed, controversies over design among downtown property owners prevented installation of a new system until 1929. All cluster lighting was removed in the business district and replaced by luminaires designed by Carl Gould of the architectural firm of Bebb and Gould. By the end of 1931, this system extended into the city's residential neighborhoods.

The last major replacement of the city's streetlighting system occurred in 1948-1954 in the business district and in 1964-1968 in the residential districts. Mercury vapor lamps were installed, but in many cases the ornamental iron bases designed by Carl Gould were retained. (Phelps and Blanchard, pp. 153-161)

Transportation

Young Frank Osgood from Boston came west to Seattle in 1883 with a desire to contribute to the development of the city. At the suggestion of Thomas Burke, Osgood developed a horse-drawn streetcar system along Second Avenue with branches to Lake Union and to Belltown. Osgood's system, begun in the Fall of 1884, was the first in Washington Territory and was a feather in Seattle's cap in the bitter rivalry with Tacoma. Osgood kept abreast of developments in electricity, and in 1888 joined forces and funds with L.H. Griffith, Morgan Carkeek, Dr. E.C. Kilbourne, Judge Thomas Burke and others to form the Seattle Electric Railway and Power Company. The purpose of the company was to electrify the existing trolley line, open new territory for development, and beat the competition of the cable-car company. (Beaton, pp. 100-105)

Osgood and Kilbourne contracted with the Thomson-Houston Electric Company for equipment. A plant was built at the foot of Pike Street with an 80-h.p. generator and a 100-h.p. engine. The rolling stock included five double-reduction Thomson-Houston 15-h.p. motor equipments, four Jones car bodies with Brill trucks. Electric trolley service began at midnight on March 30, 1889, and the horse cars were retired to car barns never to run again on Seattle streets. Citizens turned out in droves along Second Avenue the following day. When the trolleys made the grade, Seattlelites cheered and the cable car company began to worry. (Beaton, p. 106)

Seattle's electric streetcar system was a tremendous success as an advertisment for the city, as a money-making venture, and as a stimulus to real-estate development. New "streetcar" suburbs were opened up for subdivision, and thus electricity became a prime factor in the rapid growth of the city. By 1891, there were 13 separate cable and electric railway companies and 48 miles of electric trackage. (The Argus, Dec.

11, 1911) Among others, the Grant Street Electric Railway built tracks on piles around the tideflats to Georgetown in 1893. A brick powerhouse with three generators supplied power for the car system with enough left over to provide electric lighting to several establishments in Georgetown. (Blanchard, pp. 37-38)

The Panic of 1893 had a disasterous impact on Seattle's electric trolley companies. All but the Madison Street Cable Company and the Seattle Traction Company went into receivership. Many trolley enterprises revived with the business recovery brought on by the Alaska gold discoveries, but the tracks and rolling stock had begun to deteriorate. Talk of consolidation of the myriad systems became a reality when the giant eastern firm of Stone and Webster entered the field. (Phelps and Blanchard, pp. 164-166)

Stone and Webster's consolidation of Seattle's myriad streetcar lines led to immediate improvements in the system. In December of 1900, G.W. Dickinson, manager of the Seattle Electric Company, reported on these improvements in The Argus, and asked the citizen's indulgence for the torn-up condition of the streets. Dickinson also noted that it was now possible for the working public to live on the outskirts of the city within a radius of five miles, and be within twenty minutes of Pioneer Square by street railway. The following year The Argus reported that:

> . . . during the past two years the lines have been nearly all rebuilt and equipped with latest improvements, both in rolling stock and other appliances, and when improvements under construction are completed, no city in the country will have better service. (The Argus, Dec. 21, 1901)

The improvement and extension of the street railway system had a direct effect on the expansion of the city. "Streetcar suburbs" grew up overnight, and the general prosperity of the times allowed working people to purchase their own homes on the installment plan. Seattle became a city of single-family-homes and well-defined neighborhoods because of this direct access by streetcar to and from the commercial center. (Seattle of Today, p. 39)

In 1902 an interurban electric railroad line was completed between Seattle and Tacoma. This efficient, rapid means of transportation opened up still more suburban areas to settlement, and brought into existence a number of new towns and villages along its route. A branch line to the coal-mining town of Renton was soon added to the system and by 1907 a line to Everett was under construction. With the operation of these roads, electrical transportation in Seattle reached its zenith. (The Argus, Dec. 20, 1902, and Seattle of Today, p. 39)

Tourism and recreation in and around Seattle were encouraged and enhanced by the Seattle Electric Company's transportation system. "Trolley parks" at scenic locations at the end of the streetcar lines at Leschi and Madison Park on Lake Washington, were developed by the Company into popular resort facilities. During the summer months as many as eight "Seeing Seattle" tourist cars were operated on tour routes throughout the city. These proved immensely popular during the Alaska-Yukon-Pacific Exposition of 1909. ("Trolley Trips About Seattle") The AYP itself spurred construction of several new streetcar lines and the upgrading of rolling stock and terminals. Outside of the city the interurbans were tourist attractions in themselves, with miles of scenic vistas of farmlands, forests, water, and mountains. (The Argus, Dec. 20, 1902, and Dec. 16, 1911)

By 1911, Stone and Webster's rate of investment in the Seattle street railway system had slowed to the extent that criticism was being raised by municipal ownership advocates. "A Short History of Seattle's Street Railway System," an article published by The Argus on December 16, 1911 was an obvious attempt to praise and defend the Seattle Electric Company's many accomplishments over the previous decade. Nevertheless, service continued to deteriorate, and the Seattle Municipal Railway came into existence in 1911 with the construction of a new line of its own. It was a taste of things to come in the next decade when the City would incrementally enter the public transportation field, and Stone and Webster interests would subside. (Phelps and Blanchard, pp. 165-167)

When the Georgetown Steamplant was constructed in 1906-07, the city's electric car service and the region's interurban service was at its peak. The Seattle Electric Company's streetcar system was the major consumer of the company's power, and it provided service to 246,000 people over 155 miles of track. By 1912, however, the operation of the system had become less profitable, and Stone and Webster's investment in its maintenance declined. Local sentiment toward municipal ownership of the system revived once again. The city had proved its interest and ability to operate such a system with its construction of the "Division A" line in 1911 and its take-over of the Highland Park-Lake Burien line in 1913. Tension and disputes between the city and Stone and Webster (by then consolidated as Puget Sound Power and Light) continued to mount during World War I.

In 1919, the city purchased the entire street railway system at the asking price of Stone and Webster. Under the contract, the city was also to take over the substations supplying street railway current. Municipal operation of the street railway system was plagued with problems. Ineligibility for state subsidies, rigorous payment terms, management changes, increased wartime traffic followed by a business slump, and finally depression led to bankruptcy of the system in 1938.

During the twenty-year life of the Seattle Municipal Street Railway, the city had purchased absolutely no new equipment. The entire system was eventually replaced by rubber tire gasoline engine vehicles -- the last electric car ran on April 13, 1941. (Blanchard, pp. 91-94, "Chronological History," n.p.)

Industrial and Domestic Use

From the first instance of industrial use of electricity in Seattle at the Lowman-Hanford presses in 1890, the application of the new power source to industry grew rapidly. In an advertisement in The Argus, of December 23, 1899, the Northwest Fixture Company offered electric fixtures, motors, dynamos, and electrical machinery and elevators for sale. In the same issue of that magazine, the Seattle Cataract Company offered cheap power from Snoqualmie Falls to grind flour, mine coal, or smelt ores.

Local articles published throughout the first decade of the century promoted Seattle as a good place to establish manufacturing concerns, precisely because of the abundance of cheap power made available through its hydroelectric and steam plant facilities. The local utility companies advertised extensively for industrial customers, even to the extent of gathering data for prospective manufacturers. W.E. Herring, Industrial Agent for the Puget Sound Traction Power and Light Company, published two such informative articles in The Argus, (Dec. 13, 1913 and Dec. 18, 1915), describing the natural resources of the Puget Sound Region, the untapped opportunities in manufacturing, and the availability of electrical power at low cost in both urban and rural areas.

New Domestic Uses

In the first decade of the new century, the application of electricity to domestic use revolutionized the operation of Seattle households. Wider application was made possible by the lower rates associated with hydroelectric generation, and by a growing understanding of the new technology. The Municipal Lighting Department's Annual Report of 1912 reported on city-wide experiments with electric heating systems, both radiant and hot water. Cooking with electricity, the report noted, was well established in many homes.

The Seattle Electric Company's headquarters in the Electric Building on Seventh and Olive featured for a number of years a unique display of domestic electrical devices known as "The House Without a Chimney." This five room model "flat" exhibited a range of available appliances appropriate for use in each room, and clearly portrayed the ultimate in domestic luxury of the period. A 1912 Souvenir Edition of The Electric Journal described the electrical contents of the rooms as follows:

- -- drawing room -- fireplace with luminous radiator, ceiling fixtures, and "artistic applications of electric light to decorations."
- -- kitchen -- range, hot plate, percolator, water heater, tea kettle, combination cooker, frying pan, griddle, toaster oven, broiler, disc stove, egg boiler, and sterilizer.
- -- bathroom -- electric water heater attached to tub, portable luminous radiator, shaving mirror and mug, and vibrator.
- -- bedroom -- reading lamp, sewing machine, warming pad, curling iron, hair dryer, cigar lighter and water heater.

In contrast to electric transportation, domestic and industrial consumption of electricity continued to expand decade after decade. The Seattle Electric Company, followed by Puget Sound Power and Light, competed with the Municipal City Light Department in supplying users. Electric heating remained expensive and experimental until the 1950s. In 1925, for example, only 700 homes in Seattle were using electric heat exclusively. The price was double that of coal, and the average yearly cost for heating a five-room house with electricity was $175/year.

By 1910, electric ranges were on display at the Electric Building in downtown Seattle. The Seattle Lighting Department promoted their use through sales, and by providing maintenance. In 1914, Puget Sound Traction, Power and Light offered free demonstrations in "Electric Cookery -- Practical, Simple, Cheap and Economical." Seattle City Light served approximately 2,500 ranges by 1922. By the end of 1926, that number had increased to 10,556.

Refrigeration by electricity was still in its infancy in Seattle in 1926, and cost was still a major problem. The electric water heater, however, had gained widespread acceptance by 1912. (Seattle City Light Annual Reports, 1912-13, 1922, 1926) A local 1914 advertisement for an "Electric Christmas" featured small appliances from heating pads, to Christmas tree lights, to waffle irons. A 1939 ad demonstrates the growth of major appliances including "water heaters, vacuum cleaners, and other modern household electrical servants." By 1950, Seattle City Light boasted that Seattle used over three times as much electricity as the national average.

Georgetown: The Community

As a community, one of many "streetcar suburbs," Georgetown reflected the increased availability and application of electricity. In 1906, Georgetown was a separate incorporation, known for its political independence, its industrial potential and its "wide open" roadhouses. The settlement was originally the agricultural community of Duwamish, first homesteaded by the familiar names of Holgate, Van Asselt, and Horton. Italian truck gardeners were also among the earliest inhabitants. The town was platted by Julius and Ann Horton, and the name changed to Georgetown after their son George in 1901. Georgetown was incorporated in 1904 and stubbornly held out against annexation by Seattle until 1910, largely owing to the partnership of its leaders with the local brewery and saloon interests. (Peterson, pp. 1-4, 22, 71-77)

Industry was the driving force of Georgetown from an early date. The town grew from a population of 2,500 in 1901 to 7,000 in 1910, largely because of increasing industrial activity. The Denny Clay Company, a major brick manufacturing firm which supplied brick and terra cotta to build much of Seattle, was the first to locate in Georgetown. The Seattle Brewing and Malting Company was established in 1893 and soon became the community's largest and most influential employer. The census of 1900 listed a number of Seattle Electric Company employees -- conductors, brakemen, and switchmen -- as residents of Georgetown where the company car barns and an interurban station were located. The Olympic and the Union iron foundries, furniture manufacturing, and river-related industries were also situated in Georgetown by 1900. (Peterson, pp. 25-27) By 1906, the dredging and straightening of the Duwamish River was planned and its future as a major shipping center already envisioned. Streetcars first arrived in Georgetown in 1882 on the Grant Street line, running open cars over trestles above the tideflats. The Seattle Electric Company extended that line to South Park and brought its car barns to Georgetown at the turn-of-the-century. In 1906, larger car barns were built employing over 200 men, in conjunction with construction of the Georgetown Steamplant. (Pacific Building and Engineering Record, January 13, 1906 and Peterson, pp. 40-41)

In spite of its industrial economic base, Georgetown was also a community of residences, businesses, parks, and institutions. Georgetown was the site of the King County Hospital and Poor Farm. With a large German population, Oktoberfest was a major community festivity. There were many boarding and rooming houses for single male workers, including off-season carnival employees and gypsies. Entertainment in Georgetown was never puritanical. Meadows Race Track was two miles out of town, and roadhouses along the way contributed to a steady stream of joy-riders from Seattle on summer afternoons. Georgetown was a colorful, liveable place to its residents, but the community was under frequent attack by the Seattle press for its liquor laws. On November 3, 1909, the Seattle Times wrote that:

> It is one of the few places in the state where the sale of liquor has been abused and where the whole community has become a by-word

> and a reproach for all that is vile and depraved in the liquor business. (Peterson, pp. 56, 63, 77)

Although the electric car barns were eventually closed, Georgetown remains an industrial community, comfortably mixing a small residential section with much larger industrial plants. It is, like its namesake steamplant, a survivor from a past era of smaller scale and more restricted patterns of transportation. Today, both electricity and electrical users operate on much larger scales, commuting from distant suburbs, and transporting electricity on regional grids. In their heyday, Georgetown and the Georgetown Steamplant were considered leaders in a new electrical way of life. Their survival in the last decades of the twentieth century, remind us all of a national movement into the Electric Age. As an ironic comment on how quickly what seemed paramount so soon became mundane and on how much our dependence on electricity continues to accelerate. The mosaic mural in the central offices of Seattle City Light proclaims its determination to supply electricity "that man may use freely as the air he breathes . . . ."

FOOTNOTES

1. The general history of General Electric's development of the Curtis turbine is discussed in J.W. Hammond, Men and Volts: The Story of General Electric (New York: Lippincott, 1941), pp. 283 ff; E.L. Robinson, "The Steam Turbine in the United States; III--Developments by the General Electric Company," Mechanical Engineering, Volume 59 (1937) pp. 239-256; and most usefully, William Le Roy Emmet, The Autobiography of an Engineer (Albany: Fort Orange Press, 1931), Chapter 8.

2. Curtis was a patent lawyer and entrepreneur in addition to being an engineer. He studied civil engineering at Columbia College, graduating in 1881, and law at the New York Law School, graduating in 1883. After eight years as a patent lawyer, he became involved with the manufacture of electric motors. His first important patents were those for the steam turbines. He went on to obtain the first American patent on a gas turbine, in 1899, and an important patent on diesel engines, in 1930. (A.S.M.E. 1975, pp. 1-3)

3. General Electric did not keep the records of the early sales of Curtis turbines (personal communication, George Wise, Historian, General Electric Company, August 3, 1979) so it is impossible to say who bought them. The figures of the 1907 U.S. Census Special Report on Street and Electric Railways, p. 518, suggest that electric railway companies (who generally also sold electric power to the public) bought most of them:

size	number	power
all	252	535,404 H.P.
less than 500 H.P.	23	3,788
500-1000	70	49,491
1000-2000	51	69,787
over 2000	108	412,338
over 500	23	179,200

Individual manufacturing companies, producing power for their own factories, were probably the second largest group of purchasers.

4. Unlike early steam engines that varied the pressure of steam to control speed under load, the Curtis turbine used a series or belt of steam nozzles at one or two points around the turbine wheel. The governor directly controlled the number of nozzles open at any one time, thus assuring full pressure at the inlet point, no matter how many or how few nozzles were open. Greater loads on the generator would cause the governor to open more nozzles to maintain

a constant speed. "With such a machine it is possible to operate over at least half the range of the machine with maximum and minimum economy varying not more than five percent from the average." (Parker 1910, p. 78)

5. Stone and Webster Public Service Journal, Volume 1, August 1907, p. 118; September, p. 206; October, p. 272; November, p. 354; Volume 2, January, 1908, p. 535; March, p. 685-6; April, p. 773; and June, p. 950.

MAJOR BIBLIOGRAPHICAL REFERENCES

Emmet, William LeRoy
The Autobiography of an Engineer. The American Society of Mechanical Engineers: 1940.

Gilbreth, Frank B.
"Reinforced Concrete Power Station," California Journal of Technology. February, 1908, pp. 23-28.

Pacific
Pacific Building and Engineering Record, "Story of Georgetown's Prosperity," January 13, 1906.

Passer, Harold
The Electrical Manufacturers, 1975-1900, A Study in Competition, Entrepreneurship, Technical Change and Economic Growth. Harvard University Press, 1953.

Peterson, June
The Georgetown Story - That Was a Town, 1904-1910. Georgetown Designs: Seattle, 1979.

Phelps, Myra and Leslie Blanchard
Public Works in Seattle: A Narrative History, The Engineering Department 1875-1975. Seattle Engineering Department: 1978.

Seattle
The Seattle Daily Times, "Georgetown is Growing Fast: Many Industries Moving In," January 3, 1926.

Yost, Edna
Frank and Lillian Gilbreth: Partners for Life. Rutgers University Press: 1949.

Journals and Newspapers

Electrical World
Engineering News-Record
General Electric Review
Mechanical Engineering
Seattle Post-Intelligencer
Seattle Times
Stone and Webster Public Service Journal

EQUIPMENT INVENTORY (Preliminary)

EQUIPMENT	REMARKS	DATE OF MANUFACTUR OR INSTALLATION
Steam Boilers		
7 Boilers, each rated 369 boiler horsepower, equipped with superheater.	The boilers were originally coal fired, then converted to burn oil starting in 1918. Final conversion to oil was completed in 1946.	1906 & 1918
2 Boilers, each rated 473 boiler horsepower, equipped with superheater.	Babcock & Wilcox manufactured 14 of the boilers for the Seattle Electric Co. in 1906. In 1918 these two boilers were added.	
7 Boilers each rated 519 boiler horsepower. Boilers are not equipped with superheater.	Each Sterling type boiler has lettered cast manhole inspection covers, 12 per boiler. The boilers also have the name "The Seattle Electric Company" across the top.	
Boiler Steam Pressure Gauges		
0-300 psi. (Total of 16)	Manufactured by J. Marsh Co., Chicago, Illinois. These are fancy brass gauges approximately 15 inches in diameter.	1906 & 1918
Boiler Room Panel		
See remarks	Mounted on the panel is an antique brass pressure gauge (1898) manufactured by Wm. H. Birch Co., San Francisco, Calif. Range 0 to 250 psi., 10 inch. The panel also contains: an old Bristol Recorder manufactured by the Bristol Company, Waterbury,	

EQUIPMENT (Continued)	REMARKS	DATE OF MANUFACTURE OR INSTALLATION
	Conn., a small gauge manufactured by North Coast Engineering Company, Seattle, Wash., and a larger gauge manufactured by J. P. March Co., Chicago, Ill.	
<u>Donkey Boiler</u>		
Boiler Number 3535 Operating pressure 0-160 psig. Oil Fired.	Built for Bucyrus Company, by Johnston Bros., Inc. Ferrysburg, Michigan. The boiler is used for start up.	1924
<u>Induced Draft Fans</u>		
Size 998 Design 2 Fans number 1 & 2, 9 & 10, 13 & 14, 15 & 16 are Model Number 13741. Fans number 3 & 4, 5 & 6, 7 & 8, 11 & 12 are Model Number 13740.	Manufactured by B. F. Sturtevant Company.	ca. 1935
<u>Fuel Oil Storage Tank</u>		
Storage capacity 20,328 barrels.	The storage tank is buried underground.	ca. 1917
<u>Turbo-Generator Number 1</u>		
Curtis Steam Turbine (No. 3007) (4 stage vertical shaft steam turbine).	Manufactured by General Electric Co. Steam Pressure 175 psi.	1907
Alternating Current Generator 3,000 KW Vertical Type ATB No. 148684 Class 10, Volts 13,200, Amps 131.5	Manufactured by General Electric Co. Schenectady, N.Y.	1907

EQUIPMENT (Continued)	REMARKS	DATE OF MANUFACTURE OR INSTALLATION
Turbo-Generator Number 2		
Curtis Steam Turbine (No. 4137) (5 stage vertical shaft steam turbine).	Manufactured by General Electric Co. Steam Pressure 175 psi.	1908
Alternating Current Generator 8,000 KW Vertical Type ATB No. 119566 Class 10, Volts 13,800, Amps 334	Manufactured by General Electric Co., Schenectady, N.Y.	1908
Turbo-Generator Number 3		
Curtis Steam Turbine (No. 13401) (9 stage horizontal shaft steam turbine).	Manufactured by General Electric Co. Steam Pressure 175 psi.	1917
Alternating Current Generator 10,000 KW Horizontal Type ATB-4 Volts 13,800, Amps 524 No. 1181396	Manufactured by General Electric Co., Schenectady, N.Y.	1917
Barometric Condenser No. 1	Manufactured by City Light Used with Unit No. 1.	1969
Barometric Condenser No. 2	Manufactured by Hydraulic Supply Manufacturing Co., Seattle, Wash., Used with Unit No. 2.	1965
Jet Condenser	Manufactured by C. H. Wheeler. This condenser is used with Unit No. 3.	1917

EQUIPMENT (Continued)	REMARKS	DATE OF MANUFACTURE OR INSTALLATION
<u>Weiss Air Pump</u> (Vacuum)		
Number 149 Used with vertical Turbo-Generator Unit No.1.	Built by Southwark Foundry and Machine Co. Patented April 28, 1896 Philadelphia, PA	1907
<u>Weiss Air Pump</u> (Vacuum)		
Number 174 Used with vertical Turbo-Generator Unit No. 2.	Built by Southwark Foundry and Machine Co. Patented April 28, 1896 Philadelphia, PA	1908
<u>Electrical Panels</u>		
Panels are Grey Marble approximately 2 inches thick. There are 27, two piece sections.		ca. 1907 & 1917
The following equipment is panel mounted on these panels.		
1 Western Stanton Volt Meter Number 5746 Range 0-600 Volts	Manufactured by Western Electric Instrument Co., Newark, New Jersey	
Thompson Recording Watthour Range 2000 amp, 600 volt (Total of 4)	The meters appear to be in good condition. All were manufactured by General Electric Company.	
Thompson Astatic Ammeter	All meters were manufactured by General Electric Company	
1 - Range 0 - 500 amp 1 - Range 0 - 800 amp 1 - Range 0 - 1000 amp 1 - Range 0 - 1300 amp 4 - Range 0 - 1500 amp 1 - Range 0 - 2000 amp		

EQUIPMENT	REMARKS	DATE OF MANUFACTURE OR INSTALLATION
<u>Electric Panels</u> (Continued)		
Miscellaneous Meters Volt meters, Ammeters Watthour meters, Temperature indicators (Total of 50 meters)	The majority of these meters are ammeters, 34 of these. All meters were manufactured by General Electric Company	
Power Factor Meter (Antique) 1 meter	Manufactured by Westinghouse Electric Company.	
Voltage Regulator (Antique) 1 regulator Number 1661	Manufactured by General Electric Company, Schenectady, N.Y., USA.	
Synchronous Meter 1 Meter	Manufactured by Genernal Electric Company.	
Reverse Power Relays 2 Relays (small) 8 Relays (large)	Manufactured by General Electric Company	
Frequency Indicator Frahm System	Manufactured by James G. Biddle Company	
Large Solid Copper Knife Switch 8 total, miscellaneous sizes, multiple blade type.	Manufacturer unknown.	
Two Blade Knife Switch Solid Copper 13 total, misc. sizes	Manufacturer unknown.	
Single Blade Knife Switch Solid Copper 15 total, misc. sizes	Manufacturer unknown.	

EQUIPMENT (Continued)	REMARKS	DATE OF MANUFACTURE OR INSTALLATION
Framed Switch and Fuse Panels		
4 Panels, the panels have two blade knife type switches and use screw-in type fuses.	The panels are for lighting and miscellaneous circuits. Manufacturer unknown.	ca. 1907
Oil Circuit Breakers		
7 Breakers - small 36 Breakers - large	Manufactured by General Electric Company	1907 & 1917
Knife Switches		
More than 50 solid Copper multi blade type switches.	Manufacturer unknown.	1907 & 1917
Transformers		
Bank No. 1 Type WC, 500 KW 13,800 volt (2 transformers in bank)	Manufactured by General Electric Company	ca. 1907
Transformers		
Bank No. 2 13,800 1000 KVA (2 transformers in bank)	Manufactured by Westinghouse Electric Company	1907
Automatic Circuit Breakers (Antique)		
4 Circuit Breakers	Manufactured by General Electric Company	ca. 1907
Lube Oil Pump (Duplex Type)		
Steam Driven, 2 cylinder Size 9 x 3-1/8 x 10 Number 189-977	Manufactured by Worthington	ca. 1907

EQUIPMENT (Continued)	REMARKS	DATE OF MANUFACTURE OR INSTALLATION
Lube Oil Pump (Duplex Type)		
Steam Driven, 2 cylinder Size 9 x 3-18 x 10 Number 190-208	Manufactured by Worthington	ca. 1907
Lube Oil Transfer Pump (Duplex Type)		
Steam Driven, 2 cylinder Size 4-1/2 x 2-3/4 x 4 Number 164828X9	Manufactured by Knowles Pump Works New York, New York.	ca. 1917
Fuel Oil Pump (Duplex Type)		
Steam Driven, 2 cylinder Reciprocating Type Size (Data not available) 2 identical pumps	Manufactured by (Name plate data missing) Hallidie Machinery Company, Seattle, WA Sales agent.	ca. 1918
Fuel Oil Pump		
Screw Type, Electric Motor Driven Size 4, 250 Head, 80 gal/min Number 867	Manufactured by William E. Quemby, Inc., New York, New York	ca. 1930
Feed Water Pump (East)		
DeLaval Centrifugal Type 140-TC-3P5 650 gal/min 520 Head Number 56980	Manufactured by Ingersoll Rand Co. New York, New York.	ca. 1917
Steam Turbine (for feed pump) 2300 RPM Number 56980	Manufactured by DeLaval Steam Turbine Company, Trenton, New Jersey	ca. 1917

EQUIPMENT (Continued)	REMARKS	DATE OF MANUFACTURE OR INSTALLATION
Feed Water Pump (West)		
Ingersoll Rand Centrifugal 900 gal/min, Size 4GT900 552 Ft. Head Number 06493050	Manufactured by Ingersoll Rand Company, New York, New York.	1949
Steam Turbine (for feed pump) 3600 RPM Serial Number 79336 Model Number 7TDP1117AEK 180 Horsepower	Manufactured by General Electric Company, Schenectady, New York.	1949
Air Compressor		
Size 8 x 8 Electric Motor Driven Number 36175	Manufactured by Curtis St. Louis, Mo.	1950
Centrifugal Water Pump		
Spare Pump Small Electric Motor Driven (Name plate date missing.)	Name plate data missing. The Spare pump is not connected into system	ca. 1917
Hot Well Tank		
14 ft. diameter x 12 ft. deep Steel plate construction.	Manufacturer unknown	1917
Fuel Oil Strainer System	Manufactured by Bethlehem Steel	ca. 1930
Step Bearing Lube Oil Tank	Manufactured by Turner Oil Filter Co. Niles, Michigan.	1907
Mid Bearing Lube Oil Tank	"	" 1907
Spare Lube Oil Tank	"	" 1907
Air Pump Lube Oil Tank	"	" 1908

EQUIPMENT (Continued)	REMARKS	DATE OF MANUFACTURE OR INSTALLATION
Ingersoll Rand Air Compressor		
Large unit similar to the unit installed in Lake Union Steam Plant	This unit is dismantled. It will be used for parts for the Lake Union Compressor. In addition there is an Allis Chalmers 125 horsepower induction motor to run this compressor.	
Step Bearing Oil Pump (Duplex)		
Steam driven 2 cylinder Recriprocating Type Size 12 x 2-3/4 x 18 Number 192035 Used on Unit No. 1	Manufactured by Worthington.	1907
Step Bearing Oil Pump (Duplex)		
Steam driven 2 cylinder Recriprocating Type Size 12 x 2-3/4 x 18 Number 192036 Used on Unit No. 2	Manufactured by Worthington	1908
Centrifugal Pump		
Steam driven Size 4 400 gal/minute 560 ft head 2750 RPM	This is a spare pump not connected to plant system. Manufactured by Platt Iron Works Dayton, Ohio	
Turbine Drive Terry Turbine Number 1759 2750 RPM	Manufactured by Terry Steam Turbine Company Hartford, Connecticut	

EQUIPMENT (Continued)	REMARKS	DATE OF MANUFACTU[RE] OR INSTALLATION
Condenser Pump (Unit No. 3)		
Pump Size 18 D.V.S. Number 06280	The pump may be operated by either electric motor or by steam turbine. Manufactured by Wheeler Condenser Engineering Company	1917
Pump Reduction Gear Drive Number 548	Manufactured by Moore Steam Turbine Corporation.	1917
Turbine Drive Number 3555	Manufactured by Terry Turbine Company.	1917
Pump Electric Motor Drive Number 1648315	Manufacturer General Electric Company	1917
Wheeler Turbo Air Pump (Vacuum)		
Pump Size T-A-100 Number 04968	Manufactured by Wheeler Condenser & Engineering Co., New York, N.Y. The pump is used with condenser number 3 and is steam driven.	1917
Steam Turbine Drive Number 4635	Manufactured by Westinghouse Machine Co., Designers & Builders, East Pittsburgh, Pa.	1917
Overhead Bridge Crane		
Capacity 50 ton Number 715	Manufactured by Northern Engineering Works, Detroit, Mich. This is the main powerhouse crane.	1907
Overhead Bridge Crane		
Capacity 20 ton	Manufactured by Reading Crane & Hoist Works, Reading, Pa. The crane is located in the area over the Motor Generator sets	1907

EQUIPMENT (Continued)	REMARKS	DATE OF MANUFACTURE OR INSTALLATION
Small Electric Crane		
Capacity 1 ton M 1210 Frame 25	Manufacturer Budget	1955
Step Bearing Oil Pressure Balance Weight Alarm		
Set at 950 psi.	Manufacturer unknown.	1907
Simplex Water Meter		
Meter Scale measures in 100,000 lbs per hour at 70 F.	Manufactured by Simplex Valve and Meter Company, Philadelphia, Pa. This meter is a valuable antique.	1907
Per Cent Carbon Dioxide (CO_2) Wall Mounted Meter		
0 to 20% Scale Multi Point type	Used to monitor Boiler Combustion, Manufactured by Leeds & Northrup Company, Philadelphia, Pa.	1907
Panels		
The two panels (one for Turbo Generator Number 1 and the other for Turbo Generator Number 2), have solid brass gauges. One gauge for 1st stage pressure, one gauge for Steam Supply pressure, one gauge for step bearing oil pressure, one gauge for vacuum. The panel for Unit Number 1 has a frequency indicator mounted at the top. It may be used to monitor either unit's frequency.	4 Gauges were manufactured by General Electric Company. The frequency indicator was manufactured by James G. Biddle, Philadelphia, Pa.	1907 & 1908

EQUIPMENT (Continued)	REMARKS	DATE OF MANUFACTURE OR INSTALLATION
<u>Panel</u>		
Turbo-generator Unit Number 3 2 brass hydraulic pressure gauges, 0-2000 psi.	Ashcraft	1917
1 Brass steam gauge, 0-260 psi.. .	Syracuse Gauge	1917
1 Aston Brass Gauge	Aston	1917
<u>Telephones</u> (Antique)		
Hand crank type.	There are 4 or more units, one located in the pump house and at least 3 located in the plant. Manufacturer unknown	
<u>Fuel Oil Transfer Pump (Duplex)</u>		
2 Cylinder reciprocating type Electric Motor Driven	Manufactured by Fairbanks Morse Company. (ca. 1910) Brought in from Lake Union Plant	1953
<u>Motor Generator Set No. 2</u>		
Continuous current Generator No. 159471 Type MP Class 8-500-514 Form H Amperes - 833 Speed - 514 RPM Volts 600	Manufactured by General Electric Company, Schenectady, N.Y.	1907
Snychronous Motor Number 161143 Type ATI Class 14-530-514 Form C H Power - 700	Manufactured by General Electric Company, Schenectady, N.Y. Approx. Mfg. 1906	1907

EQUIPMENT	REMARKS	DATE OF MANUFACTURE OR INSTALLATION
<u>Motor Generator Set No. 2</u> (Continued)		
Speed 514 Volts 13,200 Amp 28.8 Cycles 60		
<u>Exciter No. 2</u>		
Motor Generator Set Continuous Current Generator Number 140447 Form B KW-120 Amperes 960 Speed 600 Volts 125	Manufactured by General Electric Company, Schenectady, N.Y. Approx. Manufacture 1906	1907
Induction Motor Model No. 14070 Type 10-17-12-175-600 Form K Volts 280 Amps 40 Number 161679 HP 75 Speed 580 2 Phase	Manufactured by General Electric Company, Schenectady, N.Y. Approx. Manufacture 1906	1907
<u>Direct Current Generator</u>		
No. 1201823 Type MPC - 6-200-1200 Form L Amps 1600 Volts 125 Speed 1200 RPM [illegible] KW Nominal	Manufactured by General Electric Co., Schenectady, N.Y.	1917

EQUIPMENT	REMARKS	DATE OF MANUFACTURE OR INSTALLATION
Direct Current Generator (Continued)		
Steam Turbine Drive Number 56684 Speed 3600 RPM Steam Pressure 200 psig With DeLaval Speed Reducer	Manufactured by DeLaval Steam Turbine Co., Trenton, N.Y.	1917
Exciter No. 1		
Generator No 78345 Volts 120 Amperes 125 RPM 1130	Manufactured by Allis Chalmers Company, Milwaukee, Wis.	1907
Electric Motor Number 78346 HP 22.5 Volts 220 Amps 55 3 Phase Frequency 60 H_z RPM 11,300	Manufactured by Allis Chalmers Company, Milwaukee, Wis.	1907
River Pumps		
20" Size 13,500 Gallons per Minute 85 Feet Head 690 RPM Type S Pump #1, Style A, Serial No. 1498 Pump #2, Style B, Serial No. 1497	The two pumps are in the pumphouse located on the Duwamish River. The pumps were manufactured by Allis Chalmers. The pumps are each driven by a 400 HP electric motor. The motors are type IQ, Form K, 2200 volt, 2 phase, manufactured by General Electric Company.	ca. 1935
Floor Mounted Drill Press		
Antique, Belt Driven Type	Manufactured by Champion Company.	ca. 1907

EQUIPMENT (Continued)	REMARKS	DATE OF MANUFACTUR OR INSTALLATION
Bristol Recorders		
Panel mounted Antique type (vacuum gauge)	Manufactured by Bristol Company, Waterbury, Conn.	ca. 1907 & 1918
Large Master Gauge		
Approx. 2 feet in diameter Range 150 to 210 psi. Brass construction	Manufactured by Ashton. This is an antique	1906
Air Raid Siren		
World War II model Roof Mounted Engine Driven	Engine manufactured by Chrysler. Siren manufactured by American Blower Co.	ca. 1941

ADDENDUM TO
GEORGETOWN STEAM PLANT
King County Airport
Seattle
King County
Washington

HAER No. WA-1

HAER
WASH
17-SEAT
2-

XEROGRAPHIC COPIES OF COLOR TRANSPARENCIES

HISTORIC AMERICAN ENGINEERING RECORD
National Park Service
1849 C. St. NW
Washington, DC 20240

THE GEORGETOWN STEAM PLANT IS A STEAM-DRIVEN ELECTRICAL GENERATING STATION DESIGNED BY STONE & WEBSTER ENGINEERING CORP. THE PLANT WAS BUILT BY THE SEATTLE ELECTRIC COMPANY IN 1906. THE STRUCTURE CONTAINS SIXTEEN 300 HORSEPOWER STIRLING BOILERS WHICH SUPPLY STEAM TO TWO VERTICAL TURBINES. THE SMALLER 1906 UNIT GENERATES 3000 KILOWATTS AND A LARGER 1907 UNIT GENERATES 8000 KILOWATTS. IN 1917 SEATTLE ELECTRIC INSTALLED A 10000 KILOWATT HORIZONTAL TURBINE GENERATOR UNIT MANUFACTURED BY THE GENERAL ELECTRIC COMPANY.

THE GEORGETOWN STEAM PLANT WAS USED PRIMARILY AS A STANDBY AND PEAKING FACILITY. IT PROVIDED ALTERNATING CURRENT FOR GENERAL USE AND DIRECT CURRENT FOR THE SEATTLE STREETCAR SYSTEM. IT IS THE LAST OPERATIVE EXAMPLE OF VERTICAL CURTIS TURBINES IN THE UNITED STATES.

THIS RECORDING PROJECT IS PART OF THE HISTORIC AMERICAN ENGINEERING RECORD (HAER), A LONG-RANGE PROGRAM TO DOCUMENT HISTORICALLY SIGNIFICANT ENGINEERING AND INDUSTRIAL WORKS IN THE UNITED STATES. THE HAER PROGRAM IS A DIVISION OF THE NATIONAL PARK SERVICE, U.S. DEPARTMENT OF THE INTERIOR. THE GEORGETOWN STEAM PLANT RECORDING PROJECT WAS COSPONSORED DURING THE SUMMER OF 1979 BY THE HISTORIC AMERICAN ENGINEERING RECORD, AND BY SEATTLE CITY LIGHT.

THE FIELD WORK, MEASURED DRAWINGS, HISTORICAL REPORTS, AND PHOTOGRAPHS WERE PREPARED UNDER THE DIRECTION OF T. ALLAN COMP, PH.D., CHIEF, CULTURAL RESOURCES, PACIFIC NORTHWEST REGION, NATIONAL PARK SERVICE. THE RECORDING TEAM CONSISTED OF STEPHEN P. LUBAR, ASSISTANT HISTORIAN; BARRY A. RICHARDS, ARCHITECTURAL SUPERVISOR; YOSHIHIRO KOYAMA, ARCHITECTURAL DELINEATOR. FORMAL PHOTOGRAPHY WAS DONE BY JET LOWE.

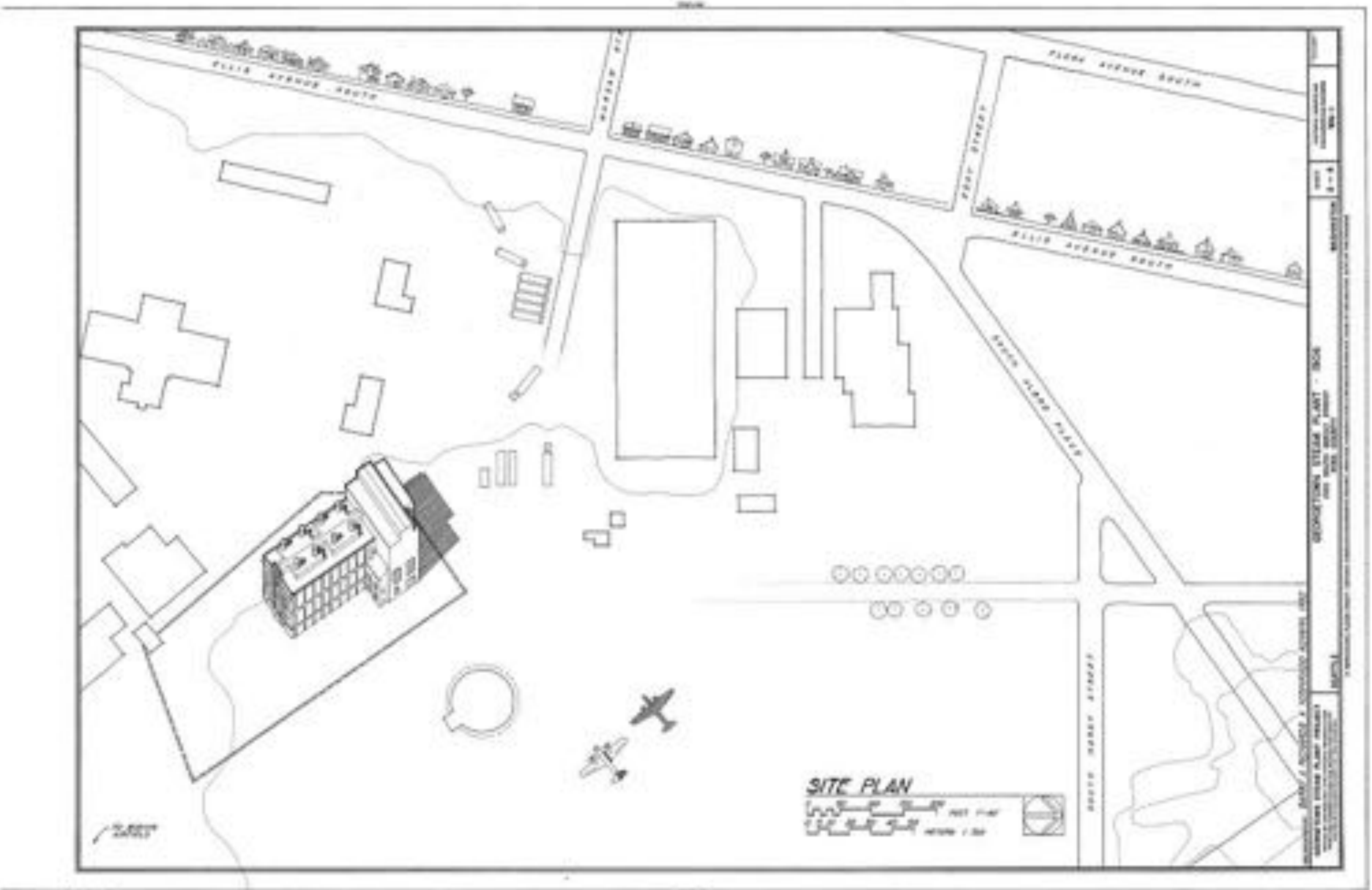
LOCATION MAP

Based on Rand McNally & Co. 1981 Seattle Street Map

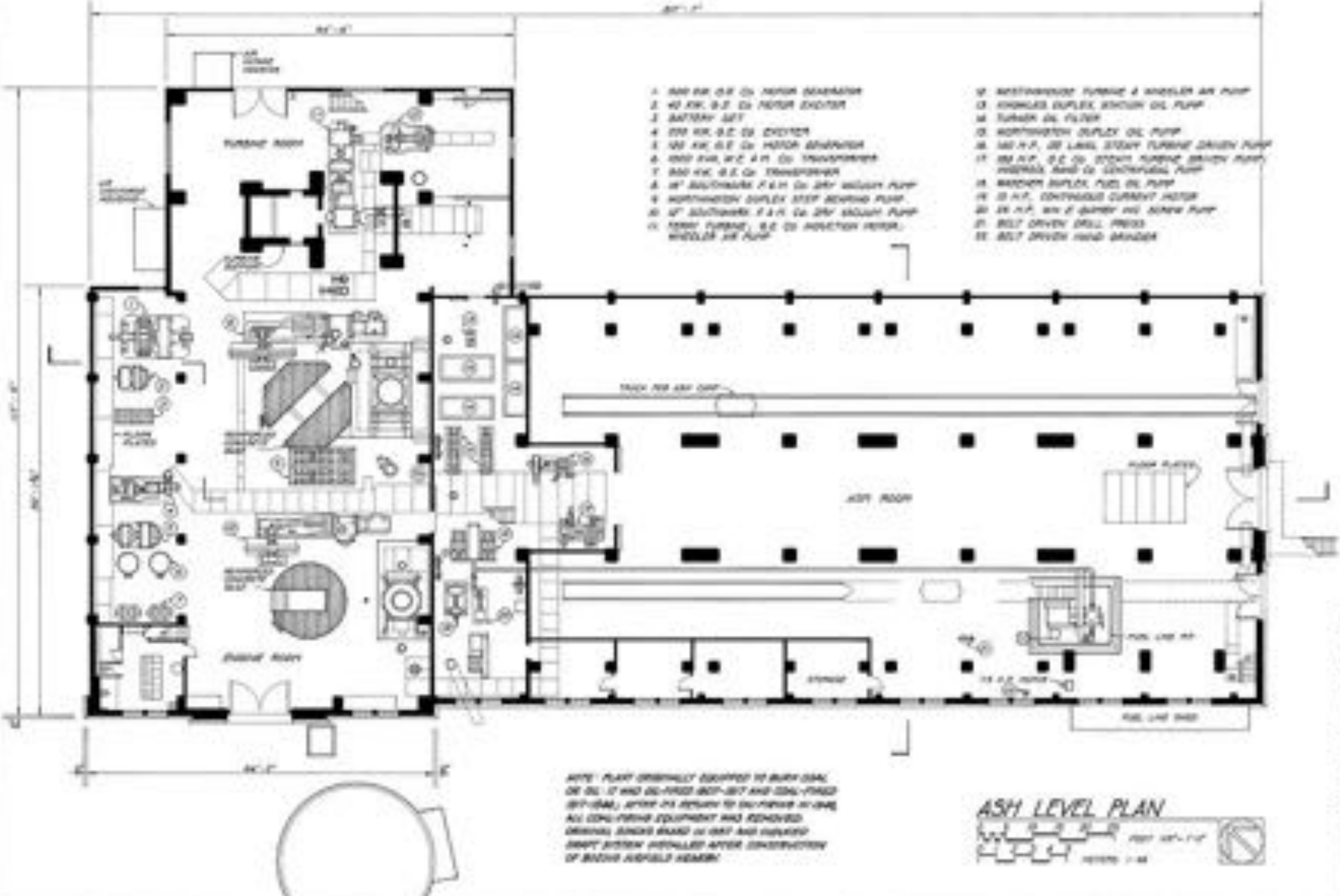
GEORGETOWN
STEAM PLANT
SEATTLE, WASHINGTON

GEORGETOWN STEAM PLANT · 1906

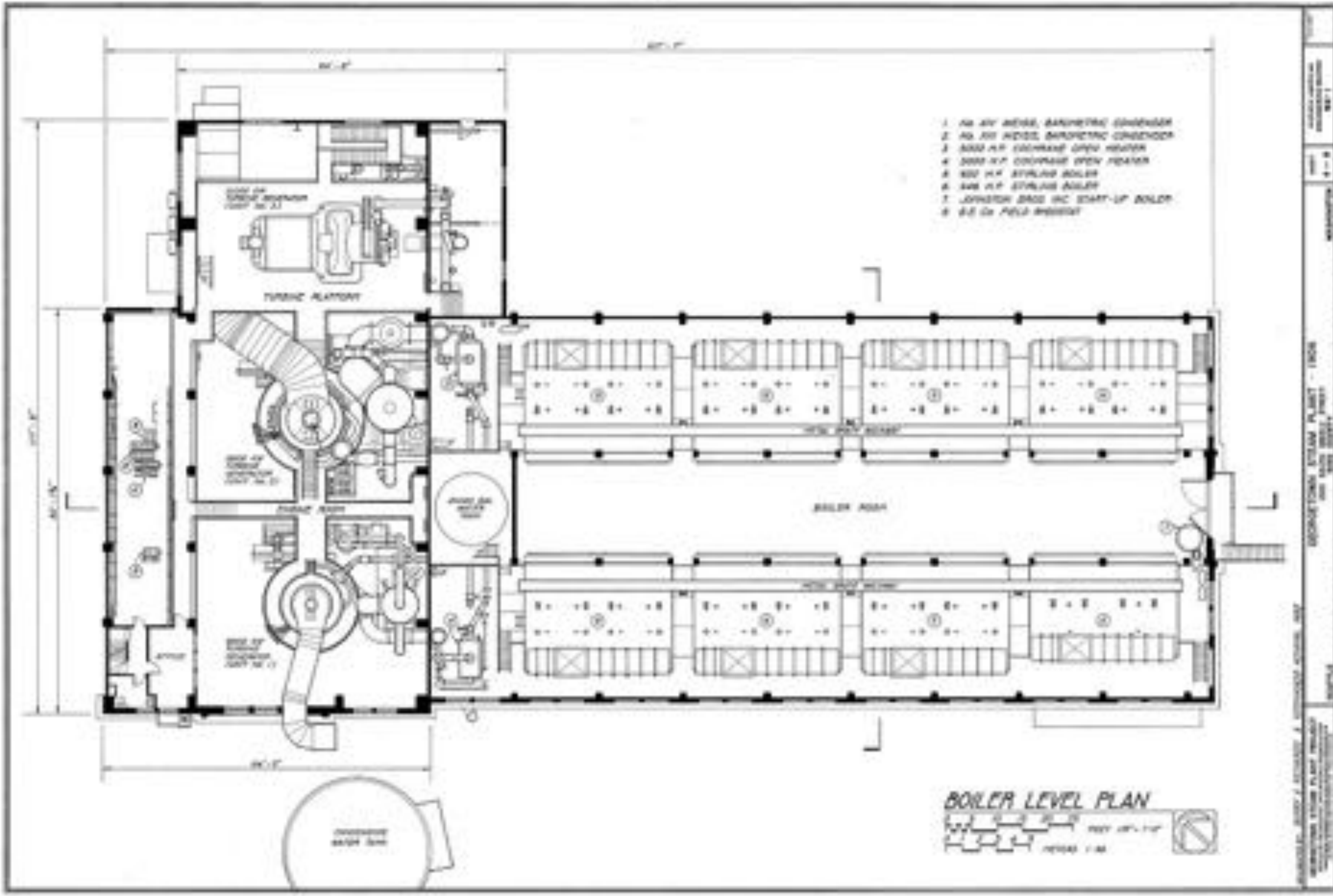
SEATTLE · WASHINGTON

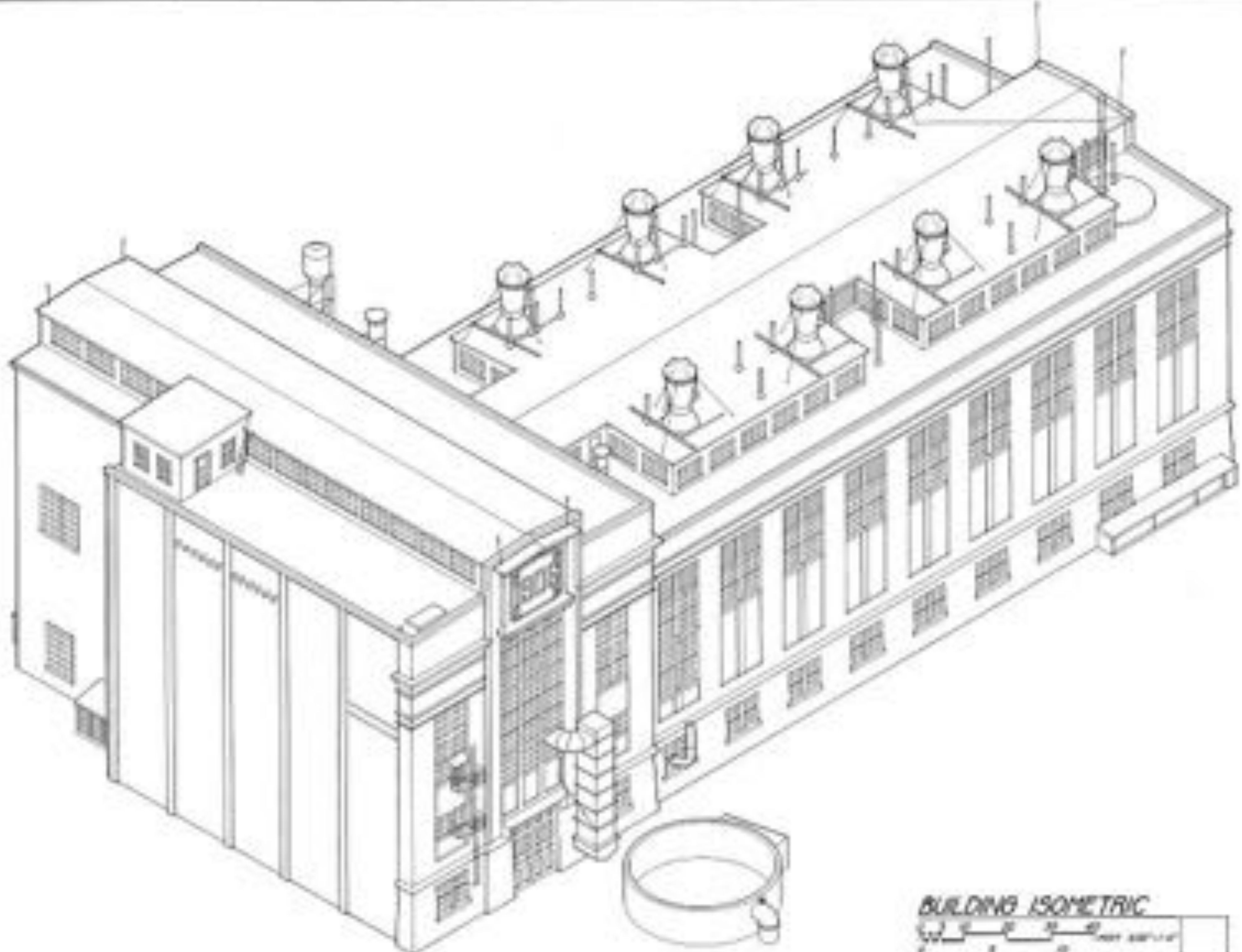


ELLIS AVENUE SOUTH
FLORA AVENUE SOUTH
SOUTH ALBRO PLACE
SITE PLAN
GEORGETOWN STEAM PLANT · 1906



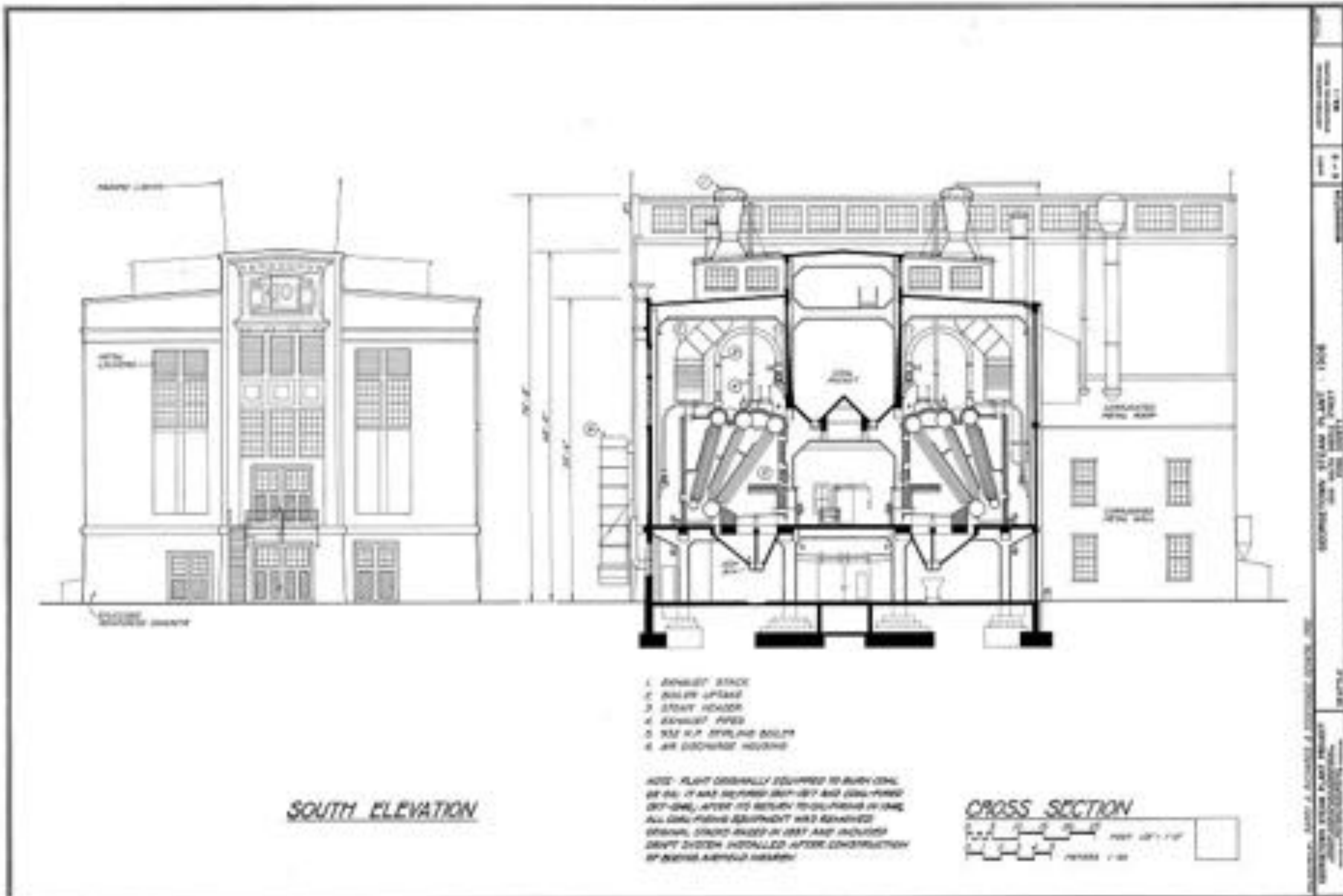
ASH LEVEL PLAN

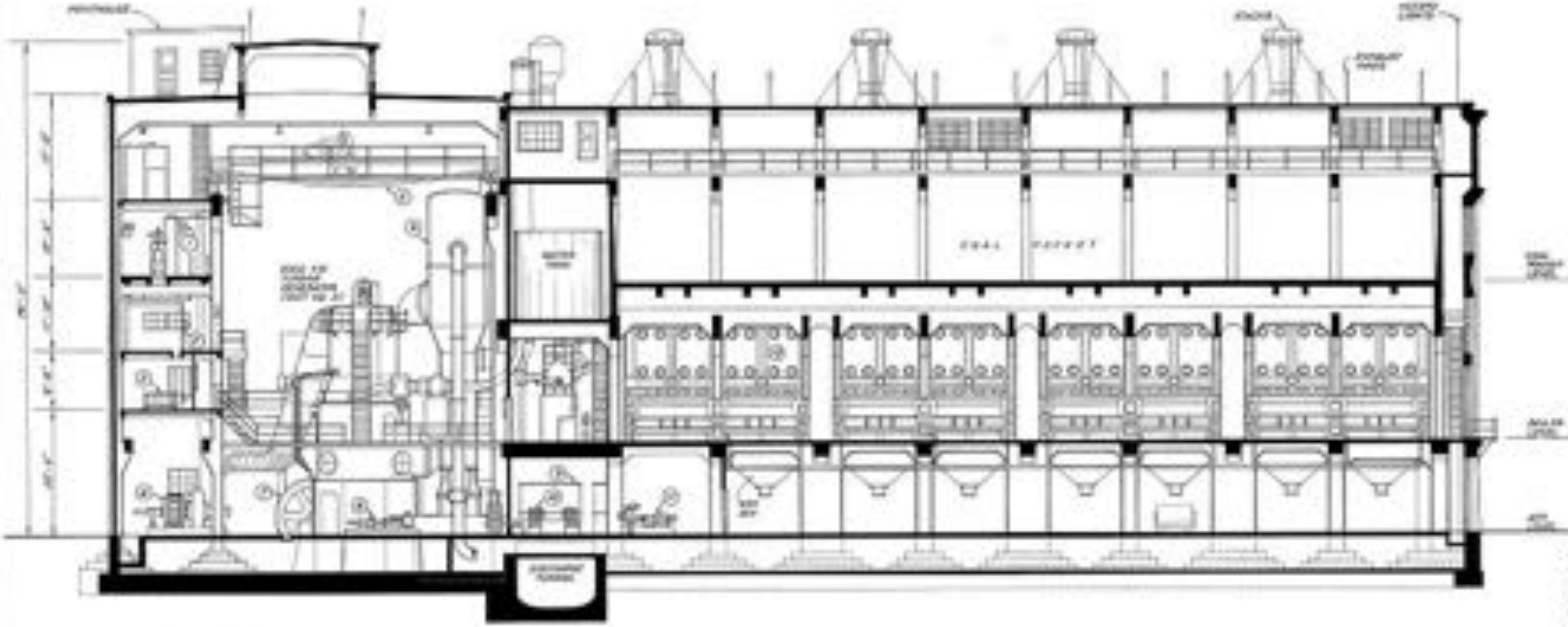

1. No. XIV WEISS, BAROMETRIC CONDENSER
2. No. XIII WEISS, BAROMETRIC CONDENSER
3. 3000 H.P. COCHRANE OPEN HEATER
4. 3000 H.P. COCHRANE OPEN HEATER
5. 600 H.P. STIRLING BOILER
6. 446 H.P. STIRLING BOILER
7. JOHNSTON BROS INC START-UP BOILER
8. G.E. Co. FIELD RHEOSTAT
TURBINE PLATFORM
BOILER ROOM
BOILER LEVEL PLAN
GEORGETOWN STEAM PLANT - 1906



BUILDING ISOMETRIC

GEORGETOWN STEAM PLANT


SOUTH ELEVATION
CROSS SECTION
1. EXHAUST STACK
2. BOILER UPTAKE
3. STEAM HEADER
4. EXHAUST PIPES
5. 532 H.P. STIRLING BOILER
6. AIR DISCHARGE HOUSING

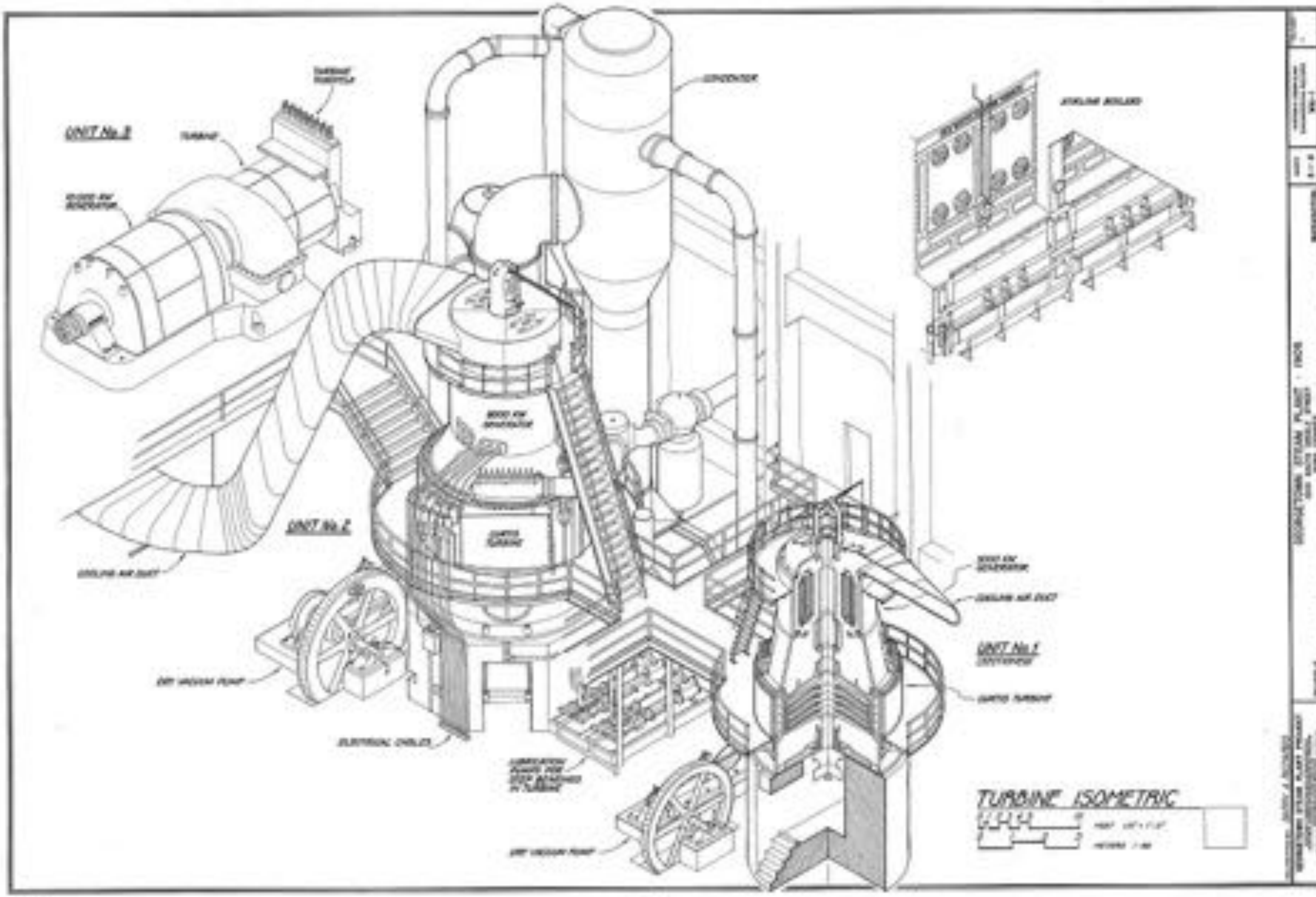


1 OIL SWITCH
2 SWITCHBOARD
3 G.E. Co. FIELD RHEOSTAT
4 500 KW. G.E. Co. MOTOR GENERATOR
5 30 TON CRANE
6 No. 6V WEISS BAROMETRIC CONDENSER
7 18" SOUTHWARK F & M. Co. DRY VACUUM PUMP
8 WORTHINGTON DUPLEX BOOT BEARING PUMP
9 TURBINE OIL FILTER
10 WORTHINGTON DUPLEX OIL PUMP
11 140 H.P. DE LAVAL STEAM TURBINE DRIVEN PUMP
12 3000 H.P. COCHRANE OPEN HEATER
13 532 H.P. STIRLING BOILER

NOTE- PLANT ORIGINALLY EQUIPPED TO BURN COAL OR OIL: IT WAS OIL-FIRED 1907-1917 AND COAL-FIRED 1917-1968; AFTER ITS RETURN TO OIL-FIRING IN 1968, ALL COAL-FIRING EQUIPMENT WAS REMOVED. ORIGINAL STACKS RAZED IN 1937 AND INDUCED DRAFT SYSTEM INSTALLED AFTER CONSTRUCTION OF BUCHAN AIRFIELD NEARBY.

LONGITUDINAL SECTION

FEET 1/8" = 1'-0"
METERS 1:96


TURBINE ISOMETRIC

APPENDIX E
RELEVANT TECHNICAL PRESERVATION BRIEFS

1 PRESERVATION BRIEFS

Assessing Cleaning and Water-Repellent Treatments for Historic Masonry Buildings

Robert C. Mack, AIA
Anne Grimmer

U.S. Department of the Interior
National Park Service
Cultural Resources
Heritage Preservation Services

Inappropriate cleaning and coating treatments are a major cause of damage to historic masonry buildings. While either or both treatments may be appropriate in some cases, they can be very destructive to historic masonry if they are not selected carefully. Historic masonry, as considered here, includes stone, brick, architectural terra cotta, cast stone, concrete and concrete block. It is frequently cleaned because cleaning is equated with improvement. Cleaning may sometimes be followed by the application of a water-repellent coating. However, unless these procedures are carried out under the guidance and supervision of an architectural conservator, they may result in irrevocable damage to the historic resource.

The purpose of this Brief is to provide information on the variety of cleaning methods and materials that are available for use on the *exterior* of historic masonry buildings, and to provide guidance in selecting the most appropriate method or combination of methods. The difference between water-repellent coatings and waterproof coatings is explained, and the purpose of each, the suitability of their application to historic masonry buildings, and the possible consequences of their inappropriate use are discussed.

The Brief is intended to help develop sensitivity to the qualities of historic masonry that makes it so special, and to assist historic building owners and property managers in working cooperatively with architects, architectural conservators and contractors (Fig. 1). Although specifically intended for historic buildings, the information is applicable to all masonry buildings. This publication updates and expands *Preservation Brief 1: The Cleaning and Waterproof Coating of Masonry Buildings*. The Brief is not meant to be a cleaning manual or a guide for preparing specifications. Rather, it provides general information to raise awareness of the many factors involved in selecting cleaning and water-repellent treatments for historic masonry buildings.

Figure 1. Low- to medium-pressure steam (hot pressurized water washing), is being used to clean the exterior of the U.S. Tariff Commission Building, the first marble building constructed in Washington, D.C., in 1839. This method was selected by an architectural conservator as the "gentlest means possible" to clean the marble. Steam can soften heavy soiling deposits such as those on the cornice and column capitals, and facilitate easy removal. Note how these deposits have been removed from the right side of the cornice which has already been cleaned.

Figure 2. Biological growth as shown on this marble foundation can usually be removed using a low-pressure water wash, possibly with a non-ionic detergent added to it, and scrubbing with a natural or synthetic bristle brush.

Figure 3. This small test area has revealed a red brick patch that does not match the original beige brick. This may explain why the building was painted, and may suggest to the owner that it may be preferable to keep it painted.

Preparing for a Cleaning Project

Reasons for cleaning. First, it is important to determine whether it is appropriate to clean the masonry. The objective of cleaning a historic masonry building must be considered carefully before arriving at a decision to clean. There are several major reasons for cleaning a historic masonry building: **improve the appearance of the building** by removing unattractive dirt or soiling materials, or non-historic paint from the masonry; **retard deterioration** by removing soiling materials that may be damaging the masonry; or **provide a clean surface** to accurately match repointing mortars or patching compounds, or to conduct a condition survey of the masonry.

Identify what is to be removed. The general nature and source of dirt or soiling material on a building must be identified to remove it in the *gentlest means possible* — that is, in the most effective, yet least harmful, manner. Soot and smoke, for example, require a different cleaning agent to remove than oil stains or metallic stains. Other common cleaning problems include biological growth such as mold or mildew, and organic matter such as the tendrils left on masonry after removal of ivy (Fig. 2).

Consider the historic appearance of the building. If the proposed cleaning is to remove paint, it is important in each case to learn whether or not unpainted masonry is historically appropriate. And, it is necessary to consider why the building was painted (Fig. 3). Was it to cover bad repointing or unmatched repairs? Was the building painted to protect soft brick or to conceal deteriorating stone? Or, was painted masonry simply a fashionable treatment in a particular historic period? Many buildings were painted at the time of construction or shortly thereafter; retention of the paint, therefore, may be more appropriate historically than removing it. And, if the building appears to have been painted for a long time, it is also important to think about whether the paint is part of the character of the historic building and if it has acquired significance over time.

Consider the practicalities of cleaning or paint removal. Some gypsum or sulfate crusts may have become integral with the stone and, if cleaning could result in removing some of the stone surface, it may be preferable not to clean. Even where unpainted masonry is appropriate, the retention of the paint may be more practical than removal in terms of long range preservation of the masonry. In some cases, however, removal of the paint may be desirable. For example, the old paint layers may have built up to such an extent that removal is necessary to ensure a sound surface to which the new paint will adhere.

Study the masonry. Although not always necessary, in some instances it can be beneficial to have the coating or paint type, color, and layering on the masonry researched before attempting its removal. Analysis of the nature of the soiling or of the paint to be removed from the masonry, as well as guidance on the appropriate cleaning method, may be provided by professional consultants, including architectural conservators, conservation scientists and preservation architects. The State Historic Preservation Office (SHPO), local historic district commissions, architectural review boards and preservation-oriented websites may also be able to supply useful information on masonry cleaning techniques.

Understanding the Building Materials

The construction of the building must be considered when developing a cleaning program because inappropriate cleaning can have a deleterious effect on the masonry as well as on other building materials. The *masonry* material or materials must be correctly identified. It is sometimes difficult to distinguish one type of stone from another; for example, certain sandstones can be easily confused with limestones. Or, what appears to be natural stone may not be stone at all, but cast stone or concrete. Historically, cast stone and architectural terra cotta were frequently used in combination with natural stone, especially for trim elements or on upper stories of a building where, from a distance, these substitute materials looked like real stone (Fig. 4). Other features on historic buildings that appear to be stone, such as decorative cornices, entablatures and window hoods, may not even be masonry, but metal.

Identify prior treatments. Previous treatments of the building and its surroundings should be researched and building maintenance records should be obtained, if available. Sometimes if streaked or spotty areas do not seem to get cleaner following an initial cleaning, closer inspection and analysis may be warranted. The discoloration may turn out not to be dirt but the remnant of a water-repellent coating applied long ago which has darkened the surface of the masonry over time (Fig. 5). Successful removal may require testing several cleaning agents to find something that will dissolve and remove the coating. Complete removal may not always be possible. Repairs may have been stained to match a dirty building, and cleaning may make these differences apparent. De-icing salts used near the building that have dissolved can

Figure 4. The foundation of this brick building is limestone, but the decorative trim above is architectural terra cotta intended to simulate stone.

Figure 5. Repeated water washing did not remove the staining inside this limestone porte cochere. Upon closer examination, it was determined to be a water-repellent coating that had been applied many years earlier. An alkaline cleaner may be effective in removing it.

migrate into the masonry. Cleaning may draw the salts to the surface, where they will appear as efflorescence (a powdery, white substance), which may require a second treatment to be removed. Allowances for dealing with such unknown factors, any of which can be a potential problem, should be included when investigating cleaning methods and materials. Just as more than one kind of masonry on a historic building may necessitate multiple cleaning approaches, unknown conditions that are encountered may also require additional cleaning treatments.

Choose the appropriate cleaner. The importance of testing cleaning methods and materials cannot be over emphasized. Applying the wrong cleaning agents to historic masonry can have disastrous results. Acidic cleaners can be extremely damaging to acid-sensitive stones, such as marble and limestone, resulting in etching and dissolution of these stones. Other kinds of masonry can also be damaged by incompatible cleaning agents, or even by cleaning agents that are usually compatible. There are also numerous kinds of sandstone, each with a considerably different geological composition. While an acid-based cleaner may be safely used on some sandstones, others are acid-sensitive and can be severely etched or dissolved by an acid cleaner. Some sandstones contain water-soluble minerals and can be eroded by water cleaning. And, even if the stone type is correctly identified, stones, as well as some bricks, may contain unexpected impurities, such as iron particles, that may react negatively with a particular cleaning agent and result in staining. Thorough understanding of the physical and chemical properties of the masonry will help avoid the inadvertent selection of damaging cleaning agents.

Figure 6. Timed water soaking can be very effective for cleaning limestone and marble as shown here at the Marble Collegiate Church in New York City. In this case, a twelve-hour water soak using a multi-nozzle manifold was followed by a final water rinse. Photo: Diane S. Kaese, Wiss, Janney, Elstner Associates, Inc., N.Y., N.Y.

Other building materials also may be affected by the cleaning process. Some chemicals, for example, may have a corrosive effect on paint or glass. The portions of building elements most vulnerable to deterioration may not be visible, such as embedded ends of iron window bars. Other totally unseen items, such as iron cramps or ties which hold the masonry to the structural frame, also may be subject to corrosion from the use of chemicals or even from plain water. The only way to prevent problems in these cases is to study the building construction in detail and evaluate proposed cleaning methods with this information in mind. However, due to the very likely possibility of encountering unknown factors, any cleaning project involving historic masonry should be viewed as unique to that particular building.

Cleaning Methods and Materials

Masonry cleaning methods generally are divided into three major groups: water, chemical, and abrasive. *Water methods* soften the dirt or soiling material and rinse the deposits from the masonry surface. *Chemical cleaners* react with dirt, soiling material or paint to effect their removal, after which the cleaning effluent is rinsed off the masonry surface with water. *Abrasive methods* include blasting with grit, and the use of grinders and sanding discs, all of which mechanically remove the dirt, soiling material or paint (and, usually, some of the masonry surface). Abrasive cleaning is also often followed with a water rinse. *Laser cleaning*, although not discussed here in detail, is another technique that is used sometimes by conservators to clean small areas of historic masonry. It can be quite effective for cleaning limited areas, but it is expensive and generally not practical for most historic masonry cleaning projects.

Although it may seem contrary to common sense, masonry cleaning projects should be carried out starting at the bottom and proceeding to the top of the building always keeping all surfaces wet below the area being cleaned. The rationale for this approach is based on the principle that dirty water or cleaning effluent dripping from cleaning in progress above will leave streaks on a dirty surface but will not streak a clean surface as long as it is kept wet and rinsed frequently.

Water Cleaning

Water cleaning methods are generally the *gentlest means possible*, and they can be used safely to remove dirt from all types of historic masonry.* There are essentially four kinds of water-based methods: soaking; pressure water washing; water washing supplemented with non-ionic detergent; and steam, or hot-pressurized water cleaning. Once water cleaning has been completed, it is often necessary to follow up with a water rinse to wash off the loosened soiling material from the masonry.

Soaking. Prolonged spraying or misting with water is particularly effective for cleaning limestone and marble. It is also a good method for removing heavy accumulations of soot, sulfate crusts or gypsum crusts that tend to form in protected areas of a building not regularly washed by rain. Water is distributed to lengths of punctured hose or pipe with non-ferrous fittings hung from moveable scaffolding or a swing stage that continuously mists the surface of the masonry with a very fine spray (Fig. 6). A timed on-off spray is another approach to using this cleaning technique. After one area has been cleaned, the apparatus is moved on to another. Soaking is often used in combination with water washing and is also followed by a final water rinse. Soaking is a very slow method — it may take several days or a week—but it is a very gentle method to use on historic masonry.

Water Washing. Washing with low-pressure or medium-pressure water is probably one of the most commonly used methods for removing dirt or other pollutant soiling from historic masonry buildings (Fig. 7). Starting with a very low pressure (100 psi or below), even using a garden hose, and progressing as needed to slightly higher pressure—generally no higher than 300-400 psi—is always the recommended way to begin. Scrubbing with natural bristle or synthetic bristle brushes—never metal which can abrade the surface and leave metal particles that can stain the masonry—can help in cleaning areas of the masonry that are especially dirty.

Water Washing with Detergents. Non-ionic detergents—which are not the same as soaps—are synthetic organic compounds that are especially effective in removing oily soil. (Examples of some of the numerous proprietary non-ionic detergents include Igepal by GAF, Tergitol by Union Carbide and Triton by Rohm & Haas.) Thus, the addition of a non-ionic detergent, or surfactant, to a low- or medium-pressure water wash can be a useful aid in the cleaning

*Water cleaning methods may not be appropriate to use on some badly deteriorated masonry because water may exacerbate the deterioration, or on gypsum or alabaster which are very soluble in water.

process. (A non-ionic detergent, unlike most household detergents, does not leave a solid, visible residue on the masonry.) Adding a non-ionic detergent and scrubbing with a natural bristle or synthetic bristle brush can facilitate cleaning textured or intricately carved masonry. This should be followed with a final water rinse.

Steam/Hot-Pressurized Water Cleaning. Steam cleaning is actually low-pressure hot water washing because the steam condenses almost immediately upon leaving the hose. This is a gentle and effective method for cleaning stone and particularly for acid-sensitive stones. Steam can be especially useful in removing built-up soiling deposits and dried-up plant materials, such as ivy disks and tendrils. It can also be an efficient means of cleaning carved stone details and, because it does not generate a lot of liquid water, it can sometimes be appropriate to use for cleaning interior masonry (Figs. 8-9).

Potential hazards of water cleaning. Despite the fact that water-based methods are generally the most gentle, even they can be damaging to historic masonry. Before beginning a water cleaning project, it is important to make sure that all mortar joints are sound and that the building is watertight. Otherwise water can seep through the walls to the interior, resulting in rusting metal anchors and stained and ruined plaster.

Some water supplies may contain traces of iron and copper which may cause masonry to discolor. Adding a chelating or complexing agent to the water, such as EDTA (ethylene diamine tetra-acetic acid), which inactivates other metallic ions, as well as softens minerals and water hardness, will help prevent staining on light-colored masonry.

Any cleaning method involving water should never be done in cold weather or if there is any likelihood of frost or freezing because water within the masonry can freeze, causing spalling and cracking. Since a masonry wall may take over a week to dry after cleaning, no water cleaning should be permitted for several days prior to the first average frost date, or even earlier if local forecasts predict cold weather.

Most essential of all, it is important to be aware that using water at too high a pressure, a practice common to "power washing" and "water blasting", is very abrasive and can easily etch marble and other soft stones, as well as some types of brick (Figs. 10-11). In addition, the distance of the nozzle from the masonry surface and the type of nozzle, as well as gallons per minute (gpm), are also important variables in a water cleaning process that can have a significant impact on the outcome of the project. This is why it is imperative that the cleaning be closely monitored to ensure that the cleaning operators do not raise the pressure or bring the nozzle too close to the masonry in an effort to "speed up" the process. The appearance of grains of stone or sand in the cleaning effluent on the ground is an indication that the water pressure may be too high.

Figure 7. Glazed architectural terra cotta often may be cleaned successfully with a low-pressure water wash and hand scrubbing supplemented, if necessary, with a non-ionic detergent. Photo: National Park Service Files.

Chemical Cleaning

Chemical cleaners, generally in the form of proprietary products, are another material frequently used to clean historic masonry. They can remove dirt, as well as paint and other coatings, metallic and plant stains, and graffiti. Chemical cleaners used to remove dirt and soiling include **acids**, **alkalies** and **organic compounds.** Acidic cleaners, of course, should not be used on masonry that is acid sensitive. Paint removers are **alkaline**, based on **organic solvents** or other chemicals.

Chemical Cleaners to Remove Dirt

Both alkaline and acidic cleaning treatments include the use of water. Both cleaners are also likely to contain surfactants (wetting agents), that facilitate the chemical reaction that removes the dirt. Generally, the masonry is wet first for both types of cleaners, then the chemical cleaner is sprayed on at very low pressure or brushed onto the surface. The cleaner is left to dwell on the masonry for an amount of time recommended by the product manufacturer or, preferably, determined by testing, and rinsed off with a low- or moderate-pressure cold, or sometimes hot, water wash. More than one application of the cleaner may be necessary, and it is always a good practice to test the product manufacturer's recommendations concerning dilution rates and dwell times. Because each cleaning situation is unique, dilution rates and dwell times can vary considerably. The masonry surface may be scrubbed lightly with natural or synthetic bristle brushes prior to rinsing. After rinsing, pH strips should be applied to the surface to ensure that the masonry has been neutralized completely.

Figure 8. (Left) Low-pressure (under 100 psi) steam cleaning (hot pressurized water washing), is part of the regular maintenance program at the Jefferson Memorial, Washington, D.C. The white marble interior of this open structure is subject to constant soiling by birds, insects and visitors. (Right) This portable steam cleaner enables prompt cleanup when necessary. Photos: National Park Service Files.

Acidic Cleaners. Acid-based cleaning products may be used on **non-acid sensitive** masonry, which generally includes: granite, most sandstones, slate, unglazed brick and unglazed architectural terra cotta, cast stone and concrete (Fig. 12). Most commercial acidic cleaners are composed primarily of hydrofluoric acid, and often include some phosphoric acid to prevent rust-like stains from developing on the masonry after the cleaning. Acid cleaners are applied to the pre-wet masonry which should be kept wet while the acid is allowed to "work", and then removed with a water wash.

Alkaline Cleaners. Alkaline cleaners should be used on **acid-sensitive** masonry, including: limestone, polished and unpolished marble, calcareous sandstone, glazed brick and glazed architectural terra cotta, and polished granite. (Alkaline cleaners may also be used sometimes on masonry materials that are not acid sensitive—after testing, of course—but they may not be as effective as they are on acid-sensitive masonry.) Alkaline cleaning products consist primarily of two ingredients: a non-ionic detergent or surfactant; and an alkali, such as potassium hydroxide or ammonium hydroxide. Like acidic cleaners, alkaline products are usually applied to pre-wet masonry, allowed to dwell, and then rinsed off with water. (Longer dwell times may be necessary with alkaline cleaners than with acidic cleaners.) Two additional steps are required to remove alkaline cleaners after the initial rinse. First the masonry is given a slightly acidic wash—often with acetic acid—to neutralize it, and then it is rinsed again with water.

Chemical Cleaners to Remove Paint and Other Coatings, Stains and Graffiti

Removing paint and some other coatings, stains and graffiti can best be accomplished with alkaline paint removers, organic solvent paint removers, or other cleaning compounds. The removal of layers of paint from a masonry surface usually involves applying the remover either by brush, roller or spraying, followed by a thorough water wash. As with any chemical cleaning, the manufacturer's recommendations regarding application procedures should always be tested before beginning work.

Alkaline Paint Removers. These are usually of much the same composition as other alkaline cleaners, containing potassium or ammonium hydroxide, or trisodium phosphate. They are used to remove oil, latex and acrylic paints, and are effective for removing multiple layers of paint. Alkaline cleaners may also remove some acrylic, water-repellent coatings. As with other alkaline cleaners, both an acidic neutralizing wash and a final water rinse are generally required following the use of alkaline paint removers.

Organic Solvent Paint Removers. The formulation of organic solvent paint removers varies and may include a combination of solvents, including methylene chloride, methanol, acetone, xylene and toluene.

Figure 9. (Left) This small steam cleaner—the size of a vacuum cleaner—offers a very controlled and gentle means of cleaning limited, or hard-to-reach areas or carved stone details. (Right) It is particularly useful for interiors where it is important to keep moisture to a minumum, such as inside the Washington Monument, Washington, D.C., where it was used to clean the commemorative stones. Photos: Audrey T. Tepper.

Figure 10. High-pressure water washing too close to the surface has abraded and, consequently, marred the limestone on this early-20th century building.

Figure 11. Rinsing with high-pressure water following chemical cleaning has left a horizontal line of abrasion across the bricks on this late-19th century row house.

Other Paint Removers and Cleaners. Other cleaning compounds that can be used to remove paint and some painted graffiti from historic masonry include paint removers based on N-methyl-2-pyrrolidone (NMP), or on petroleum-based compounds. Removing stains, whether they are industrial (smoke, soot, grease or tar), metallic (iron or copper), or biological (plant and fungal) in origin, depends on carefully matching the type of remover to the type of stain (Fig. 13). Successful removal of stains from historic masonry often requires the application of a number of different removers before the right one is found. The removal of layers of paint from a masonry surface is usually accomplished by applying the remover either by brush, roller or spraying, followed by a thorough water wash (Fig. 14).

Potential hazards of chemical cleaning. Since most chemical cleaning methods involve water, they have many of the potential problems of plain water cleaning. Like water methods, they should not be used in cold weather because of the possibility of freezing. Chemical cleaning should never be undertaken in temperatures below 40 degrees F (4 degrees C), and generally not below 50 degrees F. In addition, many chemical cleaners simply do not work in cold temperatures. Both acidic and alkaline cleaners can be dangerous to cleaning operators and, clearly, there are environmental concerns associated with the use of chemical cleaners.

If not carefully chosen, chemical cleaners can react adversely with many types of masonry. Obviously, acidic cleaners should not be used on acid-sensitive materials; however, it is not always clear exactly what the composition is of any stone or other masonry material. For, this reason, testing the cleaner on an inconspicuous spot on the building is always necessary. While certain acid-based cleaners may be appropriate if used as directed on a particular type of masonry, if left too long or if not adequately rinsed from the masonry they can have a negative effect. For example, hydrofluoric acid can etch masonry leaving a hazy residue (whitish deposits of silica or calcium fluoride salts) on the surface. While this efflorescence may usually be removed by a second cleaning—although it is likely to be expensive and time-consuming—**hydrofluoric acid** can also leave calcium fluoride salts or a colloidal silica deposit on masonry which may be impossible to remove (Fig. 15). Other acids, particularly **hydrochloric (muriatic) acid**, which is very powerful, should not be used on historic masonry, because it can dissolve lime-based mortar, damage brick and some stones, and leave chloride deposits on the masonry.

Figure 12. A mild acidic cleaning agent is being used to clean this heavily soiled brick and granite building. Additional applications of the cleaner and hand scrubbing, and even poulticing, may be necessary to remove the dark stains on the granite arches below. Photo: Sharon C. Park, FAIA.

Alkaline cleaners can stain sandstones that contain a ferrous compound. Before using an alkaline cleaner on sandstone it is always important to test it, since it may be difficult to know whether a particular sandstone may contain a ferrous compound. Some alkaline cleaners, such as **sodium hydroxide (caustic soda or lye)** and **ammonium bifluoride**, can also damage or leave disfiguring brownish-yellow stains and, in most cases, should not be used on historic masonry. Although alkaline cleaners will not etch a masonry surface as acids can, they are caustic and can burn the surface. In addition, alkaline cleaners can deposit potentially damaging salts in the masonry which can be difficult to rinse thoroughly.

Abrasive and Mechanical Cleaning

Generally, abrasive cleaning methods are not appropriate for use on historic masonry buildings. Abrasive cleaning methods are just that–abrasive. Grit blasters, grinders, and sanding discs all operate by *abrading* the dirt or paint off the surface of the masonry, rather than *reacting* with the dirt and the masonry which is how water and chemical methods work. Since the abrasives do not differentiate between the dirt and the masonry, they can also remove the outer surface of the masonry at the same time, and result in permanently damaging the masonry. Brick, architectural terra cotta, soft stone, detailed carvings, and polished surfaces are especially susceptible to physical and aesthetic damage by abrasive methods. Brick and architectural terra cotta are fired products which have a smooth, glazed surface which can be removed by abrasive blasting or grinding (Figs. 18-19). Abrasively-cleaned masonry is damaged aesthetically as well as physically, and it has a rough surface which tends to hold dirt and the roughness will make future cleaning more difficult. Abrasive cleaning processes can also increase the likelihood of subsurface cracking of the masonry. Abrasion of carved details causes a rounding of sharp corners and other loss of delicate features, while abrasion of polished surfaces removes the polished finish of stone.

Figure 13. Sometimes it may be preferable to paint over a thick asphaltic coating rather than try to remove it, because it can be difficult to remove completely. However, in this case, many layers of asphaltic coating were removed through multiple applications of a heavy duty chemical cleaner. Each application of the cleaner was left to dwell following the manufacturer's recommendations, and then rinsed thoroughly. (As much as possible of the asphalt was first removed with wooden scrapers.) Although not all the asphalt was removed, this was determined to be an acceptable level of cleanliness for the project.

Figure 14. Chemical removal of paint from this brick building has revealed that the cornice and window hoods are metal rather than masonry.

Mortar joints, especially those with lime mortar, also can be eroded by abrasive or mechanical cleaning. In some cases, the damage may be visual, such as loss of joint detail or increased joint shadows. As mortar joints constitute a significant portion of the masonry surface (up to 20 per cent in a brick wall), this can result in the loss of a considerable amount of the historic fabric. Erosion of the mortar joints may also permit increased water penetration, which will likely necessitate repointing.

Figure 15. The whitish deposits left on the brick by a chemical paint remover may have resulted from inadequate rinsing or from the chemical being left on the surface too long and may be impossible to remove.

Poulticing to Remove Stains and Graffiti


a


b


c


d

Figure 16. (a) The limestone base was heavily stained by runoff from the bronze statue above. (b) A poultice consisting of copper stain remover and ammonia mixed with fuller's earth was applied to the stone base and covered with plastic sheeting to keep it from drying out too quickly. (c) As the poultice dried, it pulled the stain out of the stone. (d) The poultice residue was removed carefully from the stone surface with wooden scrapers and the stone was rinsed with water. Photos: John Dugger.

Graffiti and stains, which have penetrated into the masonry, often are best removed by using a poultice. A poultice consists of an absorbent material or clay powder (such as kaolin or fuller's earth, or even shredded paper or paper towels), mixed with a liquid (solvent or other remover) to form a paste which is applied to the stain (Figs. 16-17). As it dries, the paste absorbs the staining material so that it is not redeposited on the masonry surface. Some commercial cleaning products and paint removers are specially formulated as a paste or gel that will cling to a vertical surface and remain moist for a longer period of time in order to prolong the action of the chemical on the stain. Pre-mixed poultices are also available as a paste or in powder form needing only the addition of the appropriate liquid. The masonry must be pre-wet before applying an alkaline cleaning agent, but not when using a solvent. Once the stain has been removed, the masonry must be rinsed thoroughly.

Figure 17. A poultice is being used to remove salts from the brownstone statuary on the facade of this late-19th century stone church. Photo: National Park Service Files.

Figure 18. The glazed bricks in the center of the pier were covered by a signboard that protected them being damaged by the sandblasting which removed the glaze from the surrounding bricks.

Figure 19. A comparison of undamaged bricks surrounding the electrical conduit with the rest of the brick facade emphasizes the severity of the erosion caused by sandblasting.

Abrasive Blasting. Blasting with abrasive grit or another abrasive material is the most frequently used abrasive method. *Sandblasting* is most commonly associated with abrasive cleaning. Finely ground silica or glass powder, glass beads, ground garnet, powdered walnut and other ground nut shells, grain hulls, aluminum oxide, plastic particles and even tiny pieces of sponge, are just a few of the other materials that have also been used for abrasive cleaning. Although abrasive blasting is not an appropriate method of cleaning historic masonry, it can be safely used to clean some materials. Finely-powdered walnut shells are commonly used for cleaning monumental bronze sculpture, and skilled conservators clean delicate museum objects and finely detailed, carved stone features with very small, micro-abrasive units using aluminum oxide.

A number of current approaches to abrasive blasting rely on materials that are not usually thought of as abrasive, and not as commonly associated with traditional abrasive grit cleaning. Some patented abrasive cleaning processes -- one dry, one wet --use finely-ground glass powder intended to "erase" or remove dirt and surface soiling only, but not paint or stains (Fig. 20). Cleaning with baking soda (sodium bicarbonate) is another patented process. Baking soda blasting is being used in some communities as a means of quick graffiti removal. However, it should not be used on historic masonry which it can easily abrade and can permanently "etch" the graffiti into the stone; it can also leave potentially damaging salts in the stone which cannot be removed. Most of these abrasive grits may be used either dry or wet, although dry grit tends to be used more frequently.

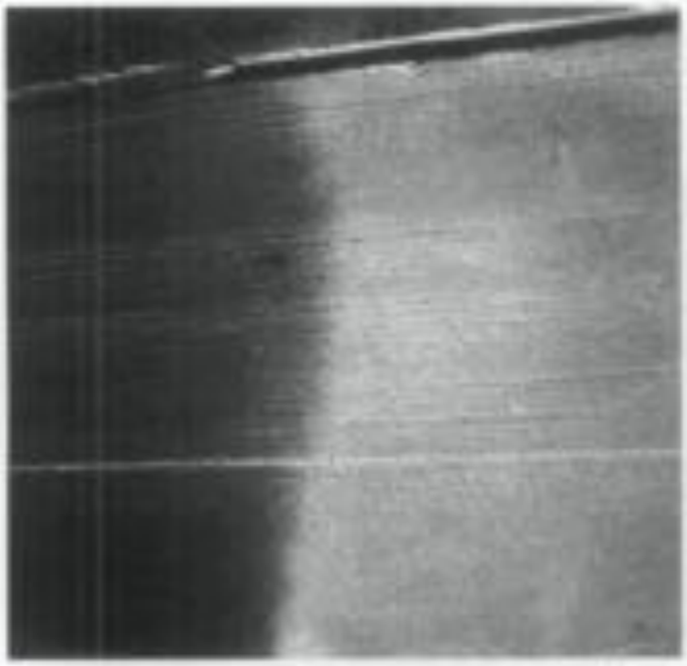


Figure 20. (Left) A comparison of the limestone surface of a 1920s office building before and after "cleaning" with a proprietary abrasive process using fine glass powder clearly shows the effectiveness of this method. But this is an abrasive technique and it has "cleaned" by removing part of the masonry surface with the dirt. Because it is abrasive, it is generally not recommended for large-scale cleaning of historic masonry, although it may be suitable to use in certain, very limited cases under controlled circumstances. (Right) A vacuum chamber where the used glass powder is collected for environmentally safe disposal is a unique feature of this particular process. The specially-trained operators in the chamber wear protective clothing, masks and breathing equipment. Photos: Tom Keohan.

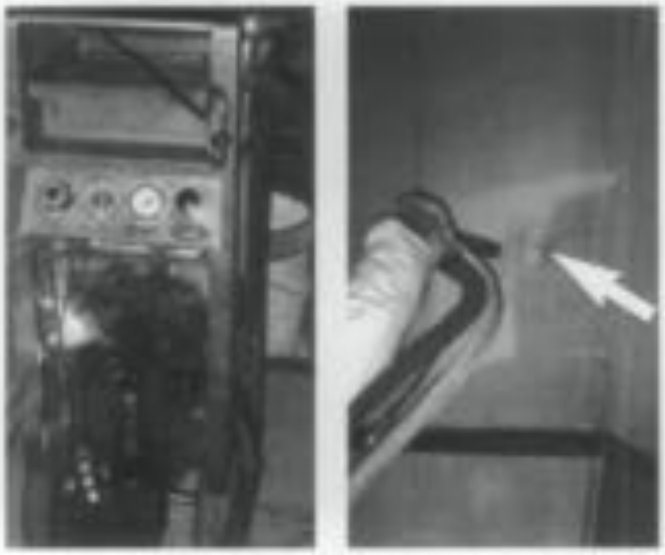


Figure 21. Low-pressure blasting with ice pellets or ice crystals (left) is an abrasive cleaning method that is sometimes recommended for use on interior masonry because it does not involve large amounts of water. However, like other abrasive materials, ice crystals "clean" by removing a portion of the masonry surface with the dirt, and may not remove some stains that have penetrated into the masonry without causing further abrasion (right). Photos: Audrey T. Tepper.

Ice particles, or pelletized dry ice (carbon dioxide or CO_2), are another medium used as an abrasive cleaner (Fig. 21). This is also too abrasive to be used on most historic masonry, but it may have practical application for removing mastics or asphaltic coatings from some substrates.

Some of these processes are promoted as being more environmentally safe and not damaging to historic masonry buildings. However, it must be remembered that they are abrasive and that they "clean" by removing a small portion of the masonry surface, even though it may be only a minuscule portion. The fact that they are essentially abrasive treatments must always be taken into consideration when planning a masonry cleaning project. *In general, abrasive methods should not be used to clean historic masonry buildings.* In some, very limited instances, highly-controlled, gentle abrasive cleaning may be appropriate on selected, hard-to-clean areas of a historic masonry building if carried out under the watchful supervision of a professional conservator. But, abrasive cleaning should never be used on an entire building.

Grinders and Sanding Disks. Grinding the masonry surface with mechanical grinders and sanding disks is another means of abrasive cleaning that should not be used on historic masonry. Like abrasive blasting, grinders and disks do not really clean masonry but instead grind away and abrasively remove and, thus, damage the masonry surface itself rather than remove just the soiling material.

Planning A Cleaning Project

Once the masonry and soiling material or paint have been identified, and the condition of the masonry has been evaluated, planning for the cleaning project can begin.

Testing cleaning methods. In order to determine the *gentlest means possible*, several cleaning methods or materials may have to be tested prior to selecting the best one to use on the building. Testing should always begin with the gentlest and least invasive method proceeding gradually, if necessary, to more complicated methods, or a combination of methods. All too often simple methods, such as low-pressure water wash, are not even considered, yet they frequently are effective, safe, and not expensive. Water of slightly higher pressure or with a non-ionic detergent additive also may be effective. It is worth repeating that these methods should always be tested prior to considering harsher methods; they are safer for the building and the environment, often safer for the applicator, and relatively inexpensive.

The level of cleanliness desired also should be determined prior to selection of a cleaning method. Obviously, the intent of cleaning is to remove most of the dirt, soiling material, stains, paint or other coating. A "brand new" appearance, however, may be inappropriate for an older building, and may require an overly harsh cleaning method to be achieved. When undertaking a cleaning project, it is important to be aware that some stains simply may not be removable. It may be wise, therefore, to agree upon a slightly lower level of cleanliness that will serve as the standard for the cleaning project. The precise amount of residual dirt considered acceptable may depend on the type of masonry, the type of soiling and difficulty of total removal, and local environmental conditions.

Cleaning tests should be carried out in an area of sufficient size to give a true indication of their effectiveness. It is preferable to conduct the test in an inconspicuous location on the building so that it will not be obvious if the test is not successful. A test area may be quite small to begin, sometimes as small as six square inches, and gradually may be increased in size as the most appropriate methods and cleaning agents are determined. Eventually the test area may be expanded to a square yard or more, and it should include several masonry units and mortar joints (Fig. 22). It should be remembered that a single building may have several types of masonry and that even similar materials may have different surface finishes. Each material and different finish should be tested separately. Cleaning tests should be evaluated only after the masonry has dried completely. *The results of the tests may indicate that several methods of cleaning should be used on a single building.*

When feasible, test areas should be allowed to weather for an extended period of time prior to final evaluation. A waiting period of a full year would be ideal in order to expose the test patch to a full range of seasons. If this is not possible, the test patch should weather for at least a month or two. For any building which is considered historically important, the delay is insignificant compared to the potential damage and disfigurement which may result from using an incompletely tested method. *The successfully cleaned test patch should be protected as it will serve as a standard against which the entire cleaning project will be measured.*

Environmental considerations. The potential effect of any method proposed for cleaning historic masonry should be evaluated carefully. Chemical cleaners and paint removers may damage trees, shrubs, grass, and plants. A plan must be provided for environmentally safe removal and disposal of the cleaning materials and the rinsing effluent before beginning the cleaning project. Authorities from the local regulatory agency – usually under the jurisdiction of the federal or state Environmental Protection Agency (EPA) should be consulted prior to beginning a cleaning project, especially if it involves anything more than plain water washing. This advance planning will ensure that the cleaning effluent or run-off, which is the combination of the cleaning agent and the substance removed from the masonry, is handled and disposed of in an environmentally sound and legal manner. Some alkaline and acidic cleaners can be neutralized so that they can be safely discharged into storm sewers. However, most solvent-based cleaners cannot be neutralized and are categorized as pollutants, and must be disposed of by a licensed transport, storage and disposal facility. Thus, it is always advisable to consult with the appropriate agencies before starting to clean to ensure that the project progresses smoothly and is not interrupted by a stop-work order because a required permit was not obtained in advance.

Vinyl guttering or polyethylene-lined troughs placed around the perimeter of the base of the building can serve to catch chemical cleaning waste as it is rinsed off the building. This will reduce the amount of chemicals entering and polluting the soil, and also will keep the cleaning waste contained until it can be removed safely. Some patented cleaning systems have developed special equipment to facilitate the containment and later disposal of cleaning waste.

Concern over the release of volatile organic compounds (VOCs) into the air has resulted in the manufacture of new, more environmentally responsible cleaners and paint removers, while some materials traditionally used in cleaning may no longer be available for these same reasons. Other health and safety concerns have created additional cleaning challenges, such as lead paint removal, which is likely to require special removal and disposal techniques.

Cleaning can also cause damage to non-masonry materials on a building, including glass, metal and wood. Thus, it is usually necessary to cover windows and doors, and other features that may be vulnerable to chemical cleaners. They should be covered with plastic or polyethylene, or a masking agent that is applied as a liquid which dries to form a thin protective film on glass, and is easily peeled off after the cleaning is finished. Wind drift, for example, can also damage other property by carrying cleaning chemicals onto nearby automobiles, resulting in etching of the glass or spotting of the paint finish. Similarly, airborne dust can enter surrounding buildings, and excess water can collect in nearby yards and basements.

Safety considerations. Possible health dangers of each method selected for the cleaning project must be considered before selecting a cleaning method to avoid harm to the

Figure 22. Cleaning test areas may be quite small at first and gradually increase in size as testing determines the "gentlest means possible". Photo: Frances Gale.

cleaning applicators, and the necessary precautions must be taken. The precautions listed in Material Safety Data Sheets (MSDS) that are provided with chemical products should always be followed. Protective clothing, respirators, hearing and face shields, and gloves must be provided to workers to be worn at all times. Acidic and alkaline chemical cleaners in both liquid and vapor forms can also cause serious injury to passers-by (Fig. 23). It may be necessary to schedule cleaning at night or weekends if the building is located in a busy urban area to reduce the potential danger of chemical overspray to pedestrians. Cleaning during non-business hours will allow HVAC systems to be turned off and vents to be covered to prevent dangerous chemical fumes from entering the building which will also ensure the safety of the building's occupants. Abrasive and mechanical methods produce dust which can pose a serious health hazard, particularly if the abrasive or the masonry contains silica.

Water-Repellent Coatings and Waterproof Coatings

To begin with, it is important to understand that waterproof coatings and water-repellent coatings are not the same. Although these terms are frequently interchanged and commonly confused with one another, they are completely different materials. **Water-repellent coatings** –often referred to incorrectly as "sealers", but which do not or should not seal– are intended to keep liquid water from penetrating the surface but to allow water vapor to enter and leave, or pass through, the surface of the masonry (Fig. 24). Water-repellent coatings are generally *transparent*, or clear, although once applied some may darken or discolor certain types of masonry while others may give it a glossy or shiny appearance. **Waterproof coatings** seal the surface from liquid water and from water vapor. They are usually *opaque*, or pigmented, and include bituminous coatings and some elastomeric paints and coatings.

Water-Repellent Coatings

Water-repellent coatings are formulated to be vapor permeable, or "breathable". They do not seal the surface completely to water vapor so it can enter the masonry wall as well as leave the wall. While the first water-repellent coatings to be developed were primarily acrylic or silicone resins in organic solvents, now most water-repellent coatings are water-based and formulated from modified siloxanes, silanes and other alkoxysilanes, or metallic stearates. While some of these products are shipped from the factory ready to use, other waterborne water repellents must be diluted at the job site. Unlike earlier water-repellent coatings which tended to form a "film" on the masonry surface, modern water-repellent coatings actually penetrate into the masonry substrate slightly and, generally, are almost invisible if properly applied to the masonry. They are also more vapor permeable than the old coatings, yet they still reduce the vapor permeability of the masonry. Once inside the wall, water vapor can condense at cold spots producing liquid water which, unlike water vapor, cannot escape through a water-repellent coating. The liquid water within the wall, whether from condensation, leaking gutters, or other sources, can cause considerable damage.

Water-repellent coatings are not consolidants. Although modern water repellents may penetrate slightly beneath the masonry surface, instead of just "sitting" on top of it, they do not perform the same function as a consolidant which is to "consolidate" and replace lost binder to strengthen deteriorating masonry. Even after many years of laboratory study and testing few consolidants have proven very effective. The composition of fired products such as brick and architectural terra cotta, as well as many types of building stone, does not lend itself to consolidation.

Some modern water-repellent coatings which contain a binder intended to replace the natural binders in stone that have been lost through weathering and natural erosion are described in product literature as both a water repellent and a consolidant. The fact that newer water-repellent coatings penetrate beneath the masonry surface instead of just forming a layer on top of the surface may indeed convey at least some consolidating properties to certain stones. However, a water-repellent coating cannot be considered a consolidant. In some instances, a water-repellent or "preservative" coating, if applied to already damaged or spalling stone, may form a surface crust which, if it fails, may exacerbate the deterioration by pulling off even more of the stone (Fig. 25).

Is a Water-Repellent Treatment Necessary?

Water-repellent coatings are frequently applied to historic masonry buildings for the wrong reason. They also are often applied without an understanding of what they are and what they are intended to do. And these coatings can be very difficult, if not impossible, to remove from the masonry if they fail or become discolored. Most importantly, the application of water-repellent coatings to historic masonry is usually unnecessary.

Figure 23. A tarpaulin protects and shields pedestrians from potentially harmful spray while chemical cleaning is underway on the granite exterior of the U.S. Treasury Building, Washington, D.C.

Most historic masonry buildings, unless they are painted, have survived for decades without a water-repellent coating and, thus, probably do not need one now. Water penetration to the interior of a masonry building is seldom due to porous masonry, but results from poor or deferred maintenance. Leaking roofs, clogged or deteriorated gutters and downspouts, missing mortar, or cracks and open joints around door and window openings are almost always the cause of moisture-related problems in a historic masonry building. **If historic masonry buildings are kept watertight and in good repair, water-repellent coatings should not be necessary.**

Rising damp (capillary moisture pulled up from the ground), or condensation can also be a source of excess moisture in masonry buildings. A water-repellent coating will not solve this problem either and, in fact, may be likely to exacerbate it. Furthermore, a water-repellent coating should never be applied to a damp wall. Moisture in the wall would reduce the ability of a coating to adhere to the masonry and to penetrate below the surface. But, if it did adhere, it would hold the moisture inside the masonry because, although a water-repellent coating is permeable to water vapor, liquid water cannot pass through it. In the case of rising damp, a coating may force the moisture to go even higher in the wall because it can slow down evaporation, and thereby retain the moisture in the wall.

