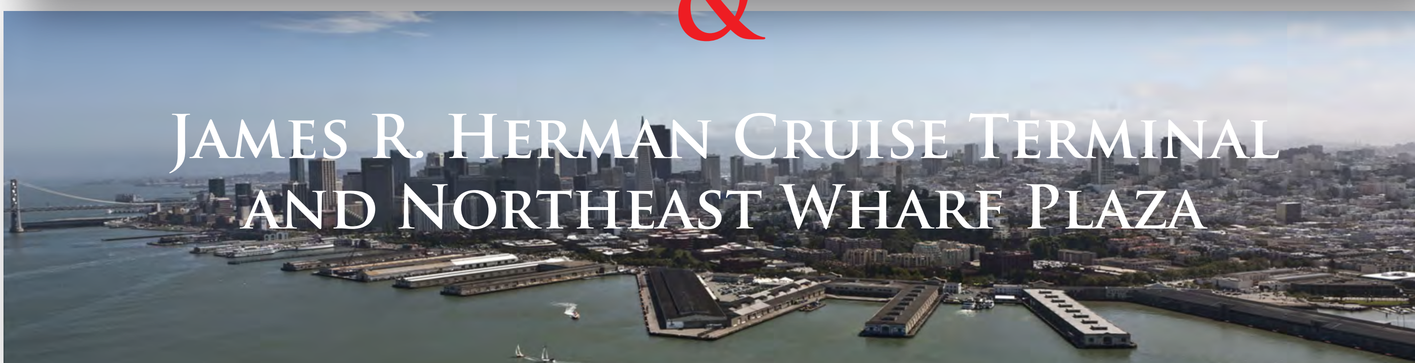
Volume 8

Comments and Responses on the Draft EIR



San Francisco Planning Department Case No. 2010.0493E
State Clearinghouse No. 2011022040

Draft EIR Publication Date: July 11, 2011
Draft EIR Public Hearing Date: August 11, 2011
Draft EIR Public Comment Period: July 11, 2011 – August 25, 2011
Comments and Responses Publication Date: December 1, 2011
Final EIR Certification Date: December 15, 2011

San Francisco
Planning
Department

Volume 8

Comments and Responses on the Draft EIR

The 34th America's Cup & James R. Herman Cruise Terminal and Northeast Wharf Plaza

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SAN FRANCISCO
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DEPARTMENT

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APPENDIX PD

Supplemental Project Description Supporting Information

PD-1A. Supplemental Spectator Boat Information from AECOM

APPENDIX PD-1A
Supplemental Spectator Boat Information from AECOM

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America's Cup 34 Visitation Analysis

Addendum #1: On the Water Visitation Estimates

INTRODUCTION

This report serves as an addendum to the *Analysis of Potential Visitation Patterns for America's Cup 34* report released on June 17, 2011. In this report, we provide refined on the water visitation estimates to be used for planning based on additional and more detailed information about the event that is now available.

The analysis included in this report builds on the previous report's methodology and was conducted by AECOM, with input from America's Cup Event Authority (ACEA) and America's Cup Race Management (ACRM). Unless otherwise stated, all assumptions described in the initial report still apply.

REVISED ESTIMATES

The previous report based the number of boats for an average peak day on Fleet Week boat count estimates from previous years. In order to provide a more accurate data point for this estimate, ESA conducted a boat count exercise during the Fleet Week. The number of boats was found to be lower than originally estimated, so we have adjusted our projections for an average peak day accordingly based upon this information. The projections for a 2013 peak weekday and 2012 have also been adjusted on a proportionate basis. Results for 2013 are shown in **Figures 1 and 2** and for 2012 are shown in **Figures 3 and 4**.

Figure 1: Estimated Number of Boats and On Water Attendance on an Average Peak Day, AC34 2013

Boat Types	% of Boats	# of Boats	Avg. # of Passengers per Boat	Total No. of Passengers
Recreational				
Motorized Pleasure Craft (e.g. small powered yachts)	19%	152	7	1,064
Sailboats (may contain small outboard motors)	80%	640	7	4,480
Non-Motorized Craft	1%	8	2	16
Total Recreational	**91%**	**800**	**7**	**5,560**
Commercial Charters	2%	20	150	3,000
Large Private Yachts	7%	60	30	1,800
TOTAL ALL CATEGORIES	**100%**	**880**	**12**	**10,360**

Source: AECOM

Figure 2: Estimated Number of Boats and On Water Attendance for a Average Peak Weekday, AC34 2013