Excessive moisture in masonry walls may carry waterborne soluble salts from the masonry units themselves or from the mortar through the walls. If the water is permitted to come to the surface, the salts may appear on the masonry surface as efflorescence (a whitish powder) upon evaporation. However, the salts can be potentially dangerous if they remain in the masonry and crystallize

Figure 24. Although the application of a water-repellent coating was probably not needed on either of these buildings, the coating on the brick building (above), is not visible and has not changed the character of the brick. But the coating on the brick column (below), has a high gloss that is incompatible with the historic character of the masonry.

beneath the surface as subflorescence. Subflorescence eventually may cause the surface of the masonry to spall, particularly if a water-repellent coating has been applied which tends to reduce the flow of moisture out from the subsurface of the masonry. Although many of the newer water-repellent products are more breathable than their predecessors, they can be especially damaging if applied to masonry that contains salts, because they limit the flow of moisture through masonry.

When a Water-Repellent Coating May be Appropriate
There are some instances when a water-repellent coating may be considered appropriate to use on a historic masonry building. Soft, incompletely fired brick from the 18th- and early-19th centuries may have become so porous that paint or some type of coating is needed to protect it from further deterioration or dissolution. When a masonry building has been neglected for a long period of time, necessary repairs may be required in order to make it watertight. If, following a reasonable period of time after the building has been made watertight and has dried out completely, moisture appears actually to be penetrating through the repointed and repaired masonry walls, then the application of a water-repellent coating may be considered *in selected areas only*. This decision should be made in consultation with an architectural conservator. And, if such a treatment is undertaken, it should not be applied to the entire exterior of the building.

Anti-graffiti or barrier coatings are another type of clear coating—although barrier coatings can also be pigmented—that may be applied to exterior masonry, but they are not formulated primarily as water repellents. The purpose of these coatings is to make it harder for graffiti to stick to a masonry surface and, thus, easier to clean. But, like water-repellent coatings, in most cases the application of anti-graffiti coatings is generally not recommended for historic masonry buildings. These coatings are often quite shiny which can greatly alter the appearance of a historic masonry surface, and they are not always effective (Fig. 26). Generally, other ways of discouraging graffiti, such as improved lighting, can be more effective than a coating. However, the application of anti-graffiti coatings may be appropriate in some instances on vulnerable areas of historic masonry buildings which are frequent targets of graffiti that are located in out-of-the-way places where constant surveillance is not possible.

Some water-repellent coatings are recommended by product manufacturers as a means of keeping dirt and pollutants or biological growth from collecting on the surface of masonry buildings and, thus, reducing the need for frequent cleaning. While this at times may be true, in some cases a coating may actually retain dirt more than uncoated masonry. Generally, the application of a water-repellent coating is not recommended on a historic masonry building as a means of preventing biological growth. Some water-repellent coatings may actually encourage biological growth on a masonry wall. Biological growth on masonry buildings has traditionally been kept at bay through regularly-scheduled cleaning as part of a maintenance plan. Simple cleaning of the masonry with low-pressure water using a natural- or synthetic-bristled scrub brush can be very effective if done on a regular basis. Commercial products are also available which can be sprayed on masonry to remove biological growth.

In most instances, a water-repellent coating is not necessary if a building is watertight. The application of a water-repellent coating is not a recommended treatment for historic masonry buildings unless there is a specific

Figure 25. The clear coating applied to this limestone molding has failed and is taking off some of the stone surface as it peels. Photo: Frances Gale.

problem which it may help solve. If the problem occurs on only part of the building, it is best to treat only that area rather than an entire building. Extreme exposures such as parapets, for example, or portions of the building subject to driving rain can be treated more effectively and less expensively than the entire building. Water-repellent coatings are not permanent and must be reapplied

Figure 26. The anti-graffiti or barrier coating on this column is very shiny and would not be appropriate to use on a historic masonry building. The coating has discolored as it has aged and whitish streaks reveal areas of bare concrete where the coating was incompletely applied.

periodically although, if they are truly invisible, it can be difficult to know when they are no longer providing the intended protection.

Testing a water-repellent coating by applying it in one small area may not be helpful in determining its suitability for the building because a limited test area does not allow an adequate evaluation of such a treatment. Since water may enter and leave through the surrounding untreated areas, there is no way to tell if the coated test area is "breathable." But trying a coating in a small area may help to determine whether the coating is visible on the surface or if it will otherwise change the appearance of the masonry.

Waterproof Coatings

In theory, waterproof coatings usually do not cause problems as long as they exclude all water from the masonry. If water does enter the wall from the ground or from the inside of a building, the coating can intensify the damage because the water will not be able to escape. During cold weather this water in the wall can freeze causing serious mechanical disruption, such as spalling.

In addition, the water eventually will get out by the path of least resistance. If this path is toward the interior, damage to interior finishes can result; if it is toward the exterior, it can lead to damage to the masonry caused by built-up water pressure (Fig. 27).

In most instances, waterproof coatings should not be applied to historic masonry. The possible exception to this might be the application of a waterproof coating to below-grade exterior foundation walls as a last resort to stop water infiltration on interior basement walls. **Generally, however, waterproof coatings, which include *elastomeric paints*, should almost never be applied above grade to historic masonry buildings.**

Figure 27. Instead of correcting the roof drainage problems, an elastomeric coating was applied to the already saturated limestone cornice. An elastomeric coating holds moisture in the masonry because it does not "breathe" and does not allow liquid moisture to escape. If the water pressure builds up sufficiently it can cause the coating to break and pop off as shown in this example, often pulling pieces of the masonry with it. Photo: National Park Service Files.

Summary

A well-planned cleaning project is an essential step in preserving, rehabilitating or restoring a historic masonry building. Proper cleaning methods and coating treatments, when determined necessary for the preservation of the masonry, can enhance the aesthetic character as well as the structural stability of a historic building. Removing years of accumulated dirt, pollutant crusts, stains, graffiti or paint, if done with appropriate caution, can extend the life and longevity of the historic resource. Cleaning that is carelessly or insensitively prescribed or carried out by inexperienced workers can have the opposite of the intended effect. It may scar the masonry permanently, and may actually result in hastening deterioration by introducing harmful residual chemicals and salts into the masonry or causing surface loss. Using the wrong cleaning method or using the right method incorrectly, applying the wrong kind of coating or applying a coating that is not needed can result in serious damage, both physically and aesthetically, to a historic masonry building. Cleaning a historic masonry building should always be done using the *gentlest means possible* that will clean, but not damage the building. It should always be taken into consideration before applying a water-repellent coating or a waterproof coating to a historic masonry building whether it is really necessary and whether it is in the best interest of preserving the building.

Selected Reading

Architectural Ceramics: Their History, Manufacture and Conservation. A Joint Symposium of English Heritage and the United Kingdom Institute for Conservation, September 22-25, 1994. London: English Heritage, 1996.

Ashurst, Nicola. *Cleaning Historic Buildings. Volume One: Substrates, Soiling & Investigation. Volume Two: Cleaning Materials & Processes.* London: Donhead Publishing Ltd., 1994.

Association for Preservation Technology. *Special Issue: Preservation of Historic Masonry.* Papers from the Symposium on Preservation Treatments for Historic Masonry: Consolidants, Coatings, and Water Repellents. New York, New York, November 11-12, 1994. *APT Bulletin.* Vol. XXVI, No. 4 (1995).

Grimmer, Anne E. *Preservation Brief 6: Dangers of Abrasive Cleaning to Historic Buildings.* Washington, D.C.: Preservation Assistance Division, National Park Service, U.S. Department of the Interior, 1979.

Grimmer, Anne E. *Keeping it Clean: Removing Exterior Dirt, Paint, Stains and Graffiti from Historic Masonry Buildings.* Washington, D.C.: Preservation Assistance Division, National Park Service, U.S. Department of the Interior, 1988.

Park, Sharon C., AIA. *Preservation Brief 39: Holding the Line: Controlling Unwanted Moisture in Historic Buildings.* Washington, D.C.: Heritage Preservation Services, National Park Service, U.S. Department of the Interior, 1996.

Powers, Robert M. *Preservation Tech Note, Masonry No. 3. "Water Soak Cleaning of Limestone".* Washington, D.C.: Preservation Assistance Division, National Park Service, U.S. Department of the Interior, 1992.

Sinvinski, Valerie. *"Gentle Blasting." Old-House Journal.* Vol. XXIV, No. 4 (July-August 1996), pp. 46-49.

Weaver, Martin E. *Conserving Buildings: A Guide to Techniques and Materials.* New York: John Wiley & Sons, Inc., 1993.

Weaver, Martin E. *Preservation Brief 38: Removing Graffiti from Historic Masonry.* Washington, D.C.: Preservation Assistance Division, National Park Service, U.S. Department of the Interior, 1995.

Winkler, E.M. *Stone in Architecture: Properties, Durability.* Third, completely revised and extended edition. Berlin, Germany: Springer-Verlag, 1997.

Acknowledgments

Robert C. Mack, FAIA, is a principal in the firm of MacDonald & Mack Architects, Ltd., an architectural firm that specializes in historic buildings in Minneapolis, Minnesota.
Anne Grimmer is a Senior Architectural Historian in the Technical Preservation Services Branch, Heritage Preservation Services Program, National Park Service, Washington, D.C.

The original version of *Preservation Brief 1: The Cleaning and Waterproof Coating of Masonry Buildings* was written by Robert C. Mack, AIA. It inaugurated the *Preservation Briefs* series when it was published in 1975.

The following historic preservation specialists provided technical review of this publication: Frances Gale, Training Director, National Center for Preservation Technology and Training, National Park Service, Natchitoches, LA; Judith M. Jacob, Architectural Conservator, Building Conservation Branch, Northeast Cultural Resources Center, National Park Service, N.Y., NY; Robert M. Powers, Architectural Conservator, Powers and Company, Inc., Philadelphia, PA; Antonio Aguilar, Kaaren Dodge, JoEllen Hensley, Gary Sachau, John Sandor and Audrey T. Tepper, Technical Preservation Services Branch, Heritage Preservation Services Program, National Park Service, Washington, D.C.; and Kay D. Weeks, Heritage Preservation Services Program, National Park Service, Washington, D.C.

This publication has been prepared pursuant to the National Historic Preservation Act of 1966, as amended, which directs the Secretary of the Interior to develop and make available information concerning historic properties. Comments on the usefulness of this publication may be directed to: Sharon C. Park, FAIA, Chief, Technical Preservation Services Branch, Heritage Preservation Services Program, National Park Service, 1849 C Street, N.W., Suite NC200, Washington, D.C. 20240 (www2.cr.nps.gov/tps).

Front Cover: Chemical cleaning of the brick and architectural terra cotta frieze on the 1880s Pension Building, Washington, D.C. (now the National Building Museum), is shown here in progress. Photo: Christina Henry.

Photographs used to illustrate this Brief were taken by Anne Grimmer unless otherwise credited.

ISSN:0885-7016 November 2000

4 PRESERVATION BRIEFS

Roofing for Historic Buildings

Sarah M. Sweetser

U.S. Department of the Interior
National Park Service
Cultural Resources
Heritage Preservation Services

Significance of the Roof

A weather-tight roof is basic in the preservation of a structure, regardless of its age, size, or design. In the system that allows a building to work as a shelter, the roof sheds the rain, shades from the sun, and buffers the weather.

During some periods in the history of architecture, the roof imparts much of the architectural character. It defines the style and contributes to the building's aesthetics. The hipped roofs of Georgian architecture, the turrets of Queen Anne, the Mansard roofs, and the graceful slopes of the Shingle Style and Bungalow designs are examples of the use of roofing as a major design feature.

But no matter how decorative the patterning or how compelling the form, the roof is a highly vulnerable element of a shelter that will inevitable fail. A poor roof will permit the accelerated deterioration of historic building materials—masonry, wood, plaster, paint—and will cause general disintegration of the basic structure. Furthermore, there is an urgency involved in repairing a leaky roof since such repair costs will quickly become prohibitive. Although such action is desirable as soon as a failure is discovered, temporary patching methods should be carefully chosen to prevent inadvertent damage to sound or historic roofing materials and related features. Before any repair work is performed, the historic value of the materials used on the roof should be understood. Then a complete internal and external inspection of the roof should be planned to determine all the causes of failure and to identify the alternatives for repair or replacement of the roofing.

Historic Roofing Materials in America

Clay Tile: European settlers used clay tile for roofing as early as the mid-17th century; many pantiles (S-curved tiles), as well as flat roofing tiles, were used in Jamestown, Virginia. In some cities such as New York and Boston, clay was popularly used as a precaution against such fire as those that engulfed London in 1666 and scorched Boston in 1679.

Tiles roofs found in the mid-18th century Moravian settlements in Pennsylvania closely resembled those found in Germany. Typically, the tiles were 14–15" long, 6–7" wide with a curved butt. A lug on the back allowed the tiles to hang on the lathing without nails or pegs. The tile surface was usually scored with finger marks to promote drainage. In the Southwest, the tile roofs of the Spanish missionaries (mission tiles) were first manufactured (ca. 1780) at the Mission San Antonio de Padua in California. These semicircular tiles were made by molding clay over sections of logs, and they were generally 22" long and tapered in width.

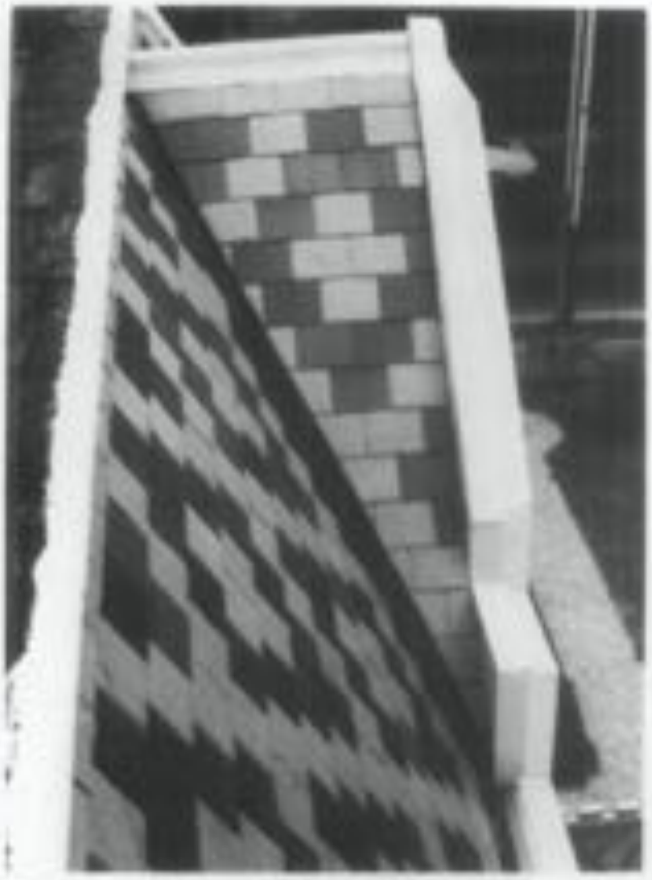
Repairs on this pantile roof were made with new tiles held in place with metal hangers. (Main Building, Ellis Island, New York)

The plain or flat rectangular tiles most commonly used from the 17th through the beginning of the 19th century measured about 10" by 6" by ½", and had two holes at one end for a nail or peg fastener. Sometimes mortar was applied between the courses to secure the tiles in a heavy wind.

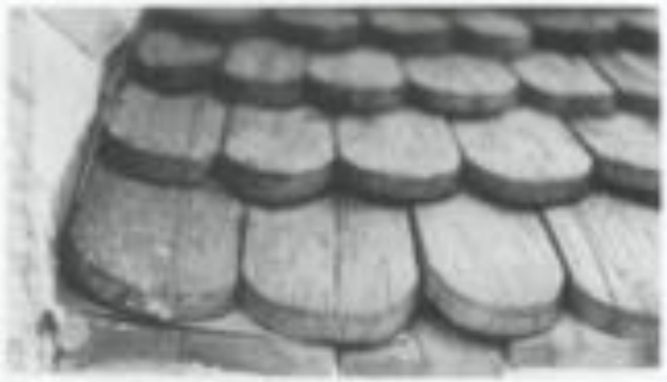
In the mid-19th century, tile roofs were often replaced by sheet-metal roofs, which were lighter and easier to install and maintain. However, by the turn of the century, the Romanesque Revival and Mission style buildings created a new demand and popularity for this picturesque roofing material.

Slate: Another practice settlers brought to the New World was slate roofing. Evidence of roofing slates have been found also among the ruins of mid-17th-century Jamestown. But because of the cost and the time required to obtain the material, which was mostly imported from Wales, the use of slate was initially limited. Even in Philadelphia (the second largest city in the English-speaking world at the time of the Revolution) slates were so rare that "The Slate Roof House" distinctly referred to William Penn's home built late in the 1600s. Sources of native slate were known to exist along the eastern seaboard from Maine to Virginia, but difficulties in inland transportation limited its availability to the cities, and contributed to its expense. Welsh slate continued to be imported until the development of canals and railroads in the mid-19th century made American slate more accessible and economical.

Slate was popular for its durability, fireproof qualities, and



The Victorians loved to used different colored slates to create decorative patterns on their roofs, an effect which cannot be easily duplicated by substitute materials. Before any repair work on a roof such as this, the slate sizes, colors, and position of the patterning should be carefully recorded to assure proper replacement. (Ebenezer Maxwell Mansion, Philadelphia, Pennsylvania, photo courtesy of William D. Hershey)



Replacement of particular historic details is important to the individual historic character of a roof, such as the treatment at the eaves of this rounded butt wood shingle roof. Also note that the surface of the roof was carefully sloped to drain water away from the side of the dormer. In the restoration, this function was augmented with the addition of carefully concealed modern metal flashing. (Mount Vernon, Virginia)

Galvanized sheet-metal shingles imitating the appearance of pantiles remained popular from the second half of the 19th century into the 20th century. (Episcopal Church, now the Jerome Historical Society Building, Jerome, Arizona, 1927)

aesthetic potential. Because slate was available in different colors (red, green, purple, and blue-gray), it was an effective material for decorative patterns on many 19th-century roofs (Gothic and Mansard styles). Slate continued to be used well into the 20th century, notably on many Tudor revival style buildings of the 1920s.

Shingles: Wood shingles were popular throughout the country in all periods of building history. The size and shape of the shingles as well as the detailing of the shingle roof differed according to regional craft practices. People within particular regions developed preferences for the local species of wood that most suited their purposes. In New England and the Delaware Valley, white pine was frequently used; in the South, cypress and oak; in the far west, red cedar or redwood. Sometimes a protective coating was applied to increase the durability of the shingle such as a mixture of brick dust and fish oil, or a paint made of red iron oxide and linseed oil.

Commonly in urban areas, wooden roofs were replaced with more fire resistant materials, but in rural areas this was not a major concern. On many Victorian country houses, the practice of wood shingling survived the technological advances of metal roofing in the 19th century, and near the turn of the century enjoyed a full revival in its namesake, the Shingle Style. Colonial revival and the Bungalow styles in the 20th century assured wood shingles a place as one of the most fashionable, domestic roofing materials.

Metal: Metal roofing in America is principally a 19th-century phenomenon. Before then the only metals commonly used were lead and copper. For example, a lead roof covered "Rosewell," one of the grandest mansions in 18th-century Virginia. But more often, lead was used for protective flashing. Lead, as well as copper, covered roof surfaces where wood, tile, or slate shingles were inappropriate because of the roof's pitch or shape.

Copper with standing seams covered some of the more notable early American roofs including that of Christ Church (1727–1744) in Philadelphia. Flat-seamed copper was used on many domes and cupolas. The copper sheets were imported from England until the end of the 18th century when facilities for rolling sheet metal were developed in America.

Sheet iron was first known to have been manufactured here by the Revolutionary War financier, Robert Morris, who had a rolling mill near Trenton, New Jersey. At his mill Morris produced the roof of his own Philadelphia mansion, which he started in 1794. The architect Benjamin H. Latrobe used sheet iron to replace the roof on Princeton's "Nassau Hall," which had been gutted by fire in 1802.

The method for corrugating iron was originally patented in England in 1829. Corrugating stiffened the sheets, and allowed greater span over a lighter framework, as well as reduced installation time and labor. In 1834 the American architect William Strickland proposed corrugated iron to cover his design for the market place in Philadelphia.

Galvanizing with zinc to protect the base metal from rust was developed in France in 1837. By the 1850s the material was used on post offices and customhouses, as well as on train sheds and factories. In 1857 one of the first metal roofs in the

Repeated repair with asphalt, which cracks as it hardens, has created a blistered surface on this sheet metal roof and built-in gutter, which will retain water. Repairs could be made by carefully heating and scraping the surface clean, repairing the holes in the metal with a flexible mastic compound or a metal patch, and coating the surface with a fibre paint. (Roane County Courthouse, Kingston, Tennessee, photo courtesy of Building Conservation Technology, Inc.)

A Chicago firm's catalog dated 1896 illustrates a method of unrolling, turning the edges, and finishing the standing seam on a metal roof.

Tin shingles, commonly embossed to imitate wood or tile, or with a decorative design, were popular as an inexpensive, textured roofing material. These shingles 8¾ inch by 12½ inch on the exposed surface were designed with interlocking edges, but they have been repaired by surface nailing, which may cause future leakage. (Ballard House, Yorktown, Virginia, photo by Gordie Whittington, National Park Service)

South was installed on the U.S. Mint in New Orleans. The Mint was thereby "fireproofed" with a 20-gauge galvanized, corrugated iron roof on iron trusses.

Tin-plate iron, commonly called "tin roofing," was used extensively in Canada in the 18th century, but it was not as common in the United States until later. Thomas Jefferson was an early advocate of tin roofing, and he installed a standing-seam tin roof on "Monticello" (ca. 1770–1802). The Arch Street Meetinghouse (1804) in Philadelphia had tin shingles laid in a herringbone pattern on a "piazza" roof.

However, once rolling mills were established in this country, the low cost, light weight, and low maintenance of tin plate made it the most common roofing material. Embossed tin shingles, whose surfaces created interesting patterns, were popular throughout the country in the late 19th century. Tin roofs were kept well-painted, usually red, or, as the architect A. J. Davis suggested, in a color to imitate the green patina of copper.

Terne plate differed from tin plate in that the iron was dipped in an alloy of lead and tin, giving it a duller finish. Historic, as well as modern, documentation often confuses the two, so much that it is difficult to determine how often actual "terne" was used.

Zinc came into use in the 1820s, at the same time tin plate was becoming popular. Although a less expensive substitute for lead, its advantages were controversial, and it was never widely used in this country.

Other Materials: Asphalt shingles and roll roofing were used in the 1890s. Many roofs of asbestos, aluminum, stainless steel, galvanized steel, and lead-coated copper may soon have historic values as well. Awareness of these and other traditions of roofing materials and their detailing will contribute to more sensitive preservation treatments.

Locating the Problem

Failures of Surface Materials

When trouble occurs, it is important to contact a professional, either an architect, a reputable roofing contractor, or a craftsman familiar with the inherent characteristics of the particular historic roofing system involved. These professionals may be able to advise on immediate patching procedures and help plan more permanent repairs. A thorough examination of the roof should start with an appraisal of the existing condition and quality of the roofing material itself. Particular attention should be given to any southern slope because year-round exposure to direct sun may cause it to break down first.

Wood: Some historic roofing materials have limited life expectancies because of normal organic decay and "wear." For example, the flat surfaces of wood shingles erode from exposure to rain and ultraviolet rays. Some species are more hardy than others, and heartwood, for example, is stronger and more durable than sapwood.

Ideally, shingles are split with the grain perpendicular to the surface. This is because if shingles are sawn across the grain, moisture may enter the grain and cause the wood to deteriorate. Prolonged moisture on or in the wood allows moss or fungi to grow, which will further hold the moisture and cause rot.

Metal: Of the inorganic roofing materials used on historic buildings, the most common are perhaps the sheet metals: lead, copper, zinc, tin plate, terne plate, and galvanized iron. In varying degrees each of these sheet metals are likely to deteriorate from chemical action by pitting or streaking. This can be caused by airborn pollutants; acid rainwater; acids from lichen or moss; alkalis found in lime mortars or portland cement, which might be on adjoining features and washes down on the roof surface; or tannic acids from adjacent wood sheathings or shingles made of red cedar or oak.

Corrosion from "galvanic action" occurs when dissimilar metals, such as copper and iron, are used in direct contact. Corrosion may also occur even though the metals are physically separated; one of the metals will react chemically against the other in the presence of an electrolyte such as rainwater. In roofing, this situation might occur when either a copper roof is decorated with iron cresting, or when steel nails are used in copper sheets. In some instances the corrosion can be prevented by inserting a plastic insulator between the dissimilar materials. Ideally, the fasteners should be a metal sympathetic to those involved.

Iron rusts unless it is well-painted or plated. Historically this problem was avoided by use of tin plating or galvinizing. But this method is durable only as long as the coating remains intact. Once the plating is worn or damaged, the exposed iron will rust. Therefore, any iron-based roofing material needs to be undercoated, and its surface needs to be kept well-painted to prevent corrosion.

One cause of sheet metal deterioration is fatigue. Depending upon the size and the gauge of the metal sheets, wear and metal failure can occur at the joints or at any protrusions in the sheathing as a result from the metal's alternating movement to thermal changes. Lead will tear because of "creep," or the gravitational stress that causes the material to move down the roof slope.

Slate: Perhaps the most durable roofing materials are slate and tile. Seemingly indestructable, both vary in quality. Some slates are hard and tough without being brittle. Soft slates are more subject to erosion and to attack by airborne and rainwater chemicals, which cause the slates to wear at nail holes, to delaminate, or to break. In winter, slate is very susceptible to breakage by ice, or ice dams.

Tile: Tiles will weather well, but tend to crack or break if hit, as by tree branches, or if they are walked on improperly. Like slates, tiles cannot support much weight. Low quality tiles that have been insufficiently fired during manufacture, will craze and spall under the effects of freeze and thaw cycles on their porous surfaces.

Failures of Support Systems

Once the condition of the roofing material has been determined, the related features and support systems should be examined on the exterior and on the interior of the roof. The gutters and downspouts need periodic cleaning and maintenance since a variety of debris fill them, causing water to back up and seep under roofing units. Water will eventually cause fasteners, sheathing, and roofing structure to deteriorate. During winter, the daily freeze-thaw cycles can cause ice floes to develop under the roof surface. The pressure from these ice floes will dislodge the roofing material, especially slates, shingles, or tiles. Moreover, the buildup of ice dams above the gutters can trap enough moisture to rot the sheathing or the structural members.

Many large public buildings have built-in gutters set within the perimeter of the roof. The downspouts for these gutters may run within the walls of the building, or drainage may be through the roof surface or through a parapet to exterior downspouts. These systems can be effective if properly maintained; however, if the roof slope is inadequate for good runoff, or if the traps are allowed to clog, rainwater will form pools on the roof surface. Interior downspouts can collect debris and thus back up, perhaps leaking water into the surrounding walls. Exterior downspouts may fill with water, which in cold weather may freeze and crack the pipes. Conduits from the built-in gutter to the exterior downspout may also leak water into the surrounding roof structure or walls.

Failure of the flashing system is usually a major cause of roof deterioration. Flashing should be carefully inspected for failure caused by either poor workmanship, thermal stress, or metal deterioration (both of flashing material itself and of the fasteners). With many roofing materials, the replacement of flashing on an existing roof is a major operation, which may require taking up large sections of the roof surface. Therefore, the installation of top quality flashing material on

This detail shows slate delamination caused by a combination of weathering and pollution. In addition, the slates have eroded around the repair nails, incorrectly placed in the exposed surface of the slates. (Lower Pontalba Building, New Orleans, photo courtesy of Building Conservation Technology, Inc.)

Temporary stabilization or "mothballing" with materials such as plywood and building paper can protect the roof of a project until it can be properly repaired or replaced. (Narbonne House, Salem, Massachusetts)

These two views of the same house demonstrate how the use of a substitute material can drastically affect the overall character of a structure. The textural interest of the original tile roof was lost with the use of asphalt shingles. Recent preservation efforts are replacing the tile roof. (Frank House, Kearney, Nebraska, photo courtesy of the Nebraska State Historical Society, Lincoln, Nebraska)

a new or replaced roof should be a primary consideration. *Remember, some roofing and flashing materials are not compatible.*

Roof fasteners and clips should also be made of a material compatible with all other materials used, or coated to prevent rust. For example, the tannic acid in oak will corrode iron nails. Some roofs such as slate and sheet metals may fail if nailed too rigidly.

If the roof structure appears sound and nothing indicates recent movement, the area to be examined most closely is the roof substrate—the sheathing or the battens. The danger spots would be near the roof plates, under any exterior patches, at the intersections of the roof planes, or at vertical surfaces such as dormers. Water penetration, indicating a breach in the roofing surface or flashing, should be readily apparent, usually as a damp spot or stain. Probing with a small pen knife may reveal any rot which may indicate previously undetected damage to the roofing membrane. Insect infestation evident by small exit holes and frass (a sawdust-like debris) should also be noted. Condensation on the underside of the roofing is undesirable and indicates improper ventilation. Moisture will have an adverse effect on any roofing material; a good roof stays dry inside and out.

Repair or Replace

Understanding potential weaknesses of roofing material also requires knowledge of repair difficulties. Individual slates can be replaced normally without major disruption to the rest of the roof, but replacing flashing on a slate roof can require substantial removal of surrounding slates. If it is the substrate or a support material that has deteriorated, many surface materials such as slate or tile can be reused if handled carefully during the repair. Such problems should be evaluated at the outset of any project to determine if the roof can be effectively patched, or if it should be completely replaced.

Will the repairs be effective? Maintenance costs tend to multiply once trouble starts. As the cost of labor escalates, repeated repairs could soon equal the cost of a new roof.

The more durable the surface is initially, the easier it will be to maintain. Some roofing materials such as slate are expensive to install, but if top quality slate and flashing are used, it will last 40-60 years with minimal maintenance. Although the installation cost of the roof will be high, low maintenance needs will make the lifetime cost of the roof less expensive.

Historical Research

In a restoration project, research of documents and physical investigation of the building usually will establish the roof's history. Documentary research should include any original plans or building specifications, early insurance surveys, newspaper descriptions, or the personal papers and files of people who owned or were involved in the history of the building. Old photographs of the building might provide evidence of missing details.

Along with a thorough understanding of any written history of the building, a physical investigation of the roofing and its structure may reveal information about the roof's construction history. Starting with an overall impression of the structure, are there any changes in the roof slope, its configuration, or roofing materials? Perhaps there are obvious patches or changes in patterning of exterior brickwork where a gable roof was changed to a gambrel, or where a whole upper story was added. Perhaps there are obvious stylistic changes in the roof line, dormers, or ornamentation. These observations could help one understand any important alteration, and could help establish the direction of further investigation.

Because most roofs are physically out of the range of careful scrutiny, the "principle of least effort" has probably limited the extent and quality of previous patching or replacing, and usually considerable evidence of an earlier roof surface remains. Sometimes the older roof will be found as an underlayment of the current exposed roof. Original roofing may still be intact in awkward places under later features on a roof. Often if there is any unfinished attic space, remnants of roofing may have been dropped and left when the roof was being built or repaired. If the configuration of the roof has been changed, some of the original material might still be in place under the existing roof. Sometimes whole sections of the roof and roof framing will have been left intact under the higher roof. The profile and/or flashing of the earlier roof may be apparent on the interior of the walls at the level of the alteration. If the sheathing or lathing appears to have survived changes in the roofing surface, they may contain evidence of the roofing systems. These may appear either as dirt marks, which provide "shadows" of a roofing material, or as nails broken or driven down into the wood, rather than pulled out during previous alterations or repairs. Wooden headers in the roof framing may indicate that earlier chimneys or skylights have been removed. Any metal ornamentation that might have existed may be indicated by anchors or unusual markings along the ridge or at other edges of the roof. This primary evidence is essential for a full understanding of the roof's history.

Caution should be taken in dating early "fabric" on the evidence of a single item, as recycling of materials is not a mid-20th-century innovation. Carpenters have been reusing materials, sheathing, and framing members in the interest of economy for centuries. Therefore, any analysis of the materials found, such as nails or sawmarks on the wood, requires an accurate knowledge of the history of local building practices before any final conclusion can be accurately reached. It is helpful to establish a sequence of construction history for the roof and roofing materials; any historic fabric or pertinent evidence in the roof should be photographed, measured, and recorded for future reference.

During the repair work, useful evidence might unexpectedly appear. It is essential that records be kept of any type of work on a historic building, before, during, and after the project. Photographs are generally the easiest and fastest method, and should include overall views and details at the gutters, flashing, dormers, chimneys, valleys, ridges, and eaves. All photographs should be immediately labeled to insure accurate identification at a later date. Any patterning or design on the roofing deserves particular attention. For example, slate roofs are often decorative and have subtle changes in size, color, and texture, such as a gradually decreasing coursing length from the eave to the peak. If not carefully noted before a project begins, there may be problems in replacing the surface. The standard reference for this phase of the work is *Recording Historic Buildings*, compiled by Harley J. McKee for the Historic American Buildings Survey, National Park Service, Washington, D.C., 1970.

Replacing the Historic Roofing Material

Professional advice will be needed to assess the various aspects of replacing a historic roof. With some exceptions, most historic roofing materials are available today. If not, an architect or preservation group who has previously worked with the same type material may be able to recommend suppliers. Special roofing materials, such as tile or embossed metal shingles, can be produced by manufacturers of related products that are commonly used elsewhere, either on the exterior or interior of a structure. With some creative thinking and research, the historic materials usually can be found.

Because of the roof's visibility, the slate detailing around the dormers is important to the character of this structure. Note how the slates swirl from a horizontal pattern on the main roof to a diamond pattern on the dormer roofs and side walls. (18th and Que Streets, NW, Washington, D.C.)

Craft Practices: Determining the craft practices used in the installation of a historic roof is another major concern in roof restoration. Early builders took great pride in their work, and experience has shown that the "rustic" or irregular designs commercially labled "Early American" are a 20th-century invention. For example, historically, wood shingles underwent several distinct operations in their manufacture including splitting by hand, and smoothing the surface with a draw knife. In modern nomenclature, the same item would be a "tapersplit" shingle which has been dressed. Unfortunately, the rustic appearance of today's commercially available "handsplit" and re-sawn shingle bears no resemblance to the hand-made roofing materials used on early American buildings.

Good design and quality materials for the roof surface, fastenings, and flashing minimize roofing failures. This is essential on roofs such as on the National Cathedral where a thorough maintenance inspection and minor repairs cannot be done easily without special scaffolding. However, the success of the roof on any structure depends on frequent cleaning and repair of the gutter system. (Washington, D.C., photo courtesy of John Burns, A.I.A.)

Early craftsmen worked with a great deal of common sense; they understood their materials. For example they knew that wood shingles should be relatively narrow; shingles much wider than about 6" would split when walked on, or they may curl or crack from varying temperature and moisture. It is important to understand these aspects of craftsmanship, remembering that people wanted their roofs to be weather-tight and to last a long time. The recent use of "mother-goose" shingles on historic structures is a gross underestimation of the early craftsman's skills.

Supervision: Finding a modern craftsman to reproduce historic details may take some effort. It may even involve some special instruction to raise his understanding of certain historic craft practices. At the same time, it may be pointless (and expensive) to follow historic craft practices in any construction that will not be visible on the finished product. But if the roofing details are readily visible, their appearance should be based on architectural evidence or on historic prototypes. For instance, the spacing of the seams on a standing-seam metal roof will affect the building's overall scale and should therefore match the original dimensions of the seams.

Many older roofing practices are no longer performed because of modern improvements. Research and review of specific detailing in the roof with the contractor before beginning the project is highly recommended. For example, one early craft practice was to finish the ridge of a wood shingle roof with a roof "comb"—that is, the top course of one slope of the roof was extended uniformly beyond the peak to shield the ridge, and to provide some weather protection for the raw horizontal edges of the shingles on the other slope. If the "comb" is known to have been the correct detail, it should be used. Though this method leaves the top course vulnerable to the weather, a disguised strip of flashing will strengthen this weak point.

Detail drawings or a sample mock-up will help ensure that the contractor or craftsman understands the scope and special requirements of the project. It should never be assumed that the modern carpenter, slater, sheet metal worker, or roofer will know all the historic details. Supervision is as important as any other stage of the process.

Special problems inherent in the design of an elaborate historic roof can be controlled through the use of good materials and regular maintenance. The shape and detailing are essential elements of the building's historic character, and should not be modified, despite the use of alternative surface materials. (Gamwell House, Bellingham, Washington)

Alternative Materials

The use of the historic roofing material on a structure may be restricted by building codes or by the availability of the materials, in which case an appropriate alternative will have to be found.

Some municipal building codes allow variances for roofing materials in historic districts. In other instances, individual variances may be obtained. Most modern heating and cooking is fueled by gas, electricity, or oil—none of which emit the hot embers that historically have been the cause of roof fires. Where wood burning fireplaces or stoves are used, spark arrestor screens at the top of the chimneys help to prevent flaming material from escaping, thus reducing the number of fires that start at the roof. In most states, insurance rates have been equalized to reflect revised considerations for the risks involved with various roofing materials.

In a rehabilitation project, there may be valid reasons for replacing the roof with a material other than the original. The historic roofing may no longer be available, or the cost of obtaining specially fabricated materials may be prohibitive. But the decision to use an alternative material should be weighed carefully against the primary concern to keep the historic character of the building. If the roof is flat and is not visible from any elevation of the building, and if there are advantages to substituting a modern built-up composition roof for what might have been a flat metal roof, then it may make better economic and construction sense to use a modern roofing method. But if the roof is readily visible, the alternative material should match as closely as possible the scale, texture, and coloration of the historic roofing material.

Asphalt shingles or ceramic tiles are common substitute materials intended to duplicate the appearance of wood shingles, slates, or tiles. Fire-retardant, treated wood shingles are currently available. The treated wood tends, however, to be brittle, and may require extra care (and expense) to install. In some instances, shingles laid with an interlay of fire-retardant building paper may be an acceptable alternative.

Lead-coated copper, terne-coated steel, and aluminum/zinc-coated steel can successfully replace tin, terne plate, zinc, or lead. Copper-coated steel is a less expensive (and less durable) substitute for sheet copper.

The search for alternative roofing materials is not new. As early as the 18th century, fear of fire cause many wood shingle or board roofs to be replaced by sheet metal or clay tile. Some historic roofs were failures from the start, based on overambitious and naive use of materials as they were first developed. Research on a structure may reveal that an inadequately designed or a highly combustible roof was replaced early in its history, and therefore restoration of a later roof material would have a valid precedent. In some cities, the substitution of sheet metal on early row houses occurred as soon as the rolled material became available.

Cost and ease of maintenance may dictate the substitution of a material wholly different in appearance from the original. The practical problems (wind, weather, and roof pitch) should be weighed against the historical consideration of scale, texture, and color. Sometimes the effect of the alternative material will be minimal. But on roofs with a high degree of visibility and patterning or texture, the substitution may seriously alter the architectural character of the building.

Temporary Stabilization

It may be necessary to carry out an immediate and temporary stabilization to prevent further deterioration until research can determine how the roof should be restored or rehabilitated, or until funding can be provided to do a proper job. A simple covering of exterior plywood or roll roofing might provide adequate protection, but any temporary covering should be applied with caution. One should be careful not to overload the roof structure, or to damage or destroy historic evidence or fabric that might be incorporated into a new roof at a later date. In this sense, repairs with caulking or bituminous patching compounds should be recognized as potentially harmful, since they are difficult to remove, and at their best, are very temporary.

Precautions

The architect or contractor should warn the owner of any precautions to be taken against the specific hazards in installing the roofing material. Soldering of sheet metals, for instance, can be a fire hazard, either from the open flame or from overheating and undetected smoldering of the wooden substrate materials.

Thought should be given to the design and placement of any modern roof appurtenances such as plumbing stacks, air vents, or TV antennas. Consideration should begin with the placement of modern plumbing on the interior of the building, otherwise a series of vent stacks may pierce the roof membrane at various spots creating maintenance problems as well as aesthetic ones. Air handling units placed in the attic space will require vents which, in turn, require sensitive design. Incorporating these in unused chimneys has been very successful in the past.

Whenever gutters and downspouts are needed that were not on the building historically, the additions should be made as unobtrusively as possible, perhaps by painting them out with a color compatible with the nearby wall or trim.

Maintenance

Although a new roof can be an object of beauty, it will not be protective for long without proper maintenance. At least twice a year, the roof should be inspected against a checklist. All changes should be recorded and reported. Guidelines should be established for any foot traffic that may be required for the maintenance of the roof. Many roofing materials should not be walked on at all. For some—slate, asbestos, and clay tile—a self-supporting ladder might be hung over the ridge of the roof, or planks might be spanned across the roof surface. Such items should be specifically designed and kept in a storage space accessible to the roof. If exterior work ever requires hanging scaffolding, use caution to insure that the anchors do not penetrate, break, or wear the roofing surface, gutters, or flashing.

Any roofing system should be recognized as a membrane that is designed to be self-sustaining, but that can be easily damaged by intrusions such as pedestrian traffic or fallen tree branches. Certain items should be checked at specific times. For example, gutters tend to accumulate leaves and debris during the spring and fall and after heavy rain. Hidden gutter screening both at downspouts and over the full length of the gutter could help keep them clean. The surface material would require checking after a storm as well. Periodic checking of the underside of the roof from the attic after a storm or winter freezing may give early warning of any leaks. Generally, damage from water or ice is less likely on a roof that has good flashing on the outside and is well ventilated and insulated on the inside. Specific instructions for the maintenance of the different roof materials should be available from the architect or contractor.

Summary

The essential ingredients for replacing and maintaining a historic roof are:

- Understanding the historic character of the building and being sympathetic to it.
- Careful examination and recording of the existing roof and any evidence of earlier roofs.
- Consideration of the historic craftsmanship and detailing and implementing them in the renewal wherever visible.
- Supervision of the roofers or maintenance personnel to assure preservation of historic fabric and proper understanding of the scope and detailing of the project.
- Consideration of alternative materials where the original cannot be used.
- Cyclical maintenance program to assure that the staff understands how to take care of the roof and of the particular trouble spots to safeguard.

With these points in mind, it will be possible to preserve the architectural character and maintain the physical integrity of the roofing on a historic building.

This Preservation Brief was written by Sarah M. Sweetser, Architectural Historian, Technical Preservation Services Division. Much of the technical information was based upon an unpublished report prepared under contract for this office by John G. and Diana S. Waite. Some of the historical information was from Charles E. Peterson, FAIA, "American Notes," *Journal of the Society of Architectural Historians*.

The illustrations for this brief not specifically credited are from the files of the Technical Preservation Services Division.

This publication was prepared pursuant to Executive Order 11593, "Protection and Enhancement of the Cultural Environment," which directs the Secretary of the Interior to "develop and make available to Federal agencies and State and local governments information concerning professional methods and techniques for preserving, improving, restoring and maintaining historic properties." The Brief has been developed under the technical editorship of Lee H. Nelson, AIA, Chief, Preservation Assistance Division, National Park Service, U.S. Department of the Interior, Washington, D.C. 20240. Comments on the usefulness of this information are welcome and can be sent to Mr. Nelson at the above address. February 1978

Decorative features such as cupolas require extra maintenance. The flashing is carefully detailed to promote run-off, and the wooden ribbing must be kept well-painted. This roof surface, which was originally tin plate, has been replaced with lead-coated copper for maintenance purposes. (Lyndhurst, Tarrytown, New York, photo courtesy of the National Trust for Historic Preservation)

Additional readings on the subject of roofing are listed below.

Boaz, Joseph N., ed. *Architectural Graphic Standards*. New York: John Wiley and Sons, Inc., 1970. (Modern roofing types and detailing)

Briggs, Martin S. *A Short History of the Building Crafts*. London: Oxford University Press, 1925. (Descriptions of historic roofing materials)

Bulletin of the Association for Preservation Technology. Vol. 2 (nos. 1-2) 1970. (Entirely on roofing)

Holmstrom, Ingmar; and Sandstrom, Christina. *Maintenance of Old Buildings: Preservation from the Technical and Antiquarian Standpoint*. Stockholm: National Swedish Building Research, 1972. (Contains a section on roof maintenance problems)

Insall, Donald. *The Care of Old Buildings Today*. London: The Architectural Press, 1972. (Excellent guide to some problems and solutions for historic roofs)

Labine, R.A. Clem. "Repairing Slate Roofs." *The Old House Journal* 3 (no. 12, Dec. 1975): 6-7.

Lefer, Henry. "A Birds-eye View." *Progressive Architecture*. (Mar. 1977), pp. 88-92. (Article on contemporary sheet metal)

National Slate Association. *Slate Roofs*. Reprint of 1926 edition, now available from the Vermont Structural Slate Co., Inc., Fairhaven, VT 05743. (An excellent reference for the many designs and details of slate roofs)

Peterson, Charles E. "Iron in Early American Roofs." *The Smithsonian Journal of History* 3 (no. 3). Edited by Peter C. Welsh. Washington, D.C.: Smithsonian Institution, 1968, pp. 41-76.

Waite, Diana S. *Nineteenth Century Tin Roofing and its Use at Hyde Hall*. Albany: New York State Historic Trust, 1971.

——. "Roofing for Early America." *Building Early America*. Edited by Charles E. Peterson. Radnor, Penn.: Chilton Book Co., 1976.

6 PRESERVATION BRIEFS

Dangers of Abrasive Cleaning to Historic Buildings

Anne E. Grimmer

U.S. Department of the Interior
National Park Service
Cultural Resources
Heritage Preservation Services

> "The surface cleaning of structures shall be undertaken with the gentlest means possible. Sandblasting and other cleaning methods that will damage the historic building materials shall not be undertaken."—The Secretary of the Interior's "Standards for Historic Preservation Projects."

Abrasive cleaning methods are responsible for causing a great deal of damage to historic building materials. To prevent indiscriminate use of these potentially harmful techniques, this brief has been prepared to explain abrasive cleaning methods, how they can be physically and aesthetically destructive to historic building materials, and why they generally are not acceptable preservation treatments for historic structures. There are alternative, less harsh means of cleaning and removing paint and stains from historic buildings. However, careful testing should precede general cleaning to assure that the method selected will not have an adverse effect on the building materials. A historic building is irreplaceable, and should be cleaned using only the "gentlest means possible" to best preserve it.

What is Abrasive Cleaning?

Abrasive cleaning methods include all techniques that physically abrade the building surface to remove soils, discolorations or coatings. Such techniques involve the use of certain *materials* which impact or abrade the surface under pressure, or abrasive *tools and equipment*. Sand, because it is readily available, is probably the most commonly used type of grit material. However, any of the following materials may be substituted for sand, and all can be classified as abrasive substances: ground slag or volcanic ash, crushed (pulverized) walnut or almond shells, rice husks, ground corncobs, ground coconut shells, crushed eggshells, silica flour, synthetic particles, glass beads and micro-balloons. Even water under pressure can be an abrasive substance. Tools and equipment that are abrasive to historic building materials include wire brushes, rotary wheels, power sanding disks and belt sanders.

The use of water in combination with grit may also be classified as an abrasive cleaning method. Depending on the manner in which it is applied, water may soften the impact of the grit, but water that is too highly pressurized can be very abrasive. There are basically two different methods which can be referred to as "wet grit," and it is important to differentiate between the two. One technique involves the addition of a stream of water to a regular sandblasting nozzle. This is done primarily to cut down dust, and has very little, if any, effect on reducing the aggressiveness, or cutting action of the grit particles. With the second technique, a very small amount of grit is added to a pressurized water stream. This method may be controlled by regulating the amount of grit fed into the water stream, as well as the pressure of the water.

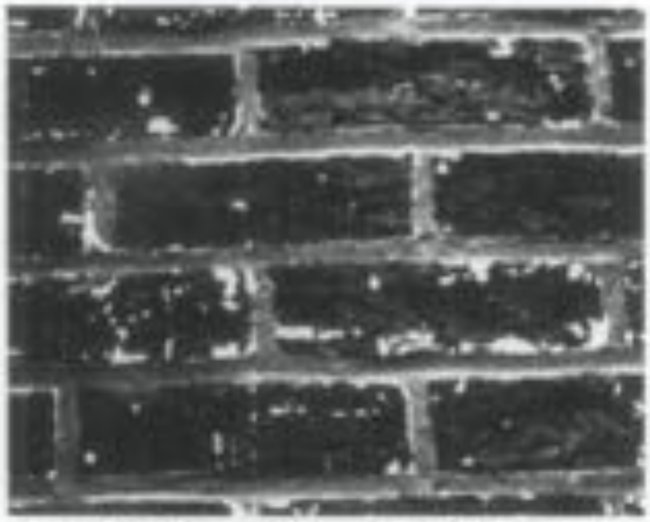
Why Are Abrasive Cleaning Methods Used?

Usually, an abrasive cleaning method is selected as an expeditious means of quickly removing years of dirt accumulation, unsightly stains, or deteriorating building fabric or finishes, such as stucco or paint. The fact that sandblasting is one of the best known and most readily available building cleaning treatments is probably the major reason for its frequent use.

Many mid-19th century brick buildings were painted immediately or soon after completion to protect poor quality brick or to imitate another material, such as stone. Sometimes brick buildings were painted in an effort to produce what was considered a more harmonious relationship between a building and its natural surroundings. By the 1870s, brick buildings

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402

Abrasively Cleaned vs. Untouched Brick. *Two brick townhouses with a common façade provide an excellent point of comparison when only one of the houses has been sandblasted. It is clear that abrasive blasting, by removing the outer surface, has left the brickwork on the left rough and pitted, while that on the right still exhibits an undamaged and relatively smooth surface. Note that the abrasive cleaning has also removed a considerable portion of the mortar from the joints of the brick on the left side, which will require repointing.*



Abrading the Surface without Removing the Paint. *Even though the entire outer surface layer of the brick has been sandblasted off, spots of paint still cling to the masonry. Sandblasting or other similarly abrasive methods are not always a successful means of removing paint.*

were often left unpainted as mechanization in the brick industry brought a cheaper pressed brick and fashion decreed a sudden preference for dark colors. However, it was still customary to paint brick of poorer quality for the additional protection the paint afforded.

It is a common 20th-century misconception that all historic masonry buildings were initially unpainted. If the intent of a modern restoration is to return a building to its original appearance, removal of the paint not only may be historically inaccurate, but also harmful. Many older buildings were painted or stuccoed at some point to correct recurring maintenance problems caused by faulty construction techniques, to hide alterations, or in an attempt to solve moisture problems. If this is the case, removal of paint or stucco may cause these problems to reoccur.

Another reason for paint removal, particularly in rehabilitation projects, is to give the building a "new image" in response to contemporary design trends and to attract investors or tenants. Thus, it is necessary to consider the purpose of the intended cleaning. While it is clearly important to remove unsightly stains, heavy encrustations of dirt, peeling paint or other surface coatings, it may not be equally desirable to remove paint from a building which originally was painted. Many historic buildings which show only a slight amount of soil or discoloration are much better left as they are. A thin layer of soil is more often protective of the building fabric than it is harmful, and seldom detracts from the building's architectural and/or historic character. Too thorough cleaning of a historic building may not only sacrifice some of the building's character, but also, misguided cleaning efforts can cause a great deal of damage to historic building fabric. Unless there are stains, graffiti or dirt and pollution deposits which are destroying the building fabric, it is generally preferable to do as little cleaning as possible, or to repaint where necessary. It is important to remember that a historic building does not have to look as if it were newly constructed to be an attractive or successful restoration or rehabilitation project. For a more thorough explanation of the philosophy of cleaning historic buildings see Preservation Briefs: No. 1 "The Cleaning and Waterproof Coating of Masonry Buildings," by Robert C. Mack, AIA.

Problems of Abrasive Cleaning

The crux of the problem is that abrasive cleaning is just that—abrasive. An abrasively cleaned historic structure may be physically as well as aesthetically damaged. Abrasive methods "clean" by eroding dirt or paint, but at the same time they also tend to erode the surface of the building material. In this way, abrasive cleaning is destructive and causes irreversible harm to the historic building fabric. If the fabric is brick, abrasive methods remove the hard, outer protective surface, and therefore make the brick more susceptible to rapid weathering and deterioration. Grit blasting may also increase the water permeability of a brick wall. The impact of the grit particles tends to erode the bond between the mortar and the brick, leaving cracks or enlarging existing cracks where water can enter. Some types of stone develop a protective patina or "quarry crust" parallel to the worked surface (created by the movement of moisture towards the outer edge), which also may be damaged by abrasive cleaning. The rate at which the material subsequently weathers depends on the quality of the inner surface that is exposed.

Abrasive cleaning can destroy, or substantially diminish, decorative detailing on buildings such as a molded brickwork or architectural terra-cotta, ornamental carving on wood or stone, and evidence of historic craft techniques, such as tool marks and other surface textures. In addition, perfectly sound and/or "tooled" mortar joints can be worn away by abrasive techniques. This not only results in the loss of historic craft detailing but also requires repointing, a step involving considerable time, skill and expense, and which might not have been necessary had a gentler method been chosen. Erosion and pitting of the building material by abrasive cleaning creates a greater surface area on which dirt and pollutants collect. In this sense, the building fabric "attracts" more dirt, and will require more frequent cleaning in the future.

In addition to causing physical and aesthetic harm to the historic fabric, there are several adverse environmental effects of dry abrasive cleaning methods. Because of the friction caused by the abrasive medium hitting the building fabric, these techniques usually create a considerable amount of dust, which is unhealthy, particularly to the operators of the abrasive equipment. It further pollutes the environment around the job site, and deposits dust on neighboring buildings, parked vehicles and nearby trees and shrubbery. Some adjacent materials not intended for abrasive treatment such as wood or glass, may also be damaged because the equipment may be difficult to regulate.

Wet grit methods, while eliminating dust, deposit a messy slurry on the ground or other objects surrounding the base of the building. In colder climates where there is the threat of frost, any wet cleaning process applied to historic masonry structures must be done in warm weather, allowing ample time for the wall to dry out thoroughly before cold weather sets in. Water which remains and freezes in cracks and openings of the masonry surface eventually may lead to spalling. High-pressure wet cleaning may force an inordinate amount of water into the walls, affecting interior materials such as plaster or joist ends, as well as metal building components within the walls.

Variable Factors

The greatest problem in developing practical guidelines for cleaning any historic building is the large number of variable and unpredictable factors involved. Because these variables make each cleaning project unique, it is difficult to establish specific standards at this time. This is particularly true of abrasive cleaning methods because their inherent potential for causing damage is multiplied by the following factors:

— the type and condition of the material being cleaned;
— the size and sharpness of the grit particles or the mechanical equipment;
— the pressure with which the abrasive grit or equipment is applied to the building surface;
— the skill and care of the operator; and
— the constancy of the pressure on all surfaces during the cleaning process.

Micro-Abrasive Cleaning. *This small, pencil-sized micro-abrasive unit is used by some museum conservators to clean small objects. This particular micro-abrasive unit is operated within the confines of a box (approximately 2 cubic feet of space), but a similar and slightly larger unit may be used for cleaning larger pieces of sculpture, or areas of architectural detailing on a building. Even a pressure cleaning unit this small is capable of eroding a surface, and must be carefully controlled.*

"Line Drop." *Even though the operator of the sandblasting equipment is standing on a ladder to reach the higher sections of the wall, it is still almost impossible to have total control over the pressure. The pressure of the sand hitting the lower portion of the wall will still be greater than that above, because of the "line drop" in the distance from the pressure source to the nozzle. (Hugh Miller)*

Pressure: The damaging effects of most of the variable factors involved in abrasive cleaning are self evident. However, the matter of pressure requires further explanation. In cleaning specifications, pressure is generally abbreviated as "psi" (pounds per square inch), which technically refers to the "tip" pressure, or the amount of pressure at the nozzle of the blasting apparatus. Sometimes "psig," or pressure at the gauge (which may be many feet away, at the other end of the hose), is used in place of "psi." These terms are often incorrectly used interchangeably.

Despite the apparent care taken by most architects and building cleaning contractors to prepare specifications for pressure cleaning which will not cause harm to the delicate fabric of a historic building, it is very difficult to ensure that the same amount of pressure is applied to all parts of the building. For example, if the operator of the pressure equipment stands on the ground while cleaning a two-story structure, the amount of force reaching the first story will be greater than that hitting the second story, even if the operator stands on scaffolding or in a cherry picker, because of the "line drop" in the distance from the pressure source to the nozzle. Although technically it may be possible to prepare cleaning specifications with tight controls that would eliminate all but a small margin of error, it may not be easy to find professional cleaning firms willing to work under such restrictive conditions. The fact is that many professional building cleaning firms do not really understand the extreme delicacy of historic building fabric, and how it differs from modern construction materials. Consequently, they may accept building cleaning projects for which they have no experience.

The amount of pressure used in any kind of cleaning treatment which involves pressure, whether it is dry or wet grit, chemicals or just plain water, is crucial to the outcome of the cleaning project. Unfortunately, no standards have been established for determining the correct pressure for cleaning each of the many historic building materials which would not cause harm. The considerable discrepancy between the way the building cleaning industry and architectural conservators define "high" and "low" pressure cleaning plays a significant role in the difficulty of creating standards.

Nonhistoric/Industrial: A representative of the building cleaning industry might consider "high" pressure water cleaning to be anything over 5,000 psi, or even as high as 10,000 to 15,000 psi! Water under this much pressure may be necessary to clean industrial structures or machinery, but would destroy most historic building materials. Industrial *chemical* cleaning commonly utilizes pressures between 1,000 and 2,500 psi.

Spalling Brick. *This soft, early 19th-century brick was sandblasted in the 1960s; consequently, severe spalling has resulted. Some bricks have almost totally disintegrated, and will eventually have to be replaced. (Robert S. Gamble)*

Historic: By contrast, conscientious dry or wet abrasive cleaning of a historic structure would be conducted within the range of 20 to 100 psi at a range of 3 to 12 inches. Cleaning at this low pressure requires the use of a very fine 180 or 220 mesh grit forced through a nozzle with a ¼ inch opening. A similar, even more delicate method being adopted by architectural conservators uses a micro-abrasive grit on small, hard-to-clean areas of carved, cut or molded ornament on a building façade. Originally developed by museum conservators for cleaning sculpture, this technique may employ glass beads, micro-balloons, or another type of micro-abrasive gently powered at approximately 40 psi by a very small, almost pencil-like pressure instrument. Although a slightly larger pressure instrument may be used on historic buildings, this technique still has limited practical applicability on a large scale building cleaning project because of the cost and the relatively few technicians competent to handle the task. In general, architectural conservators have determined that only through very controlled conditions can most historic building material be abrasively cleaned of soil or paint without measurable damage to the surface or profile of the substrate.

Yet some professional cleaning companies which specialize in cleaning historic masonry buildings use chemicals and water at a pressure of approximately 1,500 psi, while other cleaning firms recommend lower pressures ranging from 200 to 800 psi for a similar project. An architectural conservator might decide, *after testing*, that some historic structures could be cleaned properly using a moderate pressure (200-600 psi), or even a high pressure (600-1800 psi) water rinse. However, cleaning historic buildings under such high pressure should be considered an exception rather than the rule, and would require *very careful* testing and supervision to assure that the historic surface materials could withstand the pressure without gouging, pitting or loosening.

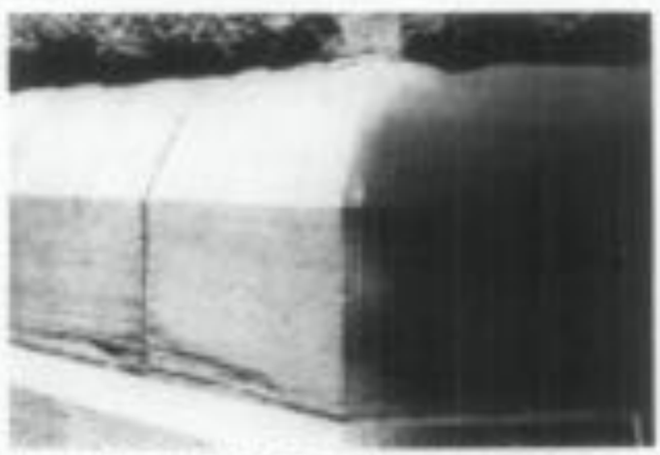
These differences in the amount of pressure used by commercial or industrial building cleaners and architectural conservators point to one of the main problems in using abrasive means to clean historic buildings: misunderstanding of the potentially fragile nature of historic building materials. There is no one cleaning formula or pressure suitable for all situations. Decisions regarding the proper cleaning process for historic structures can be made only after careful analysis of the building fabric, and testing.

How Building Materials React to Abrasive Cleaning Methods

Brick and Architectural Terra-Cotta: Abrasive blasting does not affect all building materials to the same degree. Such techniques quite logically cause greater damage to softer and more porous materials, such as brick or architectural terra-cotta. When these materials are cleaned abrasively, the hard, outer layer (closest to the heat of the kiln) is eroded, leaving the soft, inner core exposed and susceptible to accelerated weathering. Glazed architectural terra-cotta and ceramic veneer have a baked-on glaze which is also easily damaged by abrasive cleaning. Glazed architectural terra-cotta was designed for easy maintenance, and generally can be cleaned using detergent and water; but chemicals or steam may be needed to remove more persistent stains. Large areas of brick or architectural terra-cotta which have been painted are best left painted, or repainted if necessary.

Plaster and Stucco: Plaster and stucco are types of masonry finish materials that are softer than brick or terra-cotta; if treated abrasively these materials will simply disintegrate. Indeed, when plaster or stucco is treated abrasively it is usually with the intention of removing the plaster or stucco from whatever base material or substrate it is covering. Obviously, such abrasive techniques should not be applied to clean sound plaster or stuccoed walls, or decorative plaster wall surfaces.

Building Stones: Building stones are cut from the three main categories of natural rock: dense, igneous rock such as granite; sandy, sedimentary rock such as limestone or sandstone; and crystalline, metamorphic rock such as marble. As op-



Abrasive Cleaning of Tooled Granite. *Even this carefully controlled "wet grit" blasting has erased vertical tooling marks in the cut granite blocks on the left. Not only has the tooling been destroyed, but the damaged stone surface is now more susceptible to accelerated weathering.*

posed to kiln-dried masonry materials such as brick and architectural terra-cotta, building stones are generally homogeneous in character at the time of a building's construction. However, as the stone is exposed to weathering and environmental pollutants, the surface may become friable, or may develop a protective skin or patina. These outer surfaces are very susceptible to damage by abrasive or improper chemical cleaning.

Building stones are frequently cut into ashlar blocks or "dressed" with tool marks that give the building surface a specific texture and contribute to its historic character as much as ornately carved decorative stonework. Such detailing is easily damaged by abrasive cleaning techniques; the pattern of tooling or cutting is erased, and the crisp lines of moldings or carving are worn or pitted.

Occasionally, it may be possible to clean small areas of rough-cut granite, limestone or sandstone having a heavy dirt encrustation by using the "wet grit" method, whereby a small amount of abrasive material is injected into a controlled, pressurized water stream. However, this technique requires very careful supervision in order to prevent damage to the stone. Polished or honed marble or granite should *never* be treated abrasively, as the abrasion would remove the finish in much the way glass would be etched or "frosted" by such a process. It is generally preferable to underclean, as too strong a cleaning procedure will erode the stone, exposing a new and increased surface area to collect atmospheric moisture and dirt. Removing paint, stains or graffiti from most types of stone may be accomplished by a chemical treatment carefully selected to best handle the removal of the particular type of paint or stain without damaging the stone. (See section on the "Gentlest Means Possible".)

Abrasive Cleaning of Wood. *This wooden windowsill, molding and paneling have been sandblasted to remove layers of paint in the rehabilitation of this commercial building. Not only is some paint still embedded in cracks and crevices of the woodwork, but more importantly, grit blasting has actually eroded the summer wood, in effect raising the grain, and resulting in a rough surface.*

Wood: Most types of wood used for buildings are soft, fibrous and porous, and are particularly susceptible to damage by abrasive cleaning. Because the summer wood between the lines of the grain is softer than the grain itself, it will be worn away by abrasive blasting or power tools, leaving an uneven surface with the grain raised and often frayed or "fuzzy." Once this has occurred, it is almost impossible to achieve a smooth surface again except by extensive hand sanding, which is expensive and will quickly negate any costs saved earlier by sandblasting. Such harsh cleaning treatment also obliterates historic tool marks, fine carving and detailing, which precludes its use on any interior or exterior woodwork which has been hand planed, milled or carved.

Metals: Like stone, metals are another group of building materials which vary considerably in hardness and durability. Softer metals which are used architecturally, such as tin, zinc, lead, copper or aluminum, generally should not be cleaned abrasively as the process deforms and destroys the original surface texture and appearance, as well as the acquired patina. Much applied architectural metal work used on historic buildings—tin, zinc, lead and copper—is often quite thin and soft, and therefore susceptible to denting and pitting. Galvanized sheet metal is especially vulnerable, as abrasive treatment would wear away the protective galvanized layer.

In the late 19th and early 20th centuries, these metals were often cut, pressed or otherwise shaped from sheets of metal into a wide variety of practical uses such as roofs, gutters and flashing, and façade ornamentation such as cornices, friezes, dormers, panels, cupolas, oriel windows, etc. The architecture of the 1920s and 1930s made use of metals such as chrome, nickel alloys, aluminum and stainless steel in decorative exterior panels, window frames, and doorways. Harsh abrasive blasting would destroy the original surface finish of most of these metals, and would increase the possibility of corrosion.

However, conservation specialists are now employing a sensitive technique of glass bead peening to clean some of the harder metals, in particular large bronze outdoor sculpture. Very fine (75–125 micron) glass beads are used at a low pressure of 60 to 80 psi. Because these glass beads are completely spherical, ther are no sharp edges to cut the surface of the metal. After cleaning, these statues undergo a lengthy process of polishing. Coatings are applied which protect the surface from corrosion, but they must be renewed every 3 to 5 years. A similarly delicate cleaning technique employing glass beads has been used in Europe to clean historic masonry structures without causing damage. But at this time the process has not been tested sufficiently in the United States to recommend it as a building conservation measure.

Sometimes a very fine smooth sand is used at a low pressure to clean or remove paint and corrosion from copper flashing and other metal building components. Restoration architects recently found that a mixture of crushed walnut shells and copper slag at a pressure of approximately 200 psi was the only way to remove corrosion successfully from a mid-19th century terne-coated iron roof. Metal cleaned in this manner must be painted immediately to prevent rapid recurrence of corrosion. It is thought that these methods "work harden" the surface by compressing the outer layer, and actually may be good for the surface of the metal. But the extremely complex nature and the time required by such processes make it very expensive and impractical for large-scale use at this time.

Cast and wrought iron architectural elements may be gently sandblasted or abrasively cleaned using a wire brush to remove layers of paint, rust and corrosion. Sandblasting was, in fact, developed originally as an efficient maintenance procedure for engineering and industrial structures and heavy machinery—iron and steel bridges, machine tool frames, engine frames, and railroad rolling stock—in order to clean and prepare them for repainting. Because iron is hard, its surface, which is naturally somewhat uneven, will not be noticeably damaged by controlled abrasion. Such treatment will, however, result in a small amount of pitting. But this slight abrasion creates a good surface for paint, since the iron must be repainted immediately to prevent corrosion. Any abrasive cleaning of metal building components will also remove the caulking from joints and around other openings. Such areas must be recaulked quickly to prevent moisture from entering and rusting the metal, or causing deterioration of other building fabric inside the structure.

When is Abrasive Cleaning Permissible?

For the most part, abrasive cleaning is destructive to historic building materials. A limited number of special cases have been explained when it may be appropriate, if supervised by a skilled conservator, to use a delicate abrasive technique on some historic building materials. The type of "wet grit" cleaning which involves a small amount of grit injected into a stream of low pressure water may be used on small areas of stone masonry (i.e., rough cut limestone, sandstone or unpolished granite), where milder cleaning methods have not been totally successful in removing harmful deposits of dirt and pollutants. Such areas may include stone window sills, the tops of cornices or column capitals, or other detailed areas of the façade.

This is still an abrasive technique, and without proper caution in handling, it can be *just as harmful to the building surface as any other abrasive cleaning method.* Thus, the decision to use this type of "wet grit" process should be made only after consultation with an experienced building conservator. Remember that *it is very time consuming and expensive to use any abrasive technique on a historic building in such a manner that it does not cause harm to the often fragile and friable building materials.*

At this time, and only under certain circumstances, abrasive cleaning methods may be used in the rehabilitation of interior spaces of warehouse or industrial buildings for contemporary uses.

Interior spaces of factories or warehouse structures in which the masonry or plaster surfaces do not have significant design, detailing, tooling or finish, and in which wooden architectural features are not finished, molded, beaded or worked by hand, may be cleaned abrasively in order to remove layers of paint and industrial discolorations such as smoke, soot, etc. It is expected after such treatment that brick surfaces will be rough and pitted, and wood will be somewhat frayed or "fuzzy" with raised wood grain. These nonsignificant surfaces will be damaged and have a roughened texture, but because they are interior elements, they will not be subject to further deterioration caused by weathering.

Permissible Abrasive Cleaning. *In accordance with the Secretary of the Interior's* Guidelines for Rehabilitation Projects, *it may be acceptable to use abrasive techniques to clean an industrial interior space such as that illustrated here, because the masonry surfaces do not have significant design, detailing, tooling or finish, and the wooden architectural features are not finished, molded, beaded or worked by hand.*

Historic Interiors that Should Not Be Cleaned Abrasively

Those instances (generally industrial and some commercial properties), when it may be acceptable to use an abrasive treatment on the interior of historic structures have been described. But for the majority of historic buildings, the Secretary of the Interior's *Guidelines for Rehabilitation* do not recommend "changing the texture of exposed wooden architectural features (including structural members) and masonry surfaces through sandblasting or use of other abrasive techniques to remove paint, discolorations and plaster. . . ."

Thus, it is not acceptable to clean abrasively interiors of historic residential and commercial properties which have *finished* interior spaces featuring milled woodwork such as doors, window and door moldings, wainscoting, stair balustrades and mantelpieces. Even the most modest historic *house interior*, although it may not feature elaborate detailing, contains plaster and woodwork that is architecturally significant to the original design and function of the house. Abrasive cleaning of such an interior would be destructive to the historic integrity of the building.

Abrasive cleaning is also impractical. Rough surfaces of abrasively cleaned wooden elements are hard to keep clean. It is also difficult to seal, paint or maintain these surfaces which can be splintery and a problem to the building's occupants. The force of abrasive blasting may cause grit particles to lodge in cracks of wooden elements, which will be a nuisance as the grit is loosened by vibrations and gradually sifts out. Removal of plaster will reduce the thermal and insulating value of the walls. Interior brick is usually softer than exterior brick, and generally of a poorer quality. Removing surface plaster from such brick by abrasive means often exposes gaping mortar joints and mismatched or repaired brickwork which was never intended to show. The resulting bare brick wall may require repointing, often difficult to match. It also may be necessary to apply a transparent surface coating (or sealer) in order to prevent the mortar and brick from "dusting." However, a sealer may not only change the color of the brick, but may also compound any existing moisture problems by restricting the normal evaporation of water vapor from the masonry surface.

"Gentlest Means Possible"

There are alternative means of removing dirt, stains and paint from historic building surfaces that can be recommended as more efficient and less destructive than abrasive techniques. The "gentlest means possible" of removing dirt from a building surface can be achieved by using a low-pressure water wash, scrubbing areas of more persistent grime with a natural bristle (never metal) brush. Steam cleaning can also be used effectively to clean some historic building fabric. Low-pressure water or steam will soften the dirt and cause the deposits to rise to the surface, where they can be washed away.

A third cleaning technique which may be recommended to remove dirt, as well as stains, graffiti or paint, involves the use of commercially available chemical cleaners or paint removers, which, when applied to masonry, loosen or dissolve the dirt or stains. These cleaning agents may be used in combination with water or steam, followed by a clear water wash to remove the residue of dirt and the chemical cleaners from the masonry. A natural bristle brush may also facilitate this type of chemically assisted cleaning, particularly in areas of heavy dirt deposits or stains, and a wooden scraper can be

Do not Abrasively Clean these Interiors. *Most historic residential and some commercial interior spaces contain finished plaster and wooden elements such as this stair balustrade and paneling which contribute to the historic and architectural character of the structure. Such interiors should not be subjected to abrasive techniques for the purpose of removing paint, dirt, discoloration or plaster.*

useful in removing thick encrustations of soot. A limewash or absorbent talc, whiting or clay poultice with a solvent can be used effectively to draw out salts or stains from the surface of the selected areas of a building facade. It is almost impossible to remove paint from masonry surfaces without causing some damage to the masonry, and it is best to leave the surfaces as they are or repaint them if necessary.

Some physicists are experimenting with the use of pulsed laser beams and xenon flash lamps for cleaning historic masonry surfaces. At this time it is a slow, expensive cleaning method, but its initial success indicates that it may have an increasingly important role in the future.

There are many chemical paint removers which, when applied to painted wood, soften and dissolve the paint so that it can be scraped off by hand. Peeling paint can be removed from wood by hand scraping and sanding. Particularly thick layers of paint may be softened with a heat gun or heat plate, providing appropriate precautions are taken, and the paint film scraped off by hand. Too much heat applied to the same spot can burn the wood, and the fumes caused by burning paint are dangerous to inhale, and can be explosive. Furthermore, the hot air from heat guns can start fires in the building cavity. Thus, adequate ventilation is important when using a heat gun or heat plate, as well as when using a chemical stripper. A torch or open flame should never be used.

Preparations for Cleaning: It cannot be overemphasized that all of these cleaning methods must be approached with caution. When using any of these procedures which involve water or other liquid cleaning agents on masonry, it is imperative that all openings be tightly covered, and all cracks or joints be well pointed in order to avoid the danger of water penetrating the building's facade, a circumstance which might result in serious moisture related problems such as efflorescence and/or subflorescence. Any time water is used on masonry as a cleaning agent, either in its pure state or in combination with chemical cleaners, it is very important that the work be done in warm weather when there is no danger of frost for several months. Otherwise water which has penetrated the masonry may freeze, eventually causing the surface of the building to crack and spall, which may create another conservation problem more serious to the health of the building than dirt.

Each kind of masonry has a unique composition and reacts differently with various chemical cleaning substances. Water and/or chemicals may interact with minerals in stone and cause new types of stains to leach out to the surface immediately, or more gradually in a delayed reaction. What may be a safe and effective cleaner for certain stain on one type of stone, may leave unattractive discolorations on another stone, or totally dissolve a third type.

Testing: Cleaning historic building materials, particularly masonry, is a technically complex subject, and thus, should never be done without expert consultation and testing. No cleaning project should be undertaken without first applying the intended cleaning agent to a representative test patch area in an inconspicuous location on the building surface. The test patch or patches should be allowed to weather for a period of time, preferably through a complete seasonal cycle, in order to determine that the cleaned area will not be adversely affected by wet or freezing weather or any by-products of the cleaning process.

Mitigating the Effects of Abrasive Cleaning

There are certain restoration measures which can be adopted to help preserve a historic building exterior which has been damaged by abrasive methods. Wood that has been sandblasted will exhibit a frayed or "fuzzed" surface, or a harder wood will have an exaggerated raised grain. The only way to remove this rough surface or to smooth the grain is by laborious sanding. Sandblasted wood, unless it has been extensively sanded, serves as a dustcatcher, will weather faster, and will present a continuing and ever worsening maintenance problem. Such wood, after sanding, should be painted or given a clear surface coating to protect the wood, and allow for somewhat easier maintenance.

There are few successful preservative treatments that may be applied to grit-blasted exterior masonry. Harder, denser stone may have suffered only a loss of crisp edges or tool marks, or other indications of craft technique. If the stone has a compact and uniform composition, it should continue to weather with little additional deterioration. But some types of sandstone, marble and limestone will weather at an accelerated rate once their protective "quarry crust" or patina has been removed.

Softer types of masonry, particularly brick and architectural terra-cotta, are the most likely to require some remedial treatment if they have been abrasively cleaned. Old brick, being essentially a soft, baked clay product, is greatly susceptible to increased deterioration when its hard, outer skin is removed through abrasive techniques. This problem can be minimized by painting the brick. An alternative is to treat it with a clear sealer or surface coating but this will give the masonry a glossy or shiny look. It is usually preferable to paint the brick rather than to apply a transparent sealer since

Hazards of Sandblasting and Surface Coating. *In order to "protect" this heavily sandblasted brick, a clear surface coating or sealer was applied. Because the air temperature was too cold at the time of application, the sealer failed to dry properly, dripping in places, and giving the brick surface a cloudy appearance.*

sealers reduce the transpiration of moisture, allowing salts to crystallize as subflorescence that eventually spalls the brick.

If a brick surface has been so extensively damaged by abrasive cleaning and weathering that spalling has already begun, it may be necessary to cover the walls with stucco, if it will adhere.

Of course, the application of paint, a clear surface coating (sealer), or stucco to deteriorating masonry means that the historical appearance will be sacrificed in an attempt to conserve the historic building materials. However, the original color and texture will have been changed already by the abrasive treatment. At this point it is more important to try to preserve the brick, and there is little choice but to protect it from "dusting" or spalling too rapidly. As a last resort, in the case of severely spalling brick, there may be no option but to replace the brick—a difficult, expensive (particularly if custom-made reproduction brick is used), and lengthy process. As described earlier, sandblasted interior brick work, while not subject to change of weather, may require the application of a transparent surface coating or painting as a maintenance procedure to contain loose mortar and brick dust. (See Preservation Briefs: No. 1 for a more thorough discussion of coatings.)

Metals, other than cast or wrought iron, that have been pitted and dented by harsh abrasive blasting usually cannot be smoothed out. Although fillers may be satisfactory for smoothing a painted surface, exposed metal that has been damaged usually will have to be replaced.

Summary

Sandblasting or other abrasive methods of cleaning or paint removal are by their nature destructive to historic building materials and should not be used on historic buildings except in a few well-monitored instances. There are exceptions when certain types of abrasive cleaning may be permissible, but only if conducted by a trained conservator, and if cleaning is necessary for the preservation of the historic structure.

There is no one formula that will be suitable for cleaning all historic building surfaces. Although there are many commercial cleaning products and methods available, it is impossible to state definitively which of these will be the most effective without causing harm to the building fabric. It is often difficult to identify ingredients or their proportions contained in cleaning products; consequently it is hard to predict how a product will react to the building materials to be cleaned. Similar uncertainties affect the outcome of other cleaning methods as they are applied to historic building materials. Further advances in understanding the complex nature of the many variables of the cleaning techniques may someday provide a better and simpler solution to the problems. But until that time, the process of cleaning historic buildings must be approached with caution through trial and error.

It is important to remember that historic building materials are neither indestructible, nor are they renewable. They must be treated in a responsible manner, which may mean little or no cleaning at all if they are to be preserved for future generations to enjoy. If it is in the best interest of the building to clean it, then it should be done "using the gentlest means possible."

Selected Reading List

Ashurst, John. *Cleaning Stone and Brick.* Technical Pamphlet 4. London: Society for the Protection of Ancient Buildings, 1977.

Asmus, John F. "Light Cleaning: Laser Technology for Surface Preparation in the Arts." *Technology and Conservation.* 3: 3 (Fall 1978), pp. 14-18.

"The Bare-Brick Mistake." *The Old House Journal.* I: 2 (November 1973), p. 2.

Brick Institute of America. *Colorless Coatings for Brick Masonry.* Technical Notes on Brick Construction. Number 7E (September/October 1976).

Gilder, Cornelia Brooke. *Property Owner's Guide to the Maintenance and Repair of Stone Buildings.* Technical Series/ No. 5. Albany, New York: The Preservation League of New York State, 1977.

Prudon, Theodore H.M. "The Case Against Removing Paint from Brick Masonry." *The Old House Journal.* III: 2 (February 1975), pp. 6-7.

———. "Removing Stains from Masonry." *The Old House Journal.* V: 5 (May 1977), pp. 58-59.

Stambolov, T., and J.R.J. Van Asperen de Boer. *The Deterioration and Conservation of Porous Building Materials in Monuments: A Review of the Literature.* Second enlarged edition. Rome: International Centre for Conservation, 1976.

Weiss, Norman R. "Cleaning of Building Exteriors: Problems and Procedures of Dirt Removal." *Technology and Conservation.* 2/76 (Fall 1976), pp. 8-13.

———. *Exterior Cleaning of Historic Masonry Buildings.* Draft. Washington, D.C.: Office of Archeology and Historic Preservation, Heritage Conservation and Recreation Service, U.S. Department of the Interior, 1976.

This Preservation Brief was written by Anne E. Grimmer, Architectural Historian, Technical Preservation Services Division. Valuable suggestions and comments were made by Hugh C. Miller, AIA, Washington, D.C.; Martin E. Weaver, Ottawa, Ontario, Canada; Terry Bryant, Downers Grove, Illinois; Daniel C. Cammer, McLean, Virginia; and the professional staff of Technical Preservation Services Division. Deborah Cooney edited the final manuscript.

The illustrations for this brief not specifically credited are from the files of the Technical Preservation Services Division.

This publication was prepared pursuant to Executive Order 11593, "Protection and Enhancement of the Cultural Environment," which directs the Secretary of the Interior to "develop and make available to Federal agencies and State and local governments information concerning professional methods and techniques for preserving, improving, restoring and maintaining historic properties." The Brief has been developed under the technical editorship of Lee H. Nelson, AIA, Chief, Preservation Assistance Division, National Park Service, U.S. Department of the Interior, Washington, D.C. 20240. Comments on the usefulness of this information are welcome and can be sent to Mr. Nelson at the above address. This publication is not copyrighted and can be reproduced without penalty. Normal procedures for credit to the author and the National Park Service are appreciated. June 1979.

U.S. Department of the Interior
National Park Service
Cultural Resources
Heritage Preservation Services

Preservation Briefs: 9

The Repair of Historic Wooden Windows

John H. Myers

The windows on many historic buildings are an important aspect of the architectural character of those buildings. Their design, craftsmanship, or other qualities may make them worthy of preservation. This is self-evident for ornamental windows, but it can be equally true for warehouses or factories where the windows may be the most dominant visual element of an otherwise plain building (see figure 1). Evaluating the significance of these windows and planning for their repair or replacement can be a complex process involving both objective and subjective considerations. The *Secretary of the Interior's Standards for Rehabilitation*, and the accompanying guidelines, call for respecting the significance of original materials and features, repairing and retaining them wherever possible, and when necessary, replacing them in kind. This Brief is based on the issues of significance and repair which are implicit in the standards, but the primary emphasis is on the technical issues of planning for the repair of windows including evaluation of their physical condition, techniques of repair, and design considerations when replacement is necessary.

Figure 1. Windows are frequently important visual focal points, especially on simple facades such as this mill building. Replacement of the multi-pane windows here with larger panes could dramatically change the appearance of the building. The areas of missing windows convey the impression of such a change. Photo: John T. Lowe

Much of the technical section presents repair techniques as an instructional guide for the do-it-yourselfer. The information will be useful, however, for the architect, contractor, or developer on large-scale projects. It presents a methodology for approaching the evaluation and repair of existing windows, and considerations for replacement, from which the professional can develop alternatives and specify appropriate materials and procedures.

Architectural or Historical Significance

Evaluating the architectural or historical significance of windows is the first step in planning for window treatments, and a general understanding of the function and history of windows is vital to making a proper evaluation. As a part of this evaluation, one must consider four basic window functions: admitting light to the interior spaces, providing fresh air and ventilation to the interior, providing a visual link to the outside world, and enhancing the appearance of a building. No single factor can be disregarded when planning window treatments; for example, attempting to conserve energy by closing up or reducing the size of window openings may result in the use of *more* energy by increasing electric lighting loads and decreasing passive solar heat gains.

Historically, the first windows in early American houses were casement windows; that is, they were hinged at the side and opened outward. In the beginning of the eighteenth century single- and double-hung windows were introduced. Subsequently many styles of these vertical sliding sash windows have come to be associated with specific building periods or architectural styles, and this is an important consideration in determining the significance of windows, especially on a local or regional basis. Site-specific, regionally oriented architectural comparisons should be made to determine the significance of windows in question. Although such comparisons may focus on specific window types and their details, the ultimate determination of significance should be made within the context of the whole building, wherein the windows are one architectural element (see figure 2).

After all of the factors have been evaluated, *windows should be considered significant to a building if they:* 1) are original, 2) reflect the original design intent for the building, 3) reflect period or regional styles or building practices, 4) reflect changes to the building resulting from major periods or events, or 5) are examples of exceptional craftsmanship or design. Once this evaluation of significance has been completed, it is possible to pro-

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402

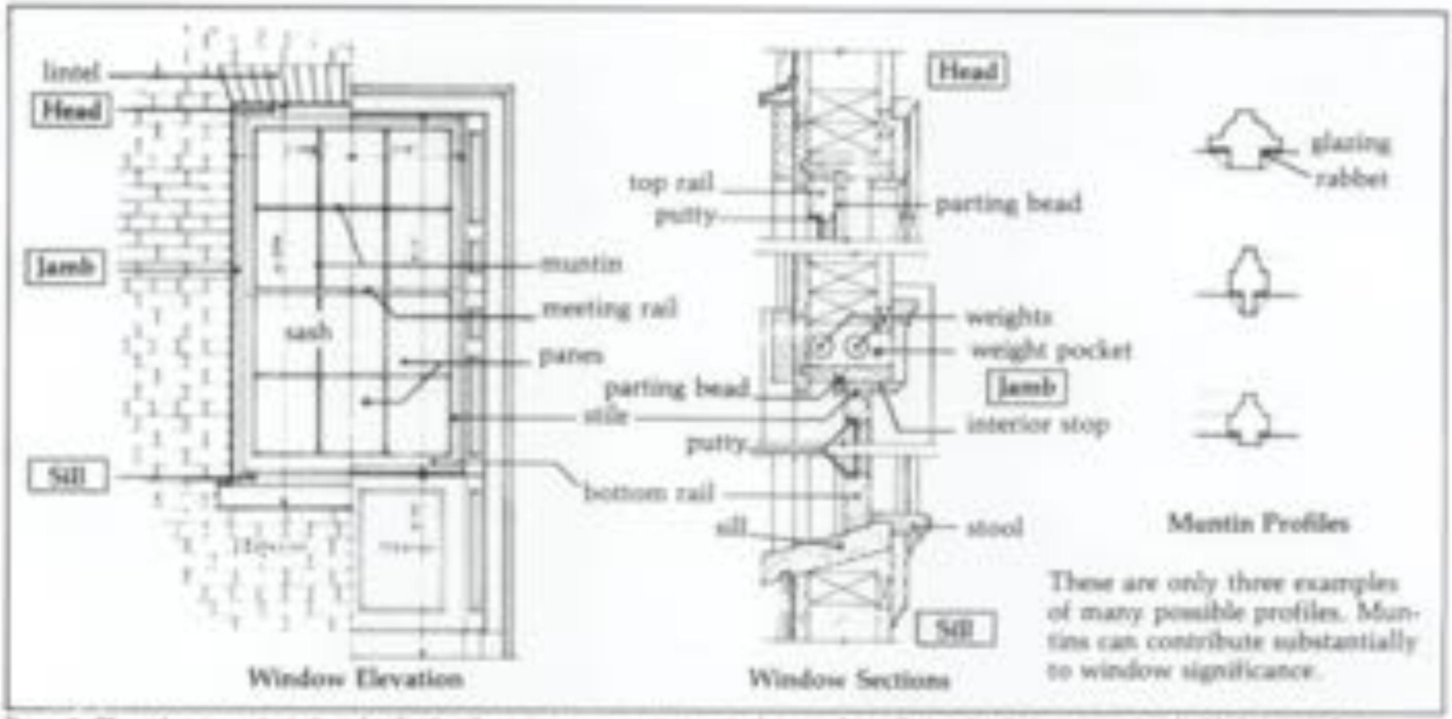


Figure 2. These drawings of window details identify major components, terminology, and installation details for a wooden double-hung window.

ceed with planning appropriate treatments, beginning with an investigation of the physical condition of the windows.

Physical Evaluation

The key to successful planning for window treatments is a careful evaluation of existing physical conditions on a unit-by-unit basis. A graphic or photographic system may be devised to record existing conditions and illustrate the scope of any necessary repairs. Another effective tool is a window schedule which lists all of the parts of each window unit. Spaces by each part allow notes on existing conditions and repair instructions. When such a schedule is completed, it indicates the precise tasks to be performed in the repair of each unit and becomes a part of the specifications. In any evaluation, one should note at a minimum, 1) window location, 2) condition of the paint, 3) condition of the frame and sill, 4) condition of the sash (rails, stiles and muntins), 5) glazing problems, 6) hardware, and 7) the overall condition of the window (excellent, fair, poor, and so forth).

Many factors such as poor design, moisture, vandalism, insect attack, and lack of maintenance can contribute to window deterioration, but moisture is the primary contributing factor in wooden window decay. All window units should be inspected to see if water is entering around the edges of the frame and, if so, the joints or seams should be caulked to eliminate this danger. The glazing putty should be checked for cracked, loose, or missing sections which allow water to saturate the wood, especially at the joints. The back putty on the interior side of the pane should also be inspected, because it creates a seal which prevents condensation from running down into the joinery. The sill should be examined to insure that it slopes downward away from the building and allows water to drain off. In addition, it may be advisable to cut a dripline along the underside of the sill. This almost invisible treatment will insure proper water run-off, particularly if the bottom of the sill is flat. Any conditions, including poor original design, which permit water to come in contact with the wood or to puddle on the sill must be corrected as they contribute to deterioration of the window.

One clue to the location of areas of excessive moisture is the condition of the paint; therefore, each window should be examined for areas of paint failure. Since excessive moisture is detrimental to the paint bond, areas of paint blistering, cracking, flaking, and peeling usually identify points of water penetration, moisture saturation, and potential deterioration. Failure of the paint should not, however, be mistakenly interpreted as a sign that the wood is in poor condition and hence, irreparable. Wood is frequently in sound physical condition beneath unsightly paint. After noting areas of paint failure, the next step is to inspect the condition of the wood, particularly at the points identified during the paint examination.

Each window should be examined for operational soundness beginning with the lower portions of the frame and sash. Exterior rainwater and interior condensation can flow downward along the window, entering and collecting at points where the flow is blocked. The sill, joints between the sill and jamb, corners of the bottom rails and muntin joints are typical points where water collects and deterioration begins (see figure 3). The operation of the window (continuous opening and closing over the years and seasonal temperature changes) weakens the joints, causing movement and slight separation. This process makes the joints more vulnerable to water which is readily absorbed into the end-grain of the wood. If severe deterioration exists in these areas, it will usually be apparent on visual inspection, but other less severely deteriorated areas of the wood may be tested by two traditional methods using a small ice pick.

An ice pick or an awl may be used to test wood for soundness. The technique is simply to jab the pick into a wetted wood surface at an angle and pry up a small sec-

Figure 3. Deterioration of poorly maintained windows usually begins on horizontal surfaces and at joints where water can collect and saturate the wood. The problem areas are clearly indicated by paint failure due to moisture. Photo: Baird M. Smith, AIA

tion of the wood. Sound wood will separate in long fibrous splinters, but decayed wood will lift up in short irregular pieces due to the breakdown of fiber strength.

Another method of testing for soundness consists of pushing a sharp object into the wood, perpendicular to the surface. If deterioration has begun from the hidden side of a member and the core is badly decayed, the visible surface may appear to be sound wood. Pressure on the probe can force it through an apparently sound skin to penetrate deeply into decayed wood. This technique is especially useful for checking sills where visual access to the underside is restricted.

Following the inspection and analysis of the results, the scope of the necessary repairs will be evident and a plan for the rehabilitation can be formulated. Generally the actions necessary to return a window to "like new" condition will fall into three broad categories: 1) routine maintenance procedures, 2) structural stabilization, and 3) parts replacement. These categories will be discussed in the following sections and will be referred to respectively as Repair Class I, Repair Class II, and Repair Class III. Each successive repair class represents an increasing level of difficulty, expense, and work time. Note that most of the points mentioned in Repair Class I are routine maintenance items and should be provided in a regular maintenance program for any building. The neglect of these routine items can contribute to many common window problems.

Before undertaking any of the repairs mentioned in the following sections all sources of moisture penetration should be identified and eliminated, and all existing decay fungi destroyed in order to arrest the deterioration process. Many commercially available fungicides and wood preservatives are toxic, so it is extremely important to follow the manufacturer's recommendations for application, and store all chemical materials away from children and animals. After fungicidal and preservative treatment the windows may be stabilized, retained, and restored with every expectation for a long service life.

Repair Class I: Routine Maintenance

Repairs to wooden windows are usually labor intensive and relatively uncomplicated. On small scale projects this allows the do-it-yourselfer to save money by repairing all or part of the windows. On larger projects it presents the opportunity for time and money which might otherwise be spent on the removal and replacement of existing windows, to be spent on repairs, subsequently saving all or part of the material cost of new window units. Regardless of the actual costs, or who performs the work, the evaluation process described earlier will provide the knowledge from which to specify an appropriate work program, establish the work element priorities, and identify the level of skill needed by the labor force.

The routine maintenance required to upgrade a window to "like new" condition normally includes the following steps: 1) some degree of interior and exterior paint removal, 2) removal and repair of sash (including reglazing where necessary), 3) repairs to the frame, 4) weatherstripping and reinstallation of the sash, and 5) repainting. These operations are illustrated for a typical double-hung wooden window (see figures 4a-f), but they may be adapted to other window types and styles as applicable.

Historic windows have usually acquired many layers of paint over time. Removal of excess layers or peeling and flaking paint will facilitate operation of the window and restore the clarity of the original detailing. Some degree of paint removal is also necessary as a first step in the proper surface preparation for subsequent refinishing (if paint color analysis is desired, it should be conducted prior to the onset of the paint removal). There are several safe and effective techniques for removing paint from wood, depending on the amount of paint to be removed. Several techniques such as scraping, chemical stripping, and the use of a hot air gun are discussed in "Preservation Briefs: 10 Paint Removal from Historic Woodwork" (see Additional Reading section at end).

Paint removal should begin on the interior frames, being careful to remove the paint from the interior stop and the parting bead, particularly along the seam where these stops meet the jamb. This can be accomplished by running a utility knife along the length of the seam, breaking the paint bond. It will then be much easier to remove the stop, the parting bead and the sash. The interior stop may be initially loosened from the sash side to avoid visible scarring of the wood and then gradually pried loose using a pair of putty knives, working up and down the stop in small increments (see figure 4b). With the stop removed, the lower or interior sash may be withdrawn. The sash cords should be detached from the sides of the sash and their ends may be pinned with a nail or tied in a knot to prevent them from falling into the weight pocket.

Removal of the upper sash on double-hung units is similar but the parting bead which holds it in place is set into a groove in the center of the stile and is thinner and more delicate than the interior stop. After removing any paint along the seam, the parting bead should be carefully pried out and worked free in the same manner as the interior stop. The upper sash can be removed in the same manner as the lower one and both sash taken to a convenient work area (in order to remove the sash the interior stop and parting bead need only be removed from one side of the window). Window openings can be covered with polyethylene sheets or plywood sheathing while the sash are out for repair.

The sash can be stripped of paint using appropriate techniques, but if any heat treatment is used (see figure 4c), the glass should be removed or protected from the sudden temperature change which can cause breakage. An

Figure 4a. The following series of photographs of the repair of a historic double-hung window use a unit which is structurally sound but has many layers of paint, some cracked and missing putty, slight separation at the joints, broken sash cords, and one cracked pane. Photo: John H. Myers

Figure 4b. After removing paint from the seam between the interior stop and the jamb, the stop can be pried out and gradually worked loose using a pair of putty knives as shown. To avoid visible scarring of the wood, the sash can be raised and the stop pried loose initially from the outer side. Photo: John H. Myers

Figure 4c. Sash can be removed and repaired in a convenient work area. Paint is being removed from this sash with a hot air gun while an asbestos sheet protects the glass from sudden temperature change. Photo: John H. Myers

Figure 4d. Reglazing or replacement of the putty requires that the existing putty be removed manually, the glazing points be extracted, the glass removed, and the back putty scraped out. To reglaze, a bed of putty is laid around the perimeter of the rabbet, the pane is pressed into place, glazing points are inserted to hold the pane (shown), and a final seal of putty is beveled around the edge of the glass. Photo: John H. Myers

Figure 4e. A common repair is the replacement of broken sash cords with new cords (shown) or with chains. The weight pocket is often accessible through a removable plate in the jamb, or by removing the interior trim. Photo: John H. Myers

Figure 4f. Following the relatively simple repairs, the window is weathertight, like new in appearance, and serviceable for many years to come. Both the historic material and the detailing and craftsmanship of this original window have been preserved. Photo: John H. Myers

overlay of aluminum foil on gypsum board or asbestos can protect the glass from such rapid temperature change. It is important to protect the glass because it may be historic and often adds character to the window. Deteriorated putty should be removed manually, taking care not to damage the wood along the rabbet. If the glass is to be removed, the glazing points which hold the glass in place can be extracted and the panes numbered and removed for cleaning and reuse in the same openings. With the glass panes out, the remaining putty can be removed and the sash can be sanded, patched, and primed with a preservative primer. Hardened putty in the rabbets may be softened by heating with a soldering iron at the point of removal. Putty remaining on the glass may be softened by soaking the panes in linseed oil, and then removed with less risk of breaking the glass. Before reinstalling the glass, a bead of glazing compound or linseed oil putty should be laid around the rabbet to cushion and seal the glass. Glazing compound should only be used on wood which has been brushed with linseed oil and primed with an oil based primer or paint. The pane is then pressed into place and the glazing points are pushed into the wood around the perimeter of the pane (see figure 4d). The final glazing compound or putty is applied and beveled to complete the seal. The sash can be refinished as desired on the inside and painted on the outside as soon as a "skin" has formed on the putty, usually in 2 or 3 days. Exterior paint should cover the beveled glazing compound or putty and lap over onto the glass slightly to complete a weathertight seal. After the proper curing times have elapsed for paint and putty, the sash will be ready for reinstallation.

While the sash are out of the frame, the condition of the wood in the jamb and sill can be evaluated. Repair and refinishing of the frame may proceed concurrently with repairs to the sash, taking advantage of the curing times for the paints and putty used on the sash. One of the most common work items is the replacement of the sash cords with new rope cords or with chains (see figure 4e). The weight pocket is frequently accessible through a door on the face of the frame near the sill, but if no door exists, the trim on the interior face may be removed for access. Sash weights may be increased for easier window operation by elderly or handicapped persons. Additional repairs to the frame and sash may include consolidation or replacement of deteriorated wood. Techniques for these repairs are discussed in the following sections.

The operations just discussed summarize the efforts necessary to restore a window with minor deterioration to "like new" condition (see figure 4f). The techniques can be applied by an unskilled person with minimal training and experience. To demonstrate the practicality of this approach, and photograph it, a Technical Preservation Services staff member repaired a wooden double-hung, two over two window which had been in service over ninety years. The wood was structurally sound but the window had one broken pane, many layers of paint, broken sash cords and inadequate, worn-out weatherstripping. The staff member found that the frame could be stripped of paint and the sash removed quite easily. Paint, putty and glass removal required about one hour for each sash, and the reglazing of both sash was accomplished in about one hour. Weatherstripping of the sash and frame, replacement of the sash cords and reinstallation of the sash, parting bead, and stop required an hour and a half. These times refer only to individual operations; the entire process took several days due to the drying and curing times for putty, primer, and paint, however work on other window units could have been in progress during these lag times.

Repair Class II: Stabilization

The preceding description of a window repair job focused on a unit which was operationally sound. Many windows will show some additional degree of physical deterioration, especially in the vulnerable areas mentioned earlier, but even badly damaged windows can be repaired using simple processes. Partially decayed wood can be waterproofed, patched, built-up, or consolidated and then painted to achieve a sound condition, good appearance, and greatly extended life. Three techniques for repairing partially decayed or weathered wood are discussed in this section, and all three can be accomplished using products available at most hardware stores.

One established technique for repairing wood which is split, checked or shows signs of rot, is to: 1) dry the wood, 2) treat decayed areas with a fungicide, 3) waterproof with two or three applications of boiled linseed oil (applications every 24 hours), 4) fill cracks and holes with putty, and 5) after a "skin" forms on the putty, paint the surface. Care should be taken with the use of fungicide which is toxic. Follow the manufacturers' directions and use only on areas which will be painted. When using any technique of building up or patching a flat surface, the finished surface should be sloped slightly to carry water away from the window and not allow it to puddle. Caulking of the joints between the sill and the jamb will help reduce further water penetration.

When sills or other members exhibit surface weathering they may also be built-up using wood putties or homemade mixtures such as sawdust and resorcinol glue, or whiting and varnish. These mixtures can be built up in successive layers, then sanded, primed, and painted. The same caution about proper slope for flat surfaces applies to this technique.

Wood may also be strengthened and stabilized by consolidation, using semi-rigid epoxies which saturate the porous decayed wood and then harden. The surface of the consolidated wood can then be filled with a semi-rigid epoxy patching compound, sanded and painted (see figure 5). Epoxy patching compounds can be used to build up

Figure 5. This illustrates a two-part epoxy patching compound used to fill the surface of a weathered sill and rebuild the missing edge. When the epoxy cures, it can be sanded smooth and painted to achieve a durable and waterproof repair. Photo: John H. Myers

missing sections or decayed ends of members. Profiles can be duplicated using hand molds, which are created by pressing a ball of patching compound over a sound section of the profile which has been rubbed with butcher's wax. This can be a very efficient technique where there are many typical repairs to be done. Technical Preservation Services has published *Epoxies for Wood Repairs in Historic Buildings* (see Additional Reading section at end), which discusses the theory and techniques of epoxy repairs. The process has been widely used and proven in marine applications; and proprietary products are available at hardware and marine supply stores. Although epoxy materials may be comparatively expensive, they hold the promise of being among the most durable and long lasting materials available for wood repair.

Any of the three techniques discussed can stabilize and restore the appearance of the window unit. There are times, however, when the degree of deterioration is so advanced that stabilization is impractical, and the only way to retain some of the original fabric is to replace damaged parts.

Repair Class III: Splices and Parts Replacement

When parts of the frame or sash are so badly deteriorated that they cannot be stabilized there are methods which permit the retention of some of the existing or original fabric. These methods involve replacing the deteriorated parts with new matching pieces, or splicing new wood into existing members. The techniques require more skill and are more expensive than any of the previously discussed alternatives. It is necessary to remove the sash and/or the affected parts of the frame and have a carpenter or woodworking mill reproduce the damaged or missing parts. Most millwork firms can duplicate parts, such as muntins, bottom rails, or sills, which can then be incorporated into the existing window, but it may be necessary to shop around because there are several factors controlling the practicality of this approach. Some woodworking mills do not like to repair old sash because nails or other foreign objects in the sash can damage expensive knives (which cost far more than their profits on small repair jobs); others do not have cutting knives to duplicate muntin profiles. Some firms prefer to concentrate on larger jobs with more profit potential, and some may not have a craftsman who can duplicate the parts. A little searching should locate a firm which will do the job, and at a reasonable price. If such a firm does not exist locally, there are firms which undertake this kind of repair and ship nationwide. It is possible, however, for the advanced do-it-yourselfer or craftsman with a table saw to duplicate moulding profiles using techniques discussed by Gordie Whittington in "Simplified Methods for Reproducing Wood Mouldings," *Bulletin* of the Association for Preservation Technology, Vol. III, No. 4, 1971, or illustrated more recently in *The Old House*, Time-Life Books, Alexandria, Virginia, 1979.

The repairs discussed in this section involve window frames which may be in very deteriorated condition, possibly requiring removal; therefore, caution is in order. The actual construction of wooden window frames and sash is not complicated. Pegged mortise and tenon units can be disassembled easily, if the units are out of the building. The installation or connection of some frames to the surrounding structure, especially masonry walls, can complicate the work immeasurably, and may even require dismantling of the wall. It may be useful, therefore, to take the following approach to frame repair: 1) conduct regular maintenance of sound frames to achieve the longest life possible, 2) make necessary repairs in place wherever possible, using stabilization and splicing techniques, and 3) if removal is necessary, thoroughly investigate the structural detailing and seek appropriate professional consultation.

Another alternative may be considered if parts replacement is required, and that is sash replacement. If extensive replacement of parts is necessary and the job becomes prohibitively expensive it may be more practical to purchase new sash which can be installed into the existing frames. Such sash are available as exact custom reproductions, reasonable facsimiles (custom windows with similar profiles), and contemporary wooden sash which are similar in appearance. There are companies which still manufacture high quality wooden sash which would duplicate most historic sash. A few calls to local building suppliers may provide a source of appropriate replacement sash, but if not, check with local historical associations, the state historic preservation office, or preservation related magazines and supply catalogs for information.

If a rehabilitation project has a large number of windows such as a commercial building or an industrial complex, there may be less of a problem arriving at a solution. Once the evaluation of the windows is completed and the scope of the work is known, there may be a potential economy of scale. Woodworking mills may be interested in the work from a large project; new sash in volume may be considerably less expensive per unit; crews can be assembled and trained on site to perform all of the window repairs; and a few extensive repairs can be absorbed (without undue burden) into the total budget for a large number of sound windows. While it may be expensive for the average historic home owner to pay seventy dollars or more for a mill to grind a custom knife to duplicate four or five bad muntins, that cost becomes negligible on large commercial projects which may have several hundred windows.

Most windows should not require the extensive repairs discussed in this section. The ones which do are usually in buildings which have been abandoned for long periods or have totally lacked maintenance for years. It is necessary to thoroughly investigate the alternatives for windows which do require extensive repairs to arrive at a solution which retains historic significance and is also economically feasible. Even for projects requiring repairs identified in this section, if the percentage of parts replacement per window is low, or the number of windows requiring repair is small, repair can still be a cost effective solution.

Weatherization

A window which is repaired should be made as energy efficient as possible by the use of appropriate weatherstripping to reduce air infiltration. A wide variety of products are available to assist in this task. Felt may be fastened to the top, bottom, and meeting rails, but may have the disadvantage of absorbing and holding moisture, particularly at the bottom rail. Rolled vinyl strips may also be tacked into place in appropriate locations to reduce infiltration. Metal strips or new plastic spring strips may be used on the rails and, if space permits, in the channels between the sash and jamb. Weatherstripping is a historic treatment, but old weatherstripping (felt) is not likely to perform very satisfactorily. Appropriate contemporary weatherstripping should be considered an integral part of the repair process for windows. The use of sash locks installed on the meeting rail will insure that the sash are kept tightly closed so that the weatherstripping will function more effectively to reduce infiltration. Although such locks will not always be historically accurate, they will usually be viewed as an acceptable contemporary modification in the interest of improved thermal performance.

Many styles of storm windows are available to improve the thermal performance of existing windows. The use of exterior storm windows should be investigated whenever feasible because they are thermally efficient, cost-effective, reversible, and allow the retention of original windows (see "Preservation Briefs: 3"). Storm window frames may be made of wood, aluminum, vinyl, or plastic; however, the use of unfinished aluminum storms should be avoided. The visual impact of storms may be minimized by selecting colors which match existing trim color. Arched top storms are available for windows with special shapes. Although interior storm windows appear to offer an attractive option for achieving double glazing with minimal visual impact, the potential for damaging condensation problems must be addressed. Moisture which becomes trapped between the layers of glazing can condense on the colder, outer prime window, potentially leading to deterioration. The correct approach to using interior storms is to create a seal on the interior storm while allowing some ventilation around the prime window. In actual practice, the creation of such a durable, airtight seal is difficult.

Window Replacement

Although the retention of original or existing windows is always desirable and this **Brief** is intended to encourage that goal, there is a point when the condition of a window may clearly indicate replacement. The decision process for selecting replacement windows should not begin with a survey of contemporary window products which are available as replacements, but should begin with a look at the windows which are being replaced. Attempt to understand the contribution of the window(s) to the appearance of the facade including: 1) the pattern of the openings and their size; 2) proportions of the frame and sash; 3) configuration of window panes; 4) muntin profiles; 5) type of wood; 6) paint color; 7) characteristics of the glass; and 8) associated details such as arched tops, hoods, or other decorative elements. Develop an understanding of how the window reflects the period, style, or regional characteristics of the building, or represents technological development.

Armed with an awareness of the significance of the existing window, begin to search for a replacement which retains as much of the character of the historic window as possible. There are many sources of suitable new windows. Continue looking until an acceptable replacement can be found. Check building supply firms, local woodworking mills, carpenters, preservation oriented magazines, or catalogs or suppliers of old building materials, for product information. Local historical associations and state historic preservation offices may be good sources of information on products which have been used successfully in preservation projects.