Boat Types	% of Boats	# of Boats	Avg. # of Passengers per Boat	Total No. of Passengers
Recreational				
Motorized Pleasure Craft (e.g. small powered yachts)	19%	24	7	168
Sailboats (may contain small outboard motors)	80%	102	7	714
Non-Motorized Craft	1%	8	2	16
Total Recreational	**91%**	**134**	**7**	**898**
Commercial Charters	2%	3	150	450
Large Private Yachts	7%	10	30	300
Total All Boats	**100%**	**147**	**11**	**1,648**

Source: AECOM

Figure 3: Estimated Number of Boats and On Water Attendance on an Average Peak Day, AC34 2012

Boat Types	% of Boats	# of Boats	Avg. # of Passengers per Boat	Total No. of Passengers
Recreational				
Motorized Pleasure Craft (e.g. small powered yachts)	19%	62	7	434
Sailboats (may contain small outboard motors)	80%	262	7	1,834
Non-Motorized Craft	1%	8	2	16
Total Recreational	**98%**	**332**	**7**	**2,284**
Commercial Charters	2%	8	150	1,200
Large Private Yachts	0%	0	30	0
TOTAL ALL CATEGORIES	**100%**	**340**	**10**	**3,484**

Source: AECOM

Figure 4: Estimated Number of Boats and On Water Attendance on an Average Weekday, AC34 2012

Boat Types	% of Boats	# of Boats	Avg. # of Passengers per Boat	Total No. of Passengers
Recreational				
Motorized Pleasure Craft (e.g. small powered yachts)	19%	24	7	166
Sailboats (may contain small outboard motors)	80%	100	7	700
Non-Motorized Craft	1%	4	2	8
Total Recreational	**98%**	**125**	**7**	**874**
Commercial Charters	2%	3	120	360
Large Private Yachts	0%	0	30	0
TOTAL ALL CATEGORIES	**100%**	**128**	**10**	**1,234**

Source: AECOM

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APPENDIX CP

Supplemental Historical Resources Supporting Information

CP-1A. Revised Historic Resource Evaluation Response

CP-5. America's Cup Improvements, Piers 27-29, Project Consistency with Secretary's Standards

CP-6. Historical Resources Report Piers 27, 29 and 31, San Francisco, California

CP-7. Northeast Wharf Plaza, Pier 27: Assessment of Project Consistency with *Secretary's Standards* and Performance Criteria

APPENDIX CP-1A
Revised Historic Resource Evaluation Response

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Historic Resource Evaluation Response

Environmental Planner: Joy Navarette
(415) 575-9040
joy.navarette@sfgov.org

Preservation Planner: Rich Sucré
(415) 575-9108
richard.sucre@sfgov.org

Project Address: **The 34th America's Cup and James R. Herman Cruise Terminal and Northeast Wharf Plaza**
Block/Lot: **Various**
Case No.: **2010.0493E**

Date of Review: July 1, 2011; November 29, 2011 (Revised)

PART I: HISTORIC RESOURCE EVALUATION

Based upon the research and evaluation prepared by the Port of San Francisco Preservation Staff and the environmental consultant and their subconsultants, Planning Department Preservation staff concurs with the list historic resources present within the project site associated with the 34th America's Cup and James R. Herman Cruise Terminal and Northeast Wharf Plaza (Proposed Project). This list of historic resources includes the following:

Resource Name	Period of Significance	Contributing Features
Fort Mason		
San Francisco Port of Embarkation, U.S. Army Historic Landmark District	1750–1949	45 buildings, 10 structures, 2 objects
Fort Mason Historic District	1750-1949	13 buildings, 5 structures
Alcatraz Historic District / Alcatraz National Historic Landmark	1824–1974	18 buildings, 28 structures
Port of San Francisco Embarcadero Historic District	1878–1946	24 buildings, 26 structures
Red's Java House	c. 1930	1 building
Northeast Waterfront Historic District	1850-1960	+/- 12 buildings
Fort Point National Historic Site	1850–1949	7 buildings, 5 structures
Presidio National Historic Landmark District	1750–1949	~778 buildings, structures, sites, and objects
Forts Baker, Barry and Cronkhite Historic District	1825–1949	~100 buildings and structures plus numerous related archeological resources and landscape features
Aquatic Park National Historic Landmark District	1900–1949	3 buildings, 5 structures

Resource Name	Period of Significance	Contributing Features
Marina Green, Seawall, and Concessionaire Stand	1915-1943	1 object, 2 structures
San Francisco Civic Center Historic District	1900–1974	9 buildings, 1 object
State Historical Landmark No. 623, Union Square	1850-1941	1 building, 1 object
Golden Gate Bridge	1937	1 structure
Angel Island Immigration Station National Historic Landmark	1910-1940	1 building
Yerba Buena Island Resources	1875–1949	4 buildings, 1 structure, 1 NRHP district
State Historical Landmark No. 987, Treasure Island	1936-1946	3 buildings

Additional information on the historic context and the character-defining features associated with the aforementioned historic resources is available within the "Cultural and Paleontological Resources" section of the Draft Environmental Impact Report for the Proposed Project.