Consider energy efficiency as one of the factors for replacements, but do not let it dominate the issue. Energy conservation is no excuse for the wholesale destruction of historic windows which can be made thermally efficient by historically and aesthetically acceptable means. In fact, a historic wooden window with a high quality storm window added should thermally outperform a new double-glazed metal window which does not have thermal breaks (insulation between the inner and outer frames intended to break the path of heat flow). This occurs because the wood has far better insulating value than the metal, and in addition many historic windows have high ratios of wood to glass, thus reducing the area of highest heat transfer. One measure of heat transfer is the U-value, the number of Btu's per hour transferred through a square foot of material. When comparing thermal performance, the lower the U-value the better the performance. According to *ASHRAE 1977 Fundamentals*, the U-values for single glazed wooden windows range from 0.88 to 0.99. The addition of a storm window should reduce these figures to a range of 0.44 to 0.49. A non-thermal break, double-glazed metal window has a U-value of about 0.6.

Conclusion

Technical Preservation Services recommends the retention and repair of original windows whenever possible. We believe that the repair and weatherization of existing wooden windows is more practical than most people realize, and that many windows are unfortunately replaced because of a lack of awareness of techniques for evaluation, repair, and weatherization. Wooden windows which are repaired and properly maintained will have greatly extended service lives while contributing to the historic character of the building. Thus, an important element of a building's significance will have been preserved for the future.

Additional Reading

ASHRAE Handbook-1977 Fundamentals. New York: American Society of Heating, Refrigerating and Air-conditioning Engineers, 1978 (chapter 26).

Ferro, Maximillian. *Preservation: Present Pathway to Fall River's Future.* Fall River, Massachusetts: City of Fall River, 1979 (chapter 7).

"Fixing Double-Hung Windows." *Old House Journal* (no. 12, 1979): 135.

Look, David W. "Preservation Briefs: 10 Paint Removal from Historic Woodwork." Washington, DC: Technical Preservation Services, U.S. Department of the Interior, forthcoming.

Morrison, Hugh. *Early American Architecture.* New York: Oxford University Press, 1952.

Phillips, Morgan, and Selwyn, Judith. *Epoxies for Wood Repairs in Historic Buildings.* Washington, DC: Technical Preservation Services, U.S. Department of the Interior (Government Printing Office, Stock No. 024-016-00095-1), 1978.

Rehab Right. Oakland, California: City of Oakland Planning Department, 1978 (pp. 78-83).

"Sealing Leaky Windows." *Old House Journal* (no. 1, 1973): 5.

Smith, Baird M. "Preservation Briefs: 3 Conserving Energy in Historic Buildings." Washington, DC: Technical Preservation Services, U.S. Department of the Interior, 1978.

1981

10 PRESERVATION BRIEFS

Exterior Paint Problems on Historic Woodwork

Kay D. Weeks and David W. Look, AIA

U.S. Department of the Interior
National Park Service
Cultural Resources

Heritage Preservation Services

A cautionary approach to paint removal is included in the guidelines to "The Secretary of the Interior Standards for Historic Preservation Projects." Removing paints down to bare wood surfaces using harsh methods can permanently damage those surfaces; therefore such methods are not recommended. Also, total removal obliterates evidence of the historical paints and their sequence and architectural context.

This Brief expands on that advice for the architect, building manager, contractor, or homeowner by identifying and describing common types of paint surface conditions and failures, then recommending appropriate treatments for preparing exterior wood surfaces for repainting[1] to assure the best adhesion and greatest durability of the new paint. Although the Brief focuses on responsible methods of "paint removal," several paint surface conditions will be described which do not require any paint removal, and still others which can be successfully handled by limited paint removal. In all cases, the information is intended to address the concerns related to *exterior wood*. It will also be generally assumed that, because houses built before 1950 involve one or more layers of lead-base paint,[2] the majority of conditions warranting paint removal will mean dealing with this toxic substance along with the dangers of the paint removal tools and chemical strippers themselves.

Purposes of Exterior Paint

Paint[3] applied to exterior wood must withstand yearly extremes of both temperature and humidity. While never expected to be more than a temporary physical shield—requiring re-application every 5-8 years—its importance should not be minimized. Because one of the main causes of wood deterioration is moisture penetration, a primary purpose for painting wood is to exclude such moisture, thereby slowing deterioration not only of a building's exterior siding and decorative features but, ultimately, its underlying structural members. Another important purpose for painting wood is, of course, to define and accent architectural features and to improve appearance.

Treating Paint Problems in Historic Buildings

Exterior paint is constantly deteriorating through the processes of weathering, but in a program of regular maintenance—assuming all other building systems are functioning properly—surfaces can be cleaned, lightly scraped, and hand sanded in preparation for a new finish coat. Unfortunately, these are ideal conditions. More often, complex maintenance problems are inherited by owners of historic buildings, including areas of paint that have failed[4] beyond the point of mere cleaning, scraping, and hand sanding (although much so-called "paint failure" is attributable to interior or exterior moisture problems or surface preparation and application mistakes with previous coats).

Although paint problems are by no means unique to historic buildings, treating multiple layers of hardened, brittle paint on complex, ornamental—and possibly fragile—exterior wood surfaces necessarily requires an extremely cautious approach (see figure 1). In the case of recent construction, this level of concern is not needed because the wood is generally less detailed and, in addition, retention of the sequence of paint layers as a partial record of the building's history is not an issue.

When historic buildings are involved, however, a special set of problems arises—varying in complexity depending upon their age, architectural style, historical importance, and physical soundness of the wood—which must be carefully evaluated so that decisions can be made that are sensitive to the longevity of the resource.

Justification for Paint Removal

At the outset of this Brief, it must be emphasized that removing paint from historic buildings—with the exception of cleaning, light scraping, and hand sanding as part of routine maintenance—should be avoided unless absolutely essential. *Once conditions warranting removal have*

---

[1] General paint type recommendations will be made, but paint color recommendations are beyond the scope of this Brief.

[2] Douglas R. Shier and William Hall, *Analysis of Housing Data Collected in a Lead-Based Paint Survey in Pittsburgh, Pennsylvania, Part 1*, National Bureau of Standards, Inter Report 77-1250, May 1977.

[3] Any pigmented liquid, liquefiable, or mastic composition designed for application to a substrate in a thin layer which is converted to an opaque solid film after application. *Paint and Coatings Dictionary*, 1978, Federation of Societies for Coatings and Technology.

[4] For purposes of this Brief, this includes any area of painted exterior woodwork displaying signs of peeling, cracking, or alligatoring to bare wood. See descriptions of these and other paint surface conditions as well as recommended treatments on pp. 3-10.

Fig. 1 Excessive paint build-up on architectural details such as this ornamental bracket does not in itself justify total paint removal. If paint is cracked and peeling down to bare wood, however, it should be removed using the gentlest means possible. Photo: David W. Look, AIA.

Fig. 2 A traditionally painted bay window has been stripped to bare wood, then varnished. In addition to being historically inaccurate, the varnish will break down faster as a result of the sun's ultraviolet rays than would primer and finish coats of paint. Photo: David W. Look, AIA.

been identified, the general approach should be to remove paint to the next sound layer using the gentlest means possible, then to repaint (see figure 2). Practically speaking as well, paint can adhere just as effectively to existing paint as to bare wood, providing the previous coats of paint are also adhering uniformly and tightly to the wood and the surface is properly prepared for repainting—cleaned of dirt and chalk and dulled by sanding. But, if painted exterior wood surfaces display continuous patterns of deep cracks or if they are extensively blistering and peeling so that bare wood is visible, then the old paint should be completely removed before repainting. The only other justification for removing all previous layers of paint is if doors, shutters, or windows have literally been "painted shut," or if new wood is being pieced-in adjacent to old painted wood and a smooth transition is desired (see figure 3).

Fig. 3 If damage to parts of a wooden element is severe, new sections of wood will need to be pieced-in. When such piecing is required, paint on the adjacent woodwork should be removed so that the old and new woods will make a smooth profile when joined. After repainting, the repair should be virtually impossible to detect. Photo: Morgan W. Phillips.

Paint Removal Precautions

Because paint removal is a difficult and painstaking process, a number of costly, regrettable experiences have occurred—and continue to occur—for both the historic building and the building owner. Historic buildings have been set on fire with blow torches; wood irreversibly scarred by sandblasting or by harsh mechanical devices such as rotary sanders and rotary wire strippers; and layers of historic paint inadvertently and unnecessarily removed. In addition, property owners, using techniques that substitute speed for safety, have been injured by toxic lead vapors or dust from the paint they were trying to remove or by misuse of the paint removers themselves.

Owners of historic properties considering paint removal should also be aware of the amount of time and labor involved. While removing damaged layers of paint from a door or porch railing might be readily accomplished within a reasonable period of time by one or two people, removing paint from larger areas of a building can, without professional assistance, easily become unmanageable and produce less than satisfactory results. The amount of work involved in any paint removal project must therefore be analyzed on a case-by-case basis. Hiring qualified professionals will often be a cost-effective decision due to the expense of materials, the special equipment required, and the amount of time involved. Further, paint removal companies experienced in dealing with the inherent health and safety dangers of paint removal should have purchased such protective devices as are needed to mitigate any dangers and should also be aware of State or local environmental and/or health regulations for hazardous waste disposal.

All in all, paint removal is a messy, expensive, and potentially dangerous aspect of rehabilitating or restoring historic buildings and should not be undertaken without careful thought concerning first, its necessity, and second, which of the available recommended methods is the safest and most appropriate for the job at hand.

Repainting Historic Buildings for Cosmetic Reasons

If existing exterior paint on wood siding, eaves, window sills, sash, and shutters, doors, and decorative features shows *no* evidence of paint deterioration such as chalking, blistering, peeling, or cracking, then there is no *physical reason* to repaint, much less remove paint! Nor is color fading, of itself, sufficient justification to repaint a historic building.

The decision to repaint may not be based altogether on paint failure. Where there is a new owner, or even where ownership has remained constant through the years, taste in colors often changes. Therefore, if repainting is primarily to alter a building's primary and accent colors, a technical factor of paint accumulation should be taken into consideration. When paint builds up to a thickness of approximately 1/16" (approximately 16-30 layers), one or more extra coats of paint may be enough to trigger cracking and peeling in limited or even widespread areas of the building's surface. This results because excessively thick paint is less able to withstand the shrinkage or pull of an additional coat as it dries and is also less able to tolerate thermal stresses. Thick paint invariably fails at the weakest point of adhesion—the oldest layers next to the wood. Cracking and peeling follow. Therefore, if there are no signs of paint failure, it may be somewhat risky to add still another layer of unneeded paint simply for color's sake (extreme changes in color may also require more than one coat to provide proper hiding power and full color). When paint appears to be nearing the critical thickness, a change of accent colors (that is, just to limited portions of the trim) might be an acceptable compromise without chancing cracking and peeling of paint on wooden siding.

If the decision to repaint is nonetheless made, the "new" color or colors should, at a minimum, be appropriate to the style and setting of the building. On the other hand, where the intent is to restore or accurately reproduce the colors originally used or those from a significant period in the building's evolution, they should be based on the results of a paint analysis.[3]

Identification of Exterior Paint Surface Conditions/Recommended Treatments

It is assumed that a preliminary check will already have been made to determine, first, that the painted exterior surfaces are indeed wood—and not stucco, metal, or other wood substitutes—and second, that the wood has not decayed so that repainting would be superfluous. For example, if any area of bare wood such as window sills has been exposed for a long period of time to standing water, wood rot is a strong possibility (see figure 4). Repair or replacement of deteriorated wood should take place before repainting. After these two basic issues have been resolved, the surface condition identification process may commence.

The historic building will undoubtedly exhibit a variety of exterior paint surface conditions. For example, paint on the wooden siding and doors may be adhering firmly; paint on the eaves peeling; and paint on the porch balusters and window sills cracking and alligatoring. The accurate identification of each paint problem is therefore the first step in planning an appropriate overall solution.

Paint surface conditions can be grouped according to their relative severity: CLASS I conditions include minor blemishes or dirt collection and generally require *no* paint removal; CLASS II conditions include failure of the top layer or layers of paint and generally require *limited* paint removal; and CLASS III conditions include substantial or multiple-layer failure and generally require *total* paint removal. It is precisely because conditions will vary at different points on the building that a careful inspection is critical. Each item of painted exterior woodwork (i.e., siding, doors, windows, eaves, shutters, and decorative elements) should be examined early in the planning phase and surface conditions noted.

CLASS I Exterior Surface Conditions Generally Requiring No Paint Removal

- **Dirt, Soot, Pollution, Cobwebs, Insect Cocoons, etc.**

Cause of Condition

Environmental "grime" or organic matter that tends to cling to painted exterior surfaces and, in particular, protected surfaces such as eaves, do not constitute a paint problem unless painted over rather than removed prior to repainting. If not removed, the surface deposits can be a barrier to proper adhesion and cause peeling.

Recommended Treatment

Most surface matter can be loosened by a strong, direct stream of water from the nozzle of a garden hose. Stubborn dirt and soot will need to be scrubbed off using ½ cup of household detergent in a gallon of water with a medium soft bristle brush. The cleaned surface should then be rinsed thoroughly, and permitted to dry before further inspection to determine if repainting is necessary. Quite often, cleaning provides a satisfactory enough result to postpone repainting.

[3] See the Reading List for paint research and documentation information. See also *The Secretary of the Interior's Standards for Historic Preservation Projects with Guidelines for Applying the Standards* for recommended approaches on paints and finishes within various types of project work treatments.

- **Mildew**

Cause of Condition

Mildew is caused by fungi feeding on nutrients contained in the paint film or on dirt adhering to any surface. Because moisture is the single most important factor in its growth, mildew tends to thrive in areas where dampness and lack of sunshine are problems such as window sills, under eaves, around gutters and downspouts, on the north side of buildings, or in shaded areas near shrubbery. It may sometimes be difficult to distinguish mildew from dirt, but there is a simple test to differentiate: if a drop of household bleach is placed on the suspected surface, mildew will immediately turn white whereas dirt will continue to look like dirt.

Recommended Treatment

Because mildew can only exist in shady, warm, moist areas, attention should be given to altering the environment that is conducive to fungal growth. The area in question may be shaded by trees which need to be pruned back to allow sunlight to strike the building; or may lack rain gutters or proper drainage at the base of the building. If the shady or moist conditions can be altered, the mildew is less likely to reappear. A recommend solution for removing mildew consists of one cup non-ammoniated detergent, one quart household bleach, and one gallon water. When the surface is scrubbed with this solution using a medium soft brush, the mildew should disappear; however, for particularly stubborn spots, an additional quart of bleach may be added. After the area is mildew-free, it should then be rinsed with a direct stream of water from the nozzle of a garden hose, and permitted to dry thoroughly. When repainting, specially formulated "mildew-resistant" primer and finish coats should be used.

- **Excessive Chalking**

Cause of Condition

Chalking—or powdering of the paint surface—is caused by the gradual disintegration of the resin in the paint film. (The amount of chalking is determined both by the formulation of the paint and the amount of ultraviolet light to which the paint is exposed.) In moderation, chalking is the ideal way for a paint to "age," because the chalk, when rinsed by rainwater, carries discoloration and dirt away with it and thus provides an ideal surface for repainting. In excess, however, it is not desirable because the chalk can wash down onto a surface of a different color beneath the painted area and cause streaking as well as rapid disintegration of the paint film itself. Also, if a paint contains too much pigment for the amount of binder (as the old white lead carbonate/oil paints often did), excessive chalking can result.

Recommended Treatment

The chalk should be cleaned off with a solution of ½ cup household detergent to one gallon water, using a medium soft bristle brush. After scrubbing to remove the chalk, the surface should be rinsed with a direct stream of water from the nozzle of a garden hose, allowed to dry thoroughly, (but not long enough for the chalking process to recur) and repainted, using a non-chalking paint.

- **Staining**

Cause of Condition

Staining of paint coatings usually results from excess

Fig. 4 *Paint films wear unevenly depending on exposure and location. Exterior locations which are susceptible to accelerated deterioration are horizontal surfaces such as window sills. These and similar areas will require repainting more often than less vulnerable surfaces. In the case of this window sill where paint has peeled off and adjacent areas have cracked and alligatored, the paint should be totally removed. Prior to repainting, any weathered wood should be rejuvenated using a solution of 3 cups exterior varnish, 1 oz. paraffin wax, and mineral spirits/paint thinner/or turpentine to make 1 gallon. Liberal brush application should be made. This formula was tested over a 20-year period by the U.S. Department of Agriculture's Forest Products Laboratory and proved to be just as effective as water-repellent preservatives containing pentachlorophenol. After the surface has thoroughly dried (2-3 days of warm weather), the treated surface can be painted. A high quality oil-base primer followed by two top coats of a semi-gloss oil-enamel or latex-enamel paint is recommended. Photo: Baird M. Smith, AIA.*

moisture reacting with materials within the wood substrate. There are two common types of staining, neither of which requires paint removal. The most prevalent type of stain is due to the oxidation or rusting of iron nails or metal (iron, steel, or copper) anchorage devices. A second type of stain is caused by a chemical reaction between moisture and natural extractives in certain woods (red cedar or redwood) which results in a surface deposit of colored matter. This is most apt to occur in new replacement wood within the first 10-15 years.

Recommended Treatment

In both cases, the source of the stain should first be located and the moisture problem corrected.

When stains are caused by rusting of the heads of nails used to attach shingles or siding to an exterior wall or by rusting or oxidizing iron, steel, or copper anchorage devices adjacent to a painted surface, the metal objects themselves should be hand sanded and coated with a rust-inhibitive primer followed by two finish coats. (Exposed nail heads should ideally be countersunk, spot primed, and the holes filled with a high quality wood filler except where exposure of the nail head was part of the original construction system or the wood is too fragile to withstand the countersinking procedure.)

Discoloration due to color extractives in replacement wood can usually be cleaned with a solution of equal parts denatured alcohol and water. After the affected area has been rinsed and permitted to dry, a "stain-blocking primer" especially developed for preventing this type of stain should be applied (two primer coats are recommended for severe cases of bleeding prior to the finish coat). Each primer coat should be allowed to dry at least 48 hours.

CLASS II Exterior Surface Conditions Generally Requiring Limited Paint Removal

• Crazing

Cause of Condition

Crazing—fine, jagged interconnected breaks in the top layer of paint—results when paint that is several layers thick becomes excessively hard and brittle with age and is consequently no longer able to expand and contract with the wood in response to changes in temperature and humidity (see figure 5). As the wood swells, the bond between paint layers is broken and hairline cracks appear. Although somewhat more difficult to detect as opposed to other more obvious paint problems, it is well worth the time to scrutinize all surfaces for crazing. If not corrected, exterior moisture will enter the crazed surface, resulting in further swelling of the wood and, eventually, deep cracking and alligatoring, a Class III condition which requires total paint removal.

Recommended Treatment

Crazing can be treated by hand or mechanically sanding the surface, then repainting. Although the hairline cracks may tend to show through the new paint, the surface will be protected against exterior moisture penetration.

Fig. 5 *Crazing—or surface cracking—is an exterior surface condition which can be successfully treated by sanding and painting. Photo: Courtesy, National Decorating Products Association.*

• Intercoat Peeling

Cause of Condition

Intercoat peeling can be the result of improper surface preparation prior to the last repainting. This most often occurs in protected areas such as eaves and covered porches because these surfaces do not receive a regular rinsing from rainfall, and salts from air-borne pollutants thus accumulate on the surface. If not cleaned off, the new paint coat will not adhere properly and that layer will peel.

Another common cause of intercoat peeling is incompatibility between paint types (see figure 6). For example, if oil paint is applied over latex paint, peeling of the top coat can sometimes result since, upon aging, the oil paint becomes harder and less elastic than the latex paint. If latex paint is applied over old, chalking oil paint, peeling can also occur because the latex paint is unable to penetrate the chalky surface and adhere.

Recommended Treatment

First, where salts or impurities have caused the peeling, the affected area should be washed down thoroughly after scraping, then wiped dry. Finally, the surface should be hand or mechanically sanded, then repainted.

Where peeling was the result of using incompatible paints, the peeling top coat should be scraped and hand or mechanically sanded. Application of a high quality oil type exterior primer will provide a surface over which either an oil or a latex topcoat can be successfully used.

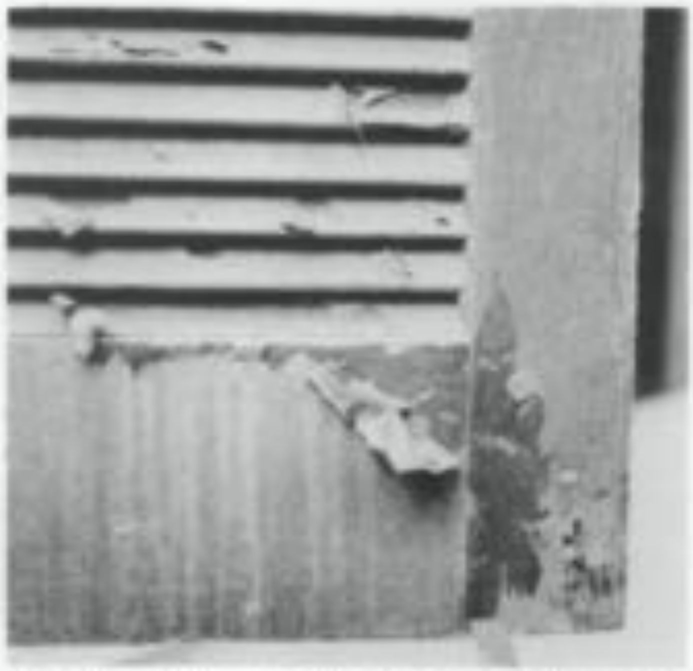


Fig. 6 This is an example of intercoat peeling. A latex top coat was applied directly over old oil paint and, as a result, the latex paint was unable to adhere. If latex is being used over oil, an oil base primer should be applied first. Although much of the peeling latex paint can be scraped off, in this case, the best solution may be to chemically dip strip the entire shutter to remove all of the paint down to bare wood, rinse thoroughly, then repaint. Photo: Mary L. Oehrlein, AIA.

• Solvent Blistering

Cause of Condition

Solvent blistering, the result of a less common application error, is not caused by moisture, but by the action of ambient heat on paint solvent or thinners in the paint film. If solvent-rich paint is applied in direct sunlight, the top surface can dry too quickly and, as a result, solvents become trapped beneath the dried paint film. When the solvent vaporizes, it forces its way through the paint film, resulting in surface blisters. This problem occurs more often with dark colored paints because darker colors absorb more heat than lighter ones. To distinguish between solvent blistering and blistering caused by moisture, a blister should be cut open. If another layer of paint is visible, then solvent blistering is likely the problem whereas if bare wood is revealed, moisture is probably to blame. Solvent blisters are generally small.

Recommended Treatment

Solvent-blistered areas can be scraped, hand or mechanically sanded to the next sound layer, then repainted. In order to prevent blistering of painted surfaces, paint should not be applied in direct sunlight.

- **Wrinkling**

Cause of Condition

Another error in application that can easily be avoided is wrinkling (see *figure 7*). This occurs when the top layer of paint dries before the layer underneath. The top layer of paint actually moves as the paint underneath (a primer, for example) is drying. Specific causes of wrinkling include: (1) applying paint too thick; (2) applying a second coat before the first one dries; (3) inadequate brushing out; and (4) painting in temperatures higher than recommended by the manufacturer.

Recommended Treatment

The wrinkled layer can be removed by scraping followed by hand or mechanical sanding to provide as even a surface as possible, then repainted following manufacturer's application instructions.

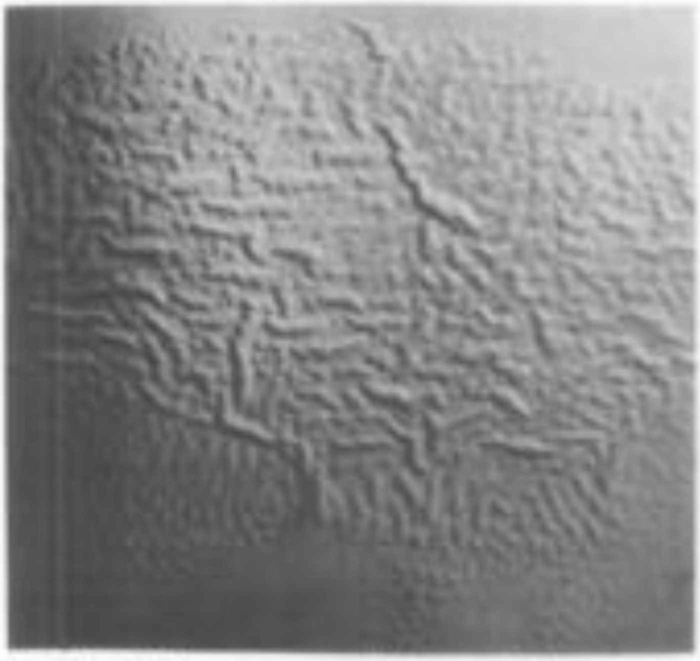


Fig. 7 *Wrinkled layers can generally be removed by scraping and sanding as opposed to total paint removal. Following manufacturers' application instructions is the best way to avoid this surface condition. Photo: Courtesy, National Decorating Products Association.*

CLASS III Exterior Surface Conditions Generally Requiring Total Paint Removal

If surface conditions are such that the majority of paint will have to be removed prior to repainting, it is suggested that a small sample of intact paint be left in an inconspicuous area either by covering the area with a metal plate, or by marking the area and identifying it in some way. (When repainting does take place, the sample should not be painted over). This will enable future investigators to have a record of the building's paint history.

- **Peeling**

Cause of Condition

Peeling to bare wood is most often caused by excess interior or exterior moisture that collects behind the paint film, thus impairing adhesion (see *figure 8*). Generally beginning as blisters, cracking and peeling occur as moisture causes the wood to swell, breaking the adhesion of the bottom layer.

Recommended Treatment

There is no sense in repainting before dealing with the moisture problems because new paint will simply fail. Therefore, the first step in treating peeling is to locate and remove the source or sources of the moisture, not only because moisture will jeopardize the protective coating of paint but because, if left unattended, it can ultimately cause permanent damage to the wood. Excess interior moisture should be removed from the building through installation of exhaust fans and vents. Exterior moisture should be eliminated by correcting the following conditions prior to repainting: faulty flashing; leaking gutters; defective roof shingles; cracks and holes in siding and trim; deteriorated caulking in joints and seams; and shrubbery growing too close to painted wood. After the moisture problems have been solved, the wood must be permitted to dry out thoroughly. The damaged paint can then be scraped off with a putty knife, hand or mechanically sanded, primed, and repainted.

Fig. 8 *Peeling to bare wood—one of the most common types of paint failure—is usually caused by an interior or exterior moisture problem. Photo: Anne E. Grimmer.*

- **Cracking/Alligatoring**

Cause of Condition

Cracking and alligatoring are advanced stages of crazing (see *figure 9*). Once the bond between layers has been broken due to intercoat paint failure, exterior moisture is able to penetrate the surface cracks, causing the wood to swell and deeper cracking to take place. This process continues until cracking, which forms parallel to grain, extends to bare wood. Ultimately, the cracking becomes an overall pattern of horizontal and vertical breaks in the paint layers that looks like reptile skin; hence, "alligatoring." In advanced stages of cracking and alligatoring, the surfaces will also flake badly.

Recommended Treatment

If cracking and alligatoring are present only in the top layers they can probably be scraped, hand or mechanically sanded to the next sound layer, then repainted. However, if cracking and/or alligatoring have progressed to bare wood and the paint has begun to flake, it will need to be totally removed. Methods include scraping or paint removal with the electric heat plate, electric heat gun, or chemical strippers, depending on the particular area involved. Bare wood should be primed within 48 hours, then repainted.

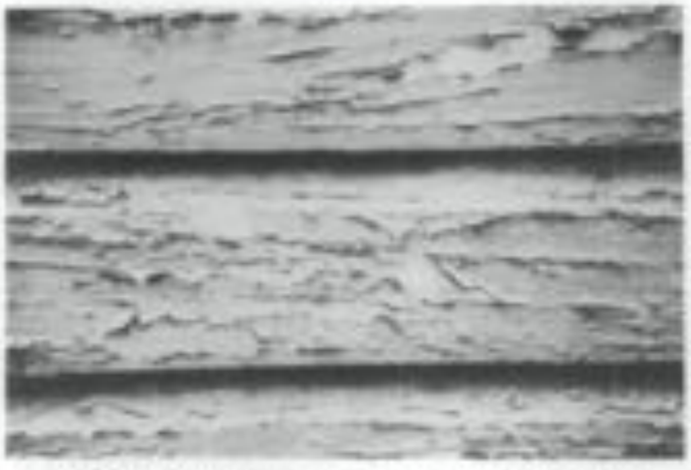


Fig. 9 Cracking, alligatoring, and flaking are evidence of long-term neglect of painted surfaces. The remaining paint on the clapboard shown here can be removed with an electric heat plate and wide-bladed scraper. In addition, unsound wood should be replaced and moisture problems corrected before primer and top coats of paint are applied. Photo: David W. Look, AIA.

Selecting the Appropriate/Safest Method to Remove Paint

After having presented the "hierarchy" of exterior paint surface conditions—from a mild condition such as mildewing which simply requires cleaning prior to repainting to serious conditions such as peeling and alligatoring which require total paint removal—one important thought bears repeating: if a paint problem has been identified that warrants either limited or total paint removal, the gentlest method possible for the particular wooden element of the historic building should be selected from the many available methods.

The treatments recommended—based upon field testing as well as onsite monitoring of Department of Interior grant-in-aid and certification of rehabilitation projects—are therefore those which take three over-riding issues into consideration (1) the continued protection and preservation of the historic exterior woodwork; (2) the retention of the sequence of historic paint layers; and (3) the health and safety of those individuals performing the paint removal. By applying these criteria, it will be seen that no paint removal method is without its drawbacks and all recommendations are qualified in varying degrees.

Methods for Removing Paint

After a particular exterior paint surface condition has been identified, the next step in planning for repainting—if paint removal is required—is selecting an appropriate method for such removal.

The method or methods selected should be suitable for the specific paint problem as well as the particular wooden element of the building. Methods for paint removal can be divided into three categories (frequently, however, a combination of the three methods is used). Each method is defined below, then discussed further and specific recommendations made:

Abrasive—"Abrading" the painted surface by manual and/or mechanical means such as scraping and sanding. Generally used for surface preparation and limited paint removal.

Thermal—Softening and raising the paint layers by applying heat followed by scraping and sanding. Generally used for total paint removal.

Chemical—Softening of the paint layers with chemical strippers followed by scraping and sanding. Generally used for total paint removal.

- **Abrasive Methods (Manual)**

If conditions have been identified that require limited paint removal such as crazing, intercoat peeling, solvent blistering, and wrinkling, scraping and hand sanding should be the first methods employed before using mechanical means. Even in the case of more serious conditions such as peeling—where the damaged paint is weak and already sufficiently loosened from the wood surface—scraping and hand sanding may be all that is needed prior to repainting.

Recommended Abrasive Methods (Manual)

Putty Knife/Paint Scraper: Scraping is usually accomplished with either a putty knife or a paint scraper, or both. Putty knives range in width from one to six inches and have a beveled edge. A putty knife is used in a pushing motion going under the paint and working from an area of loose paint toward the edge where the paint is still firmly adhered and, in effect, "beveling" the remaining layers so that as smooth a transition as possible is made between damaged and undamaged areas (see figure 10).

Paint scrapers are commonly available in 1⅝, 2½, and 3½ inch widths and have replaceable blades. In addition, profiled scrapers can be made specifically for use on moldings. As opposed to the putty knife, the paint scraper is used in a pulling motion and works by raking the damaged areas of paint away.

The obvious goal in using the putty knife or the paint scraper is to selectively remove the affected layer or layers of paint; however, both of these tools, particularly the paint scraper with its hooked edge, must be used with care to properly prepare the surface and to avoid gouging the wood.

Sandpaper/Sanding Block/Sanding sponge: After manually removing the damaged layer or layers by scraping, the uneven surface (due to the almost inevitable removal of varying numbers of paint layers in a given area) will need to be smoothed or "feathered out" prior to repainting. As stated before, hand sanding, as opposed to harsher mechanical sanding, is recommended if the area is relatively limited. A coarse grit, open-coat flint sandpaper—the least expensive kind—is useful for this purpose because, as the sandpaper clogs with paint it must be discarded and this process repeated until all layers adhere uniformly.

Blocks made of wood or hard rubber and covered with sandpaper are useful for handsanding flat surfaces. Sanding sponges—rectangular sponges with an abrasive aggregate on their surfaces—are also available for detail work that requires reaching into grooves because the sponge easily conforms to curves and irregular surfaces. All sanding should be done with the grain.

Summary of Abrasive Methods (Manual)

Recommended: Putty knife, paint scraper, sandpaper, sanding block, sanding sponge.
Applicable areas of building: All areas.
For use on: Class I, Class II, and Class III conditions.
Health/Safety factors: Take precautions against lead dust, eye damage; dispose of lead paint residue properly.

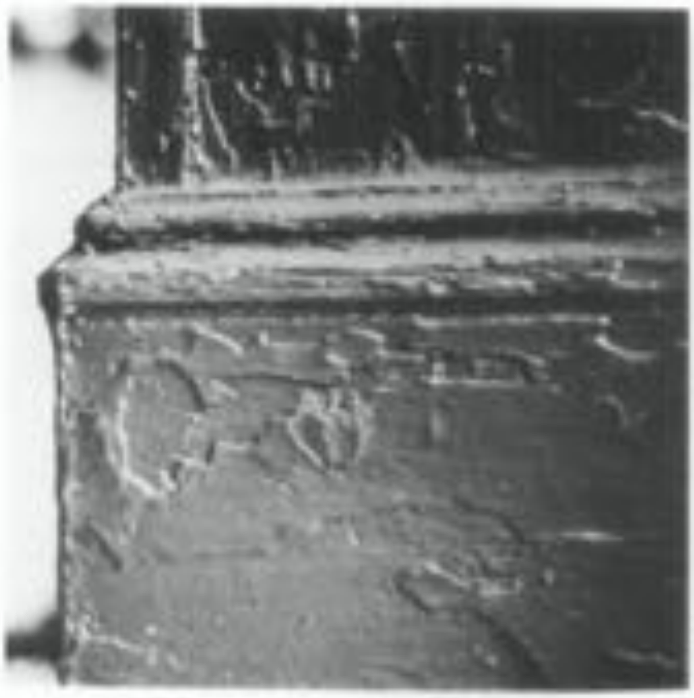


Fig. 10 *An excellent example of inadequate scraping before repainting, the problems here are far more than cosmetic. This improperly prepared surface will permit moisture to get behind the paint film which, in turn, will result in chipping and peeling. Photo: Baird M. Smith, AIA.*

• **Abrasive Methods (Mechanical)**

If hand sanding for purposes of surface preparation has not been productive or if the affected area is too large to consider hand sanding by itself, mechanical abrasive methods, i.e., power-operated tools may need to be employed; however, it should be noted that the majority of tools available for paint removal can cause damage to fragile wood and must be used with great care.

Recommended Abrasive Methods (Mechanical)

Orbital sander: Designed as a finishing or smoothing tool—not for the removal of multiple layers of paint—the orbital sander is thus recommended when limited paint removal is required prior to repainting. Because it sands in a small diameter circular motion (some models can also be switched to a back-and-forth vibrating action), this tool is particularly effective for "feathering" areas where paint has first been scraped (see figure 11). The abrasive surface varies from about 3×7 inches to 4×9 inches and sandpaper is attached either by clamps or sliding clips. A medium grit, open-coat aluminum oxide sandpaper should be used; fine sandpaper clogs up so quickly that it is ineffective for smoothing paint.

Belt sander: A second type of power tool—the belt sander—can also be used for removing limited layers of paint but, in this case, the abrasive surface is a continuous belt of sandpaper that travels at high speeds and consequently offers much less control than the orbital sander. Because of the potential for more damage to the paint or the wood, use of the belt sander (also with a medium grit sandpaper) should be limited to flat surfaces and only skilled operators should be permitted to operate it within a historic preservation project.

Fig. 11 *The orbital sander can be used for limited paint removal, i.e., for smoothing flat surfaces after the majority of deteriorated paint has already been scraped off. Photo: Charles E. Fisher, III.*

Not Recommended

Rotary Drill Attachments: Rotary drill attachments such as the rotary sanding disc and the rotary wire stripper should be avoided. The disc sander—usually a disc of sandpaper about 5 inches in diameter secured to a rubber based attachment which is in turn connected to an electric drill or other motorized housing—can easily leave visible circular depressions in the wood which are difficult to hide, even with repainting. The rotary wire stripper—clusters of metals wires similarly attached to an electric drill-type unit—can actually shred a wooden surface and is thus to be used exclusively for removing corrosion and paint from metals.

Waterblasting: Waterblasting above 600 p.s.i. to remove paint is not recommended because it can force water into the woodwork rather than cleaning loose paint and grime from the surface; at worst, high pressure waterblasting causes the water to penetrate exterior sheathing and damages interior finishes. A detergent solution, a medium soft bristle brush, and a garden hose for purposes of rinsing, is the gentlest method involving water and is recommended when cleaning exterior surfaces prior to repainting.

Sandblasting: Finally—and undoubtedly most vehemently "not recommended"—sandblasting painted exterior woodwork will indeed remove paint, but at the same time can scar wooden elements beyond recognition. As with rotary wire strippers, sandblasting erodes the soft porous fibers (spring wood) faster than the hard, dense fibers (summer wood), leaving a pitted surface with ridges and valleys. Sandblasting will also erode projecting areas of carvings and moldings before it removes paint from concave areas (see figure 12). Hence, this abrasive method is potentially the most damaging of all possibilities, even if a contractor promises that blast pressure can be controlled so that the paint is removed without harming the historic exterior woodwork. (For Additional Information, See Preservation Briefs 6, "Dangers of Abrasive Cleaning to Historic Buildings".)

Fig. 12 *Sandblasting has permanently damaged this ornamental bracket. Even paint will not be able to hide the deep erosion of the wood. Photo: David W. Look, AIA.*

Summary of Abrasive Methods (Mechanical)

Recommended: Orbital sander, belt sander (skilled operator only).

Applicable areas of building: Flat surfaces, i.e., siding, eaves, doors, window sills.

For use on: Class II and Class III conditions.

Health/Safety factors: Take precautions against lead dust and eye damage; dispose of lead paint residue properly.

Not Recommended: Rotary drill attachments, high pressure waterblasting, sandblasting.

- **Thermal Methods**

Where exterior surface conditions have been identified that warrant total paint removal such as peeling, cracking, or alligatoring, two thermal devices—the electric heat plate and the electric heat gun—have proven to be quite successful for use on different wooden elements of the historic building. One thermal method—the blow torch—is not recommended because it can scorch the wood or even burn the building down!

Recommended Thermal Methods

Electric heat plate: The electric heat plate (see figure 13) operates between 500 and 800 degrees Fahrenheit (not hot enough to vaporize lead paint), using about 15 amps of power. The plate is held close to the painted exterior surface until the layers of paint begin to soften and blister, then moved to an adjacent location on the wood while the softened paint is scraped off with a putty knife (it should be noted that the heat plate is most successful when the paint is very thick!). With practice, the operator can successfully move the heat plate evenly across a flat surface such as wooden siding or a window sill or door in a continuous motion, thus lessening the risk of scorching the wood in an attempt to reheat the edge of the paint sufficiently for effective removal. Since the electric heat plate's coil is "red hot," extreme caution should be taken to avoid igniting clothing or burning the skin. If an extension cord is used, it should be a heavy-duty cord (with 3-prong grounded plugs). A heat plate could overload a circuit or, even worse, cause an electrical fire; therefore, it is recommended that this implement be used with a single circuit and that a fire extinguisher always be kept close at hand.

Fig. 13 *The electric heat plate (with paint scraper) is particularly useful for removing paint down to bare wood on flat surfaces such as doors, window frames, and siding. After scraping, some light sanding will probably be necessary to smooth the surface prior to application of primer and top coats. Photo: David W. Look, AIA.*

Electric heat gun: The electric heat gun (electric hot-air gun) looks like a hand-held hairdryer with a heavy-duty metal case (see figure 14). It has an electrical resistance coil that typically heats between 500 and 750 degrees Fahrenheit and, again, uses about 15 amps of power which requires a heavy-duty extension cord. There are some heat guns that operate at higher temperatures but they should not be purchased for removing old paint because of the danger of lead paint vapors. The temperature is controlled by a vent on the side of the heat gun. When the vent is closed, the heat increases. A fan forces a stream of hot air against the painted woodwork, causing a blister to form. At that point, the softened paint can be peeled back with a putty knife. It can be used to best advantage when a paneled door was originally varnished, then painted a number of times. In this case, the paint will come off quite easily, often leaving an almost pristine varnished surface behind. Like the heat plate, the heat gun works best on a heavy paint build-up. (It is, however, not very successful on only one or two layers of paint or on surfaces that have only been varnished. The varnish simply becomes sticky and the wood scorches.)

Although the heat gun is heavier and more tiring to use than the heat plate, it is particularly effective for removing paint from detail work because the nozzle can be directed at curved and intricate surfaces. Its use is thus more limited than the heat plate, and most successfully used in conjunction *with* the heat plate. For example, it takes about two to three hours to strip a paneled door with a heat gun, but if used in combination with a heat plate for the large, flat area, the time can usually be cut in half. Although a heat gun seldom scorches wood, it can cause fires (like the blow torch) if aimed at the dusty cavity between the exterior sheathing and siding and interior lath and plaster. A fire may smolder for hours before flames break through to the surface. Therefore, this thermal device is best suited for use on solid decorative elements, such as molding, balusters, fretwork, or "gingerbread."

Fig. 14. The nozzle on the electric heat gun permits hot air to be aimed into cavities on solid decorative elements such as this appliqued column. After the paint has been sufficiently softened, it can be removed with a profiled scraper. Photo: Charles E. Fisher, III.

Not Recommended

Blow Torch: Blow torches, such as hand-held propane or butane torches, were widely used in the past for paint removal because other thermal devices were not available. With this technique, the flame is directed toward the paint until it begins to bubble and loosen from the surface. Then the paint is scraped off with a putty knife. Although this is a relatively fast process, at temperatures between 3200 and 3800 degrees Fahrenheit the open flame is not only capable of burning a careless operator and causing severe damage to eyes or skin, it can easily scorch or ignite the wood. The other fire hazard is more insidious. Most frame buildings have an air space between the exterior sheathing and siding and interior lath and plaster. This cavity usually has an accumulation of dust which is also easily ignited by the open flame of a blow torch. Finally, lead-base paints will vaporize at high temperatures, releasing toxic fumes that can be unknowingly inhaled. Therefore, because both the heat plate and the heat gun are generally safer to use—that is, the risks are much more controllable—the blow torch should definitely be avoided!

Summary of Thermal Methods

Recommended: Electric heat plate, electric heat gun.
Applicable areas of building: Electric heat plate—flat surfaces such as siding, eaves, sash, sills, doors. Electric heat gun—solid decorative molding, balusters, fretwork, or "gingerbread."
For use on: Class III conditions.
Health/Safety factors: Take precautions against eye damage and fire. Dispose of lead paint residue properly.
Not Recommended: Blow torch.

• Chemical Methods

With the availability of effective thermal methods for total paint removal, the need for chemical methods—in the context of preparing historic exterior woodwork for repainting—becomes quite limited. Solvent-base or caustic strippers may, however, play a supplemental role in a number of situations, including:

• Removing paint residue from intricate decorative features, or in cracks or hard to reach areas if a heat gun has not been completely effective;

• Removing paint on window muntins because heat devices can easily break the glass;

• Removing varnish on exterior doors after all layers of paint have been removed by a heat plate/heat gun if the original varnish finish is being restored;

• Removing paint from detachable wooden elements such as exterior shutters, balusters, columns, and doors by dip-stripping when other methods are too laborious.

Recommended Chemical Methods
(Use With Extreme Caution)

Because all chemical paint removers can involve potential health and safety hazards, *no* wholehearted recommendations can be made from that standpoint. Commonly known as "paint removers" or "strippers," both solvent-base or caustic products are commercially available that, when poured, brushed, or sprayed on painted exterior woodwork are capable of softening several layers of paint at a time so that the resulting "sludge"—which should be remembered is nothing less than the sequence of historic paint layers—can be removed with a putty knife. Detachable wood elements such as exterior shutters can also be "dip-stripped."

Solvent-base Strippers: The formulas tend to vary, but generally consist of combinations of organic solvents such as methylene chloride, isopropanol, toluol, xylol, and methanol; thickeners such as methyl cellulose; and various additives such as paraffin wax used to prevent the volatile solvents from evaporating before they have time to soak through multiple layers of paint. Thus, while some solvent-base strippers are quite thin and therefore unsuitable for use on vertical surfaces, others, called "semi-paste" strippers, are formulated for use on vertical surfaces or the underside of horizontal surfaces.

However, whether liquid or semi-paste, there are two important points to stress when using any solvent-base stripper: First, the vapors from the organic chemicals can be highly toxic if inhaled; skin contact is equally dangerous because the solvents can be absorbed; second, many solvent-base strippers are flammable. Even though application out-of-doors may somewhat mitigate health and safety hazards, a respirator with special filters for organic solvents is recommended and, of course, solvent-base strippers should never be used around open flames, lighted cigarettes, or with steel wool around electrical outlets.

Although appearing to be the simplest for exterior use, a particular type of solvent-base stripper needs to be mentioned here because it can actually cause the most problems. Known as "water-rinsable," such products have a high proportion of methylene chloride together with emulsifiers. Although the dissolved paint can be rinsed off with water with a minimum of scraping, this ultimately creates more of a problem in cleaning up and properly disposing of the sludge. In addition, these strippers can leave a gummy residue on the wood that requires removal with solvents. Finally, water-rinsable strippers tend to raise the grain of the wood more than regular strippers.

On balance, then, the regular strippers would seem to work just as well for exterior purposes and are perhaps even better from the standpoint of proper lead sludge disposal because they must be hand scraped as opposed to rinsed off (a coffee-can with a wire stretched across the top is one effective way to collect the sludge; when the putty knife is run across the wire, the sludge simply falls into the can. Then, when the can is filled, the wire is removed, the can capped, and the lead paint sludge disposed of according to local health regulations).

Caustic Strippers: Until the advent of solvent-base strippers, caustic strippers were used exclusively when a chemical method was deemed appropriate for total paint removal prior to repainting or refinishing. Now, it is more difficult to find commercially prepared caustic solutions in hardware and paint stores for home-owner use with the exception of lye (caustic soda) because solvent-base strippers packaged in small quantities tend to dominate the market.

Most commercial dip stripping companies, however, continue to use variations of the caustic bath process because it is still the cheapest method available for removing paint. Generally, dip stripping should be left to professional companies because caustic solutions can dissolve skin and permanently damage eyes as well as present serious disposal problems in large quantities.

If exterior shutters or other detachable elements are being sent out* for stripping in a caustic solution, it is wise to see samples of the company's finished work. While some companies do a first-rate job, others can leave a residue of paint in carvings and grooves. Wooden elements may also be soaked too long so that the wood grain is raised and roughened, requiring extensive hand sanding later. In addition, assurances should be given by these companies that caustic paint removers will be neutralized with a mild acid solution or at least thoroughly rinsed with water after dipping (a caustic residue makes the wood feel slippery). If this is not done, the lye residue will cause new paint to fail.

Summary of Chemical Methods

Recommended, with extreme caution: Solvent-base strippers, caustic strippers.

Applicable areas of buildings: decorative features, window muntins, doors, exterior shutters, columns, balusters, and railings.

For use on: Class III Conditions.

Health/Safety factors: Take precautions against inhaling toxic vapors; fire; eye damage; and chemical poisoning from skin contact. Dispose of lead residue properly.

General Paint Type Recommendations

Based on the assumption that the exterior wood has been painted with oil paint many times in the past and the existing top coat is therefore also an oil paint,* it is recommended that for CLASS I and CLASS II paint surface conditions, a top coat of high quality oil paint be applied when repainting. The reason for recommending oil rather than latex paints is that a coat of latex paint applied directly over old oil paint is more apt to fail. The considerations are twofold. First, because oil paints continue to harden with age, the old surface is sensitive to the added stress of shrinkage which occurs as a new coat of paint dries. Oil paints shrink less upon drying than latex paints and thus do not have as great a tendency to pull the old paint loose. Second, when exterior oil paints age, the binder releases pigment particles, causing a chalky surface. Although for best results, the chalk (or dirt, etc.) should always be cleaned off prior to repainting, a coat of new oil paint is more able to penetrate a chalky residue and adhere than is latex paint. Therefore, unless it is possible to thoroughly clean a heavy chalked surface, oil paints—on balance—give better adhesion.

If however, a latex top coat is going to be applied over several layers of old oil paint, an oil primer should be applied first (the oil primer creates a flat, porous surface to which the latex can adhere). After the primer has thoroughly dried, a latex top coat may be applied. In the long run, changing paint types is more time consuming and expensive. An application of a new oil-type top coat on the old oil paint is, thus, the preferred course of action.

* Marking the original location of the shutter by number (either by stamping numbers into the end grain with metal numeral dies or cutting numbers into the end with a pen knife) will minimize difficulties when rehanging them.

* If the top coat is latex paint (when viewed by the naked eye or, preferably, with a magnifying glass, it looks like a series of tiny craters) it may either be repainted with new latex paint or with oil paint. Normal surface preparation should precede any repainting.

If **CLASS III** conditions have necessitated total paint removal, there are two options, both of which assure protection of the exterior wood: (1) an oil primer may be applied followed by an oil-type top coat, preferably by the same manufacturer; or (2) an oil primer may be applied followed by a latex top coat, again using the same brand of paint. It should also be noted that primers were never intended to withstand the effects of weathering; therefore, the top coat should be applied as soon as possible after the primer has dried.

Conclusion

The recommendations outlined in this Brief are cautious because at present there is no completely safe and effective method of removing old paint from exterior woodwork. This has necessarily eliminated descriptions of several methods still in a developmental or experimental stage, which can therefore neither be recommended nor precluded from future recommendation. With the ever-increasing number of buildings being rehabilitated, however, paint removal technology should be stimulated and, in consequence, existing methods refined and new methods developed which will respect both the historic wood and the health and safety of the operator.

Reading List

Batcheler, Penelope Hartshorne. "Paint Color Research and Restoration." *Technical Leaflet 15*. Nashville: American Association for State and Local History (undated).

"Danger: Restoration May Be Hazardous to Your Health." *The Old House Journal*. Vol. 4, No. 5 (May 1976), pp. 9-11.

Gola, Edward F. "Avoiding Mistakes in Exterior Painting." *The Old House Journal*. Vol. 4, No. 6 (June 1976), pp. 1, 4-5.

"How to Assure a Satisfactory Paint Job." *Scientific Section: Circular 784*. Washington, DC: National Paint, Varnish and Lacquer Association (undated).

Labine, Clem. "Selecting the Best Exterior Paint." *The Old House Journal*. Vol. 4, No. 7 (July 1976), pp. 1, 10-11.

Morton, W. Brown III and Hume, Gary L. *The Secretary of the Interior's Standards for Historic Preservation Projects with Guidelines for Applying the Standards*. Washington, DC: Department of Interior, 1979.

Paint Problem Solver. St. Louis: National Decorating Products Association, 1980.

"Special Issue: Exterior Painting." *The Old House Journal*. Vol. 4, No. 4 (April 1981), pp. 71-94.

Thorsen, John W. "Hazardous Waste: What is it? How to Handle it." *Professional Decorating & Coating Action*. Vol. 43, No. 4 (September 1981), pp. 4-5.

Special thanks go to Baird M. Smith, AIA (formerly Chief, Preservation Technology Branch, TPS) for providing general direction in the development of the manuscript. In addition, the following individuals are to be thanked for their contributions as technical experts in the field: Royal T. Brown, National Paint and Coatings Association, Washington, D.C.; Dr. Judith E. Selwyn, Preservation Technology Associates, Boston, Massachusetts; and Dennis R. Vacca, Pratt & Lambert Co., Carlstadt, New Jersey. Finally, thanks go to several National Park Service staff members whose valuable comments were incorporated into the text and who contributed to the production of the brief: James A. Caufield, Anne E. Grimmer, Jean E. Travers, David G. Battle, Sharon C. Park, AIA, Charles E. Fisher III, Sara K. Blumenthal, and Martha A. Gutrick.

This publication has been prepared pursuant to The Economic Recovery Tax Act of 1981, which directs the Secretary of the Interior to certify rehabilitations of historic buildings that are consistent with their historic character; the advice and guidance in this brief will assist property owners in complying with the requirements of this law.

Preservation Briefs 10 has been developed under the technical editorship of Lee H. Nelson, AIA, Chief, Preservation Assistance Division, National Park Service, U.S. Department of the Interior, Washington, D.C. 20240. Comments on the usefulness of this information are welcomed and can be sent to Mr. Nelson at the above address.

September 1982

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402

13 PRESERVATION BRIEFS

The Repair and Thermal Upgrading of Historic Steel Windows

Sharon C. Park, AIA

U.S. Department of the Interior
National Park Service
Cultural Resources
Heritage Preservation Services

The Secretary of the Interior's "Standards for Rehabilitation" require that where historic windows are individually significant features, or where they contribute to the character of significant facades, their distinguishing visual qualities must not be destroyed. Further, the rehabilitation guidelines recommend against changing the historic appearance of windows through the use of inappropriate designs, materials, finishes, or colors which radically change the sash, depth of reveal, and muntin configuration; the reflectivity and color of the glazing; or the appearance of the frame.

Windows are among the most vulnerable features of historic buildings undergoing rehabilitation. This is especially the case with rolled steel windows, which are often mistakenly not deemed worthy of preservation in the conversion of old buildings to new uses. The ease with which they can be replaced and the mistaken assumption that they cannot be made energy efficient except at great expense are factors that typically lead to the decision to remove them. In many cases, however, repair and retrofit of the historic windows are more economical than wholesale replacement, and all too often, replacement units are unlike the originals in design and appearance. If the windows are important in establishing the historic character of the building (see fig. 1), insensitively designed replacement windows may diminish—or destroy—the building's historic character.

This *Brief* identifies various types of historic steel windows that dominated the metal window market from 1890-1950. It then gives criteria for evaluating deterioration and for determining appropriate treatment, ranging from routine maintenance and weatherization to extensive repairs, so that replacement may be avoided where possible.[1] This information applies to do-it-yourself jobs and to large rehabilitations where the volume of work warrants the removal of all window units for complete overhaul by professional contractors.

This *Brief* is not intended to promote the repair of ferrous metal windows in every case, but rather to insure that preservation is always the first consideration in a rehabilitation project. Some windows are not important elements in defining a building's historic character; others are highly significant, but so deteriorated that repair is infeasible. In such cases, the *Brief* offers guidance in evaluating appropriate replacement windows.

Fig. 1 Often highly distinctive in design and craftsmanship, rolled steel windows play an important role in defining the architectural character of many later nineteenth and early twentieth century buildings. Art Deco, Art Moderne, the International Style, and Post World War II Modernism depended on the slim profiles and streamlined appearance of metal windows for much of their impact. Photo: William G. Johnson.

[1] The technical information given in this brief is intended for most ferrous (or magnetic) metals, particularly rolled steel. While stainless steel is a ferrous metal, the cleaning and repair techniques outlined here must not be used on it as the finish will be damaged. For information on cleaning stainless steel and non-ferrous metals, such as bronze, Monel, or aluminum, refer to *Metals in America's Historic Buildings* (see bibliography).

HISTORICAL DEVELOPMENT

Although metal windows were available as early as 1860 from catalogues published by architectural supply firms, they did not become popular until after 1890. Two factors combined to account for the shift from wooden to metal windows about that time. Technology borrowed from the rolling industry permitted the mass production of rolled steel windows. This technology made metal windows cost competitive with conventional wooden windows. In addition, a series of devastating urban fires in Boston, Baltimore, Philadelphia, and San Francisco led to the enactment of strict fire codes for industrial and multistory commercial and office buildings.

As in the process of making rails for railroads, rolled steel windows were made by passing hot bars of steel through progressively smaller, shaped rollers until the appropriate angled configuration was achieved (see fig. 2). The rolled steel sections, generally 1/8" thick and 1" - 1 1/2" wide, were used for all the components of the windows: sash, frame,and subframe (see fig. 3). With the addition of wire glass, a fire-resistant window resulted. These rolled steel windows are almost exclusively found in masonry or concrete buildings.

A byproduct of the fire-resistant window was the strong metal frame that permitted the installation of larger windows and windows in series. The ability to have expansive amounts of glass and increased ventilation dramatically changed the designs of late 19th and early 20th century industrial and commercial buildings.

The newly available, reasonably priced steel windows soon became popular for more than just their fire-resistant qualities. They were standardized, extremely durable, and easily transported. These qualities led to the use of steel windows in every type of construction, from simple industrial and institutional buildings to luxury commercial and apartment buildings. Casement, double-hung, pivot, projecting, austral, and continuous windows differed in operating and ventilating capacities. Figure 4 outlines the kinds and properties of metal windows available then and now. In addition, the thin profiles of metal windows contributed to the streamlined appearance of the Art Deco, Art Moderne, and International Styles, among others.

The extensive use of rolled steel metal windows continued until after World War II when cheaper, noncorroding aluminum windows became increasingly popular. While aluminum windows dominate the market today, steel windows are still fabricated. Should replacement of original windows become necessary, replacement windows may be available from the manufacturers of some of the earliest steel windows. Before an informed decision can be made whether to repair or replace metal windows, however, the significance of the windows must be determined and their physical condition assessed.

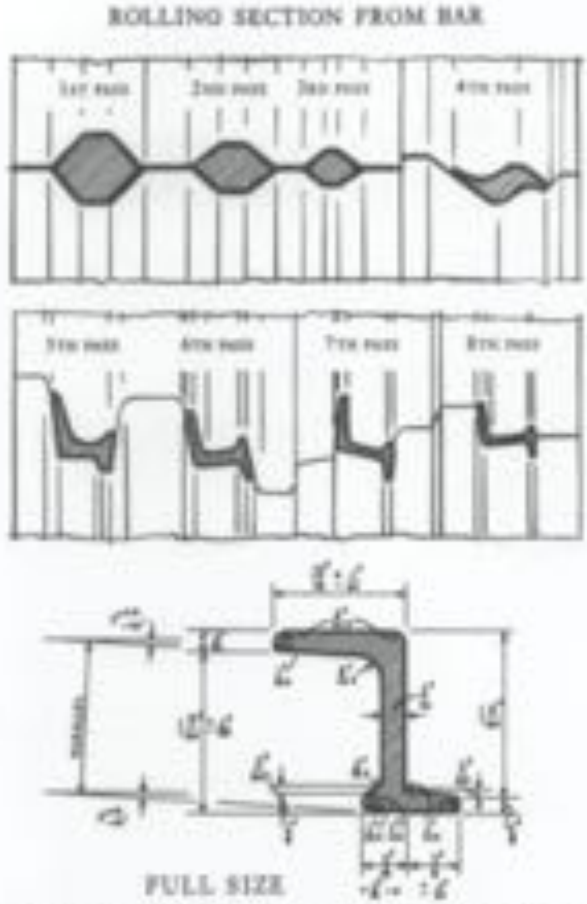


Fig. 2. The process of rolling a steel bar into an angled section is illustrated above. The shape and size of the rolled section will vary slightly depending on the overall strength needed for the window opening and the location of the section in the assembly: subframe, frame, or sash. The 1/8" thickness of the metal section is generally standard. Drawing: A Metal Window Dictionary. Used with permission.

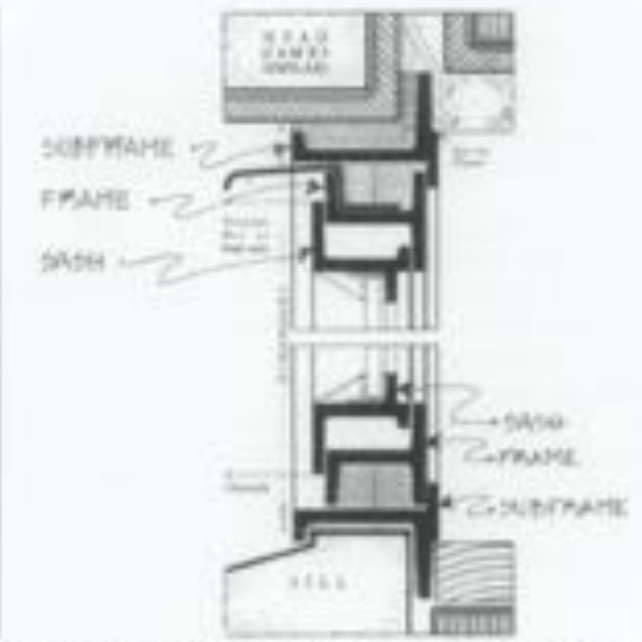


Fig. 3 A typical section through the top and bottom of a metal window shows the three component parts of the window assembly: subframe, frame, and sash. Drawings: Catalogue No. 13, January 1931; International Casement Co, Inc., presently Hope's Architectural Products, Inc., Jamestown, NY. Used with permission.

Cover illustration: from *Hope's Metal Windows and Casements: 1818-1926*, currently Hope's Architectural Products, Inc. Used with permission.

EVALUATION

Historic and Architectural Considerations

An assessment of the significance of the windows should begin with a consideration of their function in relation to the building's historic use and its historic character. Windows that help define the building's historic character should be preserved even if the building is being converted to a new use. For example, projecting steel windows used to introduce light and an effect of spaciousness to a warehouse or industrial plant can be retained in the conversion of such a building to offices or residences.

Other elements in assessing the relative importance of the historic windows include the design of the windows and their relationship to the scale, proportion, detailing and architectural style of the building. While it may be easy to determine the aesthetic value of highly ornamented windows, or to recognize the importance of streamlined windows as an element of a style, less elaborate windows can also provide strong visual interest by their small panes or projecting planes when open, particularly in simple, unadorned industrial buildings (see fig. 5).

One test of the importance of windows to a building is to ask if the overall appearance of the building would be changed noticeably if the windows were to be removed or radically altered. If so, the windows are important in defining the building's historic character, and should be repaired if their physical condition permits.

Physical Evaluation

Steel window repair should begin with a careful evaluation of the physical condition of each unit. Either drawings or photographs, liberally annotated, may be used to record the location of each window, the type of operability, the condition of all three parts—sash, frame and subframe—and the repairs essential to its continued use.

Specifically, the evaluation should include: presence and degree of corrosion; condition of paint; deterioration of the metal sections, including bowing, misalignment of the sash, or bent sections; condition of the glass and glazing compound; presence and condition of all hardware, screws, bolts, and hinges; and condition of the masonry or concrete surrounds, including need for caulking or resetting of improperly sloped sills.

Corrosion, principally rusting in the case of steel windows, is the controlling factor in window repair; therefore, the evaluator should first test for its presence. Corrosion can be light, medium, or heavy, depending on how much the rust has penetrated the metal sections. If the rusting is merely a surface accumulation or flaking, then the corrosion is light. If the rusting has penetrated the metal (indicated by a bubbling texture), but has not caused any structural damage, then the corrosion is medium. If the rust has penetrated deep into the metal, the corrosion is heavy. Heavy corrosion generally results in some form of structural damage, through delamination, to the metal section, which must then be patched or spliced. A sharp probe or tool, such as an ice pick, can be used to determine the extent of corrosion in the metal. If the probe can penetrate the surface of the metal and brittle strands can be dug out, then a high degree of corrosive deterioration is present.

In addition to corrosion, the condition of the paint, the presence of bowing or misalignment of metal sections, the amount of glass needing replacement, and the condition of the masonry or concrete surrounds must be assessed in the evaluation process. These are key factors in determining whether or not the windows can be repaired in place. The more complete the inventory of existing conditions, the easier it will be to determine whether repair is feasible or whether replacement is warranted.

Rehabilitation Work Plan

Following inspection and analysis, a plan for the rehabilitation can be formulated. The actions necessary to return windows to an efficient and effective working condition will fall into one or more of the following categories: routine mainenance, repair, and weatherization. The routine maintenance and weatherization measures described here are generally within the range of do-it-yourselfers. Other repairs, both moderate and major, require a professional contractor. Major repairs normally require the removal of the window units to a workshop, but even in the case of moderate repairs, the number of windows involved might warrant the removal of all the deteriorated units to a workshop in order to realize a more economical repair price. Replacement of windows should be considered only as a last resort.

Since moisture is the primary cause of corrosion in steel windows, it is essential that excess moisture be eliminated and that the building be made as weathertight as possible before any other work is undertaken. Moisture can accumulate from cracks in the masonry, from spalling mortar, from leaking gutters, from air conditioning condensation runoff, and from poorly ventilated interior spaces.

Finally, before beginning any work, it is important to be aware of health and safety risks involved. Steel windows have historically been coated with lead paint. The removal of such paint by abrasive methods will produce toxic dust. Therefore, safety goggles, a toxic dust respirator, and protective clothing should be worn. Similar protective measures should be taken when acid compounds are used. Local codes may govern the methods of removing lead paints and proper disposal of toxic residue.

ROUTINE MAINTENANCE

A preliminary step in the routine maintenance of steel windows is to remove surface dirt and grease in order to ascertain the degree of deterioration, if any. Such minor cleaning can be accomplished using a brush or vacuum followed by wiping with a cloth dampened with mineral spirits or denatured alcohol.

Double-hung industrial windows duplicated the look of traditional wooden windows. Metal double-hung windows were early examples of a building product adapted to meet stringent new fire code requirements for manufacturing and high-rise buildings in urban areas. Soon supplanted in industrial buildings by less expensive pivot windows, double-hung metal windows regained popularity in the 1940s for use in speculative suburban housing.

Austral windows were also a product of the 1920s. They combined the appearance of the double-hung window with the increased ventilation and ease of operation of the projected window. (When fully opened, they provided 70% ventilation as compared to 50% ventilation for double-hung windows.) Austral windows were often used in schools, libraries and other public buildings.

Pivot windows were an early type of industrial window that combined inexpensive first cost and low maintenance. Pivot windows became standard for warehouses and power plants where the lack of screens was not a problem. The window shown here is a horizontal pivot. Windows that turned about a vertical axis were also manufactured (often of iron). Such vertical pivots are rare today.

Casement windows adapted the English tradition of using wrought iron casements with leaded cames for residential use. Rolled steel casements (either single, as shown, or paired) were popular in the 1920s for cottage style residences and Gothic style campus architecture. More streamlined casements were popular in the 1930s for institutional and small industrial buildings.

Projecting windows, sometimes called awning or hopper windows, were perfected in the 1920s for industrial and institutional buildings. They were often used in "combination" windows, in which upper panels opened out and lower panels opened in. Since each movable panel projected to one side of the frame only, unlike pivot windows, for example, screens could be introduced.

Continuous windows were almost exclusively used for industrial buildings requiring high overhead lighting. Long runs of clerestory windows operated by mechanical tension rod gears were typical. Long banks of continuous windows were possible because the frames for such windows were often structural elements of the building.

Fig. 4 Typical rolled steel windows available from 1890 to the present. The various operating and ventilating capacities in combination with the aesthetics of the window style were important considerations in the selection of one window type over another. Drawings: Sharon C. Park, AIA.

If it is determined that the windows are in basically sound condition, the following steps can be taken: 1) removal of light rust, flaking and excessive paint; 2) priming of exposed metal with a rust-inhibiting primer; 3) replacement of cracked or broken glass and glazing compound; 4) replacement of missing screws or fasteners; 5) cleaning and lubrication of hinges; 6) repainting of all steel sections with two coats of finish paint compatible with the primer; and 7) caulking the masonry surrounds with a high quality elastomeric caulk.

Recommended methods for removing light rust include manual and mechanical abrasion or the application of chemicals. Burning off rust with an oxy-acetylene or propane torch, or an inert gas welding gun, should never be attempted because the heat can distort the metal. In addition, such intense heat (often as high as 3800° F) vaporizes the lead in old paint, resulting in highly toxic fumes. Furthermore, such heat will likely result in broken glass. Rust can best be removed using a wire brush, an aluminum oxide sandpaper, or a variety of power tools

Fig. 5 Windows often provide a strong visual element to relatively simple or unadorned industrial or commercial buildings. This design element should be taken into consideration when evaluating the significance of the windows. Photo: Michael Auer.

adapted for abrasive cleaning such as an electric drill with a wire brush or a rotary whip attachment. Adjacent sills and window jambs may need protective shielding.

Rust can also be removed from ferrous metals by using a number of commercially prepared anti-corrosive acid compounds. Effective on light and medium corrosion, these compounds can be purchased either as liquids or gels. Several bases are available, including phosphoric acid, ammonium citrate, oxalic acid and hydrochloric acid. Hydrochloric acid is generally not recommended; it can leave chloride deposits, which cause future corrosion. Phosphoric acid-based compounds do not leave such deposits, and are therefore safer for steel windows. However, any chemical residue should be wiped off with damp cloths, then dried immediately. Industrial blow-dryers work well for thorough drying. The use of running water to remove chemical residue is never recommended because the water may spread the chemicals to adjacent surfaces, and drying of these surfaces may be more difficult. Acid cleaning compounds will stain masonry; therefore plastic sheets should be taped to the edge of the metal sections to protect the masonry surrounds. The same measure should be followed to protect the glazing from etching because of acid contact.

Measures that remove rust will ordinarily remove flaking paint as well. Remaining loose or flaking paint can be removed with a chemical paint remover or with a pneumatic needle scaler or gun, which comes with a series of chisel blades and has proven effective in removing flaking paint from metal windows. Well-bonded paint may serve to protect the metal further from corrosion, and need not be removed unless paint build-up prevents the window from closing tightly. The edges should be feathered by sanding to give a good surface for repainting.

Next, any *bare* metal should be wiped with a cleaning solvent such as denatured alcohol, and dried immediately in preparation for the application of an anti-corrosive primer. Since corrosion can recur very soon after metal has been exposed to the air, the metal should be primed immediately after cleaning. Spot priming may be required periodically as other repairs are undertaken. Anti-corrosive primers generally consist of oil-alkyd based paints rich in zinc or zinc chromate.[3] Red lead is no longer available because of its toxicity. All metal primers, however, are toxic to some degree and should be handled carefully. Two coats of primer are recommended. Manufacturer's recommendations should be followed concerning application of primers.

REPAIR

Repair in Place

The maintenance procedures described above will be insufficient when corrosion is extensive, or when metal window sections are misaligned. Medium to heavy corrosion that has not done any structural damage to the metal sections can be removed either by using the chemical cleaning process described under "Routine Maintenance" or by sandblasting. Since sandblasting can damage the masonry surrounds and crack or cloud the glass, metal or plywood shields should be used to protect these materials. The sandblasting pressure should be low, 80-100 pounds per square inch, and the grit size should be in the range of #10-#45. Glass peening beads (glass pellets) have also been successfully used in cleaning steel sections. While sandblasting equipment comes with various nozzle sizes, pencil-point blasters are most useful because they give the operator more effective control over the direction of the spray. The small aperture of the pencil-point blaster is also useful in removing dried putty from the metal sections that hold the glass. As with any cleaning technique, once the bare metal is exposed to air, it should be primed as soon as possible. This includes the inside rabbeted section of sash where glazing putty has been removed. To reduce the dust, some local codes allow only wet blasting. In this case, the metal must be dried immediately, generally with a blow-drier (a step that the owner should consider when calculating the time and expense involved). Either form of sandblasting metal covered with lead paints produces toxic dust. Proper precautionary measures should be taken against toxic dust and silica particles.

Bent or bowed metal sections may be the result of damage to the window through an impact or corrosive expansion. If the distortion is not too great, it is possible to realign the metal sections without removing the window to a metal fabricator's shop. The glazing is generally removed and pressure is applied to the bent or bowed section. In the case of a muntin, a protective 2 x 4 wooden bracing can be placed behind the bent portion and a wire cable with a winch can apply progressively more pressure over several days until the section is realigned. The 2 x 4 bracing is necessary to distribute the pressure evenly over the damaged section. Sometimes a section, such as the bottom of the frame, will bow out as a result of pressure exerted by corrosion and it is often necessary to cut the metal section to relieve this pressure prior to pressing the section back into shape and making a welded repair.

Once the metal sections have been cleaned of all corrosion and straightened, small holes and uneven areas resulting from rusting should be filled with a patching material and sanded smooth to eliminate pockets where water can accumulate. A patching material of steel fibers and an epoxy binder may be the easiest to apply. This steel-based epoxy is available for industrial steel repair; it can also be found in auto body patching compounds or in plumber's epoxy. As with any product, it is important to follow the manufacturer's instructions for proper use and best results. The traditional patching technique—melting steel welding rods to fill holes in the metal sections—may be difficult to apply in some situations; moreover, the window glass must be removed during the repair process, or it will crack from the expansion of the heated metal sections. After these repairs, glass replacement, hinge lubrication, painting, and other cosmetic repairs can be undertaken as necessary.

[3] Refer to Table IV, Types of Paint Used for Painting Metal in *Metals in America's Historic Buildings*, p. 138. (See bibliography).

To complete the checklist for routine maintenance, cracked glass, deteriorated glazing compound, missing screws, and broken fastners will have to be replaced; hinges cleaned and lubricated; the metal windows painted, and the masonry surrounds caulked. If the glazing must be replaced, all clips, glazing beads, and other fasteners that hold the glass to the sash should be retained, if possible, although replacements for these parts are still being fabricated. When bedding glass, use only glazing compound formulated for metal windows. To clean the hinges (generally brass or bronze), a cleaning solvent and fine bronze wool should be used. The hinges should then be lubricated with a non-greasy lubricant specially formulated for metals and with an anti-corrosive agent. These lubricants are available in a spray form and should be used periodically on frequently opened windows.

Final painting of the windows with a paint compatible with the anti-corrosive primer should proceed on a dry day. (Paint and primer from the same manufacturer should be used.) Two coats of finish paint are recommended if the sections have been cleaned to bare metal. The paint should overlap the glass slightly to insure weathertightness at that connection. Once the paint dries thoroughly, a flexible exterior caulk can be applied to eliminate air and moisture infiltration where the window and the surrounding masonry meet.

Caulking is generally undertaken after the windows have received at least one coat of finish paint. The perimeter of the masonry surround should be caulked with a flexible elastomeric compound that will adhere well to both metal and masonry. The caulking used should be a type intended for exterior application, have a high tolerance for material movement, be resistant to ultraviolet light, and have a minimum durability of 10 years. Three effective compounds (taking price and other factors into consideration) are polyurethane, vinyl acrylic, and butyl rubber. In selecting a caulking material for a window retrofit, it is important to remember that the caulking compound may be covering other materials in a substrate. In this case, some compounds, such as silicone, may not adhere well. Almost all modern caulking compounds can be painted after curing completely. Many come in a range of colors, which eliminates the need to paint. If colored caulking is used, the windows should have been given two coats of finish paint prior to caulking.

Repair in Workshop

Damage to windows may be so severe that the window sash and sometimes the frame must be removed for cleaning and extensive rust removal, straightening of bent sections, welding or splicing in of new sections, and reglazing. These major and expensive repairs are reserved for highly significant windows that cannot be replaced; the procedures involved should be carried out only by skilled workmen. (see fig. 6a—6f.)

As part of the orderly removal of windows, each window should be numbered and the parts labelled. The operable metal sash should be dismantled by removing the hinges; the fixed sash and, if necessary, the frame can then be unbolted or unscrewed. (The subframe is usually left in place. Built into the masonry surrounds, it can only be cut out with a torch.) Hardware and hinges should be labelled and stored together.

The two major choices for removing flaking paint and corrosion from severely deteriorated windows are dipping in a chemical bath or sandblasting. Both treatments require removal of the glass. If the windows are to be dipped, a phosphoric acid solution is preferred, as mentioned earlier. While the dip tank method is good for fairly evenly distributed rust, deep set rust may remain after dipping. For that reason, sandblasting is more effective for heavy and uneven corrosion. Both methods leave the metal sections clean of residual paint. As already noted, after cleaning has exposed the metal to the air, it should be primed immediately after drying with an anti-corrosive primer to prevent rust from recurring.

Sections that are seriously bent or bowed must be straightened with heat and applied pressure in a workshop. Structurally weakened sections must be cut out, generally with an oxy-acetylene torch, and replaced with sections welded in place and the welds ground smooth. Finding replacement metal sections, however, may be difficult. While most rolling mills are producing modern sections suitable for total replacement, it may be difficult to find an exact profile match for a splicing repair. The best source of rolled metal sections is from salvaged windows, preferably from the same building. If no salvaged windows are available, two options remain. Either an ornamental metal fabricator can weld flat plates into a built-up section, or a steel plant can mill bar steel into the desired profile.

While the sash and frame are removed for repair, the subframe and masonry surrounds should be inspected. This is also the time to reset sills or to remove corrosion from the subframe, taking care to protect the masonry surrounds from damage.

Missing or broken hardware and hinges should be replaced on all windows that will be operable. Salvaged windows, again, are the best source of replacement parts. If matching parts cannot be found, it may be possible to adapt ready-made items. Such a substitution may require filling existing holes with steel epoxy or with plug welds and tapping in new screw holes. However, if the hardware is a highly significant element of the historic window, it may be worth having reproductions made.

Following are illustrations of the repair and thermal upgrading of the rolled steel windows in a National Historic Landmark (fig. 6). Many of the techniques described above were used during this extensive rehabilitation. The complete range of repair techniques is then summarized in the chart titled *Steps for Cleaning and Repairing Historic Steel Windows* (see fig. 7).

Fig. 6 a. View of the flanking wing of the State Capitol where the rolled steel casement windows are being removed for repair.

Fig. 6 b. View from the exterior showing the deteriorated condition of the lower corner of a window prior to repair. While the sash was in relatively good condition, the frame behind was rusted to the point of inhibiting operation.

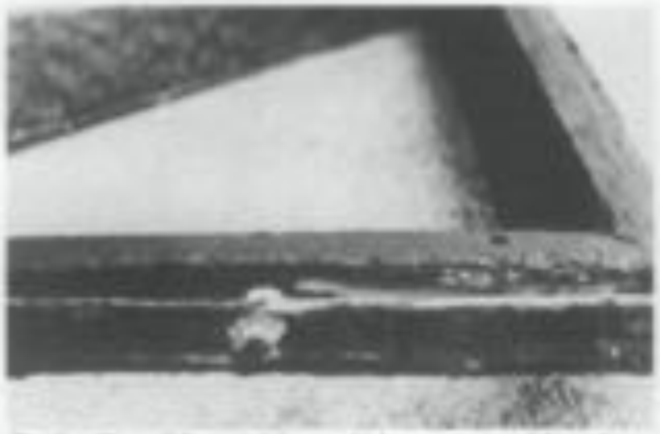


Fig. 6 c. View of the rusted frame which was unscrewed from the subframe and removed from the window opening and taken to a workshop for sandblasting. In some cases, severely deteriorated sections of the frame were replaced with new sections of milled bar steel.

Fig. 6 d. View looking down towards the sill. The subframes appeared very rusted, but were in good condition once debris was vacuumed and surface rust was removed, in place, with chemical compounds. Where necessary, epoxy and steel filler was used to patch depressions in order to make the subframe serviceable again.

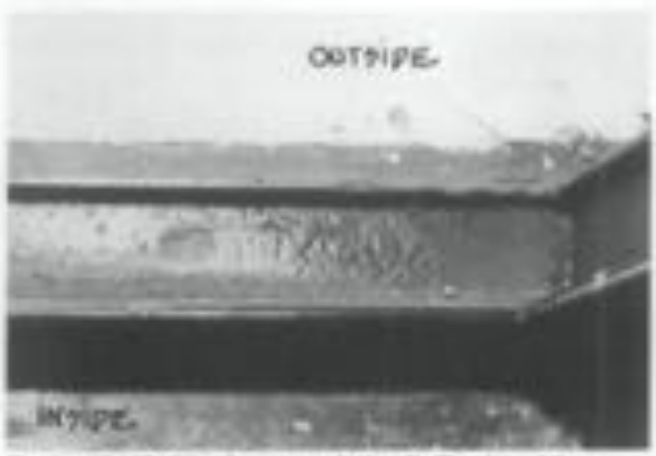


Fig. 6 e. View looking down towards the sill. The cleaned frame was reset in the window opening. The frame was screwed to the refurbished subframe at the jamb and the head only. The screw holes at the sill, which had been the cause of much of the earlier rusting, were infilled. Vinyl weatherstripping was added to the frame.

Fig. 6 f. View from the outside of the completely refurbished window. In addition to the steel repair and the installation of vinyl weatherstripping, the interior was caulked with polyurethane and the single glass was replaced with individual lights of thermal glass. The repaired and upgraded windows have comparable energy efficiency ratings to new replacement units while retaining the historic steel sash, frames and subframes.

Fig. 6. The repair and thermal upgrading of the historic steel windows at the State Capitol, Lincoln, Nebraska. This early twentieth century building, designed by Bertram Goodhue, is a National Historic Landmark. Photos: All photos in this series were provided by the State Building Division.

STEPS FOR CLEANING AND REPAIRING HISTORIC STEEL WINDOWS

Work Item	Recommended Techniques	Tools, Products and Procedures	Notes
	*(Must be done in a workshop)		
1. Removing dirt and grease from metal	General maintenance and chemical cleaning	Vacuum and bristle brushes to remove dust and dirt; solvents (denatured alcohol, mineral spirits), and clean cloths to remove grease.	Solvents can cause eye and skin irritation. Operator should wear protective gear and work in ventilated area. Solvents should not contact masonry. Do not flush with water.
2. Removing Rust/ Corrosion			
Light	Manual and mechanical abrasion	Wire brushes, steel wool, rotary attachments to electric drill, sanding blocks and disks.	Handsanding will probably be necessary for corners. Safety goggles and masks should be worn.
	Chemical cleaning	Anti-corrosive jellies and liquids (phosphoric acid preferred); clean damp cloths.	Protect glass and metal with plastic sheets attached with tape. Do not flush with water. Work in ventilated area.
Medium	Sandblasting/abrasive cleaning	Low pressure (80-100 psi) and small grit (#10-#45); glass peening beads. Pencil blaster gives good control.	Removes both paint and rust. Codes should be checked for environmental compliance. Prime exposed metal promptly. Shield glass and masonry. Operator should wear safety gear.
Heavy	*Chemical dip tank	Metal sections dipped into chemical tank (phosphoric acid preferred) from several hours to 24 hours.	Glass and hardware should be removed. Protect operator. Deepset rust may remain, but paint will be removed.
	*Sandblasting/ abrasive cleaning	Low pressure (80-100 psi) and small grit (#10-#45).	Excellent for heavy rust. Remove or protect glass. Prime exposed metal promptly. Check codes for environmental compliance. Operator should wear safety gear.
3. Removing flaking paint.	Chemical method	Chemical paint strippers suitable for ferrous metals. Clean cloths.	Protect glass and masonry. Do not flush with water. Have good ventilation and protection for operator.
	Mechanical abrasion	Pneumatic needle gun chisels, sanding disks.	Protect operator; have good ventilation. Well-bonded paint need not be removed if window closes properly.
4. Aligning bent, bowed metal sections	Applied pressure	Wooden frame as a brace for cables and winch mechanism.	Remove glass in affected area. Realignment may take several days.
	*Heat and pressure	Remove to a workshop. Apply heat and pressure to bend back.	Care should be taken that heat does not deform slender sections.

Work Item	Recommended Techniques	Tools, Products and Procedures	Notes
	*(Must be done in a workshop)		
5. Patching depressions	Epoxy and steel filler	Epoxy fillers with high content of steel fibers; plumber's epoxy or autobody patching compound.	Epoxy patches generally are easy to apply, and can be sanded smooth. Patches should be primed.
	Welded patches	Weld in patches using steel rods and oxy-acetylene torch or arc welder.	Prime welded sections after grinding connections smooth.
6. Splicing in new metal sections	*Cut out decayed sections and weld in new or salvaged sections	Torch to cut out bad sections back to 45° joint. Weld in new pieces and grind smooth.	Prime welded sections after grinding connection smooth.
7. Priming metal sections	Brush or spray application	At least one coat of anti-corrosive primer on bare metal. Zinc-rich primers are generally recommended.	Metal should be primed as soon as it is exposed. If cleaned metal will be repaired another day, spot prime to protect exposed metal.
8. Replacing missing screws and bolts	Routine maintenance	Pliers to pull out or shear off rusted heads. Replace screws and bolts with similar ones, readily available.	If new holes have to be tapped into the metal sections, the rusted holes should be cleaned, filled and primed prior to redrilling.
9. Cleaning, lubricating or replacing hinges and other hardware	Routine maintenance, solvent cleaning	Most hinges and closure hardware are bronze. Use solvents (mineral spirits), bronze wool and clean cloths. Spray with non-greasy lubricant containing anti-corrosive agent.	Replacement hinges and fasteners may not match the original exactly. If new holes are necessary, old ones should be filled.
10. Replacing glass and glazing compound	Standard method for application	Pliers and chisels to remove old glass, scrape putty out of glazing rabbet, save all clips and beads for reuse. Use only glazing compound formulated for metal windows.	Heavy gloves and other protective gear needed for the operator. All parts saved should be cleaned prior to reinstallation.
11. Caulking masonry surrounds	Standard method for application	Good quality (10 year or better) elastomeric caulking compound suitable for metal.	The gap between the metal frame and the masonry opening should be caulked; keep weepholes in metal for condensation run-off clear of caulk.
12. Repainting metal windows	Spray or brush	At least 2 coats of paint compatible with the anti-corrosive primer. Paint should lap the glass about 1/8" to form a seal over the glazing compound.	The final coats of paint and the primer should be from the same manufacturer to ensure compatibility. If spraying is used, the glass and masonry should be protected.

Fig. 7. STEPS FOR CLEANING AND REPAIRING HISTORIC STEEL WINDOWS. Compiled by Sharon C. Park, AIA.

WEATHERIZATION

Historic metal windows are generally not energy efficient; this has often led to their wholesale replacement. Metal windows can, however, be made more energy efficient in several ways, varying in complexity and cost. Caulking around the masonry openings and adding weatherstripping, for example, can be do-it-yourself projects and are important first steps in reducing air infiltration around the windows. They usually have a rapid payback period. Other treatments include applying fixed layers of glazing over the historic windows, adding operable storm windows, or installing thermal glass in place of the existing glass. In combination with caulking and weatherstripping, these treatments can produce energy ratings rivaling those achieved by new units.[1]

Weatherstripping

The first step in any weatherization program, caulking, has been discussed above under "Routine Maintenance." The second step is the installation of weatherstripping where the operable portion of the sash, often called the ventilator, and the fixed frame come together to reduce perimeter air infiltration (see fig. 8). Four types of weatherstripping appropriate for metal windows are spring-metal, vinyl strips, compressible foam tapes, and sealant beads. The spring-metal, with an integral friction fit mounting clip, is recommended for steel windows in good condition. The clip eliminates the need for an applied glue; the thinness of the material insures a tight closure. The weatherstripping is clipped to the inside channel of the rolled metal section of the fixed frame. To insure against galvanic corrosion between the weatherstripping (often bronze or brass), and the steel window, the window must be painted prior to the installation of the weatherstripping. This weatherstripping is usually applied to the entire perimeter of the window opening, but in some cases, such as casement windows, it may be best to avoid weatherstripping the hinge side. The natural wedging action of the weatherstripping on the three sides of the window often creates an adequate seal.

Vinyl weatherstripping can also be applied to metal windows. Folded into a "V" configuration, the material forms a barrier against the wind. Vinyl weatherstripping is usually glued to the frame, although some brands have an adhesive backing. As the vinyl material and the applied glue are relatively thick, this form of weatherstripping may not be appropriate for all situations.

Compressible foam tape weatherstripping is often best for large windows where there is a slight bending or distortion of the sash. In some very tall windows having closure hardware at the sash mid-point, the thin sections of the metal window will bow away from the frame near the top. If the gap is not more than 1/4", foam weatherstripping can normally fill the space. If the gap exceeds this, the window may need to be realigned to close more tightly. The foam weatherstripping comes either with an adhesive or plain back; the latter variety requires application with glue. Compressible foam requires more frequent replacement than either spring-metal or vinyl weatherstripping.

A fourth type of successful weatherstripping involves the use of a caulking or sealant bead and a polyethylene bond breaker tape. After the window frame has been thoroughly cleaned with solvent, permitted to dry, and primed, a neat bead of low modulus (firm setting) caulk, such as silicone, is applied. A bond breaker tape is then applied to the operable sash covering the metal section where contact will occur. The window is then closed until the sealant has set (2-7 days, depending on temperature and humidity). When the window is opened, the bead will have taken the shape of the air infiltration gap and the bond breaker tape can be removed. This weatherstripping method appears to be successful for all types of metal windows with varying degrees of air infiltration.

Since the several types of weatherstripping are appropriate for different circumstances, it may be necessary to use more than one type on any given building. Successful weatherstripping depends upon using the thinnest material adequate to fill the space through which air enters. Weatherstripping that is too thick can spring the hinges, thereby resulting in more gaps.

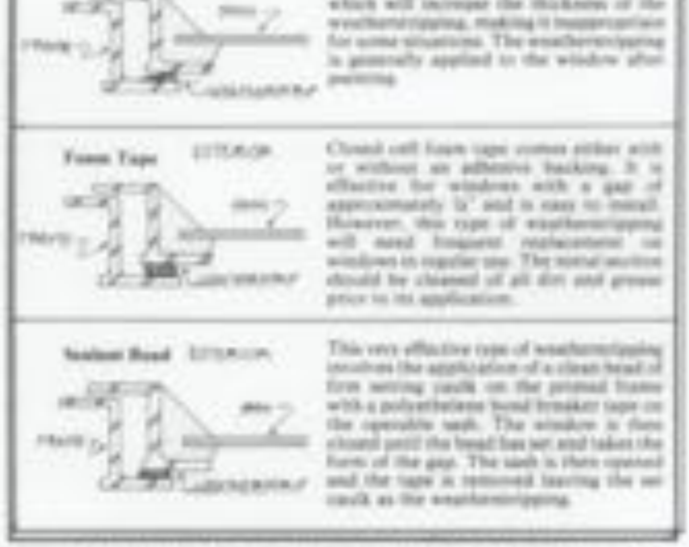


Fig. 8 APPROPRIATE TYPES OF WEATHERSTRIPPING FOR METAL WINDOWS. Weatherstripping is an important part of upgrading the thermal efficiency of historic steel windows. The chart above shows the jamb section of the window with the weatherstripping in place. Drawings: Sharon C. Park, AIA.

---

[1]One measure of energy efficiency is the U-value (the number of BTUs per hour transferred through a square foot of material). The lower the U-value, the better the performance. According to *ASHRAE HANDBOOK 1977 Fundamentals*, the U-value of historic rolled steel sash with single glazing is 1.3. Adding storm windows to the existing units or replacing with 5/8" insulating glass produces a U-value of .69. These methods of weatherizing historic steel windows compare favorably with rolled steel replacement alternatives: with factory installed 1" insulating glass (.67 U-value), with added thermal-break construction and factory finish coatings (.62 U-value).

Thermal Glazing

The third weatherization treatment is to install an additional layer of glazing to improve the thermal efficiency of the existing window. The decision to pursue this treatment should proceed from careful analysis. Each of the most common techniques for adding a layer of glazing will effect approximately the same energy savings (approximately double the original insulating value of the windows); therefore, cost and aesthetic considerations usually determine the choice of method. Methods of adding a layer of glazing to improve thermal efficiency include adding a new layer of transparent material to the window; adding a separate storm window; and replacing the single layer of glass in the window with thermal glass.

The least expensive of these options is to install a clear material (usually rigid sheets of acrylic or glass) over the original window. The choice between acrylic and glass is generally based on cost, ability of the window to support the material, and long-term maintenance outlook. If the material is placed over the entire window and secured to the frame, the sash will be inoperable. If the continued use of the window is important (for ventilation or for fire exits), separate panels should be affixed to the sash without obstructing operability (see fig. 9). Glass or acrylic panels set in frames can be attached using magnetized gaskets, interlocking material strips, screws or adhesives. Acrylic panels can be screwed directly to the metal windows, but the holes in the acrylic panels should allow for the expansion and contraction of this material. A compressible gasket between the prime sash and the storm panel can be very effective in establishing a thermal cavity between glazing layers. To avoid condensation, 1/8'' cuts in a top corner and diagonally opposite bottom corner of the gasket will provide a vapor bleed, through which moisture can evaporate. (Such cuts, however, reduce thermal performance slightly.) If condensation does occur, however, the panels should be easily removable in order to wipe away moisture before it causes corrosion.

The second method of adding a layer of glazing is to have independent storm windows fabricated. (Pivot and austral windows, however, which project on either side of the window frame when open, cannot easily be fitted with storm windows and remain operational.) The storm window should be compatible with the original sash configuration. For example, in paired casement windows, either specially fabricated storm casement windows or sliding units in which the vertical meeting rail of the slider reflects the configuration of the original window should be installed. The decision to place storm windows on the inside or outside of the window depends on whether the historic window opens in or out, and on the visual impact the addition of storm windows will have on the building. Exterior storm windows, however, can serve another purpose besides saving energy: they add a layer of protection against air pollutants and vandals, although they will partially obscure the prime window. For highly ornamental windows this protection can determine the choice of exterior rather then interior storm windows.

The third method of installing an added layer of glazing is to replace the original single glazing with thermal glass. Except in rare instances in which the original glass is of special interest (as with stained or figured glass), the glass can be replaced if the hinges can tolerate the weight of the additional glass. The rolled metal sections for steel windows are generally from 1'' - 1 1/2'' thick. Sash of this thickness can normally tolerate thermal glass, which ranges from 3/8'' - 5/8''. (Metal glazing beads, readily available, are used to reinforce the muntins, which hold the glass.) This treatment leaves the window fully operational while preserving the historic appearance. It is, however, the most expensive of the treatments discussed here. (See fig. 6f).

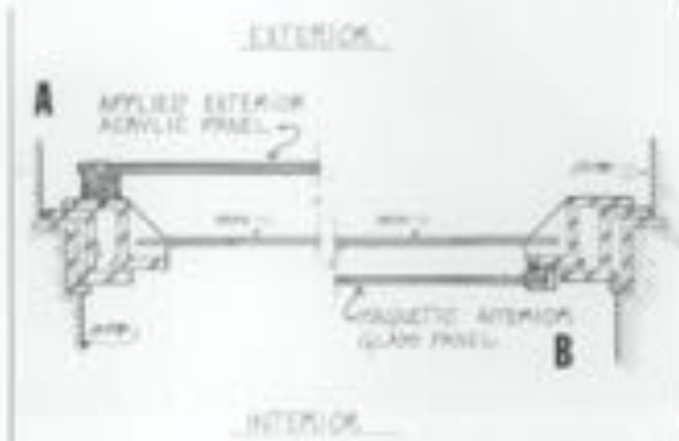


Fig. 9 Two examples of adding a second layer of glazing in order to improve the thermal performance of historic steel windows. Scheme A (showing jamb detail) is of a ¼'' acrylic panel with a closed cell foam gasket attached with self-tapping stainless steel screws directly to the exterior of the outwardly opening sash. Scheme B (showing jamb detail) is of a glass panel in a magnetized frame affixed directly to the interior of the historic steel sash. The choice of using glass or acrylic mounted on the inside or outside will depend on the ability of the window to tolerate additional weight, the location and size of the window, the cost, and the long-term maintenance outlook. Drawing: Sharon C. Park, AIA.

WINDOW REPLACEMENT

Repair of historic windows is always preferred within a rehabilitation project. Replacement should be considered only as a last resort. However, when the extent of deterioration or the unavailability of replacement sections renders repair impossible, replacement of the entire window may be justified. In the case of significant windows, replacement in kind is essential in order to maintain the historic character of the building. However, for less significant windows, replacement with compatible new windows may be acceptable. In selecting compatible replacement windows, the material, configuration, color, operability, number and size of panes, profile and proportion of metal sections, and reflective quality of the original glass should be duplicated as closely as possible.

A number of metal window manufacturing companies produce rolled steel windows. While stock modern window designs do not share the multi-pane configuration of historic windows, most of these manufacturers can reproduce the historic configuration if requested, and the cost is not excessive for large orders (see figs. 10a and 10b). Some manufacturers still carry the standard pre-World War II multi-light windows using the traditional 12" x 18" or 14" x 20" glass sizes in industrial, commercial, security, and residential configurations. In addition, many of the modern steel windows have integral weatherstripping, thermal break construction, durable vinyl coatings, insulating glass, and other desirable features.

Fig. 10 a. A six-story concrete manufacturing building prior to the replacement of the steel pivot windows. Photo: Charles Parrott.

Fig. 10 b. Close-up view of the new replacement steel windows which matched the multi-lighted originals exactly. Photo: Charles Parrott.

Windows manufactured from other materials generally cannot match the thin profiles of the rolled steel sections. Aluminum, for example, is three times weaker than steel and must be extruded into a box-like configuration that does not reflect the thin historic profiles of most steel windows. Wooden and vinyl replacement windows generally are not fabricated in the industrial style, nor can they reproduce the thin profiles of the rolled steel sections, and consequently are generally not acceptable replacements.

For product information on replacement windows, the owner, architect, or contractor should consult manufacturers' catalogues, building trade journals, or the Steel Window Institute, 1230 Keith Building, Cleveland, Ohio 44115.

SUMMARY

The National Park Service recommends the retention of significant historic metal windows whenever possible. Such windows, which can be a character-defining feature of a historic building, are too often replaced with inappropriate units that impair rather than complement the overall historic appearance. The repair and thermal upgrading of historic steel windows is more practicable than most people realize. Repaired and properly maintained metal windows have greatly extended service lives. They can be made energy efficient while maintaining their contribution to the historic character of the building.

BIBLIOGRAPHY

ASHRAE Handbook - 1977 Fundamentals. New York: American Society of Heating, Refrigerating and Airconditioning Engineers, 1978.

Crittal, W. F. *A Metal Window Dictionary.* London:Curwen Press, 1926. Reprinted by B.T. Batsford, Ltd., 1953.

Gayle, Margot; David W. Look, AIA; John G. Waite.*Metals in America's Historic Buildings: Uses and Preservation Treatments.* Technical Preservation Services, U.S. Department of the Interior. Washington,D.C.: U.S.Government Printing Office, 1980.

Gillet, William. "Steel Windows." *Windows and Glass in the Exterior of Buildings.* National Academy of Sciences Publication #478. Washington, D.C.: 1957,75-78.

Sarton, R. H. "Selecting and Specifying an Appropriate Type of Steel Window." *Metalcraft.* Vol 6, No. 1 (January, 1931): 43-48, 64-65.

Sweet's Architectural Catalogue. 13th Edition, New York, Sweets Catalogue Service, Inc., 1918.

The author gratefully acknowledges the invaluable assistance of co-worker Michael Auer in preparing this brief for publication. This publication is an extension of research initiated by Frederic E. Kleyle. Special thanks are given to Hope's Architectural Products, Inc., Jamestown, NY, for their generous contribution of historic metal window catalogues which were an invaluable source of information. The following individuals are also to be thanked for reviewing the manuscript and making suggestions: Hugh Miller, Chief, Park Historic Architecture Division, National Park Service; Barclay L. Rogers, Museum Services, National Park Service; Susan M. Young, Steel Window Institute, and Danny Schlichenmaier, State Building Division, Lincoln, Nebraska. Finally, thanks go to Technical Preservation Services Branch staff and to cultural resources staff of the National Park Service Regional Offices, whose valuable comments were incorporated into the final text and who contributed to the publication of this brief.

This publication has been prepared pursuant to the Economic Recovery Tax Act of 1981, which directs the Secretary of the Interior to certify rehabilitations of historic buildings that are consistent with their historic character; the guidance provided in this brief will assist property owners in complying with the requirements of this law.

Preservation Briefs: 13 has been developed under the technical editorship of Lee H. Nelson, AIA, Chief, Preservation Assistance Division, National Park Service, U.S. Department of the Interior, Washington, D.C. 20240. Comments on the usefulness of this information are welcomed and can be sent to Mr. Nelson at the above address.

15 PRESERVATION BRIEFS

Preservation of Historic Concrete

Paul Gaudette and Deborah Slaton

National Park Service
U.S. Department of the Interior
Heritage Preservation Services

Introduction to Historic Concrete

Concrete is an extraordinarily versatile building material used for utilitarian, ornamental, and monumental structures since ancient times. Composed of a mixture of sand, gravel, crushed stone, or other coarse material, bound together with lime or cement, concrete undergoes a chemical reaction and hardens when water is added. Inserting reinforcement adds tensile strength to structural concrete elements. The use of reinforcement contributes significantly to the range and size of building and structure types that can be constructed with concrete.

While early twentieth century proponents of modern concrete often considered it to be permanent, it is, like all materials, subject to deterioration. This Brief provides an overview of the history of concrete and its popularization in the United States, surveys the principal causes and modes of concrete deterioration, and outlines approaches to repair and protection that are appropriate to historic concrete. In the context of this Brief, historic concrete is considered to be concrete used in construction of structures of historical, architectural, or engineering interest, whether those structures are old or relatively new.

Brief History of Use and Manufacture

The ancient Romans found that a mixture of lime putty and pozzolana, a fine volcanic ash, would harden under water. The resulting hydraulic cement became a major feature of Roman building practice, and was used in many buildings and engineering projects such as bridges and aqueducts. Concrete technology was kept alive during the Middle Ages in Spain and Africa. The Spanish introduced a form of concrete to the New World in the first decades of the sixteenth century, referred to as "tapia" or "tabby." This material, a mixture of lime, sand, and shell or stone aggregate mixed with water, was placed between wooden forms, tamped, and allowed to dry in successive layers. Tabby was later used by the English settlers in the coastal southeastern United States.

The early history of concrete was fragmented, with developments in materials and construction techniques occurring on different continents and in various countries. In the United States, concrete was slow in achieving widespread acceptance in building construction and did not begin to gain popularity until the late nineteenth century. It was more readily accepted for use in transportation and infrastructure systems.

The Erie Canal in New York is an example of the early use of concrete in transportation in the United States. The natural hydraulic cement used in the canal construction was processed from a deposit of limestone found in 1818 near Chittenango, southeast of Syracuse. The use of concrete in residential construction was

Figure 1. The Sebastopol House in Seguin, Texas, is an 1856 Greek Revival-style house constructed of lime concrete. Lime concrete or "limecrete" was a popular construction material, as it could be made inexpensively from local materials. By 1900, the town had approximately ninety limecrete structures, twenty of which remain. Photo: Texas Parks and Wildlife Department.

Figure 2. Chatterton House was the home of the post trader at Fort Fred Steel in Wyoming, one of several forts established in the 1860s to protect the Union Pacific Railroad. The walls of the post trader's house were built using stone aggregate and lime, without cement. The use of this material presents special preservation challenges.

publicized in the second edition of Orson S. Fowler's *A Home for All* (1853) which described the advantages of "gravel wall" construction to a wide audience. The town of Seguin, Texas, thirty-five miles east of San Antonio, already had a number of concrete buildings by the 1850s and came to be called "The Mother of Concrete Cities," with approximately ninety concrete buildings made from local "lime water" and gravel (Fig. 1).

Impressed by the economic advantages of poured gravel wall or "lime-grout" construction, the Quartermaster General's Office of the War Department embarked on a campaign to improve the quality of building for frontier military posts. As a result, lime-grout structures were constructed at several western posts soon after the Civil War, including Fort Fred Steele and Fort Laramie, both in Wyoming (Fig. 2). By the 1880s, sufficient experience had been gained with unreinforced concrete to permit construction of much larger buildings. A notable example from this period is the Ponce de Leon Hotel in St. Augustine, Florida.

Extensive construction in concrete also occurred through the system of coastal fortifications commissioned by the federal government in the 1890s for the Atlantic, Pacific, and Gulf coasts. Unlike most concrete construction to that time, the special requirements of coastal fortifications called for concrete walls as much as 20 feet thick, often at sites that were difficult to access. Major structures in the coastal defenses of the 1890s were built of mass concrete with no internal reinforcing, a practice that was replaced by the use of reinforcing bars in fortifications constructed after about 1905.

The use of reinforced concrete in the United States dates from 1860, when S.T. Fowler obtained a patent for a reinforced concrete wall. In the early 1870s, William E. Ward built his own house in Port Chester, New York, using concrete reinforced with iron rods for all structural elements. Despite these developments, such construction remained a novelty until after 1880, when innovations introduced by Ernest L. Ransome made the use of reinforced concrete more practicable. Ransome made many contributions to the development of concrete construction technology, including the use of twisted reinforcing bars to improve bond between the concrete and the steel, which he patented in 1884. Two years later, Ransome introduced the rotary kiln to United States cement production. The new kiln had greater capacity and burned more thoroughly and uniformly, allowing development of a less expensive, more uniform, and more reliable manufactured cement. Improvements in concrete production initiated by Ransom led to a much greater acceptance of concrete after 1900.

The Lincoln Highway Association, incorporated in 1913, promoted the use of concrete in construction of a coast-to-coast roadway system. The goal of the Lincoln Highway Association and highway advocate Henry B. Joy was to educate the country in the need for good roads made of concrete, with an improved Lincoln

Figure 3. The Lincoln Highway Association promoted construction of a high quality continuous hard surface roadway across the country. The Boys Scouts of America installed concrete road markers along the Lincoln Highway in 1928.

Figure 4. The highly ornamental concrete panels on the exterior facade of the Baha'i House of Worship in Wilmette, Illinois, illustrate the work of fabricator John J. Earley, known as "the man who made concrete beautiful."

Figure 5. Following World War II, architects and engineers took advantage of improvements in concrete production, quality control, and advances in precast concrete to design structures such as the Police Headquarters building in Philadelphia, Pennsylvania, constructed in 1961. Photo: Courtesy of the Philadelphia Police Department.

Figure 6. The Bailey Magnet School in Jackson, Mississippi, was designed as the Jackson Junior High School by the firm of N.W. Overstreet & Town in 1936. The streamlined building exemplifies the applicability of concrete to creating a modern architectural aesthetic. Photo: Bill Burris, Burris/Wagnon Architects, P.A.

Highway as an example. Concrete "seedling miles" were constructed in remote areas to emphasize the superiority of concrete over unimproved dirt. The Association believed that as people learned about concrete, they would press the government to construct good roads throughout their states. Americans' enthusiasm for good roads led to the involvement of the federal government in road-building and the creation of numbered U.S. routes in the 1920s (Fig. 3).

During the early twentieth century, Ernest Ransome in Beverly, Massachusetts, Albert Kahn in Detroit, and Richard E. Schmidt in Chicago, promoted concrete for use in "Factory Style" utilitarian buildings with an exposed concrete frame infilled with expanses of glass. Thomas Edison's cast-in-place reinforced concrete homes in Union Township, New Jersey (1908), proclaimed a similarly functional emphasis in residential construction. From the 1920s onward, concrete began to be used with spectacular design results: examples include John J. Earley's Meridian Hill Park in Washington, D.C.; Louis Bourgeois' exuberant, graceful Baha'i Temple in Wilmette, Illinois (1920–1953), for which Earley fabricated the concrete (Fig. 4); and Frank Lloyd Wright's Fallingwater near Bear Run, Pennsylvania (1934). Continuing improvements in quality control and development of innovative fabrication processes, such as the Shockbeton method for precast concrete, provided increasing opportunities for architects and engineers. Wright's Guggenheim Museum in New York City (1959); Geddes Brecher Qualls & Cunningham's Police Headquarters building in Philadelphia, Pennsylvania (1961); and Eero Saarinen's soaring terminal building at Dulles International Airport outside Washington, D.C., and the TWA terminal at Kennedy Airport in New York (1962), exemplify the masterful use of concrete achieved in the modern era (Fig. 5).

Figure 7. Detailed bas reliefs as well as sculptures, such as this lion at the Bailey Magnet School, could be used as ornamentation on concrete buildings. Sculptural concrete elements were typically cast in molds.

Throughout the twentieth century, a wide range of architectural and engineering structures were built using concrete as a practical and cost-effective choice—and concrete also became valued for its aesthetic qualities. Cast in place and precast concrete were readily adapted to the Streamlined Moderne style, as exemplified by the Bailey Magnet School in Jackson, Mississippi, designed as the Jackson Junior High School by N.W. Overstreet & Town in 1936 (Figs. 6 and 7). The school is one of many concrete buildings designed and constructed under the auspices of the Public Works Administration. Recreational structures and landscape features also utilized the structural range and unique character of exposed concrete to advantage, as seen in Chicago's Lincoln Park Chess Pavilion, designed by Morris Webster in 1956 (Fig. 8), and the Ira C. Keller Fountain in Portland Oregon, designed by Lawrence Halprin in 1969 (Fig. 9). Concrete was also popular for building interiors, with ornamental features and exposed structural elements recognized as part of the design aesthetic (See Figs. 10 and 11 in sidebar).