CEQA HISTORIC RESOURCE DETERMINATION

☐ No Historic Resource Present

If there is no historic resource present, please have the Senior Preservation Planner review, sign, and process for the Environmental Planning Division.

☐ No Historic Resource Present, but is located within a California Register-eligible historic district

If there is a California Register-eligible historic district present, please fill out the *Notice of Additional Environmental Evaluation Review* and have the project sponsor file the **Part II: Project Evaluation** application fee directly to the Environmental Planning Division.

☒ Historic Resource Present

If a historic resource is present, please fill out the *Notice of Additional Environmental Evaluation Review* and have the project sponsor file the **Part II: Project Evaluation** application fee directly to the Environmental Planning Division.

PART I: SENIOR PRESERVATION PLANNER REVIEW

Signature: Tina Tam Date: 11-29-11

Tina Tam, *Senior Preservation Planner*

PART II: PROJECT EVALUATION

PROPOSED PROJECT

☒ Demolition ☐ Alteration ☒ New Construction

PROJECT DESCRIPTION

The Proposed Project is described in detail within the Draft Environmental Impact Report and Responses to Comments.

PROJECT EVALUATION

Planning Department Preservation staff has reviewed the project description and concurs with the project evaluation provided by the Port of San Francisco and the environmental consultant and their associated subconsultants. Department staff has worked closely within the Project Team to develop the analysis of the impacts to historic resources within the project site. Impacts upon archaeological resources are not addressed within this response.

Impact Summary
Provided below is a summary of the proposed project's impacts upon historic resources:

Impact-America's Cup
Construction and operation of the proposed AC34 project could cause a substantial adverse change in the significance of a historical resource as defined in CEQA Guidelines Section 15064.5, including those resources listed in Article 10 or Article 11 of the San Francisco Planning Code. Staff has determined that this aspect of the proposed project will have a less than significant impact upon historic resources.

Impact-Cruise Terminal
Construction and operation of the proposed Pier 27 Cruise Ship Terminal would not result in a substantial adverse change in the significance of a historical resource. Staff has determined that this aspect of the proposed project will have a less than significant impact upon historic resources.

Impact-Northeast Wharf Plaza
Construction of the proposed Northeast Wharf Plaza could cause a substantial adverse change in the significance of a historical resource. Staff has determined that this aspect of the proposed project will have a less than significant impact upon historic resources with the incorporation of Mitigation Measure M-CP-6.

Proposed fill removal within Port properties associated with amendments to the BCDC Special Area Plan for the Pier 27 Cruise Ship Terminal and Northeast Wharf Plaza would not cause a substantial adverse change in the significance of a historical resource. Staff has determined that this aspect of the proposed project will not have an impact upon historic resources.

Impact-Long Term Development
Long-term development would result in redevelopment of existing Port properties at Piers 30-32, which could result in a significant impact to historic resources. Staff has determined that this aspect of the proposed project will have a significant adverse impact upon historic resources.

Long-term development would result in redevelopment of existing Port properties within the Embarcadero Historic District, which could result in a significant impact to historic resources. Staff has determined that this aspect of the proposed project will have a less than significant impact upon historic resources.

Cumulative Impact
The combination of AC34, including 2012 and 2013 events, and the Cruise Ship Terminal projects, in combination with other past, present and foreseeable future projects, could have a cumulatively considerable effect on cultural resources. Staff has determined that this aspect of the proposed project will have a less than significant cumulative impact upon historic resources with the incorporation of Mitigation M-CP -6 and MT-LT-CP.

Details upon the impact analysis are provided within the Draft Environmental Impact Report and Responses to Comments.