Historic Interiors

The expanded use of concrete provided new opportunities to create dramatic spaces and ornate architectural detail on the interiors of buildings, at a significant cost savings over traditional construction practices. The architectural design of the Berkeley City Club in Berkeley, California, expressed Moorish and Gothic elements in concrete on the interior of the building (Fig. 10). Used as a woman's social club, the building was designed by noted California architect Julia Morgan and constructed in 1929. The vaulted ceilings, columns, and ornamental capitals of the lobby and the ornamental arches and beamed ceiling at the "plunge" are all constructed of concrete.

Figure 10. The Berkeley City Club has significant interior spaces and features of concrete construction, including the lobby and pool. Photos: Lisa Gilmartin (left) and Brian Kehoe (right), Wiss, Janney, Elstner Associates, Inc.

The historic character of a building's interior can also be conveyed in a more utilitarian manner in terms of concrete features and finishes (Fig. 11). The exposed concrete structure – columns, capitals, and drop panels – is an integral part of the character of this old commercial building in Minneapolis. In concrete warehouse and factory buildings of the early twentieth century, exposed concrete columns and formboard finish concrete slab ceilings are common features as seen in this warehouse, now converted for use as a parking garage and shops.

Figure 11. Whether in a circa 1925 office (left) or in a parking garage and retail facility (right), exposed concrete structures help characterize these building interiors. Photo: Minnesota Historical Society (left).

Concrete Characteristics

Concrete is composed of fine (sand) and coarse (crushed stone or gravel) aggregates and paste made of portland cement and water. The predominant material in terms of bulk is the aggregate. Portland cement is the binder most commonly used in modern concrete. It is commercially manufactured by blending limestone or chalk with clays that contain alumina, silica, lime, iron oxide and magnesia, and heating the compounds together to high temperatures. The hydration process that occurs between the portland cement and water results in formation of an alkali paste that surrounds and binds the aggregate together as a solid mass.

The quality of the concrete is dependent on the ratio of water to the binder; binder content; sound, durable, and well-graded aggregates; compaction during placement; and proper curing. The amount of water used in the mix affects the concrete permeability and strength. The use of excess water beyond that required in the hydration process results in more permeable concrete, which is more susceptible to weathering and deterioration. Admixtures are commonly added to concrete to adjust concrete properties such as setting or hardening time, requirements for water, workability, and other characteristics. For example, the advent of air entraining agents in the 1930s provided enhanced durability for concrete.

During the twentieth century, there was a steady rise in the strength of ordinary concrete as chemical processes became better understood and quality control measures improved. In addition, the need to protect embedded reinforcement against corrosion was acknowledged. Requirements for concrete cover over reinforcing steel, increased cement content, decreased water-cement ratio, and air entrainment all contributed to greater concrete strength and improved durability.

Mechanisms and Modes of Deterioration

Causes of Deterioration

Concrete deterioration occurs primarily because of corrosion of the embedded steel, degradation of the concrete itself, use of improper techniques or materials in construction, or structural problems. The causes of concrete deterioration must be understood in order to select an appropriate repair and protection system.

While reinforcing steel has played a pivotal role in expanding the applications of concrete in twentieth century architecture, corrosion of this steel has also caused deterioration in many historic structures. Reinforcing steel embedded in the concrete is normally surrounded by a passivating oxide layer that, when present, protects the steel from corrosion and aids in bonding the steel and concrete. When the concrete's normal alkaline environment (above a pH of 10) is compromised and the steel is exposed to water, water vapor, or high relative humidity, corrosion of the steel reinforcing takes place. A reduction in alkalinity results from carbonation, a process that occurs when the carbon dioxide in the atmosphere reacts with calcium hydroxide and moisture in the concrete. Carbonation starts at the concrete's exposed surface but may extend to the reinforcing steel over time. When carbonation reaches the metal reinforcement, the concrete no longer protects the steel from corrosion.

Corrosion of embedded reinforcing steel may be initiated and accelerated if calcium chloride was added to the concrete as a set accelerator during original construction to promote more rapid curing. It may also take place if the concrete is later exposed to deicing salts, as may occur during the winter in northern climates. Seawater or other marine environments can also provide large amounts of chloride, either from inadequately washed original aggregate or from exposure of the concrete to seawater.

Corrosion-related damage to reinforced concrete is the result of rust, a product of the corrosion process of steel, which expands and thus requires more space in the concrete than the steel did at the time of installation. This change in volume of the steel results in expansive forces, which cause cracking and spalling of the adjacent concrete (Fig. 12). Other signs of corrosion of embedded steel include delamination of the concrete (planar separations parallel to the surface) and rust staining (often a precursor to spalling) on the concrete near the steel.

Figure 8. The Chess Pavilion in Chicago's Lincoln Park was designed by architect Morris Webster and constructed in 1956. The pavilion is a distinctive landscape feature, with its reinforced concrete cantilevered slab that provides cover for chess players.

Figure 9. The Ira C. Keller Fountain in Portland, Oregon, was designed by Lawrence Halprin and constructed in 1969. The fountain is constructed primarily of concrete pillars with formboard textures and surrounding elements, patterned with geometric lines, which facilitate the path of water. Photo: Anita Washko, Wiss, Janney, Elstner Associates, Inc.

Lack of proper maintenance of building elements such as roofs and drainage systems can contribute to water-related deterioration of the adjacent concrete, particularly when concrete is saturated with water and then exposed to freezing temperatures. As water within the concrete freezes, it expands and exerts forces on the adjacent concrete. Repeated freezing and thawing can result in the concrete cracking and delaminating. Such damage appears as surface degradation, including severe scaling and micro-cracking that extends into the concrete. The condition is most often observed near the surface of the concrete but can also eventually occur deep within the concrete. This type of deterioration is usually most severe at joints, architectural details, and other areas with more surface exposure to weather. In the second half of the twentieth century, concrete has utilized entrained air (the incorporation of microscopic air bubbles) to provide enhanced protection against damage due to cyclic freezing of saturated concrete.

The use of certain aggregates can also result in deterioration of the concrete. Alkali-aggregate reactions – in some cases alkali-silica reaction (ASR) – occur when alkalis normally present in cement react with certain aggregates, leading to the development of an expansive crystalline gel. When this gel is exposed to moisture, it expands and causes cracking of the aggregate and concrete matrix. Deleterious aggregates are typically found only in certain areas of the country and can be detected through analysis by an experienced petrographer. Low-alkali cements as well as fly ash are used today in new construction to prevent such reactions where this problem may occur.

Problems Specifically Encountered with Historic Concrete

Materials and workmanship used in the construction of historic concrete structures, particularly those built before the First World War, sometimes present potential sources of problems. For example, where the aggregate consisted of cinder from burned coal or crushed brick,

Figure 12. The concrete lighthouse at the Kilauea Point Light Station, Kilauea, Kauai, Hawaii, was constructed circa 1913. The concrete, which was a good quality, high strength mix for its day, is in good condition after almost one hundred years in service. Deterioration in the form of spalling related to corrosion of embedded reinforcing steel has occurred primarily in areas of higher ornamentation such as projecting bands and brackets (see close-up photo).

the concrete tends to be weak and porous because these aggregates absorb water. Some of these aggregates can be extremely susceptible to deterioration when exposed to moisture and cyclic freezing and thawing. Concrete was sometimes compromised by inclusion of seawater or beach sand that was not thoroughly washed with fresh water, a condition more common with coastal fortifications built prior to 1900. The sodium chloride present in seawater and beach sand accelerates the rate of corrosion of the reinforced concrete.

Another problem encountered with historic concrete is related to poor consolidation of the concrete during its placement in forms, or in molds in the case of precasting. This problem is especially prevalent in highly ornamental units. Early twentieth century concrete was often tamped or rodded into place, similar to techniques used in forming cast stone. Poorly consolidated concrete often contains voids ("bugholes" or "honeycombs"), which can reduce the protective concrete cover over the embedded reinforcing bars, entrap water, and, if sufficiently large and strategically numerous, reduce localized concrete strength. Vibration technology has improved over time and flowability agents are also used today to address this problem.

A common type of deterioration observed in concrete is the effect of weathering from exposure to wind, rain, snow, and salt water or spray. Weathering appears as erosion of the cement paste, a condition more prevalent in northern regions where precipitation can be highly acidic. This results in the exposure of the aggregate particles on the exposed concrete surface. Variations may occur in the aggregate exposure due to differential erosion or dissolution of exposed cement paste. Erosion can also be caused by the mechanical action of water channeled over concrete, such as by the lack of drip grooves in belt courses and sills, and by inadequate drainage. In addition, high-pressure water when used for cleaning can also erode the concrete surface.

In concrete structures built prior to the First World War, concrete was often placed into forms in relatively short vertical lifts due to limitations in lifting and pouring techniques available at the time. Joints between different concrete placements (often termed cold joints or lift lines) may sometimes be considered an important part of the character of a concrete element (Fig. 13). However, wide joints may permit water to infiltrate the concrete, resulting in more rapid paste erosion or freeze-thaw deterioration of adjacent concrete in cold climates.

In the early twentieth century, concrete was sometimes placed in several layers parallel to the exterior surface. A base concrete was first created with formwork and then a more cement rich mortar layer was applied to the exposed vertical face of the

Figure 13. Fort Casey on Admiralty Head, Fort Casey, Washington, was constructed in 1898. The lift lines from placement of concrete are clearly visible on the exterior walls and characterize the finished appearance.

base concrete. The higher cement content in the facing concrete provided a more water-resistant outer layer and finished surface. The application of a cement-rich top layer, referred to in some early concrete publications as "waterproofing," was also used on top surfaces of concrete walls, or as the top layer in sidewalks. With this type of concrete construction, deterioration can occur over time as a result of debonding between layers, and can proceed very rapidly once the protective cement-rich layer begins to break down.

It is common for historic concrete to have a highly variable appearance, including color and finish texture. Different levels of aggregate exposure due to paste erosion are often found in exposed aggregate concrete. This variability in the appearance of historic concrete increases the level of difficulty in assessing and repairing weathered concrete.

Signs of Distress and Deterioration

Characteristic signs of failure in concrete include cracking, spalling, staining, and deflection. Cracking occurs in most concrete but will vary in depth, width, direction, pattern, and location, and can be either active or dormant (inactive). Active cracks can widen, deepen, or migrate through the concrete, while dormant cracks remain relatively unchanged in size. Some dormant cracks, such as those caused by early age shrinkage of the concrete during curing, are not a structural concern but when left unrepaired, can provide convenient channels for moisture penetration and subsequent damage. Random surface cracks, also called map cracks due to their resemblance to lines on a map, are usually related to early-age shrinkage but may also indicate other types of deterioration such as alkali-silica reaction.

Structural cracks can be caused by temporary or continued overloads, uneven foundation settling, seismic forces, or original design inadequacies. Structural cracks are active if excessive loads are applied to a structure, if the overload is continuing, or if settlement is ongoing. These cracks are dormant if the temporary overloads have been removed or if differential settlement has stabilized. Thermally-induced cracks result from stresses produced by the expansion and contraction of the concrete during temperature changes. These cracks frequently occur at the ends or re-entrant corners of older concrete structures that were built without expansion joints to relieve such stress.

Spalling (the loss of surface material) is often associated with freezing and thawing as well as cracking and delamination of the concrete cover over embedded reinforcing steel. Spalling occurs when reinforcing bars corrode and the corrosion by-products expand, creating high stresses on the adjacent concrete, which cracks and is displaced. Spalling can also occur when water absorbed by the concrete freezes and thaws (Fig. 14). In addition, surface spalling or scaling may result from the improper finishing, forming, or other surface

Figures 14. Layers of architectural concrete that have debonded (spalled) from the surface were removed from a historic water tank during the investigation performed to assess existing conditions. Photos: Anita Washko, Wiss, Janney, Elstner Associates, Inc.

phenomena when water-rich cement paste (laitance) rises to the surface. The resulting weak material is vulnerable to spalling of thin layers, or scaling. In some cases, spalling of the concrete can diminish the load-carrying capacity of the structure.

Deflection is the bending or sagging of structural beams, joists, or slabs, and can be an indication of deficiencies in the strength and structural soundness of concrete. This condition can be produced by overloading, corrosion of embedded reinforcing, or inadequate design or construction, such as use of low-strength concrete or undersized reinforcing bars.

Staining of the concrete surface can be related to soiling from atmospheric pollutants or other contaminants, dirt accumulation, and the presence of organic growth. However, stains can also indicate more serious underlying problems, such as corrosion of embedded reinforcing steel, improper previous surface treatments, alkali-aggregate reaction, or efflorescence, the deposition of soluble salts on the surface of the concrete as a result of water migration (Fig. 15).

Planning for Concrete Preservation

The significance of a historic concrete building or structure—including whether it is important for its architectural or engineering design, for its materials and construction techniques, or both—guides decision making about repair and, if needed, replacement methods. Determining the causes of deterioration is also central to the development of a conservation and repair plan. With historic concrete buildings, one of the more difficult challenges is allowing for sufficient time during the planning phase to analyze the concrete, develop mixes, and provide time for adequate aging of mock-ups for matching to the original concrete.

An understanding of the original construction techniques (cement characteristics, mix design, original intent of assembly, type of placement, precast versus cast in place, etc.) and previous repair work performed on the concrete is important in determining causes of existing deterioration and the susceptibility of the structure to potential other types of deterioration. For example, concrete placed in short lifts (individual concrete placements) or constructed in precast segments will have numerous joints that can provide entry points for water infiltration. Inappropriate prior repairs, such as installation of patches using an incompatible material, can affect the future performance of the concrete. Such prior repairs may require corrective work.

As with other preservation projects, three primary approaches are usually considered for historic concrete structures: ***maintenance***, ***repair***, or ***replacement***. Maintenance and repair best achieve the preservation goal of minimal intervention and the greatest retention of existing historic fabric. However, where elements of the building are severely deteriorated or where inherent problems with the material lead to ongoing failures, replacement may be necessary.

During planning, information is gathered through research, visual survey, inspection openings, and laboratory studies. The material should then be reviewed by professionals experienced in concrete deterioration to help evaluate the nature and causes of the concrete problems, to assess both the short-term and long-term effects of the deterioration, and to formulate proper repair approaches.

Condition Assessment

A condition assessment of a concrete building or structure should begin with a review of all available documents related to original construction and prior repairs. While plans and specifications for older concrete buildings are not always available, they can be an invaluable resource and every attempt should be made to find them. They may provide information on the composition of the concrete mix or on the type and location of reinforcing bars. If available, documents related to past repairs should also be reviewed to

Figure 15. Evidence of moisture movement through concrete is apparent in the form of mineral deposits on the concrete surface. Cyclic freezing and thawing of entrapped moisture, and corrosion of embedded reinforcement, have also contributed to deterioration of the concrete column on this fence at Crocker Field in Fitchburg, Massachusetts, designed by the Olmsted Brothers.

understand how the repairs were made and to help evaluate their anticipated performance and service life. Archival photographs can also provide a valuable source of information about original construction.

A visual condition survey will help identify and evaluate the extent, types, and patterns of distress and deterioration. The American Concrete Institute offers several useful guides on how to perform a visual condition survey of concrete. Generally, the condition assessment begins with an overall visual survey, followed by a close-up investigation of representative areas to obtain more detailed information about modes of deterioration.

A number of nondestructive testing methods can be used in the field to evaluate concealed conditions. Basic techniques include sounding with a hand-held hammer (or for horizontal surfaces, a chain) to help identify areas of delamination. More sophisticated techniques include impact-echo testing (Fig. 16), ground penetrating radar, pulse velocity, and other methods that characterize concrete thickness and locate voids or delaminations. Magnetic detection instruments are used to locate embedded reinforcing steel and can be calibrated to identify the size and depth of reinforcement. Corrosion measurements can be taken using copper-copper sulfate half-cell tests or linear polarization techniques to determine the probability or rate of active corrosion of the reinforcing steel.

To further evaluate the condition of the concrete, samples may be removed for laboratory study to determine material components and composition, and causes of deterioration. Samples need to be representative of existing conditions but should be taken from unobtrusive locations. Laboratory studies of the concrete may include petrographic evaluation following ASTM C856, *Practice for Petrographic Examination of Hardened Concrete*. Petrographic examination, consisting of microscopical studies performed by a geologist specializing in the evaluation of construction materials, is performed to determine air content, water-cement ratio, cement content, and general aggregate characteristics. Laboratory studies can also include chemical analyses to determine chloride content, sulfate content, and alkali levels of the concrete; identification of deleterious aggregates; and determination of depth of carbonation. Compressive strength studies can be conducted to evaluate the strength of the existing concrete and provide information for repair work. The laboratory studies provide a general identification of the original concrete's components and aggregates, and evidence of damage due to various mechanisms including cyclic freezing and thawing, alkali-aggregate reactivity, or sulfate attack. Information gathered through laboratory studies can also be used to help develop a mix design for the repair concrete.

Cleaning

As with other historic structures, concrete structures are cleaned for several reasons: to improve the appearance of the concrete, as a cyclical maintenance measure, or in preparation for repairs. Consideration should first be given to whether the historic concrete structure needs to be cleaned at all. If cleaning is required, then the gentlest system that will be effective should be selected.

Three primary methods are used for cleaning concrete: water methods, abrasive surface treatments, and chemical surface treatments. Low-pressure water (less than 200 psi) or steam cleaning can effectively remove surface soiling from sound concrete; however, care is required on fragile or deteriorated surfaces. In addition, water and steam methods are typically not effective in removing staining or severe soiling. Power washing with high-pressure water is sometimes used to clean or remove coatings from sound, high-strength concrete, but high-pressure water washing is generally damaging to and not appropriate for concrete on historic structures.

When used with proper controls and at very low pressures (typically 35 to 75 psi), microabrasive surface treatments using very fine particulates, such as dolomitic limestone powder, can sometimes clean effectively. However, microabrasive cleaning may alter the texture and surface reflectivity of concrete. Some concrete can be damaged even by fine particulates applied at very low pressures.

Figure 16. Impact echo testing is performed on a concrete structural slab to help determine depth of deterioration. In this method, a short pulse of energy is introduced into the structure and a transducer mounted on the impacted surface of the structure receives the reflected input waves or echoes. These waves are analyzed to help identify flaws and deterioration within the concrete.

Chemical surface treatments can clean effectively but may also alter the appearance of the concrete by bleaching the concrete, removing the paste, etching the aggregate, or otherwise altering the surface. Detergent cleaners or mild, diluted acid cleaners may be appropriate for removal of staining or severe soiling. Cleaning products that contain strong acids such as hydrochloric (muriatic) or hydrofluoric acid, which will damage concrete and are harmful to persons, animals, site features, and the environment, should not be used.

For any cleaning process, trial samples should be performed prior to full-scale implementation. The intent of the cleaning program should not be to return the structure to a like new appearance. Concrete can age gracefully, and as long as soiling is not severe or deleterious, many structures can still be appreciated without extensive cleaning.

Methods of Maintenance and Repair

The maintenance of historic concrete often is thought of in terms of appropriate cleaning to remove unattractive dirt or soiling materials. However, the implementation of an overall maintenance plan for a historic structure is the most effective way to help protect historic concrete. For examples, the lack of maintenance to roofs and drainage systems can promote water related damage to adjacent concrete features. The repeated use of deicing salts in winter climates can pit the surface of old concrete and also may promote decay in embedded steel reinforcements. Inadequate protection of concrete walls adjacent to driveways and parking areas can result in the need for repair work later on.

The maintenance of historic concrete involves the regular inspection of concrete to establish baseline conditions and identify needed repairs. Inspection tasks involve monitoring protection systems, including sealant joints, expansion joints, and protective coatings; reviewing existing conditions for development of distress such as cracking and delaminations; documenting conditions observed; and developing and implementing a cyclical repair program.

Sealants are an important part of maintenance of historic concrete structures. Elastomeric sealants, which have replaced traditional oil-resin based caulks for many applications, are used to seal cracks and joints to keep out moisture and reduce air infiltration. Sealants are commonly used at windows and door perimeters, at interfaces between concrete and other materials, and at attachments to or through walls or roofs, such as with lamps, signs, or exterior plumbing fixtures.

Figure 17. (a) The 63rd Street Beach House was constructed on the shoreline of Chicago in 1919. The highly exposed aggregate concrete of the exterior walls of the beach house was used for many buildings in the Chicago parks as an alternative to more expensive stone construction. Photo: Leslie Schwartz Photography. (b) Concrete deterioration included cracking, spalling, and delamination caused by corrosion of embedded reinforcing steel and concrete damage due to cyclic freezing and thawing. (c) Various sizes and types of aggregates were reviewed for matching to the original concrete materials. (d) Mock-ups of the concrete repair mix were prepared for comparison to the original concrete. Considerations included aggregate type and size, cement color, proportions, aggregate exposure, and surface finish. (e) The craftsman finished the surface to replicate the original appearance in a mock-up on the structure. Here, he used a nylon bristle brush to remove loose paste and expose the aggregate, creating a variable surface to match the adjacent original concrete.

Where used for crack repairs on historic facades, the finished appearance of the sealant application must be considered, as it may be visually intrusive. In some cases, sand can be broadcast onto the surface of the sealant to help conceal the repair.

Urethane and polyurethane sealants are often used to seal joints and cracks in concrete structures, paving, and walkways; these sealants provide a service life of up to ten years. High-performance silicone sealants also are often used with concrete, as they provide a range of movement capabilities and a service life of twenty years or more. Some silicone sealants may stain adjacent materials, which may be a problem with more porous concrete, and may also tend to accumulate dust and dirt. The effectiveness of sealants for sealing joints and cracks depends on numerous factors including proper surface preparation and application. Sealants should be examined as part of routine maintenance inspections, as these materials deteriorate faster than their substrates and must be replaced periodically as a part of cyclical maintenance.

Repair of historic concrete may be required to address deterioration because the original design and construction did not provide for long-term durability, or to facilitate a change in use of the structure. Examples include increasing concrete cover to protect reinforcing steel and reducing water infiltration into the structure by repair of joints. Any such improvements must be thoroughly evaluated for compatibility with the original design and appearance. Care is required in all aspects of historic concrete repair, including surface preparation; installation of formwork; development of the concrete mix design; and concrete placement, consolidation, and curing.

An appropriate repair program addresses existing distress and reduces the rate of future deterioration, which in many cases involves moisture-related issues. The repair program should incorporate materials and methods that are sympathetic to the existing materials in character and appearance, and which provide good long-term performance. In addition, repair materials should age and weather similarly to the original materials. In order to best achieve these goals, concrete repair projects should be divided into three phases: development of trial repair procedures, trial repairs and evaluation, and production repair work.

For any concrete repair project, the process of investigation, laboratory analysis, trial samples, mock-ups, and full-scale repairs allows ongoing refinement of the repair work as well as implementation of quality-control measures. The trial repair process provides an opportunity for the owner, architect, engineer, and contractor to evaluate the concrete mix design and the installation and finishing techniques for the repairs from both technical and aesthetic standpoints. The final repair materials and procedures should match the original concrete in appearance while meeting the established criteria for durability. Information gathered through trial repairs and mock-ups is invaluable in refining the construction documents prior to the start of the overall repair project (Fig. 17).

Surface Preparation

In undertaking surface preparation for historic concrete repair, care must be taken to limit removal of existing material while still providing an appropriate substrate for repairs. This is particularly important where ornamentation and fine details are involved. Preparation for localized repairs usually begins with removal of the loose concrete to determine the general extent of the repair, followed by saw-cutting the perimeter of the repair area. The repair area should extend beyond the area of concrete deterioration to a sufficient extent to provide a sound substrate. When repairing concrete with an exposed aggregate or other special surface texture, a sawcut edge may be too visually evident. To hide the repair edge, techniques such as lightly hand-chipping the edge of the patch may be used to conceal the joint between the original concrete and the new repair material. The depth to which the concrete needs to be removed may be difficult to determine without invasive probing in the repair area. Removal of concrete should typically extend beyond the level of the reinforcing steel, if present, so that the patch encapsulates the reinforcing steel, which provides mechanical attachment for the repair.

If the concrete was originally of lower strength and quality, the assessment of present soundness is more difficult. Deteriorated and unsound concrete is typically removed using pneumatic chipping hammers. Removal of concrete in historic structures is better controlled by using smaller chipping hammers or hand tools. The area of the concrete to be repaired and the exposed reinforcing steel are then cleaned, usually by careful sandblast and air blast procedures applied only within the repair area. Adjacent original concrete surfaces should be protected during this work. In some cases, project constraints such as dust control may limit the ability to thoroughly clean the concrete and steel. For example, it may be necessary to use needle scaling (a small pneumatic impact device) and wire brushing instead of sandblasting.

Supplemental steel may be needed when existing reinforcing steel is severely deteriorated, or if reinforcing steel is not present in repair areas. Exposed existing reinforcing and other embedded steel elements can be cleaned, primed, and painted with a corrosion-inhibiting coating. The patching material should be reinforced and mechanically attached to the existing concrete. Reinforcement materials used in repairs most often include mild steel, epoxy-coated steel, or stainless steel, depending on existing conditions.

Formwork and Molds

Special formwork is needed to recreate ornamental concrete features—which may be complex, in high relief, or architecturally detailed—and to provide special surface finishes such as wood form board textures. Construction of the formwork itself requires particular skill and craftsmanship. Reusable forms can be used for concrete ornamentation that is repeated across a building facade, or precast concrete elements may be used to replace missing or unrepairable architectural features. Formwork for ornamental concrete is often created using a four-step process: a casting of the original concrete is taken; a plaster replica of the unit is prepared; a mold or form is made from the plaster replica; and a new concrete unit is cast. Custom formwork and molds are often the work of specialty companies, such as precasters and cast stone fabricators.

The process of forming architectural features or special surface textures is particularly challenging if early age stripping (removal of formwork early in the concrete curing process) is needed to perform surface treatment on the concrete. Timing for formwork removal is related to strength gain, which in turn is partly dependent on temperature and weather conditions. Early age removal of formwork in highly detailed concrete can lead to damage of the new concrete that has not yet gained sufficient strength through curing.

Selection of Repair Materials and Mix Design

Selection and design of proper repair materials is a critical component of the repair project. This process requires evaluation of the performance, characteristics, and limitations of the repair materials, and may involve laboratory testing of proposed materials and trial repairs. The materials should be selected to address the specific type of repair required and to be compatible with special characteristics of the original concrete. Some modern repair materials are designed to have a high compressive strength and to be impermeable. Even though inherently durable, these newer materials may not be appropriate for use in repairing a low strength historic concrete.

The concrete's durability, or resistance to deterioration, and the materials and methods selected for repair depend on its composition, design, and quality of workmanship. In most cases, a mix design for durable replacement concrete should use materials similar to those of the original concrete mix. Prepackaged materials are often not appropriate for repair of historic concrete. The concrete patching material can be air entrained or polymer-modified if subject to exterior exposure, and should incorporate an appropriate selection of aggregate and cement type, and proper water content and water

Figure 18. (a) Exposed aggregate precast concrete is sounded with a hammer to detect areas of deterioration. Corrosion of the exposed reinforcing steel bar has led to spalling of the adjacent concrete. (b) Samples of aggregate considered for use in repair concrete are compared to the original concrete materials in terms of size, color, texture, and reflectance. (c) Various sample panels are made using the selected concrete repair mix design for comparison to the original concrete on the building, and the mix design is adjusted based on review of the samples. (d) After removal of the spall, the concrete surface is prepared for installation of a formed patch. (e) Prior to placement of the concrete, a retarding agent is brush-applied to the inside face of the formwork to slow curing at the surface. After the concrete is partially cured, the forms are removed and the surface of the concrete is rubbed to remove some of the paste and expose the aggregate to match the original concrete.

to cement ratio. Some admixtures, including polymer modifiers, may change the appearance of the concrete mix. Design of the concrete patching material should address characteristics required for durability, workability, strength gain, compressive strength, and other performance attributes. During installation of the repair, skilled workmanship is required to ensure proper mixing procedures, placement, consolidation, and curing.

Matching and Repair Techniques for Historic Concrete

Repair measures should be selected that retain as much of the original material as possible, while providing for removal of an adequate amount of deteriorated concrete to provide a sound substrate for a durable repair. The installed repair must visually match the existing concrete as closely as possible and should be similar in other aspects such as compressive strength, permeability, and other characteristics important in the mix design of the concrete (Fig. 18).

Understanding the original construction techniques often provides opportunities in the design of repairs. For example, joints between the new and old concrete can be hidden in changes in surface profile and cold joints. The required patching mix for the concrete to be used in the repair will likely need to be specially designed to replicate the appearance of the adjacent historic concrete. A high level of craftsmanship is required for finishing of historic concrete, in particular to create the sometimes inconsistent finish and variation in the original concrete in contrast to the more even appearance required for most non-historic repairs.

To match the various characteristics of the original concrete, trial mixes should be developed. These mixes need to take into account the types and colors of aggregates and paste present in the original concrete. Different mixes may be needed because of variations in the appearance and composition of the historic concrete. The trials should utilize different forming and finishing techniques to achieve the best possible match to the original concrete. Initial trials should first take place on site but off the structure. The mix designs providing the best match are then installed as trial repairs on the structure, and assessed after they have cured.

Achieving compatibility between repair work and original concrete may be difficult, especially given the variability often present in historic concrete materials and finishes. Formed rather than trowel-applied patch repairs are recommended for durability, as forming permits better ranges of mix ingredients (such as coarse aggregates) and improved consolidation as compared to trowel-applied repairs. Parge coatings usually are not recommended as they do not provide as durable repair as formed concrete. However, in some cases parge coatings may be appropriate to match an original parged surface treatment. Proper placement and finishing of the repair are important to obtain a match with the original concrete. To minimize problems associated with rapid curing of concrete, such as surface cracking, it is important to use proper curing methods and to allow for sufficient time.

Hairline cracks that show no sign of increasing in size may often be left unrepaired. The width of the crack and the amount of movement usually limits the selection of crack repair techniques that are available. Although it is difficult to determine whether cracks are moving or non-moving, and therefore most cracks should be assumed to be moving, it is possible to repair non-moving cracks by installation of a cementitious repair mortar matching the adjacent concrete. It is generally desirable not to widen cracks prior to the mortar application. Repair mortar containing sand in the mix may be used for wider cracks; unsanded repair mortar may be used for narrower cracks.

When it is desirable to re-establish the structural integrity of a concrete structure involving dormant cracks, epoxy injection repair has proven to be an effective procedure. Such a repair is made by first sealing the crack on both sides of a wall or structural member with epoxy, polyester, wax, tape, or cement slurry, and then injecting epoxy through small holes or ports drilled in the concrete. Once the epoxy in the crack has hardened, the surface sealing material may be removed; however, this type of repair is usually quite apparent. Although it may be possible to inject epoxy without leaving noticeable residue, this process is difficult and, in general, the use of epoxy repairs in visible areas of concrete on historic structures is not recommended.

Active structural cracks (which move as loads are added or removed) and thermal cracks (which move as temperatures fluctuate) must be repaired in a manner that will accommodate the anticipated movement. In some more extreme cases, expansion joints may have to be introduced before crack repairs are undertaken. Active cracks may be filled with sealants that will adhere to the sides of the cracks and will compress or expand during crack movement. The design, detailing, and execution of sealant repairs require considerable attention, or they will detract from the appearance of the historic building. The routing and cleaning of a crack, and installation of an elastomeric sealant to prevent water penetration, is used to address cracks where movement is anticipated. However, unless located in a concealed area of the concrete, this technique is often not acceptable for historic structures because the repair will be visually intrusive (Fig. 19). Other approaches, such as installation of a cementitious crack repair, may need to be considered even though this type of repair may be less effective or have a shorter service life than a sealant repair.

Replacement

If specific components of historic concrete structures are beyond repair, replacement components can be cast to match historic ones. Replacement of original concrete should be carefully considered and viewed as a method of last resort. In some cases, such as for repeated ornamental units, it may be more cost-effective to fabricate precast concrete units to replace missing elements. The forms created for precast or cast-in-place units can then be used again during future repair projects.

Careful mix formulation, placement, and finishing are required to ensure that replacement concrete units will match the historic concrete. There is often a tendency to make replacement concrete more consistent in appearance than the original concrete. The consistency can be in stark contrast with the variability of the original concrete

Figure 19. A high-speed grinder is used to widen a crack in preparation for installation of a sealant. This process is called "routing." After the crack is prepared, the sealant is installed to prevent moisture infiltration through the crack. Although sealant repairs can provide a durable, watertight repair for moving cracks, they tend to be very visible.

due to original construction techniques, architectural design, or differential exposure to weather. Trial repairs and mock-ups are used to evaluate the proposed replacement concrete work and to refine construction techniques (Fig 20).

Protection Systems

Coatings and Penetrating Sealers. Protection systems such as a penetrating sealers or film forming coating are often used with non-historic structures to protect the concrete and increase the length of the service life of concrete repairs. However, film-forming coatings are often inappropriate for use on a historic structure, unless the structure was coated historically. Film-forming coatings will often change the color and appearance of a surface, and higher build coatings can also mask architectural finishes and ornamental details. For example, the application of a coating on concrete having a formboard finish may hide the wood texture of the surface. Pigmented film-forming coatings are also typically not appropriate for use over exposed aggregate concrete, where the uncoated exposed surface contributes significantly to the historic character of

Figure 20. (a) The Jefferson Davis Memorial in Fairview, Kentucky, constructed from 1917–1924, is 351 feet tall and constructed of unreinforced concrete. The walls of the memorial are 8 feet thick at the base and 2 feet thick at the top of the wall. Access to the monument for investigation was provided by rappelling techniques, while ground supported and suspended scaffolding was used to access the exterior during repairs. (b) The concrete was severely deteriorated at isolated locations, with spalling and damage from cyclic freezing and thawing of entrapped water. In addition, previous repairs were at the end of their service life and removal of deteriorated concrete and failed previous repairs was required. Light duty chipping hammers were used to avoid damage to adjacent material when removing deteriorated concrete to the level of sound concrete. (c) Field samples were performed to match the color, finish, and texture of the original concrete. A challenge in matching of historic concrete is achieving variability of appearance. (d) The completed surface after repairs exhibits intentional variability of the concrete surface to match the appearance of the original concrete. Some formwork imperfections that would normally be removed by finishing were intentionally left in place, to replicate the highly variable finish of the original concrete. (e) The Jefferson Davis Memorial after completion of repairs in 2004. Photo e: Joseph Lenzi, Senler, Campbell & Associates, Inc.

concrete. In cases where the color of a substrate needs to be changed, such as to modify the appearance of existing repairs, an alternative to pigmented film-forming coatings is the use of pigmented stains.

Many proprietary clear, penetrating sealers are currently available to protect concrete substrates. These products render fine cracks and pores within the concrete hydrophobic; however, they do not bridge or fill cracks. Clear sealers may change the appearance of the concrete in that treated areas become more visible *after* rain in contrast to the more absorptive areas of original concrete. Once applied, penetrating sealers cannot be effectively removed and are therefore considered irreversible. They should not be used on historic concrete without thorough prior consideration. However, clear penetrating sealers provide an important means of protection for historic concrete that is not of good quality and can help to avoid more extensive future repairs or replacement. Thus they are sometimes appropriate for use on historic concrete. Once applied, these sealers will require periodic re-application.

Waterproofing membranes are systems used to protect concrete surfaces such as roofs, terraces, plazas, or balconies, as well as surfaces below grade. Systems range from coal tar pitch membranes used on older buildings, to asphalt or urethane-based systems. On historic buildings, membrane systems are typically used only on surfaces that were originally protected by a similar system and surfaces that are not visible from grade. Waterproofing membranes may be covered by roofing, paving, or other architectural finishes.

Laboratory and field testing is recommended prior to application of a protection system or treatment on any concrete structure; testing is even more critical for historic structures because many such treatments are not reversible. As with other repairs, trial samples are important to evaluate the effectiveness of the treatment and to determine whether it will harm the concrete or affect its appearance.

Cathodic Protection. Corrosion is an electrochemical process in which electrons flow between cathodic (positively charged) and anodic (negatively charged) areas on a metal surface; corrosion occurs at the anodes. Cathodic protection is a technique used to control the corrosion of metal by making the whole metal surface the cathode of an electrochemical cell. This technique is used to protect metal structures from corrosion and is also sometimes used to protect steel reinforcement embedded in concrete. For reinforced concrete, cathodic protection is typically accomplished by connecting an auxiliary anode to the reinforcing so that the entire reinforcing bar becomes a cathode. In sacrificial anode (passive) systems, current flows naturally by galvanic action between the less noble anode (such as zinc) and the cathode. In impressed-current (active) systems, current is impressed between an inert anode (such as titanium) and the cathode. Cathodic protection is intended to reduce the rate of corrosion of embedded steel in concrete, which in turn reduces overall deterioration. Protecting embedded steel from corrosion helps to prevent concrete cracking and spalling.

Impressed-current cathodic protection is the most effective means of mitigating steel corrosion and has been used in practical structural applications since the 1970s. However, impressed-current cathodic protection systems are typically the most costly to install and require substantial ongoing monitoring, adjustment, and maintenance to ensure a proper voltage output (protection current) over time. Sacrificial anode cathodic protection dates back to the 1800s, when the hulls of ships were protected using this technology. Today many industries utilize the concept of sacrificial anode cathodic protection for the protection of steel exposed to corrosive environments. It is less costly than an impressed-current system, but is somewhat less effective and requires reapplication of the anode when it becomes depleted.

Re-alkalization. Another technique currently available to protect concrete is realkalization, which is a process to restore the alkalinity of carbonated concrete. The treatment involves soaking the concrete with an alkaline solution, in some cases forcing it into the concrete to the level of the reinforcing steel by passage of direct current. These actions increase the alkalinity of the concrete around the reinforcement, thus restoring the protective alkaline environment for the reinforcement. Like impressed-current cathodic protection methods, it is costly. Other corrosion methods are also available but have a somewhat shorter history of use.

Careful evaluation of existing conditions, the causes and nature of distress, and environmental factors is essential before a protection method is selected and implemented. Not every protection system will be effective on each structure. In addition, the level of intrusion caused by the protection system must be carefully evaluated before it is used on a historic concrete structure.

Summary

In the United States, concrete has been a popular construction material since the late nineteenth century and recently has gained greater recognition as a historic material. Preservation of historic concrete requires a thorough understanding of the causes and types of deterioration, as well as of repair and replacement materials and methods. It is important that adequate time is allotted during the planning phase of a project to provide for trial repairs and mock-ups in order to evaluate the effectiveness and aesthetics of the repairs. Careful design is essential and, as with other preservation efforts, the skill of those performing the work is critical to the success of the repairs. The successful repair of many historic concrete structures in recent years demonstrates that the techniques and materials now available can extend the life of such structures and help ensure their preservation.

Selected Reading

American Concrete Institute. *Guide for Making a Condition Survey of Concrete in Service.* ACI Committee 201, ACI 201.1R-92.

American Concrete Institute. *Guide to Evaluation of Concrete Structures before Rehabilitation.* ACI Committee 364, ACI 364.1R-07.

American Concrete Institute. *Concrete Repair Guide.* ACI Committee 546, ACI 546R-04.

American Concrete Institute. *Guide for Evaluation of Existing Concrete Buildings.* ACI Committee 437, ACI 437R-03.

Childe, H.L. *Manufacture and Uses of Concrete Products and Cast Stone.* London: Concrete Publications Limited, 1930.

Collins, Peter. *Concrete: The Vision of a New Architecture.* New York, New York: Faber and Faber, 1959.

Cowden, Adrienne B., comp. *Historic Concrete: An Annotated Bibliography.* Washington, D.C.: National Park Service, 1993.

Komandant, August E. *Contemporary Concrete Structures.* New York, New York: McGraw Hill, 1972.

Erlemann, Gustav G. "Steel Reinforcing Bar Specification in Old Structures." *Concrete International,* April 1999, 49–50.

Federal Highway Administration. *Guide to Nondestructive Testing of Concrete.* FHWA Publication Number FHWA-SA-97-105.

Gaudette, Paul E. "Special Considerations in Repair of Historic Concrete." *Concrete Repair Bulletin,* January/February 2000, 12–13.

Jester, Thomas C., ed. *Twentieth Century Building Materials.* New York, New York: McGraw-Hill, 1995.

Johnson, Anne P., and Seung Kyoung Lee. "Protection Methods for Historic Concrete at Soldier Field." *Preserve and Play: Preserving Historic Recreation and Entertainment Sites.* Washington, D.C.: Historic Preservation Education Foundation, National Council for Preservation Education, and National Park Service, 2006.

Macdonald, Susan, ed. *Concrete: Building Pathology.* Osney Mead, Oxford, U.K.: Blackwell Science, 2003.

McGovern, Martin S. "A Clear View of Sealers." *Concrete Construction,* January 2000, 53–58.

Morton, W. Brown III, Gary L. Hume, Kay D. Weeks, H. Ward Jandl, and Anne E. Grimmer. *The Secretary of the Interior's Standards for Rehabilitation & Illustrated Guidelines for Rehabilitating Historic Buildings.* Washington, D.C.: National Park Service, 1983, reprinted 1997.

"Repairing Cracks." *Concrete Repair Digest,* August/September 1992, 160–164. Condensed from ACI document 224.1R-93.

Slaton, Deborah. "Cleaning Historic Concrete." *Concrete Repair Bulletin,* January/February 2000, 14–15.

Acknowledgements

Paul Gaudette is an engineer with Wiss, Janney, Elstner Associates, Inc., in Chicago, Illinois. Deborah Slaton is an architectural conservator with Wiss, Janney, Elstner Associates, Inc., in Northbrook, Illinois. All photographs by Paul Gaudette unless otherwise stated. Front cover image: Kyle Normandin, Wiss, Janney, Elstner Associates, Inc.

The authors wish to thank William Bing Coney, author of the first edition of this preservation brief, who served as a peer reviewer for the current edition. In addition, the authors gratefully acknowledge the assistance of the following individuals as peer reviewers of this brief: Anne Johnson and Una Gilmartin, Wiss, Janney, Elstner Associates, Inc.; Robert Joyce, Quality Restorations, Inc.; Susan Macdonald, New South Wales Heritage Office; Miles T. Murray, Restruction Corporation; and Jack Pyburn, OJP/Architect, Inc. Anne E. Grimmer, Chad Randl, and former staff Sharon C. Park, FAIA, of the Technical Preservation Services, National Park Service, offered valuable comments during development of the brief. Charles E. Fisher of the National Park Service was the technical editor for this publication project.

This publication has been prepared pursuant to the National Historic Preservation Act of 1966, as amended, which directs the Secretary of the Interior to develop and make available information concerning historic properties. Comments about this publication should be addressed to: Charles E. Fisher, Technical Preservation Publications Program Manager, Technical Preservation Services – 2255, National Park Service, 1849 C Street, NW, Washington, DC 20240. This publication is not copyrighted and can be reproduced without penalty. Normal procedures for credit to the authors and the National Park Service should be provided. The photographs used in this publication may not be used to illustrate other publications without permission of the owners. For more information about the programs of the National Park Service's Technical Preservation Services see our website at http://www.nps.gov/history/hps/tps.htm

ISBN: 978-0-16-078946-5
U.S. Government Printing Office Stock Number: 024-005-01253-2 2007

16 PRESERVATION BRIEFS

The Use of Substitute Materials on Historic Building Exteriors

Sharon C. Park, AIA

U.S. Department of the Interior
National Park Service
Cultural Resources

Heritage Preservation Services

> The Secretary of the Interior's *Standards for Rehabilitation* require that "deteriorated architectural features be repaired rather than replaced, wherever possible. In the event that replacement is necessary, the new material should match the material being replaced in composition, design, color, texture, and other visual properties." Substitute materials should be used only on a limited basis and only when they will match the appearance and general properties of the historic material and will not damage the historic resource.

Introduction

When deteriorated, damaged, or lost features of a historic building need repair or replacement, it is almost always best to use historic materials. In limited circumstances substitute materials that imitate historic materials may be used if the appearance and properties of the historic materials can be matched closely and no damage to the remaining historic fabric will result.

Great care must be taken if substitute materials are used on the exteriors of historic buildings. Ultra-violet light, moisture penetration behind joints, and stresses caused by changing temperatures can greatly impair the performance of substitute materials over time. Only after consideration of all options, in consultation with qualified professionals, experienced fabricators and contractors, and development of carefully written specifications should this work be undertaken.

The practice of using substitute materials in architecture is not new, yet it continues to pose practical problems and to raise philosophical questions. On the practical level the inappropriate choice or improper installation of substitute materials can cause a radical change in a building's appearance and can cause extensive physical damage over time. On the more philosophical level, the wholesale use of substitute materials can raise questions concerning the integrity of historic buildings largely comprised of new materials. In both cases the integrity of the historic resource can be destroyed.

Some preservationists advocate that substitute materials should be avoided in all but the most limited cases. The fact is, however, that substitute materials are being used more frequently than ever in preservation projects, and in many cases with positive results. They can be cost-effective, can permit the accurate visual duplication of historic materials, and last a reasonable time. Growing evidence indicates that with proper planning, careful specifications and supervision, substitute materials can be used successfully in the process of restoring the visual appearance of historic resources.

This Brief provides general guidance on the use of substitute materials on the exteriors of historic buildings. While substitute materials are frequently used on interiors, these applications are not subject to weathering and moisture penetration, and will not be discussed in this Brief. Given the general nature of this publication, specifications for substitute materials are not provided. The guidance provided should not be used in place of consultations with qualified professionals. This Brief includes a discussion of when to use substitute materials, cautions regarding their expected performance, and descriptions of several substitute materials, their advantages and disadvantages. This review of materials is by no means comprehensive, and attitudes and findings will change as technology develops.

Historical Use of Substitute Materials

The tradition of using cheaper and more common materials in imitation of more expensive and less available materials is a long one. George Washington, for example, used wood painted with sand-impregnated paint at Mount Vernon to imitate cut ashlar stone. This technique along with scoring stucco into block patterns was fairly common in colonial America to imitate stone (see illus. 1, 2).

Molded or cast masonry substitutes, such as dry-tamp cast stone and poured concrete, became popular in place of quarried stone during the 19th century. These masonry units were fabricated locally, avoiding

Illus. 1. An early 18th-century technique for imitating carved or quarried stone was the use of sand-impregnated paint applied to wood. The facade stones and quoins are of wood. The Lindens (1754), Washington, D.C. Photo: Sharon C. Park, AIA.

Illus. 2. Stucco has for many centuries represented a number of building materials. Seen here is the ground floor of a Beaux Arts mansion, circa 1900, which represents a finely laid stone foundation wall executed in scored stucco. Photo: Sharon C. Park, AIA.

Illus. 3. Casting concrete to represent quarried stone was a popular late 19th-century technique seen in this circa 1910 mail-order house. While most components were delivered by rail, the foundations and exterior masonry were completed by local craftsmen. Photo: Sharon C. Park, AIA.

Illus. 4. The 19th-century also produced a variety of metal products used in imitation of other materials. In this case, the entire exterior of the Long Island Safety Deposit Company is cast-iron representing stone. Photo: Becket Logan, Friends of Cast Iron Architecture.

expensive quarrying and shipping costs, and were versatile in representing either ornately carved blocks, plain wall stones or rough cut textured surfaces. The end result depended on the type of patterned or textured mold used and was particularly popular in conjunction with mail order houses (see illus. 3). Later, panels of cementitious perma-stone or formstone and less expensive asphalt and sheet metal panels were used to imitate brick or stone.

Metal (cast, stamped, or brake-formed) was used for storefronts, canopies, railings, and other features, such as galvanized metal cornices substituting for wood or stone, stamped metal panels for Spanish clay roofing tiles, and cast-iron column capitals and even entire building fronts in imitation of building stone (see illus. no. 4).

Terra cotta, a molded fired clay product, was itself a substitute material and was very popular in the late 19th and early 20th centuries. It simulated the appearance of intricately carved stonework, which was expensive and time-consuming to produce. Terra cotta could be glazed to imitate a variety of natural stones, from brownstones to limestones, or could be colored for a polychrome effect.

Nineteenth century technology made a variety of materials readily available that not only were able to imitate more expensive materials but were also cheaper to fabricate and easier to use. Throughout the century, imitative materials continued to evolve. For example, ornamental window hoods were originally made of wood or carved stone. In an effort to find a cheaper substitute for carved stone and to speed fabrication time, cast stone, an early form of concrete, or cast-iron hoods often replaced stone. Toward the end of the century, even less expensive sheet metal hoods, imitating stone, also came into widespread use. All of these materials, stone, cast stone, cast-iron, and various pressed metals were in

Illus. 5. The four historic examples of various window hoods shown are: (a) stone; (b) cast stone; (c) cast-iron; and (d) sheet metal. The criteria for selecting substitute materials today (availability, quality, delivery dates, cost) are not much different from the past. Photo: Sharon C. Park, AIA.

production at the same time and were selected on the basis of the availability of materials and local craftsmanship, as well as durability and cost (see illus. 5). The criteria for selection today are not much different.

Many of the materials used historically to imitate other materials are still available. These are often referred to as the traditional materials: wood, cast stone, concrete, terra cotta and cast metals. In the last few decades, however, and partly as a result of the historic preservation movement, new families of synthetic materials, such as fiberglass, acrylic polymers, and epoxy resins, have been developed and are being used as substitute materials in construction. In some respects these newer products (often referred to as high tech materials) show great promise; in others, they are less satisfactory, since they are often difficult to integrate physically with the porous historic materials and may be too new to have established solid performance records.

When to Consider Using Substitute Materials in Preservation Projects

Because the overzealous use of substitute materials can greatly impair the historic character of a historic structure, all preservation options should be explored thoroughly before substitute materials are used. It is important to remember that the purpose of repairing damaged features and of replacing lost and irreparably damaged ones is both to match visually what was there and to cause no further deterioration. For these reasons it is not appropriate to cover up historic materials with synthetic materials that will alter the appearance, proportions and details of a historic building and that will conceal future deterioration (see illus. 6).

Some materials have been used successfully for the repair of damaged features such as epoxies for wood infilling, cementitious patching for sandstone repairs, or plastic stone for masonry repairs. Repairs are preferable to replacement whether or not the repairs are in kind or with a synthetic substitute material (see illus. 7).

In general, four circumstances warrant the consideration of substitute materials: 1) the unavailability of historic materials; 2) the unavailability of skilled craftsmen; 3) inherent flaws in the original materials; and 4) code-required changes (which in many cases can be extremely destructive of historic resources).

Cost may or may not be a determining factor in considering the use of substitute materials. Depending on the area of the country, the amount of material needed, and the projected life of less durable substitute materials, it may be cheaper in the long run to use the original material, even though it may be harder to find. Due to many early failures of substitute materials, some preservationist are looking abroad to find materials (especially stone) that match the historic materials in an effort to restore historic

Illus. 6. Substitute materials should never be considered as a cosmetic cover-up for they can cause great physical damage and can alter the appearance of historic buildings. For example, a fiberglass coating was used at Ranchos de Taos, NM, in place of the historic adobe coating which had deteriorated. The waterproof coating sealed moisture in the walls and caused the spalling shown. It was subsequently removed and the walls were properly repaired with adobe. Photo: Lee H. Nelson, FAIA.

Illus. 7. Whenever possible, historic materials should be repaired rather than replaced. Epoxy, a synthetic resin, has been used to repair the wood window frame and sill at the Auditors Building (1878) Washington, DC. The cured resin is white in this photo and will be primed and painted. Photo: Lee H. Nelson, FAIA.

Illus. 8. Even when materials are not locally available, it may be possible and cost effective to find sources elsewhere. For example, the local sandstone was no longer available for the restoration of the New York Shakespeare Festival Public Theater. The deteriorated sandstone window hoods, were replaced with stone from Germany that closely matched the color and texture of the historic sandstone. Photo: John G. Waite.

Illus. 9. Simple solutions should not be overlooked when materials are no longer available. In the case of the Morse-Libby Mansion (1859), Portland, ME, the deteriorated brownstone porch beam was replaced with a carved wooden beam painted with sand impregnated paint. Photo: Stephen Sewall.

Illus. 10. The use of substitute materials is not necessarily cheaper or easier than using the original materials. The complex process of fabricating the polyester bronze reproduction pieces of the gilded wood molding for the clockcase at Independence Hall required talented artisans and substantial mold-making time. From left to right is the final molded polyester bronze detail; the plaster casting mold; the positive and negative interim neoprene rubber molds; and the expertly carved wooden master. Photo: Courtesy of Independence National Historical Park.

buildings accurately and to avoid many of the uncertainties that come with the use of substitute materials.

1. The unavailability of the historic material. The most common reason for considering substitute materials is the difficulty in finding a good match for the historic material (particularly a problem for masonry materials where the color and texture are derived from the material itself). This may be due to the actual unavailability of the material or to protracted delivery dates. For example, the local quarry that supplied the sandstone for a building may no longer be in operation. All efforts should be made to locate another quarry that could supply a satisfactory match (see illus. 8). If this approach fails, substitute materials such as dry-tamp cast stone or textured precast concrete may be a suitable substitute if care is taken to ensure that the detail, color and texture of the original stone are matched. In some cases, it may be possible to use a sand-impregnated paint on wood as a replacement section, achieved using readily available traditional materials, conventional tools and work skills. (see illus. 9). Simple solutions should not be overlooked.

2. The unavailability of historic craft techniques and lack of skilled artisans. These two reasons complicate any preservation or rehabilitation project. This is particularly true for intricate ornamental work, such as carved wood, carved stone, wrought iron, cast iron, or molded terra cotta. However, a number of stone and wood cutters now employ sophisticated carving machines, some even computerized. It is also possible to cast substitute replacement pieces using

Illus. 11. The unavailability of historic craft techniques is another reason to consider substitute materials. The original first floor cast iron front of the Grand Opera House, Wilmington, DE, was missing; the expeditious reproduction in cast aluminum was possible because artisans working in this medium were available. Photo: John G. Waite.

Illus. 12. Substitute materials may be considered when the original materials have not performed well. For example, early sheet metals used for roofing, such as tinplate, were reasonably durable, but the modern equivalent, terne-coated steel, is subject to corrosion once the thin tin plating is damaged. Terne-coated stainless steel or lead-coated copper (shown here) are now used as substitutes. Photo: John G. Waite.

aluminum, cast stone, fiberglass, polymer concretes, glass fiber reinforced concretes and terra cotta. Mold making and casting takes skill and craftsmen who can undertake this work are available. (see illus. 10, 11). Efforts should always be made, prior to replacement, to seek out artisans who might be able to repair ornamental elements and thereby save the historic features in place.

3. Poor original building materials. Some historic building materials were of inherently poor quality or their modern counterparts are inferior. In addition, some materials were naturally incompatible with other materials on the building, causing staining or galvanic corrosion. Examples of poor quality materials were the very soft sandstones which eroded quickly. An example of poor quality modern replacement material is the tin coated steel roofing which is much less durable than the historic tin or terne iron which is no longer available. In some cases, more durable natural stones or precast concrete might be available as substitutes for the soft stones and modern terne-coated stainless steel or lead-coated copper might produce a more durable yet visually compatible replacement roofing (see illus. 12).

4. Code-related changes. Sometimes referred to as life and safety codes, building codes often require changes to historic buildings. Many cities in earthquake zones, for example, have laws requiring that overhanging masonry parapets and cornices, or freestanding urns or finials be securely reanchored to new structural frames or be removed completely. In some cases, it may be acceptable to replace these heavy historic elements with light replicas (see illus. 13). In other cases, the extent of historic fabric removed may be so great as to diminish the integrity of the resource. This could affect the significance of the structure and jeopardize National Register status. In addition, removal of repairable historic materials could result in loss of Federal tax credits for rehabilitation. Department of the Interior regulations make clear that the Secretary of the Interior's Standards for Rehabilitation take precedence over other regulations and codes in determining whether a project is consistent with the historic character of the building undergoing rehabilitation.

Illus. 13. Code-related changes are of concern in historic preservation projects because the integrity of the historic resource may be irretrievably affected. In the case of the Old San Francisco Mint, the fiberglass cornice was used to bring the building into seismic conformance. The original cornice was deteriorated, and the replacement (1982) was limited to the projecting pediment. The historic stone fascia was retained as were the stone columns. The limited replacement of deteriorated material did not jeopardize the integrity of the building. Photo: Walter M. Smalheimer.

Two secondary reasons for considering the use of substitute materials are their lighter weight and for some materials, a reduced need of maintenance. These reasons can become important if there is a need to keep dead loads to a minimum or if the feature being replaced is relatively inaccessible for routine maintenance.

Cautions and Concerns

In dealing with exterior features and materials, it must be remembered that moisture penetration, ultra-violet degradation, and differing thermal expansion and contraction rates of dissimilar materials make any repair or replacement problematic. To ensure that a repair or replacement will perform well over time, it is critical to understand fully the properties of both the original and the substitute materials, to install replacement materials correctly, to assess their impact on adjacent historic materials, and to have reasonable expectations of future performance.

Many high tech materials are too *new* to have been tested thoroughly. The differences in vapor permeability between some synthetic materials and the historic materials have in some cases caused unexpected further deterioration. It is therefore difficult to recommend substitute materials if the historic materials are still available. As previously mentioned, consideration should always be given first to using traditional materials and methods of repair or replacement before accepting unproven techniques, materials or applications.

Substitute materials must meet three basic criteria before being considered: they must be compatible with the historic materials in appearance; their physical properties must be similar to those of the historic materials, or be installed in a manner that tolerates differences; and they must meet certain basic performance expectations over an extended period of time.

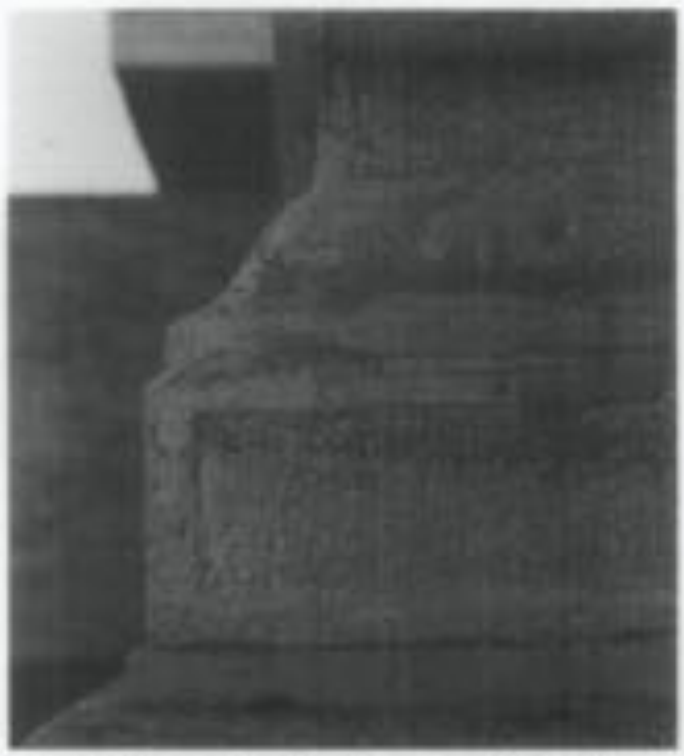
Matching the Appearance of the Historic Materials

In order to provide an appearance that is compatible with the historic material, the new material should match the details and craftsmanship of the original as well as the color, surface texture, surface reflectivity and finish of the original material (see illus. 14). The closer an element is to the viewer, the more closely the material and craftsmanship must match the original.

Matching the color and surface texture of the historic material with a substitute material is normally difficult. To enhance the chances of a good match, it is advisable to clean a portion of the building where new materials are to be used. If pigments are to be added to the substitute material, a specialist should determine the formulation of the mix, the natural aggregates and the types of pigments to be used. As all exposed material is subject to ultra-violet degradation, if possible, samples of the new materials made during the early planning phases should be tested or allowed to weather over several seasons to test for color stability.

Fabricators should supply a sufficient number of samples to permit on-site comparison of color, texture, detailing, and other critical qualities (see illus. 15, 16). In situations where there are subtle variations in color and texture within the original materials, the

Illus. 14. The visual qualities of the historic feature must be matched when using substitute materials. In this illustration, the lighter weight mineral fiber cement shingles used to replace the deteriorated historic slate roof were detailed to match the color, size, shape and pattern of the original roofing and the historic snow birds were reattached. Photo: Sharon C. Park, AIA.



Illus. 15. Poor quality workmanship can be avoided. In this example, the crudely cast concrete entrance pier (shown) did not match the visual qualities of the remaining historic sandstone (not shown). The aggregate is too large and exposed; the casting is not crisp; the banded tooling edges are not articulated; and the color is too pale. Photo: Sharon C. Park, AIA.

Illus. 16. The good quality substitute materials shown here do match the historic sandstone in color, texture, tooling and surface details. Dry-tamp cast stone was used to match the red sandstone that was no longer available. The reconstructed first floor incorporated both historic and substitute materials. Sufficient molds were made to avoid the problem of detecting the substitutes by their uniformity. Photo: Sharon C. Park, AIA.

Illus. 17. Care must be taken to ensure that the replacement materials will work within a predesigned system. At the Norris Museum, Yellowstone National Park, the 12-inch diameter log rafters, part of an intricate truss system, had rotted at the inner core from the exposed ends back to a depth of 48 inches. The exterior wooden shells remained intact. Fiberglass rods (left photo) and specially formulated structural epoxy were used to fill the cleaned out cores and a cast epoxy wafer end with all the detail of the original wood graining was laminated onto the log end (right photo). This treatment preserved the original feature with a combination of repair and replacement using substitute materials as part of a well thought out system. Photos: Courtesy of Harrison Goodall.

substitute materials should be similarly varied so that they are not conspicuous by their uniformity.

Substitute materials, notably the masonry ones, may be more water-absorbent than the historic material. If this is visually distracting, it may be appropriate to apply a protective vapor-permeable coating on the substitute material. However, these clear coatings tend to alter the reflectivity of the material, must be reapplied periodically, and may trap salts and moisture, which can in turn produce spalling. For these reasons, they are *not* recommended for use on historic materials.

Illus. 18. Substitute materials must be properly installed to allow for expansion, contraction, and structural security. The new balustrade (a polymer concrete modified with glass fibers) at Carnegie Hall, New York City, was installed with steel structural supports to allow window-washing equipment to be suspended securely. In addition, the formulation of this predominantly epoxy material allowed for the natural expansion and contraction within the predesigned joints. Photo: Courtesy of MJM Studios.

Matching the Physical Properties

While substitute materials can closely match the appearance of historic ones, their physical properties may differ greatly. The chemical composition of the material (i.e., presence of acids, alkalines, salts, or metals) should be evaluated to ensure that the replacement materials will be compatible with the historic resource. Special care must therefore be taken to integrate and to anchor the new materials properly (see illus. 17). The thermal expansion and contraction coefficients of each adjacent material must be within tolerable limits. The function of joints must be understood and detailed either to eliminate moisture penetration or to allow vapor permeability. Materials that will cause galvanic corrosion or other chemical reactions must be isolated from one another.

To ensure proper attachment, surface preparation is critical. Deteriorated underlying material must be cleaned out. Non-corrosive anchoring devices or fasteners that are designed to carry the new material and to withstand wind, snow and other destructive elements should be used (see illus. 18). Properly chosen fasteners allow attached materials to expand and contract at their own rates. Caulking, flexible sealants or expansion joints between the historic material and the substitute material can absorb slight differences of movement. Since physical failures often result from poor anchorage or improper installation techniques, a structural engineer should be a member of any team undertaking major repairs.

Some of the new high tech materials such as epoxies and polymers are much stronger than historic materials and generally impermeable to moisture. These differences can cause serious problems unless the new materials are modified to match the expansion and contraction properties of adjacent historic materials more closely, or unless the new materials are isolated from the historic ones altogether. When stronger or vapor impermeable new materials are used alongside historic ones, stresses from trapped moisture or differing expansion and contraction rates generally hasten deterioration of the weaker historic material. For this reason, a conservative approach to repair or replacement is recommended, one that uses more pliant materials rather than high-strength ones (see illus. 19). Since it is almost impossible for substitute materials to match the properties of historic materials perfectly, the new system incorporating new and historic materials should be designed so that if material failures occur, they occur within the new material rather than the historic material.

Performance Expectations

While a substitute material may appear to be acceptable at the time of installation, both its appearance and its performance may deteriorate rapidly. Some materials are so new that industry standards are not available, thus making it difficult to specify quality control in fabrication, or to predict maintenance requirements and long term performance. Where possible, projects involving substitute materials in similar circumstances should be examined. Material specifications outlining stability of color and texture; compressive or tensile strengths if appropriate; the acceptable range of thermal coefficients, and the durability of coatings and finishes should be included in the contract documents. Without these written documents, the owner may be left with little recourse if failure occurs (see illus. 20, 21).

The tight controls necessary to ensure long-term performance extend beyond having written performance standards and selecting materials that have a successful track record. It is important to select qualified fabricators and installers who know what they are doing and who can follow up if repairs are necessary. Installers and contractors unfamiliar with specific substitute materials and how they function in your local environmental conditions should be avoided.

The surfaces of substitute materials may need special care once installed. For example, chemical residues or mold release agents should be removed completely prior to installation, since they attract pollutants and cause the replacement materials to appear dirtier than the adjacent historic materials. Furthermore, substitute materials may require more frequent cleaning, special cleaning products and protection from impact by hanging window-cleaning scaffolding. Finally, it is critical that the substitute materials be identified as part of the historical record of the building so that proper care and maintenance of all the building materials continue to ensure the life of the historic resource.

Illus. 19. When the physical properties are not matched, particularly thermal expansion and contraction properties, great damage can occur. In this case, an extremely rigid epoxy replacement unit was installed in a historic masonry wall. Because the epoxy was not modified with fillers, it did not expand or contract systematically with the natural stones in the wall surrounding it. Pressure built up resulting in a vertical crack at the center of the unit, and spalled edges to every historic stone that was adjacent to the rigid unit. Photo: Walter M. Sontheimer.

Illus. 20. Long-term performance can be affected by where the substitute material is located. In this case, fiberglass was used as part of a storefront at street level. Due to the brittle nature of the material and the frequency of impact likely to occur at this location, an unsightly chip has resulted. Photo: Sharon C. Park, AIA.

Illus. 21. Change of color over time is one of the greatest problems of synthetic substitute materials used outdoors. Ultra-violet light can cause materials to change color over time; some will lighten and others will darken. In this photograph, the synthetic patching material to the sandstone banding to the left of the window has aged to a darker color. Photos: Sharon C. Park, AIA.

Choosing an Appropriate Substitute Material

Once all reasonable options for repair or replacement in kind have been exhausted, the choice among a wide variety of substitute materials currently on the market must be made (see illus. 22). The charts at the end of this Brief describe a number of such materials, many of them in the family of modified concretes which are gaining greater use. The charts do not include wood, stamped metal, mineral fiber cement shingles and some other traditional imitative materials, since their properties and performance are better known. Nor do the charts include vinyls or molded urethanes which are sometimes used as cosmetic claddings or as substitutes for wooden millwork. Because millwork is still readily available, it should be replaced in kind.

The charts describe the properties and uses of several materials finding greater use in historic preservation projects, and outline advantages and disadvantages of each. It should not be read as an endorsement of any of these materials, but serves as a reminder that numerous materials must be studied carefully before selecting the appropriate treatment. Included are three predominantly masonry materials (cast stone, precast concrete, and glass fiber reinforced concrete); two predominantly resinous materials (epoxy and glass fiber reinforced polymers also known as fiberglass), and cast aluminum which has been used as a substitute for various metals and woods.

Illus. 22. A fiber reinforced polymer (fiberglass) cornice and precast concrete elements replaced deteriorated features on the 19th-century exterior. Photo: Sharon C. Park, AIA.

Summary

Substitute materials—those products used to imitate historic materials—should be used only after all other options for repair and replacement in kind have been ruled out. Because there are so many unknowns regarding the long-term performance of substitute materials, their use should not be considered without a thorough investigation into the proposed materials, the fabricator, the installer, the availability of specifications, and the use of that material in a similar situation in a similar environment.

Substitute materials are normally used when the historic materials or craftsmanship are no longer available, if the original materials are of a poor quality or are causing damage to adjacent materials, or if there are specific code requirements that preclude the use of historic materials. Use of these materials should be limited, since replacement of historic materials on a large scale may jeopardize the integrity of a historic resource. Every means of repairing deteriorating historic materials or replacing them with identical materials should be examined *before* turning to substitute materials.

The importance of matching the appearance and physical properties of historic materials and, thus, of finding a successful long-term solution cannot be overstated. The successful solutions illustrated in this Brief were from historic preservation projects involving professional teams of architects, engineers, fabricators, and other specialists. Cost was not necessarily a factor, and all agreed that whenever possible, the historic materials should be used. When substitute materials were selected, the solutions were often expensive and were reached only after careful consideration of all options, and with the assistance of expert professionals.

FOLLOWING ARE DESCRIPTIONS OF VARIOUS SUBSTITUTE MATERIALS

PROs and CONs of VARIOUS SUBSTITUTE MATERIALS

Cast Aluminum

Material: Cast aluminum is a molten aluminum alloy cast in permanent (metal) molds or one-time sand molds which must be adjusted for shrinkage during the curing process. Color is from paint applied to primed aluminum or from a factory finished coating. Small sections can be bolted together to achieve intricate or sculptural details. Unit castings are also available for items such as column plinth blocks.

Application: Cast aluminum can be a substitute for cast-iron or other decorative elements. This would include grillwork, roof crestings, cornices, ornamental spandrels, storefront elements, columns, capitals, and column bases and plinth blocks. If not self-supporting, elements are generally screwed or bolted to a structural frame. As a result of galvanic corrosion problems with dissimilar metals, joint details are very important.

Close-up detail showing the crisp casting in aluminum of this 19th-century replica column and capital for a storefront. Photo: Sharon C. Park, AIA.

Advantages:
- light weight (1/2 of cast-iron)
- corrosion-resistant, non-combustible
- intricate castings possible
- easily assembled, good delivery time
- can be prepared for a variety of colors
- long life, durable, less brittle than cast iron

Disadvantages:
- lower structural strength than cast-iron
- difficult to prevent galvanic corrosion with other metals
- greater expansion and contraction than cast-iron; requires gaskets or caulked joints
- difficult to keep paint on aluminum

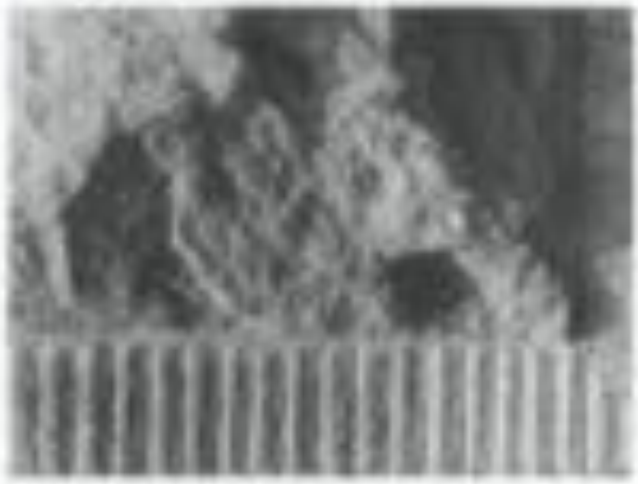
Checklist:
- Can existing be repaired or replaced in-kind?
- How is cast aluminum to be attached?
- Have full-size details been developed for each piece to be cast?
- How are expansion joints detailed?
- Will there be a galvanic corrosion problem?
- Have factory finishes been protected during installation?
- Are fabricators/installers experienced?

The new cast aluminum storefront replaced the lost 19th-century cast-iron original. Photo: Sharon C. Park, AIA.

Cast Stone *(dry-tamped)*

Material: Cast stone is an almost-dry cement, lime and aggregate mixture which is dry-tamped into a mold to produce a dense stone-like unit. Confusion arises in the building industry as many refer to high quality precast concrete as cast stone. In fact, while it is a form of precast concrete, the dry-tamp fabrication method produces an outer surface resembling a stone surface. The inner core can be either dry-tamped or poured full of concrete. Reinforcing bars and anchorage devices can be installed during fabrication.

Application: Cast stone is often the most visually similar material as a replacement for unveined deteriorated stone, such as brownstone or sandstone, or terra cotta in imitation of stone. It is used both for surface wall stones and for ornamental features such as window and door surrounds, voussoirs, brackets and hoods. Rubber-like molds can be taken of good stones on site or made up at the factory from shop drawings.



Dry-tamped cast stone can reproduce the sandy texture of some natural stones. Photo: Harold C. Fink, AIA.

Advantages:
- replicates stone texture with good molds (which can come from extant stone) and fabrication
- expansion/contraction similar to stone
- minimal shrinkage of material
- anchors and reinforcing bars can be built in
- material is fire-rated
- range of color available
- vapor permeable

Disadvantages:
- heavy units may require additional anchorage
- color can fade in sunlight
- may be more absorbent than natural stone
- replacement stones are obvious if too few models and molds are made

Checklist:
- Are the original or similar materials available?
- How are units to be installed and anchored?
- Have performance standards been developed to ensure color stability?
- Have large samples been delivered to site for color, finish and absorption testing?
- Has mortar been matched to adjacent historic mortar to achieve a good color/tooling match?
- Are fabricators/installers experienced?

Glass Fiber Reinforced Concretes (GFRC)

Material: Glass fiber reinforced concretes are lightweight concrete compounds modified with additives and reinforced with glass fibers. They are generally fabricated as thin shelled panels and applied to a separate structural frame or anchorage system. The GFRC is most commonly sprayed into forms although it can be poured. The glass must be alkaline resistant to avoid deteriorating effects caused by the cement ions. The color is derived from the natural aggregates and if necessary a small percentage of added pigments.

Application: Glass fiber reinforced concretes are used in place of features originally made of stone, terra cotta, metal or wood, such as cornices, projecting window and door trims, brackets, finials, or wall murals. As a molded product it can be produced in long sections of repetitive designs or as sculptural elements. Because of its low shrinkage, it can be produced from molds taken directly from the building. It is installed with a separate non-corrosive anchorage system. As a predominantly cementitious material, it is vapor permeable.

This glass fiber reinforced concrete sculptural wall panel will replace the seriously damaged stucco and plaster original. A finely textured surface was achieved by spraying the GFRC into the molds that were created from the historic panel and sculpted based on historic photographs. Photo: Courtesy of MDH Studios.

Advantages:
- lightweight, easily installed
- good molding ability, crisp detail possible
- weather resistant
- can be left uncoated or else painted
- little shrinkage during fabrication
- molds made directly from historic features
- coatings generally breathable
- material is fire-rated

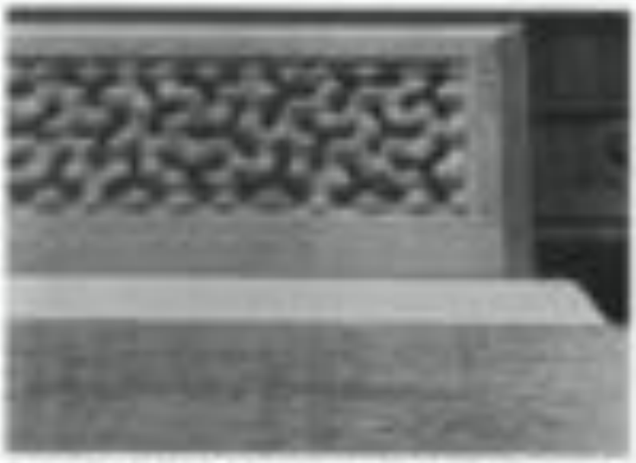
Disadvantages:
- non-loadbearing use only
- generally requires separate anchorage system
- large panels must be reinforced
- color additives may fade with sunlight
- joints must be properly detailed
- may have different absorption rate than adjacent historic material

Checklist:
- Are the original materials and craftsmanship still available?
- Have samples been inspected on the site to ensure detail/texture match?
- Has anchorage system been properly designed?
- Have performance standards been developed?
- Are fabricators/installers experienced?

Precast Concrete

Material: Precast concrete is a wet mix of cement and aggregate poured into molds to create masonry units. Molds can be made from existing good surfaces on the building. Color is generally integral to the mix as a natural coloration of the sand or aggregate, or as a small percentage of pigment. To avoid unsightly air bubbles that result from the natural curing process, great care must be taken in the initial and long-term vibration of the mix. Because of its weight it is generally used to reproduce individual units of masonry and not thin shell panels.

Application: Precast concrete is generally used in place of masonry materials such as stone or terra cotta. It is used both for flat wall surfaces and for textured or ornamental elements. This includes wall stones, window and door surrounds, stair treads, paving pieces, parapets, urns, balusters and other decorative elements. It differs from cast stone in that the surface is more dependent on the textured mold than the hand tamping method of fabrication.



Textured molds can produce a variety of high quality vermiculated, and tooled surfaces in concrete.
Photo: Sharon C. Park, AIA.

Advantages:
- readily fabricated, takes shape well
- rubber molds can be made from building stones
- minimal shrinkage of material
- can be load bearing or anchorage can be cast in
- expansion/contraction similar to stone
- material is fire-rated
- range of color and aggregate available
- vapor permeable

Disadvantages:
- may be more moisture absorbent than stone although coatings may be applied
- color fades in sunlight
- heavy units may require additional anchorage
- small air bubbles may disfigure units
- replacement stones are conspicuous if too few models and molds are made

Checklist:
- Is the historic material still available?
- What are the structural/anchorage requirements?
- Have samples been matched for color/texture/absorption?
- Have shop drawings been made for each shape?
- Are there performance standards?
- Has mortar been matched to adjacent historic mortar to achieve good color/tooling match?
- Are fabricators/installers experienced?

Fiber Reinforced Polymers—
Known as Fiberglass

Material: Fiberglass is the most well known of the FRP products generally produced as a thin rigid laminate shell formed by pouring a polyester or epoxy resin gel-coat into a mold. When tack-free, layers of chopped glass or glass fabric are added along with additional resins. Reinforcing rods and struts can be added if necessary; the gel coat can be pigmented or painted.

Application: Fiberglass, a non load-bearing material attached to a separate structural frame, is frequently used as a replacement where a lightweight element is needed or an inaccessible location makes frequent maintenance of historic materials difficult. Its good molding ability and versatility to reproduce stone, wood, metal and terra cotta make it an alternative to ornate or carved building elements such as column capitals, bases, spandrel panels, beltcourses, balustrades, window hoods or parapets. Its ability to reproduce bright colors is a great advantage.

A fiberglass cornice for the reconstruction of an 18th-century wooden clocktower is being lifted in pre-fabricated sections. The level of detail is intricate and of high quality. Photo: Courtesy of Independence National Historical Park.

Advantages:
- lightweight, long spans available with a separate structural frame
- high ratio of strength to weight
- good molding ability
- integral color with exposed high quality pigmented gel-coat or takes paint well
- easily installed, can be cut, patched, sanded
- non-corrosive, rot-resistant

Disadvantages:
- requires separate anchorage system
- combustible (fire retardants can be added), fragile to impact
- high co-efficient of expansion and contraction requires frequently placed expansion joints
- ultra-violet sensitive unless surface is coated or pigments are in gel-coat
- vapor impermeability may require ventilation detail

Checklist:
- Can original materials be saved/used?
- Have expansion joints been designed to avoid unsightly appearance?
- Are there standards for color stability/durability?
- Have shop drawings been made for each piece?
- Have samples been matched for color and texture?
- Are fabricators/installers experienced?
- Do codes restrict use of FRP?

Epoxies (Epoxy Concretes, Polymer Concretes)

Material: Epoxy is a resinous two-part thermosetting material used as a consolidant, an adhesive, a patching compound, and as a molding resin. It can repair damaged material or recreate lost features. The resins which are poured into molds are usually mixed with fillers such as sand, or glass spheres, to lighten the mix and modify their expansion/contraction properties. When mixed with aggregates, such as sand or stone chips, they are often called epoxy concrete or polymer concrete, which is a misnomer as there are no cementitious materials contained within the mix. Epoxies are vapor impermeable, which makes detailing of the new elements extremely important so as to avoid trapping moisture behind the replacement material. It can be used with wood, stone, terra cotta, and various metals.

Application: Epoxy is one of the most versatile of the new materials. It can be used to bind together broken fragments of terra cotta, to build up or infill missing sections of ornamental metal, or to cast missing elements of wooden ornaments. Small cast elements can be attached to existing materials or entire new features can be cast. The resins are poured into molds and due to the rapid setting of the material and the need to avoid cracking, the molded units are generally small or hollow inside. Multiple molds can be combined for larger elements. With special tools, the epoxies can be structurally reinforced. Examples of epoxy replacement pieces include: finials, sculptural details, small column capitals, and medallions.

This replica column capital was made using epoxy resins poured into a mold taken from the building. The historic wooden column shaft was repaired during the restoration. Photo: Courtesy Dell Corporation.

Advantages:
- can be used for repair/replacement
- lightweight, easily installed
- good casting ability; molds can be taken from building
- material can be sanded and carved
- color and ultra-violet screening can be added; takes paint well
- durable, rot and fungus resistant

Disadvantages:
- materials are flammable and generate heat as they cure and may be toxic when burned
- toxic materials require special protection for operation and adequate ventilation while curing
- material may be subject to ultra-violet deterioration unless coated or fillers added
- rigidity of material often must be modified with fillers to match expansion coefficients
- vapor impermeable

Checklist:
- Are historic materials available for molds, or for splicing-in as a repair option?
- Has the epoxy resin been formulated within the expansion/contraction coefficients of adjacent materials?
- Have samples been matched for color/finish?
- Are fabricators/installers experienced?
- Is there a sound sub-strate of material to avoid deterioration behind new material?
- Are there performance standards?

Columns were repaired and a capital was replaced in epoxy on this 19th-century 2-story porch. Photo: Dell Corporation.

Further Reading: Substitute Materials

Berryman, Nancy D., Susan M. Tindall. *Terra Cotta: Preservation of an Historic Material.* Chicago: Landmarks Preservation Council of Illinois, 1984.

Bondon, A.L. *Cladding of Buildings.* New York: Longman Inc., 1983.

Fisher, Thomas. "The Sincerest Form of Flattery." *Progressive Architecture* (Nov. 1985).

Gayle, Margot, David W. Look, AIA, John G. Waite. *Metals in America's Historic Buildings: Uses and Preservation Treatments.* Washington, D.C.: Preservation Assistance Division, National Park Service, U.S. Department of the Interior, 1980.

Historic Building Facades. New York: New York Landmarks Conservancy, 1986.

Hornbostel, Caleb. *Construction Materials: Types, Uses and Applications.* New York: John Wiley and Sons, Inc., 1978.

Lynch, Michael F., William J. Higgins. *The Maintenance and Repair of Architectural Sandstone.* New York Landmarks Conservancy, 1982.

National Park Service, Rocky Mountain Regional Office. *Preservation Briefs 12: The Preservation of Historic Pigmented Structural Glass.* Washington, D.C.: Preservation Assistance Division, National Park Service, U.S. Department of the Interior, 1984.

Phillips, Morgan and Judith Selwyn. *Epoxies for Wood Repairs in Historic Buildings.* Washington, D.C.: Preservation Assistance Division, National Park Service, U.S. Department of the Interior, 1978.

Phillips, Morgan W.. *The Morse-Libby Mansion: A Report on Restoration Work.* Washington, D.C.: Preservation Assistance Division, National Park Service, U.S. Department of the Interior, 1977.

Tiller, deTeel Patterson. *Preservation Briefs 7: The Preservation of Historic Glazed Architectural Terra-Cotta.* Washington, D.C.: Preservation Assistance Division, National Park Service, U.S. Department of the Interior, 1979.

Acknowledgements

The author gratefully acknowledges the invaluable assistance of co-worker Michael Auer in editing this manuscript. The following individuals are to be thanked for their technical assistance: Mary Oehrlein, A.I.A., Washington, D.C.; John G. Waite, Albany, NY; Hyman Myers, R.A., Philadelphia, PA; Thomas Fisher, Stamford, CT; Harrison Goodall, Kinnelon, NJ. In addition, the staff of Preservation Assistance Division, the cultural resources staff of the National Park Service Regional Offices, and Stan Graves, on behalf of the National Conference of State Historic Preservation Officers, provided useful comments that were incorporated into the manuscript.

This publication has been prepared pursuant to Section 101(h) of the National Historic Preservation Act, as amended, which directs the Secretary of the Interior to develop and make available information concerning historic properties. The guidance provided in this Brief will also assist property owners in complying with the requirements of the Internal Revenue Code of 1986.

Preservation Briefs 16 has been developed under the technical editorship of Lee H. Nelson, FAIA, Chief, Preservation Assistance Division, National Park Service, U.S. Department of the Interior, P.O. Box 37127, Washington, D.C. 20013-7127. Comments on the usefulness of this information are welcome and can be sent to Mr. Nelson at the above address.

Cover photograph: Independence Hall, Philadelphia, PA; the 1972 installation of a combination wood and fiberglass steeple duplicating the lost 18th century original. Photo: Courtesy of Independence National Historical Park.

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402

17 PRESERVATION BRIEFS

Architectural Character: Identifying the Visual Aspects of Historic Buildings as an Aid to Preserving Their Character

Lee H. Nelson, FAIA

U.S. Department of the Interior
National Park Service
Cultural Resources
Heritage Preservation Services

The Secretary of the Interior's "Standards for Historic Preservation Projects" embody two important goals: 1) the preservation of historic materials and, 2) the preservation of a building's distinguishing character. Every old building is unique, with its own identity and its own distinctive character. Character refers to all those visual aspects and physical features that comprise the appearance of every historic building. Character-defining elements include the overall shape of the building, its materials, craftsmanship, decorative details, interior spaces and features, as well as the various aspects of its site and environment.

The purpose of this Brief is to help the owner or the architect identify those features or elements that give the building its *visual character* and that should be taken into account in order to preserve them to the maximum extent possible.

There are different ways of understanding old buildings. They can be seen as examples of specific building types, which are usually related to a building's function, such as schools, courthouses or churches. Buildings can be studied as examples of using specific materials such as concrete, wood, steel, or limestone. They can also be considered as examples of an historical period, which is often related to a specific architectural style, such as Gothic Revival farmhouses, one-story bungalows, or Art Deco apartment buildings.

There are many other facets of an historic building besides its functional type, its materials or construction or style that contribute to its historic qualities or significance. Some of these qualities are feelings conveyed by the sense of time and place or in buildings associated with events or people. A complete understanding of any property may require documentary research about its style, construction, function, its furnishings or contents; knowledge about the original builder, owners, and later occupants; and knowledge about the evolutionary history of the building. Even though buildings may be of historic, rather than architectural significance, it is their tangible elements that embody its significance for association with specific events or persons and it is those *tangible elements* both on the exterior and interior that should be preserved.

Therefore, the approach taken in this Brief is limited to identifying those visual and tangible aspects of the historic building. While this may aid in the planning process for carrying out any ongoing or new use or restoration of the building, this approach is not a substitute for developing an understanding about the significance of an historic building and the district in which it is located.

If the various materials, features and spaces that give a building its visual character are not recognized and preserved, then essential aspects of its character may be damaged in the process of change.

A building's character can be irreversibly damaged or changed in many ways, for example, by inappropriate repointing of the brickwork, by removal of a distinctive side porch, by changes to the window sash, by changes to the setting around the building, by changes to the major room arrangements, by the introduction of an atrium, by painting previously unpainted woodwork, etc.

A Three-Step Process to Identify A Building's Visual Character

This Brief outlines a three-step approach that can be used by anyone to identify those materials, features and spaces that contribute to the visual character of a building. This approach involves first examining the building *from afar* to understand its overall setting and architectural context; then moving up very close to appreciate its materials and the craftsmanship and surface finishes evident in these materials; and then going into and through the building to perceive those spaces, rooms and details that comprise its interior visual character.

Step 1: Identify the Overall Visual Aspects

Identifying the overall visual character of a building is nothing more than looking at its distinguishing physical aspects without focusing on its details. The major contributors to a building's overall character are embodied in the general aspects of its *setting*; the *shape* of the building; its *roof* and roof features, such as chimneys or cupolas; the various *projections* on the building, such as porches or bay windows; the *recesses* or voids in a building, such as open galleries, arcades, or recessed balconies; the *openings* for windows and doorways; and finally the various exterior *materials* that contribute to the building's character. Step one involves looking at the building from a distance to understand the character of its site and setting, and it involves walking around the building where that is possible. Some buildings will have one or more sides that are more important than the others because they are more highly visible. This does not mean that the rear of the building is of no value whatever but it simply means that it is less important to the overall character. On the other hand, the rear may have an interesting back porch or offer a private garden space or some other aspect that may contribute to the visual character. Such a general approach to looking at the building and site will provide a better understanding of its overall character without having to resort to an infinitely long checklist of its possible features and details. Regardless of whether a building is complicated or relatively plain, it is these broad categories that contribute to an understanding of the overall character rather than the specifics of architectural features such as moldings and their profiles.

Step 2: Identify the Visual Character at Close Range

Step two involves looking at the building at close range or arm's length, where it is possible to see all the surface qualities of the materials, such as their *color* and *texture*, or surface evidence of craftsmanship or age. In some instances, the visual character is the result of the juxtaposition of materials that are contrastingly different in their color and texture. The surface qualities of the materials may be important because they impart the very sense of craftsmanship and age that distinguishes historic buildings from other buildings. Furthermore, many of these close up qualities can be easily damaged or obscured by work that affects those surfaces. Examples of this could include painting previously unpainted masonry, rotary disk sanding of smooth wood siding to remove paint, abrasive cleaning of tooled stonework, or repointing reddish mortar joints with gray portland cement.

There is an almost infinite variety of surface materials, textures and finishes that are part of a building's character which are fragile and easily lost.

Step 3: Identify the Visual Character of the Interior Spaces, Features and Finishes

Perceiving the character of interior spaces can be somewhat more difficult than dealing with the exterior. In part, this is because so much of the exterior can be seen at one time and it is possible to grasp its essential character rather quickly. To understand the interior character, it is necessary to move through the spaces one at a time. While it is not difficult to perceive the character of one individual room, it becomes more difficult to deal with spaces that are interconnected and interrelated. Sometimes, as in office buildings, it is the vestibules or lobbies or corridors that are important to the interior character of the building. With other groups of buildings the visual qualities of the interior are related to the plan of the building, as in a church with its axial plan creating a narrow tunnel-like space which obviously has a different character than an open space like a sports pavilion. Thus the shape of the space may be an essential part of its character. With some buildings it is possible to perceive that there is a visual linkage in a sequence of spaces, as in a hotel, from the lobby to the grand staircase to the ballroom. Closing off the openings between those spaces would change the character from visually linked spaces to a series of closed spaces. For example, in a house that has a front and back parlor linked with an open archway, the two rooms are perceived together, and this visual relationship is part of the character of the building. To close off the open archway would change the character of such a residence.

The importance of interior features and finishes to the character of the building should not be overlooked. In relatively simple rooms, the primary visual aspects may be in features such as fireplace mantels, lighting fixtures or wooden floors. In some rooms, the absolute plainness is the character-defining aspect of the interior. So-called secondary spaces also may be important in their own way, from the standpoint of history or because of the family activities that occurred in those rooms. Such secondary spaces, while perhaps historically significant, are not usually perceived as important to the visual character of the building. Thus we do not take them into account in the visual understanding of the building.

Conclusion

Using this three-step approach, it is possible to conduct a walk through and identify all those elements and features that help define the visual character of the building. In most cases, there are a number of aspects about the exterior and interior that are important to the character of an historic building. The visual emphasis of this brief will make it possible to ascertain those things that should be preserved because their loss or alteration would diminish or destroy aspects of the historic character whether on the outside, or on the inside of the building.

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402

Overall Visual Character: Shape

The shape of a building can be an important aspect of its overall visual character. The building illustrated here, for example, has a distinctive horizontal box-like shape with the middle portion of the box projecting up an extra story. This building has other visual aspects that help define its overall character, including the pattern of vertical bands of windows, the decorative horizontal bands which separate the base of the building from the upper floors, the dark brown color of the brick, the large arched entranceway, and the castle-like tower behind the building.

Overall Visual Character: Shape

It should not be assumed that only large or unusual buildings have a shape that is distinctive or identifiable. The front wall of this modest commercial building has a simple three-part shape that is the controlling aspect of its overall visual character. It consists of a large center bay with a two-story opening that combines the storefront and the windows above. The upward projecting parapet and the decorative stonework also relate to and emphasize its shape. The flanking narrow bays enframe the side windows and the small iron balconies, and the main entrance doorway into the store. Any changes to the center portion of this three-part shape, could drastically affect the visual character of this building. Photo by Emogene A. Bevitt

Overall Visual Character: Openings

Window and door openings can be important to the overall visual character of historic buildings. This view shows only part of a much larger building, but the windows clearly help define its character, partly because of their shape and rhythm: the upper floor windows are grouped in a 4,3,4,1,4 rhythm, and the lower floor windows are arranged in a regular 1,1,1,... rhythm. The individual windows are tall, narrow and arched, and they are accented by the different colored arched heads, which are connected where there are multiple windows so that the color contrast is a part of its character. If additional windows were inserted in the gap of the upper floors, the character would be much changed, as it would if the window heads were painted to match the color of the brick walls. Photo by Susan I. Dynes

Overall Visual Character: Openings

The opening illustrated here dominates the visual character of this building because of its size, shape, location, materials, and craftsmanship. Because of its relation to the generous staircase, this opening places a strong emphasis on the principal entry to the building. Enclosing this arcade-like entry with glass, for example, would materially and visually change the character of the building. Photo by Lee H. Nelson.

Overall Visual Character: Roof and Related Features

This building has a number of character-defining aspects which include the windows and the decorative stonework, but certainly the roof and its related features are visually important to its overall visual character. The roof is not only highly visible, it has elaborate stone dormers, and it also has decorative metalwork and slatework. The red and black slates of differing sizes and shapes are laid in patterns that extend around the roof of this large and freestanding building. Any changes to this patterned slatework, or to the other roofing details would damage the visual character of the building. Photo by Laurie R. Hammel

Overall Visual Character: Roof and Related Features

On this building, the most important visual aspects of its character are the roof and its related features such as the dormers and chimneys. The roof is important to the visual character because its steepness makes it highly visible, and its prominence is reinforced by the patterned tinwork, the six dormers and the two chimneys. Changes to the roof or its features, such as removal or alterations to the dormers, for example, would certainly change the character of this building. This does not discount the importance of its other aspects, such as the porch, the windows, the brickwork, or its setting; but the roof is clearly crucial to understanding the overall visual character of this building as seen from a distance. Photo by Lee H. Nelson

Overall Visual Character: Projections

A projecting porch or balcony can be very important to the overall visual character of almost any building and to the district in which it is located. Despite the size of this building (3 1/2 stories), and its distinctive roofline profile, and despite the importance of the very large window openings, the lacy wrap-around iron balcony is singularly important to the visual character of this building. It would seriously affect the character to remove the balcony, to enclose it, or to replace it with a balcony lacking the same degree of detail of the original material. Photo by Baird M. Smith

Overall Visual Character: Projections

Since these are row houses, any evaluation of their visual exterior character is necessarily limited to the front and rear walls; and while there are a number of things competing for attention in the front, it is the half round projecting bays with their conical roofs that contribute most prominently to the visual character. Their removal would be a devastating loss to the overall character, but even if preserved, the character could be easily damaged by changes to their color (as seen in the left bay which has been painted a dark color), or changes to their windows, or changes to their tile roofs. Though these houses have other fine features that contribute to the visual character and are worthy of preservation, these half-round bays demonstrate the importance of projecting features on an already rich and complex facade. Because of the repetitive nature of these projecting bays on adjacent row houses, along with the buildings' size, scale, openings, and materials, they also contribute to the overall visual character of the streetscape in the historic district. Any evaluation of the visual character of such a building should take into account the context of this building within the district. Photo by Lee H. Nelson

Overall Visual Character: Projections

Many buildings have projecting features such as porches, bay windows, or overhanging roofs, that help define their overall visual character. This projecting porch because of its size and shape, and because it copies the pitch and material of the main roof, is an important contributor to the visual character of this simple farmhouse. The removal or alteration of this porch would drastically alter the character of this building. If the porch were enclosed with wood or glass, or if gingerbread brackets were added to the porch columns, if the tin roof was replaced with asphalt, or if the porch railing was opened to admit a center stairway, the overall visual character could be seriously damaged. Although this projecting porch is an important feature, almost any other change to this house, such as changes to the window pattern, or changes to the main roof, or changes to the setting, would also change its visual character. Photo by Hugh C. Miller

Overall Visual Character: Trim

If one were to analyze the overall shape or form of this building, it would be seen that it is a gable-roofed house with dormers and a wrap-around porch. It is similar to many other houses of the period. It is the wooden trim on the eaves and around the porch that gives this building its own identify and its special visual character. Although such wooden trim is vulnerable to the elements, and must be kept painted to prevent deterioration; the loss of this trim would seriously damage the overall visual character of this building, and its loss would obliterate much of the close-up visual character so dependent upon craftsmanship for the moldings, carvings, and the see-through jigsaw work. Photo by Hugh C. Miller

Overall Visual Character: Setting

In the process of identifying the overall visual character, the aspect of setting should not be overlooked. Obviously, the setting of urban row houses differs from that of a mansion with a designed landscape. However, there are many instances where the relationship between the building and its place on the streetscape, or its place in the rural environment, in other words its setting, may be an important contributor to its overall character.

In this instance, the corner tower and the arched entryway are important contributors to the visual character of the building itself, but there is also a relationship between the building and the two converging streets that is also an important aspect of this historic building. The curb, sidewalk, fence, and the yard interrelate with each other to establish a setting that is essential to the overall visual character of the historic property. Removing these elements or replacing them with a driveway or parking court would destroy an important visual aspect. Photo by Lee H. Nelson

Overall Visual Character: Setting

Even architecturally modest buildings frequently will have a setting that contributes to their overall character. In this very urban district, set-backs are the exception, so that the small front yard is something of a luxury, and it is important to the overall character because of its design and materials, which include the iron fence along the sidewalk, the curved walk leading to the porch, and the various plantings. In a district where parking spaces are in great demand, such front yards are sometimes converted to off-street parking, but in this instance, that would essentially destroy its setting and would drastically change the visual character of this historic property. Photo by Lee H. Nelson

Overall Visual Character: Setting

Among the various visual aspects relating to the setting of an historic property are such site features as gardens, walks, fences, etc. This can include their design and materials. There is a dramatic difference in the visual character between these two fence constructions—one utilizing found materials with no particular regard to their uniformity of size or placement, and the other being a product of the machine age utilizing cast iron components assembled into a pattern of precision and regularity. If the corral fence were to be repaired or replaced with lumberyard materials its character would be dramatically compromised. The rhythm and regularity of the cast iron fence is so important to its visual character that its character could be altered by accidental damage or vandalism, if some of the fence top spikes were broken off thus interrupting the rhythm or pattern. Photos by Lee H. Nelson

Arm's Length Visual Character: Materials

At arm's length, the visual character is most often determined by the surface qualities of the materials and craftsmanship; and while these aspects are often inextricably related, the original choice of materials often plays the dominant role in establishing the close-range character because of the color, texture, or shape of the materials.

In this instance, the variety and arrangement of the materials is important in defining the visual character, starting with the large pieces of broken stone which form the projecting base for the building walls, then changing to a wall of roughly rectangular stones which vary in size, color, and texture, all with accentuated, projecting beads of mortar, then there is a rather precise and narrow band of cut and dressed stones with minimal mortar joints, and finally, the main building walls are composed of bricks, rather uniform in color, with fairly generous mortar joints. It is the juxtaposition and variety of these materials (and of course, the craftsmanship) that is very important to the visual character. Changing the raised mortar joints, for example, would drastically alter the character at arm's length. Photo by Lee H. Nelson

Arm's Length Visual Character: Craft Details

There are many instances where craft details dominate the arm's length visual character. As seen here, the craft details are especially noticeable because the stones are all of a uniform color, and they are all squared off, but their surfaces were worked with differing tools and techniques to create a great variety of textures, resulting in a tour-de-force of craft details. This texture is very important at close range. It was a deliberately contrived surface that is an important contributor to the visual character of this building. Photo by Lee H. Nelson

Arm's Length Visual Character: Craft Details

The arm's length visual character of this building is a combination of the materials and the craft details. Most of the exterior walls of this building consist of early 20th century Roman brick, precisely made, unusually long bricks, in varying shades of yellow-brown, with a noticeable surface spotting of dark iron pyrites. While this brick is an important contributor to the visual character, the related craft details are perhaps more important, and they consist of: unusually precise coursing of the bricks, almost as though they were laid up using a surveyor's level; a row of recessed bricks every ninth course, creating a shadow pattern on the wall; deeply recessed mortar joints, creating a secondary pattern of shadows; and a toothed effect where the bricks overlap each other at the corner of the building. The cumulative effect of this artisanry is important to the arm's length visual character, and it is evident that it would be difficult to match if it were damaged, and the effect could be easily damaged through insensitive treatments such as painting the brickwork or by careless repointing. Photo by Lee H. Nelson

Arm's Length Visual Character: Craft Details

On some buildings, there are subtle aspects of visual character that cannot be perceived from a distance. This is especially true of certain craft details that can be seen only at close range. On this building, it is easily understood that the narrow, unpainted, and weathered clapboards are an important aspect of its overall visual character; but at close range there are a number of subtle but very important craft details that contribute to the handmade quality of this building, and which clearly differentiate it from a building with machine sawn clapboards. The clapboards seen here were split by hand and the bottom edges were not dressed, so that the boards vary in width and thickness, and thus they give a very uneven shadow pattern. Because they were split from oak that is unpainted, there are occasional wavy rays in the wood that stand against the grain. Also noticeable is the fact that the boards are of relatively short lengths, and that they have feather-edged ends that overlap each other, a detail that is very different from butted joints. The occasional large nail heads and the differential silver-gray weathering add to the random quality of the clapboards. All of these qualities contribute to the arm's length visual character. Photo by Lee H. Nelson

Arm's Length Visual Character: Craft Details

While hand-split clapboards are distinctive visual elements in their own way, machine-sawn and painted wood siding is equally important to the overall visual character in most other instances. At arm's length, however, the machine sawn siding may not be so distinctive; but there might be other details that add visual character to the wooden building, such as the details of wooden trim and louvered shutters around the windows (as seen here), or similar surface textures on other buildings, such as the saw marks on wall shingles, the joints in leaded glass, decorative tinwork on a rain conductor box, the rough surface of pebble-dash stuccowork, or the pebbly surface of exposed aggregate concrete. Such surfaces can only be seen at arm's length and they add to the visual character of a historic building. Photo by Hugh C. Miller

Interior Visual Character: Individually Important Spaces

In assessing the interior visual character of any historic building, it is necessary to ask whether there are spaces that are important to the character of this particular building, whether the building is architecturally rich or modest, or even if it is a simple or utilitarian structure.

The character of the individually important space which is illustrated here is a combination of its size, the twin curving staircases, the massive columns and curving vaulted ceilings, in addition to the quality of the materials in the floor and in the stairs. If the ceiling were to be lowered to provide space for heating ducts, or if the stairways were to be enclosed for code reasons, the shape and character of this space would be damaged, even if there was no permanent physical damage. Such changes can easily destroy the visual character of an individually important interior space. Thus, it is important that the visual aspects of a building's interior character be recognized before planning any changes or alterations. Photo by National Portrait Gallery

Interior Visual Character: Related Spaces

Many buildings have interior spaces that are visually or physically related so that, as you move through them, they are perceived not as separate spaces, but as a sequence of related spaces that are important in defining the interior character of the building. The example which is illustrated here consists of three spaces that are visually linked to each other.

The first of these spaces is the vestibule which is of a generous size and unusual in its own right, but more important, it visually relates to the second space which is the main stairhall.

The hallway is the circulation artery for the building, and leads both horizontally and vertically to other rooms and spaces, but especially to the open and inviting stairway.

The stairway is the third part of this sequence of related spaces, and it provides continuing access to the upper floors.

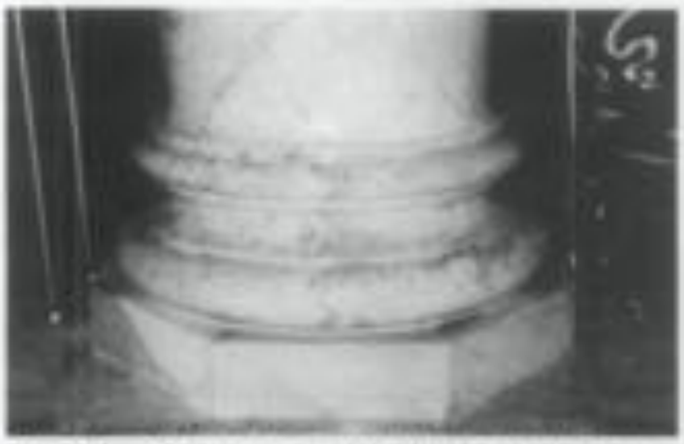
These related spaces are very important in defining the interior character of this building. Almost any change to these spaces, such as installing doors between the vestibule and the hallway, or enclosing the stair would seriously impact their character and the way that character is perceived. Top photo by Mel Chamowitz, others by John Tennant

Interior Visual Character: Interior Features

Interior features are three-dimensional building elements or architectural details that are an integral part of the building as opposed to furniture. Interior features are often important in defining the character of an individual room or space. In some instances, an interior feature, like a large and ornamental open stairway may dominate the visual character of an entire building. In other instances, a modest iron stairway (like the one illustrated here) may be an important interior feature, and its preservation would be crucial to preserving the interior character of the building. Such features can also include the obvious things like fireplace mantles, plaster ceiling medallions, or panelling, but they also extend to features like hardware, lighting fixtures, bank tellers cages, decorative elevator doors, etc. Photo by David W. Look

Interior Visual Character: Interior Features

Modern heating or cooling devices usually add little to the interior character of a building; but historically, radiators, for instance, may have contributed to the interior character by virtue of their size or shape, or because of their specially designed bases, piping, and decorative grillage or enclosures. Sometimes they were painted with several colors to highlight their integral, cast-in details. In more recent times, it has been common to overpaint and conceal such distinctive aspects of earlier heating and plumbing devices, so that we seldom have the opportunity to realize how important they can be in defining the character of interior rooms and spaces. For that reason, it is important to identify their character-defining potential, and consider their preservation, retention, or restoration. Photo by David W. Look



Interior Visual Character: Surface Materials and Finishes

When identifying the visual character of historic interior spaces one should not overlook the importance of those materials and finishes that comprise the surfaces of walls, floors and ceilings. The surfaces may have evidence of either hand-craft or machine-made products that are important contributors to the visual character, including patterned or inlaid designs in the wood flooring, decorative painting practices such as stenciling, imitation marble or wood grain, wallpapering, tinwork, tile floors, etc.

The example illustrated here involves a combination of real marble at the base of the column, imitation marble patterns on the plaster surface of the column (a practice called scagliola), and a tile floor surface that uses small mosaic tiles arranged to form geometric designs in several different colors. While such decorative materials and finishes may be important in defining the interior visual character of this particular building, it should be remembered that in much more modest buildings, the plainness of surface materials and finishes may be an essential aspect of their historic character. Photo by Lee H. Nelson

Fragility of A Building's Visual Character

Some aspects of a building's visual character are fragile and are easily lost. This is true of brickwork, for example, which can be irreversibly damaged with inappropriate cleaning techniques or by insensitive repointing practices. At least two factors are important contributors to the visual character of brickwork, namely the brick itself and the craftsmanship. Between these, there are many more aspects worth noting, such as color range of bricks, size and shape variations, texture, bonding patterns, together with the many variable qualities of the mortar joints, such as color, width of joint and tooling. These qualities could be easily damaged by painting the brick, by raking out the joint with power tools, or repointing with a joint that is too wide. As seen here during the process of repointing, the visual character of this front wall is being dramatically changed from a wall where the bricks predominate, to a wall that is visually dominated by the mortar joints. Photo by Lee H. Nelson

The Architectural Character Checklist/Questionnaire

Lee H. Nelson, FAIA
National Park Service

This checklist can be taken to the building and used to identify those aspects that give the building and setting its essential visual qualities and character. This checklist consists of a series of questions that are designed to help in identifying those things that contribute to a building's character. The use of this checklist involves the three-step process of looking for: 1) the overall visual aspects, 2) the visual character at close range, and 3) the visual character of interior spaces, features and finishes.

Because this is a process to identify *architectural character*, it does not address those intangible qualities that give a property or building or its contents its historic significance, instead this checklist is organized on the assumption that historic significance is embodied in those tangible aspects that include the building's setting, its form and fabric.

Step One

1. Shape

What is there about the form or shape of the building that gives the building its identity? Is the shape distinctive in relation to the neighboring buildings? Is it simply a low, squat box, or is it a tall, narrow building with a corner tower? Is the shape highly consistent with its neighbors? Is the shape so complicated because of wings, or ells, or differences in height, that its complexity is important to its character? Conversely, is the shape so simple or plain that adding a feature like a porch would change that character? Does the shape convey its historic function as in smoke stacks or silos?

Notes on the Shape or Form of the Building:

---

2. Roof and Roof Features

Does the roof shape or its steep (or shallow) slope contribute to the building's character? Does the fact that the roof is highly visible (or not visible at all) contribute to the architectural identity of the building? Are certain roof features important to the profile of the building against the sky or its background, such as cupolas, multiple chimneys, dormers, cresting, or weathervanes? Are the roofing materials or their colors or their patterns (such as patterned slates) more noticeable than the shape or slope of the roof?

Notes on the Roof and Roof Features:

---

3. Openings

Is there a rhythm or pattern to the arrangement of windows or other openings in the walls; like the rhythm of windows in a factory building, or a three-part window in the front bay of a house; or is there a noticeable relationship between the width of the window openings and the wall space between the window openings? Are there distinctive openings, like a large arched entranceway, or decorative window lintels that accentuate the importance of the window openings, or unusually shaped windows, or patterned window sash, like small panes of glass in the windows or doors, that are important to the character? Is the plainness of the window openings such that adding shutters or gingerbread trim would radically change its character? Is there a hierarchy of facades that make the front windows more important than the side windows? What about those walls where the absence of windows establishes its own character?

Notes on the Openings:

---

4. Projections

Are there parts of the building that are character-defining because they project from the walls of the building like porches, cornices, bay windows, or balconies? Are there turrets, or widely overhanging eaves, projecting pediments or chimneys?

Notes on the Projections:

---

5. Trim and Secondary Features

Does the trim around the windows or doors contribute to the character of the building? Is there other trim on the walls or around the projections that, because of its decoration or color or patterning contributes to the character of the building? Are there secondary features such as shutters, decorative gables, railings, or exterior wall panels?

Notes on the Trim and Secondary Features:

---

6. Materials

Do the materials or combination of materials contribute to the overall character of the building as seen from a distance because of their color or patterning, such as broken faced stone, scalloped wall shingling, rounded rock foundation walls, boards and battens, or textured stucco?

Notes on the Materials:

---

7. Setting

What are the aspects of the setting that are important to the visual character? For example, is the alignment of buildings along a city street and their relationship to the sidewalk the essential aspect of its setting? Or, conversely, is the essential character dependent upon the tree plantings and out buildings which surround the farmhouse? Is the front yard important to the setting of the modest house? Is the specific site important to the setting such as being on a hilltop, along a river, or, is the building placed on the site in such a way to enhance its setting? Is there a special relationship to the adjoining streets and other buildings? Is there a view? Is there fencing, planting, terracing, walkways or any other landscape aspects that contribute to the setting?

Notes on the Setting:

Step Two

8. Materials at Close Range

Are there one or more materials that have an inherent texture that contributes to the close range character, such as stucco, exposed aggregate concrete, or brick textured with vertical grooves? Or materials with inherent colors such as smooth orange-colored brick with dark spots of iron pyrites, or prominently veined stone, or green serpentine stone? Are there combinations of materials, used in juxtaposition, such as several different kinds of stone, combinations of stone and brick, dressed stones for window lintels used in conjunction with rough stones for the wall? Has the choice of materials or the combinations of materials contributed to the character?

Notes on the Materials at Close Range:

---

9. Craft Details

Is there high quality brickwork with narrow mortar joints? Is there hand-tooled or patterned stonework? Do the walls exhibit carefully struck vertical mortar joints and recessed horizontal joints? Is the wall shinglework laid up in patterns or does it retain evidence of the circular saw marks or can the grain of the wood be seen through the semi-transparent stain? Are there hand split or hand-dressed clapboards, or machine smooth beveled siding, or wood rusticated to look like stone, or Art Deco zigzag designs executed in stucco?

Almost any evidence of craft details, whether handmade or machinemade, will contribute to the character of a building because it is a manifestation of the materials, of the times in which the work was done, and of the tools and processes that were used. It further reflects the effects of time, of maintenance (and/or neglect) that the building has received over the years. All of these aspects are a part of the surface qualities that are seen only at close range.

Notes on the Craft Details:

Step Three

10. Individual Spaces

Are there individual rooms or spaces that are important to this building because of their size, height, proportion, configuration, or function, like the center hallway in a house, or the bank lobby, or the school auditorium, or the ballroom in a hotel, or a courtroom in a county courthouse?

Notes on the Individual Spaces:

---

11. Related Spaces and Sequences of Spaces

Are there adjoining rooms that are visually and physically related with large doorways or open archways so that they are perceived as related rooms as opposed to separate rooms? Is there an important sequence of spaces that are related to each other, such as the sequence from the entry way to the lobby to the stairway and to the upper balcony as in a theater; or the sequence in a residence from the entry vestibule to the hallway to the front parlor, and on through the sliding doors to the back parlor; or the sequence in an office building from the entry vestibule to the lobby to the bank of elevators?

Notes on the Related Spaces and Sequences of Spaces:

---

12. Interior Features

Are there interior features that help define the character of the building, such as fireplace mantels, stairways and balustrades, arched openings, interior shutters, inglenooks, cornices, ceiling medallions, light fixtures, balconies, doors, windows, hardware, wainscotting, panelling, trim, church pews, courtroom bars, teller cages, waiting room benches?

Notes on the Interior Features:

---

13. Surface Finishes and Materials

Are there surface finishes and materials that can affect the design, the color or the texture of the interior? Are there materials and finishes or craft practices that contribute to the interior character, such as wooden parquet floors, checkerboard marble floors, pressed metal ceilings, fine hardwoods, grained doors or marbleized surfaces, or polychrome painted surfaces, or stencilling, or wallpaper that is important to the historic character? Are there surface finishes and materials that, because of their plainness, are imparting the essential character of the interior such as hard or bright, shiny wall surfaces of plaster or glass or metal?

Notes on the Surface Finishes and Materials:

---

14. Exposed Structure

Are there spaces where the exposed structural elements define the interior character such as the exposed posts, beams, and trusses in a church or train shed or factory? Are there rooms with decorative ceiling beams (non-structural) in bungalows, or exposed vigas in adobe buildings?

Notes on the Exposed Structure:

This concludes the three-step process of identifying the visual aspects of historic buildings and is intended as an aid in preserving their character and other distinguishing qualities. It is not intended as a means of understanding the significance of historical properties or districts, nor of the events or people associated with them. That can only be done through other kinds of research and investigation.

This Preservation Brief was originally developed as a slide talk/methodology in 1982 to discuss the use of the Secretary of the Interior's Standards for Rehabilitation in relation to preserving historic character; and it was amplified and modified in succeeding years to help guide preservation decisionmaking, initially for maintenance personnel in the National Park Service. A number of people contributed to the evolution of the ideas presented here. Special thanks go to Emogene Bevitt and Gary Hume, primarily for the many and frequent discussions relating to this approach in its evolutionary stages; to Mark Fram, Ontario Heritage Foundation, Toronto, for suggesting several additions to the Checklist; and more recently, to my co-workers, both in Washington and in our regional offices, especially Ward Jandl, Sara Blumenthal, Charles Fisher, Sharon Park, AIA, Jean Travers, Camille Martone, Susan Dynes, Michael Auer, Anne Grimmer, Kay Weeks, Betsy Chittenden, Patrick Andrus, Carol Shull, Hugh Miller, FAIA, Jerry Rogers, Paul Alley, David Look, AIA, Margaret Pepin-Donat, Bonnie Halda, Keith Everett, Thomas Keohan, the Preservation Services Division, Mid-Atlantic Region, and several reviewers in state preservation offices, especially Ann Haaker, Illinois; and Stan Graves, AIA, Texas, for providing very critical and constructive review of the manuscript.

This publication has been prepared pursuant to the National Historic Preservation Act of 1966, as amended. Comments on the usefulness of this information are welcomed and can be sent to Mr. Nelson, Preservation Assistance Division, National Park Service, U.S. Department of the Interior, P.O. Box 37127, Washington, D.C. 20013-7127.

22 PRESERVATION BRIEFS

The Preservation and Repair of Historic Stucco

Anne Grimmer

U.S. Department of the Interior
National Park Service
Preservation Assistance Division

The term "stucco" is used here to describe a type of exterior plaster applied as a two-or-three part coating directly onto masonry, or applied over wood or metal lath to a log or wood frame structure. Stucco is found in many forms on historic structures throughout the United States. It is so common, in fact, that it frequently goes unnoticed, and is often disguised or used to imitate another material. Historic stucco is also sometimes incorrectly viewed as a sacrificial coating, and consequently removed to reveal stone, brick or logs that historically were never intended to be exposed. Age and lack of maintenance hasten the deterioration of many historic stucco buildings. Like most historic building materials, stucco is at the mercy of the elements, and even though it is a protective coating, it is particularly susceptible to water damage.

Stucco is a material of deceptive simplicity: in most cases its repair should not be undertaken by a property owner unfamiliar with the art of plastering. Successful stucco repair requires the skill and experience of a professional plasterer. Therefore, this Brief has been prepared to provide background information on the nature and components of traditional stucco, as well as offer guidance on proper maintenance and repairs. The Brief will outline the requirements for stucco repair, and, when necessary, replacement. Although several stucco mixes representative of different periods are provided here for reference, this Brief does not include specifications for carrying out repair projects. Each project is unique, with its own set of problems that require individual solutions.

Historical Background

Stucco has been used since ancient times. Still widely used throughout the world, it is one of the most common of traditional building materials (Fig. 1). Up until

Fig. 1. These two houses in a residential section of Winchester, Virginia, illustrate the continuing popularity of stucco (a) from this early 19th century Federal style house on the left, (b) to the English Cotswold style cottage that was built across the street in the 1930's. Photos: Anne Grimmer.

the late 1800's, stucco, like mortar, was primarily lime-based; but the popularization of portland cement changed the composition of stucco, as well as mortar, to a harder material. Historically, the term "plaster" has often been interchangeable with "stucco"; the term is still favored by many, particularly when referring to the traditional lime-based coating. By the nineteenth century "stucco," although originally denoting fine interior ornamental plasterwork, had gained wide acceptance in the United States to describe exterior plastering. "Render" and "rendering" are also terms used to describe stucco, especially in Great Britain. Other historic treatments and coatings related to stucco in that they consist at least in part of a similarly plastic or malleable material include: pargeting and pargeting, wattle and daub, "cob" or chalk mud, pisé de terre, rammed earth, briqueté entre poteaux or bousillage, half-timbering, and adobe. All of these are regional variations on traditional mixtures of mud, clay, lime, chalk, cement, gravel or straw. Many are still used today.

The Stucco Tradition in the United States

Stucco is primarily used on residential buildings and relatively small-scale commercial structures. Some of the earliest stucco buildings in the United States include examples of the Federal, Greek and Gothic Revival styles of the eighteenth and the nineteenth centuries that emulated European architectural fashions. Benjamin Henry Latrobe, appointed by Thomas Jefferson as Surveyor of Public Buildings of the United States in 1803, was responsible for the design of a number of important stucco buildings, including St. John's Church (1816), in Washington, D.C. (Fig. 2). Nearly half a century later Andrew Jackson Downing also advocated the use of stucco in his influential book *The Architecture of Country Houses*, published in 1850. In Downing's opinion, stucco was superior in many respects to plain brick or stone because it was cheaper, warmer and dryer, and could be "agreeably" tinted. As a result of his advice, stuccoed Italianate style urban and suburban villas proliferated in many parts of the country during the third quarter of the nineteenth century.

Revival Styles Promote Use of Stucco

The introduction of the many revival styles of architecture around the turn of the twentieth century, combined with the improvement and increased availability of portland cement resulted in a "craze" for stucco as a building material in the United States. Beginning about 1890 and gaining momentum into the 1930's and 1940's, stucco was associated with certain historic architectural styles, including: Prairie; Art Deco, and Art Moderne; Spanish Colonial, Mission, Pueblo, Mediterranean, English Cotswold Cottage, and Tudor Revival styles; as well as the ubiquitous bungalow and "four-square" house (Fig. 3). The fad for Spanish Colonial Revival, and other variations on this theme, was especially important in furthering stucco as a building material in the United States during this period, since stucco clearly looked like adobe (Fig. 4).

Fig. 2. St. John's Church, Washington, D.C., constructed of brick and stuccoed immediately upon completion in 1816, reflects the influence of European, and specifically English, architectural styles. Photo: Russell Jones, HABS Collection.

Fig. 3. The William Gray and Edna S. Purcell House, Minneapolis, Minnesota, was designed in 1913 by the architects Purcell and Elmslie in the Prairie style. Stuccoed in a salmon-pink, sand (float) finish, it is unusual in that it featured a 3-color geometric frieze stencilled below the eaves of the 2nd story. The Minneapolis Institute of Art has removed the cream-colored paint added at a later date, and restored the original color and texture of the stucco. Photo: Courtesy MacDonald and Mack Partnership.

Although stucco buildings were especially prevalent in California, the Southwest and Florida, ostensibly because of their Spanish heritage, this period also spawned stucco-coated, revival-style buildings all over the United States and Canada. The popularity of stucco as a cheap, and readily available material meant that by the 1920's, it was used for an increasing variety of building types. Resort hotels, apartment buildings, private mansions and movie theaters, railroad stations, and even gas stations and tourist courts took advantage

Fig. 4. The elaborate Spanish Colonial Revival style of this building designed by Bertram Goodhue for the 1915 Panama California Exposition held in San Diego's Balboa Park emphasizes the sculptural possibilities of stucco. Photo: C.W. Snell, National Historic Landmark Files.

of the "romance" of period styles, and adopted the stucco construction that had become synonymous with these styles (Fig. 5).

A Practical Building Material

Stucco has traditionally been popular for a variety of reasons. It was an inexpensive material that could simulate finely dressed stonework, especially when "scored" or "lined" in the European tradition. A stucco coating over a less finished and less costly substrate such as rubblestone, fieldstone, brick, log or wood frame, gave the building the appearance of being a more expensive and important structure. As a weather-repellent coating, stucco protected the building from wind and rain penetration, and also offered a certain amount of fire protection. While stucco was usually applied during construction as part of the building design, particularly over rubblestone or fieldstone, in some instances it was added later to protect the structure, or when a rise in the owner's social status demanded a comparable rise in his standard of living.

Composition of Historic Stucco

Before the mid-to-late nineteenth century, stucco consisted primarily of hydrated or slaked lime, water and sand, with straw or animal hair included as a binder. Natural cements were frequently used in stucco mixes after their discovery in the United States during the 1820's. Portland cement was first manufactured in the United States in 1871, and it gradually replaced natural cement. After about 1900, most stucco was composed primarily of portland cement, mixed with some lime. With the addition of portland cement, stucco became even more versatile and durable. No longer used just as a coating for a substantial material like masonry or log, stucco could now be applied over wood or metal lath attached to a light wood frame. With this increased strength, stucco ceased to be just a veneer and became a more integral part of the building structure.

Fig. 5. During the 19th and 20th centuries stucco has been a popular material not only for residential, but also for commercial buildings in the Spanish style. Two such examples are (a) the 1851 Ernest Hemingway House, Key West, Florida, built of stuccoed limestone in a Spanish Caribbean style; and (b) the Santa Fe Depot (Union Station), San Diego, California, designed by the architects Bakewell and Brown in 1914 in a Spanish Colonial Revival style, and constructed of stucco over brick and hollow tile. Photos: (a) J.F. Brooks, HABS Collection, (b) Marvin Rand, HABS Collection.

Today, gypsum, which is hydrated calcium sulfate or sulfate of lime, has to a great extent replaced lime. Gypsum is preferred because it hardens faster and has less shrinkage than lime. Lime is generally used only in the finish coat in contemporary stucco work.

The composition of stucco depended on local custom and available materials. Stucco often contained substantial amounts of mud or clay, marble or brick dust, or even sawdust, and an array of additives ranging from animal blood or urine, to eggs, keratin or gluesize (animal hooves and horns), varnish, wheat paste, sugar, salt, sodium silicate, alum, tallow, linseed oil, beeswax, and wine, beer, or rye whiskey. Waxes, fats and oils were included to introduce water-repellent properties, sugary materials reduced the amount of water needed and slowed down the setting time, and alcohol acted as an air entrainer. All of these additives contributed to the strength and durability of the stucco.

The appearance of much stucco was determined by the color of the sand—or sometimes burnt clay, used in the mix, but often stucco was also tinted with natural pigments, or the surface whitewashed or colorwashed after stuccoing was completed. Brick dust could provide color, and other coloring materials that were not affected by lime, mostly mineral pigments, could be added to the mix for the final finish coat. Stucco was also marbled or marbleized—stained to look like stone by diluting oil of vitriol (sulfuric acid) with water, and mixing this with a yellow ochre, or another color (Fig. 6). As the twentieth century progressed, manufactured or synthetic pigments were added at the factory to some prepared stucco mixes.

Methods of Application

Stucco is applied directly, without lath, to masonry substrates such as brick, stone, concrete or hollow tile (Fig. 7). But on wood structures, stucco, like its interior counterpart plaster, must be applied over lath in order to obtain an adequate key to hold the stucco. Thus, when applied over a log structure, stucco is laid on horizontal wood lath that has been nailed on vertical wood furring strips attached to the logs (Fig. 8). If it is applied over a wood frame structure, stucco may be applied to wood or metal lath nailed directly to the wood frame; it may also be placed on lath that has been attached to furring strips. The furring strips are themselves laid over building paper covering the wood sheathing (Fig. 9). Wood lath was gradually superseded by expanded metal lath introduced in the late-nineteenth and early-twentieth century. When stuccoing over a stone or brick substrate, it was customary to cut back or rake out the mortar joints if they were not already recessed by natural weathering or

Fig. 6. Arlington House, Arlington, Virginia, was built between 1802-1818 of brick covered with stucco. It was designed by George Hadfield for George Washington Parke Custis, grandson of Martha Washington, and was later the home of Robert E. Lee. This photograph taken on June 28, 1864, by Captain Andrew J. Russell, a U.S. Signal Corps photographer, shows the stucco after it had been marbleized during the 1850's. Yellow ochre and burnt umber pigments were combined to imitate Sienna marble, and the stucco, with the exception of the roughcast foundation, was scored to heighten the illusion of stone. Photo: National Archives, Arlington House Collection, National Park Service.

Fig. 7. Patches of stucco have fallen off this derelict 19th century structure exposing the rough-cut local stone substrate. The missing wood entablature on the side and the rough wood lintel now exposed above a second-floor window, offer clues that the building was stuccoed originally. Photo: National Park Service Files.

Fig. 8. Removal of deteriorated stucco in preparation for stucco repair on this late-18th century log house in Middleway, West Virginia, reveals that the stucco was applied to hand-riven wood lath nailed over vertical wood strips attached to the logs. Photo: Anne Grimmer.

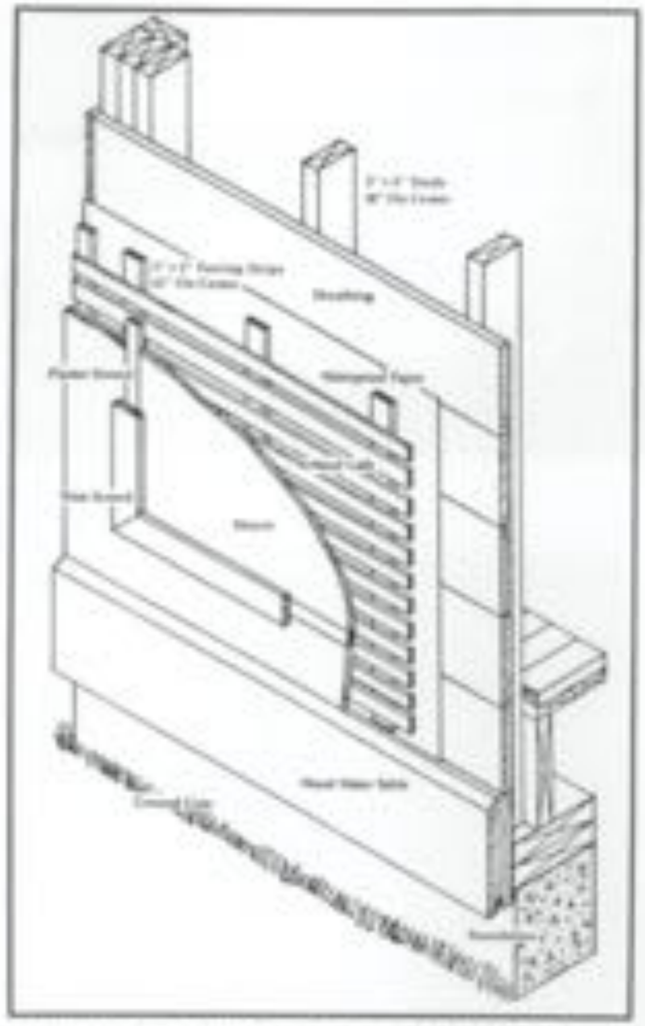
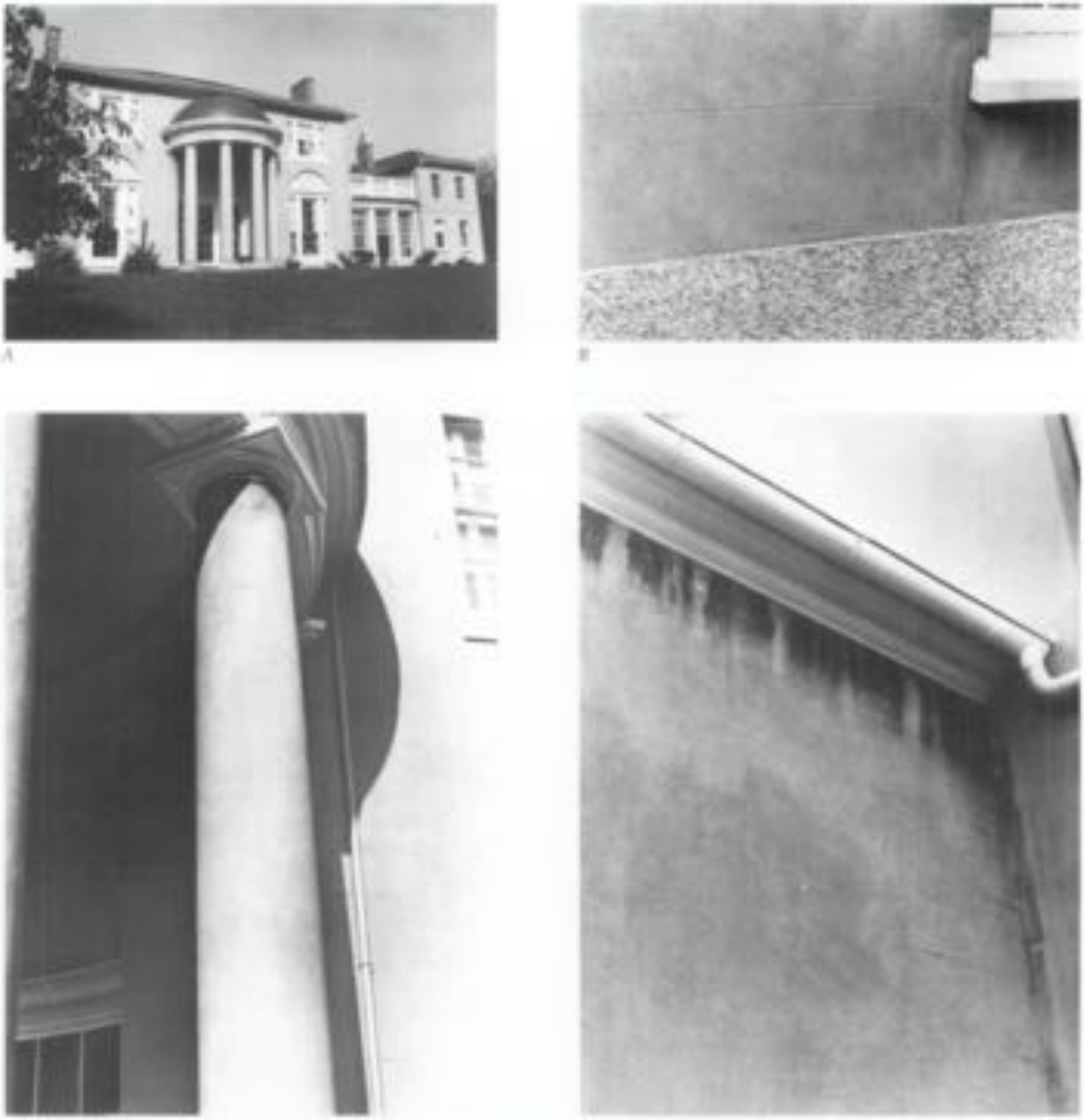


Fig. 9. This cutaway drawing shows the method of attachment for stucco commonly used on wood frame or balloon frame structures from the late-19th to the 20th century. Drawing: Brian Conway, "Illinois Preservation Series Number 2: Stucco."

erosion, and sometimes the bricks themselves were gouged to provide a key for the stucco. This helped provide the necessary bond for the stucco to remain attached to the masonry, much like the key provided by wood or metal lath on frame buildings.

Like interior wall plaster, stucco has traditionally been applied as a multiple-layer process, sometimes consisting of two coats, but more commonly as three. Whether applied directly to a masonry substrate or onto wood or metal lath, this consists of a first "scratch" or "pricking-up" coat, followed by a second scratch coat, sometimes referred to as a "floating" or "brown" coat, followed finally by the "finishing" coat. Up until the late-nineteenth century, the first and the second coats were of much the same composition, generally consisting of lime, or natural cement, sand, perhaps clay, and one or more of the additives previously mentioned. Straw or animal hair was usually added to the first coat as a binder. The third, or finishing coat, consisted primarily of a very fine mesh grade of lime and sand, and sometimes pigment. As already noted, after the 1820's, natural cement was also a common ingredient in stucco until it was replaced by portland cement.



A

B

C

D

Fig. 10. (a) Tudor Place, Washington, D.C. (1805–1816), was designed by Dr. William Thornton. Like its contemporary, Arlington House, it is stuccoed and scored, with a roughcast base, but here the stucco is a monochromatic sandstone color tinted by sand and mineral pigments (b). Although the original stucco was replaced in the early-20th century with a portland cement-based stucco, the family, who retained ownership until 1984 when the house was opened to the public, left explicit instructions for future stucco repairs. The mix recommended for repairing hairline cracks (c), consists of sharp sand, cement and lime, burnt umber, burnt sienna, and a small amount of raw sienna. Preparation of numerous test samples, the size of "a thick griddle cake," will be necessary to match the stucco color, and when the exact color has been achieved, the mixture is to be diluted to the "consistency of cream," brushed on the wall and rubbed into the cracks with a rubber sponge or float. Note the dark color visible under the eaves intended to replicate the stronger color of the original limewashed stucco (d). Photos: Anne Grimmer.

Both masonry and wood lath must be kept wet or damp to ensure a good bond with the stucco. Wetting these materials helps to prevent them from pulling moisture out of the stucco too rapidly, which results in cracking, loss of bond, and generally poor quality stuccowork.

Traditional Stucco Finishes

Until the early-twentieth century when a variety of novelty finishes or textures were introduced, the last coat of stucco was commonly given a smooth, troweled finish, and then scored or lined in imitation of ashlar. The illusion of masonry joints was sometimes enhanced by a thin line of white lime putty, graphite, or some other pigment. Some nineteenth century buildings feature a water table or raised foundation of rough-cast stucco that differentiates it from the stucco surface above, which is smooth and scored (Fig. 10). Other novelty or textured finishes associated with the "period" or revival styles of the early-twentieth century include: the English cottage finish, adobe and Spanish, pebble-dashed or dry-dash surface, fan and sponge texture, reticulated and vermiculated, roughcast (or wet dash), and sgraffito (Fig. 11).

Repairing Deteriorated Stucco

Regular Maintenance

Although A. J. Downing alluded to stuccoed houses in Pennsylvania that had survived for over a century in relatively good condition, historic stucco is inherently not a particularly permanent or long-lasting building material. Regular maintenance is required to keep it in good condition. Unfortunately, many older or historic buildings are not always accorded this kind of care.

Because building owners knew stucco to be a protective, but also somewhat fragile coating, they employed a variety of means to prolong its usefulness. The most common treatment was to whitewash stucco, often annually. The lime in the whitewash offered protection and stability and helped to harden the stucco. Most importantly, it filled hairline cracks before they could develop into larger cracks and let in moisture. To improve water repellency, stucco buildings were also sometimes coated with paraffin, another type of wax, or other stucco-like coatings, such as oil mastics.

Assessing Damage

Most stucco deterioration is the result of water infiltration into the building structure, either through the roof, around chimneys, window and door openings, or excessive ground water or moisture penetrating through, or splashing up from the foundation. Potential causes of deterioration include: ground settlement, lintel and door frame settlement, inadequate or leaking gutters and downspouts, intrusive vegetation, moisture migration within walls due to interior condensation and humidity, vapor drive problems caused by furnace, bathroom and kitchen vents, and rising damp resulting from excessive ground water and poor drainage around the foundation. Water infiltration will cause wood lath to rot, and metal lath and nails to rust, which eventually will cause stucco to lose its bond and pull away from its substrate.

*Fig. 11. The Hotel Washington, Washington, D.C. (1916–1917), is notable for its decorative **sgraffito** surfaces. Stucco panels under the cornice and around the windows feature classical designs created by artists who incised the patterns in the outer layer of red-colored stucco while still soft, thereby exposing a stucco undercoat of a contrasting color. Photo: Kaye Ellen Simonson.*

After the cause of deterioration has been identified, any necessary repairs to the building should be made first before repairing the stucco. Such work is likely to include repairs designed to keep excessive water away from the stucco, such as roof, gutter, downspout and flashing repairs, improving drainage, and redirecting rainwater runoff and splash-back away from the building. Horizontal areas such as the tops of parapet walls or chimneys are particularly vulnerable to water infiltration, and may require modifications to their original design, such as the addition of flashing to correct the problem.

Previous repairs inexpertly carried out may have caused additional deterioration, particularly if executed in portland cement, which tends to be very rigid, and therefore incompatible with early, mostly soft lime-based stucco that is more "flexible." Incompatible repairs, external vibration caused by traffic or construction, or building settlement can also result in cracks which permit the entrance of water and cause the stucco to fail (Fig. 12).

Before beginning any stucco repair, an assessment of the stucco should be undertaken to determine the extent of the damage, and how much must be replaced or repaired. Testing should be carried out systematically on all elevations of the building to determine the overall condition of the stucco. Some areas in need of repair will be clearly evidenced by missing sections of stucco or stucco layers. Bulging or cracked areas are obvious places to begin. Unsound, punky or soft areas that have lost their key will echo with a hollow sound when tapped gently with a wooden or acrylic hammer or mallet.

Identifying the Stucco Type

Analysis of the historic stucco will provide useful information on its primary ingredients and their proportions, and will help to ensure that the new replacement stucco will duplicate the old in strength, composition, color and texture as closely as possible. However, unless authentic, period restoration is required, it may not be worthwhile, nor in many instances possible, to attempt to duplicate *all* of the ingredients (particularly some of the additives), in creating the new stucco mortar. Some items are no longer available, and others, notably sand and lime—the major components of traditional stucco—have changed radically over time. For example, most sand used in contemporary masonry work is manufactured sand, because river sand, which was used historically, is difficult to obtain today in many parts of the country. The physical and visual qualities of manufactured sand versus river sand, are quite different, and this affects the way stucco works, as well as the way it looks. The same is true of lime, which is frequently replaced by gypsum in modern stucco mixes. And even if identification of all the items in the historic stucco mix were possible, the analysis would still not reveal how the original stucco was mixed and applied.

There are, however, simple tests that can be carried out on a small piece of stucco to determine its basic makeup. A dilute solution of hydrochloric (muriatic) acid will dissolve lime-based stucco, but not portland cement. Although the use of portland cement became common after 1900, there are no precise cut-off dates, as stuccoing practices varied among individual plasterers, and from region to region. Some plasterers began using portland cement in the 1880's, but others may have continued to favor lime stucco well into the early-twentieth century. While it is safe to assume that a late-eighteenth or early-nineteenth century stucco is lime-based, late-nineteenth or early-twentieth century

Fig. 12. (a) Water intrusion caused by rusting metal, or (b) plant growth left unattended will gradually enlarge these cracks, resulting in spalling, and eventually requiring extensive repair of the stucco. Photos: National Park Service Files.

Fig. 13. (a) In preparation for repainting, hairline cracks on this Mediterranean style stucco apartment building were filled with a commercial caulking compound; (b) dirt is attracted and adheres to the texture of the caulked areas, and a year after painting, these inappropriate repairs are highly obvious. Photos: Anne Grimmer.

stucco may be based on either lime or portland cement. Another important factor to take into consideration is that an early lime-stucco building is likely to have been repaired many times over the ensuing years, and it is probable that at least some of these patches consist of portland cement.

Planning the Repair

Once the extent of damage has been determined, a number of repair options may be considered. Small hairline cracks usually are not serious and may be sealed with a thin slurry coat consisting of the finish coat ingredients, or even with a coat of paint or whitewash. Commercially available caulking compounds are not suitable materials for patching hairline cracks. Because their consistency and texture is unlike that of stucco, they tend to weather differently, and attract more dirt; as a result, repairs made with caulking compounds may be highly visible, and unsightly (Fig. 13). Larger cracks will have to be cut out in preparation for more extensive repair. Most stucco repairs will require the skill and expertise of a professional plasterer (Fig. 14).

In the interest of saving or preserving as much as possible of the historic stucco, patching rather than wholesale replacement is preferable. When repairing heavily textured surfaces, it is not usually necessary to replace an entire wall section, as the textured finish, if well-executed, tends to conceal patches, and helps them to blend in with the existing stucco. However, because of the nature of smooth-finished stucco, patching a number of small areas scattered over one elevation may not be a successful repair approach unless the stucco has been previously painted, or is to be painted following the repair work. On unpainted stucco such patches are hard to conceal, because they may not match exactly or blend in with the rest of the historic stucco surface. For

Fig. 14. This poorly executed patch is not the work of a professional plasterer. While it may serve to keep out water, it does not match the original surface, and is not an appropriate repair for historic stucco. Photo: Betsy Chittenden.

this reason it is recommended, if possible, that stucco repair be carried out in a contained or well-defined area, or if the stucco is scored, the repair patch should be "squared-off" in such a way as to follow existing scoring. In some cases, especially in a highly visible location, it may be preferable to restucco an entire wall section or feature. In this way, any differences between the patched area and the historic surface will not be so readily apparent.

Repair of historic stucco generally follows most of the same principles used in plaster repair. First, all deteriorated, severely cracked and loose stucco should be removed down to the lath (assuming that the lath is securely attached to the substrate), or down to the masonry if the stucco is directly applied to a masonry substrate. A clean surface is necessary to obtain a good bond between the stucco and substrate. The areas to be patched should be cleaned of all debris with a bristle brush, and all plant growth, dirt, loose paint, oil or grease should be removed (Fig. 15). If necessary, brick or stone mortar joints should then be raked out to a depth of approximately 5/8" to ensure a good bond between the substrate and the new stucco.

To obtain a neat repair, the area to be patched should be squared-off with a butt joint, using a cold chisel, a hatchet, a diamond blade saw, or a masonry bit. Sometimes it may be preferable to leave the area to be patched in an irregular shape which may result in a less conspicuous patch. Proper preparation of the area to be patched requires very sharp tools, and extreme caution on the part of the plasterer not to break keys of surrounding good stucco by "over-sounding" when removing deteriorated stucco. To ensure a firm bond, the new patch must not overlap the old stucco. If the stucco has lost its bond or key from wood lath, or the lath has deteriorated or come loose from the substrate, a decision must be made whether to try to reattach the old lath, to replace deteriorated lath with new wood lath, or to leave the historic wood lath in place and supplement it with modern expanded metal lath. Unless authenticity is important, it is generally preferable (and easier) to nail new metal lath over the old wood lath to support the patch. Metal lath that is no longer securely fastened to the substrate may be removed and replaced in kind, or left in place, and supplemented with new wire lath.

When repairing lime-based stucco applied directly to masonry, the new stucco should be applied in the same manner, directly onto the stone or brick. The stucco will bond onto the masonry itself without the addition of lath because of the irregularities in the masonry or those of its mortar joints, or because its surface has been scratched, scored or otherwise roughened to provide an additional key. Cutting out the old stucco at a diagonal angle may also help secure the bond between the new and the old stucco. For the most part it is not advisable to insert metal lath when restuccoing historic masonry in sound condition, as it can hasten deterioration of the repair work. Not only will attaching the lath damage the masonry, but the slightest moisture penetration can cause metal lath to rust. This will cause metal to expand, eventually resulting in spalling of the stucco, and possibly the masonry substrate too.

If the area to be patched is properly cleaned and prepared, a bonding agent is usually not necessary. However, a bonding agent may be useful when repairing hairline cracks, or when dealing with substrates that do not offer a good bonding surface. These may include dense stone or brick, previously painted or stuccoed

Fig. 15. (a) After reattaching any loose wood lath to the furring strips underneath, the area to be patched has been cleaned, the lath thoroughly wetted, and (b) the first coat of stucco has been applied and scratched to provide a key to hold the second layer of stucco. Photos: Betsy Chittenden.

masonry, or spalling brick substrates. A good mechanical bond is always preferable to reliance on bonding agents. Bonding agents should not be used on a wall that is likely to remain damp or where large amounts of salts are present. Many bonding agents do not survive well under such conditions, and their use could jeopardize the longevity of the stucco repair.

A stucco mix compatible with the historic stucco should be selected after analyzing the existing stucco. It can be adapted from a standard traditional mix of the period, or based on one of the mixes included here. Stucco consisting mostly of portland cement generally will not be physically compatible with the softer, more flexible lime-rich historic stuccos used throughout the eighteenth and much of the nineteenth centuries. The differing expansion and contraction rates of lime stucco and portland cement stucco will normally cause the stucco to crack. Choosing a stucco mix that is durable and compatible with the historic stucco on the building is likely to involve considerable trial and error, and probably will require a number of test samples, and even more if it is necessary to match the color. It is best to let the stucco test samples weather as long as possible—ideally one year, or at least through a change of seasons, in order to study the durability of the mix and its compatibility with the existing stucco, as well as the weathering of the tint if the building will not be painted and color match is an important factor. If the test samples are not executed on the building, they should be placed next to the stucco remaining on the building to compare the color, texture and composition of the samples with the original. The number and thickness of stucco coats used in the repair should also match the original.

After thoroughly dampening the masonry or wood lath, the first, scratch coat should be applied to the masonry substrate, or wood or metal lath, in a thickness that corresponds to the original if extant, or generally about 1/4" to 3/8". The scratch coat should be scratched or cross-hatched with a comb to provide a key to hold the second coat. It usually takes 24-72 hours, and longer in cold weather, for each coat to dry before the next coat can be applied. The second coat should be about the same thickness as the first, and the total thickness of the first two coats should generally not exceed about 5/8". This second or leveling coat should be roughened using a wood float with a nail protruding to provide a key for the final or finish coat. The finish coat, about 1/4" thick, is applied after the previous coat has initially set. If this is not feasible, the base coat should be thoroughly dampened when the finish coat is applied later. The finish coat should be worked to match the texture of the original stucco (Fig. 36).

Colors and Tints for Historic Stucco Repair

The color of most early stucco was supplied by the aggregate included in the mix—usually the sand. Sometimes natural pigments were added to the mix, and eighteenth and nineteenth-century scored stucco was often marbleized or painted in imitation of marble or granite. Stucco was also frequently coated with whitewash or a colorwash. This tradition later evolved into the use of paint, its popularity depending on the vagaries of fashion as much as a means of concealing repairs. Because most of the early colors were derived from nature, the resultant stucco tints tended to be mostly earth-toned. This was true until the advent of brightly colored stucco in the early decades of the twentieth century. This was the so-called "Jazz Plaster" developed by O.A. Malone, the "man who put color into California," and who founded the California Stucco Products Corporation in 1927. California Stucco was revolutionary for its time as the first stucco/plaster to contain colored pigment in its pre-packaged factory mix.

When patching or repairing a historic stucco surface known to have been tinted, it may be possible to determine through visual or microscopic analysis whether the source of the coloring is sand, cement or pigment. Although some pigments or aggregates used traditionally may no longer be available, a sufficiently close color-match can generally be approximated using sand, natural or mineral pigments, or a combination of these. Obtaining such a match will require testing and comparing the color of dried test samples with the original. Successfully combining pigments in the dry stucco mix prepared for the finish coat requires considerable skill. The amount of pigment must be carefully measured for each batch of stucco. Overworking the mix can make the pigment separate from the lime. Changing the amount of water added to the mix, or using water to apply the tinted finish coat, will also affect the color of the stucco when it dries.

Generally, the color obtained by hand-mixing these ingredients will provide a sufficiently close match to cover an entire wall or an area distinct enough from the rest of the structure that the color differences will not be obvious. However, it may not work for small patches conspicuously located on a primary elevation, where color differences will be especially noticeable. In these instances, it may be necessary to conceal the repairs by painting the entire patched elevation, or even the whole building.

Many stucco buildings have been painted over the years and will require repainting after the stucco repairs have been made. Limewash or cement-based paint, latex paint, or oil-based paint are appropriate coatings for stucco buildings. The most important factor to consider when repainting a previously painted or coated surface is that the new paint be compatible with any coating already on the surface. In preparation for repainting, all loose or peeling paint or other coating material not firmly adhered to the stucco must be removed by hand-scraping or natural bristle brushes. The surface should then be cleaned.

Cement-based paints, most of which today contain some portland cement and are really a type of limewash, have traditionally been used on stucco buildings. The ingredients were easily obtainable. Furthermore, the lime in such paints actually bonded or joined with the stucco and provided a very durable coating. In many regions, whitewash was applied annually during spring cleaning. Modern, commercially available premixed masonry and mineral-based paints may also be used on historic stucco buildings.

Fig. A

Fig. B

Fig. C

Fig. D

Fig. 36. (a) In preparation for stucco repair, this plasterer is mixing the dry materials in a mortar box with a mortar hoe (note the 2 holes in the blade), pulling it through the box using short choppy strokes. After the dry materials are thoroughly combined, water is added and mixed with them using the same choppy, but gradually lengthening stokes, making sure that the hoe cuts completely through the mix to the bottom of the box. (b) The deteriorated stucco has been cut away, and new metal lath has been nailed to the clapboarding in the area to be patched. (Although originally clapboarded when built in the 19th century, the house was stuccoed around the turn-of-the-century on metal lath nailed over the clapboard.) (c) The first, scratch coat and the second coat have been applied here, and await the spatterdash or rough-cast finish of the final coat (d) which was accomplished by the plasterer using a whisk broom to throw the stucco mortar against the wall surface. This well-executed patch is barely discernable, and lacks only a coat of paint to make it blend completely with the rest of the painted wall surface. Photos: Anne Grimmer.

If the structure must be painted for the first time to conceal repairs, almost any of these coatings may be acceptable depending on the situation. Latex paint, for example, may be applied to slightly damp walls or where there is an excess of moisture, but latex paint will not stick to chalky or powdery areas. Oil-based, or alkyd paints must be applied only to dry walls; new stucco must cure up to a year before it can be painted with oil-based paint.

Contemporary Stucco Products

There are many contemporary stucco products on the market today. Many of them are not compatible, either physically or visually, with historic stucco buildings. Such products should be considered for use only after consulting with a historic masonry specialist. However, some of these prepackaged tinted stucco coatings may be suitable for use on stucco buildings dating from the late-nineteenth or early-twentieth century, as long as the color and texture are appropriate for the period and style of the building. While some masonry contractors may, as a matter of course, suggest that a water-repellent coating be applied after repairing old stucco, in most cases this should not be necessary, since color-washes and paints serve the same purpose, and stucco itself is a protective coating.

Cleaning Historic Stucco Surfaces

Historic stucco buildings often exhibit multiple layers of paint or limewash. Although some stucco surfaces may be cleaned by water washing, the relative success of this procedure depends on two factors: the surface texture of the stucco, and the type of dirt to be removed. If simply removing airborne dirt, **smooth unpainted stucco,** and **heavily-textured painted stucco** may sometimes be cleaned using a low-pressure water wash, supplemented by scrubbing with soft natural bristle brushes, and possibly non-ionic detergents. Organic plant material, such as algae and mold, and metallic stains may be removed from stucco using poultices and appropriate solvents. Although these same methods may be employed to clean **unpainted roughcast, pebble-dash, or any stucco surface featuring exposed aggregate,** due to the surface irregularities, it may be difficult to remove dirt, without also removing portions of the decorative textured surface. Difficulty in cleaning these surfaces may explain why so many of these textured surfaces have been painted.

When Total Replacement is Necessary

Complete replacement of the historic stucco with new stucco of either a traditional or modern mix will probably be necessary only in cases of extreme deterioration—that is, a loss of bond on over 40-50 per cent of the stucco surface. Another reason for total removal might be that the physical and visual integrity of the historic stucco has been so compromised by prior incompatible and ill-conceived repairs that patching would not be successful.

When stucco no longer exists on a building there is more flexibility in choosing a suitable mix for the replacement. Since compatibility of old and new stucco will not be an issue, the most important factors to consider are durability, color, texture and finish. Depending on the construction and substrate of the building, in some instances it may be acceptable to use a relatively strong cement-based stucco mortar. This is certainly true for many late-nineteenth and early-twentieth century buildings, and may even be appropriate to use on some stone substrates even if the original mortar would have been weaker, as long as the historic visual qualities noted above have been replicated. Generally, the best principle to follow for a masonry building is that the stucco mix, whether for repair or replacement of historic stucco, should be somewhat weaker than the masonry to which it is to be applied in order not to damage the substrate.

General Guidance for Historic Stucco Repair

A skilled professional plasterer will be familiar with the properties of materials involved in stucco repair and will be able to avoid some of the pitfalls that would hinder someone less experienced. General suggestions for successful stucco repair parallel those involving restoration and repair of historic mortar or plaster. In addition, the following principles are important to remember:

- Mix only as much stucco as can be used in one and one-half to two hours. This will depend on the weather (mortar will harden faster under hot and dry, or sunny conditions); and experience is likely to be the best guidance. Any remaining mortar should be discarded; it should not be retempered.

- Stucco mortar should not be over-mixed. (Hand mix for 10–15 minutes after adding water, or machine mix for 3–4 minutes after all ingredients are in mixer.) Over-mixing can cause crazing and discoloration, especially in tinted mortars. Over-mixing will also tend to make the mortar set too fast, which will result in cracking and poor bonding or keying to the lath or masonry substrate.

- Wood lath or a masonry substrate, but not metal lath, must be thoroughly wetted before applying stucco patches so that it does not draw moisture out of the stucco too rapidly. To a certain extent, bonding agents also serve this same purpose. Wetting the substrate helps retard drying.

- To prevent cracking, it is imperative that stucco not dry too fast. Therefore, the area to be stuccoed should be shaded, or even covered if possible, particularly in hot weather. It is also a good idea in hot weather to keep the newly stuccoed area damp, at approximately 90 per cent humidity, for a period of 48 to 72 hours.

- Stucco repairs, like most other exterior masonry work, should not be undertaken in cold weather (below 40 degrees fahrenheit, and preferably warmer), or if there is danger of frost.

Historic Stucco Textures

Most of the oldest stucco in the U.S. dating prior to the late-nineteenth century, will generally have a **smooth, troweled finish** (sometimes called a **sand** or **float finish**), possibly scored to resemble ashlar masonry units. Scoring may be incised to simulate masonry joints, the scored lines may be emphasized by black or white penciling, or the lines may simply be drawn or painted on the surface of the stucco. In some regions, at least as early as the first decades of the nineteenth century, it was not uncommon to use a **roughcast finish** on the foundation or base of an otherwise **smooth-surfaced** building (Fig. a). **Roughcast** was also used as an overall stucco finish for some outbuildings, and other less important types of structures.

A wide variety of decorative surface textures may be found on revival style stucco buildings, particularly residential architecture. These styles evolved in the late-nineteenth century and peaked in popularity in the early decades of the twentieth century. Frank Lloyd Wright favored a **smooth finish** stucco, which was imitated on much of the Prairie style architecture inspired by his work. Some of the more picturesque surface textures include: **English Cottage** or **English Cotswold finish**; **sponge finish** (Fig. b); **fan texture**; **adobe finish** (Fig. c), and **Spanish** or **Italian finish**. Many of these finishes and countless other regional and personalized variations on them are still in use.

The most common early-twentieth century stucco finishes are often found on bungalow-style houses, and include: **spatter** or **spatterdash** (sometimes called **roughcast, harling,** or **wetdash**), and **pebbledash** or **drydash.** The **spatterdash** finish is applied by throwing the stucco mortar against the wall using a whisk broom or a stiff fiber brush, and it requires considerable skill on the part of the plasterer to achieve a consistently rough wall surface. The mortar used to obtain this texture is usually composed simply of a regular sand, lime, and cement mortar, although it may sometimes contain small pebbles or crushed stone aggregate, which replaces one-half the normal sand content. The **pebbledash** or **drydash finish** is accomplished manually by the plasterer throwing or "dashing" dry pebbles (about 1/8" to 1/4" in size), onto a coat of stucco freshly applied by another plasterer. The pebbles must be thrown at the wall with a scoop with sufficient force and skill that they will stick to the stuccoed wall. A more even or uniform surface can be achieved by patting the stones down with a wooden float. This finish may also be created using a texturing machine (Figs. d-f illustrate 3 versions of this finish. Photos: National Park Service Files).

Fig. A

Fig. B

Fig. C

Fig. D

Fig. E

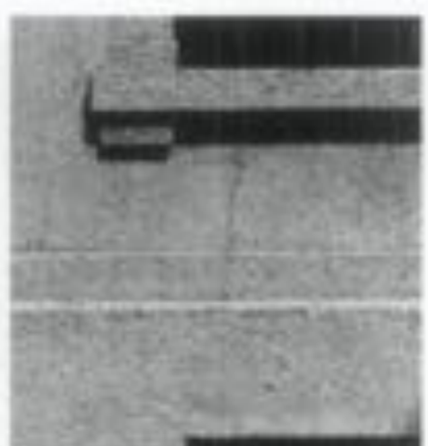


Fig. F

Summary

Stucco on historic buildings is especially vulnerable not only to the wear of time and exposure to the elements, but also at the hands of well-intentioned "restorers," who may want to remove stucco from eighteenth and nineteenth century structures, to expose what they believe to be the original or more "historic" brick, stone or log underneath. Historic stucco is a character-defining feature and should be considered an important historic building material, significant in its own right. While many eighteenth and nineteenth century buildings were stuccoed at the time of construction, others were stuccoed later for reasons of fashion or practicality. As such, it is likely that this stucco has acquired significance over time, as part of the history and evolution of a building. Thus, even later, non-historic stucco should be retained in most instances; and similar logic dictates that new stucco should not be applied to a historic building that was not stuccoed previously. When repairing historic stucco, the new stucco should duplicate the old as closely as possible in strength, composition, color and texture.

Mixes for Repair of Historic Stucco

Historic stucco mixes varied a great deal regionally, depending as they did on the availability of local materials. There are probably almost as many mixes that can be used for repair of historic stucco as there are historic stucco buildings. For this reason it is recommended that at least a rudimentary analysis of the existing historic stucco be carried out in order to determine its general proportions and primary ingredients. However, if this is not possible, or if test results are inconclusive, the following mixes are provided as reference. Many of the publications listed under "Selected Reading" include a variety of stucco mixes and should also be consulted for additional guidance.

Materials Specifications should conform to those contained in *Preservation Briefs 2: Repointing Mortar Joints in Historic Brick Buildings*, and are as follows:

- Lime should conform to ASTM C-207, Type S, Hydrated Lime for Masonry Purposes.
- Sand should conform to ASTM C-144 to assure proper gradation and freedom from impurities. Sand, or other type of aggregate, should match the original as closely as possible.
- Cement should conform to ASTM C-150, Type II (white, non-staining), portland cement.
- Water should be fresh, clean and potable.
- If hair or fiber is used, it should be goat or cattle hair, or pure manilla fiber of good quality, 1/2" to 2" in length, clean, and free of dust, dirt, oil, grease or other impurities.
- Rules to remember: More lime will make the mixture more plastic, but stucco mortar with a very large proportion of lime to sand is more likely to crack because of greater shrinkage; it is also weaker and slower to set. More sand or aggregate, will minimize shrinkage, but make the mixture harder to trowel smooth, and will weaken the mortar.

Soft Lime Stucco (suitable for application to buildings dating from 1700–1850)

A.J. Downing's Recipe for Soft Lime Stucco

1 part lime
2 parts sand
(A.J. Downing, "The Architecture of Country Houses," 1850)

Vieux Carre Masonry Maintenance Guidelines

Base Coats (2):
1 part by volume hydrated lime
3 parts by volume aggregate [sand]—size to match original
6 pounds/cubic yards hair or fiber
Water to form a workable mix.
Finish Coat:
1 part by volume hydrated lime
3 parts aggregate [sand]—size to match original
Water to form a workable mix.

Note: No portland cement is recommended in this mix, but if it is needed to increase the workability of the mix and to decrease the setting time, the amount of portland cement added should never exceed 1 part to 12 parts lime and sand.
("Vieux Carre Masonry Maintenance Guidelines," June, 1980.)

"Materials for Soft Brick Mortar and for Soft Stucco"

5 gallons hydrated lime
10 gallons sand
1 quart white, non-staining portland cement (1 cup only for pointing)
Water to form a workable mix.
(Koch and Wilson, Architects, New Orleans, Louisiana, February, 1980)

Mix for Repair of Traditional Natural Cement or Hydraulic Lime Stucco

1 part by volume hydrated lime
2 parts by volume white portland cement
3 parts by volume fine mason's sand
If hydraulic lime is available, it may be used instead of lime-cement blends.
("Conservation Techniques for the Repair of Historical Ornamental Exterior Stucco, January, 1990)

Early-twentieth century Portland Cement Stucco

1 part portland cement
2 1/2 parts sand
Hydrated lime = to not more than 15% of the cement's volume
Water to form a workable mix.
The same basic mix was used for all coats, but the finish coat generally contained more lime than the undercoats. ("Illinois Preservation Series No. 2: Stucco," January, 1980)

American Portland Cement Stucco Specifications (c. 1929)

Base Coats:
5 pounds, dry, hydrated lime
1 bag portland cement (94 lbs.)
Not less than 3 cubic feet (3 bags) sand (passed through a #8 screen)
Water to make a workable mix.
Finish Coat:
Use WHITE portland cement in the mix in the same proportions as above.
To color the stucco add not more than 10 pounds pigment for each bag of cement contained in the mix.

Selected Reading

Ashurst, John, and Nicola Ashurst. *Practical Building Conservation. English Heritage Technical Handbook. Volume 3: Mortars, Plasters and Renders.* New York: Halsted Press, 1988.

Conway, Brian D. *Illinois Preservation Series Number 2: Stucco.* Springfield, IL: Illinois Department of Conservation, Division of Historic Sites, 1980.

Grimmer, Anne E. *Keeping it Clean: Removing Exterior Dirt, Paint, Stains and Graffiti from Historic Masonry Buildings.* Washington, D.C.: National Park Service, U.S. Department of the Interior, 1988.

Hodgson, Frederick T. *Plaster and Plastering. Mortars and Cements, How to Make, and How to Use . . . with An Illustrated Glossary of Terms.* New York: The Industrial Publication Company, 1901.

Johnson, LeRoy, Jr. (editor). *Handbook of Maintenance Techniques for Building Conservation in the Strand Historic District, Galveston, Texas.* (Revised edition originally published in 1980 as *Preservation Maintenance Handbook*, prepared by Michael Emrick, AIA, for the Galveston Historical Foundation.) Austin, TX: Texas Historical Commission, 1984.

Jowers, Walter. "Bungalow Building Materials: How to Repair Stucco." *The Old-House Journal.* Vol. XIII, No. 4 (May 1985), pp. 80-83.

MacDonald, Marylee. *Preservation Briefs 21: Repairing Historic Flat Plaster-Walls and Ceilings.* Washington, D.C.: National Park Service, U.S. Department of the Interior, 1989.

Mack, Robert C., AIA, de Teel Patterson Tiller, and James S. Askins. *Preservation Briefs 2: Repointing Mortar Joints in Historic Brick Buildings.* Washington, D.C.: National Park Service, U.S. Department of the Interior, 1980.

McKee, Harley J., FAIA. *Introduction to Early American Masonry—Stone, Brick, Mortar and Plaster.* Washington, D.C.: National Trust for Historic Preservation and Columbia University, 1973.

Matero, Frank G., Mary Hardy, Antonio Rava and Joel Snodgrass. *Conservation Techniques for the Repair of Historical Ornamental Exterior Stucco.* (With a Case Study for the Repair of the Cabildo Pedimental Sculpture). Report prepared for the Division of Historic Preservation, Office of Cultural Development, Louisiana Department of Culture, Recreation and Development by The Center for Preservation Research, Columbia University, New York. January 1990.

Portland Cement Plaster (Stucco) Manual. Skokie, IL: Portland Cement Association, 1980.

Van Den Branden, F., and Thomas L. Hartsell. *Plastering Skills.* Second edition. Homewood, IL: American Technical Publishers, Inc., 1984.

Vieux Carre Masonry Maintenance Guidelines. Revised from the initial report prepared by Mary L. Oehrlein in 1977. New Orleans, LA: Vieux Carre Commission, 1980.

Whitewash & Coldwater Paints. Bulletin No. 304-G. Washington, D.C.: National Lime Association, 1955.

Wrenham, Gibson. "Exterior Plaster Restoration at the Lord Morton House, Lexington, Kentucky." *Association for Preservation Technology Bulletin.* Vol. XIII, No. 4 (1981), pp. 27-33.

Acknowledgements

The author gratefully acknowledges the technical expertise contributed to the preparation of this publication by Gilbert Wolf, National Plastering Industries; Walter Jowers; Brian Conway, Michigan Bureau of History; and master plasterer, Lawrence Ring, Sr. In addition, invaluable comments were provided by Michael Auer, Charles Fisher, Lauren Meier, Sharon Park, and Kay Weeks, professional staff of the Technical Preservation Services Branch, National Park Service; professional staff of the Cultural Resources program, Mid-Atlantic Regional Office, National Park Service; and S. Elizabeth Sasser of the Williamsport Preservation Training Center, National Park Service.

This publication has been prepared pursuant to the National Historic Preservation Act of 1966, as amended, which directs the Secretary of the Interior to develop and make available information concerning historic properties. Comments on the usefulness of this publication may be directed to H. Ward Jandl, Chief, Technical Preservation Services Branch, Preservation Assistance Division, National Park Service, P.O. Box 37127, Washington, D.C. 20013-7127.

October 1990

Cover Photograph: St. James Church, Goose Creek, Berkeley County, South Carolina (1713–1719), is constructed of brick covered with stucco. Although much restored, it is notable for its ornamental stucco detailing, including rusticated quoins, cherub head "keystones" above the windows, flaming hearts, and a pelican in piety—symbol of the sacrament, in the pediment over the front door. Photo: Gary Hume.

24 PRESERVATION BRIEFS

Heating, Ventilating, and Cooling Historic Buildings: Problems and Recommended Approaches

Sharon C. Park, AIA

U.S. Department of the Interior
National Park Service
Cultural Resources
Heritage Preservation Services

The need for modern mechanical systems is one of the most common reasons to undertake work on historic buildings. Such work includes upgrading older mechanical systems, improving the energy efficiency of existing buildings, installing new heating, ventilation or air conditioning (HVAC) systems, or—particularly for museums—installing a climate control system with humidification and dehumidification capabilities. Decisions to install new HVAC or climate control systems often result from concern for occupant health and comfort, the desire to make older buildings marketable, or the need to provide specialized environments for operating computers, storing artifacts, or displaying museum collections. Unfortunately, occupant comfort and concerns for the objects within the building are sometimes given greater consideration than the building itself. In too many cases, applying modern standards of interior climate comfort to historic buildings has proven detrimental to historic materials and decorative finishes.

This Preservation Brief underscores the importance of careful planning in order to balance the preservation objectives with interior climate needs of the building. It is not intended as a technical guide to calculate tonnage or to size piping or ductwork. Rather, this Brief identifies some of the problems associated with installing mechanical systems in historic buildings and recommends approaches to minimizing the physical and visual damage associated with installing and maintaining these new or upgraded systems.

Historic buildings are not easily adapted to house modern precision mechanical systems. Careful planning must be provided early on to ensure that decisions made during the design and installation phases of a new system are appropriate. Since new mechanical and other related systems, such as electrical and fire suppression, can use up to 10% of a building's square footage and 30%–40% of an overall rehabilitation budget, decisions must be made in a systematic and coordinated manner. The installation of inappropriate mechanical systems may result in any or all of the following:

- large sections of historic materials are removed to install or house new systems.
- historic structural systems are weakened by carrying the weight of, and sustaining vibrations from, large equipment.
- moisture introduced into the building as part of a new system migrates into historic materials and causes damage, including biodegradation, freeze/thaw action, and surface staining.
- exterior cladding or interior finishes are stripped to install new vapor barriers and insulation.
- historic finishes, features, and spaces are altered by dropped ceilings and boxed chases or by poorly located grilles, registers, and equipment.
- systems that are too large or too small are installed before there is a clearly planned use or a new tenant.

For historic properties it is critical to understand what spaces, features, and finishes are historic in the building, what should be retained, and what the *realistic* heating, ventilating, and cooling needs are for the building, its occupants, and its contents. A systematic approach, involving preservation planning, preservation design, and a follow-up program of monitoring and maintenance, can ensure that new systems are successfully added—or existing systems are suitably upgraded—while preserving the historic integrity of the building.

No set formula exists for determining what type of mechanical system is best for a specific building. Each building and its needs must be evaluated separately. Some buildings will be so significant that every effort must be made to protect the historic materials and systems in place with minimal intrusion from new systems. Some buildings will have museum collections that need special climate control. In such cases, curatorial needs must be considered—but not to the ultimate detriment of the historic building resource. Other buildings will be rehabilitated for commercial use. For them, a variety of systems might be acceptable, as long as significant spaces, features, and finishes are retained.

Most mechanical systems require upgrading or replacement within 15–30 years due to wear and tear or the availability of improved technology. Therefore, historic buildings should not be greatly altered or otherwise sacrificed in an effort to meet short-term systems objectives.

History of Mechanical Systems

The history of mechanical systems in buildings involves a study of inventions and ingenuity as building owners, architects, and engineers devised ways to improve the interior climate of their buildings. Following are highlights in the evolution of heating, ventilating, and cooling systems in historic buildings.

Eighteenth Century. Early heating and ventilation in America relied upon common sense methods of *managing the environment* (see figure 1). Builders purposely sited houses to capture winter sun and prevailing summer cross breezes; they chose materials that could help protect the inhabitants from the elements, and took precautions against precipitation and damaging drainage patterns. The location and sizes of windows, doors, porches, and the floor plan itself often evolved to maximize ventilation. Heating was primarily from fireplaces or stoves and, therefore, was at the source of delivery. In 1744, Benjamin Franklin designed his "Pennsylvania stove" with a fresh air intake in order to maximize the heat radiated into the room and to minimize annoying smoke.

Thermal insulation was rudimentary—often wattle and daub, brick and wood nogging. The comfort level for occupants was low, but the relatively small difference between internal and external temperatures and relative humidity allowed building materials to expand and contract with the seasons.

Regional styles and architectural features reflected regional climates. In warm, dry and sunny climates, thick adobe walls offered shelter from the sun and kept the inside temperatures cool. Verandas, courtyards, porches, and high ceilings also reduced the impact of the sun. Hot and humid climates called for elevated living floors, louvered grilles and shutters, balconies, and interior courtyards to help circulate air.

Nineteenth Century. The industrial revolution provided the technological means for *controlling the environment* for the first time (see figure 2). The dual developments of steam energy from coal and industrial mass production made possible early central heating systems with distribution of heated air or steam using metal ducts or pipes. Improvements were made to early wrought iron boilers and by late century, steam and low pressure hot water radiator systems were in common use, both in offices and residences. Some large institutional buildings heated air in furnaces and distributed it throughout the building in brick flues with a network of metal pipes delivering heated air to individual rooms. Residential designs of the period often used gravity hot air systems utilizing decorative floor and ceiling grilles.

Ventilation became more scientific and the introduc-

1. Eighteenth century and later vernacular architecture depended on the siting of the building, deciduous trees, cross ventilation, and the placement of windows and chimneys to maximize winter heating and natural summer cooling. Regional details, as seen in this Virginia house, include external chimneys and a separate summer kitchen to reduce fire risk and isolate heat in the summer. Photo: NPS Files.

2. Nineteenth century buildings continued to use architectural features such as porches, cupolas, and awnings to make the buildings more comfortable in summer, but heating was greatly improved by hot water or steam radiators. Photo: NPS Files tion of fresh air into buildings became an important component of heating and cooling. Improved forced air ventilation became possible in mid-century with the introduction of power-driven fans. Architectural features such as porches, awnings, window and door transoms, large open-work iron roof trusses, roof monitors, cupolas, skylights and clerestory windows helped to dissipate heat and provide healthy ventilation.

Cavity wall construction, popular in masonry structures, improved the insulating qualities of a building and also provided a natural cavity for the dissipation of moisture produced on the interior of the building. In some buildings, cinder chips and broken masonry filler between structural iron beams and jack arch floor vaults provided thermal insulation as well as fireproofing. Mineral wool and cork were new sources of lightweight insulation and were forerunners of contemporary batt and blanket insulation.

The technology of the age, however, was not sufficient to produce "tight" buildings. There was still only a moderate difference between internal and external temperatures. This was due, in part, to the limitations of early insulation, the almost exclusive use of single glazed windows, and the absence of air-tight construction. The presence of ventilating fans and the reliance on architectural features, such as operable windows, cupolas and transoms, allowed sufficient air movement to keep buildings well ventilated. Building materials could behave in a fairly traditional way, expanding and contracting with the seasons.

Twentieth Century. The twentieth century saw intensive development of new technologies and the notion of fully *integrating mechanical systems* (see figure 3). Oil and gas furnaces developed in the nineteenth century were improved and made more efficient, with electricity becoming the critical source of power for building systems in the latter half of the century. Forced air heating systems with ducts and registers became popular for all types of buildings and allowed architects to experiment with architectural forms free from mechanical encumbrances. In the 1920s large-scale theaters and auditoriums introduced central air conditioning, and by mid-century forced air systems which combined heating and air conditioning in the same ductwork set a new standard for comfort and convenience. The combination and coordination of a variety of systems came together in the post-World War II highrise buildings; complex heating and air conditioning plants, electric elevators, mechanical towers, ventilation fans, and full service electric lighting were integrated into the building's design.

The insulating qualities of building materials improved. Synthetic materials, such as spun fiberglass batt insulation, were fully developed by mid-century. Prototypes of insulated thermal glazing and integral storm window systems were promoted in construction journals. Caulking to seal out perimeter air around window and door openings became a standard construction detail.

The last quarter of the twentieth century has seen making HVAC systems more energy efficient and better integrated. The use of vapor barriers to control moisture migration, thermally efficient windows, caulking and gaskets, compressed thin wall insulation, has become standard practice. New integrated systems now combine interior climate control with fire suppression, lighting, air filtration, temperature and humidity control, and security detection. Computers regulate the performance of these integrated systems based on the time of day, day of the week, occupancy, and outside ambient temperature.

3. The circa 1928 Fox Theater in Detroit, designed by C. Howard Crane, was one of the earliest twentieth century buildings to provide air conditioning to its patrons. The early water-cooled system was recently restored. Commercial and highrise buildings of the twentieth century were able, mostly through electrical power, to provide sophisticated systems that integrated many building services. Photo: William Kessler and Associates, Architects.

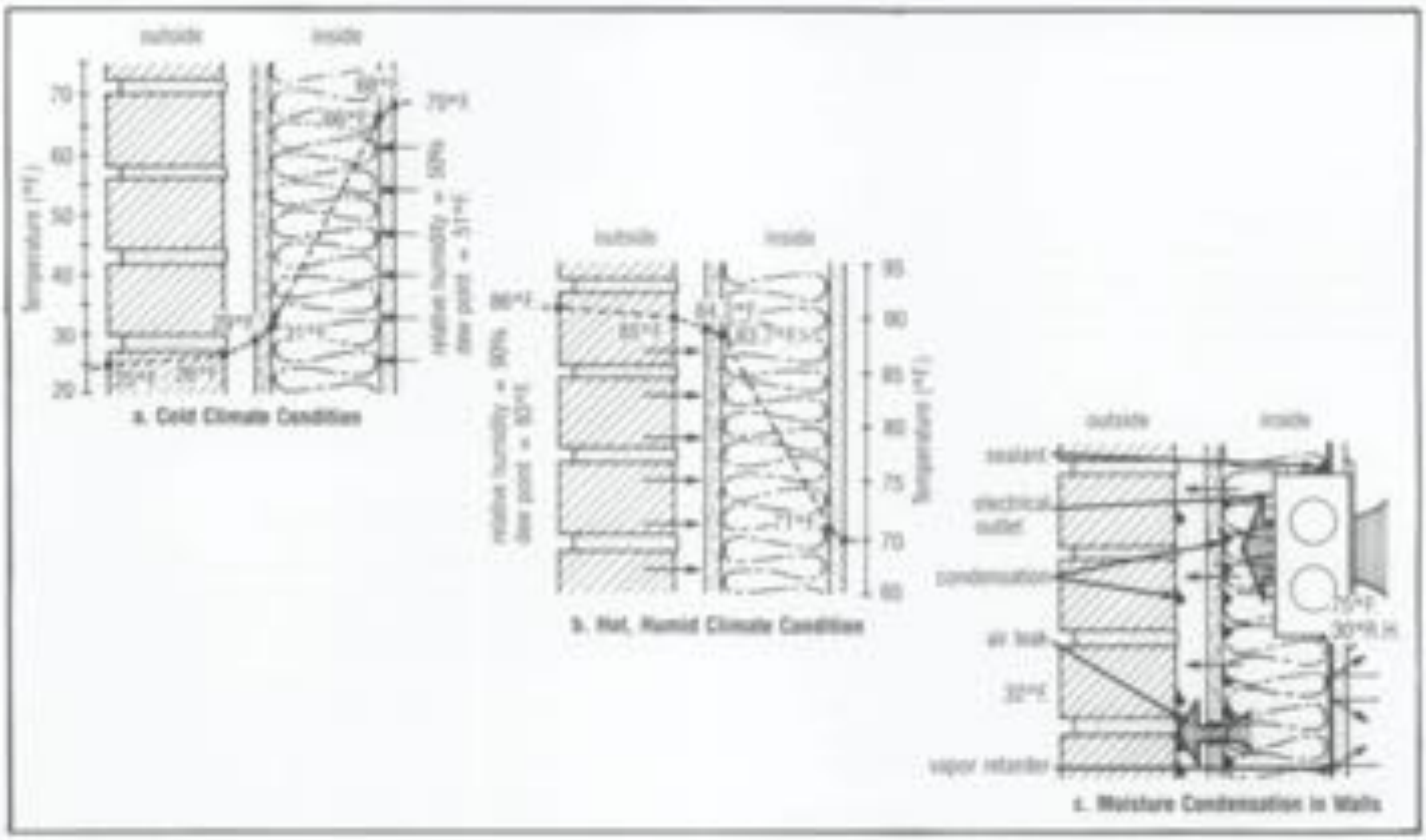
Climate Control and Preservation

Although twentieth century mechanical systems technology has had a tremendous impact on making historic buildings comfortable, the introduction of these new systems in older buildings is not without problems. The attempt to meet and maintain modern climate control standards *may in fact be damaging to historic resources.* Modern systems are often over-designed to compensate for inherent inefficiencies of some historic buildings materials and plan layouts. Energy retrofit measures, such as installing exterior wall insulation and vapor barriers or the sealing of operable window and vents, ultimately affect the performance and can reduce the life of aging historic materials.

In general, the greater the differential between the interior and exterior temperature and humidity levels, the greater the potential for damage. As natural vapor pressure moves moisture from a warm area to a colder, dryer area, condensation will occur on or in building materials in the colder area (see figure 4). Too little humidity in winter, for example, can dry and crack historic wooden or painted surfaces. Too much humidity in winter causes moisture to collect on cold surfaces, such as windows, or to migrate into walls. As a result, this condensation deteriorates wooden or metal windows and causes rotting of walls and wooden structural elements, dampening insulation and holding moisture against exterior surfaces. Moisture migration through walls can cause the corrosion of metal anchors, angles, nails or wire lath, can blister and peel exterior paint, or can leave efflorescence and salt deposits on exterior masonry. In cold climates, freeze-thaw damage can result from excessive moisture in external walls.

To avoid these types of damage to a historic building, it is important to understand how building components work together as a system. Methods for controlling interior temperature and humidity and improving ventilation must be considered in any new or upgraded HVAC or climate control system. While certain energy retrofit measures will have a positive effect on the overall building, installing effective vapor barriers in historic walls is difficult and often results in destruction of significant historic materials (see figure 5).

5. The installation of vapor retarders in walls of historic buildings in an effort to contain interior moisture can cause serious damage to historic finishes as shown here. In this example, all the wall plaster and lath have been stripped in preparation for a vapor barrier prior to replastering. Controlling interior temperature and relative humidity can be more effective than adding insulation and vapor barriers to historic perimeter walls. Photo: Ernest A. Conrad, P.E.



4. Mechanical heating and cooling systems change the interior climate of a building. Moisture in the air will dissipate from the warmer area of a building to the colder area and can cause serious deterioration of historic materials. Condensation can form if the dew point occurs within the building wall, particularly one that has been insulated (as a and b). Even when vapor retarders are installed (c), any non-continuous areas will provide spaces for moisture to pass. Wall Section Drawings: NPS files.

Planning the New System

Climate control systems are generally classified according to the medium used to condition the temperature: air, water, or a combination of both (see overview on page 6). The complexity of choices facing a building owner or manager means that a *systematic approach* is critical in determining the most suitable system for a building, its contents, and its occupants. No matter which system is installed, a change in the interior climate will result. This physical change will in turn affect how the building materials perform. New registers, grilles, cabinets, or other accessories associated with the new mechanical system will also visually change the interior (and sometimes the exterior) appearance of the building. Regardless of the type or extent of a mechanical system, the owner of a historic building should know *before* a system is installed what it will look like and what problems can be anticipated during the life of that system. The potential harm to a building and costs to an owner of selecting the wrong mechanical system are very great.

The use of a building and its contents will largely determine the best type of mechanical system. The historic building materials and construction technology as well as the size and availability of secondary spaces within the historic structure will affect the choice of a system. It may be necessary to investigate a combination of systems. In each case, the needs of the user, the needs of the building, and the needs of a collection or equipment must be considered. It may not be necessary to have a comprehensive climate control system if climate-sensitive objects can be accommodated in special areas or climate-controlled display cases. It may not be necessary to have central air conditioning in a mild climate if natural ventilation systems can be improved through the use of operable windows, awnings, exhaust fans, and other "low-tech" means. Modern standards for climate control developed for new construction may not be achievable or desirable for historic buildings. *In each case, the lowest level of intervention needed to successfully accomplish the job should be selected.*

Before a system is chosen, the following planning steps are recommended:

1. **Determine the use of the building.** The proposed use of the building (museum, commercial, residential, retail) will influence the type of system that should be installed. The number of people and functions to be housed in a building will establish the level of comfort and service that must be provided. Avoid uses that require major modifications to significant architectural spaces. What is the intensity of use of the building: intermittent or constant use, special events or seasonal events? Will the use of the building require major new services such as restaurants, laundries, kitchens, locker rooms, or other areas that generate moisture that may exacerbate climate control within the historic space? In the context of historic preservation, uses that require radical reconfigurations of historic spaces are inappropriate for the building.

2. **Assemble a qualified team.** This team ideally should consist of a preservation architect, mechanical engineer, electrical engineer, structural engineer, and preservation consultants, each knowledgeable in codes and local requirements. If a special use (church, museum, art studio) or a collection is involved, a specialist familiar with the mechanical requirements of that building type or collection should also be hired.

Team members should be familiar with the needs of historic buildings and be able to balance complex factors: the preservation of the historic architecture (aesthetics and conservation), requirements imposed by mechanical systems (quantified heating and cooling loads), building codes (health and safety), tenant requirements (quality of comfort, ease of operation), access (maintenance and future replacement), and the overall cost to the owner.

3. **Undertake a condition assessment of the existing building and its systems.** What are the existing construction materials and mechanical systems? What condition are they in and are they reusable (see figure 6)? Where are existing chillers, boilers, air handlers, or cooling towers located? Look at the condition of all other services that may benefit from being integrated into a new system, such as electrical and fire suppression systems. Where can energy efficiency be improved to help downsize any new equipment added, and which of the historic features, e.g. shutters, awnings, skylights, can be reused (see figure 7)? Evaluate air infiltration through the exterior envelope; monitor the interior for temperature and humidity levels with hygrothermographs for at least a year. Identify building, site, or equipment deficiencies or the presence of asbestos that must be corrected prior to the installation or upgrading of mechanical systems.

6. A condition assessment during the planning stage would identify this round radiator in a small oval-shaped vestibule as a significant element of the historic heating system. In upgrading the mechanical system, the radiator should be retained. Photo: Michael C. Henry, P.E., AIA.

Overview of HVAC Systems

WATER SYSTEMS: Hydronic radiators, Fan coil, or radiant pipes

Water systems are generally called *hydronic* and use a network of pipes to deliver water to hot water radiators, radiant pipes set in floors or fan coil cabinets which can give both heating and cooling. Boilers produce hot water or steam; chillers produce chilled water for use with fan coil units. Thermostats control the temperature by zone for radiators and radiant floors. Fan coil units have individual controls. Radiant floors provide quiet, even heat, but are not common.

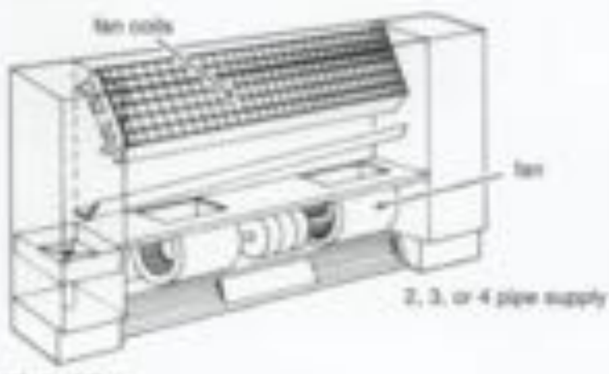
Advantages: Piped systems are generally easier to install in historic buildings because the pipes are smaller than ductwork.
Disadvantages: There is the risk, however, of hidden leaks in the wall or burst pipes in winter if boilers fail. Fan coil condensate pans can overflow if not properly maintained. Fan coils may be noisy.

Hydronic Radiators: Radiators or baseboard radiators are looped together and are usually set under windows or along perimeter walls. New boilers and circulating pumps can upgrade older systems. Most piping was cast iron although copper systems can be used if separately zoned. Modern cast iron baseboards and copper fin-tubes are available. Historic radiators can be reconditioned.


cast iron radiator


cast iron baseboard

Fan Coil Units: Fan coil systems use terminal cabinets in each room serviced by 2, 3, or 4 pipes approximately 1-1/2" each in diameter. A fan blows air over the coils which are serviced by hot or chilled water. Each fan coil cabinet can be individually controlled. Four-pipe fan coils can provide both heating and cooling all year long. Most piping is steel. Non-cabinet units may be concealed in closets or custom cabinetry, such as benches, can be built.



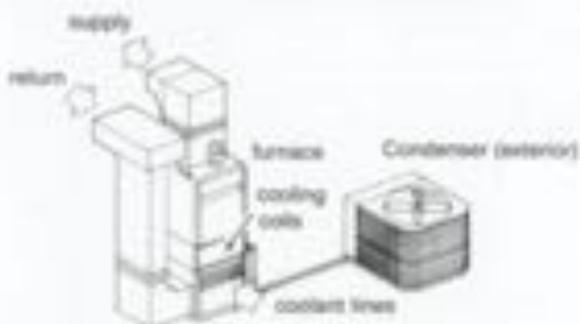
Fan coil unit

CENTRAL AIR SYSTEMS

The basic heating, ventilation and air conditioning (HVAC) system is all-air, single zone fan driven designed for low, medium or high pressure distribution. The system is composed of compressor drives, chillers, condensers, and furnace depending on whether the air is heated, chilled or both. Condensers, generally air cooled, are located outside. The ducts are sheet metal or flexible plastic and can be insulated. Fresh air can be circulated. Registers can be designed for ceilings, floors and walls. The system is controlled by thermostats; one per zone.

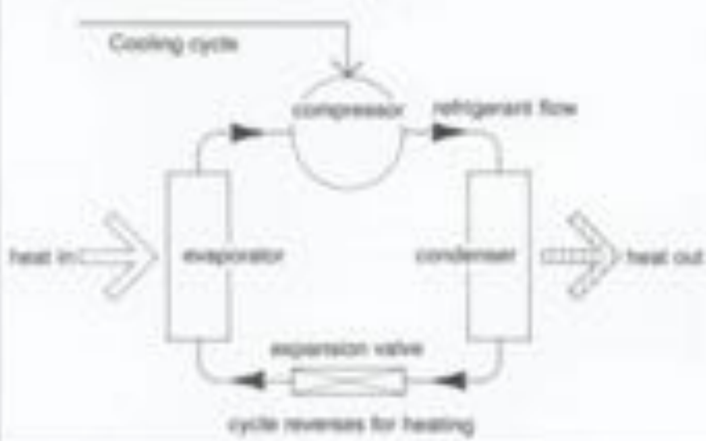
Advantages: Ducted systems offer a high level of control of interior temperature, humidity, and filtration. Zoned units can be relatively small and well concealed.
Disadvantages: The damage from installing a ducted system without adequate space can be serious for a historic building. Systems need constant balancing and can be noisy.

Basic HVAC: Most residential or small commercial systems will consist of a basic furnace with a cooling coil set in the unit and a refrigerant compressor or condenser located outside the building. Heating and cooling ductwork is usually shared. If sophisticated humidification and dehumidification is added to the basic HVAC system, a full climate control system results. This can often double the size of the equipment.



Heating furnace with cooling coil

Basic Heat Pump/Air System: The heat pump is a basic HVAC system as described above except for the method of generating hot and cold air. The system operates on the basic refrigeration cycle where latent heat is extracted from the ambient air and is used to evaporate refrigerant vapor under pressure. Functions of the condenser and evaporator switch when heating is needed. Heat pumps, somewhat less efficient in cold climates, can be fitted with electric resistance coil.



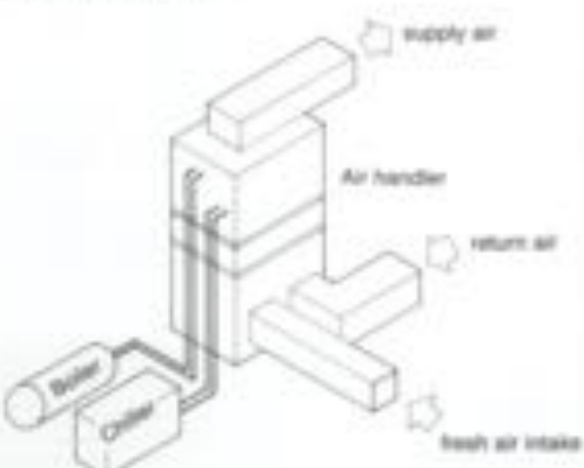
COMBINED AIR AND WATER SYSTEMS

These systems are popular for restoration work because they combine the ease of installation for the piped system with the performance and control of the ducted system. Smaller air handling units, not unlike fan coils, may be located throughout a building with service from a central boiler and chiller. In many cases the water is delivered from a central plant which services a complex of buildings.

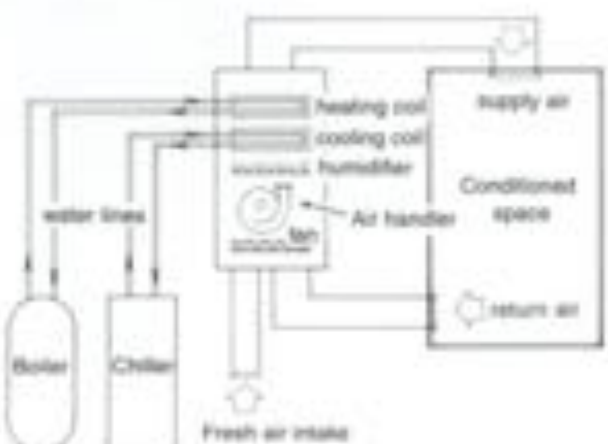
This system overcomes the disadvantages of a central ducted system where there is not adequate horizontal or vertical runs for the ductwork. The equipment, being smaller, may also be quieter and cause less vibration. If only one air handler is being utilized for the building, it is possible to house all the equipment in a vault outside the building and send only conditioned air into the structure.

Advantages: flexibility for installation using greater piping runs with shorter ducted runs; Air handlers can fit into small spaces.
Disadvantages: piping areas may have undetected leaks; air handlers may be noisy.

Water-serviced Air Handlers:



Typical Systems Layout:



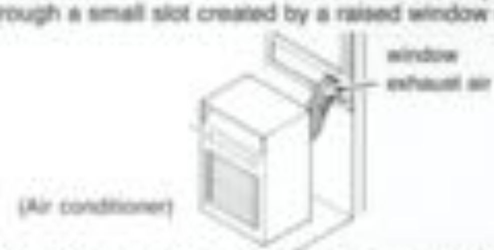
OTHER SYSTEM COMPONENTS

Non-systems components should not be overlooked if they can make a building more comfortable without causing damage to the historic resource or its collection.

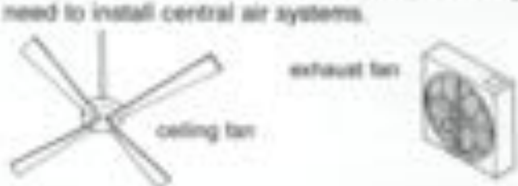
Advantages: components may provide acceptable levels of comfort without the need for an entire system.
Disadvantages: Spot heating, cooling and fluxuations in humidity may harm sensitive collections or furnishings. If an integrated system is desirable, components may provide only a temporary solution.

Portable Air Conditioning:

Most individual air conditioners are set in windows or through exterior walls which can be visually as well as physically damaging to historic buildings. Newer portable air conditioners are available which sit in a room and exhaust directly to the exterior through a small slot created by a raised window sash.



Fans: Fans should be considered in most properties to improve ventilation. Fans can be located in attics, at the top of stairs, or in individual rooms. In moderate climates, fans may eliminate the need to install central air systems.



Dehumidifiers: For houses without central air handling systems, a dehumidifier can resolve problems in humid climates. Seasonal use of dehumidifiers can remove moisture from damp basements and reduce fungal growth.

Heaters: Portable radiant heaters, such as those with water and glycol, may provide temporary heat in buildings used infrequently or during systems breakdowns. Care should be taken not to create a fire hazard with improperly wired units.

Compiled by Sharon C. Park. Sketches adapted from *Architectural Graphic Standards* with permission from John Wiley and Sons.

4. **Prioritize architecturally significant spaces, finishes, and features to be preserved.** Significant architectural spaces, finishes and features should be identified and evaluated at the outset to ensure their preservation. This includes significant existing mechanical systems or elements such as hot water radiators, decorative grilles, elaborate switchplates, and non-mechanical architectural features such as cupolas, transoms, or porches. Identify non-significant spaces where mechanical equipment can be placed and secondary spaces where equipment and distribution runs on both a horizontal and vertical basis can be located. Appropriate secondary spaces for housing equipment might include attics, basements, penthouses, mezzanines, false ceiling or floor cavities, vertical chases, stair towers, closets, or exterior below-grade vaults (see figure 8).

5. **Become familiar with local building and fire codes.** Owners or their representatives should meet early and often with local officials. Legal requirements should be checked; for example, can existing ductwork be reused or modified with dampers? Is asbestos abatement required? What are the energy, fire, and safety codes and standards in place, and how can they be met while maintaining the historic character of the building? How are fire separation walls and rated mechanical systems to be handled between multiple tenants? Is there a requirement for fresh air intake for stair towers that will affect the exterior appearance of the building? Many of the health, energy, and safety code requirements will influence decisions made for mechanical equipment for climate control. It is importance to know what they are before the design phase begins.

6. **Evaluate options for the type and size of systems.** A matrix or feasibility studies should be developed to balance the benefits and drawbacks of various systems. Factors to consider include heating and/or cooling, fuel type, distribution system, control devices, generating equipment and accessories such as filtration, and humidification. What are the initial installation costs, projected fuel costs, long-term maintenance, and life-cycle costs of these components and systems? Are parts of an existing system being reused and upgraded? The benefits of added ventilation should not be overlooked (see figure 9). What are the trade-offs between one large central system and multiple smaller systems? Should there be a forced air ducted system, a 2-pipe fan coil system, or a combined water and air system? What space is available for the equipment and distribution system? Assess the fire-risk levels of various fuels. Understand the advantages and disadvantages of the various types of mechanical systems available. *Then evaluate each of these systems in light of the preservation objectives established during the design phase of planning.*

7. Operable skylights and grilles that can be adapted for return air should be identified as part of the planning phase for new or upgraded mechanical systems. Photo: Dianne Pierce, NPS files.

8. In considering options for new systems, existing spaces should be evaluated for their ability to house new equipment. This sketch shows several areas where new mechanical equipment could be located to avoid damaging significant spaces. Sketch: NPS files

9. Improving ventilation through traditional means should not be overlooked in planning new or upgraded HVAC systems. In mild climates, good exhaust fans can often eliminate the need for air conditioning or can reduce equipment size by reducing cooling loads. Photo: Ernest A. Conrad, P.E.

Designing the new system

In designing a system, it is important to anticipate how it will be installed, how damage to historic materials can be minimized, and how visible the new mechanical system will be within the restored or rehabilitated spaces (see figure 10 a–f). Mechanical equipment space needs are often overwhelming; in some cases, it may be advantageous to look for locations outside of the building, including ground vaults, to house some of the equipment but only if it there is no adverse impact to the historic landscape or adjacent archeological resources. Various means for reducing the heating and cooling loads (and thereby the size of the equipment) should be investigated. This might mean reducing slightly the comfort levels of the interior, increasing the number of climate control zones, or improving the energy efficiency of the building.

The following activities are suggested during the design phase of the new system:

1. Establish specific criteria for the new or upgraded mechanical system. New systems should be *installed with a minimum of damage* to the resource and should be visually *compatible with the architecture* of the building. They should be installed in a way that is *easy to service,* maintain, and upgrade in the future. There should be *safety and back-up monitors in place* if buildings have collections, computer rooms, storage vaults or special conditions that need monitoring. The *new systems should work within the structural limits* of the historic building. They should produce *no undue vibration, no undue noise, no dust or mold,* and *no excess moisture* that could damage the historic building materials. If any equipment is to be located outside of the building, there should be *no impact to the historic appearance of building or site,* and there should be *no impact on archeological resources.*

2. Prioritize the requirements for the new climate control system. The use of the building will determine the level of interior comfort and climate control. Sometimes, various temperature zones may safely be created within a historic building. This zoned approach may be appropriate for buildings with specialized collections storage, for buildings with mixed uses, or for large buildings with different external exposures, occupancy patterns, and delivery schedules for controlled air. Special archives, storage vaults or computer rooms may need a completely different climate control from the rest of the building. Determine temperature and humidity levels for occupants and collections and ventilation requirements between differing zones. Establish if the system is to run 24 hours a day or only during operating or business hours. Determine what controls are optimum (manual, computer, preset automatic, or other). The size and location of the equipment to handle these different situations will ultimately affect the design of the overall system as well.

3. Minimize the impact of the new HVAC on the existing architecture. Design criteria for the new system should be based on the type of architecture of the historic resource. Consideration should be given as to whether or not the delivery system is visible or hidden. Utilitarian and industrial spaces may be capable of accepting a more visible and functional system. More formal, ornate spaces which may be part of an interpretive program may require a less visible or disguised system. A ducted system should be installed without ripping into or boxing out large sections of floors, walls, or ceilings. A wet pipe system should be installed so that hidden leaks will not damage important decorative finishes. In each case, not only the type of system (air, water, combination), but its distribution (duct, pipe) and delivery appearance (grilles, cabinets, or registers) must be evaluated. It may be necessary to use a combination of different systems in order to preserve the historic building. Existing chases should be reused whenever possible.

4. Balance quantitative requirements and preservation objectives. The ideal system may not be achievable for each historic resource due to cost, space limitations, code requirements, or other factors beyond the owner's control. However, significant historic spaces, finishes, and features can be preserved in almost every case, even given these limitations. For example, if some ceiling areas must be slightly lowered to accommodate ductwork or piping, these should be in secondary areas away from decorative ceilings or tall windows. If modern fan coil terminal units are to be visible in historic spaces, consideration should be given to custom designing the cabinets or to using smaller units in more locations to diminish their impact. If grilles and registers are to be located in significant spaces, they should be designed to work within the geometry or placement of decorative elements. All new elements, such as ducts, registers, pipe-runs, and mechanical equipment should be installed in a reversible manner to be removed in the future without further damage to the building (see fig 11).

Systems Performance and Maintenance

Once the system is installed, it will require routine maintenance and balancing to ensure that the proper performance levels are achieved. In some cases, extremely sophisticated, computerized systems have been developed to control interior climates, but these still need monitoring by trained staff. If collection exhibits and archival storage are important to the resource, the climate control system will require constant monitoring and tuning. Back-up systems are also needed to prevent damage when the main system is not working. The owner, manager, or chief of maintenance should be aware of all aspects of the new climate control system and have a plan of action before it is installed.

Regular training sessions on operating, monitoring, and maintaining the new system should be held for both curatorial and building maintenance staff. If there are curatorial reasons to maintain constant temperature or humidity levels, only individuals thoroughly trained in how the HVAC systems operates should be able to adjust thermostats. Ill-informed and haphazard attempts to adjust comfort levels, or to save energy over weekends and holidays, can cause great damage.

10. The following photographs illustrate recent preservation projects where careful planning and design retained the historic character of the resources.

before

after

a. Before and after of a circa 1900 school entrance. The radiators have been replaced with a two-pipe fan coil system built into bench seats. The ceiling was preserved and no exposed elements were required to add air conditioning. Piping runs are under the benches and there was no damage to the masonry walls. Photos: Notter Finegold + Alexander Inc. and Lautman Photography, Washington.

historic

after

d. Auditors Buildings, Washington, D.C. This upper floor workspace had been modified over the years with dropped ceilings and partitions. In the recent restoration, the open plan workspace was restored, the false ceiling was removed, and the fireproof construction was exposed. A variable air volume (VAV) system using round double shell exposed ductwork is in keeping with the industrial character of the architectural space. Photo: Kenneth Wyner Photography, courtesy of Notter Finegold + Alexander Inc. Before view provided by Notter Finegold + Alexander/Mariani.

b. Central air conditioning was installed in the corridors of this circa 1900 school building by adding an air handler over the entrance from a vestibule. The custom-designed slot registers provide linear diffusers without detracting from the architecture of the space. Photo: Lautman Photography courtesy of Notter Finegold + Alexander Inc.

c. Conference room, Auditors Building, Washington, D.C. The historic steam radiators were retained for heating. The cast iron ceiling register was retained as a decorative element, but made inoperable to meet fire codes. Photo: Kenneth Wyner Photography courtesy of Notter Finegold + Alexander Inc.

e. Town Hall, Andover, MA. The upstairs auditorium was restored and new mechanical systems were installed. Perimeter baseboard radiation provides heat and air handlers, located in the attic space provide air conditioning. The cast iron ceiling grille was adapted for return air and the supply registers were installed in a symmetrical and regular manner to minimize impact on the historic ceiling. Photo: David Hewitt/Anne Garrison for Ann Beha Associates.

f. Homewood, Baltimore, MD. This elegant circa 1806 residence is now a house museum. The registers for the forced air ducted system seen behind the table legs, are grained to blend with the historic baseboards. The HVAC system uses a water/air system where chilled water and steam heat are converted to conditioned air. Photo: Courtesy Homewood Museum, Johns Hopkins University.

HVAC Do's and Don'ts

DO's:

- Use shutters, operable windows, porches, curtains, awnings, shade trees and other historically appropriate non-mechanical features of historic buildings to reduce the heating and cooling loads. Consider adding sensitively designed storm windows to existing historic windows.
- Retain or upgrade existing mechanical systems whenever possible: for example, reuse radiator systems with new boilers, upgrade ventilation within the building, install proper thermostats or humidistats.
- Improve energy efficiency of existing buildings by installing insulation in attics and basements. Add insulation and vapor barriers to exterior walls *only* when it can be done without further damage to the resource.
- In major spaces, retain decorative elements of the historic system whenever possible. This includes switchplates, grilles and radiators. Be creative in adapting these features to work within the new or upgraded system.
- Use space in existing chases, closets or shafts for new distribution systems.
- Design climate control systems that are compatible with the architecture of the building: hidden system for formal spaces, more exposed systems possible in industrial or secondary spaces. In formal areas, avoid standard commercial registers and use custom slot registers or other less intrusive grilles.
- Size the system to work within the physical constraints of the building. Use multi-zoned smaller units in conjunction with existing vertical shafts, such as stacked closets, or consider locating equipment in vaults underground, if possible.
- Provide adequate ventilation to the mechanical rooms as well as to the entire building. Selectively install air intake grilles in less visible basement, attic, or rear areas.
- Maintain appropriate temperature and humidity levels to meet requirements without accelerating the deterioration of the historic building materials. Set up regular monitoring schedules.
- Design the system for maintenance access and for future systems replacement.
- For highly significant buildings, install safety monitors and backup features, such as double pans, moisture detectors, lined chases, and battery packs to avoid or detect leaks and other damage from system failures.
- Have a regular maintenance program to extend equipment life and to ensure proper performance.
- Train staff to monitor the operation of equipment and to act knowledgeably in emergencies or breakdowns.
- Have an emergency plan for both the building and any curatorial collections in case of serious malfunctions or breakdowns.

DON'TS:

- Don't install a new system if you don't need it.
- Don't switch to a new type of system (e.g. forced air) unless there is sufficient space for the new system or an appropriate place to put it.
- Don't over-design a new system. Don't add air conditioning or climate control if they are not absolutely necessary.
- Don't cut exterior historic building walls to add through-wall heating and air conditioning units. These are visually disfiguring, they destroy historic fabric, and condensation runoff from such units can further damage historic materials.
- Don't damage historic finishes, mask historic features, or alter historic spaces when installing new systems.
- Don't drop ceilings or bulkheads across window openings.
- Don't remove repairable historic windows or replace them with inappropriately designed thermal windows.
- Don't seal operable windows, unless part of a museum where air pollutants and dust are being controlled.
- Don't place condensers, solar panels, chimney stacks, vents or other equipment on visible portions of roofs or at significant locations on the site.
- Don't overload the building structure with the weight of new equipment, particularly in the attic.
- Don't place stress on historic building materials through the vibrations of the new equipment.
- Don't allow condensation on windows or within walls to rot or spall adjacent historic building materials.

Maintenance staff should learn how to operate, monitor, and maintain the mechanical equipment. They must know where the maintenance manuals are kept. Routine maintenance schedules must be developed for changing and cleaning filters, vents, and condensate pans to control fungus, mold, and other organisms that are dangerous to health. Such growths can harm both inhabitants and equipment. (In piped systems, for example, molds in condensate pans can block drainage lines and cause an overflow to leak onto finished surfaces). Maintenance staff should also be able to monitor the appropriate gauges, dials, and thermographs. Staff must be trained to intervene in emergencies, to know where the master controls are, and whom to call in an emergency. As new personnel are hired, they will also require maintenance training.

In addition to regular cyclical maintenance, thorough inspections should be undertaken from time to time to evaluate the continued performance of the climate control system. As the system ages, parts are likely to fail, and signs of trouble may appear. Inadequately ventilated areas may smell musty. Wall surfaces may show staining, wet patches, bubbling or other signs of moisture damage. Routine tests for air quality, humidity, and temperature should indicate if the system is performing properly. If there is damage as a result of the new system, it should be repaired immediately and then closely monitored to ensure complete repair.

Equipment must be accessible for maintenance and should be visible for easy inspection. Moreover, since mechanical systems last only 15–30 years, the system itself must be "reversible." That is, the system must be installed in such a way that later removal will not damage the building. In addition to servicing, the back-up monitors that signal malfunctioning equipment must be routinely checked, adjusted, and maintained. Checklists should be developed to ensure that all aspects of routine maintenance are completed and that data is reported to the building manager.

Conclusion

The successful integration of new systems in historic buildings can be challenging. Meeting modern HVAC requirements for human comfort or installing controlled climates for museum collections or for the operation of complex computer equipment can result in both visual and physical damage to historic resources. Owners of historic buildings must be aware that the final result will involve balancing multiple needs; no perfect heating, ventilating, and air conditioning system exists. In undertaking changes to historic buildings, it is best to have the advice and input of trained professionals who can:

- assess the condition of the historic building,
- evaluate the significant elements that should be preserved or reused,
- prioritize the preservation objectives,
- understand the impact of new interior climate conditions on historic materials,
- integrate preservation with mechanical and code requirements,
- maximize the advantages of various new or upgraded mechanical systems,
- understand the visual and physical impact of various installations,
- identify maintenance and monitoring requirements for new or upgraded systems, and
- plan for the future removal or replacement of the system.

Too often the presumed climate needs of the occupants or collections can be detrimental to the long-term preservation of the building. With a careful balance between the preservation needs of the building and the interior temperature and humidity needs of the occupants, a successful project can result.

a

b

11. During the restoration of this 1806 National Historic Landmark (photo a), a new climate control system was installed. The architects removed all the earlier mechanical equipment from the house and installed new equipment in a 30' x 40' concrete vault located underground 150 feet from the house itself (photo b). Only conditioned air is blown into the house reusing much of the circa 1930s ductwork. Photos: Thomas C. Jester.

Bibliography

Banham, Reyner. *The Architecture of the Well-Tempered Environment*. London: The Architectural Press, 1969.

Burns, John A., AIA. *Energy Conserving Features Inherent in Older Homes*. Washington: U.S. Department of Housing and Urban Development and U.S. Department of the Interior, 1982.

Cowan, Henry J. *Science and Building: Structural and Environmental Design in the Nineteenth and Twentieth Centuries*. New York: John Wiley & Sons, 1978.

Ferguson, Eugene S. "An Historical Sketch of Central Heating: 1800-1860," in *Building Early America* (Charles Peterson, editor) Philadelphia: Chilton Book Co., 1976.

Fitch, James Marston. *American Building: The Environmental Forces That Shape It*. Boston: Houghton Mifflin Co., 1972.

Giedion, Siegfried. *Mechanization Takes Command; a Contribution to Anonymous History*. New York: Oxford University Press, 1948.

Merritt, Frederick S. *Building Engineering and Systems Design*. New York: Van Nostrand Reinhold Co. 1979.

Smith, Baird M. *Preservation Briefs 3: Conserving Energy in Historic Buildings*. Washington, DC: U.S. Department of the Interior, 1978.

Turberg, Edward. *A History of American Building Technology*. Durham: Durham Technical Institute, 1981.

cover photo: This historic coal boiler continues in use after its conversion to an oil-fired boiler. Photo: NPS files

Acknowledgements

The author gratefully acknowledges the invaluable assistance of Michael C. Henry, P.E., AIA, in the development and technical editing of this Preservation Brief. Technical review was also provided by Ernest A. Conrad, P.E. Thanks is also given to staff members of the National Park Service Cultural Resources Programs, including Tom Keohan and Catherine Colby, Rocky Mountain Region; Michael Crowe, Western Region; Mark Chavez, Midwest Region; Randall J. Biallas, AIA, Chief, Park Historic Architecture Division, and George A. Thomas, Historical Architect, Denver Service Center. Special thanks is also given to Michael J. Auer of Technical Preservation Services for his editorial assistance in preparing this paper and Tim Buehner for his assistance with the illustrations.

This publication has been prepared pursuant to the National Historic Preservation Act of 1966, as amended, which directs the Secretary of the Interior to develop and make available information concerning historic properties. Preservation Brief 24 was developed under the editorship of H. Ward Jandl, Chief, Technical Preservation Services. Comments on the usefulness of this publication may be directed to Chief, Technical Preservation Services Branch, Preservation Assistance Division, National Park Service, P.O. Box 37127, Washington, D.C. 20013-7127. This publication is not copyrighted and can be reproduced without penalty. Normal procedures for credit to the author and the National Park Service are appreciated.

Washington, DC 1991

31 PRESERVATION BRIEFS

Mothballing Historic Buildings

Sharon C. Park, AIA

U.S. Department of the Interior
National Park Service
Cultural Resources
Heritage Preservation Services

When all means of finding a productive use for a historic building have been exhausted or when funds are not currently available to put a deteriorating structure into a useable condition, it may be necessary to close up the building temporarily to protect it from the weather as well as to secure it from vandalism. This process, known as mothballing, can be a necessary and effective means of protecting the building while planning the property's future, or raising money for a preservation, rehabilitation or restoration project. If a vacant property has been declared unsafe by building officials, stabilization and mothballing may be the only way to protect it from demolition.

This Preservation Brief focuses on the steps needed to "de-activate" a property for an extended period of time. The project team will usually consist of an architect, historian, preservation specialist, sometimes a structural engineer, and a contractor. Mothballing should not be done without careful planning to ensure that needed physical repairs are made prior to securing the building. The steps discussed in this Brief can protect buildings for periods of up to ten years; long-term success will also depend on continued, although somewhat limited, monitoring and maintenance. For all but the simplest projects, hiring a team of preservation specialists is recommended to assess the specific needs of the structure and to develop an effective mothballing program.

A vacant historic building cannot survive indefinitely in a boarded-up condition, and so even marginal interim uses where there is regular activity and monitoring, such as a caretaker residence or non-flammable storage, are generally preferable to mothballing. In a few limited cases when the vacant building is in good condition and in a location where it can be watched and checked regularly, closing and locking the door, setting heat levels at just above freezing, and securing the windows may provide sufficient protection for a period of a few years. But if long-term mothballing is the only remaining option, it must be done properly (see fig. 1 & 2). This will require stabilization of the exterior, properly designed security protection, generally some form of interior ventilation - either through mechanical or natural air exchange systems - and continued maintenance and surveillance monitoring.

Figure 1. Proper mothballing treatment: This building has been successfully mothballed for 10 years because the roof and walls were repaired and structurally stabilized, ventilation louvers were added, and the property is maintained. Photo: Charles E. Fisher, NPS.

Comprehensive mothballing programs are generally expensive and may cost 10% or more of a modest rehabilitation budget. However, the money spent on well-planned protective measures will seem small when amortized over the life of the resource. Regardless of the location and condition of the property or the funding available, the following 9 steps are involved in properly mothballing a building:

Figure 2. Improper treatment: Boarding up without adequate ventilation, lack of maintenance, and neglect of this property have accelerated deterioration. Photo: NPS file.

Documentation

1. Document the architectural and historical significance of the building.

2. Prepare a condition assessment of the building.

Stabilization

3. Structurally stabilize the building, based on a professional condition assessment.

4. Exterminate or control pests, including termites and rodents.

5. Protect the exterior from moisture penetration.

Mothballing

6. Secure the building and its component features to reduce vandalism or break-ins.

7. Provide adequate ventilation to the interior.

8. Secure or modify utilities and mechanical systems.

9. Develop and implement a maintenance and monitoring plan for protection.

These steps will be discussed in sequence below. Documentation and stabilization are critical components of the process and should not be skipped over. Mothballing measures should not result in permanent damage, and so each treatment should be weighed in terms of its reversibility and its overall benefit.

Documentation

Documenting the historical significance and physical condition of the property will provide information necessary for setting priorities and allocating funds. The project team should be cautious when first entering the structure if it has been vacant or is deteriorated. It may be advisable to shore temporarily areas appearing to be structurally unsound until the condition of the structure can be fully assessed (see fig. 3). If pigeon or bat droppings, friable asbestos or other health hazards are present, precautions must be taken to wear the appropriate safety equipment when first inspecting the building. Consideration should be given to hiring a firm specializing in hazardous waste removal if these highly toxic elements are found in the building.

Documenting and recording the building. Documenting a building's history is important because evidence of its true age and architectural significance may not be readily evident. The owner should check with the State Historic Preservation Office or local preservation commission for assistance in researching the building. If the building has never been researched for listing in the National Register of Historic Places or other historic registers, then, at a minimum, the following should be determined:

- The overall historical significance of the property and dates of construction;
- the chronology of alterations or additions and their approximate dates; and,
- types of building materials, construction techniques, and any unusual detailing or regional variations of craftsmanship.

Old photographs can be helpful in identifying early or original features that might be hidden under modern materials. On a walk-through, the architect, historian, or preservation specialist should identify the architecturally significant elements of the building, both inside and out (see fig.4).

Figure 3. Buildings seriously damaged by storms or deterioration may need to be braced before architectural evaluations can be made. Jethro Coffin House. Photo: John Milner Architects.

Figure 4. Documenting the building's history, preparing schematic plans, and assessing the condition of the building will provide necessary information on which to set priorities for stabilization and repair prior to securing the building. Photo: Frederick Lindstrom, HABS.

By understanding the history of the resource, significant elements, even though deteriorated, may be spared the trash pile. For that reason alone, any materials removed from the building or site as part of the stabilization effort should be carefully scrutinized and, if appearing historic, should be photographed, tagged with a number, inventoried, and safely stored, preferably in the building, for later retrieval (see fig. 5).

A site plan and schematic building floor plans can be used to note important information for use when the building is eventually preserved, restored, or rehabilitated. Each room should be given a number and notations added to the plans regarding the removal of important features to storage or recording physical treatments undertaken as part of the stabilization or repair.

Because a mothballing project may extend over a long period of time, with many different people involved, clear records should be kept and a building file established. Copies of all important data, plans, photographs, and lists of consultants or contractors who have worked on the property should be added to the file as the job progresses.

Figure 5. Loose or detached elements should be identified, tagged and stored, preferably on site. Photo: NPS files.

Recording all actions taken on the building will be helpful in the future.

The project coordinator should keep the building file updated and give duplicate copies to the owner. A list of emergency numbers, including the number of the key holder, should be kept at the entrance to the building or on a security gate, in a transparent vinyl sleeve.

Preparing a condition assessment of the building. A condition assessment can provide the owner with an accurate overview of the current condition of the property. If the building is deteriorated or if there are significant interior architectural elements that will need special protection during the mothballing years, undertaking a condition assessment is highly recommended, but it need not be exhaustive.

A modified condition assessment, prepared by an architect or preservation specialist, and in some case a structural engineer, will help set priorities for repairs necessary to stabilize the property for both the short and long-term. It will evaluate the age and condition of the following major elements: foundations; structural systems; exterior materials; roofs and gutters; exterior porches and steps; interior finishes; staircases; plumbing, electrical, mechanical systems; special features such as chimneys; and site drainage.

To record existing conditions of the building and site, it will be necessary to clean debris from the building and to remove unwanted or overgrown vegetation to expose foundations. The interior should be emptied of its furnishing (unless provisions are made for mothballing these as well), all debris removed, and the interior swept with a broom. Building materials too deteriorated to repair, or which have come detached, such as moldings, balusters, and decorative plaster, and which can be used to guide later preservation work, should be tagged, labeled and saved.

Photographs or a videotape of the exterior and all interior spaces of the resource will provide an invaluable record of "as is" conditions. If a videotape is made, oral commentary can be provided on the significance of each space and architectural feature. If 35mm photographic prints or slides are made, they should be numbered, dated, and appropriately identified. Photographs should be cross-referenced with the room numbers on the schematic plans. A systematic method for photographing should be developed; for example, photograph each wall in a room and then take a corner shot to get floor and ceiling portions in the picture. Photograph any unusual details as well as examples of each window and door type.

For historic buildings, the great advantage of a condition assessment is that architectural features, both on the exterior as well as the interior, can be rated on a scale of their importance to the integrity and significance of the building. Those features of the highest priority should receive preference when repairs or protection measures are outlined as part of the mothballing process. Potential problems with protecting these features should be identified so that appropriate interim solutions can be selected. For example, if a building has always been heated and if murals, decorative plaster walls, or examples of patterned wall paper are identified as highly significant, then special care should be taken to regulate the interior climate and to monitor it adequately during the mothballing years. This might require retaining electrical service to provide minimal heat in winter, fan exhaust in summer, and humidity controls for the interior.

Stabilization

Stabilization as part of a mothballing project involves correcting deficiencies to slow down the deterioration of the building while it is vacant. Weakened structural members that might fail altogether in the forthcoming years must be braced or reinforced; insects and other pests removed and discouraged from returning; and the building protected from moisture damage both by weatherizing the exterior envelope and by handling water run-off on the site. Even if a modified use or caretaker services can eventually be found for the building, the following steps should be addressed.

Structurally stabilizing the building. While bracing may have been required to make the building temporarily safe for inspection, the condition assessment may reveal areas of hidden structural damage. Roofs, foundations, walls, interior framing, porches and dormers all have structural components that may need added reinforcement. Structural stabilization by a qualified contractor should be done under the direction of a structural engineer or a preservation specialist to ensure that the added weight of the reinforcement can be sustained by the building and that the new members do not harm historic finishes (see fig. 6). Any major vertical post added during the stabilization should be properly supported and, if necessary, taken to the ground and underpinned.

Figure 6. Interior bracing which will last the duration of the mothballing will protect weakened structural members. Jethro Coffin House. Photo: John Milner Architects.

If the building is in a northern climate, then the roof framing must be able to hold substantial snow loads. Bracing the roof at the ridge and mid-points should be considered if sagging is apparent. Likewise, interior framing around stair openings or under long ceiling spans should be investigated. Underpinning or bracing structural piers weakened by poor drainage patterns may be a good precaution as well. Damage caused by insects, moisture, or from other causes should be repaired or reinforced and, if possible, the source of the damage removed. If features such as porches and dormers are so severely deteriorated that they must be removed, they should be documented, photographed, and portions salvaged for storage prior to removal.

If the building is in a southern or humid climate and termites or other insects are a particular problem, the foundation and floor framing should be inspected to ensure that there are no major structural weaknesses. This can usually be done by observation from the crawl space or basement. For those structures where this is not possible, it may be advisable to lift selective floor boards to expose the floor framing. If there is evidence of pest damage, particularly termites, active colonies should be treated and the structural members reinforced or replaced, if necessary.

Controlling pests. Pests can be numerous and include squirrels, raccoons, bats, mice, rats, snakes, termites, moths, beetles, ants, bees and wasps, pigeons, and other birds. Termites, beetles, and carpenter ants destroy wood. Mice, too, gnaw wood as well as plaster, insulation, and electrical wires. Pigeon and bat droppings not only damage wood finishes but create a serious and sometimes deadly health hazard.

If the property is infested with animals or insects, it is important to get them out and to seal off their access to the building. If necessary, exterminate and remove any nests or hatching colonies. Chimney flues may be closed off with exterior grade plywood caps, properly ventilated, or protected with framed wire screens. Existing vents, grills, and louvers in attics and crawl spaces should be screened with bug mesh or heavy duty wire, depending on the type of pest being controlled. It may be advantageous to have damp or infected wood treated with insecticides (as permitted by each state) or preservatives, such as borate, to slow the rate of deterioration during the time that the building is not in use.

Securing the exterior envelope from moisture penetration. It is important to protect the exterior envelope from moisture penetration before securing the building. Leaks from deteriorated or damaged roofing, from around windows and doors, or through deteriorated materials, as well as ground moisture from improper site run-off or rising damp at foundations, can cause long-term damage to interior finishes and structural systems. Any serious deficiencies on the exterior, identified in the condition assessment, should be addressed.

To the greatest extent possible, these weatherization efforts should not harm historic materials. The project budget may not allow deteriorated features to be fully repaired or replaced in-kind. Non-historic or modern materials may be used to cover historic surfaces temporarily, but these treatments should not destroy valuable evidence necessary for future preservation work. Temporary modifications should be as visually compatible as possible with the historic building.

Roofs are often the most vulnerable elements on the building exterior and yet in some ways they are the easiest element to stabilize for the long term, if done correctly. "Quick fix" solutions, such as tar patches on slate roofs, should be avoided as they will generally fail within a year or so and may accelerate damage by trapping moisture. They are difficult to undo later when more permanent repairs are undertaken. Use of a tarpaulin over a leaking roof should be thought of only as a very temporary

Figure 7. Non-historic materials are appropriate for mothballing projects when they are used to protect historic evidence remaining for future preservation. This lightweight aluminum channel frame and roofing covers the historic wooden shingle roof. Galvanized mesh panels secure the window openings from intrusion by raccoons and other unwanted guests. Photo: Williamsport Preservation Training Center, NPS.

Figure 8. Appropriate mortar mixes should be used when masonry repairs are undertaken. In this case, a soft lime based mortar is used as an infill between the brick and wooden elements. When full repairs are made during the restoration phase, this soft mortar can easily be removed and missing bricks replaced.

emergency repair because it is often blown off by the wind in a subsequent storm.

If the existing historic roof needs moderate repairs to make it last an additional ten years, then these repairs should be undertaken as a first priority. Replacing cracked or missing shingles and tiles, securing loose flashing, and reanchoring gutters and downspouts can often be done by a local roofing contractor. If the roof is in poor condition, but the historic materials and configuration are important, a new temporary roof, such as a lightweight aluminum channel system *over* the existing, might be considered (see fig. 7). If the roofing is so deteriorated that it must be replaced and a lightweight aluminum system is not affordable, various inexpensive options might be considered. These include covering the existing deteriorated roof with galvanized corrugated metal roofing panels, or 90 lb. rolled roofing, or a rubberized membrane (refer back to cover photo). These alternatives should leave as much of the historic sheathing and roofing in place as evidence for later preservation treatments.

For masonry repairs, appropriate preservation approaches are essential. For example, if repointing deteriorated brick chimneys or walls is necessary to prevent serious moisture penetration while the building is mothballed, the mortar should match the historic mortar in composition, color, and tooling. The use of hard portland cement mortars or vapor-impermeable waterproof coatings are not appropriate solutions as they can cause extensive damage and are not reversible treatments (see fig. 8).

For wood siding that is deteriorated, repairs necessary to keep out moisture should be made; repainting is generally warranted. Cracks around windows and doors can be beneficial in providing ventilation to the interior and so should only be caulked if needed to keep out bugs and moisture. For very deteriorated wall surfaces on wooden frame structures, it may be necessary to sheathe in plywood panels, but care should be taken to minimize installation damage by planning the location of the nailing or screw patterns or by installing panels over a frame of battens (see fig. 9). Generally, however, it is better to repair deteriorated features than to cover them over.

Foundation damage may occur if water does not drain away from the building. Run-off from gutters and downspouts should be directed far away from the foundation wall by using long flexible extender pipes equal in length to twice the depth of the basement or crawl space. If underground drains are susceptible to clogging, it is recommended that the downspouts be disconnected from the drain boot and attached to flexible piping. If gutters and downspouts are in bad condition, replace them with inexpensive aluminum units.

Figure 9. Severely deteriorated wooden siding on a farm building has been covered over with painted plywood panels as a temporary measure to eliminate moisture penetration to the interior. Foundation vents and loose floor boards allow air to circulate inside.

If there are no significant landscape or exposed archeological elements around the foundation, consideration should be given to regrading the site if there is a documented drainage problem (see fig. 10). If building up the grade, use a fiber mesh membrane to separate the new soil from the old and slope the new soil 6 to 8 feet (200 cm-266 cm) away from the foundation making sure not to cover up the dampcourse layer or come into contact with skirting boards. To keep vegetation under control, put down a layer of 6 mil black polyethylene sheeting or fiber mesh matting covered with a 2"-4" (5-10 cm.) of washed gravel. If the building suffers a serious rising damp problem, it may be advisable to eliminate the plastic sheeting to avoid trapping ground moisture against foundations.

Figure 10. Regrading around the Booker Tenement at Colonial Williamsburg has protected the masonry foundation wall from excessive damp. This building has been successfully mothballed for over 10 years. Note the attic and basement vents, the temporary stairs, and the information sign interpreting the history of this building.

Mothballing

The actual mothballing effort involves controlling the long-term deterioration of the building while it is unoccupied as well as finding methods to protect it from sudden loss by fire or vandalism. This requires securing the building from unwanted entry, providing adequate ventilation to the interior, and shutting down or modifying existing utilities. Once the building is de-activated or secured, the long-term success will depend on periodic maintenance and surveillance monitoring.

Securing the building from vandals, break-ins, and natural disasters. Securing the building from sudden loss is a critical aspect of mothballing. Because historic buildings are irreplaceable, it is vital that vulnerable entry points are sealed. If the building is located where fire and security service is available then it is highly recommended that some form of monitoring or alarm devices be used.

To protect decorative features, such as mantels, lighting fixtures, copper downspouts, iron roof cresting, or stained glass windows from theft or vandalism, it may be advisable to temporarily remove them to a more secure location if they cannot be adequately protected within the structure.

Mothballed buildings are usually boarded up, particularly on the first floor and basement, to protect fragile glass windows from breaking and to reinforce entry points (see fig. 11). Infill materials for closing door and window openings include plywood, corrugated panels, metal grates, chain fencing, metal grills, and cinder or cement blocks (see fig. 12). The method of installation should not result in the destruction of the opening and all associated sash, doors, and frames should be protected or stored for future reuse.

Figure 11. Urban buildings often need additional protection from unwanted entry and graffiti. This commercial building uses painted plywood panels to cover expansive glass storefronts and chain link fencing is applied on top of the panels. The upper windows on the street sides have been covered and painted to resemble 19th century sash. Photo: Thomas Jester, NPS.

Generally exterior doors are reinforced and provided with strong locks, but if weak historic doors would be damaged or disfigured by adding reinforcement or new locks, they may be removed temporarily and replaced with secure modern doors (see fig. 13). Alternatively, security gates in a new metal frame can be installed within existing door openings, much like a storm door, leaving the historic door in place. If plywood panels are installed over door openings, they should be screwed in place, as opposed to nailed, to avoid crowbar damage each time the panel is removed. This also reduces pounding vibrations from hammers and eliminates new nail holes each time the panel is replaced.

For windows, the most common security feature is the closure of the openings; this may be achieved with wooden or pre-formed panels or, as needed, with metal sheets or concrete blocks. Plywood panels, properly installed to protect wooden frames and properly ventilated, are the preferred treatment from a preservation standpoint.

There are a number of ways to set insert plywood panels into windows openings to avoid damage to frame and sash (see fig. 14). One common method is to bring the upper and lower sash of a double hung unit to the mid-point of the opening and then to install pre-cut plywood panels using long carriage bolts anchored into horizontal wooden bracing, or strong backs, on the inside face of the window. Another means is to build new wooden blocking frames set into deeply recessed openings, for example in an industrial mill or warehouse, and then to affix the plywood panel to the blocking frame. If sash must be removed prior to installing panels, they should be labeled and stored safely within the building.

Plywood panels are usually 1/2"-3/4" (1.25-1.875 cm.) thick and made of exterior grade stock, such as CDX, or marine grade plywood. They should be painted to protect them from delamination and to provide a neater appearance. These panels may be painted to resemble operable windows or treated decoratively (see fig. 15). With extra attention to detail, the plywood panels can be

Figure 12. First floor openings have been filled with cinderblocks and doors, window sash and frames have been removed for safe keeping. Note the security light over the windows and the use of a security metal door with heavy duty locks. Photo: H. Ward Jandl, NPS.

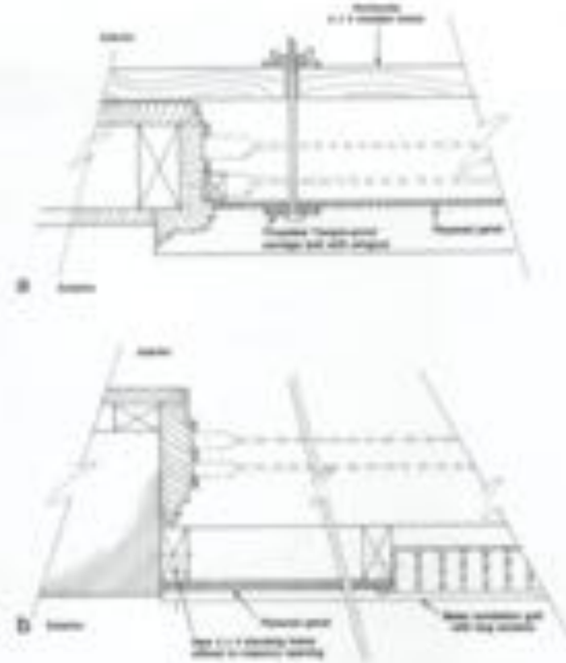


Figure 14. A: Plan detail showing plywood security panel anchored with carriage bolts through to the inside horizontal bracing, or strong backs. B: Plan detail showing section of plywood window panel attached to a new pressure treated wood frame set within the masonry opening. Ventilation should be included whenever possible or necessary.

Figure 13. If historic doors would be damaged by adding extra locks, they should be removed and stored and new security doors added. At this lighthouse, the historic door has been replaced with a new door (seen both inside and outside) with an inset vent and new deadbolt locks. The heavy historic hinges have not been damaged. Photo: Williamsport Preservation Training Center, NPS.

Figure 15. Painting trompe l'oeil scenes on plywood panels is a neighborhood friendly device. In addition, the small sign at the bottom left corner gives information for contacting the organization responsible for the care of the mothballed building. Photo: Lee H. Nelson, FAIA.

trimmed out with muntin strips to give a shadow line simulating multi-lite windows. This level of detail is a good indication that the building is protected and valued by the owner and the community.

If the building has shutters, simply close the shutters and secure them from the interior (see fig. 16). If the building had shutters historically, but they are missing, it may be appropriate to install new shutters, even in a modern material, and secure them in the closed position. Louvered shutters will help with interior ventilation if the sash are propped open behind the shutters.

Figure 16. Historic louvered shutters make excellent security closures with passive ventilation.

There is some benefit from keeping windows unboarded if security is not a problem. The building will appear to be occupied, and the natural air leakage around the windows will assist in ventilating the interior. The presence of natural light will also help when periodic inspections are made. Rigid polycarbonate clear storm glazing panels may be placed on the window exterior to protect against glass breakage. Because the sun's ultraviolet rays can cause fading of floor finishes and wall surfaces, filtering pull shades or inexpensive curtains may be options for reducing this type of deterioration for significant interiors. Some acrylic sheeting comes with built-in ultraviolet filters.

Securing the building from catastrophic destruction from fire, lightning, or arson will require additional security devices. Lightning rods properly grounded should be a first consideration if the building is in an area susceptible to lightning storms. A high security fence should also be installed if the property cannot be monitored closely. These interventions do not require a power source for operation. Since many buildings will not maintain electrical power, there are some devices available using battery packs, such as intrusion alarms, security lighting, and smoke detectors which through audible horn alarms can alert nearby neighbors. These battery packs must be replaced every 3 months to 2 years, depending on type and usage. In combination with a cellular phone, they can also provide some level of direct communication with police and fire departments.

If at all possible, new temporary electric service should be provided to the building (see fig. 17). Generally a telephone

Figure 17. Security systems are very important for mothballed buildings if they are located where fire and security services are available. A temporary electric service with battery back-up has been installed in this building. Intrusion alarms and ionization smoke/fire detectors are wired directly to the nearby security service.

line is needed as well. A hard wired security system for intrusion and a combination rate-of-rise and smoke detector can send an immediate signal for help directly to the fire department and security service. Depending on whether or not heat will be maintained in the building, the security system should be designed accordingly. Some systems cannot work below 32°F (0°C). Exterior lighting set on a timer, photo electric sensor, or a motion/infra-red detection device provides additional security.

Providing adequate ventilation to the interior. Once the exterior has been made weathertight and secure, it is essential to provide adequate air exchange throughout the building. Without adequate air exchange, humidity may rise to unsafe levels, and mold, rot, and insect infestation are likely to thrive (see fig. 18). The needs of each historic resource must be individually evaluated because there are so many variables that affect the performance of each interior space once the building has been secured. A

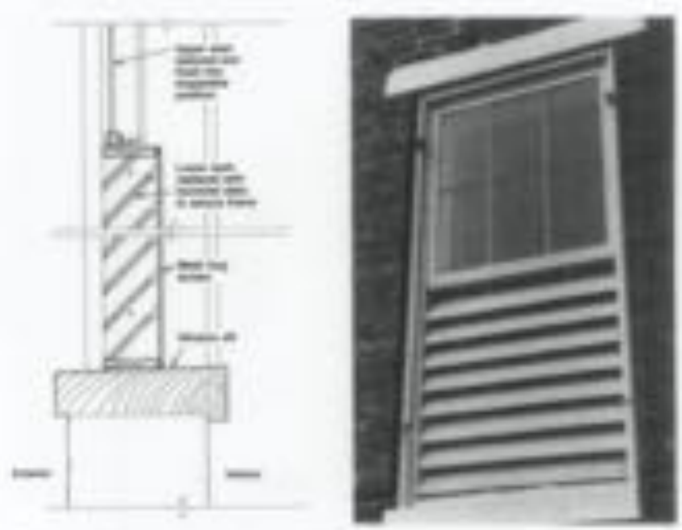


Figure 18. Heavy duty wooden slatted louvers were custom fabricated to replace the deteriorated lower sash. The upper sash were rebuilt to retain the historic appearance and to allow light into this vacant historic building. Refer back to Fig. 1 for a view of the building. Photo: Charles E. Fisher, NPS. Drawing by Thomas Vitanza.

mechanical engineer or a specialist in interior climates should be consulted, particularly for buildings with intact and significant interiors. In some circumstances, providing heat during the winter, even at a minimal 45° F (7°C), and utilizing forced-fan ventilation in summer will be recommended and will require retaining electrical service. For masonry buildings it is often helpful to keep the interior temperature above the spring dew point to avoid damaging condensation. In most buildings it is the need for summer ventilation that outweighs the winter requirements.

Many old buildings are inherently leaky due to loose-fitting windows and floorboards and the lack of insulation. The level of air exchange needed for each building, however, will vary according to geographic location, the building's construction, and its general size and configuration.

There are four critical climate zones when looking at the type and amount of interior ventilation needed for a closed up building: hot and dry (southwestern states); cold and damp (Pacific northwest and northeastern states); temperate and humid (Mid-Atlantic states, coastal areas); and hot and humid (southern states and the tropics). (See fig. 19 for a chart outlining guidance on ventilation.)

Once closed up, a building interior will still be affected by the temperature and humidity of the exterior. Without proper ventilation, moisture from condensation may occur and cause damage by wetting plaster, peeling paint, staining woodwork, warping floors, and in some cases even causing freeze thaw damage to plaster. If moist conditions persist in a property, structural damage can result from rot or returning insects attracted to moist conditions. Poorly mothballed masonry buildings, particularly in damp and humid zones have been so damaged on the interior with just one year of unventilated closure that none of the interior finishes were salvageable when the buildings were rehabilitated.

The absolute minimum air exchange for most mothballed buildings consists of one to four air exchanges every hour; one or two air exchanges per hour in winter and often twice that amount in summer. Even this minimal exchange may foster mold and mildew in damp climates, and so monitoring the property during the stabilization period and after the building has been secured will provide useful information on the effectiveness of the ventilation solution.

There is no exact science for how much ventilation should be provided for each building. There are, however, some general rules of thumb. Buildings, such as adobe structures, located in hot and arid climates may need no additional ventilation if they have been well weatherized and no moisture is penetrating the interior. Also frame buildings with natural cracks and fissures for air infiltration may have a natural air exchange rate of 3 or 4 per hour, and so in arid as well as temperate climates may need no additional ventilation once secured. The most difficult

VENTILATION GUIDANCE CHART							
CLIMATE	AIR EXCHANGES		VENTILATION				
Temperature and Humidity	Winter air exchange per hour	Summer air exchange per hour	Frame Buildings passive louvering % of openings louvered winter	 summer	Masonry Buildings passive louvering % of openings louvered winter	 summer	Masonry Buildings fan combination one fan + % louvered summer
hot and dry Southwestern areas	less than 1	less than 1	N/A	N/A	N/A	N/A	N/A
cold and damp Northeastern & Pacific northwestern areas	1	2-3	5%	10%	10%	30%	20%
temperate/humid Mid-Atlantic & coastal areas	2	3-4	10%	20%	20%	40%	30%
hot and humid Southern states & tropical areas	3	4 or more	20%	30%	40% or more	80%	40% or more

Figure 19. This is a general guide for the amount of louvering which might be expected for a medium size residential structure with an average amount of windows, attic, and crawl space ventilation. There is currently research being done on effective air exchanges, but each project should be evaluated individually. It will be noticed from the chart that summer louvering requirements can be reduced with the use of an exhaust fan. Masonry buildings need more ventilation than frame buildings. Chart prepared by Sharon C. Park, AIA and Ernest A. Conrad, P.E.

buildings to adequately ventilate without resorting to extensive louvering and/or mechanical exhaust fan systems are masonry buildings in humid climates. Even with basement and attic vent grills, a masonry building many not have more than one air exchange an hour. This is generally unacceptable for summer conditions. For these buildings, almost every window opening will need to be fitted out with some type of passive, louvered ventilation.

Depending on the size, plan configuration, and ceiling heights of a building, it is often necessary to have louvered opening equivalent to 5%-10% of the square footage of each floor. For example, in a humid climate, a typical 20'x30' (6.1m x 9.1m) brick residence with 600 sq. ft.(55.5 sq.m) of floor space and a typical number of windows, may need 30-60 sq. ft.(2.75sq.m-5.5 sq. m) of louvered openings per floor. With each window measuring 3'x5'(.9m x 1.5 m) or 15 sq. ft. (1.3 sq.m), the equivalent of 2 to 4 windows per floor may need full window louvers.

Small pre-formed louvers set into a plywood panel or small slit-type registers at the base of inset panels generally cannot provide enough ventilation in most moist climates to offset condensation, but this approach is certainly better than no louvers at all. Louvers should be located to give cross ventilation, interior doors should be fixed ajar at least 4" (10cm) to allow air to circulate, and hatches to the attic should be left open.

Monitoring devices which can record internal temperature and humidity levels can be invaluable in determining if the internal climate is remaining stable. These units can be powered by portable battery packs or can be wired into electric service with data downloaded into laptop computers periodically (see fig. 20). This can also give long-term information throughout the mothballing years. If it is determined that there are inadequate air exchanges to keep interior moisture levels under control, additional passive ventilation can be increased, or, if there is electric service, mechanical exhaust fans can be installed. One fan in a small to medium sized building can reduce the amount of louvering substantially.

Figure 20. Portable monitors used to record temperature and humidity conditions in historic buildings during mothballing can help identify ventilation needs. This data can be downloaded directly into a lap top computer on site. These monitors are especially helpful over the long term for buildings with significant historic interiors or which are remaining furnished. If interiors are remaining damp or humid, additional ventilation should be added or the source of moisture controlled.

If electric fans are used, study the environmental conditions of each property and determine if the fans should be controlled by thermostats or automatic timers. Humidistats, designed for enclosed climate control systems, generally are difficult to adapt for open mothballing conditions. How the system will draw in or exhaust air is also important. It may be determined that it is best to bring dry air in from the attic or upper levels and force it out through lower basement windows (see fig. 21). If the basement is damp, it may be best to zone it from the rest of the building and exhaust its air separately. Additionally, less humid day air is preferred over damper night air, and this can be controlled with a timer switch mounted to the fan.

The type of ventilation should not undermine the security of the building. The most secure installations use custom-made grills well anchored to the window frame, often set in plywood security panels. Some vents are formed using heavy millwork louvers set into existing window openings (refer back to fig.18). For buildings where security is not a primary issue, where the interior is modest, and where there has been no heat for a long time, it may be possible to use lightweight galvanized metal grills in the window openings (refer back to fig.7). A cost effective grill can be made from the expanded metal mesh lath used by plasterers and installed so that the mesh fins shed rainwater to the exterior.

Securing mechanical systems and utilities. At the outset, it is important to determine which utilities and services, such as electrical or telephone lines, are kept and which are cut off. As long as these services will not constitute a fire

Figure 21. This electric thermostat/humidistat mounted in the attic now controls a modified ducted air/fan system. The unit uses temporary exposed sheet metal ducts to pull air through the building and exhaust it out of the basement. For over ten years this fan system in combination with 18" x 18" preformed louvers in selective windows has kept the interior dry and with good air exchanges.

hazard, it is advisable to retain those which will help protect the property. Since the electrical needs will be limited in a vacant building, it is best to install a new temporary electric line and panel (100 amp) so that all the wiring is new and exposed. This will be much safer for the building, and allows easy access for reading the meter (see fig. 22).

Most heating systems are shut down in long term mothballing. For furnaces fueled by oil, there are two choices for dealing with the tank. Either it must be filled to the top with oil to eliminate condensation or it should be drained. If it remains empty for more than a year, it will likely rust and not be reusable. Most tanks are drained if a newer type of system is envisioned when the building is put back into service. Gas systems with open flames should be turned off unless there is regular maintenance and frequent surveillance of the property. Gas lines are shut off by the utility company.

If a hot water radiator system is retained for low levels of heat, it generally must be modified to be a self-contained system and the water supply is capped at the meter. This recirculating system protects the property from extensive damage from burst pipes. Water is replaced with a water/glycol mix and the reserve tank must also be filled with this mixture. This keeps the modified system from freezing, if there is a power failure. If water service is cut off, pipes should be drained. Sewerage systems will require special care as sewer gas is explosive. Either the traps must be filled with glycol or the sewer line should be capped off at the building line.

Developing a maintenance and monitoring plan. While every effort may have been made to stabilize the property and to slow the deterioration of materials, natural disasters, storms, undetected leaks, and unwanted intrusion can still occur. A regular schedule for surveillance, maintenance, and monitoring should be established (See fig. 23 for maintenance chart).

Figure 22. All systems except temporary electric have been shut off at this residence which has been mothballed over 10 years; the electric meter and 100 amp panel box have been set on a plywood panel at the front of the building. It is used for interior lighting and various alarm systems. The building, however, is showing signs of moisture problems with efflorescent stains on the masonry indicating the need for gutter maintenance and additional ventilation for the interior. The vegetation on the walls, although picturesque, traps moisture and is damaging to the masonry. Photo: H. Ward Jandl, NPS.

MAINTENANCE CHART

periodic
- ❑ regular drive by surveillance
- ❑ check attic during storms if possible

monthly walk arounds
- ❑ check entrances
- ❑ check window panes for breakage
- ❑ mowing as required
- ❑ check for graffiti or vandalism

enter every 3 months to air out
- ❑ check for musty air
- ❑ check for moisture damage
- ❑ check battery packs and monitoring equipment
- ❑ check light bulbs
- ❑ check for evidence of pest intrusion

every 6 months, spring and fall
- ❑ site clean-up; pruning and trimming
- ❑ gutter and downspout check
- ❑ check crawlspace for pests
- ❑ clean out storm drains

every 12 months
- ❑ maintenance contract inspections for equipment/utilities
- ❑ check roof for loose or missing shingles
- ❑ termite and pest inspection/treatment
- ❑ exterior materials spot repair and touch up painting
- ❑ remove bird droppings or other stains from exterior
- ❑ check and update building file

Figure 23. Maintenance Chart. Many of the tasks on the maintenance chart can be done by volunteer help or service contracts. Regular visits to the site will help deter intrusion, storm damage, or poor water drainage.

The fire and police departments should be notified that the property will be vacant. A walk-through visit to familiarize these officials with the building's location, construction materials, and overall plan may be invaluable if they are called on in the future.

The optimum schedule for surveillance visits to the property will depend on the location of the property and the number of people who can assist with these activities. The more frequent the visits to check the property, the sooner that water leaks or break-ins will be noticed. Also, the more frequently the building is entered, the better the air exchange. By keeping the site clean and the building in good repair, the community will know that the building has not been abandoned (see fig. 24). The involvement of neighbors and community groups in caring for the property can ensure its protection from a variety of catastrophic circumstances.

The owner may utilize volunteers and service companies to undertake the work outlined in the maintenance chart. Service companies on a maintenance contract can provide yard, maintenance, and inspection services, and their reports or itemized bills reflecting work undertaken should be added to update the building file.

Figure 24. Once mothballed, a property must still be monitored and maintained. The openings in this historic barn has been mothballed with a combination of wood louvers and metal mesh panels which require little maintenance. The grounds are regularly mowed, even inside the chain link security fence. Photo: Williamsport Preservation Training Center, NPS.

Components of a Mothballing Project

Document: Brearley House, New Jersey: 2½ story center hall plan house contains a high degree of integrity of circa 1761 materials and significant early 19th century additions. Deterioration was attributable to leaking roof, unstable masonry at gables and chimneys, deteriorating attic windows, poor site drainage, and partially detached gutters. Mothballing efforts are required for approximately 7-10 years.

Stabilize: Remove bat droppings from attic using great caution. Secure historic chimneys and gable ends with plywood panels. Do not take historic chimneys down. Reroof with asphalt shingles and reattach or add new gutters and downspouts. Add extenders to downspouts. Add bug screens to any ventilation areas. Add soil around foundation and slope to gain positive drain; do not excavate as this will disturb archeological evidence.

Mothball: Install security fence around the property. Secure doors and windows with plywood panels (3/4" exterior grade). Install preformed metal grills in basement and attic openings. Add surface-mounted wiring for ionization smoke and fire detection with direct wire to police and fire departments. Shut off heat and drain pipes. Add window exhaust fan set on a thermostatic control. Provide for periodic monitoring and maintenance of the property.

Figure 25. Above is a summary of the tasks that were necessary in order to protect this significant property while restoration funds are raised. Photographs: Michael Mills, Ford Farewell Mills Gatsch Architects.

a. A view showing the exterior of the house in its mothballed condition.

b. Plywood panels stabilize the chimneys. Note the gable vents.

c. The exhaust fan has tamper-proof housing.

MOTHBALLING CHECKLIST

Mothballing Checklist In reviewing mothballing plans, the following checklist may help to ensure that work items are not inadvertently omitted.	Yes	No	Date of action or comment
Moisture • Is the roof watertight? • Do the gutters retain their proper pitch and are they clean? • Are downspout joints intact? • Are drains unobstructed? • Are windows and doors and their frames in good condition? • Are masonry walls in good condition to seal out moisture? • Is wood siding in good condition? • Is site properly graded for water run-off? • Is vegetation cleared from around the building foundation to avoid trapping moisture?			
Pests • Have nests/pests been removed from the building's interior and eaves? • Are adequate screens in place to guard against pests? • Has the building been inspected and treated for termites, carpenter ants, and rodents? • If toxic droppings from bats and pigeons are present, has a special company been brought in for its disposal?			
Housekeeping • Have the following been removed from the interior: trash, hazardous materials such as inflammable liquids, poisons, and paints and canned goods that could freeze and burst? • Is the interior broom clean? • Have furnishings been removed to a safe location? • If furnishings are remaining in the building, are they properly protected from dust, pests, ultraviolet light, and other potentially harmful problems? • Have significant architectural elements that have become detached from the building been labeled and stored in a safe place? • Is there a building file?			
Security • Have fire and police departments been notified that the building will be mothballed? • Are smoke and fire detectors in working order? • Are the exterior doors and windows securely fastened? • Are plans in place to monitor the building on a regular basis? • Are the keys to the building in a secure but accessible location? • Are the grounds being kept from becoming overgrown?			
Utilities • Have utility companies disconnected/shut off or fully inspected water, gas, and electric lines? • If the building will not remain heated, have water pipes been drained and glycol added? • If the electricity is to be left on, is the wiring in safe condition?			
Ventilation • Have steps been taken to ensure proper ventilation of the building? • Have interior doors been left open for ventilation purposes? • Has the secured building been checked within the last 3 months for interior dampness or excessive humidity?			

Figure 26. MOTHBALL CHECKLIST. This checklist will give the building owner or manager a handy reference guide to items that should be addressed when mothballing a historic building. Prepared by H. Ward Jandl, NPS.

Conclusion

Providing temporary protection and stabilization for vacant historic buildings can arrest deterioration and buy the owner valuable time to raise money for preservation or to find a compatible use for the property. A well planned mothballing project involves documenting the history and condition of the building, stabilizing the structure to slow down its deterioration, and finally mothballing the structure to secure it (See fig. 25). The three highest priorities for the building while it is mothballed are 1) to protect the building from sudden loss, 2) to weatherize and maintain the property to stop moisture penetration, and 3) to control the humidity levels inside once the building has been secured. See Mothballing Checklist Figure 26.

While issues regarding mothballing may seem simple, the variables and intricacies of possible solutions make the decision-making process very important. Each building must be individually evaluated prior to mothballing. In addition, a variety of professional services as well as volunteer assistance are needed for careful planning and repair, sensitively designed protection measures, follow-up security surveillance, and cyclical maintenance (see fig. 27).

In planning for the future of the building, complete and systematic records must be kept and generous funds allocated for mothballing. This will ensure that the historic property will be in stable condition for its eventual preservation, rehabilitation, or restoration.

Figure 27. This residential building blends into the neighborhood even though all the windows have been covered over and the front steps are missing. The grounds are maintained and the special attention to decoratively painting the window panels shows that the property is being well cared for until it can be rehabilitated. Photo: Ohio Historical Society.

Acknowledgements

This publication has been prepared pursuant to the National Historic Preservation Act of 1966, as amended, which directs the Secretary of the Interior to develop and make available information concerning historic properties. Comments on the usefulness of this publication may be directed to H. Ward Jandl, Deputy Chief, Preservation Assistance Division, National Park Service, P.O. Box 37127, Washington, D.C. 20013-7127. This publication is not copyrighted and can be reproduced without penalty. Normal procedures for credit to the author and the National Park Service are appreciated.

The author, Sharon C. Park, Senior Historical Architect, Preservation Assistance Division, National Park Service, would like to acknowledge the assistance of the following individuals in the preparation and review of this publication. H. Ward Jandl served as the technical editor and assisted with producing this Preservation Brief. In addition the following persons have provided invaluable information and illustrations: Bryan A. Everett, PNL; [illegible], NPS Williamsport Preservation Training Center; Thomas C. Taylor, Colonial Williamsburg; Karen Gordon, Seattle Urban Conservation Office; [illegible], Seattle Department of Parks and Recreation; Michael Mills, AIA; [illegible], architect; Mary Beth Hirsch, Ohio Historical Society. Thanks also to Preservation Assistance Division staff members Michael J. Auer, Anne E. Grimmer, Kay D. Weeks, Timothy A. Buehner and Jean Travers, and to the numerous staff members of the NPS Regional offices who submitted comments.

All photographs and drawings are by the author unless otherwise noted.

Cover photograph: Mothballing of this historic house involved a new membrane roof covering over the historic roof and slatted window covers for security and ventilation. Photo: Williamsport Preservation Training Center, NPS.

ISSN: 0885-7016
September 1993

Further Reading

Cotton, J. Randall. "Mothballing Buildings." The Old House Journal. July/August, 1993.

Fisher, Charles E. and Thomas A. Vitanza. "Temporary Window Vents in Unoccupied Historic Buildings." Preservation Tech Note (Windows, No. 10). Washington, DC: National Park Service, 1985.

Frazier Associates. "Mothballing Historic Buildings." Preserving Prince William. 2. County of Prince William, VA, 1990.

Mitchell, Eleanor. *Emergency Repairs for Historic Buildings*. London: Butterworth Architecture, 1988.

"Mothballing Vacant Buildings." *An Anti-Arson Kit for Preservation and Neighborhood Action*. Washington, DC: Federal Emergency Management Agency, 1982.

Nelson, Lee H. *Preservation Briefs 17: Architectural character—Identifying the Visual Aspects of Historic Buildings as an Aid to Preserving Their Character*. Washington, DC: Government Printing Office, 1988.

Sefcik, Thomas E. "Security Panels for the Fenner Armstrong House." *Association for Preservation Technology Bulletin*. Vol. XVI, no. 3 & 4, 1984. (note the design of the panels, but be aware that additional louvering may be needed on other projects).

32 PRESERVATION BRIEFS

Making Historic Properties Accessible

Thomas C. Jester and Sharon C. Park, AIA

U.S. Department of the Interior
National Park Service
Cultural Resources

Heritage Preservation Services

Historically, most buildings and landscapes were not designed to be readily accessible for people with disabilities. In recent years, however, emphasis has been placed on preserving historically significant properties, and on making these properties—and the activities within them—more accessible to people with disabilities. With the passage of the Americans with Disabilities Act in 1990, access to properties open to the public is *now* a civil right.

This Preservation Brief introduces the complex issue of providing accessibility at historic properties, and underscores the need to balance accessibility and historic preservation. It provides guidance on making historic properties accessible while preserving their historic character; the Brief also provides examples to show that independent physical accessibility at historic properties can be achieved with careful planning, consultation, and sensitive design. While the Brief focuses primarily on making buildings and their sites accessible, it also includes a section on historic landscapes. The Brief will assist historic property owners, design professionals, and administrators in evaluating their historic properties so that the highest level of accessibility can be provided while minimizing changes to historic materials and features. Because many projects encompassing accessibility work are complex, it is advisable to consult with experts in the fields of historic preservation and accessibility before proceeding with permanent physical changes to historic properties.

Modifications to historic properties to increase accessibility may be as simple as a small, inexpensive ramp to overcome one entrance step, or may involve changes to exterior and interior features. The Brief does not provide a detailed explanation of local or State accessibility laws as they vary from jurisdiction to jurisdiction. A concise explanation of several federal accessibility laws is included on page 13.

Planning Accessibility Modifications

Historic properties are distinguished by features, materials, spaces, and spatial relationships that contribute to their historic character. Often these elements, such as steep terrain, monumental steps, narrow or heavy doors, decorative ornamental hardware, and narrow pathways and corridors, pose barriers to persons with disabilities, particularly to wheelchair users (See Figure 1).

A three-step approach is recommended to identify and implement accessibility modifications that will protect the integrity and historic character of historic properties:

1) Review the historical significance of the property and identify character-defining features;

2) Assess the property's existing and required level of accessibility; and

3) Evaluate accessibility options within a preservation context.

1) Review the Historical Significance of the Property

If the property has been designated as historic (properties that are listed in, or eligible for listing in the National Register of Historic Places, or designated under State or local law), the property's nomination file should be reviewed to learn about its significance. Local preservation commissions and State Historic Preservation Offices can usually provide

Figure 1. It is important to identify the materials, features, and spaces that should be preserved when planning accessibility modifications. These may include stairs, railings, doors, and door surrounds. Photo: National Park Service files.

copies of the nomination file and are also resources for additional information and assistance. Review of the written documentation should always be supplemented with a physical investigation to identify which character-defining features and spaces must be protected whenever any changes are anticipated. If the level of documentation for a property's significance is limited, it may be necessary to have a preservation professional identify specific historic features, materials, and spaces that should be protected.

For most historic properties, the construction materials, the form and style of the property, the principal elevations, the major architectural or landscape features, and the principal public spaces constitute some of the elements that should be preserved. Every effort should be made to minimize damage to the materials and features that convey a property's historical significance when making modifications for accessibility. Very small or highly significant properties that have never been altered may be extremely difficult to modify.

Secondary spaces and finishes and features that may be less important to the historic character should also be identified; these may generally be altered without jeopardizing the historical significance of a property. Non-significant spaces, secondary pathways, later additions, previously altered areas, utilitarian spaces, and service areas can usually be modified without threatening or destroying a property's historical significance.

2) Assess the Property's Existing and Required Level of Accessibility

A building survey or assessment will provide a thorough evaluation of a property's accessibility. Most surveys identify accessibility barriers in the following areas: building and site entrances; surface textures, widths and slopes of walkways; parking; grade changes; size, weight and configuration of doorways; interior corridors and path of travel restrictions; elevators; and public toilets and amenities (See Figure 2). Simple audits can be completed by property owners using readily available checklists (See Further Reading). Accessibility specialists can be hired to assess barriers in more complex properties, especially those with multiple buildings, steep terrain, or interpretive programs. Persons with disabilities can be particularly helpful in assessing specific barriers.

Figure 2. Surveys of historic properties can identify accessibility barriers. Persons with disabilities and accessibility consultants should participate whenever possible. Photo: Thomas Jester.

All applicable accessibility requirements—local codes, State codes and federal laws— should be reviewed carefully before undertaking any accessibility modification. Since many States and localities have their own accessibility regulations and codes (each with their own requirements for dimensions and technical requirements), owners should use the most stringent accessibility requirements when implementing modifications. The Americans with Disability Act Accessibility Guidelines (ADAAG) is the document that should be consulted when complying with the Americans with Disabilities Act (ADA) requirements.

3) Identify and Evaluate Accessibility Options within a Preservation Context

Once a property's significant materials and features have been identified, and existing and required levels of accessibility have been established, solutions can be developed (See Figure 3). Solutions should provide the greatest amount of accessibility without threatening or destroying those materials and features that make a property significant. Modifications may usually be phased over time as funds are available, and interim solutions can be considered until more permanent solutions are implemented. A team comprised of persons with disabilities, accessibility and historic preservation professionals, and building inspectors should be consulted as accessibility solutions are developed.

Modifications to improve accessibility should generally be based on the following priorities:

1) Making the main or a prominent public entrance and primary public spaces accessible, including a path to the entrance;
2) Providing access to goods, services, and programs;
3) Providing accessible restroom facilities; and,
4) Creating access to amenities and secondary spaces.

All proposed changes should be evaluated for conformance with the Secretary of the Interior's "Standards for the Treatment of Historic Properties," which were created for property owners to guide preservation work. These Standards stress the importance of retaining and protecting the materials and features that convey a property's historical significance. Thus, when new features are incorporated for accessibility, historic materials and features should be retained whenever possible. Accessibility modifications should be in scale with the historic property, visually compatible, and, whenever possible, reversible. Reversible means that if the new feature were removed at a later date, the essential form and integrity of the property would be unimpaired. The design of new features should also be differentiated from the design of the historic property so that the evolution of the property is evident. See Making Historic Buildings Accessible on page 9.

In general, when historic properties are altered, they should be made as accessible as possible. However, if an owner or a project team believes that certain modifications would threaten or destroy the significance of the property, the State Historic Preservation Officer should be consulted to determine whether or not any special accessibility provisions may be used. Special accessibility provisions for historic properties will vary depending on the applicable accessibility requirements.

A.

B.

C.

Figure 3. Before implementing accessibility modifications, owners should consider the potential effect on their historic property. At the Derby House in Salem, Massachusetts, several solutions to make the entrance accessible were considered, including regrading (a), a lift (b), and a ramp (c). The solution, an entrance on a secondary elevation, preserves the building's architectural significance and is convenient to designated parking. Drawings: National Park Service Files.

In some cases, programmatic access may be the only option for extremely small or unaltered historic properties, such as a two-story house museum with no internal elevator. Programmatic access for historic properties refers to alternative methods of providing services, information, and experiences when physical access cannot be provided. It may mean offering an audio-visual program showing an inaccessible upper floor of a historic house museum, providing interpretive panels from a vista at an inaccessible terraced garden, or creating a tactile model of a historic monument for people with visual impairments.

Accessibility Solutions

The goal in selecting appropriate solutions for specific historic properties is to provide a high level of accessibility without compromising significant features or the overall character of the property. The following sections describe accessibility solutions and offer guidance on specific historic property components, namely the building site, entrances, interiors, landscapes, amenities, and new additions. Several solutions are discussed in each section, referencing dimensions and technical requirements from the ADA's accessibility guidelines, ADAAG. State and local requirements, however, may differ from the ADA requirements. Before making any modification owners should be aware of all applicable accessibility requirements.

The Building Site

An accessible route from a parking lot, sidewalk, and public street to the entrance of a historic building or facility is essential. An accessible route, to the maximum extent possible, should be the circulation route used by the general public. Critical elements of accessible routes are their widths, slopes, cross slopes, and surface texture. Each of these route elements must be appropriately designed so that the route can be used by everyone, including people with disabilities. The distance between the arrival and destination points should also be as short as possible. Sites containing designed landscapes should be carefully evaluated before making accessibility modifications. Historic landscapes are described in greater detail on pages 10 and 11.

Providing Convenient Parking. If parking is provided, it should be as convenient as possible for people with disabilities. Specially designated parking can often be created to improve accessibility (See Figure 4). Modifications to parking configurations and pathways should not alter significant landscape features.

Creating an Accessible Route. The route or path through a site to a historic building's entrance should be wide enough, generally at least 3 feet (91 cm), to accommodate visitors

Figure 4. Parking designated for people with disabilities is provided near an accessible entrance to the Springfield Library in Springfield, Massachusetts. Photo: William Smith.

with disabilities and must be appropriately graded with a stable, firm, and slip-resistant surface. Existing paths should be modified to meet these requirements whenever possible as long as doing so would not threaten or destroy significant materials and features.

Existing surfaces can often be stabilized by providing a new base and resetting the paving materials, or by modifying the path surface. In some situations it may be appropriate to create a new path through an inaccessible area. At large properties, it may be possible to regrade a slope to less than 1:20 (5%), or to introduce one or more carefully planned ramps. Clear directional signs should mark the path from arrival to destination.

Entrances

Whenever possible, access to historic buildings should be through a primary public entrance. In historic buildings, if this cannot be achieved without permanent damage to character-defining features, at least one entrance used by the public should be made accessible. If the accessible entrance is not the primary public entrance, directional signs should direct visitors to the accessible entrance (See Figure 5). A rear or service entrance should be avoided as the only mean of entering a building.

Figure 5. A universal access symbol clearly marks the Arts and Industries Building in Washington, D.C., and a push plate (right) engages the automatic door-opener. Photo: Thomas Jester.

Creating an accessible entrance usually involves overcoming a change in elevation. Steps, landings, doors, and thresholds, all part of the entrance, often pose barriers for persons with disabilities. To preserve the integrity of these features, a number of solutions are available to increase accessibility. Typical solutions include regrading, incorporating ramps, installing wheelchair lifts, creating new entrances, and modifying doors, hardware, and thresholds.

Regrading an Entrance. In some cases, when the entrance steps and landscape features are not highly significant, it may be possible to regrade to provide a smooth entrance into a building. If the existing steps are historic masonry, they should be buried, whenever possible, and not removed (See Figure 6).

Incorporating Ramps. Permanent ramps are perhaps the most common means to make an entrance accessible. As a new feature, ramps should be carefully designed and appropriately located to preserve a property's historic character (See Figure 7). Ramps should be located at public

Figure 6. Entrances can be regraded to make a building accessible as long as no significant landscape features will be destroyed and as long as the building's historic character is preserved. The Houghton Chapel (a) in Wellesley, Massachusetts, was made accessible by regrading over the historic steps (b). Photos: Carol R. Johnson & Associates.

Figure 7. This ramp is convenient for visitors with disabilities and preserves the building's historic character. The design is also compatible in scale with the building. Photo: William Smith.

entrances used by everyone whenever possible, preferably where there is minimal change in grade. Ramps should also be located to minimize the loss of historic features at the connection points—porch railings, steps, and windows—and should preserve the overall historic setting and character of the property. Larger buildings may have below grade areas that can accommodate a ramp down to an entrance (See Figure 8). Below grade entrances can be considered if the ramp leads to a publicly used interior, such as an auditorium, or if the building is serviced by a public elevator. Ramps can often be incorporated behind

Figure 8. A new below-grade ramp provides access to Lake MacDonald Lodge in Glacier National Park. Photo: Thomas Jester

historic features, such as cheek-walls or railings, to minimize the visual effect (See Figure 9).

The steepest allowable slope for a ramp is usually 1:12 (8%), but gentler slopes should be used whenever possible to accommodate people with limited strength. Greater changes in elevation require larger and longer ramps to meet accessibility scoping provisions and may require an intermediate landing. Most codes allow a slightly steeper ramp for historic buildings to overcome one step.

Ramps can be faced with a variety of materials, including wood, brick, and stone. Often the type and quality of the materials determines how compatible a ramp design will be with a historic property (See Figure 10). Unpainted pressure-treated wood should not be used to construct ramps because it usually appears temporary and is not visually compatible with most historic properties. Railings

Figure 9. This ramp was created by infilling the window-well and slightly modifying the historic railing. The ramp preserves this building's historic character. Photo: Thomas Jester.

Figure 10. This brick ramp provides access to St. Anne's Episcopal Church in Annapolis, Maryland. Its design is compatible with the historic building. Photo: Charity V. Davidson

should be simple in design, distinguishable from other historic features, and should extend one foot beyond the sloped area (See Figure 11).

Ramp landings must be large enough for wheelchair users, usually at least 5 feet by 5 feet (152.5 cm by 152.5 cm), and the top landing must be at the level of the door threshold. It may be possible to reset steps by creating a ramp to accommodate minor level changes and to meet the threshold without significantly altering a property's historic character. If a building's existing landing is not wide or deep enough to accommodate a ramp, it may be

Figure 11. Simple, contemporary railings that extend beyond the ramp slope make this ramp compatible with the industrial character of this building. Photo: Thomas Jester.

necessary to modify the entry to create a wider landing. Long ramps, such as switchbacks, require intermediate landings, and all ramps should be detailed with an appropriate edge and railing for wheelchair users and visually impaired individuals.

Temporary or portable ramps are usually constructed of light-weight materials and, thus, are rarely safe or visually compatible with historic properties. Moreover, portable ramps are often stored until needed and, therefore, do not meet accessibility requirements for independent access. Temporary and portable ramps, however, may be an acceptable interim solution to improve accessibility until a permanent solution can be implemented (See Figure 12).

Figure 12. The Smithsonian Institution installed a temporary ramp on its visitor's center to allow adequate time to design an appropriate permanent ramp. Photo: Thomas Jester.

Installing Wheelchair Lifts. Platform lifts and inclined stair lifts, both of which accommodate only one person, can be used to overcome changes of elevation ranging from three to 10 feet (.9 m-3 m) in height. However, many States have restrictions on the use of wheelchair lifts, so all applicable codes should be reviewed carefully before installing one. Inclined stair lifts, which carry a wheelchair on a platform up a flight of stairs, may be employed selectively. They tend to be visually intrusive, although they are relatively reversible. Platform lifts can be used when there is inadequate space for a ramp. However, such lifts should be installed in unobtrusive locations and under cover to minimize maintenance if at all possible (See Figure 13). A similar, but more expensive platform lift has a retracting railing that lowers into the ground, minimizing the visual effect to historic properties (See Figure 14). Mechanical lifts have drawbacks at historic properties with high public visitation because their capacity is limited, they sometimes cannot be operated independently, and they require frequent maintenance.

Considering a New Entrance. When it is not possible to modify an existing entrance, it may be possible to develop a new entrance by creating an entirely new opening in an appropriate location, or by using a secondary window for an opening. This solution should only be considered after exhausting all possibilities for modifying existing entrances (See Figure 15).

Retrofitting Doors. Historic doors generally should not be replaced, nor should door frames on the primary elevation be widened, as this may alter an important feature of a historic design. However, if a building's historic doors have been removed, there may be greater latitude in designing a compatible new entrance. Most accessibility standards require at least a 32" (82 cm) clear opening with manageable door opening pressures. The most desirable preservation solution to improve accessibility is retaining historic doors and upgrading the door pressure with one of several devices. Automatic door openers

Figure 13. Platform lifts like the one used on this building require minimal space and can be removed without damaging historic materials. Shielded with lattice work, this lift is also protected by the roof eaves. Approach path should be stable, firm, and slip resistant. Photo: Sharon Park.

Readily Achievable Accessibility Modifications

Many accessibility solutions can be implemented easily and inexpensively without destroying the significance of historic properties. While it may not be possible to undertake all of the modifications listed below, each change will improve accessibility.

Sites and Entrances

- Creating a designated parking space.
- Installing ramps.
- Making curb cuts.

Interiors

- Repositioning shelves.
- Rearranging tables, displays, and furniture.
- Repositioning telephones.
- Adding raised markings on elevator control buttons.
- Installing flashing alarm lights.
- Installing offset hinges to widen doorways.
- Installing or adding accessible door hardware.
- Adding an accessible water fountain, or providing a paper cup dispenser at an inaccessible water fountain.

Restrooms

- Installing grab bars in toilet stalls.
- Rearranging toilet partitions to increase maneuvering space.
- Insulating lavatory pipes under sinks to prevent burns.
- Installing a higher toilet seat.
- Installing a full-length bathroom mirror.
- Repositioning the paper towel dispenser.

Figure 14. At the Lieutenant Governor's Mansion in Frankfort, Kentucky, a retracting lift (b) was installed to minimize the visual effect on this historic building when not in use (a). Photos: Aging Technology Incorporated.

Figure 15. A new entrance to the elevator lobby replaces a window at Faneuil Hall in Boston, Massachusetts. The new entrance is appropriately differentiated from the historic design. Photo: Paul Holtz.

(operated by push buttons, mats, or electronic eyes) and power-assisted door openers can eliminate or reduce door pressures that are accessibility barriers, and make single or double-leaf doors fully operational (See Figure 16).

Adapting Door Hardware. If a door opening is within an inch or two of meeting the 32" (81 cm) clear opening requirement, it may be possible to replace the standard hinges with off-set hinges to increase the size of the door opening as much as 1 1/2" (3.8 cm). Historic hardware can be retained in place, or adapted with the addition of an automatic opener, of which there are several types. Door hardware can also be retrofitted to reduce door pressures. For example, friction hinges can be retrofitted with ball-bearing inserts, and door closers can be rethreaded to reduce the door pressure.

Altering Door Thresholds. A door threshold that exceeds the allowable height, generally 1/2" (1.3 cm), can be altered or removed with one that meets applicable accessibility

Figure 16. During the rehabilitation of the Rookery in Chicago, the original entrance was modified to create an accessible entrance. Two revolving doors were replaced with a new one flanked by new doors, one of which is operated with a push-plate door opener. Photo: Thomas Jester.

requirements. If the threshold ... deemed to be significant, a bevel can be added on each side to reduce its height (See Figure 17). Another solution is to replace the threshold with one that meets applicable accessibility requirements and is visually compatible with the historic entrance.

Moving Through Historic Interiors

Persons with disabilities should have independent access to all public areas and facilities inside historic buildings. The extent to which a historic interior can be modified depends on the significance of its materials, plan, spaces, features, and finishes. Primary spaces are often more difficult to modify without changing their character. Secondary spaces may generally be changed without compromising a building's historic character. Signs should clearly mark the route to accessible restrooms, telephones, and other accessible areas.

Installing Ramps and Wheelchair Lifts. If space permits, ramps and wheelchair lifts can also be used to increase accessibility inside buildings (See Figures 18 & 19). However, some States and localities restrict interior uses of wheelchair lifts for life-safety reasons. Care should be taken to install these new features where they can be readily accessed. Ramps and wheelchair lifts are described in detail on pages 4-6.

Upgrading Elevators. Elevators are an efficient means of providing accessibility between floors. Some buildings have existing historic elevators that are not adequately accessible for persons with disabilities because of their size, location, or detailing, but they may also contribute to the historical significance of a building. Significant historic elevators can usually be upgraded to improve accessibility. Control panels can be modified with a "wand" on a cord to make the control panel accessible, and timing devices can usually be adjusted.

Retrofitting Door Knobs. Historic door knobs and other hardware may be difficult to grip and turn. In recent years, lever-handles have been developed to replace door knobs. Other lever-handle devices can be added to existing hardware. If it is not possible or appropriate to retrofit existing door knobs, doors can be left open during operating hours (unless doing so would violate life safety codes), and power-assisted door openers can be installed. It may only be necessary to retrofit specific doorknobs to create an accessible path of travel and accessible restrooms.

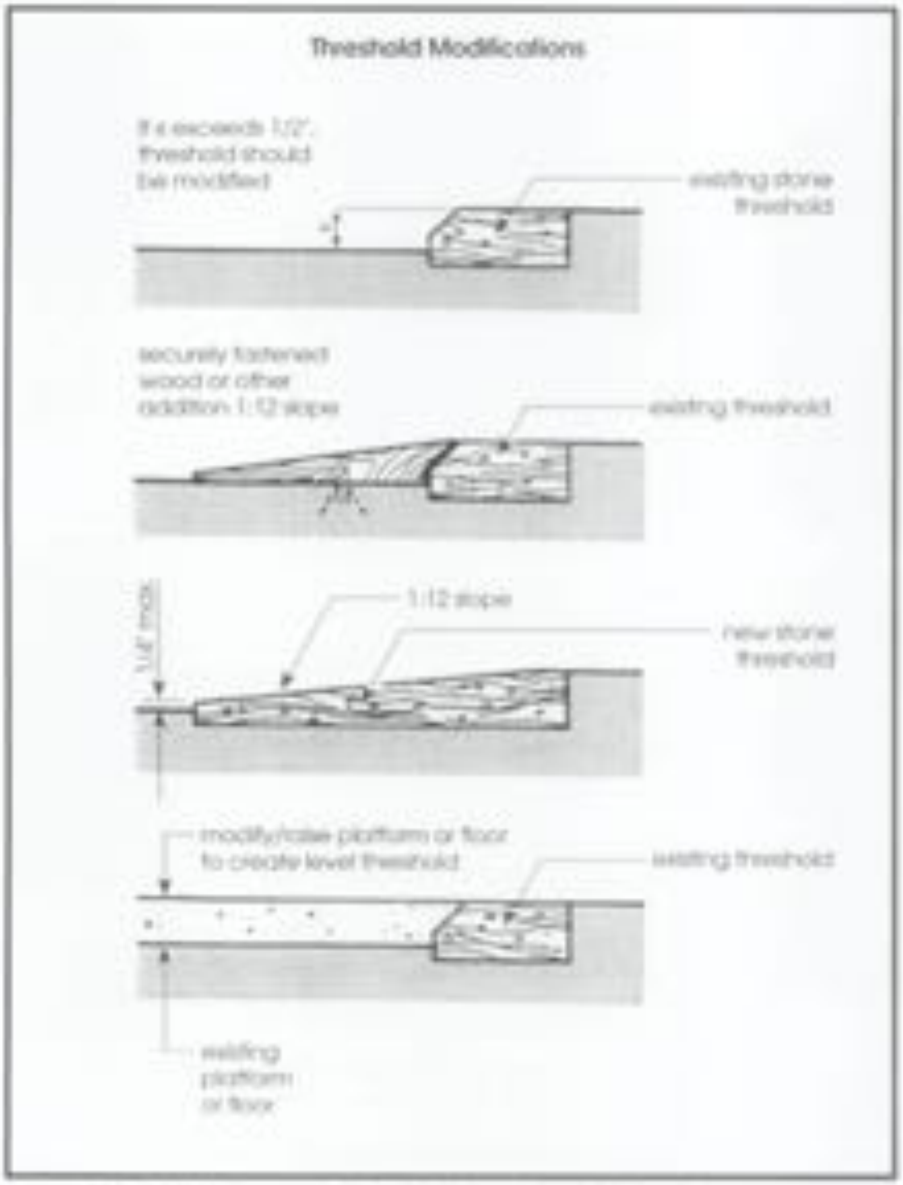


Figure 17. Thresholds that exceed allowable heights can be modified several ways to increase accessibility. Source: Uniform Federal Accessibility Standard (UFAS) Retrofit Manual.

be retained in the process of making modifications. For example, larger restrooms can sometimes be reconfigured by relocating or combining partitions to create an accessible toilet stall. Other changes to consider are adding grab bars around toilets, covering hot water pipes under sinks with insulation to prevent burns, and providing a sink, mirror, and paper dispenser at a height suitable for wheelchair users. A unisex restroom may be created if it is technically infeasible to create two fully accessible restrooms, or if doing so would threaten or destroy the significance of the building. It is important to remember that restroom fixtures, such as sinks, urinals, and partitions, may be historic, and therefore, should be preserved whenever possible.

Modifying Other Amenities. Other amenities inside historic buildings may require modification. Seating in a theater, for example, can be made accessible by removing some seats in several areas (See Figure 21). New seating that is accessible can also be added at the end of existing rows, either with or without a level floor surface. Readily removable seats may be installed in wheelchair spaces when the spaces are not required to accommodate wheelchair users. Historic water fountains can be retained and new, two-tiered fountains installed if space permits. If public telephones are provided, it may be necessary to install at least a Text Telephone (TT), also known as a Telecommunication Device for the Deaf (TDD) (See Figure 22). Historic service counters commonly found in banks, theaters, and hotels generally should not be altered. It is preferable to add an accessible counter on the end of a historic counter if feasible. Modified or new counters should not exceed 36" (91.5 cm) in height.

Modifying Interior Stairs. Stairs are the primary barriers for many people with disabilities. However, there are some ways to modify stairs to assist people who are able to navigate them. It may be appropriate to add hand railings if none exist. Railings should be 1 1/4" (3.8 cm) in diameter and return to the wall so straps and bags do not catch. Color-contrasting, slip-resistant strips will help people with visual impairments. Finally, beveled or closed risers are recommended unless the stairs are highly significant, because open risers catch feet (See Figure 20).

Building Amenities

Some amenities in historic buildings, such as restrooms, seating, telephones, drinking fountains, counters, may contribute to a building's historic character. They will often require modification to improve their use by persons with disabilities. In many cases, supplementing existing amenities, rather than changing or removing them, will increase access and minimize changes to historic features and materials.

Upgrading Restrooms. Restrooms may have historic fixtures such as sinks, urinals, or marble partitions that can

Figure 18. Symmetrical ramps at the Mayflower Hotel in Washington, D.C., provide access to the hotel's lower level. The design for the ramps respects the historic character of this landmark building. Photo: Thomas Jester.

MAKING A HISTORIC BUILDING ACCESSIBLE

The Orange County Courthouse (a), located in Santa Ana, California, was rehabilitated in the late 1980s as a county museum. As part of the rehabilitation, the architect sensitively integrated numerous modifications to increase accessibility. To preserve the building's primary elevation, a new public entrance was created on the rear elevation where parking spaces are located. A ramp (b) leads to the accessible entrance that can be opened with a push-plate automatic door-opener (c). Modifications to interior features also increased accessibility. To create an accessible path of travel, offset hinges (d) were installed on doors that were narrower than 32 inches (81.3 cm). Other doors were rethreaded to reduce the door pressure. Beveling the 1" high thresholds (e) reduced their height to approximately 1/4 inch (.64 cm). The project architect also converted a storeroom into an accessible restroom (f). The original stairway, which has open grillwork, was made more accessible by applying slip-resistant pressure tape to the marble steps (g). And the original elevator was upgraded with raised markings, alarm lights, and voice floor indicators. Photos: Milford Wayne Donaldson, FAIA.

MAKING HISTORIC LANDSCAPES ACCESSIBLE

To successfully incorporate access into historic landscapes, the planning process is similar to that of other historic properties. Careful research and inventory should be undertaken to determine which materials and features convey the landscape's historical significance. As part of this evaluation, those features that are character-defining (topographical variation, vegetation, circulation, structures, furnishings, objects) should be identified. Historic finishes, details, and materials that also contribute to a landscape's significance should also be documented and evaluated prior to determining an approach to landscape accessibility. For example, aspects of the pedestrian circulation system that need to be understood include walk width, aggregate size, pavement pattern, texture, relief, and joint details. The context of the walk should be understood including its edges and surrounding area. Modifications to surface textures or widths of pathways can often be made with minimal effect on significant landscape features (a) and (b).

Additionally, areas of secondary importance such as altered paths should be identified -- especially those where the accessibility modifications will not destroy a landscape's significance. By identifying those features that are contributing or non-contributing, a sympathetic circulation experience can then be developed.

After assessing a landscape's integrity, accessibility solutions can be considered. Full access throughout a historic landscape may not always be possible. Generally, it is easier to provide accessibility to larger, more open sites where there is a greater variety of public experiences. However, when a landscape is uniformly steep, it may only be possible to make discrete portions of a historic landscape accessible, and viewers may only be able to experience the landscape from selected vantage points along a prescribed pedestrian or vehicular access route. When defining such a route, the interpretive value of the user experience should be considered; in other words, does the route provide physical or visual access to those areas that are critical to understand the meaning of the landscape?

The following accessibility solutions address three common landscape situations: 1) structures with low integrity landscapes; 2) structures and landscapes of equal significance; and, 3) landscapes of primary significance with inaccessible terrain.

1. The Hunnewell Visitors Center at the Arnold Arboretum in Jamaica Plain, Massachusetts, was constructed in 1892. Its immediate setting has changed considerably over time (c). Since the existing landscape immediately surrounding this structure has little remaining integrity, the new accessibility solution has the latitude to integrate a broad program including site orientation, circulation, interpretation, and maintenance.

   The new design, which has few ornamental plants, references the original planting design principles, with a strong emphasis on form, color, and texture. In contrast with the earlier designs, the new plantings were set away from the facade of this historic building,

(a.) To improve accessibility in Boston's Emerald Necklace Parks, standard asphalt paving was replaced in selected areas with an imbedded aggregate surface that is more in keeping with the landscape's historic appearance. Photo: Charles Birnbaum.

(b.) The Friendly Garden at Rancho Los Alamitos, a historic estate with designed gardens in southern California, was made accessible with limited widening of its existing approach path. Photo: Rancho Los Alamitos Foundation.

(c.) Hunnewell Visitor's Center before rehabilitation, revealing the altered landscapes. Photo: Jennifer Jones, Carol R. Johnson and associates.

(d.) Hunnewell Visitors Center's entrance following rehabilitation, integrating an accessible path (left), platform, and new steps. Photo: Charles Birnbaum.

allowing the visitor to enjoy its architectural detail. A new walk winds up the gentle earthen berm and is vegetated with plantings that enhance the interpretive experience from the point of orientation (d). The new curvilinear walks also provide a connection to the larger arboretum landscape for everyone.

2. The Eugene O'Neill National Historic Site overlooks the San Ramon Valley, twenty-seven miles east of San Francisco, California. The thirteen-acre site includes a walled courtyard garden on the southeast side of the Tao House, which served as the O'Neill residence from 1937-44 (e). Within this courtyard are character-defining walks that are too narrow by today's accessibility standards, yet are a character-defining element of the historic design. To preserve the garden's integrity, the scale and the characteristics of the original circulation were maintained by creating a wheelchair route which, in part, utilizes reinforced turf. This route allows visitors with disabilities to experience the main courtyard as well.

3. Morningside Park in New York City, New York, designed by Frederick Olmstead, Sr., and Calvert Vaux in 1879, is sited on generally steep, rocky terrain (f). Respecting these dramatic grade changes, which are only accessible by extensive flights of stone stairs, physical access cannot be provided without destroying the park's integrity. In order to provide some accessibility, scenic overlooks were created that provide broad visual access to the park.

(e.) This view shows the new reinforced turf path at the Eugene O'Neill National Historic Site that preserved the narrow Historic Path. Photo: Patricia M. O'Donnell.

(f.) Steep terrain at Morningside Park in New York City cannot be made accessible without threatening or destroying this landscape's integrity. Photo: Quennell Rothschild Associates.

Figure 19. Inclined lifts can sometimes overcome interior changes of elevation where space is limited. This lift in Boston's Faneuil Hall created access to the floor and stage level of the State Room. Photo: Paul Holtz.

Considering a New Addition as an Accessibility Solution

Many new additions are constructed specifically to incorporate modern amenities such as elevators, restrooms, fire stairs, and new mechanical equipment. These new additions often create opportunities to incorporate access for people with disabilities. It may be possible, for example, to create an accessible entrance, path to public levels via a ramp, lift, or elevator (See Figure 23). However, a new addition has the potential to change a historic property's appearance and destroy significant building and landscape features. Thus, all new additions should be compatible with the size, scale, and proportions of historic features and materials that characterize a property (See Figure 24).

New additions should be carefully located to minimize connection points with the historic building, such that if the addition were to be removed in the future, the essential form and integrity of the building would remain intact. On the other hand, new additions should also be conveniently located near parking that is connected to an accessible route for people with disabilities. As new additions are incorporated, care should be taken to protect significant landscape features and archeological resources. Finally, the design for any new addition should be differentiated from the historic design so that the property's evolution over time is clear. New additions frequently make it possible to increase accessibility, while simultaneously reducing the level of change to historic features, materials, and spaces.

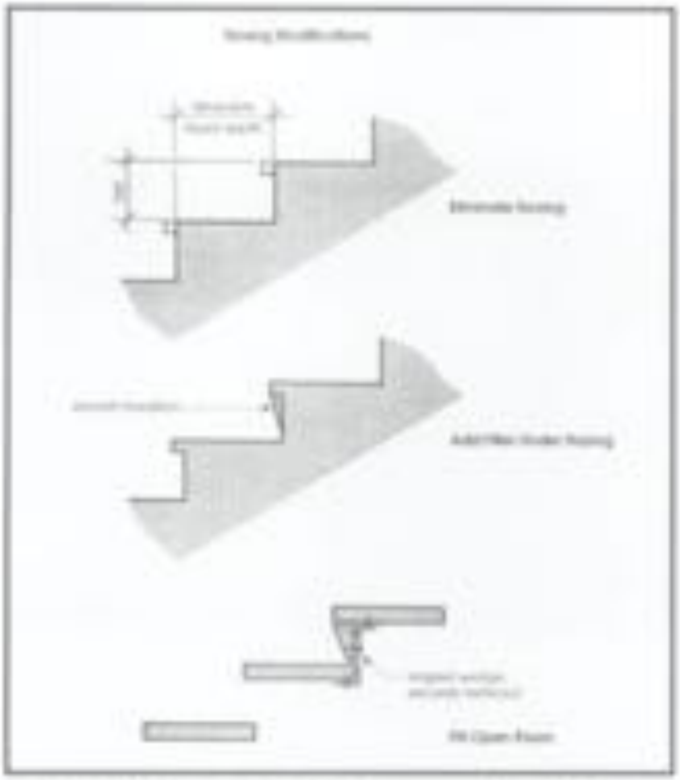


Figure 20. In certain situations it may be appropriate to modify stair nosings for persons with mobility impairments. Whenever possible, stairs should be modified by adding new materials rather than removing historic materials. Source: UFAS Retrofit Manual.

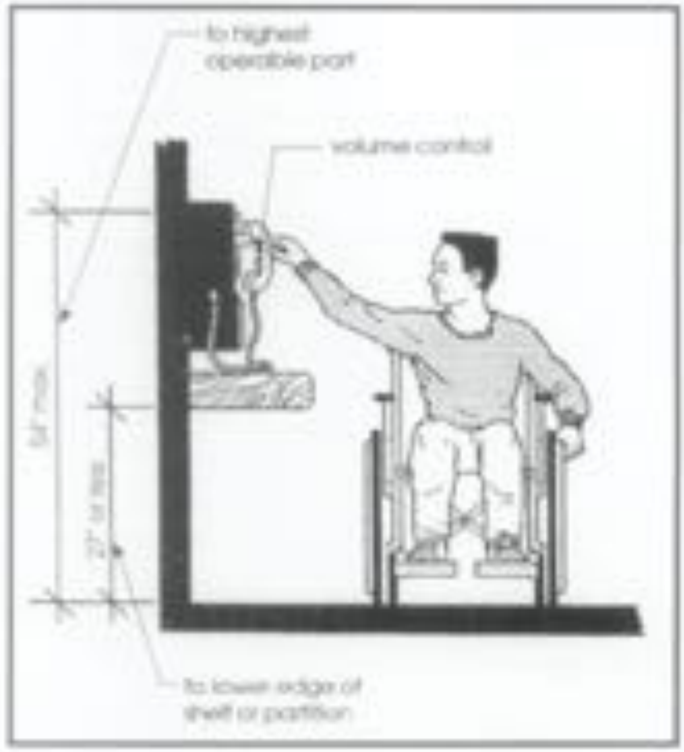


Figure 22. Amenities such as telephones should be at height that wheelchair users can reach. Changes to many amenities can be adapted with minimal effect on historic materials, features, and spaces. Source: UFAS Retrofit Manual.

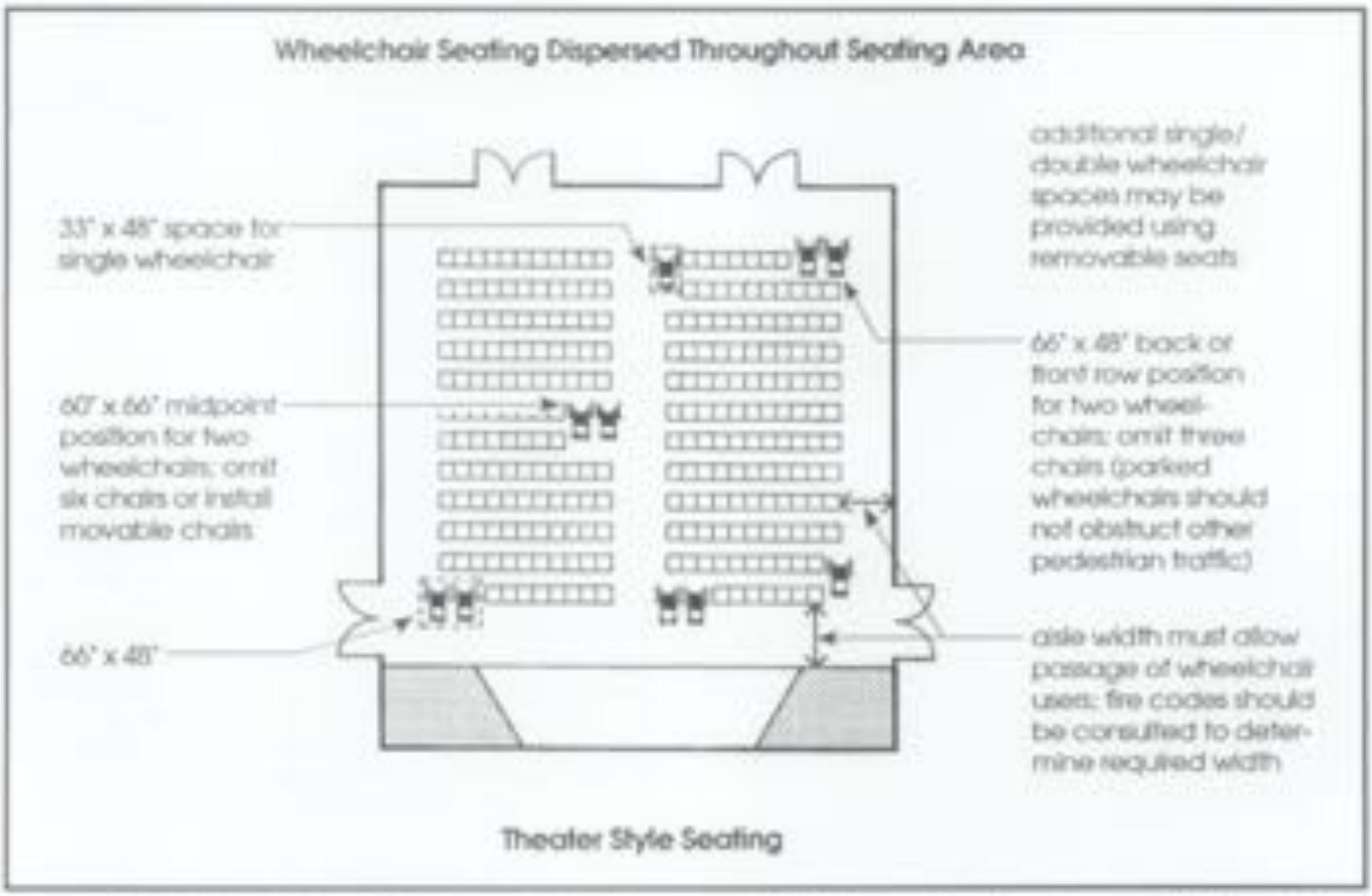


Figure 21. Seating in historic theaters and auditoriums can be changed to accommodate wheelchair users. Accessible seating areas should be connected to an accessible route from the building entrance. Source: UFAS Retrofit Manual.

Federal Accessibility Laws

Today, few building owners are exempt from providing accessibility for people with disabilities. Before making any accessibility modification, it is imperative to determine which laws and codes are applicable. In addition to local and State accessibility codes, the following federal accessibility laws are currently in effect:

Architectural Barriers Act (1968)

The Architectural Barriers Act stipulates that all buildings designed, constructed, and altered by the Federal Government, or with federal assistance, must be accessible. Changes made to federal buildings must meet the Uniform Federal Accessibility Standards (UFAS). Special provisions are included in UFAS for historic buildings that would be threatened or destroyed by meeting full accessibility requirements.

Rehabilitation Act (1973)

The Rehabilitation Act requires recipients of federal financial assistance to make their programs and activities accessible to everyone. Recipients are allowed to make their properties accessible by altering their building, by moving programs and activities to accessible spaces, or by making other accommodations.

Americans with Disabilities Act (1990)

Historic properties are not exempt from the Americans with Disabilities Act (ADA) requirements. To the greatest extent possible, historic buildings must be as accessible as non-historic buildings. However, it may not be possible for some historic properties to meet the general accessibility requirements.

Under Title II of the ADA, State and local governments must remove accessibility barriers either by shifting services and programs to accessible buildings, or by making alterations to existing buildings. For instance, a licensing office may be moved from a second floor to an accessible first floor space, or if this is not feasible, a mail service might be provided. However, State and local government facilities that have historic preservation as their main purpose—State-owned historic museums, historic State capitols that offer tours—must give priority to physical accessibility.

Under Title III of the ADA, owners of "public accommodations" (theaters, restaurants, retail shops, private museums) must make "readily achievable" changes; that is, changes that can be easily accomplished without much expense. This might mean installing a ramp, creating accessible parking, adding grab bars in bathrooms, or modifying door hardware. The requirement to remove barriers when it is "readily achievable" is an ongoing responsibility. When alterations, including restoration and rehabilitation work, are made, specific accessibility requirements are triggered.

Recognizing the national interest in preserving historic properties, Congress established alternative requirements for properties that cannot be made accessible without "threatening or destroying" their significance. A consultation process is outlined in the ADA's Accessibility Guidelines for owners of historic properties who believe that making specific accessibility modifications would "threaten or destroy" the significance of their property. In these situations, after consulting with persons with disabilities and disability organizations, building owners should contact the State Historic Preservation Officer (SHPO) to determine if the special accessibility provisions for historic properties may be used. Further, if it is determined in consultation with the SHPO that compliance with the minimum requirements would also "threaten or destroy" the significance of the property, alternative methods of access, such as home delivery and audio-visual programs, may be used.

Figure 23. New additions to historic buildings can be designed to increase accessibility. A new addition links two adjacent buildings used for the Albany, New York, Visitor's Center, and incorporates an accessible entrance, restrooms, and signage. Photo: Clare Adams.

Figure 24. Creating an accessible entrance with a new elevator tower requires a compatible design. This elevator addition blends in with the historic building's materials and provides access to all public levels. Photo: Sharon Park.

Conclusion

Historic properties are irreplaceable and require special care to ensure their preservation for future generations. With the passage of the Americans with Disabilities Act, access to historic properties open to the public is a new civil right, and owners of historic properties must evaluate existing buildings and determine how they can be made more accessible. It is a challenge to evaluate properties thoroughly, to identify the applicable accessibility requirements, to explore alternatives and to implement solutions that provide independent access and are consistent with accepted historic preservation standards. Solutions for accessibility should not destroy a property's significant materials, features and spaces, but should increase accessibility as much as possible. Most historic buildings are not exempt from providing accessibility, and with careful planning, historic properties can be made more accessible, so that all citizens can enjoy our Nation's diverse heritage.

Photo: Massachusetts Historical Commission.

Additional Reading

Ballantyne, Duncan S. and Harold Russell Associates, Inc. *Accommodation of Disabled Visitors at Historic Sites in the National Park System.* Washington, D.C.: Park Historic Architecture Division, National Park Service, U.S. Department of the Interior, 1983.

Goldman, Nancy. Ed. *Readily Achievable Checklist: A Survey for Accessibility.* Boston: Adaptive Environments Center, 1993.

Hayward, Judith L. and Thomas C. Jester, compilers. *Accessibility and Historic Preservation Resource Guide.* Windsor, Vermont: Historic Windsor, Inc., 1992, revised 1993.

Jester, Thomas C. *Preserving the Past and Making it Accessible for People with Disabilities.* Washington, D.C.: Preservation Assistance Division , National Park Service, U.S. Department of the Interior, 1992.

Parrott, Charles. *Access to Historic Buildings for the Disabled.* Washington, D.C.: U.S. Department of the Interior, 1980.

Secretary of the Interior's Standards for the Treatment of Historic Properties. Washington, D.C.: Preservation Assistance Division, National Park Service, U.S. Department of the Interior, 1993.

Smith, William D. and Tara Goodwin Frier. *Access to History: A Guide to Providing Access to Historic Buildings for People with Disabilities.* Boston: Massachusetts Historical Commission, 1989.

Standards for Accessible Design: ADA Accessibility Guidelines (ADAAG). Washington, D.C.: U.S. Department of Justice, 1991.

Acknowledgements

Thomas C. Jester is an Architectural Historian with the Preservation Assistance Division of the National Park Service. Sharon C. Park, AIA, is the Senior Historical Architect with the Preservation Assistance Division, National Park Service.

The authors wish to thank Charles A. Birnbaum, ASLA, Historical Landscape Architect with the Preservation Assistance Division, National Park Service, for contributing the section on historic landscapes. The authors gratefully acknowledge the invaluable comments made by the following individuals who reviewed the draft manuscript: William Smith, Massachusetts Historical Commission; Kay Weeks, H. Ward Jandl, Michael Auer, and Charles A. Birnbaum, Preservation Assistance Division, National Park Service; Clare Adams, New York Department of Parks, Recreation and Historic Preservation; Lauren Bowlin, Maryland Historical Trust; Tom Mayes, National Trust for Historic Preservation; Elizabeth Igleheart, Maine Historic Preservation Commission; Milford Wayne Donaldson, FAIA; Paul Beatty, U.S. Architectural and Transportation Barriers Compliance Board; Mid-Atlantic Regional Office, National Park Service; Western Regional Office, National Park Service.

This publication has been prepared pursuant to the National Historic Preservation Act of 1966, as amended, which directs the Secretary of the Interior to develop and make available information concerning historic properties. Comments about this publication should be directed to H. Ward Jandl, Deputy Chief, Preservation Assistance Division, National Park Service, P.O. Box 37127, Washington, D.C. 20013-7127.

ISSN: 0885-7016 September 1993

35 PRESERVATION BRIEFS

Understanding Old Buildings: The Process of Architectural Investigation

Travis C. McDonald, Jr.

U.S. Department of the Interior
National Park Service
Cultural Resources
Heritage Preservation Services

If you have ever felt a sense of excitement and mystery going inside an old building—whether occupied or vacant—it is probably because its materials and features resonate with the spirit of past people and events. Yet excitement about the unknown is heightened when a historic structure is examined architecturally, and its evolution over time emerges with increasing clarity to reveal the lives of its occupants. Architectural investigation is the critical first step in planning an appropriate treatment—understanding how a building has changed over time and assessing levels of deterioration.

Whether as a home owner making sympathetic repairs, a craftsman or contractor replacing damaged or missing features, or a conservator reconstituting wood or restoring decorative finishes, some type of investigative skill was used to recognize and solve an architectural question or explain a difficult aspect of the work itself.

To date, very little has been written for the layman on the subject of architectural investigation. This Preservation Brief thus addresses the often complex investigative process in broad, easy-to-understand terminology. The logical sequence of planning, investigation and analysis presented in this Brief is applicable to all buildings, geographic locations, periods, and construction types. It is neither a "how to" nor an exhaustive study on techniques or methodologies; rather, it serves to underscore the need for meticulous planning prior to work on our irreplaceable cultural resources.

Determining the Purpose of Investigation

Both the purpose and scope of investigation need to be determined before formulating a particular approach. For example, investigation strictly for research purposes could produce information for an architectural survey or for an historic designation application at the local, state or national level.

Within the framework of ***The Secretary of the Interior's Standards for the Treatment of Historic Properties***, investigation is crucial for "identifying, retaining, and preserving the form and detailing of those architectural materials and features that are important in defining the historic character" of a property, whether for repair or replacement. A rehabilitation project, for instance, might require an investigation to determine the historic configuration of interior spaces prior to partitioning a room to meet a compatible new use. Investigation for preservation work can entail more detailed information about an entire building, such as determining the physical sequence of construction to aid in interpretation. Investigation for a restoration project must be even more comprehensive in order to re-capture the exact form, features, finishes, and detailing of every component of the building.

Whether investigation will be undertaken by professionals—architects, conservators, historians—or by interested homeowners, the process is essentially comprised of a preliminary four-step procedure: historical research, documentation, inventory, and stabilization.

Historical Research. Primary historical research of an old building generally encompasses written, visual and oral resources that can provide valuable site-specific information. Written resources usually include letters, legal transactions, account books, insurance policies, institutional papers, and diaries. Visual resources consist of drawings, maps, plats, paintings and photographs. Oral resources are people's remembrances of the past. Secondary resources, comprised of research or history already compiled and written about a subject, are also important for providing a broad contextual setting for a project.

Historical research should be conducted well in advance of physical investigation. This allows time for important written, visual, and oral information to be located, transcribed, organized, studied and used for planning the actual work.

A thorough scholarly study of a building's history provides a responsible framework for the physical investigation; in fact, the importance of the link between written historical research and structural investigation cannot be overestimated. For example, the historical research of a building through deed records may merely determine the sequence of owners. This, in turn, aids the investigation of the building by establishing a chronology and identifying the changes each occupant made to the building. A letter

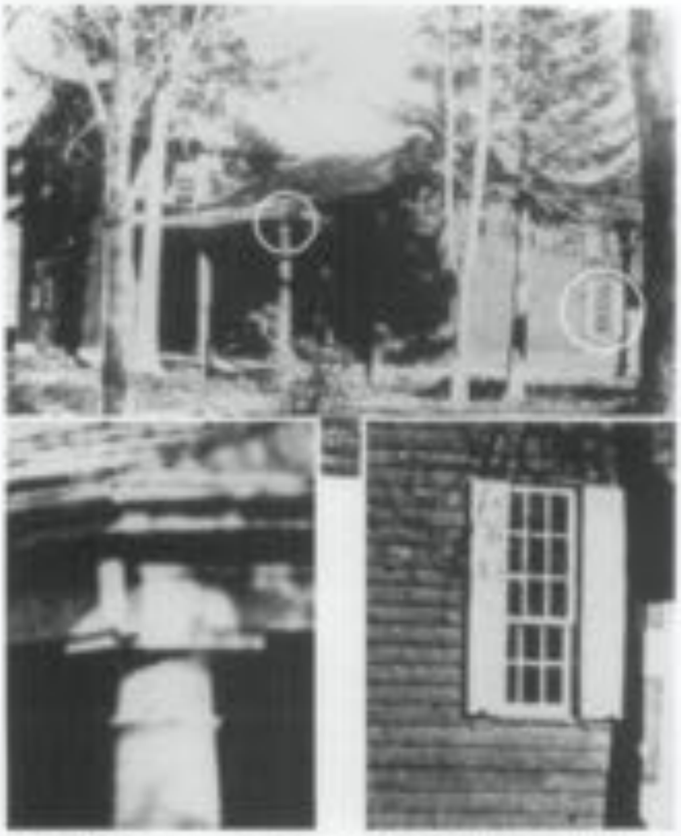


Figure 2. Early photographs discovered during historical research can be enhanced through photo-micrography to accurately recreate missing elements and details during restoration. The enlargements helped clarify questions about the porch column detail and the type of shutter hardware. photo: E. C. Stanton House, courtesy Seneca Falls Historical Society, New York; insets: NPS North Atlantic Cultural Resource Center, Building Conservation Branch.

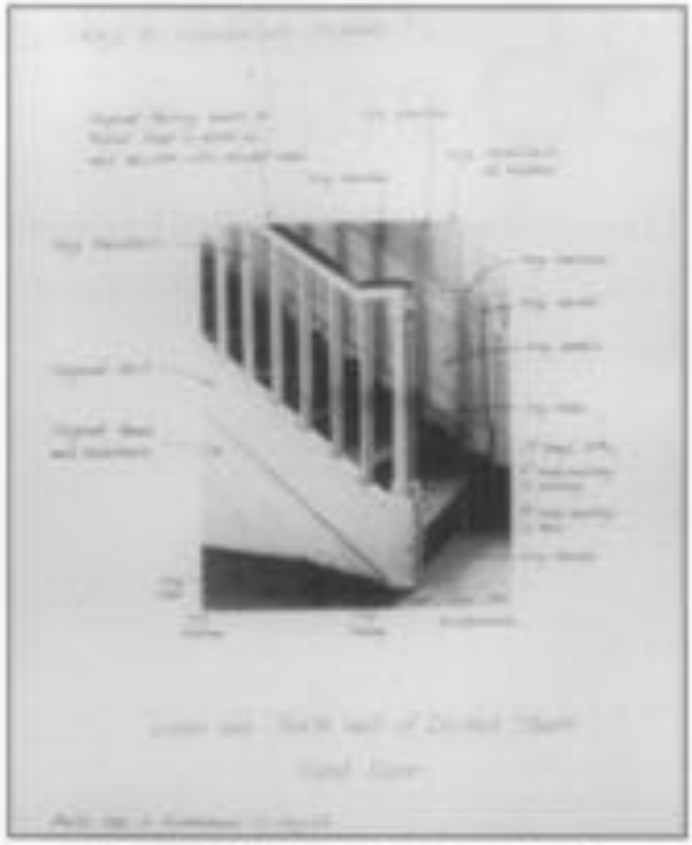


Figure 3. Dating, labeling, and providing annotated photographs is a simple, yet effective, way to document today's preservation efforts for future work and research. A useful document can be created by mounting a photograph upon archival paper and writing the annotations by hand. photo: NPS Preservation Assistance Division Files.

may indicate that an occupant painted the building in a certain year; the courthouse files contain the occupant's name and paint analysis of the building will yield the actual color. Two-dimensional documentary research and three-dimensional physical investigation go hand-in-hand in analyzing historic structures. The quality and success of any restoration project is founded upon the initial research.

Documentation. A building should be documented prior to any inventory, stabilization or investigative work in order to record crucial material evidence. A simple, comprehensive method is to take 35 mm photographs of every wall elevation (interior and exterior), as well as general views, and typical and unusual details. The systematic numbering of rooms, windows and doors on the floor plan will help organize this task and also be useful for labelling the photographs. Video coverage with annotated sound may supplement still photographs. Additional methods of documentation include written descriptions, sketches, and measured drawings.

Significant structures, such as individually listed National Register properties or National Historic Landmarks, benefit from professional photographic documentation and accurate measured drawings. Professionals frequently use ***The Secretary of the Interior's Standards and Guidelines for Architectural and Engineering Documentation: HABS/HAER Standards.*** It should be remembered that the documents created during investigation might play an unforeseen role in future treatment and interpretation.

Documentation is particularly valuable when a feature will be removed or altered.

Inventory. The historic building and its components should be carefully inventoried prior to taking any action; premature clean-up of a structure or site can be a mistake. A careful look at all spaces in and around a building may reveal loose architectural artifacts, fragile evidence or clues to historic landscape features. This thorough observation includes materials and features which have fallen off due to deterioration, fragments removed and stored in basements, attics or outbuildings, and even materials which have seemingly been discarded.

In the beginning, anything that seems even remotely meaningful should be saved. A common mistake is to presume to know the value of artifacts or features at the beginning of a project. Even if the period of significance or interpretation is known from the beginning, evidence from all periods should be protected. Documentation for future study or use includes labelling and, if possible, photographing prior to storage in a secure place.

Stabilization. In many cases, emergency stabilization is necessary to ensure that a structure does not continue to deteriorate prior to a final treatment or to ensure the safety of current occupants, investigators, or visitors. Although severe cases might call for structural remedies, in more common situations, preliminary stabilization would be undertaken on a maintenance level. Such work could involve installing a temporary roof covering to keep water out; diverting water away from foundation walls; removing plants that hold water too close to the walls; or securing a

Figure 4. An inventory of animal nests found within hidden spaces of a structure may yield unexpected evidence, such as information about food, decorative arts, and cultural or social traditions of every day life. Typical items of paper, fabric and wood are important artifacts which are generally not found during archeology digs in the ground. photo: Tom Graves, Jr., courtesy Jefferson's Poplar Forest.

Figure 5. Investigation frequently identifies urgent needs of stabilization. Priority must be given to issues of safety and structural integrity. Supplemental support, such as temporary shoring, may be required to prevent collapse and should be reviewed by a structural engineer.

structure against intruding insects, animals and vandals.

An old building may require temporary remedial work on exterior surfaces such as reversible caulking or an impermanent, distinguishable mortar. Or if paint analysis is contemplated in the future, deteriorated paint can be protected without heavy scraping by applying a recognizable "memory" layer over all the historic layers. Stabilization adds to the cost of any project, but human safety and the protection of historical evidence are well worth the extra money.

Investigators and Investigative Skills

General and Specialized Skills. The essential skill needed for any level of investigation is the ability to observe closely and to analyze. These qualities are ideally combined with a hands-on familiarity of historic buildings—and an open mind! Next, whether acquired in a university or in a practical setting, an investigator should have a good general knowledge of history, building design history and, most important, understand both construction and finish technologies.

But it is not enough to know architectural style and building technology from a national viewpoint; the investigator needs to understand regional and local differences as well. While investigative skills are transferable between regions and chronological periods, investigators must be familiar with the peculiarities of any given building type and geographical area.

Architectural survey and comparative fieldwork provides a crucial database for studying regional variations in historic buildings. For example, construction practices can reflect shared experiences of widely diverse backgrounds and traditions within a small geographical area. Contemporary construction practice in an urban area might vary dramatically from that of rural areas in the same region. Neighbors or builders within the same geographical area

Figure 6. An investigator must have the skill and ability to closely observe and analyze the materials with a broad understanding of historic construction practices and technologies. Through the collection of samples and analysis of materials, investigative questions are either answered, refined, or formulated.

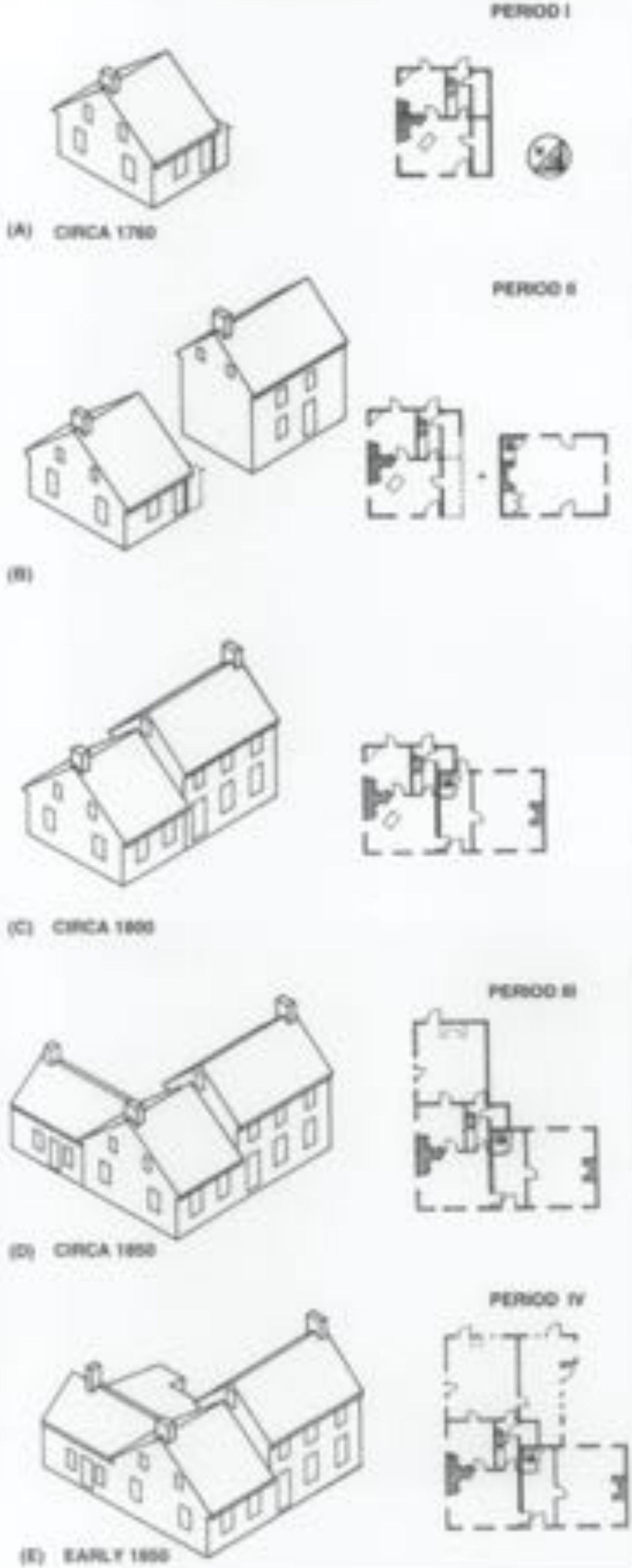
Showing the Evolution of an 18th Century Farmhouse

Most structures evolve over time. Houses, perhaps more than other building types, are often subjected to a full range of change that reflects a wide variety of solutions for creating new living space or eliminating outmoded spaces. Architectural changes to historic houses can be studied through the close physical examination of construction and decorative details. Tracing the history of alterations over time is tantamount to "excavating" the structure, somewhat like an archeological investigation. By peeling back its layers of occupation and assembling plan changes, a sequence of consecutive solutions or transformations can be developed that reveals people's ongoing desires for new and improved living conditions.

The example of a Sussex County, Delaware, house—from ca. 1790 to the early 1900s—illustrates how complicated the pattern of change over time can become in outlining an individual house history. The Hunter Farm House was built in the 18th century as a double-cell, double-pile, half-passage plan (a). Two bays across the front and two stories tall, the house possessed back-to-back corner fireplaces with fully paneled fireplace walls in the front and back rooms. A stair in the rear passage provided access to the second floor. A one-story, two-room shed that was attached to the gable wall farthest from the fireplace was accessed by a low door leading from the front room.

During the course of its history, the house was altered at least three times. The five-part illustration shows the house's transformation from an open plan to a Georgian plan and the subsequent addition and re-arrangement of service rooms for cooking and storage. The first remodelling occurred in the early nineteenth century when the lean-to shed was removed, and a two-story, single-pile, two-bay house was moved up and attached to the northwest gable of the existing building (b). (The newly attached building had originally been furnished with opposing doors and windows on the front and back facades, a fireplace on the southeast gable, and double windows on the opposite end.) When the second building was joined to the first, the fireplace in the newer building was relocated to the opposite gable; the front door in the older house moved to a more central position; and a center-hall plan created with a roughly symmetrical front elevation (c). A subsequent alteration later in the nineteenth century included the addition of a one-story rear service ell (d). Finally, in the early 1900s, the one-story service wing was increased. During this last remodeling, the large kitchen hearth was demolished and replaced with a stove and new brick flue (e).

Sidebar: Bernard L. Herman and Gabrielle M. Lanier, University of Delaware. Drawings by: Center for Historic Architecture and Engineering, University of Delaware.



often practice different techniques of constructing similar types of structures contemporaneously. Reliable dating clues for a certain brick bond used in one state might be unreliable for the same period in a different state. Regional variation holds true for building materials as well as construction.

Finally, even beyond regional and local variation, an investigator needs to understand that each building has its own unique history of construction and change over time. Form, features, materials and detailing often varied according to the tastes and finances of both builder and supplier; construction quality and design were also inconsistent, as they are today.

Specialists on a Team. Because architectural investigation requires a wide range of knowledge and many different skills, various people are likely to interact on the same project. While homeowners frequently execute small-scale projects, more complex projects might be directed by a craftsman, an architect or a conservator. For large-scale projects, a team approach may need to be adopted, consisting of professionals interacting with additional consultants. Consulting specialists may include architectural historians, architectural conservators, craftsmen, historic finish analysts, historians, archeologists, architects, curators, and many others. The scope and needs of a specific project dictate the skills of key players.

Architectural investigation often includes the related fields of landscape and archeological investigation. Landscape survey or analysis by horticulturists and landscape architects identify pre-existing features or plantings or those designed as separate or complementary parts of the site. Both above and below-ground archeology contribute information about missing or altered buildings, construction techniques, evidence of lifestyle and material culture, and about the evolution of the historic landscape itself.

Architectural Evidence: Studying the Fabric of the Historic Building:

Original Construction and Later Changes. Research prior to investigation may have indicated the architect, builder or a building's date of construction. In the absence of such information, architectural histories and field guides to architectural style can help identify a structure's age through its form and style.

Any preliminary date, however, has to be corroborated with other physical or documentary facts. Dates given for stylistic periods are general and tend to be somewhat arbitrary, with numerous local variations. Overall form and style can also be misleading due to subsequent additions and alterations. When the basic form seems in conflict with the details, it may indicate a transition between styles or that a style was simply upgraded through new work.

The architectural investigation usually determines original construction details, the chronology of later alterations, and the physical condition of a structure. Most structures over fifty years old have been altered, even if only by natural forces. People living in a house or using a building for any length of time leave some physical record of their time there, however subtle.

A longer period of occupancy generally counts for greater physical change. Buildings acquire a "historic character" as changes are made over time.

Changes to architectural form over time are generally attributable to material durability, improvement in convenience systems, and aesthetics. First, the durability of building materials is affected by weathering, temperature and humidity, by disasters such as storms, floods or fire, or by air pollution from automobiles and industry. Second, changes in architectural form have always been made for convenience' sake—fueled by technological innovations—as people embrace better lighting, plumbing, heating, sanitation, and communication. People alter living spaces to meet changing family needs. Finally, people make changes to architectural form, features, and detailing to conform to current taste and style.

Conducting the Architectural Investigation

Architectural investigation can range from a simple one hour walk-through to a month long or even multi-year project—and varies from looking at surfaces to professional sub-surface examination and laboratory work.

All projects should begin with the simplest, non-destructive processes and proceed as necessary. The sequence of investigation starts with reconnaissance and progresses to surface examination and mapping, sub-surface non-destructive testing, and various degrees of sub-surface destructive testing.

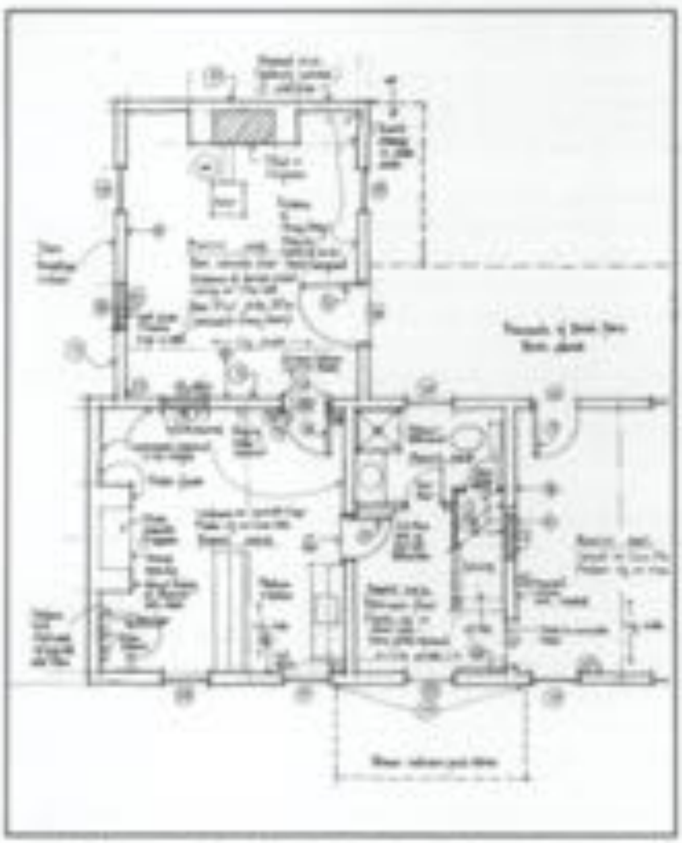


Figure 8. During the initial visit, the architectural investigator may be able to resolve many questions about the building's condition and chronology while recording their observations through field notes and annotated sketches. Drawing by Marianne Graham, courtesy Jefferson's Poplar Forest Restoration Field School.

Looking More Closely at Historic Building Materials and Features

Although brick or wood frame buildings are the most common in this country, similar sets of characteristics and questions can be established for examining log, adobe, steel, or any other material.

Figure A. Careful examination of the masonry reveals different periods of construction and repair through the composition and detailing of bricks and mortar. Depending upon location, open vertical joints may indicate the location of nailing blocks for decorative trim or weeps for drainage. These open joints at the building's cornice show evidence of an earlier wooden entablature extending down two courses below the present trim. The paint ghosts below the lowest blocks confirms the entablature's existence and provides clues to its size and finish.

Masonry. Studying historic brickwork can provide important information about methods of production and construction. For example, the color, size, shape and texture of brick reveals whether it was hand molded and traditionally fired in a clamp with hardwoods, or whether it was machine molded and fired in a kiln using modern fuels. Similarly, the principal component part of masonry mortar, the lime or cement, reveals whether it was produced in a traditional or modern manner. Certain questions need to be asked during investigation. Is the mortar made with a natural or a Portland cement? If a natural cement, did it come from an oyster shell or a limestone source? Is it hydrated or hydraulic? As a construction unit, brick and mortar further reveal something about the time, place and human variables of construction, such as the type of bond, special brick shapes, decorative uses of glazed or rubbed brick, coatings and finishes, and different joints, striking and tooling. Does the bond conform with neighboring or regional buildings of the same period? Does the pattern of "make up" bricks in a Flemish Bond indicate the number of different bricklayers? What is the method of attaching wood trim to the masonry? The same types of questions related to production and construction characteristics can be applied to all types of masonry work, including stone, concrete, terra cotta, adobe and coquina construction. A complete survey undertaken during "surface mapping" can outline the materials and construction practices for the various periods of a structure, distinguishing the original work as well as the additions, alterations, and replacements.

Figure B. Without damaging or altering historic fabric, X-ray images of wood connections provide internal views of construction materials and techniques. These x-ray images show nails being used to form the connections of a door opening in a wood stud wall covered with plaster and cut wooden lath. A single technician can operate the portable equipment and develop the film on site for immediate analysis. photos: NPS North Atlantic Cultural Resource Center, Building Conservation Branch.

Wood. Buildings constructed with wood have a very different set of characteristics, requiring a different line of questioning. Is the wooden structural system log, timber frame, or balloon frame construction? Evidence seen on the wood surface indicates whether production was by ax, adze, pit saw, mill saw (sash or circular), or band saw. What are the varying dimensions of the lumber used? Finished parts can be sawn, gouged, carved, or planed (by hand or by machine). Were they fastened by notching, mortise and tenon, pegs, or nailing? If nails were used, were they wrought by hand, machine cut with wrought heads, entirely machine cut, or machine wire nails? For much of the nineteenth century the manufacture of nails underwent a series of changes and improvements that are dateable, allowing nails to be used as a tool in establishing periods of construction and alteration. Regardless of region or era, the method of framing, joining and finishing a wooden structure will divulge something about the original construction, its alterations, and the practices of its builders. Finally, does some of the wood appear to be re-used or re-cycled? Re-used and reproduction materials used in early restoration projects have confused many investigators. When no identification record was kept, it can be a problems distinguishing between materials original to the house and later replacement materials.

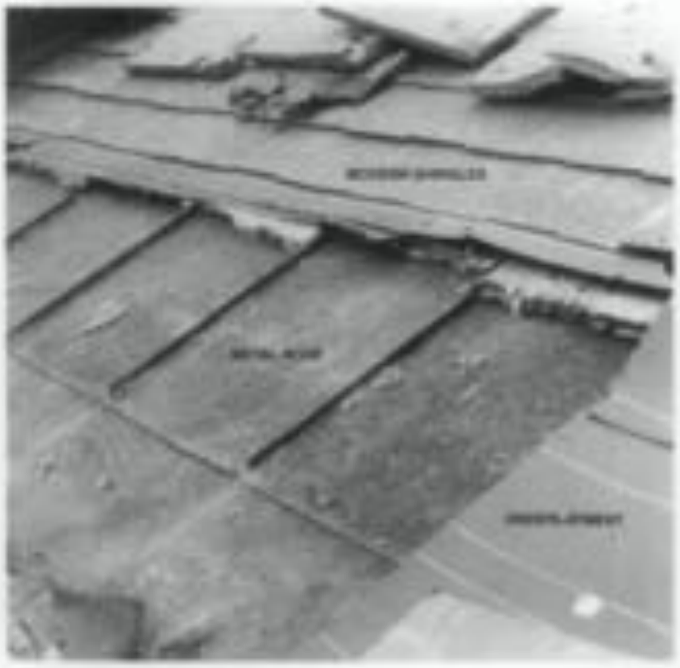


Figure C. In many cases, new materials or coverings are placed directly over existing exterior features, preserving the original materials underneath. Here, the removal of a modern shingle roof and its underlayment revealed an historic standing seam metal roof. photo: courtesy, Phillips and Opperman, P.A.

Roofs. Exterior features are especially prone to alteration due to weathering and lack of maintenance. Even in the best preserved structures, the exterior often consists of replaced or repaired roofing parts. Roof coverings typically last no more than fifty years. Are several generation of roof coverings still in place? Can the layers be identified? If earlier coverings were removed, the sheathing boards frequently provide clues to the type of covering as well as missing roof features. Dormers, cupolas, finials, cresting, weathervanes, gutters, lightning rods, skylights, balustrades, parapets and platforms come and go as taste, function and maintenance dictate. The roof pitch itself can be a clue to stylistic dating and is unlikely to change unless the entire roof has been rebuilt. Chimneys might hold clues to original roof pitch, flashings, and roof feature attachments. Is it possible to look down a chimney and count the number of flues? This practice has occasionally turned up a missing fireplace. In many parts of the country, nineteenth-century roof coverings evolved from wooden shingles or slate shingles, to metal shingles, to sheet metal, and still later in the twentieth century, to asphaltic or asbestos shingles. Clay tiles can be found covering roofs in seventeenth and eighteenth-century settlements of the east coast as well as western and southwestern Spanish settlements from the same period. Beyond the mid-nineteenth century, and into the twentieth, the range and choice of roof coverings greatly expanded.

Floors. In addition to production and construction clues, floors reveal other information about the interior, such as circulation patterns, furniture placement, the use of carpets, floor cloths, and applied floor finishes. Is there a pattern of tack holes? Tacks or tack holes often indicate the position and even the type of a floor covering. A thorough understanding of the seasonal uses of floor coverings and the technological history of their manufacture provide the background for identifying this type of evidence.

Figure D. Building styles change over time as moldings and trims are added and removed. The ghosts of the previous woodwork are often left behind and preserved under the new trim. This photograph shows distinct profiles of architectural trim from three successive periods. photo: courtesy, Valentine Museum, Richmond, Virginia.

Walls. Walls and their associated trim, both outside and inside, hold many clues to the building's construction and changes made over time. The overall style of moldings, trim and finishes, and their hierarchical relationship, can help explain original construction as well as room usage and social interaction between rooms. Holes, scars, patches, nails, nail holes, screws and other hardware indicate former attachments. Are there "ghosts," or shadow outlines of missing features, or trim attachments such as bases, chair rails, door and window casings, entablatures, cornices, mantels and shelves? Ghosts can be formed by paint, plaster, stucco, wear, weathering or dirt. Interior walls from the eighteenth and early nineteenth-century were traditionally plastered after grounds or finished trim was in place, leaving an absence of plaster on the wall behind them. Evidence of attachments on window casings can also be helpful in understanding certain interior changes. Other clues to look for include the installation of re-used material brought into a house or moved about within a house; worker's or occupant's graffiti, especially on the back of trim; and hidden finishes or wallpaper stuck in crevices or underneath pieces of trim. Stylistic upgrading often resulted in the re-use of outdated trim for blocking or shims. Unexpected discoveries are particularly rewarding. Investigators frequently tell stories about clues that were uncovered from architectural fragments carried off by rats and later found, or left by workers in attics, between walls and under floors.

1812 house disclosed the following information during an investigation: first period bell system, identification of a servant's hall, hidden fireplace, displacement of the service stairs, identification of a servants' quarters, an 1850s furnace system, 1850s gas and plumbing systems, relocation of the kitchen in 1870, early use of 1890s concrete floor slabs and finally, twentieth century utility systems. While the earliest era had been established as the interpretation period, evidence from all periods was documented in order to understand and interpret how the house evolved or changed over time.

Figure E. Discarded items are routinely stored within attics, then forgotten, only to be discovered during a later investigation. Seemingly worthless clutter and debris may help answer many questions. A thorough inventory should be performed before evaluating any object's usefulness.

Figure F. Outdated fixtures and systems are frequently abandoned in place when more modern units are installed. Examining and documenting their existence can provide a technological reference to the history and use of many rooms or structures. photo: NPS Preservation Assistance Division Files.

Attics and Basements. Attics and basements have been known as collection points for out-of-date, out-of-style and cast-off pieces such as mechanical systems, furnishings, family records and architectural fragments. These and other out-of-the-way places of a structure provide an excellent opportunity for non-destructive investigation. Not only are these areas where structural and framing members might be exposed to view, they are also areas which may have escaped the frequent alteration campaigns that occur in the more lived-in parts of a building. If a building has been raised or lowered in height, evidence of change would be found in the attic as well as on the exterior. Evidence of additions might also be detected in both the attic and the basement. Attics frequently provide a "top-side" view at the ceiling below, revealing its material, manner of production and method of attachment. A "bottom-side" view of the roof sheathing or roof covering can be seen from the attic as well.

Basements generally relate more to human service functions in earlier buildings and to mechanical services in more recent eras. For example, a cellar of an urban

Mechanical, Electrical, Plumbing and Other Systems. Systems of utility and convenience bear close scrutiny during investigation. All historic buildings inhabited and used by people reveal some association, at the very minimum, with the necessities of lighting, climate control, water, food preparation, and waste removal. Later installations in a building may include communication, hygiene, food storage, security, and lightning protection systems. Other systems, such as transportation, are related to more specific functions of commercial or public structures. Although research into the social uses of rooms and their furnishings has borne many new studies, parallel research into how people actually carried out the most mundane tasks of everyday life has been fairly neglected. Utility and convenience systems are most prone to alteration and upgrading and, at the same time, less apt to be preserved, documented or re-used. Understanding the history or use of a building, and the history of systems technology can help predict the physical evidence that might be found, and what it will look like after it is found.

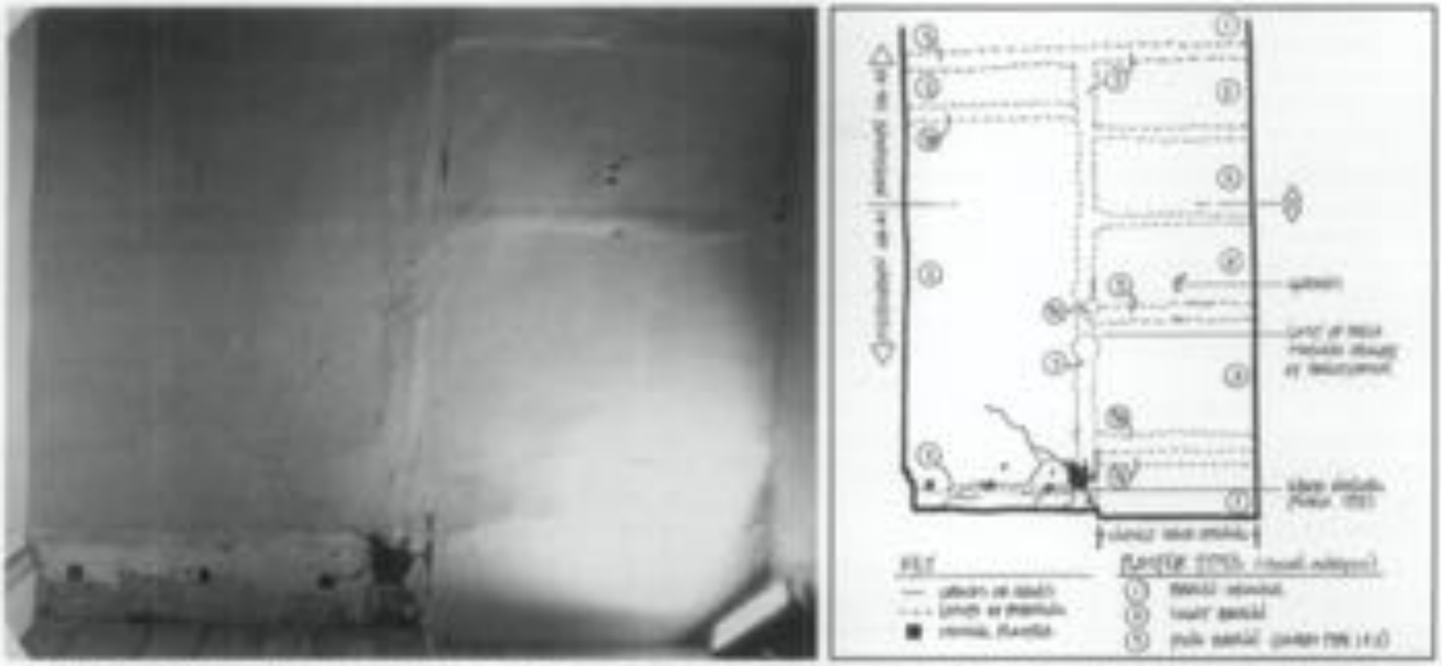


Figure 9. Raking light is used to show irregularities on flat surfaces. Patches, repairs, and alterations can then be mapped by the shadows or ghosts they cast. In this case, the pattern of patched plaster suggested the removal shelves and a balustrade handrail from the wall. Historical research and plaster analysis confirmed the findings and the sequence of change.

Reconnaissance. An initial reconnaissance trip through a structure—or visual overview—provides the most limited type of investigation. But experienced investigators accustomed to observation and analysis can resolve many questions in a two-to-four hour preliminary site visit. They may be able to determine the consistency of the building's original form and details as well as major changes made over time.

Surface Mapping. The first step in a thorough, systematic investigation is the examination of all surfaces. Surface investigation is sometimes called "surface mapping" since it entails a minute look at all the exterior and interior surfaces. The fourfold purpose of surface mapping is to observe every visible detail of design and construction; develop questions related to evidence and possible alterations; note structural or environmental problems; and help develop plans for any further investigation. Following investigation, a set of documentary drawings and photographs is prepared which record or "map" the evidence.

While relying upon senses of sight and touch, the most useful tool for examining surfaces is a high-powered, portable light used for illuminating dark spaces as well as for enhancing surface subtleties. Raking light at an angle on a flat surface is one of the most effective means of seeing evidence of attachments, repairs or alterations.

Non-Destructive Testing. The next level of investigation consists of probing beneath surfaces using non-destructive methods. Questions derived from the surface mapping examination and analysis will help determine which areas to probe. Investigators have perfected a number of tools and techniques which provide minimal damage to historic fabric. These include x-rays to penetrate surfaces in order to see nail types and joining details; boroscopes, fiber optics and small auto mechanic or dentists' mirrors to look inside of tight spaces; and ultra violet or infra-red lights to observe differences in materials and finishes. The most advanced

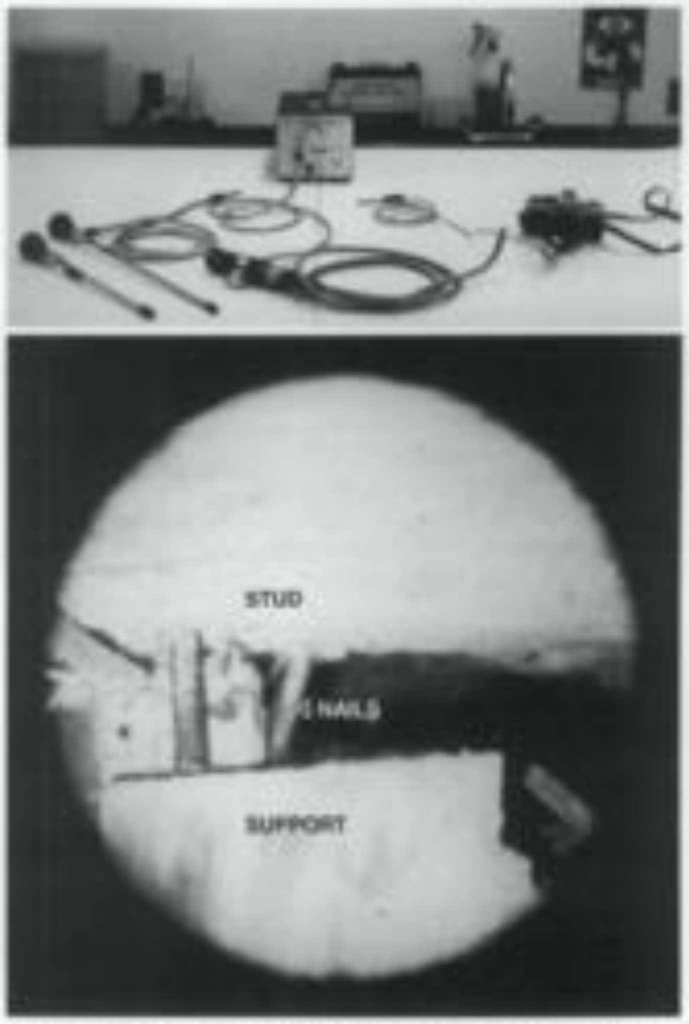


Figure 10. Top: A boroscope is a fiber-optic tube which can provide views into the framing connections of a wall through an existing crack or hole. Bottom: Once the image is oriented, the investigator can see an open joint between the wood stud and its nailed lateral support. photos: NPS North Atlantic Cultural Resource Center, Building Conservation Branch.

technology combines the boroscope with video cameras using fiber optic illumination. In addition to the more common use of infra-red photography, similar non-destructive techniques used in archeological investigations include remote sensing and ground-penetrating radar.

Small material samples of wood, plaster, mortar, or paint can also be taken for laboratory analysis at this stage of investigation. For instance, a surface examination of a plaster wall using a raking light may show clear evidence of patching which corresponds to a shelf design. Were the shelves original or a later addition? A small sample of plaster from the patched area is analyzed in the laboratory and matches plaster already dated to a third period of construction. A probe further reveals an absence of first period plaster on the wall underneath. The investigator might conclude from this evidence that the shelves were an original feature and that the plaster fill dates their removal and patching to a third period of construction.

Destructive Testing. Most investigations require nothing more than historical research, surface examination and non-destructive testing. In very rare instances the investigation may require a sub-surface examination and the removal of fabric. Destructive testing should be carried out by a professional only after historical research and surface mapping have been fully accomplished and *only after* non-destructive testing has failed to produce the necessary information. Owners should be aware that the work is a form of demolition in which the physical record may be destroyed. Sub-surface examination begins with the most accessible spaces, such as retrofitted service and mechanical chases; loose or previously altered trim, ceilings or floor boards; and pieces of trim or hardware which can be easily removed and replaced.

Non-destructive testing techniques do not damage historic fabric. If non-destructive techniques are not sufficient to resolve important questions, small "windows" can be opened in surface fabric at predetermined locations to see beneath the surface. This type of subsurface testing and removal is sometimes called "architectural archeology" because of its similarity to the more well-known process of trenching in archeology. The analogy is apt because both forms of archeology use a method of destructive investigation.

Photographs, video and drawings should record the before, during and after evidence when the removal of historic fabric is necessary. The selection and sequence of material to be removed requires careful study so that original extant fabric remains *in situ* if possible. If removed, original fabric should be carefully put back or labelled and stored. At least one documentary patch of each historic finish should be retained *in situ* for future research. Treatment and interpretation, no matter how accurate, are usually not final; treatment tends to be cyclical, like history, and documentation must be left for future generations, both on the wall and in the files.

Laboratory Analysis. Laboratory analysis plays a scientific role in the more intuitive process of architectural investigation. One of the most commonly known laboratory procedures used in architectural investigation is that of historic paint analysis. The chronology and stratigraphy of applied layers can establish appropriate colors, finishes, designs or wall coverings. When conducted simultaneously with architectural investigation, the stratigraphy of finishes, like that of stratigraphic soils in archeology, helps determine the sequence of construction or alterations in a building. Preliminary findings from *in situ* examinations of painted finishes on walls or trim are common, but more accurate results come from extensive

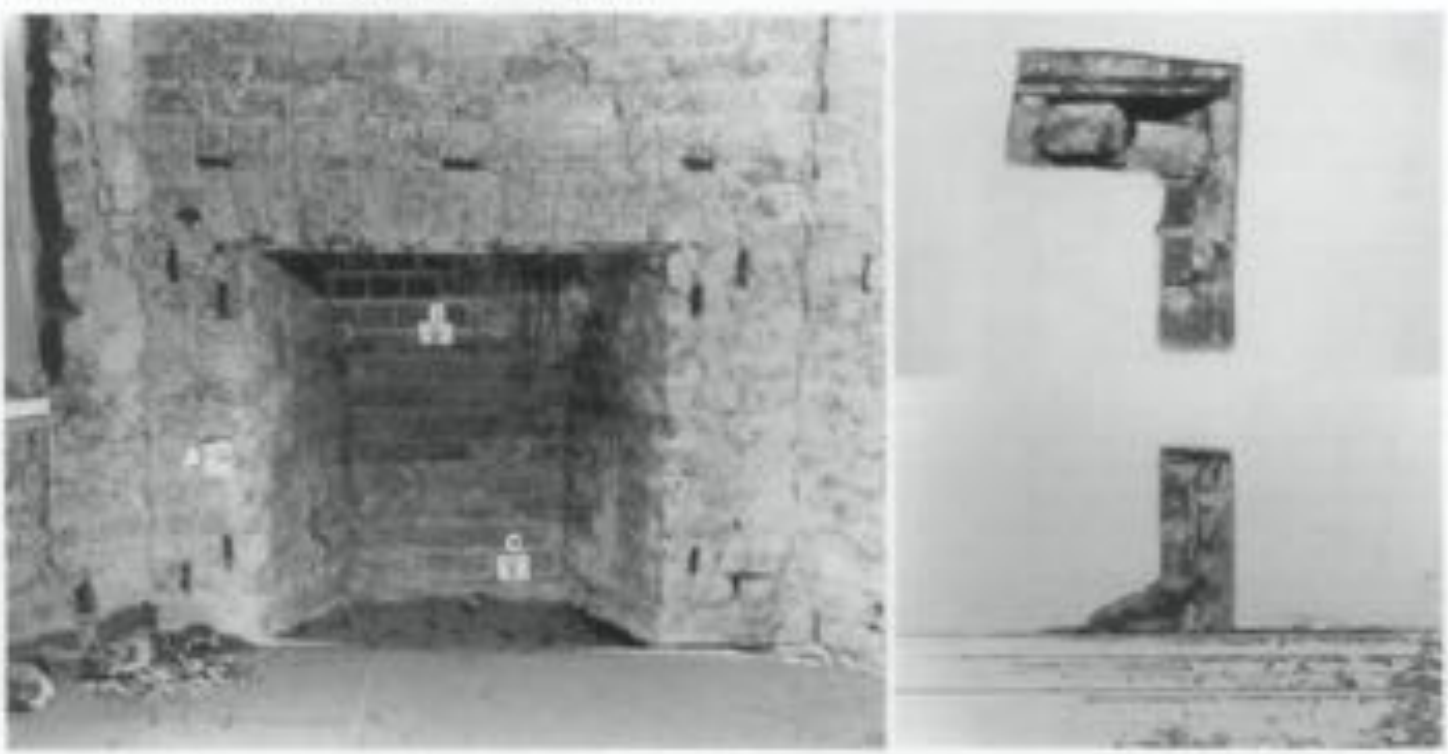


Figure 11. The physical evidence of cracks and patches seen during surface mapping suggested an abandoned fireplace. Right: Exploratory testing was used to verify its location. Left: Museum restoration required more detailed probing to discover the original detailing. Plaster and brick were carefully documented and removed to determine the fireplace's type, size, and decoration. The rectangular slots held wooden nailing blocks supporting the mantel and surround. A indicates the inside edge of the surround; B points to the ghost from an iron fireback and C shows the original floor level of the hearth.

Figure 12. During a thorough investigation, the mortar sample is viewed under a microscope using various lighting to find the presence of coatings or additives. It is then ground and washed in an acid bath to separate and free the sand and fibers. After further cleaning, these fines are stored and used for comparison in matching or dating repairs and alterations. photos: NPS North Atlantic Cultural Resource Center, Building Conservation Branch.

sampling and microscopic laboratory work using chemical analysis and standardized color notations. Consultants without the proper knowledge have been known to cause far more harm than good.

Mortar and plaster analysis often provide a basis for dating construction with minimal intervention. Relatively small samples of the lime-based materials can be chemically separated into their component parts of sands and fines, which are then visually compared to equivalent parts of known or dated samples. A more thorough scientific approach may be used to accurately profile and compare samples of other materials through elemental analysis. Two similar methods in common use are Neutron Activation and Energy Dispersive Spectroscopy (EDS). Neutron Activation identifies the sample's trace elements by monitoring their response to neutron bombardment. EDS measures the response to electron bombardment through the use of an electron microscope. In both tests, the gathered information is plotted and matched with the reactions of known elements. The results provide a quantitative and qualitative profile of the sample's elemental components for use in further comparisons.

Dendrochronology presents a minimally destructive process for dating wooden members. Also called tree ring dating, this process relies on the comparative wet and dry growth seasons of trees as seen in their rings via a core sample. This technique has two limitations: a very extensive data base must be compiled for climatic conditions over a long span of years and matched with corresponding tree ring samples; and the core samples can only be taken from timber which still has a bark edge. Simple identification of wood species during an investigation can be determined from small samples sent to a forest products laboratory.

After Architectural Investigation: Weighing the Evidence

Evidence, questions, and hypotheses must be continually evaluated during investigation. Like a detective constructing a case, an investigator must sort out information to get at "the facts." Yet, are the "facts" conclusive at any time?

Observations made during the surface mapping may identify random features. These features begin to form patterns; then, sets of patterns, perhaps representing alterations from multiple eras, begin to appear. If the right questions are not asked, the evidence can remain hidden. Hypotheses are formed, questioned, tested, re-formed and either rejected or substantiated. This process is repeated as more "facts" are uncovered and questions asked. Eventually the evidence seems conclusive. These conclusions, in turn, may lead to re-examination, more historical research, and the advice of specialized consultants. At some point, treatment generally follows based on the collective, educated conclusions of an entire professional team.

Keeping a Responsible Record for Future Investigators

The evidence collected during investigation, and any conclusions which can be drawn from it, should be documented in a written report. The complexity of a project dictates the complexity of the resulting record. It may be wise to maintain a report in an expandable format if long or extensive work is expected—additional evidence will undoubtedly need to be incorporated that alters previous conclusions. Reports tend to range from annotated photographs in loose-leaf binders to full-length bound "books."

Putting findings and conclusions in an accessible form helps those who are planning treatment. For example, a rehabilitation project may require documentation to satisfy grant funding or tax credit program requirements; preservation and restoration projects always need careful documentation to guide the work. After work, the investigation report and notes on the treatment itself are made into a permanent file record. Whether or not work is being planned, the architectural investigation report will always be of value to future researchers or owners of the building.

The most common professional document is called an ***Historic Structure Report***. This invaluable tool for preservation typically contains historical as well as physical information. Sections include a history of the building, an architectural description of the original structure and changes made over time, the results of all investigations, a record of current conditions or problems, of past repairs and treatments, and recommendations for current and future action. They are seldom definitive; thus, research is a continuing process.

Conclusion

Architectural investigation plays a critical role in making responsible decisions about treating and interpreting historic buildings. A successful project to research, inventory, document, and ultimately treat and interpret a building is directly linked to the knowledge and skills of architectural investigators and other historic preservation specialists. The expressed goal of historic preservation is to protect and preserve materials and features that convey the significant history of a place. Careful architectural investigation—together with historical research—provides a firm foundation for this goal.

Bibliography

Bullock, Orin M. Jr., *The Restoration Manual*. Norwalk, CT.: Silvermine Publishers, 1966.

Burns, John A., editor. *Recording Historic Structures*. Washington, D.C.: The AIA Press, 1989.

Howard, Hugh. *How Old Is This House?*. New York: Noonday Press, 1989.

Howe, Barbara J., Dolores A. Fleming, Emory L. Kemp, and Ruth Ann Overbeck. *Houses and Homes: Exploring Their History*. Nashville, TN.: American Association for State and Local History, 1987.

Judd, Henry A., *Before Restoration Begins*. Nashville, TN.: American Association for State and Local History, 1973.

Kitchen, Judith L., *Caring For Your Old House*. Washington, D.C.: The Preservation Press, 1991.

Seale, William, *Recreating the Historic House Interior*. Nashville, TN.: American Association for State and Local History, 1979.

Secretary of the Interior's Standards for the Treatment of Historic Properties. Washington, D.C.: Preservation Assistance Division, National Park Service, U.S. Department of the Interior, 1992.

Secretary of the Interior's Standards and Guidelines for Architectural and Engineering Documentation: HABS/HAER Standards. Washington, D.C.: HABS/HAER, National Park Service, U.S. Department of the Interior, 1990.

Cover Photo:

An historical architect analyzes and records his investigative findings while on site. photo: courtesy Valentine Museum.

Acknowledgements

Travis C. McDonald, Jr. is an architectural historian who serves as the Restoration Coordinator at Thomas Jefferson's Poplar Forest near Lynchburg, Virginia. He respectfully dedicates this work to three masters of architectural investigation: Henry A. Judd, former Chief Historical Architect of the National Park Service; Lee H. Nelson, former Chief, Preservation Assistance Division NPS; and Paul E. Buchanan, former Director of Architectural Research at the Colonial Williamsburg Foundation. The author gratefully acknowledges the following professionals for their help in reviewing this manuscript: Edward A. Chappell, Colonial Williamsburg; E. Blaine Cliver, Preservation Assistance Division NPS; Stanley O. Graves, National Conference of State Historic Preservation Officers; Bernard L. Herman, University of Delaware; H. Ward Jandl, Preservation Assistance Division NPS; Hugh C. Miller, Virginia State Historic Preservation Office; Orlando Ridout V, Maryland Historical Trust; William Seale; and professional staff members of the National Park Service. Timothy A. Buehner served as project coordinator and Kay D. Weeks as project editor.

All photographs are by the Author unless otherwise noted.

This publication has been prepared pursuant to the National Historic Preservation Act of 1966, as amended, which directs the Secretary of the Interior to develop and make available information concerning historic properties. Comments on the usefulness of this publication may be directed to: Preservation Assistance Division, National Park Service, P.O. Box 37127, Washington, D.C. 20013-7127. This publication is not copyrighted and can be reproduced without penalty. Normal procedures for credit to the authors and the National Park Service are appreciated.

ISSN: 0885-7016

36 PRESERVATION BRIEFS

Protecting Cultural Landscapes:
Planning, Treatment and Management of Historic Landscapes

Charles A. Birnbaum, ASLA

U.S. Department of the Interior
National Park Service
Cultural Resources
Preservation Assistance

Cultural landscapes can range from thousands of acres of rural tracts of land to a small homestead with a front yard of less than one acre. Like historic buildings and districts, these special places reveal aspects of our country's origins and development through their form and features and the ways they were used. Cultural landscapes also reveal much about our evolving relationship with the natural world.

A ***cultural landscape*** is defined as "a geographic area, including both cultural and natural resources and the wildlife or domestic animals therein, associated with a historic event, activity, or person or exhibiting other cultural or aesthetic values." There are four general types of cultural landscapes, not mutually exclusive: *historic sites, historic designed landscapes, historic vernacular landscapes, and ethnographic landscapes.* These are defined on the Table on page 2.[1]

Historic landscapes include residential gardens and community parks, scenic highways, rural communities, institutional grounds, cemeteries, battlefields and zoological gardens. They are composed of a number of character-defining features which individually or collectively contribute to the landscape's physical appearance as they have evolved over time. In addition to vegetation and topography, cultural landscapes may include water features such as ponds, streams, and fountains; circulation features such as roads, paths, steps, and walls; buildings; and furnishings, including fences, benches, lights and sculptural objects.

Figure 1. The New York Peace Monument atop Lookout Mountain in the 8,100 acre Chickamauga and Chattanooga National Military Park, Chattanooga, Tennessee, commemorates the reconciliation of the Civil War between the North and South. The strategic high point provides panoramic views to the City of Chattanooga and the Moccasin Bend. Today, it is recognized for its cultural and natural resource value. The memorial, which was added in 1910 is part of this landscape's historic continuum. (courtesy Sam Abell and National Geographic.)

DEFINITIONS

Historic Designed Landscape - a landscape that was consciously designed or laid out by a landscape architect, master gardener, architect, or horticulturist according to design principles, or an amateur gardener working in a recognized style or tradition. The landscape may be associated with a significant person(s), trend, or event in landscape architecture; or illustrate an important development in the theory and practice of landscape architecture. Aesthetic values play a significant role in designed landscapes. Examples include parks, campuses, and estates.

Historic Vernacular Landscape - a landscape that evolved through use by the people whose activities or occupancy shaped that landscape. Through social or cultural attitudes of an individual, family or a community, the landscape reflects the physical, biological, and cultural character of those everyday lives. Function plays a significant role in vernacular landscapes. They can be a single property such as a farm or a collection of properties such as a district of historic farms along a river valley. Examples include rural villages, industrial complexes, and agricultural landscapes.

Historic Site - a landscape significant for its association with a historic event, activity, or person. Examples include battlefields and president's house properties.

Ethnographic Landscape - a landscape containing a variety of natural and cultural resources that associated people define as heritage resources. Examples are contemporary settlements, religious sacred sites and massive geological structures. Small plant communities, animals, subsistence and ceremonial grounds are often components.

Most historic properties have a cultural landscape component that is integral to the significance of the resource. Imagine a residential district without sidewalks, lawns and trees or a plantation with buildings but no adjacent lands. A historic property consists of all its cultural resources — landscapes, buildings, archeological sites and collections. In some cultural landscapes, there may be a total absence of buildings.

This Preservation Brief provides preservation professionals, cultural resource managers, and historic property owners a step-by-step process for preserving historic designed and vernacular landscapes, two types of cultural landscapes. While this process is ideally applied to an entire landscape, it can address a single feature such as a perennial garden, family burial plot, or a sentinel oak in an open meadow. This Brief provides a framework and guidance for undertaking projects to ensure a successful balance between historic preservation and change.

Developing a Strategy and Seeking Assistance

Nearly all designed and vernacular landscapes evolve from, or are often dependent on, natural resources. It is these interconnected systems of land, air and water,

Figures 2-4. Character-defining landscape features (top to bottom): "Bird Fence" near D. H. Lawrence Ranch, Questa, New Mexico, 1991 (courtesy Cheryl Wagner); paving detail at Ernest Hemingway House National Historic Site, Key West, Florida, 1994 (courtesy author); and, tree planting detail for Jefferson Memorial Park, St. Louis, Missouri (courtesy Office of Dan Kiley).

vegetation and wildlife which have dynamic qualities that differentiate cultural landscapes from other cultural resources, such as historic structures. Thus, their documentation, treatment, and ongoing management require a comprehensive, multi-disciplinary approach.

Today, those involved in preservation planning and management for cultural landscapes represent a broad array of academic backgrounds, training, and related project experience. Professionals may have expertise in landscape architecture, history, landscape archeology, forestry, agriculture, horticulture, pomology, pollen analysis, planning, architecture, engineering (civil, structural, mechanical, traffic), cultural geography, wildlife, ecology, ethnography, interpretation, material and object conservation, landscape maintenance and management. Historians and historic preservation professionals can bring expertise in the history of the landscape, architecture, art, industry, agriculture, society and other subjects. Landscape preservation teams, including on-site management teams and independent consultants, are often directed by a landscape architect with specific expertise in landscape preservation. It is highly recommended that disciplines relevant to the landscapes' inherent features be represented as well.

Additional guidance may be obtained from State Historic Preservation Offices, local preservation commissions, the National Park Service, local and state park agencies, national and state chapters of the American Society of Landscape Architects, the Alliance for Historic Landscape Preservation, the National Association of Olmsted Parks, and the Catalog of Landscape Records in the United States at Wave Hill among others.[2]

A range of issues may need to be addressed when considering how a particular cultural landscape should be treated. This may include the in-kind replacement of declining vegetation, reproduction of furnishings, rehabilitation of structures, accessibility provisions for people with disabilities, or the treatment of industrial properties that are rehabilitated for new uses.

Preservation Planning for Cultural Landscapes

Careful planning prior to undertaking work can help prevent irrevocable damage to a cultural landscape. Professional techniques for identifying, documenting, evaluating and preserving cultural landscapes have advanced during the past 25 years and are continually being refined. Preservation planning generally involves the following steps: historical research; inventory and documentation of existing conditions; site analysis and evaluation of integrity and significance; development of a cultural landscape preservation approach and treatment plan; development of a cultural landscape management plan and management philosophy; the development of a strategy for ongoing maintenance; and preparation of a record of treatment and future research recommendations.

The steps in this process are not independent of each other, nor are they always sequential. In fact, information gathered in one step may lead to a re-examination or refinement of previous steps. For example, field inventory and historical research are likely to occur simultaneously, and may reveal unnoticed cultural resources that should be protected.

The treatment and management of cultural landscape should also be considered in concert with the management of an entire historic property. As a result, many other studies may be relevant. They include management plans, interpretive plans, exhibit design, historic structures reports, and other.

CULTURAL LANDSCAPE REPORTS

A Cultural Landscape Report (CLR) is the primary report that documents the history, significance and treatment of a cultural landscape. A CLR evaluates the history and integrity of the landscape including any changes to its geographical context, features, materials, and use.

CLR's are often prepared when a change (e.g. a new visitor's center or parking area to a landscape) is proposed. In such instances, a CLR can be a useful tool to protect the landscape's character-defining features from undue wear, alteration or loss. A CLR can provide managers, curators and others with information needed to make management decisions.

A CLR will often yield new information about a landscape's historic significance and integrity, even for those already listed on the National Register. Where appropriate, National Register files should be amended to reflect the new findings.

These steps can result in several products including a Cultural Landscape Report (also known as a Historic Landscape Report), statements for management, interpretive guide, maintenance guide and maintenance records.

Historical Research

Research is essential before undertaking any treatment. Findings will help identify a landscape's historic period(s) of ownership, occupancy and development, and bring greater understanding of the associations and characteristics that make the landscape or history significant. Research findings provide a foundation to make educated decisions for work, and can also facilitate ongoing maintenance and management operations, interpretation and eventual compliance requirements.

A variety of primary and secondary sources may be consulted. Primary archival sources can include historic plans, surveys, plats, tax maps, atlases, U. S. Geological Survey maps, soil profiles, aerial photographs, photographs, stereoscopic views, glass lantern slides, postcards, engravings, paintings, newspapers, journals, construction drawings, specifications, plant lists, nursery catalogs, household records, account books and personal correspondence. Secondary sources include monographs, published histories, theses, National Register forms, survey data, local preservation plans, state contexts and scholarly articles. (See Figures 5-7, page 4.)

Contemporary documentary resources should also be consulted. This may include recent studies, plans, surveys, aerial and infrared photographs, Soil Conservation Service soil maps, inventories, investigations and interviews. Oral histories of residents, managers, and maintenance personnel with a long tenure or historical association can be valuable sources of information about changes to a landscape over many years. (Figures 8-9, page 4) For properties listed in the National Register, nomination forms should be consulted.

Figures 5-7: Atlases and aerial photographs were useful for understanding the evolution of burial grounds in Lancaster County, Pennsylvania. Comparing the plans from the 1864 and 1875 atlases (courtesy Lancaster County Historical Society) with a 1980 aerial photograph (courtesy Lancaster County Planning Commission) revealed the growth and development of Woodward Hill Cemetery and its geographic context for over a century.

Figures 8, 9: Mary Smith Nelson spent her childhood at the Zane Grey family compound in Lackawaxen, Pennsylvania. Recently, her recollections of nearly eighty years ago helped landscape architects to document the evolution of this cultural landscape. These oral memoirs have since been confirmed by archeological and archival findings. (courtesy National Park Service, Zane Grey House Archives and LANDSCAPES)

Figure 10: Traditional land uses are often the key to long term preservation. Therefore, a knowledge of prior landscape management practices is essential as part of the research phase. Land use patterns were often the result of traditional activities such as agriculture, fishing or mining. In Hanalei, Hawaii for example, taro fields are important because they reflect the continuity of use of the land over time. (courtesy Land and Community Associates)

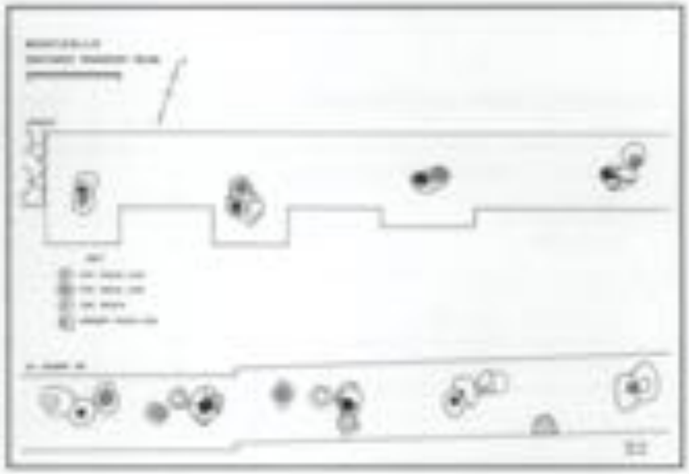


Figure 11: Landscape archeology is an important research tool that can provide location, dating and detail verification for landscape features. At Monticello, the estate of Thomas Jefferson in Charlottesville, Virginia, archeological research has employed both excavational and non-invasive methods. This has included aerial photography, soil resistivity, transect and stratified sampling and photogrammetric recording. As illustrated in the plan above, fence post spacing and alignment can be confirmed with a transect trenching technique.[7] (courtesy Thomas Jefferson Memorial Foundation)

Preparing Period Plans

In the case of designed landscapes, even though a historic design plan exists, it does not necessarily mean that it was realized fully, or even in part. Based on a review of the archival resources outlined above, and the extant landscape today, an as-built *period plan* may be delineated. For all successive tenures of ownership, occupancy and landscape change, *period plans* should be generated (see Figure 13, page 6). Period plans can document to the greatest extent possible the historic appearance during a particular period of ownership, occupancy, or development. Period plans should be based on primary archival sources and should avoid conjecture. Features that are based on secondary or less accurate sources should be graphically differentiated. Ideally, all referenced archival sources should be annotated and footnoted directly on *period plans*.

Where historical data is missing, period plans should reflect any gaps in the CLR narrative text and these limitations considered in future treatment decisions (See Treatments for Cultural Landscapes on page 13.)

Inventorying and Documenting Existing Conditions

Both physical evidence in the landscape and historic documentation guide the historic preservation plan and treatments. To document existing conditions, intensive field investigation and reconnaissance should be conducted at the same time that documentary research is being gathered. Information should be exchanged among preservation professionals, historians, technicians, local residents, managers and visitors.

To assist in the survey process, National Register Bulletins have been published by the National Park Service to aid in identifying, nominating and evaluating designed and rural historic landscapes. Additionally, Bulletins are available for specific landscape types such as battlefields, mining sites, and cemeteries.[6]

Although there are several ways to inventory and document a landscape, the goal is to create a baseline from a detailed record of the landscape and its features as they exist at the present (considering seasonal variations).[7] Each landscape inventory should address issues of boundary delineation, documentation methodologies and techniques, the limitations of the inventory, and the scope of inventory efforts. These are most often influenced by the timetable, budget, project scope, and the purpose of the inventory and, depending on the physical qualities of the property, its scale, detail, and the interrelationship between natural and cultural resources. For example, inventory objectives to develop a treatment plan may differ considerably compared to those needed to develop an ongoing maintenance plan. Once the criteria for a landscape inventory are developed and tested, the methodology should be explained.

Preparing Existing Condition Plans

Inventory and documentation may be recorded in plans, sections, photographs, aerial photographs, axonometric perspectives, narratives, video—or any combination of techniques. Existing conditions should generally be documented to scale, drawn by hand or generated by computer. The scale of the drawings is often determined by the size and complexity of the landscape. Some landscapes may require documentation at more than one scale. For example, a large estate may be documented at a small scale to depict its spatial and visual relationships, while the discrete area around an estate mansion may require a larger scale to illustrate individual plant materials, pavement patterns and other details. The same may apply to an entire rural historic district and a fenced vegetable garden contained within. (See Figures 14-15, page 8).

When landscapes are documented in photographs, *registration points* can be set to indicate the precise location and orientation of features. Registration points should correspond to significant forms, features and spatial relationships within the landscape and its surrounds (see

HISTORIC LANDSCAPE FEATURES	DEGREE OF DOCUMENTATION					
	SITE EVIDENCE	MANNING PLAN	HISTORIC PHOTOS	LETTERS 1914-1946	1955-1993 RECORDS	SECONDARY SOURCES
NATURAL SYSTEMS/TOPOGRAPHY	▲	▲	▲	▲	▲	?
Bedrock (Quarry)	●	●	●	●		
Land Contour	●	●	●	●	●	
Rockwork	●	●	●	●	●	
WATER FEATURES	▲	▲	▲	▲	▲	?
Alignment—Cascade	●		●	●	●	
Alignment—Pools & Streams	●	●	●	●	●	
Materials—Cascade	●		●	●	●	
Materials—Pools & Streams	●		●	●	●	
CIRCULATION	▲	▲	▲	▲	▲	?
Alignment—Upland Area		●	●		●	
Alignment—Perimeter Paths	●	●	●	●	●	
Alignment—Internal Paths		●	●		●	
Materials—Upland Area		●	●		●	
Materials—Perimeter Paths	●	●	●	●		
Materials—Internal Paths		●	●	●	●	
SPATIAL RELATIONSHIPS	▲	▲	▲	▲	▲	?
Garden Site (Quarry)	●	●	●	●		
Viewshed (Cuyahoga Valley)	●		●	●		
Vista over Garden from Terrace			●	●		
Views within Garden		●	●	●	●	
Views within Upland		●	●	●		
Views from Croquet Lawn		●	●			
VEGETATION	▲	▲	▲	▲	▲	?
Native Forest Trees	●	●	●	●	●	
Ornamental Shrubs in Garden	●		●	●	●	
Groundcovers in Garden	●		●	●	●	
Herbaceous Plants in Garden			●	●	●	
SITE FURNISHINGS	▲	▲	▲	▲	▲	?
Lanterns	●		●	●	●	
Seats	●		●	●		
STRUCTURES	▲	▲	▲	▲	▲	?
Torii Gate	●		●		●	
Cistern	●	●		●	●	
Stone Wall Concealing Cistern	●		●	●	●	
Lagoon Bridges			●	●	●	
Umbrella House			●	●		
Trellis/Lattice			●	●		

Figure 12: This chart measures available documentation for character-defining features in the Japanese Garden at Stan Hywet Hall, Akron, Ohio designed by Warren Manning. Areas with little or no historic documentation are noted, thus identifying areas where future treatment options may be restricted. As illustrated, restoration or reconstruction are viable alternatives based on the rich research findings. (courtesy Stan Hywet Hall Foundation, Inc. and Doell and Doell)

Figure 13: Period plans show the evolution of Aspet, the home of Augustus St. Gaudens, Cornish, New Hampshire. Plans were developed at two scales: first for the entire estate's development, and second for the core area around the house, studio and gardens. For both, plans were generated for five time periods: 1885-1903, 1903-1907, 1907-1926, 1926-1965 and 1965-1992. Illustrated above are the 1885-1903, 1907-1926, and the 1926-1965 plans for the core area. (courtesy National Park Service, North Atlantic Region and Pressley Associates)

READING THE LANDSCAPE

A noted geographer stated, "The attempt to derive meaning from landscapes possesses overwhelming virtue. It keeps us constantly alert to the world around us, demanding that we pay attention not just to some of the things around us but to all of them—the whole visible world in all of its rich, glorious, messy, confusing, ugly, and beautiful complexity."[4]

Landscapes can be read on many levels—landscape as nature, habitat, artifact, system, problem, wealth, ideology, history, place and aesthetic.[5] When developing a strategy to document a cultural landscape, it is important to attempt to read the landscape in its context of place and time. (See Figures 16-17, page 8)

Reading the landscape, like engaging in archival research, requires a knowledge of the resource and subject area as well as a willingness to be skeptical. As with archival research, it may involve serendipitous discoveries. Evidence gained from reading the landscape may confirm or contradict other findings and may encourage the observer and the historian to revisit both primary and secondary sources with a fresh outlook. Landscape investigation may also stimulate other forms of research and survey, such as oral histories or archeological investigations, to supplement what appeared on-site.

There are many ways to read a landscape—whatever approach is taken should provide a broad overview. This may be achieved by combining on-the-ground observations with a bird's-eye perspective.To begin this process, aerial photographs should be reviewed to gain an orientation to the landscape and its setting. Aerial photographs come in different sizes and scales, and can thus portray different levels of detail in the landscape. Aerial photographs taken at a high altitude, for example, may help to reveal remnant field patterns or traces of an abandoned circulation system; or, portions of axial relationships that were part of the original design, since obscured by encroaching woodland areas. Low altitude aerial photographs can point out individual features such as the arrangement of shrub and herbaceous borders, and the exact locations of furnishings, lighting, and fence alignments. This knowledge can prove beneficial before an on-site visit.

Aerial photographs provide clues that can help orient the viewer to the landscape. The next step may be to view the landscape from a high point such as a knoll or an upper floor window. Such a vantage point may provide an excellent transition before physically entering the cultural landscape.

On ground, evidence should then be studied, including character-defining features, visual and spatial relationships. By reviewing supporting materials from historic research, individual features can be understood in a systematic fashion that show the continuum that exists on the ground today. By classifying these features and relationships, the landscape can be understood as an artifact, possessing evidence of evolving natural systems and human interventions over time.

For example, the on-site investigation of an abandoned turn-of-the-century farm complex reveals the remnant of a native oak and pine forest which was cut and burned in the mid-nineteenth century. This previous use is confirmed by a small stand of mature oaks and the presence of these plants in the emerging secondary woodland growth that is overtaking this farm complex in decline. A ring count of the trees can establish a more accurate age. By *reading* other character-defining features—such as the traces of old roads, remnant hedgerows, ornamental trees along boundary roads, foundation plantings, the terracing of grades and remnant fences —the visual, spatial and contextual relationships of the property as it existed a century ago may be understood and its present condition and integrity evaluated.

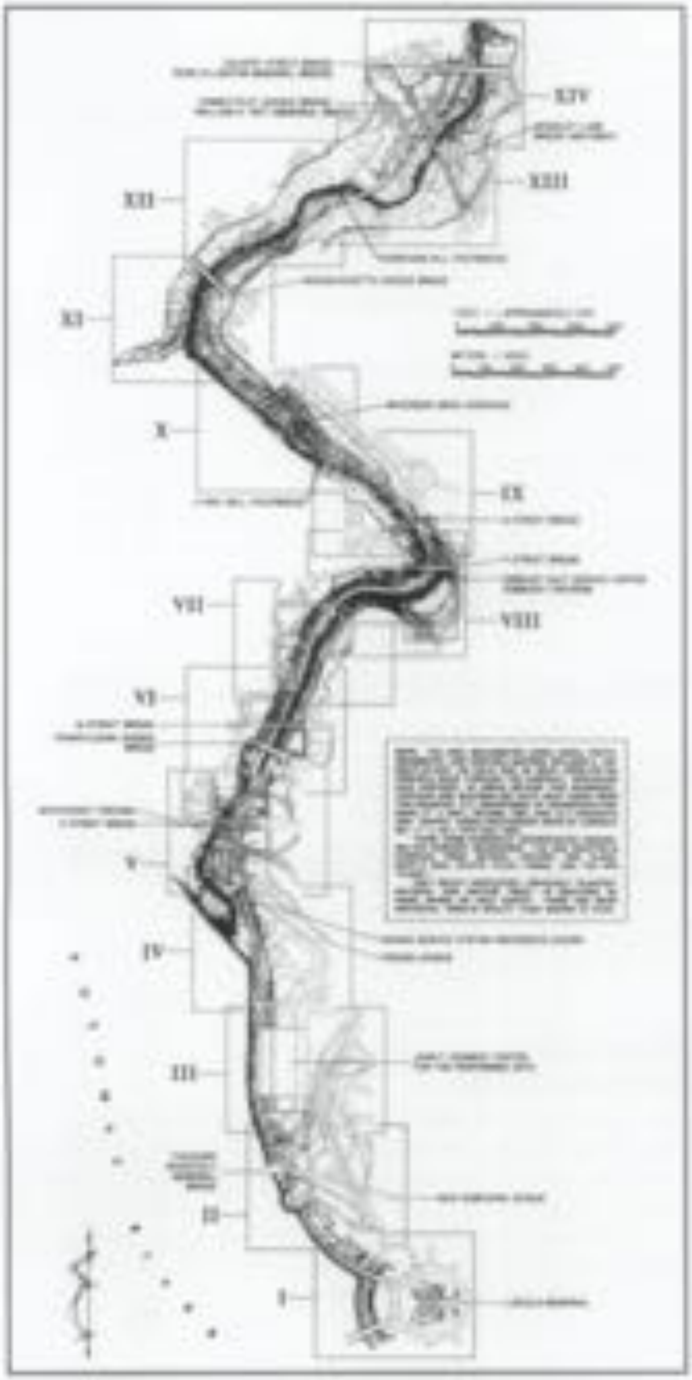
The findings of on-site reconnaissance, such as materials uncovered during archival research, may be considered primary data. These findings make it possible to inventory and evaluate the landscape's features in the context of the property's current condition. Character-defining features are located in situ, in relationship to each other and the greater cultural and geographic contexts.

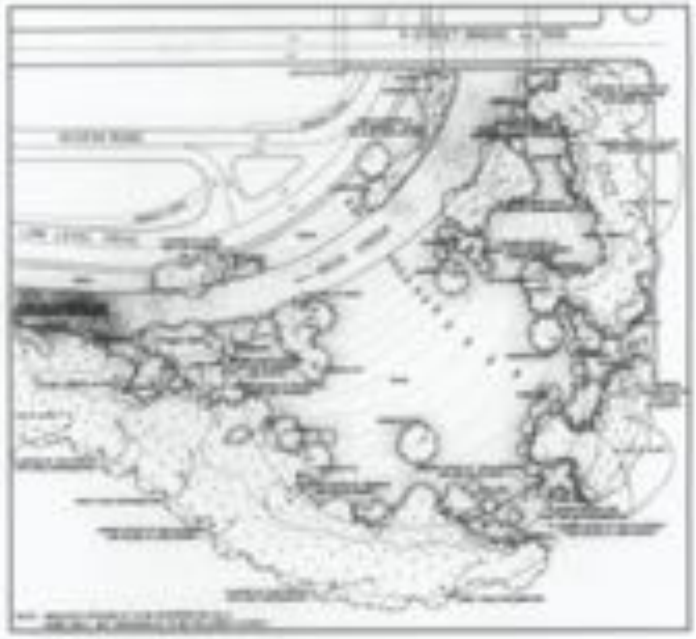
Figure 22, page 11 for an example.) The points may also correspond to historic views to illustrate the change in the landscape to date. These locations may also be used as a management tool to document the landscape's evolution, and to ensure that its character-defining features are preserved over time through informed maintenance operations and later treatment and management decisions.

All features that contribute to the landscape's historic character should be recorded. These include the physical features described on page 1 (e.g. topography, circulation), and the visual and spatial relationships that are character-defining. The identification of existing plants, should be specific, including genus, species, common name, age (if known) and size. The woody, and if appropriate, herbaceous plant material should be accurately located on the existing conditions map. To ensure full representation of successional herbaceous plants, care should be taken to document the landscape in different seasons, if possible.

Treating living plant materials as a curatorial collection has also been undertaken at some cultural landscapes. This process, either done manually or by computer, can track the condition and maintenance operations on individual plants. Some sites, such as the Frederick Law Olmsted National Historic Site, in Brookline, Massachusetts have developed a field investigation numbering system to track all woody plants. (See Table, page 9) Due to concern for the preservation of genetic diversity and the need to replace significant plant materials, a number of properties are beginning to propagate historically important rare plants that are no longer commercially available, unique, or possess significant historic associations. Such herbarium collections become a part of a site's natural history collection.

Once the research and the documentation of existing conditions have been completed, a foundation is in place to analyze the landscape's continuity and change, determine its significance, assess its integrity, and place it within the historic context of similar landscapes.





Figures 14 and 15: Existing conditions plans for large corridor landscapes can employ a variety of documentation methodologies. For the 2-1/2 mile Rock Creek and Potomac Parkway, Washington, D.C., the Historic American Buildings Survey (HABS) used aerial photogrammetric photographs as the basis for digitized mapping and delineated drawings. Overall documentation was done at a scale of 1" = 40' with a 100' either side geographic context. Contours were shown at 2' intervals, tree canopy with trunk placement for specimen species, bridges (also drawn in detail), roads, and the creek itself. In all, there are 36 drawings measuring 34" x 44" for the project. These two sample drawings include the index to plans (above) and an area of existing conditions documentation (opposite top). (courtesy Historic American Buildings Survey)

Figures 16 and 17: Landscapes cannot be inventoried in a vacuum. Therefore, an understanding of its geographic context or setting should be part of inventory process. At Rancho Los Alamitos, Long Beach, California (middle and bottom opposite), a comparison between the 1936 aerial view with a present day aerial photograph illustrates the encroachments and adjacent developments that will affect the future treatment of visual and spatial relationships. (courtesy Rancho Los Alamitos Foundation)

HISTORIC PLANT INVENTORY

Within cultural landscapes, plants may have historical or botanical significance. A plant may have been associated with a historic figure or event or be part of a notable landscape design. A plant may be an uncommon cultivar, exceptional in size, age, rare and commercially/unavailable. If such plants are lost, there would be a loss of historic integrity and biological diversity of the cultural landscape. To ensure that significant plants are preserved, an inventory of historic plants is being conducted at the North Atlantic Region of the National Park Service.[5] Historical landscape architects work with landscape managers and historians to gather oral and documented history on the plant's origin and potential significance. Each plant is then examined in the field by an expert horticulturist who records its name, condition, age, size, distribution, and, any notable botanic characteristics.

Plants that are difficult to identify or are of potential historical significance are further examined in the laboratory by a plant taxonomist who compares leaf, fruit, and flower characteristics with herbarium specimens for named species, cultivars and varieties. For plants species with many cultivars, such as apples, roses, and grapes, specimens may be sent to specialists for identification.

If a plant cannot be identified, is dying or in decline, and unavailable from commercial nurseries, it may be propagated. Propagation ensures that when rare and significant plants decline, they can be replaced with genetically-identical plants. Cuttings are propagated and grown to replacement size in a North Atlantic Region Historic Plant Nursery.

1. The Arnold Arboretum's preservation technician, lilac specialist, and horticulturist compare lilacs from the Vanderbilt Mansion National Historic Site in Hyde Park, New York with lilac specimens in the Arboretum's living collection. (courtesy Olmsted Center)

3. The Arnold Arboretum's horticulturist, landscape historian, and preservation technician examine shrubs at the Longfellow National Historic Site in Cambridge, MA. (courtesy Olmsted Center)

2. The Arnold Arboretum's horticulturist and preservation technician examine an enormous black locust tree at the Home of F.D. Roosevelt National Historic Site in Hyde Park, NY. (courtesy Olmsted Center)

Site Analysis: Evaluating Integrity and Significance

By analyzing the landscape, its change over time can be understood. This may be accomplished by overlaying the various period plans with the existing conditions plan. Based on these findings, individual features may be attributed to the particular period when they were introduced, and the various periods when they were present.

It is during this step that the *historic significance* of the landscape component of a historic property and its integrity are determined. Historic significance is the recognized importance a property displays when it has been evaluated, including when it has been found to meet National Register Criteria.[8] A landscape may have several areas of historical significance. An understanding of the landscape as a continuum through history is critical in assessing its cultural and historic value. In order for the landscape to have integrity, these character-defining features or qualities that contribute to its significance must be present.

While National Register nominations document the significance and integrity of historic properties, in general, they may not acknowledge the significance of the landscape's design or historic land uses, and may not contain an inventory of landscape features or characteristics. Additional research is often necessary to provide the detailed information about a landscape's evolution and significance useful in making decision for the treatment and maintenance of a historic landscape. Existing National Register forms may be amended to recognize additional areas of significance and to include more complete descriptions of historic properties that have significant land areas and landscape features.

Integrity is a property's historic identity evidenced by the survival of physical characteristics from the property's historic or prehistoric period. The seven qualities of integrity are location, setting, feeling, association, design, workmanship and materials.[9] When evaluating these qualities, care should be taken to consider change itself. For example, when a second-generation woodland overtakes an open pasture in a battlefield landscape, or a woodland edge encloses a scenic vista. For situations such as these, the *reversibility* and/or *compatibility* of those features should be considered, both individually, and in the context of the overall landscape. Together, evaluations of significance and integrity, when combined with historic research, documentation of existing conditions, and analysis findings, influence later treatment and interpretation decisions. (See Figure 21-23)

Developing a Historic Preservation Approach and Treatment Plan

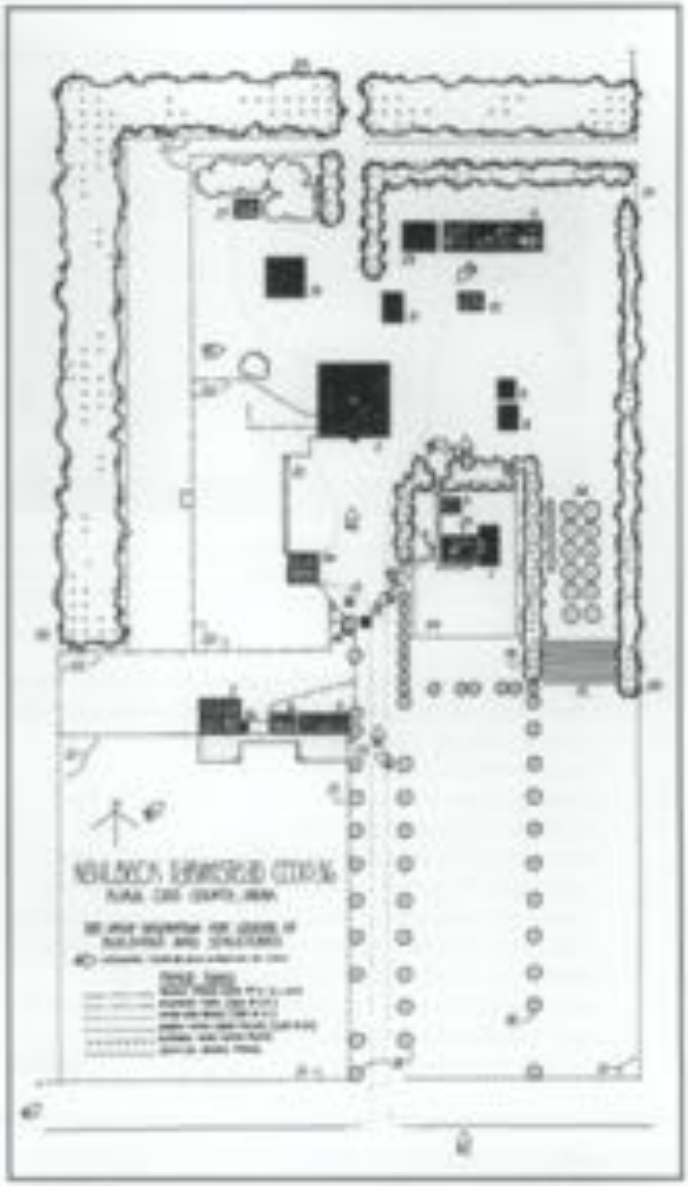
Treatment may be defined as work carried out to achieve a historic preservation goal—it cannot be considered in a vacuum. There are many practical and philosophical factors that may influence the selection of a treatment for a landscape. These include the relative historic value of the property, the level of historic documentation, existing physical conditions, its historic significance and integrity, historic and proposed use (e.g. educational, interpretive, passive, active public, institutional or private), long- and short-term objectives, operational and code requirements (e.g. accessibility, fire, security) and costs for anticipated capital improvement, staffing and maintenance. The value of any significant archeological and natural resources

Figure 18: At Lawnfield, the home of President James A. Garfield near Cleveland, Ohio, the Sugar Maple that shadowed the porch during Garfield's 1880 "Front Porch Campaign" is in decline. Cuttings were taken from the historically significant tree by the Holden Arboretum and the National Park Service for eventual in-kind replacement. (courtesy NPS, Midwest Region)

Figure 19: The landscape of Lyndhurst, Tarrytown, New York is significant in American culture and meets Criterion C of the National Register because it embodies the distinctive character of a type and period in American landscape architecture, known as early Picturesque; it possesses high artistic value; and it is the work of a recognized master gardener, Ferdinand Mangold. (courtesy National Trust for Historic Preservation)

Figure 20: Cultural landscapes often contain plant communities such as orchards or meadows—both of which may or may not require a management intervention. When analyzing a landscape, it is important to recognize the present-day biodiversity of these resources—for example at the Fruita Rural Historic District in Capitol Reef National Park in Utah, the landscape contains 2,500 fruit trees associated with settlement and agriculture on the Colorado Plateau (courtesy D. White).

Figure 21: Integrity can involve both continuity and change. This can be evidenced by a detailed review of materials. Although the surface material has changed on some roads through the Port Oneida (near Empire, Michigan) community, the character-defining alignment, width and rows of Sugar Maple trees remain intact. (courtesy NPS, Midwest Region).



Figures 22 and 23: The plan for the Kehlbeck Farmstead, located in Cass County in Southeastern Nebraska, illustrates a well-planned, and aesthetically arranged general farm complex of the twentieth century. The farmstead is composed of 23 contributing and 5 non-contributing resources. Integrity was judged uniformly high because many character-defining resources were present and the visual and spatial relationships intact. Note the varied graphic techniques used to document a variety of fence types, and, the key to photographs illustrating the various landscape features and spatial relationships. The photograph above, labeled #3 on the farmstead, is looking north along the farm lane allee. (courtesy National Register Files).

LANDSCAPE INTERPRETATION

Figures A and B: Archeology and restoration of the Privy Garden at Hampton Court Palace gardens, England. The project is being interpreted to the public in the garden, an indoor exhibition and a multimedia show. The outdoor interpretive display, (above left) includes period plans, aerial photographs and historic images that detail the history of the garden and current work, 1994. (courtesy the author)

Landscape interpretation is the process of providing the visitor with tools to experience the landscape as it existed during its period of significance, or as it evolved to its present state. These tools may vary widely, from a focus on existing features to the addition of interpretive elements. These could include exhibits, self-guided brochures, or a new representation of a lost feature. The nature of the cultural landscape, especially its level of significance, integrity, and the type of visitation anticipated may frame the interpretive approach. Landscape interpretation may be closely linked to the integrity and condition of the landscape, and therefore, its ability to convey the historic character and character-defining features of the past. If a landscape has high integrity, the interpretive approach may be to direct visitors to surviving historic features without introducing obtrusive interpretive devices such as free-standing signs. For landscapes with a diminished integrity, where limited or no fabric remains, the interpretive emphasis may be on using extant features and visual aids (e.g. markers, photographs, etc.) to help visitors visualize the resource as it existed in the past. The primary goal in these situations is to educate the visitor about the landscape's historic themes, associations and lost character-defining features or broader historical, social and physical landscape contexts.

should also be considered in the decision-making process. Therefore, a cultural landscape's preservation plan and the treatment selected will consider a broad array of dynamic and interrelated considerations. It will often take the form of a plan with detailed guidelines or specifications.

Adopting such a plan, in concert with a preservation maintenance plan (page 18-19), acknowledges a cultural landscape's ever-changing existence and the interrelationship of treatment and ongoing maintenance. Performance standards, scheduling and record keeping of maintenance activities on a day-to-day or month-to-month basis, may then be planned for. Treatment, management, and maintenance proposals can be developed by a broad range of professionals and with expertise in such fields as landscape preservation, horticulture, ecology, and landscape maintenance.

The selection of a primary treatment for the landscape, utilizing the Secretary of the Interior's Standards for the Treatment of Historic Properties, establishes an overall historic preservation approach, as well as a philosophical framework from which to operate. Selecting a treatment is based on many factors. They include management and interpretation objectives for the property as a whole, the period(s) of significance, integrity, and condition of individual landscape features.

For all treatments, the landscape's existing conditions and its ability to convey historic significance should be carefully considered. For example, the life work, design philosophy and extant legacy of an individual designer should all be understood for a designed landscape such as an estate, prior to treatment selection. For a vernacular landscape, such as a battlefield containing a largely intact mid-nineteenth century family farm, the uniqueness of that agrarian complex within a local, regional, state, and national context should be considered in selecting a treatment.

The overall historic preservation approach and treatment approach can ensure the proper retention, care, and repair of landscapes and their inherent features.[11] In short, the Standards act as a preservation and management tool for cultural landscapes. The four potential treatments are described in the box opposite.

Landscape treatments can range from simple, inexpensive preservation actions, to complex major restoration or reconstruction projects. The progressive framework is inverse in proportion to the retention of historic features and materials. Generally, preservation involves the least change, and is the most respectful of historic materials. It maintains the form and material of the existing landscape. Rehabilitation usually accommodates contemporary

Figure 24. On some occasions, especially larger landscapes, it is possible to have a primary treatment, with discrete, or secondary areas of another treatment. This is most common for an individual feature in a larger landscape. At the Eugene and Carlotta O'Neill Historic Site, Danville, California the primary treatment selected for the courtyard was restoration. When accommodating universal accessibility requirements, the introduction of a grass paver walk was installed which warranted the removal of a few historic shrubs. This discrete project would be considered a rehabilitation treatment. (courtesy Patricia M. O'Donnell)

TREATMENTS FOR CULTURAL LANDSCAPES

Prior to undertaking work on a landscape, a treatment plan or similar document should be developed. The four primary treatments identified in the Secretary of the Interior's Standards for the Treatment of Historic Properties[27], are :

Preservation *is defined as the act or process of applying measures necessary to sustain the existing form, integrity, and materials of an historic property. Work, including preliminary measures to protect and stabilize the property, generally focuses upon the ongoing maintenance and repair of historic materials and features rather than extensive replacement and new construction. New additions are not within the scope of this treatment; however, the limited and sensitive upgrading of mechanical, electrical and plumbing systems and other code-required work to make properties functional is appropriate within a preservation project.*

Rehabilitation *is defined as the act or process of making possible a compatible use for a property through repair, alterations, and additions while preserving those portions or features which convey its historical or cultural values.*

Restoration *is defined as the act or process of accurately depicting the form, features, and character of a property as it appeared at a particular period of time by means of the removal of features from other periods in its history and reconstruction of missing features from the restoration period. The limited and sensitive upgrading of mechanical, electrical and plumbing systems and other code-required work to make properties functional is appropriate within a restoration project.*

Reconstruction *is defined as the act or process of depicting, by means of new construction, the form, features, and detailing of a non-surviving site, landscape, building, structure, or object for the purpose of replicating its appearance at a specific period of time and in its historic location.*

Figures 25 and 26: When the American Elm (Ulmus americana) was plagued with Dutch Elm Disease many historic properties relied on the Japanese Zelkova (Zelkova serrata) as a substitute plant. As illustrated, the overall form and scale of these trees is really quite different, and would therefore not be an appropriate substitute plant material under a restoration or reconstruction treatment.

alterations or additions without altering significant historic features or materials, with successful projects involving minor to major change. Restoration or reconstruction attempts to recapture the appearance of a property, or an individual feature at a particular point in time, as confirmed by detailed historic documentation. These last two treatments most often require the greatest degree of intervention and thus, the highest level of documentation.

In all cases, treatment should be executed at the appropriate level reflecting the condition of the landscape, with repair work identifiable upon close inspection and/or indicated in supplemental interpretative information. When repairing or replacing a feature, every effort should be made to achieve visual and physical compatibility. Historic materials should be matched in design, scale, color and texture.

A landscape with a high level of integrity and authenticity may suggest preservation as the primary treatment. Such a treatment may emphasize protection, stabilization, cyclical maintenance, and repair of character-defining landscape features. Changes over time that are part of the landscape's continuum and are significant in their own right may be

Figure 27: The historic birch allee at Stan Hywet Hall, Akron, Ohio was suffering from borer infestation and leaf miner. Dying trees were topped and basal sprout growth encouraged. Next, trees were selectively thinned, and ultimately, when the new growth matured, older trunks were removed. Original rootstock and genetic material were preserved. As illustrated, this preservation treatment took fifteen years to realize. (courtesy Child Associates)

Figure 28: Patterns on the land have been preserved through the continuation of traditional uses such as the grape fields at the Sterling Vineyards in Calistoga, California. (courtesy author)

Figures 29. Rehabilitation was selected as the primary treatment for Columbus Park, Chicago, Illinois. Originally designed and executed between 1917 and 1920 by Jens Jensen, the waterfall, cascades, rocky brook and associated landscape; are well documented and possesses a high level of integrity. (courtesy author)

Figure 30, 31: A 75-mile portion of Skyline Drive at Shenandoah National Park overlooking the Blue Ridge Mountains of Virginia required the rehabilitation of a 22"-high, dry-laid stone wall. The new wall was built to a height of 27" – code normally requires a height of 36". The wall was constructed of precast concrete, clad with split stone and mortar joints. To achieve visual compatibility recessed mortar joints were arranged in a random pattern (courtesy Robert R. Page)

retained, while changes that are not significant, yet do not encroach upon or erode character may also be maintained. Preservation entails the essential operations to safeguard existing resources. (Figures 27-28)

Rehabilitation is often selected in response to a contemporary use or need—ideally such an approach is compatible with the landscape's historic character and historic use. Rehabilitation may preserve existing fabric along with introducing some compatible changes, new additions and alterations. Rehabilitation may be desirable at a private residence in a historic district where the homeowner's goal is to develop an appropriate landscape treatment for a front yard, or in a public park where a support area is needed for its maintenance operations. (Figures 29-31)

When the most important goal is to portray a landscape and its character-defining features at an exact period of time, restoration is selected as the primary treatment. Unlike preservation and rehabilitation, interpreting the landscape's continuum or evolution is not the objective. Restoration may include the removal of features from other periods and/or the construction of missing or lost features and materials from the reconstruction period. In all cases, treatment should be substantiated by the historic research findings and existing conditions documentation. Restoration and reconstruction treatment work should avoid the creation of a landscape whose features did not exist historically. For example, if features from an earlier period did not co-exist with extant features from a later period that are being retained, their restoration would not be appropriate. (Figures 32-34)

In rare cases, when evidence is sufficient to avoid conjecture, and no other property exists that can adequately explain a certain period of history, reconstruction may be utilized to depict a vanished landscape. The accuracy of this work is critical. In cases where topography and the subsurface of soil have not been disturbed, research and existing conditions findings may be confirmed by thorough archeological investigations. Here too, those features that are intact should be repaired as necessary, retaining the original historic features to the greatest extent possible. The greatest danger in reconstruction is creating a false picture of history.

False historicism in every treatment should be avoided. This applies to individual features as well as the entire landscape. Examples of inappropriate work include the introduction of historic-looking benches that are actually a new design, a fanciful gazebo placed in what was once an open meadow, executing an unrealized historic design, or designing a historic-looking landscape for a relocated historic structure within "restoration."

Figure 32-34: Tower Grove Park in St. Louis, Missouri, is a National Historic Landmark. The music pavilion, just north of the main drive is a circular lawn area with radiating walks, white marble busts of eminent composers, walks, and curb. The area was in general decline, especially the marble busts which were suffering from acid rain damage. Based on the excellent documentation in nineteenth century annual reports, postcards and photographic images, this area was recently restored. Illustrated above are a sample historic view, work in progress and the completed restoration project. (courtesy Tower Grove Park)

Figure 35-37: Central Park has developed an in-house historic preservation crew to undertake small projects. A specialized crew has been trained to specifically repair and rebuild rustic furnishings. As illustrated, the restoration of the Dene rustic shelter was achieved by constructing it in the Ramble compound, moving in place opposite 67th street and completed. (courtesy Central Park Conservancy)

Developing a Preservation Maintenance Plan and Implementation Strategy

Throughout the preservation planning process, it is important to ensure that existing landscape features are retained. Preservation maintenance is the practice of monitoring and controlling change in the landscape to ensure that its historic integrity is not altered and features are not lost. This is particularly important during the research and long-term treatment planning process. To be effective, the maintenance program must have a guiding philosophy, approach or strategy; an understanding of preservation maintenance techniques; and a system for documenting changes in the landscape.

The philosophical approach to maintenance should coincide with the landscape's current stage in the preservation planning process. A Cultural Landscape Report and Treatment Plan can take several years to complete, yet during this time managers and property owners will likely need to address immediate issues related to the decline, wear, decay, or damage of landscape features. Therefore, initial maintenance operations may focus on the stabilization and protection of all landscape features to provide temporary, often emergency measures to prevent deterioration, failure, or loss, without altering the site's existing character.

After a Treatment Plan is implemented, the approach to preservation maintenance may be modified to reflect the objectives defined by this plan. The detailed specifications prepared in the Treatment Plan relating to the retention, repair, removal, or replacement of features in the landscape should guide and inform a comprehensive preservation maintenance program. This would include schedules for monitoring and routine maintenance, appropriate preservation maintenance procedures, as well as ongoing record keeping of work performed. For vegetation, the preservation maintenance program would also include thresholds for growth or change in character, appropriate pruning methods, propagation and replacement procedures.

To facilitate operations, a property may be divided into discrete management zones (Figure 41). These zones are sometimes defined during the Cultural Landscape Report process and are typically based on historically defined areas. Alternatively, zones created for maintenance practices and priorities could be used. Examples of maintenance zones would include woodlands, lawns, meadow, specimen trees, and hedges.

Training of maintenance staff in preservation maintenance skills is essential. Preservation maintenance practices differ from standard maintenance practices because of the focus on perpetuating the historic character or use of the landscape rather than beautification. For example, introducing new varieties of turf, roses or trees is likely to be inappropriate. Substantial earth moving (or movement of soil) may be inappropriate where there are potential archeological resources. An old hedge or shrub should be rejuvenated, or propagated, rather than removed and replaced. A mature specimen tree may require cabling and careful monitoring to ensure that it is not a threat to visitor safety. Through training programs and with the assistance of preservation maintenance specialists, each property could develop maintenance specifications for the care of landscape features.

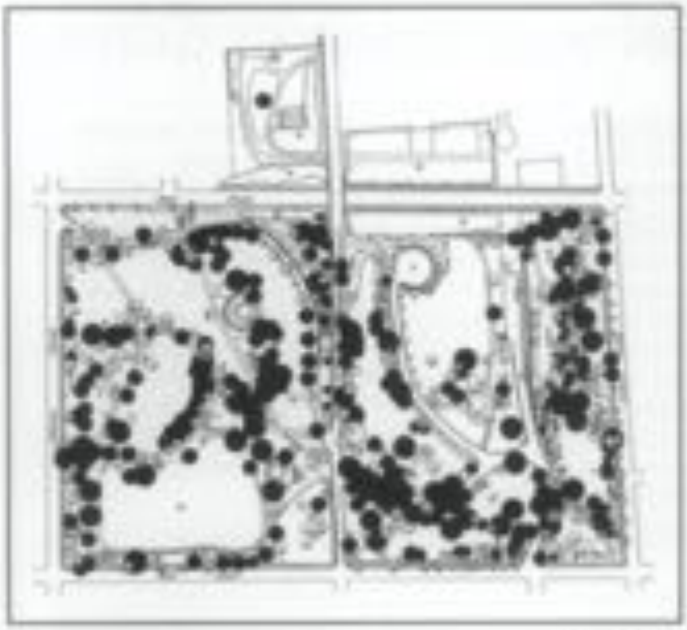
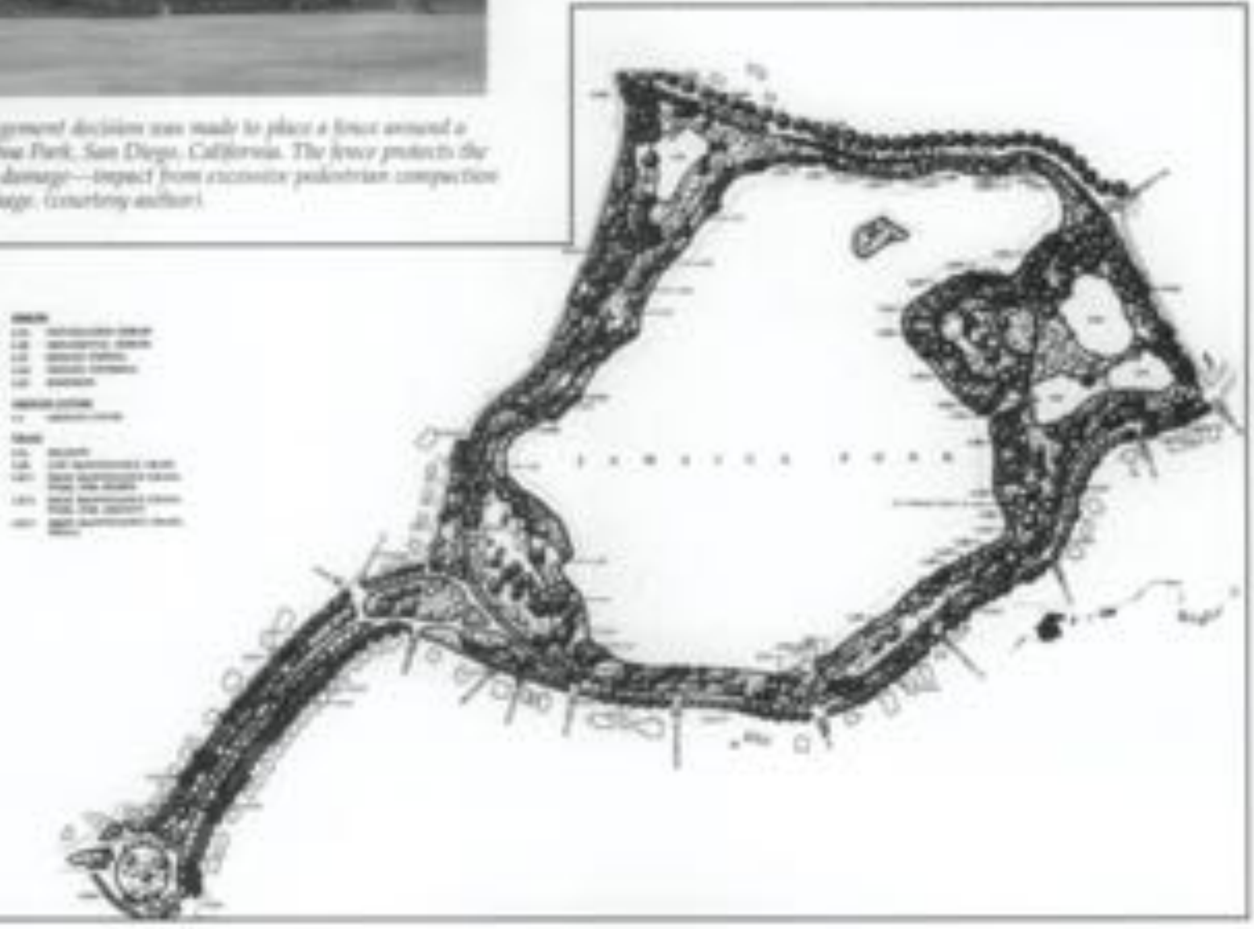


Figure 38 and 39 (above, left and right): The importance of landscape analysis and its ability to inform treatment and maintenance decisions is reflected in these two plans for Downing Park, Newburgh, New York. The plan, rendered in black, top left, illustrates all extant historic plants, while the plan, top right, depicts plantings which are non-historic or invasive for removal or relocation outside of the historic park. (courtesy LANDSCAPES)

Figure 40: A management decision was made to place a fence around a sentinel tree in Balboa Park, San Diego, California. The fence protects the specimen from root damage—impact from excessive pedestrian compaction or lawn mower damage. (courtesy author)

Figure 41 (below): A small property of under an acre may only have a few management zones including lawn, trees over lawn, shrub and herbaceous borders. Larger, more complex landscapes such as Jamaica Pond Park, Boston and Brookline, Massachusetts, contains a broader range of management zones including: forests, trees over grass—broad areas, trees over grass—narrow areas, meadows, and mown grass for active recreation amenities or passive use. (courtesy Walmsley/Pressley Joint Venture)



DEVELOPING A PRESERVATION MAINTENANCE GUIDE

In the past, there was rarely adequate record-keeping to fully understand the ways a landscape was maintained. This creates gaps in our research findings. Today, we recognize that planning for ongoing maintenance and on-site applications should be documented—both routinely and comprehensively. An annual work program or calendar records the frequency of maintenance work on built or natural landscape features. It can also monitor the age, health and vigor of vegetation. For example, on-site assessments may document the presence of weeds, pests, dead leaves, pale color, wilting, soil compaction—all of which signal particular maintenance needs. For built elements, the deterioration of paving or drainage systems may be noted and the need for repair or replacement indicated before hazards develop. An overall maintenance program can assist in routine and cyclic maintenance of the landscape and can also guide long term treatment projects.

To help structure a comprehensive maintenance operation that is responsive to staff, budget, and maintenance priorities, the National Park Service has developed two computer-driven programs for its own landscape resources. A Maintenance Management Program (MM) is designed to assist maintenance managers in their efforts to plan, organize, and direct the park maintenance system. An Inventory and Condition Assessment Program (ICAP) is designed to complement MM by providing a system for inventorying, assessing conditions, and for providing corrective work recommendations for all site features.

Another approach to documenting maintenance and recording changes over time is to develop a manual or computerized graphic information system. Such a system should have the capability to include plans and photographs that would record a site's living collection of plant materials. (Also see discussion of the use of photography under Preparing Existing Conditions Plans, page 5.) This may be achieved using a computer-aided drafting program along with an integrated database management system.

To guide immediate and ongoing maintenance, a systematic and flexible approach has been developed by the Olmsted Center for Landscape Preservation. Working with National Park Service landscape managers and maintenance specialists, staff assemble information and make recommendations for the care of individual landscape features.

Each landscape feature is inspected in the field to document existing conditions and identify field work needed. Recommendations include maintenance procedures that are sensitive to the integrity of the landscape.

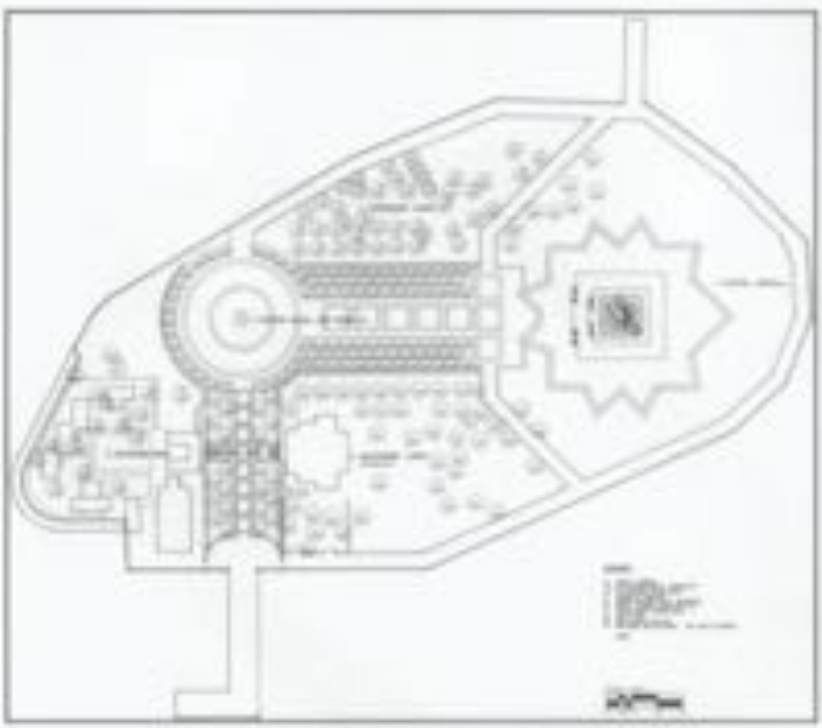


Figure A- Existing Conditions: *A map of the existing trees at the Statue of Liberty National Monument is used to indicate necessary preservation maintenance work. (Drawn by Margaret Coffin, 1992)*

Figure B - Field Inventory, Inspection, and work needed: *Within areas of the landscape, each feature is assigned a field identification number. An inspection is conducted to assess the condition, potential problems, such as deadwood or integral decay, and specify work needed. A map (above) is used to locate features that require attention.*

Figure C - Feature Data: For each feature that requires special care, a detailed sheet is developed. This contains notes on when to monitor and carry out work, specific procedures, cite potential problems, and perform repair or replacement.

Figure D - Calendar for Monitoring and for Work: All feature-specific monitoring and work recommendations are combined into one seasonal calendar for all areas of the landscape to ensure that important work activities are not overlooked.

Figure E - Record Keeping: A record sheet is created for each type of feature. Maintenance staff may record information relating to changes in condition, major work performed, removal, replacement, propagation and any other events. As records are added too through the years, they become a valuable source of documentation of the landscape's history.

Because landscapes change through the seasons, specifications for ongoing preservation maintenance should be organized in a calendar format. During each season or month, the calendar can be referenced to determine when, where, and how preservation maintenance is needed. For example, for some trees structural pruning is best done in the late winter while other trees are best pruned in the late summer. Serious pests are monitored at specific times of the year, in certain stages of their life cycle. This detailed calendar will in turn identify staff needs and work priorities.

Depending on the level of sophistication desired, one approach to documenting maintenance data and recording change over time is to use a computerized geographical or visual information system.[13] Such a system would have the capability to include plans and photographs that would focus on a site's landscape features.

If a computer is not available, a manual or notebook can be developed to organize and store important information. This approach allows managers to start at any level of detail and to begin to collect and organize information about landscape features (see Box opposite and above). The value of these maintenance records cannot be overstated. These records will be used in the future by historians to understand how the landscape has evolved with the ongoing care of the maintenance staff.

Recording Treatment Work and Future Research Recommendations

The last and on-going step in the preservation planning process records the treatment work as carried out. It may include a series of as-built drawings, supporting photographic materials, specifications and a summary assessment. New technologies that have been successfully used should be highlighted. Ideally, this information should be shared with interested national organizations for further dissemination and evaluation.

The need for further research or additional activities should also be documented. This may include site-specific or contextual historical research, archeological investigations, pollen analysis, search for rare or unusual plant materials, or, material testing for future applications.

Finally, in consultation with a conservator or archivist—to maximize the benefit of project work and to minimize the potential of data loss—all primary documents should be organized and preserved as archival materials. This may include field notes, maps, drawings, photographs, material samples, oral histories and other relative information.

Summary

The planning, treatment, and maintenance of cultural landscapes requires a multi-disciplinary approach. In landscapes, such as parks and playgrounds, battlefields, cemeteries, village greens, and agricultural land preserves—more than any other type of historic resource—communities rightly presume a sense of stewardship. It is often this grass roots commitment that has been a catalyst for current research and planning initiatives. Individual residential properties often do not require the same level of public outreach, yet a systematic planning process will assist in making educated treatment, management and maintenance decisions.

Wise stewardship protects the character, and or spirit of a place by recognizing history as change over time. Often, this also involves our own respectful changes through treatment. The potential benefits from the preservation of cultural landscapes are enormous. Landscapes provide scenic, economic, ecological, social, recreational and educational opportunities that help us understand ourselves as individuals, communities and as a nation. Their ongoing preservation can yield an improved quality of life for all, and, above all, a sense of place or identity for future generations.

Selected Reading

Birnbaum, Charles A., guest editor. *Preservation Forum*. "Focus on Landscape Preservation". Washington, D.C.: National Trust for Historic Preservation, Volume 7, No. 3, May/June 1992.

Boggey Susan, guest editor. *APT Bulletin. Special Issue: Conserving Historic Landscapes*. Fredericksburg, VA: Association for Preservation Technology International, Volume XXIV, No. 3-4, 1992.

Burns, John A. and the Staff of HABS/HAER. *Recording Historic Structures*. American Institute of Architects Press, 1989. (Includes chapter on the documentation of Meridian Hill Park, pp. 206-219.)

Diehl, Janet and Thomas S. Barrett, et al. *The Conservation Easement Handbook. Managing Land Conservation and Historic Preservation Easement Programs*. The Land Trust Exchange (now Alliance) and the Trust for Public Land, 1988.

International Committee of Historic Gardens and Sites, ICOMOS-IFLA. *Jardins et Sites Historiques*, Scientific Journal ICOMOS 1993. Compilation of papers on the subject, in both english and french.

Kelso, William M., and Rachel Most. *Earth Patterns: Essays in Landscape Archaeology*. Charlottesville, VA: University Press of Virginia, 1990.

Stokes, Samuel, N., et al. *Saving America's Countryside: A Guide to Rural Conservation*. Baltimore and London: John Hopkins University Press, 1989.

Tishler, William, editor. American Landscape *Architecture, Designers and Places*. Washington, DC: The Preservation Press, 1989.

Several publications available from the National Park Service deal directly with the preservation of historic landscapes. These include:

America's Landscape Legacy, Brochure, Preservation Assistance Division, 1992.

Guidelines for the Treatment of Historic Landscapes, Preservation Assistance Division, 1992 (Draft).

Case Studies in Landscape Preservation, Preservation Assistance Division in cooperation with the Alliance for Landscape Preservation, 1995.

Cultural Landscapes Bibliography: An Annotated Bibliography of Resources in the National Park System, Park Historic Architecture Division, 1992.

Historic Landscape Directory; A Source Book of Agencies, Organizations, and Institutions Providing Information on Historic Landscape Preservation, Preservation Assistance Division, 1991.

CRM, Cultural Resource Management, Thematic Issues: *The Preservation of Cultural Landscapes*, Volume 14, No.6, 1991; *A Reality Check for Our Nation's Parks*, Volume 16, No. 4, 1993; *Historic Transportation Corridors*, Volume 16, No. 11, 1993; and, *The Interpretation of Cultural Landscapes*, Volume 17, No. 8, 1994.

Pioneers of American Landscape Design: An Annotated Bibliography, Preservation Assistance Division, 1993 (ISBN 0-16-041974-3);

Making Educated Decisions: A Landscape Preservation Bibliography, Preservation Assistance Division, 1994 (ISBN 0-16-045145-0)

National Register Bulletin 18: How to Evaluate and Nominate Designed Historic Landscapes; National Register Bulletin 30: Guidelines for Evaluating and Documenting Rural Historic Landscapes; National Register Bulletin 40: Guidelines for Evaluating and Registering Battlefields; and, National Register Bulletin 41: Guidelines for Evaluating and Registering Cemeteries, Interagency Resources Division.

Endnotes

[1] The cultural landscape definitions are contained in *NPS-28, Cultural Resource Management Guideline*, Release No. 4, 1994, National Park Service.

[2] For an expanded list of offices to contact, see *America's Landscape Legacy* brochure. Free from the National Park Service Preservation Assistance Division.

[3] From Kelso, William, *A Report on the Archeological Excavations at Monticello, Charlottesville, VA, 1979-1981*, Thomas Jefferson Memorial Foundation, 1982.

[4] Lewis, Pierce, "Common Landscapes as Historic Documents," Lubar, Steven and Kingery, W. David (eds.), *Essays on Material Culture*, Smithsonian Institution Press, Washington, DC, 1993, p. 138.

[5] Meinig, D. W. "The Beholding Eye: Ten Versions of the Same Scene," *The Interpretation of Ordinary Landscapes*, Oxford University Press, New York, 1979, pp. 33-48.

[6] See National Park Service *National Register Bulletins* under Selected Reading (opposite).

[7] The Historic American Buildings Survey, HABS, has generated standards for landscape documentation that they now utilize on a number of projects. Specifically, a case study on recording historic landscapes is included in *Recording Historic Structures*, pp. 206-219. See Selected Reading (opposite).

[8] This is being undertaken with technical assistance from the Olmsted Center for Landscape Preservation a partnership between the National Park Service and the Arnold Arboretum of Harvard University that provides cultural landscape technical assistance, technology development and training.

[9] See *National Register Bulletin 16A, How to Complete the National Register Registration Form*. Washington, DC.: U.S. Department of the Interior, National Park Service, Interagency Resources Division, 1991.

[10] Ibid.

[11] The standards are general principles for the treatment of buildings, structures, sites, objects, districts and landscapes. The treatment standards are one set of standards included in the broader group known as the *Secretary of the Interior's Standards for Archaeology and Historic Preservation*.

[12] The Secretary of the Interior is responsible for establishing professional standards and providing advice on the preservation and protection of all cultural resources listed on or eligible for the National Register of Historic Places. For a copy of the brochure, *The Secretary of the Interior's Standards for the Treatment of Historic Properties, 1992* contact the National Park Service Preservation Assistance Division (424) Box 37127 Washington, DC 20013-7127.

[13] A visual information system, a computer-aided mapping program with a linked database, has been developed for the historic landscape at the Frederick Olmsted National Historic Site. Data can be accessed directly from a digitized map such as information on each plant including identification, age, location, size, condition, and maintenance history.

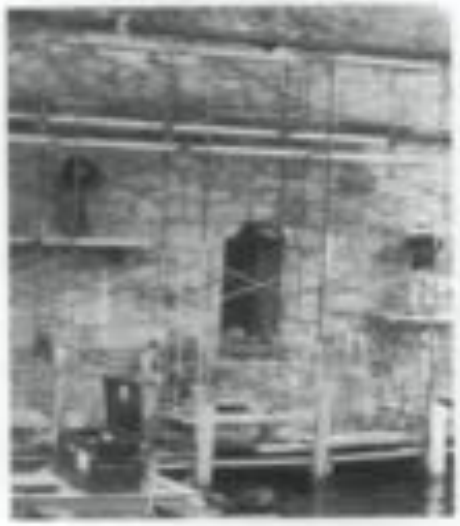
Acknowledgements

This publication has been prepared pursuant to the National Historic Preservation Act of 1966, as amended, which directs the Secretary of the Interior to develop and make information concerning historic properties. Comments on the usefulness of this publication may be directed to H. Ward Jandl, Deputy Chief, Preservation Assistance Division, National Park Service, P. O. Box 37127, Washington, D.C. 20013-7127. This publication is not copyrighted and can be reproduced without penalty. Normal procedures for credit to the author and the National Park Service are appreciated.

The author, Charles A. Birnbaum, Coordinator, Historic Landscape Initiative, Preservation Assistance Division, National Park Service would like to acknowledge the assistance of H. Ward Jandl and Kay Weeks. The Olmsted Center for Landscape Preservation at the Frederick Law Olmsted National Historic Site including Margie Coffin, Lauren Meier, Nora Mitchell, and Charlie Pepper provided invaluable support. In particular, the proposed rewrite on preservation maintenance and historic plant materials was written by Margie Coffin. Significant contributions were also made by Patricia M. O'Donnell, Linda McClelland, Ellen Lipsey, Christine Capella Peters, Robert Page, Ian Firth and Robert Melnick. Useful comments and technical assistance were provided by regional NPS staff (Mary Hughes, Lucy Lawliss, Jill Cowley, Sherda Williams, Michael Crowe, Robbyn Jackson) and staff at the Preservation Assistance Division (Cheryl Wagner, Michael Auer and Anne Grimmer).

September 1994

39 PRESERVATION BRIEFS



Holding the Line: Controlling Unwanted Moisture in Historic Buildings

Sharon C. Park, AIA

U.S. Department of the Interior
National Park Service
Cultural Resources
Heritage Preservation Services

Uncontrolled moisture is the most prevalent cause of deterioration in older and historic buildings. It leads to erosion, corrosion, rot, and ultimately the destruction of materials, finishes, and eventually structural components. Ever-present in our environment, moisture can be *controlled* to provide the differing *levels* of moisture necessary for human comfort as well as the longevity of historic building materials, furnishings, and museum collections. The challenge to building owners and preservation professionals alike is to understand the patterns of moisture movement in order to better manage it — not to eliminate it. There is never a single answer to a moisture problem. Diagnosis and treatment will always differ depending on where the building is located, climatic and soil conditions, ground water effects, and local traditions in building construction.

Remedial Actions within an Historic Preservation Context

In this Brief, advice about controlling the sources of unwanted moisture is provided within a preservation context based on philosophical principles contained in the *Secretary of the Interior's Standards for the Treatment of Historic Properties*. Following the Standards means significant materials and features that contribute to the historic character of the building should be preserved, not damaged during remedial treatment (see fig.1). It also means that physical treatments should be *reversible*, whenever possible. The majority of treatments for moisture management in this Brief stress preservation maintenance for materials, effective drainage of troublesome ground moisture, and improved interior ventilation.

The Brief encourages a systematic approach for evaluating moisture problems which, in some cases, can be undertaken by a building owner. Because the source of moisture can be elusive, it may be necessary to consult with historic preservation professionals prior to starting work that would affect historic materials. Architects, engineers, conservators, preservation contractors, and staff of State Historic Preservation Offices (SHPOs) can provide such advice.

Regardless of who does the work, however, these are the principles that should guide treatment decisions:

- Avoid remedial treatments without prior careful diagnosis.
- Undertake treatments that protect the historical significance of the resource.
- Address issues of ground-related moisture and rain run-off thoroughly.
- Manage existing moisture conditions before introducing humidified / dehumidified mechanical systems.
- Implement a program of ongoing monitoring and maintenance once moisture is controlled or managed.
- Be aware of significant landscape and archeological resources in areas to be excavated.

Finally, mitigating the effects of catastrophic moisture, such as floods, requires a different approach and will not be addressed fully in this Brief.

Fig. 1. Moisture problems, if not properly corrected, will increase damage to historic buildings. This waterproof coating trapped moisture from the leaking roof, causing portions of the masonry parapet to fail. Photo: NPS Files.

How and Where to Look for Damaging Moisture

Finding, treating, and managing the sources of damaging moisture requires a systematic approach that takes time, patience, and a thorough examination of all aspects of the problem—including a series of variable conditions (See this page). Moisture problems may be a direct result of one of these factors or may be attributable to a combination of interdependent variables.

Factors Contributing to Moisture Problems

A variety of simultaneously existing conditions contribute to moisture problems in old buildings. For recurring moisture problems, it may be necessary for the owner or preservation professional to address many, if not all, of the following variables:

- Types of building materials and construction systems
- Type and condition of roof and site drainage systems and their rates of discharge
- Type of soil, moisture content, and surface / subsurface water flow adjacent to building
- Building usage and moisture generated by occupancy
- Condition and absorption rates of materials
- Type, operation, and condition of heating, ventilating, cooling, humidification / dehumidification, and plumbing systems
- Daily and seasonal changes in sun, prevailing winds, rain, temperature, and relative humidity (inside and outside), as well as seasonal or tidal variations in groundwater levels
- Unusual site conditions or irregularities of construction
- Conditions in affected wall cavities, temperature and relative humidity, and dewpoints
- Amount of air infiltration present in a building
- Adjacent landscape and planting materials

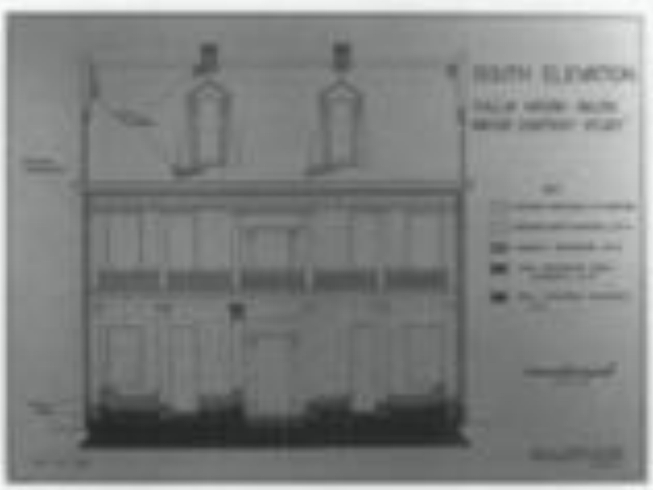


Fig. 2. Historic buildings plagued by dampness problems will benefit from systematic documentation to set a baseline against which moisture changes can be measured. Exterior areas with higher moisture levels may have algae growth or discoloration stains. Drawing: John H. Stubbs.

Diagnosing and treating the cause of moisture problems requires looking at both the localized decay, as well as understanding the performance of the entire building and site. Moisture is notorious for traveling far from the source, and moisture movement within concealed areas of the building construction make accurate diagnosis of the source and path difficult. Obvious deficiencies, such as broken pipes, clogged gutters, or cracked walls that contribute to moisture damage, should always be corrected promptly.

For more complicated problems, it may take several months or up to four seasons of monitoring and evaluation to complete a full diagnosis. Rushing to a solution without adequate documentation can often result in the unnecessary removal of historic materials—and worse—the creation of long-term problems associated with an increase, rather than a decrease, in the unwanted moisture.

Looking for Signs

Identifying the type of moisture damage and discovering its source or sources usually involves the human senses of sight, smell, hearing, touch, and taste combined with intuition. Some of the more common signs of visible as well as hidden moisture damage (see fig. 2, 3) include:

- Presence of standing water, mold, fungus, or mildew
- Wet stains, eroding surfaces, or efflorescence (salt deposits) on interior and exterior surfaces
- Flaking paint and plaster, peeling wallpaper, or moisture blisters on finished surfaces
- Dank, musty smells in areas of high humidity or poorly ventilated spaces
- Rust and corrosion stains on metal elements, such as anchorage systems and protruding roof nails in the attic
- Cupped, warped, cracked, or rotted wood
- Spalled, cracked masonry or eroded mortar joints
- Faulty roofs and gutters including missing roofing slates, tiles, or shingles and poor condition of flashing or gutters
- Condensation on window and wall surfaces
- Ice dams in gutters, on roofs, or moisture in attics

Fig. 3. The deterioration of this window cover was a sign that water was leaking from the fan coil unit behind. Photo: author.

Uncovering and Analyzing Moisture Problems

Moisture comes from a variety of external sources. Most problems begin as a result of the weather in the form of rain or snow, from high ambient relative humidity, or from high water tables. But some of the most troublesome moisture damage in older buildings may be from internal sources, such as leaking plumbing pipes, components of heating, cooling, and climate control systems, as well as sources related to use or occupancy of the building. In some cases, moisture damage may be the result of poorly designed original details, such as projecting outriggers in rustic structures that are vulnerable to rotting, and may require special treatment.

The five most common sources of unwanted moisture include:

- Above grade exterior moisture entering the building
- Below grade ground moisture entering the building
- Leaking plumbing pipes and mechanical equipment
- Interior moisture from household use and climate control systems
- Water used in maintenance and construction materials.

Above grade exterior moisture generally results from weather related moisture entering through deteriorating materials as a result of deferred maintenance, structural settlement cracks, or damage from high winds or storms (see fig. 4). Such sources as faulty roofs, cracks in walls, and open joints around window and door openings can be corrected through either repair or limited replacement. Due to their age, historic buildings are notoriously "drafty," allowing rain, wind, and damp air to enter through missing mortar joints; around cracks in windows, doors, and wood siding; and into uninsulated attics. In some cases, excessively absorbent materials, such as soft sandstone, become saturated from rain or gutter overflows, and can allow moisture to dampen interior surfaces. Vines or other vegetative materials allowed to grow directly on building materials without trellis or other framework can cause damage from roots eroding mortar joints and foundations as well as dampness being held against surfaces. In most cases, keeping vegetation off buildings, repairing damaged materials, replacing flashings, rehanging gutters, repairing downspouts, repointing mortar, caulking perimeter joints around windows and doors, and repainting surfaces can alleviate most sources of unwanted exterior moisture from entering a building above grade.

Below grade ground moisture is a major source of unwanted moisture for historic and older buildings. *Proper handling of surface rain run-off is one of the most important measures of controlling unwanted ground moisture.* Rain water is often referred to as "bulk moisture" in areas that receive significant annual rainfalls or infrequent, but heavy, precipitation. For example, a heavy rain of 2" per hour can produce 200 gallons of water from downspout discharge alone for a house during a one hour period. When soil is saturated at the base of the building, the moisture will wet footings and crawl spaces or find its way through cracks in foundation walls and enter into basements (see fig. 5). Moisture in saturated basement or foundation walls—also exacerbated by high water tables—will generally rise up within a wall and eventually cause deterioration of the masonry and adjacent wooden structural elements.

Builders traditionally left a working area, known as a builder's trench, around the exterior of a foundation wall. These trenches have been known to increase moisture problems if the infill soil is less than fully compacted or includes rubble backfill, which, in some cases, may act as a reservoir holding damp materials against masonry walls. Broken subsurface pipes or downspout drainage can leak into the builder's trench and dampen walls some distance from the source. Any subsurface penetration of the foundation wall for sewer, water, or other piping also can act as a direct conduit of ground moisture unless these holes are well sealed. A frequently unsuspected, but serious, modern source of ground moisture is a landscape irrigation system set too close to the building. Incorrect placement of sprinkler heads can add a tremendous amount of moisture at the foundation level and on wall surfaces.

Fig. 4. Deferred maintenance often leads to blocked gutters and downspouts. This cracked gutter system allowed moisture to penetrate the upper exterior wall, erode mortar joints, and rot fascia boards. Photo: NPS files.

Fig. 5. Excavating this foundation revealed that the downspout pipe had corroded at the "s-trap" and was leaking moisture into the soil. Openings around the horizontal water supply line and cracks in the wall allowed moisture to penetrate the basement in multiple locations. Photo: author.

The ground, and subsequently the building, will stay much drier by 1) re-directing rain water away from the foundation through sloping grades, 2) capturing and disposing downspout water well away from the building, 3) developing a controlled ground gutter or effective drainage for buildings historically without gutters and downspouts, and 4) reducing splash-back of moisture onto foundation walls. The excavation of foundations and the use of dampproof coatings and footing drains should only be used after the measures of reducing ground moisture listed above have been implemented.

Leaking plumbing pipes and mechanical equipment can cause immediate or long-term damage to historic building interiors. Routine maintenance, repair, or, if necessary, replacement of older plumbing and mechanical equipment are common solutions. Older water and sewer pipes are subject to corrosion over time. Slow leaks at plumbing joints hidden within walls and ceilings can ultimately rot floor boards, stain ceiling plaster, and lead to decay of structural members. Frozen pipes that crack can damage interior finishes (see fig. 6). In addition to leaking plumbing pipes, old radiators in some historic buildings have been replaced with water-supplied fan coil units which tend to leak. These heating and cooling units, as well as central air equipment, have overflow and condensation pans that require cyclical maintenance to avoid mold and mildew growth and corrosion blockage of drainage channels. Uninsulated forced-air sheet metal ductwork and cold water pipes in walls and ceilings often allow condensation to form on the cold metal, which then drips and causes bubbling plaster and peeling paint. Careful design and vigilant maintenance, as well as repair and insulating pipes or ductwork, will generally rid the building of these common sources of moisture.

Fig. 6. Uninsulated plumbing pipes close to the exterior wall froze and cracked, wetting this ornamental plaster ceiling before the water supply line could be shut off. As a result, limited portions of the ceiling needed reattaching. Photo: author.

Interior moisture from building use and modern humidified heating and cooling systems can create serious problems. In northern U.S. climates, heated buildings will have winter-time relative humidity levels ranging from 10%-35% Relative Humidity (RH). A house with four occupants generates between 10 and 16 pounds of water a day (approximately 1 – 2 gallons) from human residents. Moisture from food preparation, showering, or laundry use will produce condensation on windows in winter climates.

When one area or floor of a building is air-conditioned and another area is not, there is the chance for condensation to occur between the two areas. Most periodic condensation does not create a long-term problem.

Humidified climate control systems are generally a major problem in museums housed within historic buildings. They produce between 35%-55% RH on average which, as a vapor, will seek to dissipate and equalize with adjacent spaces (see fig. 7). Moisture can form on single-glazed windows in winter with exterior temperatures below 30 F and interior temperatures at 70 F with as little as 35% RH. Frequent condensation on interior window surfaces is an indication that moisture is migrating into exterior walls, which can cause long-term damage to historic materials. Materials and wall systems around climate controlled areas may need to be made of moisture resistant finishes in order to handle the additional moisture in the air. Moist interior conditions in hot and humid climates will generate mold and fungal growth. Unvented mechanical equipment, such as gas stoves, driers, and kerosene heaters, generate large quantities of moisture. It is important to provide adequate ventilation and find a balance between interior temperature, relative humidity, and airflow to avoid interior moisture that can damage historic buildings.

Fig. 7. Condensation dripping from the large overhead courtyard skylight was damaging the masonry in this museum. A new skylight with thermal glazing was installed, replacing the deteriorated single-glazed unit. A new climate control system monitors interior temperature and humidity. Photo © Isabella Stewart Gardner Museum, Boston.

Moisture from maintenance and construction materials can cause damage to adjacent historic materials. Careless use of liquids to wash floors can lead to water seepage through cracks and dislodge adhesives or cup and curl materials. High-pressure power washing of exterior walls and roofing materials can force water into construction joints where it can dislodge mortar, lift roofing tiles, and saturate frame walls and masonry. Replastered or newly plastered interior walls or the construction of new additions attached to historic buildings may hold moisture for months; new plaster, mortar, or concrete should be fully cured before they are painted or finished. The use of materials in projects that have been damaged by moisture prior to installation or have too high a moisture content may cause concealed damage (see fig. 8).

Fig. 8. Damaging moisture conditions can occur during construction. Peeling paint on this newly rehabilitated frame wall was attributed to wall insulation that had become wet during the project and was not discovered. Photo: NPS Files.

Transport or Movement of Moisture

Knowing the five most common sources of moisture that cause damage to building materials is the first step in diagnosing moisture problems. But it is also important to understand the basic mechanisms that affect moisture movement in buildings. Moisture transport, or movement, occurs in two states: liquid and vapor. It is directly related to pressure differentials. For example, water in a gaseous or vapor state, as warm moist air, will move from its high pressure area to a lower pressure area where the air is cooler and drier. Liquid water will move as a result of differences in hydrostatic pressure or wind pressure. *It is the pressure differentials that drive the rate of moisture migration in either state.* Because the building materials themselves resist this moisture movement, the rate of movement will depend on two factors: the permeability of the materials when affected by vapor and the absorption rates of materials in contact with liquid.

The mechanics, or physics, of moisture movement is complex, but if the driving force is difference in pressure, then an approach to reducing moisture movement and its damage is to reduce the difference in pressure, not to increase it. That is why the treatments discussed in this Brief will look at *managing moisture by draining bulk moisture and ventilating vapor moisture* before setting up new barriers with impermeable coatings or over-pressurized new climate control systems that threaten aging building materials and archaic construction systems.

Three forms of moisture transport are particularly important to understand in regards to historic buildings — *infiltration, capillary action, and vapor diffusion* —remembering, at the same time, that the subject is infinitely complex and, thus, one of continuing scientific study (see fig. 9). Buildings were traditionally designed to deal with the movement of air. For example, cupolas and roof lanterns allowed hot air to rise and provided a natural draft to pull air through buildings. Cavity walls in both frame and masonry buildings were constructed to allow moisture to dissipate in the air space between external and internal walls. Radiators were placed in front of windows to keep cold surfaces warm, thereby reducing condensation on these surfaces. Many of these features, however, have been altered over time in an effort to modernize appearances, improve energy efficiency, or accommodate changes in use. The change in use will also affect moisture movement, particularly in commercial and industrial buildings with modern mechanical systems. Therefore, the way a building handles air and moisture today may be different from that intended by the original builder or architect, and poorly conceived changes may be partially responsible for chronic moisture conditions.

Moisture moves into and through materials as both a visible liquid (capillary action) and as a gaseous vapor (infiltration and vapor diffusion). Moisture from leaks, saturation, rising damp, and condensation can lead to the deterioration of materials and cause an unhealthy environment. Moisture in its solid form, ice, can also cause damage from frozen, cracked water pipes, or split gutter seams or spalled masonry from freeze-thaw action. Moisture from melting ice dams, leaks, and condensation often can travel great distances down walls and along construction surfaces, pipes, or conduits. The amount of moisture and how it deteriorates materials is dependent upon complex forces and variables that must be considered for each situation.

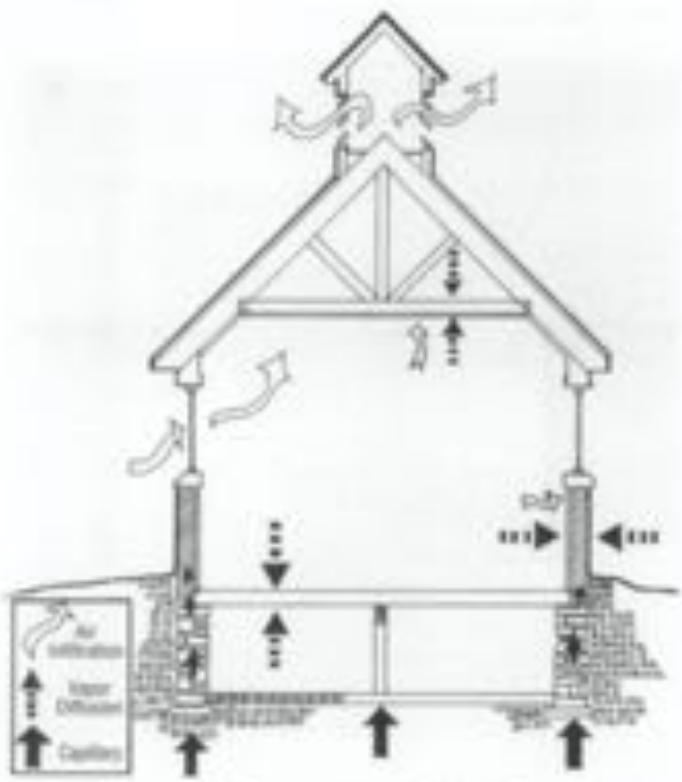


Fig. 9. The dynamic forces that move air and moisture through a building are important to understand particularly when selecting a treatment to correct a moisture problem. Air infiltration, capillary action, and vapor diffusion all affect the wetting and drying of materials. Drawing: NPS Files.

Determining the way moisture is handled by the building is further complicated because each building and site is unique. Water damage from blocked gutters and downspouts can saturate materials on the outside, and high levels of interior moisture can saturate interior materials. Difficult cases may call for technical evaluation by consultants specializing in moisture monitoring and diagnostic evaluation. In other words, it may take a team to effectively evaluate a situation and determine a proper approach to controlling moisture damage in old buildings.

Infiltration is created by wind, temperature gradients (hot air rising), ventilation fan action, and the stack or chimney effect that draws air up into tall vertical spaces. Infiltration as a dynamic force does not actually move liquid water, but is the vehicle by which dampness, as a component of air, finds its way into building materials. Older buildings have a natural air exchange, generally from 1 to 4 changes per hour, which, in turn, may help control moisture by diluting moisture within a building. The tighter the building construction, however, the lower will be the infiltration rate and the natural circulation of air. In the process of infiltration, however, moisture that has entered the building and saturated materials can be drawn in and out of materials, thereby adding to the dampness in the air (see fig. 10). Inadequate air circulation where there is excessive moisture (i.e., in a damp basement), accelerates the deterioration of historic materials. To reduce the unwanted moisture that accompanies infiltration, it is best to incorporate maintenance and repair treatments to close joints and weatherstrip windows, while providing controlled air exchanges elsewhere. The worst approach is to seal the building so completely, while limiting fresh air intake, that the building cannot breathe.

Fig. 10. Infiltration of damp air can occur around loose fitting or deteriorated window sash and through cracks or open joints in building exteriors. Photo: Ann Brooks Prasher

Capillary action occurs when moisture in saturated porous building materials, such as masonry, wicks up or travels vertically as it evaporates to the surface. In capillary attraction, liquid in the material is attracted to the solid surface of the pore structure causing it to rise vertically; thus, it is often called "rising damp," particularly when found in conjunction with ground moisture. It should not, however, be confused with moisture that laterally penetrates a foundation wall through cracks and settles in the basement. Not easily controlled, most rising damp comes from high water tables or a constant source under the footing. In cases of damp masonry walls with capillary action, there is usually a whitish stain or horizontal tide mark of efflorescence that seasonally fluctuates about 1-3 feet above grade where the excess moisture evaporates from the wall (see fig. 11). This tide mark is full of salt crystals, that have been drawn from the ground and building materials along with the water, making the masonry even more sensitive to additional moisture absorption from the surrounding air. Capillary migration of moisture may occur in any material with a pore structure where there is a constant or recurring source of moisture.

Fig. 11. Capillary rise of moisture in masonry is often accompanied with a horizontal tide mark line several feet above the grade, as seen here. Removing or redirecting as much ground moisture as possible usually helps reduce moisture within a wall. Photo: NPS Files

The best approach for dealing with capillary rise in building materials is to reduce the amount of water in contact with historic materials. If that is not possible due to chronically high water tables, it may be necessary to introduce a horizontal damp-proof barrier, such as slate course or a lead or plastic sheet, to stop the vertical rise of moisture. Moisture should not be sealed into the wall with a waterproof coating, such as cement parging or vinyl wall coverings, applied to the inside of damp walls. This will only increase the pressure differential as a vertical barrier and force the capillary action, and its destruction of materials, higher up the wall.

Vapor diffusion is the natural movement of pressurized moisture vapor through porous materials. It is most readily apparent as humidified interior air moves out through walls to a cooler exterior. In a hot and humid climate, the reverse will happen as moist hot air moves into cooler, dryer, air-conditioned, interiors. The movement of the moisture vapor is not a serious problem until the dewpoint temperature is reached and the vapor changes into liquid moisture known as *condensation*. This can occur within a wall or on interior surfaces. Vapor diffusion will be more of a problem for a frame structure with several layers of infill materials within the frame cavity than a dense masonry structure. Condensation as a result of vapor migration usually takes place on a surface or film, such as paint, where there is a change in permeability.

The installation of climate control systems in historic buildings (mostly museums) that have *not* been properly designed or regulated and that force pressurized damp *air* to diffuse into perimeter walls is an ongoing concern. These newer systems take constant monitoring and back-up warning systems to avoid moisture damage.

Long-term and undetected condensation or high moisture content can cause serious structural damage as well as an unhealthy environment, heavy with mold and mildew spores. Reducing the interior/exterior pressure differential and the difference between interior and exterior temperature and relative humidity helps control unwanted vapor diffusion. This can sometimes be achieved by reducing interior relative humidity. In some instances, using vapor barriers, such as heavy plastic sheeting laid over damp crawl spaces, can have remarkable success in stopping vapor diffusion from damp ground into buildings. Yet, knowledgeable experts in the field differ regarding the appropriateness of vapor barriers and when and where to use them, as well as the best way to handle natural diffusion in insulated walls.

Adding insulation to historic buildings, particularly in walls of wooden frame structures, has been a standard modern weatherization treatment, but it can have a disastrous effect on historic buildings. The process of installing the insulation destroys historic siding or plaster, and it is very difficult to establish a tight vapor barrier. While insulation has the benefit of increasing the efficiency of heating and cooling by containing temperature controlled air, it does not eliminate surfaces on which damaging moisture can condense. For insulated residential frame structures, the most obvious sign of a moisture

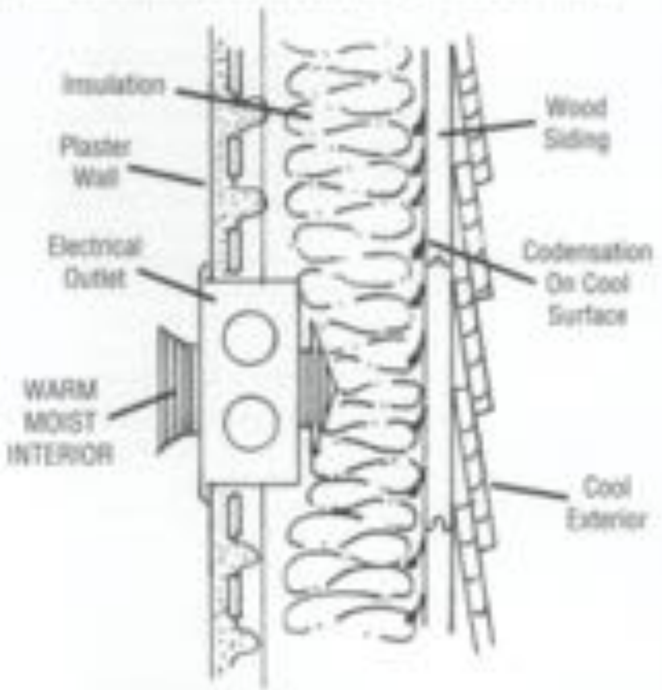


Fig. 12. Vapor diffusion can result in damp air migrating into absorbent materials and condensing on colder surfaces, thereby wetting insulation, damaging electrical conduits, and causing deterioration of the wooden framing. Drawing: NPS Files.

diffusion problem is peeling paint on wooden siding, even after careful surface preparation and repainting. Vapor impermeable barriers such as plastic sheeting, or more accurately, *vapor retarders*, in cold and moderate climates generally help slow vapor diffusion where it is not wanted.

In regions where *humidified* climate control systems are installed into insulated frame buildings, it is important to stop interstitial, or in-wall, dewpoint condensation. This is very difficult because humidified air can penetrate breaches in the vapor barrier, particularly around electrical outlets (see fig. 12). Improperly or incompletely installed retrofit vapor barriers will cause extensive damage to the building, just in the installation process, and will allow trapped condensation to wet the insulation and sheathing boards, corrode metal elements such as wiring cables and metal anchors, and blister paint finishes. Providing a tight wall vapor barrier, as well as a ventilated cavity behind wooden clapboards or siding appears to help insulated frame walls, if the interior relative humidity can be adjusted or monitored to avoid condensation. Correct placement of vapor retarders within building construction will vary by region, building construction, and type of climate control system.

Surveying and Diagnosing Moisture Damage: Key Questions to Ask

It is important for the building to be surveyed first and the evidence and location of suspected moisture damage systematically recorded before undertaking any major work to correct the problem. This will give a baseline from which relative changes in condition can be noted.

When materials become wet, there are specific physical changes that can be detected and noted in a record book or on survey sheets. Every time there is a heavy rain, snow storm, water in the basement, or mechanical systems failure, the owner or consultant should note and record the way moisture is moving, its appearance, and what variables might contribute to the cause. *Standing outside to observe a building in the rain may answer many questions and help trace the movement of water into the building.* Evidence of deteriorating materials that cover more serious moisture damage should also be noted, even if it is not immediately clear what is causing the damage. (For example, water stains on the ceiling may be from leaking pipes, blocked fan coil drainage pans above, or from moisture which has penetrated around a poorly sloped window sill above.) Don't jump to conclusions, but use a systematic approach to help establish an educated theory — or hypothesis — of what is causing the moisture problem or what areas need further investigation.

Surveying moisture damage must be systematic so that relative changes can be noted. Tools for investigating can be as simple as a notebook, sketch plans, binoculars, camera, aluminum foil, smoke pencil, and flashlight. The systematic approach involves looking at buildings from the top down and from the outside to the inside. Photographs, floor plans, site plan, and exterior elevations — even roughly sketched — should be used to indicate all evidence of damp or damaged materials, with notations for musty or poorly ventilated areas. Information might be needed on the absorption and permeability characteristics of the building materials and soils. Exterior drainage patterns should be noted and these base plans referred to on a regular basis in different seasons and in differing types of weather (see fig. 13).

Glossary:

Air flow/ infiltration: The movement that carries moist air into and through materials. Air flow depends on the difference between indoor and outdoor pressures, wind speed and direction as well as the permeability of materials.

Bulk water: The large quantity of moisture from roof and ground run-off that can enter into a building either above grade or below grade.

Capillary action: The force that moves moisture through the pore structure of materials. Generally referred to as rising damp, moisture at or below the foundation level will rise vertically in a wall to a height at which the rate of evaporation balances the rate at which it can be drawn up by capillary forces.

Condensation: The physical process by which water vapor is transformed into a liquid when the relative humidity of the air reaches 100% and the excess water vapor forms, generally as droplets, on the colder adjacent surface.

Convection: Heat transfer through the atmosphere by a difference in force or air pressure is one type of air transport. Sometimes referred to as the "stack effect," hotter less dense air will rise, colder dense air will fall creating movement of air within a building.

Dewpoint: The temperature at which water vapor condenses when the air is cooled at a constant pressure and constant moisture content.

Diffusion: The movement of water vapor through a material. Diffusion depends on vapor pressure, temperature, relative humidity, and the permeability of a material.

Evaporation: The transformation of liquid into a vapor, generally as a result of rise of temperature, is the opposite of condensation. Moisture in damp soil, such as in a crawl space, can evaporate into the air, raise the relative humidity in that space, and enter the building as a vapor.

Ground moisture: The saturated moisture in the ground as a result of surface run-off and naturally occuring water tables. Ground moisture can penetrate through cracks and holes in foundation walls or can migrate up from moisture under the foundation base.

Monitoring instrumentation: These devices are generally used for long term diagnostic analysis of a problem, or to measure the performance of a treatment, or to measure changes of conditions or environment. In-wall probes or sensors are often attached to data-loggers which can be down-loaded into computers.

Permeability: A characteristic of porosity of a material generally listed as the rate of diffusion of a pressurized gas through a material. The pore structure of some materials allows them to absorb or adsorb more moisture than other materials. Limestones are generally more permeable than granites.

Relative humidity (RH): Dampness in the air is measured as the percent of water vapor in the air at a specific temperature relative to the amount of water vapor that can be held in a vapor form at that specific temperature.

Survey instrumentation: technical instrumentation that is used on-site to provide quick readings of specific physical conditions. Generally these are hand-held survey instruments, such as moisture, temperature and relative humidity readers, dewpoint sensors, and fiber optic boroscopes.

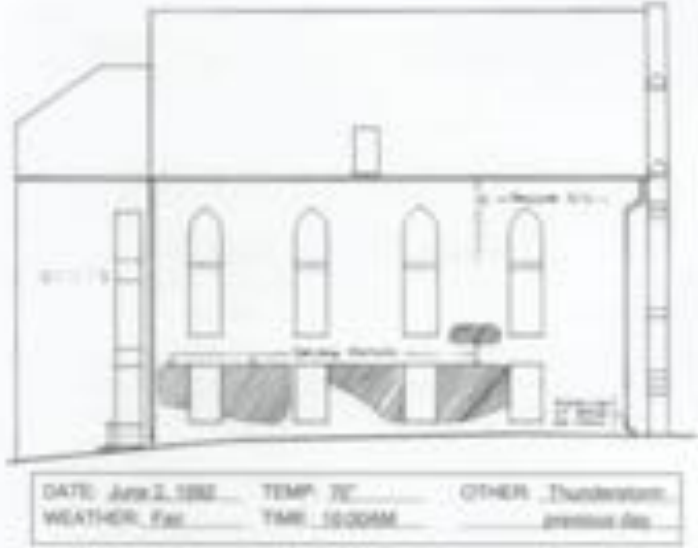


Fig. 13. Using sketch plans and elevation drawings to record the moisture damage along with the date, time, and weather conditions will show how moisture is affecting buildings over time. Drawing: Courtesy, Quinn Evans Architects.

It is best to start with one method of periodic documentation and to use this same method each time. Because moisture is affected by gravity, many surveys start with the roof and guttering systems and work down through the exterior walls. Any obvious areas of water penetration, damaged surfaces, or staining should be noted. Any recurring damp or stain patterns, both exterior and interior, should also be noted with a commentary on the temperature, weather, and any other facts that may be relevant (driving rains, saturated soil, high interior humidity, recent washing of the building, presence of a lawn watering system, etc.).

The interior should be recorded as well, beginning with the attic and working down to the basement and crawl space. It may be necessary to remove damaged materials selectively in order to trace the path of moisture or to pinpoint a source, such as a leaking pipe in the ceiling. The use of a basic resistance moisture meter, available in many hardware stores, can identify moisture contents of materials and show, over time, if wall surfaces are drying or becoming damper (see fig. 14). A smoke pencil can chart air infiltration around windows or draft patterns in interior spaces. For a quick test to determine if a damp basement is caused by saturated walls or is a result of condensation, tape a piece of foil onto a masonry surface and check it after a day or two; if moisture has developed behind the foil, then it is coming from the masonry. If condensation is on the surface of the foil, then moisture is from the air.

Comparing current conditions with previous conditions, historic drawings, photographs, or known alterations may also assist in the final diagnosis. A chronological record, showing improvement or deterioration, should be backed up with photographs or notations as to the changing size, condition, or features of the deterioration and how these changes have been affected by variables of temperature and rainfall. If a condition can be related in time to a particular event, such as efflorescence developing on a chimney after the building is no longer heated, it may be possible to isolate a cause, develop a hypothesis, and then test the hypothesis (by adding some temporary heat), before applying a remedial treatment.

Fig. 14. Using instruments in this damp-check kit can help determine the relative change in wet conditions over time. This involves readings of air temperature, computing dewpoint temperatures, and tracking the moisture content of materials to indicate if they are drying properly. Photo: Dell Corporation.

If the owner or consultant has access to moisture survey and monitoring equipment such as resistance moisture meters, dewpoint indicators, salt detectors, infrared thermography systems, psychrometer, fiber-optic borescopes, and miniaturized video cameras, additional quantified data can be incorporated into the survey (see fig. 15). If it is necessary to track the wetting and drying of walls over a period of time, deep probes set into walls and in the soil with connector cables to computerized data loggers or the use of long-term recording of hygrothermographs may require a trained specialist. Miniaturized fiber-optic video cameras can record the condition of subsurface drain lines without excavation (see fig. 16). It should be noted, however, that *instrumentation, while extremely useful, cannot take the place of careful personal observation and analysis.* Relying on instrumentation alone rarely will give the owner the information needed to fully diagnose a moisture problem.

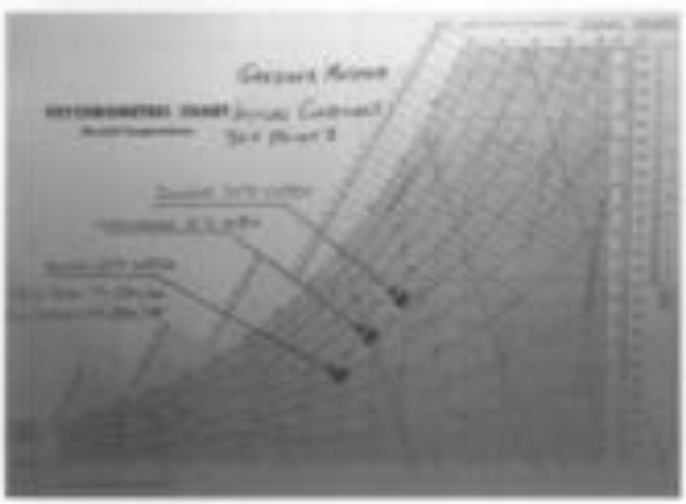


Fig. 15. Psychrometric charts quantify the amount of relative humidity a building can tolerate before dewpoint condensation occurs. This is important when the range of temperature and humidity are critical to both collections management and historic building preservation. Chart: Landmark Facilities Group.

Fig. 16. Contractors specializing in building diagnostics often have video cameras or fiber optic equipment that allow the viewing of inaccessible areas. This is particularly helpful in chimney flues or subsurface drains, as shown here. In the past, these areas would need to be excavated for visual inspection. Photo: author.

To avoid jumping to a quick—potentially erroneous—conclusion, a series of questions should be asked first. This will help establish a theory or hypothesis that can be tested to increase the chances that a remedial treatment will control or manage existing moisture.

How is water draining around building and site? What is the effectiveness of gutters and downspouts? Are the slopes or grading around foundations adequate? What are the locations of subsurface features such as wells, cisterns, or drainage fields? Are there subsurface drainage pipes (or drainage boots) attached to the downspouts and are they in good working condition? Does the soil retain moisture or allow it to drain freely? Where is the water table? Are there window wells holding rain water? What is the flow rate of area drains around the site (can be tested with a hose for several minutes)? Is the storm piping out to the street sufficient for heavy rains, or does water chronically back up on the site? Has adjacent new construction affected site drainage or water table levels?

How does water/moisture appear to be entering the building? Have all five primary sources of moisture been evaluated? What is the condition of construction materials and are there any obvious areas of deterioration? Did this building have a builder's trench around the foundation that could be holding water against the exterior walls? Are the interior bearing walls as well as the exterior walls showing evidence of rising damp? Is there evidence of hydrostatic pressure under the basement floor such as water percolating up through cracks? Has there been moisture damage from an ice dam in the last several months? Is damage localized, on one side of the building only, or over a large area?

What are the principal moisture dynamics? Is the moisture condition from liquid or vapor sources? Is the attic moisture a result of vapor diffusion as damp air comes up through the cavity walls from the crawl space or is it from a leaking roof? Is the exterior wall moisture from rising damp with a tide mark or are there uneven spots of dampness from foundation splash back, or other ground moisture conditions? Is there adequate air exchange in the building, particularly in damp areas, such as the basement? Has the height of the water table been established by inserting a long pipe into the ground in order to record the water levels?

How is the interior climate handling moisture? Are there areas in the building that do *not* appear to be ventilating well and where mold is growing? Are there historic features that once helped the building control air and moisture that can be reactivated, such as operable skylights or windows? Could dewpoint condensation be occurring behind surfaces, since there is often condensation on the windows? Does the building feel unusually damp or smell in an unusual way that suggest the need for further study? Is there evidence of termites, carpenter ants, or other pests attracted to moist conditions? Is a dehumidifier keeping the air dry or is it, in fact, creating a cycle where it is actually drawing moisture through the foundation wall?

Does the moisture problem appear to be intermittent, chronic, or tied to specific events? Are damp conditions occuring within two hours of a heavy rain or is there a delayed reaction? Does rust on most nail heads in the attic indicate a condensation problem? What are the wet patterns that appear on a building wall during and after a rain storm? Is it localized or in large areas? Can these rain patterns be tied to gutter over-flows, faulty flashing, or saturation of absorbent materials? Is a repaired area holding up well over time or is there evidence that moisture is returning? Do moisture meter readings of wall cavities indicate they are wet, suggesting leaks or condensation in the wall?

Once a hypothesis of the source or sources of the moisture has been developed from observation and recording of data, it is often useful to prove or disprove this hypothesis with interim treatments, and, if necessary, the additional use of instrumentation to verify conditions. For damp basements, test solutions can help determine the cause. For example, surface moisture in low spots should be redirected away from the foundation wall with regrading to determine if basement dampness improves. If there is still a problem, determine if subsurface downspout collection pipes or cast iron boots are not functioning properly. The above grade downspouts can be disconnected and attached to long, flexible extender pipes and redirected away from the foundation (see fig. 17). If, after a heavy rain or a simulation using a hose, there is no improvement, look for additional ground moisture sources such as high water tables, hidden cisterns, or leaking water service lines as a cause of moisture in the basement. New data will lead to a new hypothesis that should be tested and verified. *The process of elimination can be frustrating, but is required if a systematic method of diagnosis is to be successful.*

Selecting an Appropriate Level of Treatment

The treatments in chart format at the back of this publication are divided into levels based on the degree of moisture problems. Level I covers preservation maintenance; Level II focuses on repair using historically compatible materials and essentially mitigating damaging moisture conditions; and Level III discusses replacement and alteration of materials that permit continued use in a chronically moist environment. It is important to begin

Fig. 17. In testing a theory for the cause of basement wetness, the owner used long black extender pipes to direct roof run-off away from the foundation. This test established that the owner did not need expensive waterproofing of the foundation, but a better drainage system. Photo: Baird M. Smith.

with Level I and work through to a manageable treatment as part of the control of moisture problems. Buildings in serious decay will require treatments in Level II, and difficult or unusual site conditions may require more aggressive treatments in Level III. Caution should always be exercised when selecting a treatment. The treatments listed are a guide and not intended to be recommendations for specific projects as the key is always proper diagnosis.

Start with the repair of any obvious deficiencies using sound preservation maintenance. If moisture cannot be managed by maintenance alone, it is important to reduce it by mitigating problems *before* deteriorated historic materials are replaced (see fig. 18). Treatments should not remove materials that can be preserved; should not involve extensive excavation unless there is a documented need; and should not include coating buildings with waterproof sealers that can exacerbate an existing problem. Some alteration to historic materials, structural systems, mechanical systems, windows, or finishes may be needed when excessive site moisture cannot be controlled by drainage systems, or in areas prone to floods. These changes, however, should be sensitive to preserving those materials, features, and finishes that convey the historic character of the building and site.

Ongoing Care

Once the building has been repaired and the larger moisture issues addressed, it is important to keep a record of additional evidence of moisture problems and *to protect the historic or old building through proper cyclical maintenance* (see fig. 19). In some cases, particularly in museum environments, it is critical to monitor areas vulnerable to moisture damage. In a number of historic buildings, in-wall moisture monitors are used to ensure that the moisture purposely generated to keep relative humidity at ranges appropriate to a museum collection does not migrate into walls and cause deterioration. The potential problem with all systems is the failure of controls, valves, and panels over time. Back-up systems, warning devices, properly trained staff and an emergency plan will help control damage if there is a system failure.

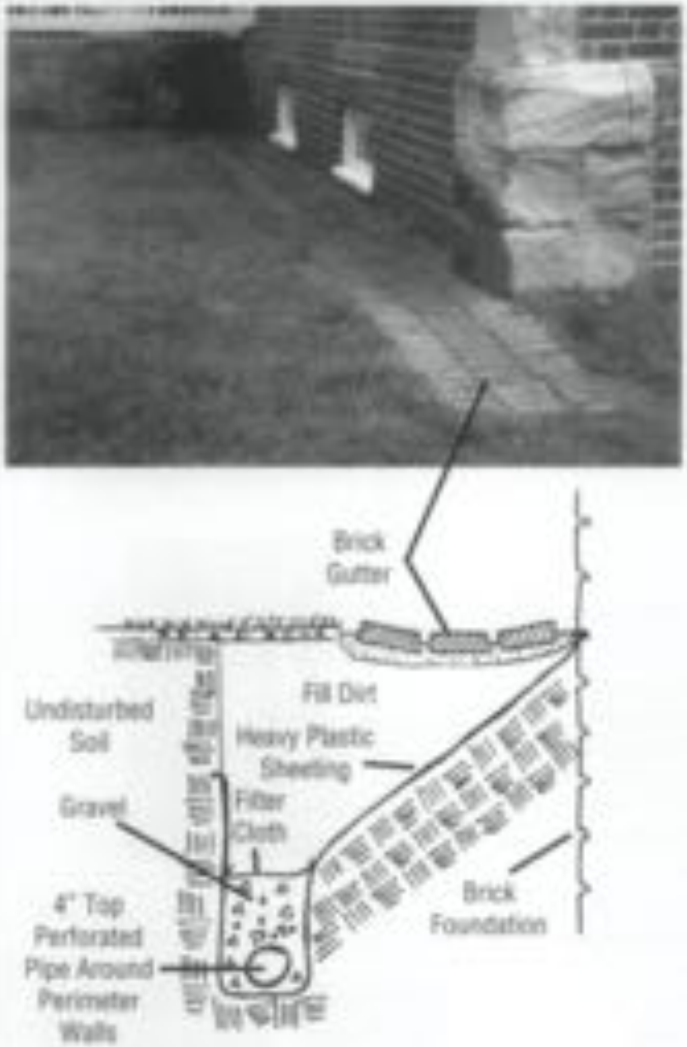


Fig. 18. This detail drawing shows a sub-surface perimeter drain in conjunction with a historic brick ground gutter system to help control roof run-off moisture from entering the historic foundation. Detail Courtesy: Gunston Hall Plantation. Photo: Elizabeth Sasser.

Fig. 19. Maintaining gutters and downspouts in good operable condition, repairing exteriors to keep water out, redirecting damaging moisture away from foundations and controlling interior moisture and condensation are all important when holding the line on moisture deterioration. Photo: Nebraska State Historical Society.

Ongoing maintenance and vigilance to situations that could potentially cause moisture damage must become a routine part of the everyday life of a building. The owner or staff responsible for the upkeep of the building should inspect the property weekly and note any leaks, mustiness, or blocked drains. Again, observing the building during a rain will test whether ground and gutter drainage are working well.

For some buildings a back-up power system may be necessary to keep sump pumps working during storms when electrical power may be lost. For mechanical equipment rooms, condensation pans, basement floors, and laundry areas where early detection of water is important, there are alarms that sound when their sensors come into contact with moisture.

Conclusion

Moisture in old and historic buildings, though difficult to evaluate, can be systematically studied and the appropriate protective measures taken. Much of the documentation and evaluation is based on common sense combined with an understanding of historic building materials, construction technology, and the basics of moisture and air movement. Variables can be evaluated step by step and situations creating direct or secondary moisture damage can generally be corrected. The majority of moisture problems can be mitigated with maintenance, repair, control of ground and roof moisture, and improved ventilation. For more complex situations, however, a thorough diagnosis and an understanding of how the building handles moisture at present, can lead to a treatment that solves the problem without damaging the historic resource.

It is usually advantageous to eliminate one potential source of moisture at a time. Simultaneous treatments may set up a new dynamic in the building with its own set of moisture problems. Implementing changes sequentially will allow the owner or preservation professional to track the success of each treatment.

Moisture problems can be intimidating to a building owner who has diligently tried to control them. Keeping a record of evidence of moisture damage, results of diagnostic tests, and remedial treatments, is beneficial to a building's long-term care. The more complete a survey and evaluation, the greater the success in controlling unwanted moisture now and in the future.

Holding the line on unwanted moisture in buildings will be successful if 1) there is constant concern for signs of problems and 2) there is ongoing physical care provided by those who understand the building, site, mechanical systems, and the previous efforts to deal with moisture. For properties with major or difficult-to-diagnose problems, a team approach is often most effective. The owner working with properly trained staff, contractors and consultants can monitor, select, and implement treatments within a preservation context in order to manage moisture and to protect the historic resource.

MOISTURE: LEVEL I PRESERVATION MAINTENANCE

Exterior: Apply cyclical maintenance procedures to eliminate rain and moisture infiltration.

Roofing/ guttering: Make weather-tight and operational; inspect and clean gutters as necessary depending on number of nearby trees, but at least twice a year; inspect roofing at least once a year, preferably spring; replace missing or damaged roofing shingles, slates, or tiles; repair flashing; repair or replace cracked downspouts.

Walls: Repair damaged surface materials; repoint masonry with appropriately formulated mortar; prime and repaint wooden, metal, or masonry elements or surfaces; remove efflorescence from masonry with non-metallic bristle brushes.

Window and door openings: Eliminate cracks or open joints; caulk or repoint around openings or steps; repair or reset weatherstripping; check flashing; repaint, as necessary.

A. Inspecting the overall building on at least an annual basis will identify areas needing maintenance. A bucket lift is helpful for large buildings. Photo: author.

Ground: Apply regular maintenance procedures to eliminate standing water and vegetative threats to building/site.

Grade: Eliminate low spots around building foundations; clean out existing downspout boots twice a year or add extension to leaders to carry moisture away from foundation; do a hose test to verify that surface drains are functioning; reduce moisture used to clean steps and walks; eliminate the use of chlorides to melt ice which can increase freeze/thaw spalling of masonry; check operation of irrigation systems, hose bib leaks, and clearance of air conditioning condensate drain outlets.

B. Repair exterior surfaces, paint, and recaulk as needed. Photo: Williamsport Preservation Training Center (WPTC), NPS.

Crawl space: Check crawl space for animal infestation, termites, ponding moisture, or high moisture content; check foundation grilles for adequate ventilation; seasonally close grilles when appropriate — in winter, if not needed, or in summer if hot humid air is diffusing into air conditioned space.

Foliage: Keep foliage and vines off buildings; trim overhanging trees to keep debris from gutters and limbs from rubbing against building; remove moisture retaining elements, such as firewood, from foundations.

C. Cleaning out gutters and downspouts should be done at least twice a year. Photo: WPTC, NPS.

Basements and foundations: Increase ventilation and maintain surfaces to avoid moisture.

Equipment: Check dehumidifiers, sump pump, vent fans, and water detection or alarm systems for proper maintenance as required; check battery back-up twice a year.

Piping/ductwork: Check for condensation on pipes and insulate/seal joints, if necessary.

Interior: Maintain equipment to reduce leaks and interior moisture.

Plumbing pipes: Add insulation to plumbing or radiator pipes located in areas subject to freezing, such as along outside walls, in attics, or in unheated basements.

D. Protect the building from damage by maintaining equipment and using alarms, like this floor water sensor. Photo: DVD Corporation.

Mechanical equipment: Check condensation pans and drain lines to keep clear; insulate and seal joints in exposed metal ductwork to avoid drawing in moist air.

Cleaning: Routinely dust and clean surfaces to reduce the amount of water or moist chemicals used to clean building; caulk around tile floor and wall connections; and maintain floor grouts in good condition.

Ventilation: Reduce household-produced moisture, if a problem, by increasing ventilation; vent clothes driers to the outside; install and always use exhaust fans in restrooms, bathrooms, showers, and kitchens, when in use.

MOISTURE: LEVEL II REPAIR AND CORRECTIVE ACTION

Exterior: Repair features that have been damaged. Replace an extensively deteriorated feature with a new feature that matches in design, color, texture, and where possible, materials.

Roofing: Repair roofing, parapets and overhangs that have allowed moisture to enter; add ice and water shield membrane to lower 3-4 feet of roofing in cold climates to limit damage from ice dams; increase attic ventilation, if heat and humidity build-up is a problem. Make gutters slope @ 1/8" to the foot. Use professional handbooks to size gutters and reposition, if necessary and appropriate to historic architecture. Add ventilated chimney caps to unused chimneys that collect rain water.

Walls: Repair spalled masonry, terra cotta, etc. by selectively installing new masonry units to match; replace rotted clapboards too close to grade and adjust grade or clapboards to achieve adequate clearance; protect or cover open window wells.

A. Mitigate poor drainage with gravel, filter cloth, or the use of subsurface drainage mats under finished paving. Photo: Larry D. Dermody.

Ground: Correct serious ground water problems; capture and dispose of downspout water away from foundation; and control vapor diffusion of crawlspace moisture.

Grade: Re-establish positive sloping of grade; try to obtain 6" of fall in the first 10' surrounding building foundation; for buildings without gutter systems, regrade and install a positive subsurface collection system with gravel, or waterproof sheeting and perimeter drains; adjust pitch or slope of eave line grade drains or French drains to reduce splash back onto foundation walls; add subsurface drainage boots or extension pipes to take existing downspout water away from building foundation to the greatest extent feasible.

Crawl space: Add polyethylene vapor barrier (heavy construction grade or Mylar) to exposed dirt in crawlspace if monitoring indicates it is needed and there is no rising damp; add ventilation grilles for additional cross ventilation, if determined advisable.

B. Repair roofs and add ice and water shields at eaves and under valleys in cold climates. Photo: Larry D. Dermody.

Foundations and Basements: Correct existing high moisture levels, if other means of controlling ground moisture are inadequate.

Mechanical devices: Add interior perimeter drains and sump pump; add dehumidifiers for seasonal control of humidity in confined, unventilated space (but don't create a problem with pulling dampness out of walls); add ventilator fans to improve air flow, but don't use both the dehumidifier and ventilator fan at the same time.

Walls: Remove cementitious coatings, if holding rising damp in walls; coat walls with vapor permeable lime based rendering plaster, if damp walls need a sacrificial coating to protect mortar from erosion; add termite shields, if evidence of termites and dampness cannot be controlled.

C. Develop new drainage systems for roof run-off that remove moisture from the base of the building. Photo: WPTC, NPS.

Framing: Reinforce existing floor framing weakened by moisture by adding lolly column support and reinforcing joist ends with sistered or parallel supports. Add a vapor impermeable shield, preferably non-ferrous metal, under wood joists coming into contact with moist masonry.

Interior: Eliminate areas where moisture is leaking or causing a problem.

Plumbing: Replace older pipes and fixtures subject to leaking or overflowing; insulate water pipes subject to condensation.

Ventilation: Add exhaust fans and whole house fans to increase air flow through buildings, if areas are damp or need more ventilation to control mold and mildew.

Climate: Adjust temperature and relative humidity to manage interior humidity; Correct areas of improperly balanced pressure for HVAC systems that may be causing a moisture problem.

D. Install ventilating fans when additional air circulation will improve damp conditions in buildings or reduce cooling loads. Photo: Ernest A. Conrad, P. E.

A. This lead sheet was installed at the base of the replacement column to stop rising damp. Photo: Bryan Blundell.

Exterior: Undertake exterior rehabilitation work that follows professional repair practices —i.e., replace a deteriorated feature with a new feature to match the existing in design, color, texture, and when possible, materials. In some limited situations, non-historic materials may be necessary in seasonally wet areas.

Roofs: Add ventilator fans to exhaust roofs but avoid large projecting features whose designs might negatively affect the appearance of the historic roof. When replacing roofs, correct conditions that have caused moisture problems, but keep the overall appearance of the roof; for example, ventilate under wooden shingles, or detail standing seams to avoid buckling and cracking. Be attentive to provide extra protection for internal or built-in gutters by using the best quality materials, flashing, and vapor impermeable connection details.

Walls: If insulation and vapor barriers are added to frame walls, consider maintaining a ventilation channel behind the exterior cladding to avoid peeling and blistering paint occurrences.

Windows: Consider removable exterior storm windows, but allow operation of windows for periodic ventilation of cavity between exterior storm and historic sash. For stained glass windows using protective glazing, use only ventilated storms to avoid condensation as well as heat build-up.

B. Wood sills set on grade were replaced with concrete pier foundation and new wooden sill plates. Changes were not visible on the exterior (see C). Photo: WPTC, NPS.

Ground: Control excessive ground moisture. This may require extensive excavations, new drainage systems, and the use of substitute materials. These may include concrete or new sustainable recycled materials for wood in damp areas where they do not impact the historic appearance of the building.

Grade: Excavate and install water collection systems to assist with positive run-off of low lying or difficult areas of moisture drainage; use drainage mats under finished grade to improve run-off control; consider the use of column plinth blocks or bases that are ventilated or constructed of non-absorbent substitute materials in chronically damp areas. Replace improperly sloped walks; repair non-functioning catch basins and site drains; repair settled areas around steps and other features at grade.

C. The new ground gutter gravel base helps drainage around the concrete foundation (see B above) which is not visible behind the replaced wooden wall shingles. Photo: WPTC, NPS.

D. In a flood plain, rotted joists were replaced with a concrete slab and sleepers designed to drain water. Spaced flooring allowed drainage and room for damp wood to swell without buckling. Harper's Ferry Center, NPS.

E. Mechanical systems on the lower level were placed on platforms above the flood line. Harper's Ferry Center, NPS.

— — FOR CHRONICALLY DAMP CONDITIONS

Foundations: Improve performance of foundation walls with damp-proof treatments to stop infiltration or damp course layers to stop rising damp. Some substitute materials may need to be selectively integrated into new features.

Walls: excavate, repoint masonry walls, add footing drains, and waterproof exterior subsurface walls; replace wood sill plates and deteriorated structural foundations with new materials, such as pressure treated wood, to withstand chronic moisture conditions; materials may change, but overall appearance should remain similar. Add dampcourse layer to stop rising damp; avoid chemical injections as these are rarely totally effective, are not reversible, and are often visually intrusive.

Interior: Control the amount of moisture and condensation on the interiors of historic buildings. Most designs for new HVAC systems will be undertaken by mechanical engineers, but systems should be selected that are appropriate to the resource and intended use.

Windows, skylights: Add double and triple glazing, where necessary to control condensation. Avoid new metal sashes or use thermal breaks where prone to heavy condensation.

Mechanical systems: Design new systems to reduce stress on building exterior. This might require insulating and tightening up the building exterior, but provisions must be made for adequate air flow. A new zoned system, with appropriate transition insulation, may be effective in areas with differing climatic needs.

Control devices/Interior spaces: If new climate control systems are added design back-up controls and monitoring systems to protect from interior moisture damage.

Walls: If partition walls sit on floors that periodically flood, consider spacers or isolation membranes behind baseboards to stop moisture from wicking up through absorbent materials.

F. Triple glazed windows replaced the originals to control condensation. Photo: © Isabella Stewart Gardner Museum, Boston.

G. New sensors which monitor temperature and relative humidity are located throughout this museum and tied to a computer that controls the climate control system. Photo: © Isabella Stewart Gardner Museum, Boston.

I. Critically damp foundation walls were protected with a layer of bentonite clay to reduce moisture penetration. This work was in combination with new downspouts that were connected to drainage boots that deposited captures roof run-off away from the foundation. Photo: Courtesy, Larry D. Dermody and the National Trust for Historic Preservation.

H. New computers tie a variety of monitoring and security features into a comprehensive system which provides warning and backup alerts when any of the system components are not functioning properly. Photo: © Isabella Stewart Gardner Museum, Boston.

Back Cover: The Diagnosing Moisture in Historic Building Symposium held in Washington, DC, May, 1996, brought together practitioners in the field of historic preservation to discuss the issues contained in this Preservation Brief. Attendees are standing in front of the cascading fountains at Meridian Hill Park, a National Historic Landmark. Photo: Eric Anner

Reading List

Conrad, Ernest A., P.E. "The Dews and Don'ts of Insulating." *Old House Journal*. May/June, 1996.

Cumberland, Don, Jr. "Museum Collection Storage in an Historic Building Using a Prefabricated Structure." *Preservation Tech Notes*. Washington, DC: National Park Service, issue PTN-14. September, 1985.

Jessup, Wendy Claire, Ed. *Conservation in Context: Finding a Balance for the Historic House Museum*. Washington, DC: National Trust for Historic Preservation (Symposium Proceedings March 7-8, 1994).

Labine, Clem. "Managing Moisture in Historic Buildings" Special Report and Moisture Monitoring Source List. *Traditional Building*, Vol 9, No.2, May-June 1996.

Leeke, John. "Detecting Moisture; Methods and Tools for Evaluating Water in Old Houses." *Old House Journal*. May/June, 1996.

Moisture Control in Buildings. Heinz R. Trechsel, Editor. Philadelphia: American Society for Testing and Materials (ASTM manual series: MNL 18), 1993.

Museums in Historic Buildings (Special Issue). *APT Bulletin*. The Journal of Preservation Technology, Vol 26, No. 3. Williamsburg, VA: APT, 1996.

Oxley, T.A. and A. E. Gobert. *Dampness in Buildings: Diagnosis, Treatment, Instruments*. London, Boston: Butterworth-Heinemann, 1994.

Park, Sharon C. AIA. *Preservation Brief 24: Heating, Ventilating, and Cooling Historic Buildings: Problems and Recommended Approaches*. Washington, DC: Department of the Interior, Government Printing Office, 1991.

Rose, William. "Effects of Climate Control on the Museum Building Envelope." *Journal of the American Institute for Conservation*, Vol. 33, No. 2. Summer, 1994.

Smith, Baird M. *Moisture Problems in Historic Masonry Walls: Diagnosis and Treatment*. Washington, DC.: Department of the Interior, Government Printing Office, 1984.

Tolpin, Jim. "Builder's Guide to Moisture Meters," Tools of the Trade Vol 2, No. 1 (Quarterly Supplement to *The Journal of Light Construction*). Richmond, Vermont: Builderburg Group Inc. Summer, 1994.

Acknowledgments

Sharon C. Park, AIA is the Senior Historical Architect, Technical Preservation Services, Heritage Preservation Services Program, National Park Service, Washington, D.C. The author wishes to thank the following individuals and organizations for providing technical review and other assistance in developing this publication: The attendees, speakers, and sponsors of the Diagnosing Moisture in Historic Buildings Symposium held in Washington, DC in 1996 and funded by a grant from the National Center for Preservation Technology and Training, National Park Service; Hugh C. Miller, FAIA; Michael Henry, AIA, PE, PP; Baird M. Smith, AIA; Ernest A. Conrad, P.E.; William B. Rose; Rebecca Stevens, AIA; Wendy Claire Jessup; Elizabeth Sasser, AIA; Bryan Blundell; George Siekkinen, AIA; Larry D. Dermody; Kimberly A. Konrad; Barbara J. Mangum and the Isabella Stewart Gardner Museum, Boston; Gunston Hall Plantation; Friends of Meridian Hill; Friends of Great Falls Tavern; The National Trust for Historic Preservation; Thomas McGrath, Douglas C. Hicks and The Williamsport Preservation Training Center, NPS; the staff of Heritage Preservation Services, NPS: Charles E. Fisher, Brooks Prueher, Anne E. Grimmer, Antoinette Lee, and especially Kay D. Weeks.

This publication has been prepared pursuant to the National Historic Preservation Act, as amended, which directs the Secretary of the Interior to develop and make available information concerning historic properties. Comments about this publication should be directed to de Teel Patterson Tiller, Acting Manager, Heritage Preservation Services Program, National Park Service, P.O. Box 37127, Washington, DC 20013-7127.

Cover Photo: Masonry repointing in a wet environment. Photo: Williamsport Preservation Training Center, NPS.

ISSN: 0885-7016

October, 1996

41 PRESERVATION BRIEFS

The Seismic Retrofit of Historic Buildings: Keeping Preservation in the Forefront

David W. Look, AIA, Terry Wong, PE,
and Sylvia Rose Augustus

U.S. Department of the Interior
National Park Service
Cultural Resources
Heritage Preservation Services

Violent, swift, and unpredictable, earthquakes result from sudden movements of the geological plates that form the earth's crust, generally along cracks or fractures known as "faults." If a building has not been designed and constructed to absorb these swaying ground motions, then major structural damage, or outright collapse, can result, with grave risk to human life. Historic buildings are especially vulnerable in this regard. As a result, more and more communities are beginning to adopt stringent requirements for seismic retrofit of existing buildings. And despite popular misconceptions, the risks of earthquakes are not limited to the West Coast, as the Seismic Zone Map on page 14 illustrates.

Although historic and other older buildings can be retrofitted to survive earthquakes, many retrofit practices damage or destroy the very features that make such buildings significant. Life-safety issues are foremost and, fortunately, there are various approaches which can save historic buildings both from the devastation caused by earthquakes and from the damage inflicted by well-intentioned but insensitive retrofit procedures. Building owners, managers, consultants, and communities need to be actively involved in preparing documents and readying irreplaceable historic resources from these damages (see illus.1).

This Preservation Brief provides essential information on how earthquakes affect historic buildings, how a historic preservation ethic can guide responsible decisions, and how various methods of seismic retrofit can protect human lives and historic structures. Because many of the terms used in this Brief are technical, a glossary is provided on page 7. The Brief focuses on unreinforced masonry buildings because these are the most vulnerable of our older resources, but the guidance is appropriate for all historic buildings. Damage to non-structural elements such as furnishings and collections is beyond the scope of this Brief, but consideration should be given to securing and protecting these cultural resources as well.

Planning the retrofit of historic buildings before an earthquake strikes is a process that requires teamwork on the part of engineers, architects, code officials, and agency administrators. Accordingly, this Brief also presents guidance on assembling a professional team and ensuring its successful interaction. Project personnel working together can ensure that the architectural, engineering, financial, cultural, and social values of historic buildings are preserved, while rendering them safe for continued use.

1. Earthquake damage to historic buildings can be repaired in a manner sensitive to their historic character as seen in this ca. 1928 five story apartment building. The owners used a combination of federal rehabilitation tax credits, community development block grants, and post earthquake grants to fund a portion of the rehabilitation and seismic upgrade costs. Photos: Historic Resources Group, Los Angeles.

Balancing Seismic Retrofit and Preservation

Reinforcing a historic building to meet new construction requirements, as prescribed by many building codes, can destroy much of a historic building's appearance and integrity. This is because the most expedient ways to reinforce a building according to such codes are to impose structural members and to fill irregularities or large openings, regardless of the placement of architectural detail. The results can be quite intrusive (see illus. 2). However, structural reinforcement can be introduced sensitively. In such cases, its design, placement, patterning, and detailing respect the historic character of the building, even when the reinforcement itself is visible.

Three important preservation principles should be kept in mind when undertaking seismic retrofit projects:

- *Historic materials should be preserved and retained to the greatest extent possible and not replaced wholesale in the process of seismic strengthening;*
- *New seismic retrofit systems, whether hidden or exposed, should respect the character and integrity of the historic building and be visually compatible with it in design; and,*
- *Seismic work should be "reversible" to the greatest extent possible to allow removal for future use of improved systems and traditional repair of remaining historic materials.*

It is strongly advised that all owners of historically significant buildings contemplating seismic retrofit become familiar with The Secretary of the Interior's *Standards for the Treatment of Historic Properties*, which are published by the National Park Service and cited in the bibliography of this publication. These standards identify approaches for working with historic buildings, including preservation, rehabilitation, and restoration. Code-required work to make buildings functional and safe is an integral component of each approach identified in the *Standards*. While some seismic upgrading work is more permanent than reversible, care must be taken to preserve historic materials to the greatest extent possible and for new work to have a minimal visual impact on the historic appearance of the building.

2. Standard approaches to seismic retrofit, as seen with the diagonally braced frame crossing in front of the historic windows, are visually intrusive. Solutions, such as using hidden moment frames around the perimeter of the window, will meet the goals of historic preservation and seismic retrofit. Photo: Shade Craige.

Earthquake Damage to Historic Buildings: Assessing Principal Risk Factors

Typical earthquake damage to most older and historic buildings results from poor ductility—or flexibility—of the building and, specifically, poor structural connections between walls, floors, and foundations combined with the very heavy weight and mass of historic materials that are moved by seismic forces and must be resisted. In buildings that have not been seismically upgraded, particularly unreinforced masonry buildings, parapets, chimneys, and gable ends may dislodge and fall to the ground during a moderate to severe earthquake (see illus. 3). Walls, floors, roofs, skylights, porches, and stairs which rely on tied connections may simply fail. Interior structural supports may partially or totally collapse. Unreinforced masonry walls between openings often exhibit shear (or diagonal) cracking. Upper stories may collapse onto under-reinforced lower floors with large perimeter openings or atriums. Unbraced infill material between structural or rigid frame supports may dislodge. Adjacent buildings with separate foundations may move differently in an earthquake creating damage between them. Poorly anchored wood frame buildings tend to slide off their foundations. Ruptured gas and water lines often cause fire and water damage. Many of these vulnerabilities can be mitigated by understanding how the forces unleashed in an earthquake affect the building, then planning and implementing appropriate remedial treatments.

3. Forces from moderate to serious earthquakes caused a) the unbraced gable to fail, b) the first floor to collapse c) cracks from the pounding effect of adjacent buildings, and d) and diagonal cracks in exterior masonry between windows to form. Photos: David Look.

Six principal factors influence how and why historic buildings are damaged in an earthquake: (1) depth of the earthquake and subsequent strength of earthquake waves reaching the surface; (2) duration of the earthquake, including after-shock tremors; (3) proximity of the building to the earthquake epicenter, although distance is not necessarily a direct relationship; (4) geological and soil conditions; (5) building construction details, including materials, structural systems, and plan configuration; and (6) existing building condition, including maintenance level.

The first three factors—the depth, duration, and proximity to the fault—are beyond human control. Recent earthquakes have shown the fourth factor, geological soil conditions, to be as important as any of the other factors because loose, soft soils tend to amplify ground motion, thereby increasing damage. Further, there is the tendency of soft, unstable soils to "liquefy" as the ground vibrates, causing the building foundations to sink unevenly. This fourth factor, geological and soil conditions, is difficult to address in a retrofit situation, although it can be planned for in new construction. The last two factors—the building's construction type and its existing physical condition—are the two factors over which building owners and managers have control and can ultimately affect how the historic property performs in an earthquake (see illus. 4).

4. The compact size and good condition of the masonry building on the left withstood the earthquake except for the loss of the unsupported chimney at the roof line. The brick building on the right appears to have sustained more damage. Photo: Stade Craigo.

Although historic buildings present problems, the way they were constructed often has intrinsic benefits that should not be overlooked. Diagonal subflooring under tongue-and-groove nailed flooring can provide a diaphragm, or horizontal membrane, that ties the building together. Interior masonry walls employing wire lath with plaster also add strength that binds materials together. The typical construction of older buildings with partition walls that extend from floor to ceiling (instead of just to the underside of a dropped ceiling) also provides additional support and load transfer during an earthquake that keeps shifting floors from collapsing. Moreover, buildings constructed of unreinforced masonry with a wall thickness to height ratio that does not exceed code requirements can often survive shaking without serious damage. The stability of unreinforced masonry walls should not be underestimated; while the masonry may crack, it often does not shift out of plumb enough to collapse.

Type of Building and Construction

A historic building's construction and materials determine its behavior during an earthquake. Some buildings, such as wooden frame structures, are quite ductile and, thus, able to absorb substantial movements. Others, such as unreinforced brick or adobe buildings comprised of heavy individual load-bearing units, are more susceptible to damage from shaking. If an earthquake is strong, or continues for a long time, building elements that are poorly attached or unreinforced may collapse. Most historic buildings still standing in earthquake zones have survived some shaking, but may be structurally weakened.

Buildings of more rigid construction techniques may also have seismic deficiencies. Masonry infill-wall buildings are generally built of steel or concrete structural frames with unreinforced masonry sections or panels set within the frame. While the structural frames may survive an earthquake, the masonry infill can crack and, in some cases, dislodge. The reaction of concrete buildings and concrete frame structures is largely dependent upon the extent and configuration of iron or steel reinforcement. Early buildings constructed of concrete are often inadequately reinforced, inadequately tied, or both, and are thus susceptible to damage during earthquakes.

Recognition of the configuration of the historic structure and inherent areas of weakness are essential to addressing appropriate alternatives for seismic retrofit. For example, the plan and elevation may be as important as building materials and structural systems in determining a historic building's survival in an earthquake. Small round, square, or rectangular buildings generally survive an earthquake because their geometry allows for equal resistance of lateral forces in all directions. The more complex and irregular the plan, however, the more likely the building will be damaged during an earthquake because of its uneven strength and stiffness in different directions. Structures having an "L," "T," "H," "U," or "E" shape have unequal resistance, with the stress concentrated at corners and intersections. This is of particular concern if the buildings have flexible structural systems and/or an irregular layout of shear walls which may *cause* portions of the building to pull apart.

Similarly, the more complex and irregular a building elevation, the more susceptible it is to damage, especially in tall structures. Large or multiple openings around the building on the ground level, such as storefronts or garage openings, or floors with columns and walls running in only one direction are commonly known as "soft stories" and are prone to structural damage.

Building Condition

Much of the damage that occurs during an earthquake is directly related to the building's existing condition and maintenance history. Well maintained buildings, even without added reinforcement, survive better than buildings weakened by lack of maintenance. The capacity of the structural system to resist earthquakes may be severely reduced if previous alterations or earthquakes have weakened structural connections or if materials have deteriorated from moisture, termite, or other damage. Furthermore, in unreinforced historic masonry buildings, deteriorated mortar joints can weaken entire walls. Cyclical maintenance, which reduces moisture penetration and erosion of materials, is therefore essential. Because damage can be cumulative, it is important to analyze the structural capacity of the building.

Over time, structural members can become loose and pose a major liability. Unreinforced historic masonry buildings typically have a friction-fit connection between horizontal and vertical structural members, and the shaking caused by an earthquake pulls them apart. With insufficient bearing surface for beams, joists, and rafters against the load bearing walls or support columns, they fail. The resulting structural inadequacy may cause a partial or complete building collapse, depending on the severity of the earthquake and the internal wall configuration. Tying the building together by making a positive anchored or braced connection between walls, columns, and framing members, is key to the seismic retrofit of historic buildings.

Putting a Team Together

The two goals of the seismic retrofit in historic buildings are life safety and the protection of older and historic buildings during and after an earthquake. Because rehabilitation should be sensitive to historic materials and the building's historic character, it is important to put together a team experienced in both seismic requirements and historic preservation. Team members should be selected for their experience with similar projects, and may include architects, engineers, code specialists, contractors, and preservation consultants. Because the typical seismic codes are written for new construction, it is important that both the architect and structural engineer be knowledgeable about historic buildings and about meeting building code equivalencies and using alternative solutions. Local and state building officials can identify regulatory requirements, alternative approaches to meeting these requirements, and if the jurisdiction uses a historic preservation or building conservation code. Even on small projects that cannot support a full professional team, consultants should be familiar with historic preservation goals. The State Historic Preservation Office and the local historic preservation office or commission may be able to identify consultants who have been successful in preserving historic buildings during seismic retrofit work. Once the team has been assembled, their tasks include:

Compiling documentation. The team should review all available documentation on the historic building, including any previous documentation assembled to nominate the structure to the National Register of Historic Places, and any previous Historic Structures Reports. Original plans and specifications as well as those showing alterations through time often detail structural connections. Early real estate or insurance plans, such as the *Sanborn Maps*, note changes over time. Historic photographs of the building under construction or before and after previous earthquakes are invaluable. Base maps for geological or seismic studies and utility maps showing the location of water, gas, and electric lines should be also identified. The municipal or state office of emergency preparedness can provide data on earthquake hazard plans for the community.

Evaluating significant features and spaces. The team must also identify areas of a historic building and its site that exhibit design integrity or historical significance which must be preserved. It is critical, and a great challenge, to protect these major features, such as domes, atriums, and vaulted spaces or highly decorative elements, such as mosaics, murals, and frescoes. In some cases, secondary areas of the building can provide spaces for additional reinforcement behind these major features, thus saving them from damage during seismic retrofit work. Both primary and secondary spaces, features, and finishes should, thus, be identified.

Assessing the condition of the building and the risk hazards. The team then assesses the general physical condition of the building's interior and exterior, and identifies areas vulnerable to seismic damage. This often requires a structural engineer or testing firm to determine the strength and durability of materials and connections (see illus. 5). A sliding scale of potential damage is established, based on the probability of hazard by locale and building use. This helps the owner distinguish between areas in which repairable damage, such as cracking, may occur and those in which life-threatening problems may arise. These findings help guide cost-benefit decisions, especially when budgets are limited.

5. A careful program of in-place testing is essential to evaluate the existing seismic capacity of a building. This masonry push test uses hydraulic jacks to estimate the shear capacity of the wall. Test locations should be in areas that do not destroy significant features and repairs should be carried out carefully. Photo: Architectural Resources Group, San Francisco.

Evaluating local and state codes and requirements. Few codes consider historic buildings, but the California State Historical Code and the Uniform Code for Building Conservation provide excellent models for jurisdictions to adopt. Code officials should always be asked where alternative approaches can be taken to provide life safety if the specified requirements of a code would destroy significant historic materials and features. Some jurisdictions require the removal of parapets, chimneys, or projecting decoration from unreinforced masonry buildings which is not a preservation approach. Professionals on the team should be prepared with alternatives that allow for mitigating potential damage to such features while retaining them through reattachment or strengthening.

Developing a retrofit plan. The final task of the project team is to develop a retrofit plan. The plan may require multiple treatments, each more comprehensive than the last. Treating life-safety issues as well as providing a safe route of exit should be evaluated for all buildings. Developing more comprehensive plans, often combined with future rehabilitation, is reasonable. Long-term restoration solutions phased in over time as funding is available should also be considered. In every case, owners and their planning teams should consider options that keep preservation goals in mind.

There are significant advantages of completing a seismic survey and analysis even if resources for implementing a retrofit are not yet available. Once the retrofit plan is finished, the project team will have a document by which to assess future damage and proceed with emergency repairs. If construction is phased, its impact to the whole building should be understood. Some partially completed retrofit measures have left buildings more rigid in one area than in others, thereby contributing to more extensive damage during an ensuing earthquake.

Planning for Seismic Retrofit: How Much and Where?

The integrity and significance of the historic building, paired with the cost and benefit of seismic upgrading, need to be weighed by the owner and the consulting team. Buildings in less active seismic areas may need little or no further bracing or tying. Buildings in more active seismic zones, however, may need more extensive intervention. Options for the level of seismic retrofit generally fall into four classifications, depending on the expected seismic activity and the desired level of performance. Realistically, for historic buildings, only the first three categories apply.

1) *Basic Life Safety.* This addresses the most serious life-safety concerns by correcting those deficiencies that could lead to serious human injury or total building collapse. Upgrades may include bracing and tying the most vulnerable elements of the building, such as parapets, chimneys, and projecting ornamentation or reinforcing routes of exit. (see illus. 6). It is expected that if an earthquake were to occur, the building would not collapse but would be seriously damaged requiring major repairs.

2) *Enhanced Life Safety.* In this approach, the building is upgraded using a flexible approach to the building codes for moderate earthquakes. Inherent deficiencies found in older buildings, such as poor floor to wall framing connections and unbraced masonry walls would be corrected (see illus. 7). After a design level earthquake, some structural damage is anticipated, such as masonry cracking, and the building would be temporarily unusable.

6. Often simple approaches, such as nailing plywood stiffeners between crawlspace studs and onto floor joist above and bolting sill plates to foundations can make a dramatic difference in protecting a building from seismic damage. Illustration: Reproduced with permission from Home Earthquake Preparedness Guide, EQE Incorporated, San Francisco, CA.

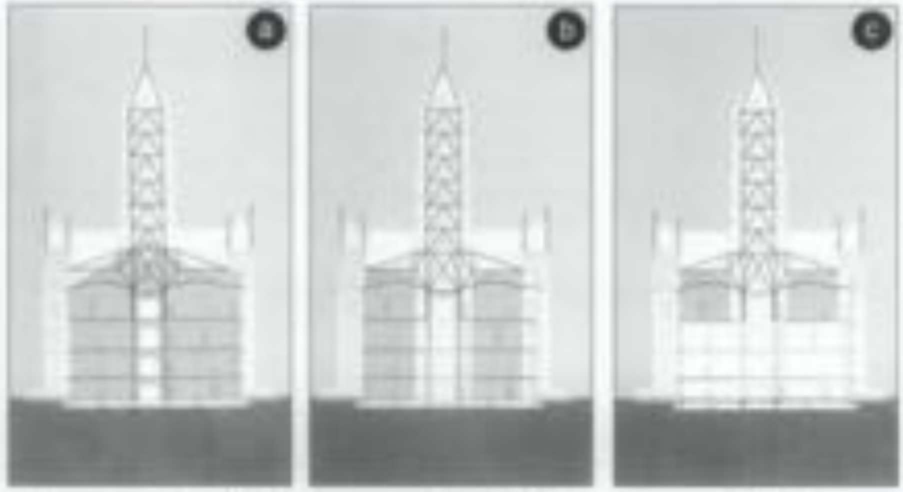
7. More extensive seismic issues can be addressed through structural reinforcement, the most common methods using anchor ties and braces. Shown here is an interior diagonal frame, to be covered, which will dampen and transfer seismic loads in a designed path from foundation to roof. Photo: David Look.

8. Full seismic restructuring to ensure that buildings survive a major earthquake with a minimum of damage may involve extensive reinforcement. Upon completion, the changes to this ca. 1932 Gothic Revival building to add base isolation at the foundation were not visually apparent. Photo: © Jonathan Farrer, courtesy University of California at Los Angeles (UCLA), Capital Programs.

3) *Enhanced Damage Control.* Historic buildings are substantially rehabilitated to meet, to the extent possible, the prescribed building code provision (See illus. 8). Some minor repairable damage would be expected after a major earthquake.

4) *Immediate Occupancy.* This approach is intended for designated hospitals and emergency preparedness centers remaining open and operational after a major earthquake. Even most modern buildings do not meet this level of construction, and so for a historic building to meet this requirement, it would have to be almost totally reconstructed of new materials which, philosophically, does not reflect preservation criteria.

Devising the most appropriate approach for a particular historic building will depend on a variety of factors, including the building's use, whether it remains occupied during construction, applicable codes, budgetary constraints, and projected risk of damage. From a design perspective, the vast majority of historic buildings can tolerate a well-planned hidden system of reinforcement. Utilitarian structures, such as warehouses, may be able to receive fairly visible reinforcement systems without undue damage to their historic character. Other more architecturally detailed buildings or those with more finished interior surfaces, however, will benefit from more hidden systems; installation of such systems may even require the temporary removal of significant features to assure their protection. Most buildings, particularly commercial rehabilitations, can incorporate seismic strengthening during other construction work in a way that ensures a high degree of retention of historic materials in place.



9 These studies for a public building compared, in the shaded areas, the amount of historic material that would be affected by (a) the Uniform Building Code requirements, (b) engineering alternatives that protected significant historic materials, and (c) the use of base isolation systems. The cost for implementing the 3 proposals was similar, and while proposal (c) was selected there were many positive aspects to both (b) and (c). Photos: George Siekkinen, with permission from Ehrenkrantz, Eckstut, & Kuhn Architects.

Assessing the Cost of Seismic Retrofit

Cost plays a critical role in selecting the most appropriate retrofit measure. It is always best to undertake retrofit measures before an earthquake occurs, when options are available for strengthening existing members. Once damage is done, the cost will be substantially higher and finding engineers, architects, and contractors available to do the work on a constricted schedule will be more difficult.

Planned seismic retrofit work may add between $10 and $100 per square foot to the cost of rehabilitation work depending on the level of intervention, the condition of the building, and whether work will be undertaken while the building is occupied. Costs can exceed several hundred dollars a square foot for combined restoration and seismic upgrade costs in major public buildings, in order to provide a level of structural reinforcement that would require only minor repairs after a major earthquake. But maintenance and incremental improvements to eliminate life-safety risks are within the cost realm of responsible upkeep.

Each property owner has to weigh the costs and benefits of undertaking seismic retrofit in a timely manner. Owners may find that an extended engineering study evaluating a wide range of options is worthwhile. Not only can such a study consider the most sensitive historic preservation solution, but the most cost-effective one as well. In many cases, actual retrofit expenses have been lower than anticipated because a careful analysis of the existing building was made that took the durability and performance of existing historic materials into consideration. Most seismic retrofit is done incrementally or incorporated into other rehabilitation work. In large public buildings, seemingly expensive "high-tech" solution such as installing foundation base isolators can turn out to be justified because significant historic materials do not have to be removed, replaced, or replicated (see illus. 9). The cost for a fully retrofitted building can offset the potential loss of income, relocation, and rebuilding after an earthquake. Without careful study, these solutions often are not evaluated.

Some municipalities and states provide low-interest loans, tax relief, municipal bonds, or funding grants targeted to seismic retrofit. Federal tax incentives for the rehabilitation of income-producing historic buildings include seismic strengthening as an allowable expense. Information on these incentives is available from the State Historic Preservation Office. It is also in the best interest of business communities to support the retrofit of buildings in seismically active areas to reduce the loss of sales and property taxes, should an earthquake occur.

Seismic Strengthening Approaches

Seismic strength within buildings is achieved through the reinforcement of structural elements. Such reinforcement can include anchored ties, reinforced mortar joints, braced frames, bond beams, moment-resisting frames, shear walls, and horizontal diaphragms. Most historic buildings can use these standard, traditional methods of strengthening successfully, if properly designed to conform to the historic character of the building. In addition, there are new technologies and better designs for traditional connection devices as well as a greater acceptance of alternative approaches to meeting seismic requirements. While some technologies may still be new for retrofit, the key preservation principles on page 2 should be applied, to ensure that historic buildings will not be damaged by them. For an illustrated design guideline for using some of the more traditional methods on the exteriors of historic unreinforced masonry buildings, see illustration 10 on pages 8-9.

There are varying levels of intervention for seismically retrofitting historic buildings based on the owner's program, the recommendations of the team, applicable codes, and the availability of funds. The approaches to strengthening buildings beginning on page 10 are to show a range of treatments and are not intended to cover all methods. Each building should be evaluated by qualified professionals prior to initiating any work.

Maintenance/Preparedness

Adequate maintenance ensures that existing historic materials remain in good condition and are not weakened by rot, rust, decay or other moisture problems. Without exception, historic buildings should be well maintained and an evacuation plan developed. Expectation that an earthquake will occur sometime in the future should prepare the owner to have emergency information and supplies on hand.

- Check roofs, gutters, and foundations for moisture problems, and for corrosion of metal ties for parapets and chimneys. Make repairs and keep metal painted and in good condition.
- Inspect and keep termite and wood boring insects away from wooden structural members. Check exit steps and porches to ensure that they are tightly connected and will not collapse during an emergency exit.
- Check masonry for deteriorating mortar, and never defer repairs. Repoint, matching the historic mortar in composition and detailing.
- Contact utility companies for information on flexible connectors for gas and water lines, and earthquake activated gas shut-off valves. Strap oil tanks down and anchor water heaters to wall framing.
- Collect local emergency material for reference and implement simple household or office mitigation measures, such as installing latches to keep cabinets from flying open or braces to attach tall bookcases to walls. Keep drinking water, tarpaulins, and other emergency supplies on hand.

Basic/Traditional Measures

This is not an exhaustive list, but illustrates that most measures to reduce life-safety risks rely on using mechanical fasteners to tie a building together. Incorporating these measures can be done incrementally without waiting for extensive rehabilitation (see illus.11-12). An architectural or engineering survey should identify what is needed. Care should be taken to integrate these changes with the visual appearance of the building.

11. Limited intervention should correct obvious structural deficiencies, such as tying vulnerable elements together and repointing masonry. Seen here is 1) anchored bolt, 2) metal joist strap, and 3) repointing and reinforcing masonry joints. Upon replastering and painting these reinforcements will not be visible. Photo: Historic Preservation Partners for Earthquake Response.

GLOSSARY:

Anchor Ties or bolts: Generally threaded rods or bolt which connect walls to floor and roof framing. Washers, plates, or rosettes anchor the bolt in place.

Base isolation: the ability to isolate the structures from the damaging effects of earthquakes by providing a flexible layer between the foundations and vertical supports.

Diagonal Braces: the use of diagonal, chevron or other type of bracing (X or K) to provide lateral resistance to adjacent walls.

Core drilling: a type of vertical reinforcement of masonry walls that relies on drilling a continuous vertical core that is filled with steel reinforcing rods and grouting to resist in-plane shear and out-of-plane bending.

Cripple wall: A frame wall between a building's first floor and foundation.

Diaphragm: A floor, roof, or continuous membrane that provides for the transfer of earthquake loading to the exterior or interior shear walls of the structure.

Fiber wrap reinforcement: A synthetic compound of filaments that increase the shear capacity of structural members.

Grouted bolts: anchor bolts set, generally on an angle, in a concrete grout mixture, avoid the problem of using an exposed washer. Requires a greater diameter hole than an anchor bolt with washer.

Lateral forces: Generally the horizontal forces transferred to the building from the dynamic effects of wind or seismic forces.

Life-safety: providing a level of assurance that risk of loss of life is kept to minimal levels. For buildings, this includes strengthening to reduce 1)structural collapse, 2) falling debris, 3)blocking exits or emergency routes, and 4) prevention of consequential fire.

Moment-resisting frame: A steel frame designed to provide in-plane resistance to lateral loads particularly by reinforcing the joint connection between column and beams without adding a diagonal brace. Often used as a perimeter frame around storefronts or large door and window openings.

Seismic retrofit: All measures that improve the earthquake performance of a building especially those that affect structural stability and reduce the potential for heavy structural damage or collapse.

Shear stress: A concept in physics where forces act on a body in opposite directions, but not in the same line. Horizontal forces applied to a wall that is insufficient to move with these forces will crack, often in a diagonal or X pattern. Connections at beams and walls will also crack from shear stress.

Shear wall: A wall deliberately designed to transfer the building's loads from the roof and floors to the foundation thereby preventing a building from collapse from wind or earthquake forces.

Unreinforced Masonry (URM): This designation refers to traditional brick, block, and adobe construction that relies on the weight of the masonry and the bonding capacity of mortar to provide structural stability.

Anchor Bolts:

Typically 1/2" bolts with flat metal washers (sometimes called plates or rosettes) are probably the most common retrofit procedure. The tie the exterior wall to the floors and roof causing the building to move as a single unit.

The washers are the most noticeable part of the system. Anchor bolt locations are determined by the structural engineer. Decorative washers, such as cast iron stars, carefully placed, can enhance the building. Poorly placed or carelessly aligned washers are very noticeable.

It is important to control rust by painting ferrous metal washers. New washers can be specified as stainless or galvanized steel. In circumstances where washers are visibly intrusive, the preferable solution would be to recess them below the face material. This is particularly applicable to stucco buildings.

Recommended
- Use decorative washers in areas with high visibility.
- Align washers to create orderly appearance.
- Use stainless or galvanized steel and paint when appropriate, to prevent rust streaks.
- Attempt to conceal the bolts and washers below the exterior finish, when appropriate.

Not Recommended
- The anchor bolts on this building were placed in a haphazard fashion. More care should be taken to align the anchor bolt washers. Also, painting the washers can reduce the unsightly rust streaks that result from weathering.
- Do not place anchor bolts at locations with high relief ornamentation.

Infill Windows:

From an architectural standpoint, infill of openings is not a desirable remedy and should be used only as a last resort. It is often possible to use a braced frames instead of infilling openings, but it may be more expensive.

The purpose of filling the openings is to increase the shear capacity and reduce the stresses on the unreinforced masonry wall. It is not adequate to just infill with the same unreinforced masonry, but generally a reinforced concrete, reinforced block or reinforced brick is specified. If infilling the openings appears to be the only realistic method, the design solution should be sensitive, and if possible, limited to secondary elevations. The opening should be set back and the facing material should be compatible with the surrounding material.

Recommended
- Infill of windows should be avoided in all cases. Where absolutely required, however, the appearance of a window opening should be retained to suggest the original visual rhythm of the facade.

Not Recommended
- Infill techniques such as this are not encouraged. Suggestion of a former window opening should have been emphasized by slightly recessing the former opening.

KEY QUEST

Questions to Ask When Planning Seismic Retrofit:

These questions should be asked with the assistance of the team to determine acceptable alternatives. Since there is never a single right answer, the design team and code officials should work together to determine the appropriate level of seismic retrofit with the lowest visual impact on the significant spaces, features, and finishes of both the interior and exterior of historic buildings.

As with the illustrations above, this guide is not intended to proscribe how seismic retrofit should be done, but rather, to illustrate that every *physical* change to a building will have some consequence. By asking how impacts can be reduced, the owner will have several options from which to choose.

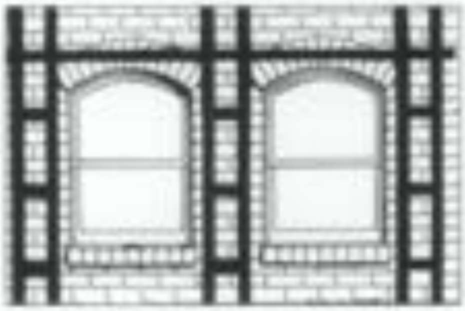
- Can bracing be installed without damaging decorative details or appearance of parapets, chimneys, or balconies?
- Are the visible features of the reinforcement, such as anchor washers or exterior buttresses adequately designed to blend with the historic building?
- Can hidden or grouted bolts be set on an angle to tie floors and walls together, instead of using traditional bolts and exposed washers or rosettes on ornamental exteriors?
- Are diagonal frames, such as X, K, or struts located to have a minimal impact on the primary facade?
- Are they set back and painted a receding color if visible through windows or storefronts?
- Can moment frames or reinforced bracing be added around historic storefronts in order to avoid unsightly exposed reinforcement, such as X braces, within the immediate viewing range of the public?

IN THE FOREFRONT

Recommended
- All original building ornamentation enhances the architectural value and should be retained and maintained.

Not Recommended
- If it is determined that ornamentation must be secured or removed, effort should be made to secure it. The parapet of this building shows a "scar" where ornamentation was removed.

Recommended
- Exterior bracing or buttressing should incorporate the building's natural lines. The exterior steel bracing appears to be an original building element because it runs parallel to the cornice line.



Not Recommended
- The exterior bracing on this building dominates its appearance. Care should be taken to design exterior bracing to blend with or enhance the building's natural lines.

Adapted from "Architectural Design Guide for Exterior Treatments of Unreinforced Masonry Buildings During Seismic Retrofit." Used with permission from the San Francisco Chapter, The American Institute of Architects. Drawings © Cassandra Mettling-Davis.

Securing Exterior Ornamentation:

Ornament is one of the character-defining features of a building. Careful forethought and analysis should always precede alteration of a building's ornament.

Generally methods to secure ornamentation by repair and reinforcing connections should be undertaken. Repairs or reinforcement should blend with the appearance of the ornamentation and should be designed to prevent future failures such as cracking due to thermal and seismic stress or unsightly differential weathering.

If ornamental elements must be removed during the repair process, they should be reinstalled or replaced in-kind. The use of substitute materials may be acceptable if no other options exist.

Exterior Buttresses:

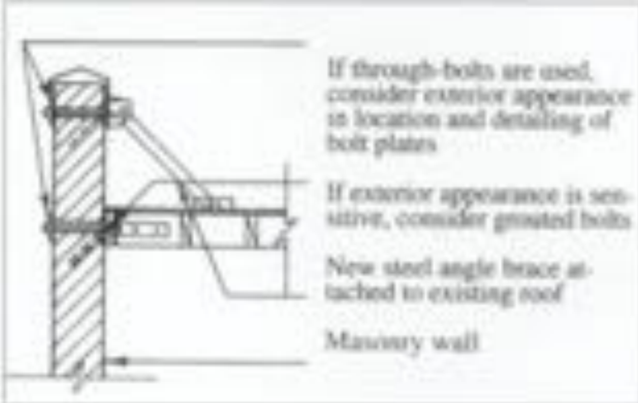
Exterior buttresses, an integral part of Gothic architecture, are not traditionally part of our architecture. In retrofitting an existing building, it is usually better to use an in-wall or interior bracing system rather than a visible exterior system. When used as an exterior bracing system, care must be taken to avoid damage to existing decorative elements. Even if saved, exterior buttresses can obscure decorative elements.

Another problem requiring careful study is the integration of the buttresses with the existing structural system. Their attachment penetrates the building skin making the building more vulnerable to moisture damage. In a few cases where the interior building fabric is highly significant, exterior buttresses may be preferred. Care should be taken to avoid damage or obscuring existing architectural details.

S TO ASK:

- Can shorter sections of reinforcement be "stitched" into the existing building to avoid removal of large sections of historic materials? This is particularly true for the insertion of roof framing supports.
- Can shear walls be located in utilitarian interior spaces to reduce the impact on finishes in the primary areas?
- Are there situations where thinner applied fiber reinforced coating would adequately strengthen walls or supports without the need for heavier reinforced concrete?
- Can diaphragms be added to non-significant floors in order to protect highly decorated ceilings below, or the reverse if the floor is more ornamental than the ceiling?
- Are there adequate funds to retain, repair, or reinstall ornamental finishes once structural reinforcements have been installed?
- Should base isolation, wall damping systems, or core drilling be considered? Are they protecting significant materials by reducing the amount of intervention?
- Are the seismic treatments being considered "reversible" in a way that allows the most amount of historic materials to be retained and allows future repair and restoration?

III. Keeping preservation in the forefront is a critical aspect of seismic retrofit of historic buildings. These key questions will help keep preservation in mind as decisions are made about how best to improve the structural performance of historic buildings.



12. Bracing parapets, as illustrated here, and supporting chimneys using metal struts or ties, are simple methods to protect these heavy elements from falling. Drawing: Architectural Resources Group.

- Bolt sill plates to foundations and add plywood stiffeners to cripple wall framing around wood frame buildings. Keep reinforcement behind decorative crawlspace lattice or other historic features.
- Reinforce floor and roof framing connections to walls using joist hangers, metal straps, threaded bolts, or other means of mechanical fasteners. Tie columns to beams; reinforce porch and stair connections as well.
- Repair weakened wooden structural systems by adding, pairing, or bracing existing members. Consider adding non-ferrous metal straps in alternating mortar joints if extensive repointing is done in masonry walls.
- Reinforce projecting parapets and tie parapets, chimneys, balconies, and unsecured decorative elements to structural framing. Make the connections as unobtrusive as possible. In some cases, concrete bond beams can be added to reinforce the top of unreinforced masonry or adobe walls.
- Properly install and anchor new diaphragms, such as roof sheathing or subflooring, to the walls of a structure prior to installing finish materials.
- Avoid awkwardly placed exposed metal plates or rosettes when using threaded bolts through masonry walls. When exposed plates will interfere with the decorative elements of the facade, use less visible grouted bolts or plates that can be set underneath exposed finished materials.
- Use sensitively designed metal bracing along building exteriors to tie the unsupported face of long exterior walls to the floor framing. This is often seen along side or party walls in commercial or industrial buildings.

Rehabilitation

When buildings are being rehabilitated, it is generally the most cost effective time to make major upgrades that affect the structural performance of the building (see illus. 13-17). New elements, such as concrete shear walls or fiber reinforcing systems can be added while the structure is exposed for other rehabilitation or code compliance work.

- Inspect and improve all lateral tie connections and diaphragms.

13. Installing diagonal frames, underway in this rehabilitation, are a traditional method of seismic reinforcement. To reduce the impact of the X, K, or diagonal braces, they should be on the inside of the perimeter wall, designed to cross behind solid walls as much as possible, and painted a receding color where visible. Photo: David Look.

14. The use of a steel moment frame to support the large open storefront during a rehabilitation eliminated the need to place diagonal braces or other intrusive supports in a highly visible area of a historic building. Photo: David Look.

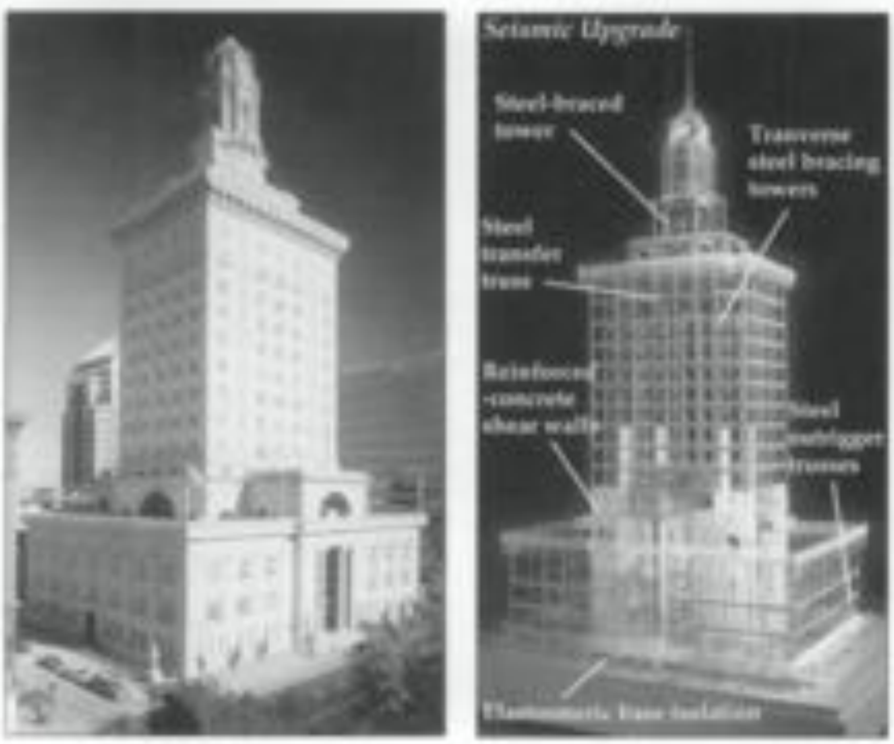
15. The use of fiber composite materials can enhance the shear capacity of existing structural components -beams, columns, and surface elements, such as walls and floors. In this roofing application, the existing roof diaphragm is being strengthened and there is additional benefit to the shear reinforcement of the parapet wall. Photo: The Crosby Group.

16. During the extensive rehabilitation of this historic building, new concrete, behind the new plaster finishes, strengthened the exterior brick walls and additional roof reinforcement was hidden behind the repaired/reconstructed coffered ceiling. Photo: © Jonathan Ferrar, courtesy UCLA Capital Programs.

- Reinforce walls and large openings to improve shear strength in locations of doors, windows, and storefront openings. Carefully locate "X" and "K" bracing to avoid visual intrusion, or use moment frames, which are a hidden perimeter bracing in large openings. From a preservation perspective, the use of a more hidden system in finished spaces is generally preferable.
- Strengthen masonry walls or columns with new concrete reinforcement or fiber wrap systems. Avoid the use of heavy spray concrete or projecting reinforced walls that seriously alter the historic relationship of the wall to windows, trim, and other architectural moldings or details.

17. The internal grout injection of rubble walls can improve seismic capacity. Care must be taken in formulating the mortar grout and repairing the area where injection occurs. Photo: Architectural Resources Group, San Francisco.

- Selectively locate new shear walls constructed to assist the continuous transfer of loads from the foundation to the roof. If these walls cannot be set behind historic finishes, they should be located in secondary spaces in conjunction with other types of reinforcement of the primary spaces or features.
- Consider the internal grouting of rubble masonry walls using an injected grout mixture that is compatible in composition with existing mortar. Ensure that exposed areas are repaired and that the mortar matches all visual qualities of the historic mortar joints in tooling, width, color and texture.
- Evaluate odd-shaped buildings and consider the reinforcement of corners and connections instead of infilling openings with new construction. Altering the basic configuration and appearance of primary facades of buildings is damaging to those qualities that make the building architecturally significant.



18. Oakland City Hall, California, completed in 1914, was restored to its original appearance and the computer model illustrates the comprehensive methods used to fully reinforce the building for the future. Photo: © Vittoria Visuals; Computer Model: © Douglas Symes, San Francisco. VBN, Architects and Carey & Co, Inc. Architecture.

Specialized Technologies

New technologies, being developed all the time, may have applicability to historic preservation projects. These specialized technologies include: vertical and center core drilling systems for unreinforced masonry buildings, base isolation at the foundations, superstructure damping systems, bonded resin coatings, and reproducing lost elements in lighter materials (see illus. 18-20). However, many new technologies may also be non-reversible treatments resulting in difficulties of repair after an earthquake. The reinforcement of historic materials with special resins, or the use of core drilling to provide a reinforced vertical connection from foundation to roof may not be as repairable after an earthquake as would more traditional means of wall reinforcement. New technologies should be carefully evaluated by the design team for both their benefits as well as their shortcomings.

Using computer modeling of how historic buildings may act in an earthquake suggests options for seismic upgrade using a combination of traditional methods and new technologies. While most projects involving base isolation and other complex damping

19. A system of core drilling, shown here, removes internal cored sections of unreinforced masonry from roof to foundations and fills them with grout and reinforcing rods. This may be an option for some unreinforced masonry buildings with significant interiors and exteriors, although it is a less reversible treatment than traditional diagonal braces or shear walls. Photo: David Look.

20. The new base isolator allows the structural support member at the foundation to move horizontally as it absorbs the earthquake forces. While expensive, base isolation may be justified by reducing the amount of damage to interior finishes and features with traditional methods of seismic retrofit. Photo: Photo © Jonathan Farrer, courtesy UCLA, Capital Programs.

systems constitute only a small percentage of the projects nationwide that are seismically reinforced, they may be appropriate for buildings with significant interior spaces that should not be disturbed or removed during the retrofit. Each building will needs its own survey and evaluation to determine the most appropriate seismic reinforcement.

Post-Earthquake Issues

Should a historic building suffer damage during an earthquake, it is the *owner who has a plan in place* who will be able to play a critical role in determining its ultimate fate. If the owner has previously assembled a team for the purpose of seismic upgrading, there is a greater chance for the building to be evaluated in a timely fashion and for independent emergency stabilization to occur. In most municipalities, a survey, often by trained volunteers, will be conducted as soon as possible after an earthquake, and buildings will be tagged on the front with a posted notice according to their ability to be entered. Typically red, yellow, and green tags are used to indicate varying levels of damage—*no entry, limited entry, and useable*—to warn citizens of their relative safety. Heavily damaged areas are often secured off-limits and many red tagged, but repairable, buildings have been torn down unnecessarily because owners were unable to evaluate and present a stabilization plan in time (see illus. 21). Owners or members of the preservation community may engage their own engineers with specialized knowledge to challenge a demolition order. Because seismic retrofit is complex and many jurisdictions are involved, the coordination between various regulatory bodies needs to be accomplished *before* an earthquake.

21. Without a plan in place before an earthquake, buildings that could be repaired are often torn down. The loss of significant numbers of buildings within historic districts can further erode the financial and cultural assets of an area. Photo: David Look.

During times of emergencies, many communities, banks, and insurance agencies will not be in a position to evaluate alternative approaches to dealing with damaged historic buildings, and so they often require full compliance with codes for new construction for the major rehabilitation work required. Because seismic after-shocks often create more damage to a weakened building, the inability to act quickly—even to shore up the structure on a temporary basis—can result in the building's demolition. Penetrating rain, uneven settlement, vandalism, and continuing after-shocks can easily undermine a building's remaining structural integrity. Moreover, the longer a building is unoccupied and non-income-producing, the sooner it will be torn down in a negotiated settlement with the insurance company. All of these factors work against saving buildings damaged in earthquakes, and make having an action plan essential.

Having an emergency plan in place, complete with access to plywood, tarpaulins, bracing timbers, and equipment, will allow quick action to save a building following an earthquake. Knowing how the community evaluates buildings and the steps taken to secure an area will give the owner the ability to be a helpful resource to the community in a time of need.

If the federal government is asked to intervene after a natural disaster, technical assistance programs are available. Often after a disaster, grant funds or low-cost loans from federal, state, and congressional special appropriations are targeted to qualified properties, which can help underwrite the high cost of rehabilitation (see information about FEMA on page 15.)

Conclusion

Recent earthquakes have shown that historic buildings retrofitted to withstand earthquakes survive better than those that have not been upgraded. Even simple efforts, such as bracing parapets, tying buildings to foundations, and anchoring brick walls at the highest, or roof level, have been extremely effective. It has also been proven that well maintained buildings have faired better than those in poor condition during and after an earthquake. Thus, maintenance and seismic retrofit are two critical components for the protection of historic buildings in areas of seismic activity. It makes no sense to retrofit a building, then leave the improvements, such as braced parapets or metal bolts with plates, to deteriorate due to lack of maintenance.

Damage to historic buildings *after an earthquake* can be as great as the initial damage from the earthquake itself. The ability to act quickly to shore up and stabilize a building and to begin its sensitive rehabilitation is imperative. Communities without earthquake hazard reduction plans in place put their historic buildings—as well as the safety and economic well-being of their residents — at risk.

Having the right team in place is important. Seismic strengthening of existing historic buildings and knowledge of community planning for earthquake response makes the professional opinions of the team members that much more important when obtaining permits to do the work. Local code enforcement officials can only implement the provisions of the model or historic preservation codes if the data and calculations work to ensure public safety.

22. When undertaking a substantial rehabilitation to include seismic reinforcement, it is also an opportune time to restore lost or damaged features. The owner of this commercial building, using the Historic Rehabilitation Tax Credits, restored the original bay and parapet gable and stone detailing that had been removed in an earlier insensitive remodeling. Photo: David Look.

23. Both exteriors and interiors can be severely damaged in an earthquake. This Craftsman Style bungalow was successfully restored and seismically upgraded after the Northridge earthquake in California. Photographs: Historic Preservation Partners in Earthquake Response.

Buildings do not need to be over-retrofitted. A cost-effective balance between protecting the public and the building recognizes that planned for repairable damage can be addressed after an earthquake. Engineers and architects, *who specialize in historic buildings* and who have a working knowledge of alternative options and expected performance for historic structures, are critical to the process.

It is clear that historic and older buildings can be seismically upgraded in a cost-effective manner while retaining or restoring important historic character-defining qualities (see illus. 22, 23). Seismic upgrading measures exist that preserve the historic character and materials of a buildings. However, it takes a multi-disciplined team to plan and to execute sensitive seismic retrofit. It also takes commitment on the part of city, state, and federal leaders to ensure that historic districts are protected from needless demolition after an earthquake so that historic buildings and their communities are preserved for the future.

Seismic Risk Zones

Most local jurisdictions measure seismic risk based on seismic zones established by code, such as the Uniform Building Code with its 4 risk zones [1=low to 4=high]. There are also maps, such as this one, which identify the Effective Peak Acceleration (EPA) which further reflect the light, moderate, and severe shaking risks as a percentage of the acceleration of gravity that can be expected in an area.

In the United States, the greatest activity areas are the western states, Alaska, and some volcanic island areas. However, noted historical earthquakes occurred in Massachusetts (1755), Missouri (1811), South Carolina (1886), and Alaska (1964). The Caribbean Islands and Puerto Rico have been sites of severe earthquakes. The history of earthquakes in the United States has been recorded for over 200 years and new areas of concern include moderate risk areas in southern and mid-western states.

The Richter Magnitude Scale, first published in 1935, records the size of an earthquake at its source, as measured on a seismograph. Magnitudes are expressed in whole numbers and decimals between 1 and 9. An earthquake of a magnitude of 6 or more will cause moderate damage, while one of over 7 will be considered a major earthquake. It is important to remember that an increase of one whole number on the Richter Scale is a tenfold increase in the size of the earthquake.

24. Seismic Map. The shading indicates areas in the United States and Puerto Rico that are affected by the probability of varying shaking intensities. The risk of severe shaking is not limited to the west coast. Map adapted from Federal Emergency Management Agency, FEMA 74 Guide.

FURTHER READING

Buildings at Risk: Seismic Design Basics for Practicing Architects. Washington, DC. AIA/ACSA Council on Architectural Research. February, 1992.

Controlling Disaster: Earthquake-Hazard Reduction for Historic Buildings. Washington, DC. National Trust for Historic Preservation. 1992.

Earthquake-Damaged Historic Chimneys: A Guide to the Rehabilitation and Reconstruction of Chimneys. Oakland, CA. Historic Preservation Partners for Earthquake Response. July, 1995.

Eichenfield, Jeffrey. *20 Tools That Protect Historic Resources After an Earthquake; Lessons learned from the Northridge Earthquake.* Oakland, CA. California Preservation Foundation.1996.

History at Risk, Loma Prieta: Seismic Safety & Historic Buildings. Oakland, CA. California Preservation Foundation. 1990.

Kariotis, John C., Roselund, Nels; and Krakower, Michael. *Loma Prieta, An Engineer's Viewpoint.* Oakland, CA; California Preservation Foundation. 1990.

Langenbach, Randolph. "Bricks, Mortar, and Earthquakes; Historic Preservation vs. Earthquake Safety." *Apt Bulletin,* Vol.21, Nos.3/4 (1989), pp.30-43.

Langenbach, Randolph. "Earthquakes: A New Look at Cracked Masonry." *Civil Engineering.* November, 1992. pp. 56-58.

NEHRP Commentary on the Guidelines for the Seismic Rehabilitation of Buildings (second ballot version). Washington, DC. Building Seismic Safety Council (Prepared for Federal Emergency Management Agency) Draft, April, 1997. FEMA 274.

NEHRP Handbook of Techniques for the Seismic Rehabilitation of Existing Buildings. Washington, DC. Building Seismic Safety Council (Prepared for Federal Emergency Management Agency) 1992. FEMA 273.

The Secretary of the Interior's Standards for Rehabilitation with Illustrated Guidelines for Rehabilitating Historic Buildings. Washington, DC. Government Printing Office, 1992.

Seismic Retrofit Alternatives for San Francisco's Unreinforced Masonry Buildings: Estimates of Construction Cost & Seismic Damage. San Francisco, CA. City and County of San Francisco Department of City Planning (prepared by Rutherford & Chekene, Consulting Engineers). 1990.

The Seismic Retrofit of Historic Buildings Conference Workbook. San Francisco, CA. Association for Preservation Technology, Western Chapter. 1991. [contains an excellent bibliography of additional sources].

Schuller, M.P. Atkinson, R.H. and Noland, J.L. "Structural Evaluation of Historic Masonry Buildings." *APT Bulletin,* Vol 26, No. 2/3,pp. 51-61.

State Historical Building Code. Sacramento, CA: State Historical Building Code Board. 1990.

Uniform Code for Building Conservation. Whittier, CA: International Conference of Building Officials, 1991.

The Federal Emergency Management Agency

The Federal Emergency Management Agency (FEMA) — is an independent agency of the federal government, reporting to the President. Since its founding in 1979, FEMA's mission has been to reduce loss of life and property and protect our nation's critical infrastructure from all types of hazards through a comprehensive, risk-based, emergency management program. FEMA works with the state and local governments and the private sector to stimulate increased participation in emergency preparedness, mitigation, response and recovery programs related to natural disasters. To minimize damage-repair-damage cycles, FEMA carries out and encourages preventive activities referred to as hazard mitigation.

The FEMA Hazard Mitigation Program, established in 1988 with the passage of the Robert T. Stafford Disaster Relief and Emergency Assistance Act, offers a framework for protecting historic structures from natural disasters. In the event of a federally declared disaster, state and local governments as well as eligible non-profit applicants may receive financial and technical assistance to identify and carry out cost-effective hazard mitigation activities.

FEMA encourages hazard mitigation projects, including the restoration of buildings, by providing technical assistance and funding through the Hazard Mitigation Grant Program (HMPG), which can underwrite up to 50% of the cost of the project.

FEMA's public-assistance program provides financial and other assistance to rebuild disaster-damaged facilities that serve a public purpose, such as schools, hospitals, government buildings and public utilities.

In terms of technical assistance, FEMA, under a cooperative agreement with the Building Seismic Safety Council has produced two volumes of comprehensive material dealing with the seismic retrofit of existing buildings (see Further Reading). In addition an ongoing project ATC-43 involves earthquake analysis procedures for Unreinforced Masonry Buildings and Reinforced Concrete Buildings. These documents contain nationally applicable technical criteria intended to ensure that buildings will withstand earthquakes better than before. There is a great deal of information that is applicable to historic buildings, although historic buildings are not necessarily identified as a category. Write for FEMA publications at:

FEMA, PO Box 70274, Washington, DC 20024

For current information about emergency activities, federally declared disaster areas, or how to contact regional offices see the

FEMA website: http://www.fema.gov/

For additional information on cultural resource preservation and Historic Rehabilitation Tax Credits see the National Park Service's

NPS website: http://www.cr.nps.gov/

Before

After

23. While it is best to seismically retrofit historic buildings before an earthquake strikes, if earthquake damage is to be repaired, it should be done in a manner respecting the historic character of the building. For this ca. 1925 Mediterranean Revival style building damaged in the Northridge Earthquake in California, financial and planning assistance from the Historic Preservation Partners for Earthquake Response made possible a sensitive rehabilitation. New structural steel and restoration of the historic stucco and decorative tile work and a repaired tile roof reinstated this earthquake damaged building as a major element of the historic district. Photo: Courtesy Historic Preservation Partners for Earthquake Response, M2A Architects.

The Historic Preservation Partners for Earthquake Response was formed after the Northridge Earthquake of 1994 and was comprised of members of the National Park Service, the National Trust for Historic Preservation, The Getty Institute, The California Office of Historic Preservation, the California Preservation Foundation, and the Los Angeles Conservancy. After the earthquake, this organization provided technical assistance and grant funding to various historic buildings. Funding of 10 million dollars from the National Park Service, U.S. Department of the Interior, was made available for the restoration and rehabilitation of cultural resources damaged during this natural disaster. In addition, sub-grants were provided by the National Trust for Historic Preservation and the California Office of Historic Preservation. A number of projects assisted by the Historic Preservation Partners for Earthquake Response are included and used with permission in this *Preservation Brief*.

Acknowledgements

David W. Look, AIA, is the Chief, Cultural Resource Team, Pacific Great Basin Support Office, National Park Service. **Terry Wong, PE,** is the Chief, Structural Engineering, Denver Service Center, National Park Service. **Sylvia Rose Augustus,** is the Historical Architect, Yosemite National Park.

The authors wish to thank their collaborator, **Sharon C. Park, FAIA,** Senior Historical Architect, Heritage Preservation Services, NPS, who undertook the technical editing of the publication and took the authors' original manuscript and developed it into the Preservation Brief complete with compiling information from other sources and selecting the photographs. Kay D. Weeks and Michael J. Auer, Heritage Preservation Services, NPS, contributed substantially to the published manuscript by revising the draft with an eye to articulation of policy, organizational structure, and cohesiveness of language.

The authors also wish to thank the following for providing information for the publication and/or reviewing the final draft: Steade R. Craigo, AIA, Senior Restoration Architect, State of California; Randolph Langenbach, Architect, FEMA; Bruce Judd, FAIA, Architectural Resources Group; Melvyn Green & Associates; Cassandra Mettling-Davis and Carey & Co. Inc. Architecture; Curt Ginther, Architect, the University of California, Los Angeles (UCLA) Capital Program; The Crosby Group; American Institute of Architects, San Francisco Chapter; Jeffrey L. Eichenfield, California Preservation Foundation; Michael Jackson, Illinois Historic Preservation Agency; George Siekkinen, the National Trust for Historic Preservation; and colleagues at Heritage Preservation Services, NPS, including: de Teel Patterson Tiller, Chief; Charles E. Fisher, Anne E. Grimmer, John Sandor, and Jason Fenwick.

This publication has been prepared pursuant to the National Historic Preservation Act, as amended, which directs the Secretary of the Interior to develop and make available information concerning historic properties. Comments about this publication should be directed to de Teel Patterson Tiller, Chief, Heritage Preservation Services Program, National Park Service, 1849 C Street, NW, Washington, DC 20240.

Front Cover: Historic buildings damaged by earthquakes can be rehabilitated and seismically retrofitted. The posted tag in the window warns that this building, temporarily, cannot be entered. Photo: David Look.

ISSN: 0885-7016

October, 1997