Mitigation
In order to lessen and/or mitigate the significant adverse impacts on the historic resources present within the project site, the proposed project would incorporate the following mitigation measures:

- Mitigation Measure M-CP-1b: Protection of Historical Resources due to Indirect Damage
- Mitigation Measure M-CP-1c: Protection of Historical Resources due to Direct Damage
- Mitigation Measure M-CP-1d: Protection of the Northeast Waterfront Historic District from Teatro Zinzanni Relocation
- Mitigation Measure M-CP-6: Northeast Wharf Plaza Performance Criteria
- Mitigation Measure M-LT-CP
    - *Archeological Testing, Monitoring, Data Recovery and Reporting*
    - *Review of New Construction within the Port of San Francisco Embarcadero Historic District for Compliance with the Secretary's Standards*
    - *Documentation and Interpretation for Demolition or Alteration of Buildings*

  a) *Piers 30-32 Performance Criteria*

  b) Performance Criteria for Long-Term Development on Historic Piers

Planning Department Preservation staff assisted in drafting these mitigation measures, which are described in full within the Draft Environmental Impact Report and Responses to Comments.

PART II: SENIOR PRESERVATION PLANNER REVIEW

Signature: ____________________ Date: 11-29-11

Tina Tam, *Senior Preservation Planner*

cc: Virnaliza Byrd / Historic Resource Impact Review File
Beth Skrondal / Historic Resource Survey Team
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RS: G:\Documents\Environmental\2010.0493E America's Cup\HRER_America's Cup_2011-11-29.doc

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APPENDIX CP-5
America's Cup Improvements, Piers 27-29, Project Consistency with Secretary's Standards

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ARCHITECTURAL RESOURCES GROUP, INC.
Architects, Planners & Conservators

MEMORANDUM

To: Scott Preston
PE, LEED AP
AECOM
150 Chestnut Street
San Francisco, CA 94111

Project: America's Cup Improvements, Piers 27-29

Project #: 11015

Date: April 13, 2011

Phone: 415-955-2847

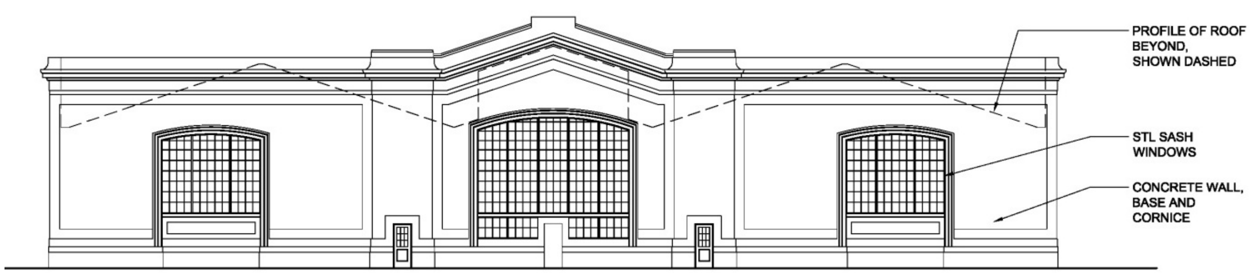
Via: e-mail

Re: America's Cup Improvements, Piers 27-29
Project Consistency with *Secretary's Standards* – Revised Draft

1. Introduction

In response to your request, Architectural Resources Group (ARG) has completed this assessment of the changes to Pier 29 proposed in connection with the 2013 America's Cup for consistency with the *Secretary of the Interior's Standards for Rehabilitation*. The proposed project includes demolition of Pier 27 to accommodate a new cruise ship terminal and use of Pier 29 and the adjacent deck area for events related to the 2013 America's Cup. To complete this evaluation, ARG Principal Charles Chase and Preservation Planner Matthew Davis visited the project site and reviewed and updated the Historic Resources Report that ARG completed for the site in 1999.

Pier 29 is listed on the National Register of Historic Places as a contributor to the Port of San Francisco Embarcadero Historic District. Because it was built outside the district's period of significance, Pier 27 is a non-contributor to the historic district and is not considered a historical resource.



Original reinforced concrete wall at outshore end of Pier 29. This wall was demolished when Pier 27 was constructed in 1965. Drawing courtesy AECOM.

Pier 9, The Embarcadero . San Francisco, California 94111
415.421.1680 . 415.421.0127 *fax*
www.argsf.com

2. The Secretary of the Interior's Standards for Rehabilitation
The Secretary of the Interior is responsible for establishing standards for all programs under Departmental authority and for advising Federal agencies on the preservation of historic properties listed in or eligible for listing in the National Register of Historic Places. The *Standards for Rehabilitation* (codified in 36 CFR 67 for use in the Federal Historic Preservation Tax Incentives program) address the most prevalent treatment. "Rehabilitation" is defined as "the process of returning a property to a state of utility, through repair or alteration, which makes possible an efficient contemporary use while preserving those portions and features of the property which are significant to its historic, architectural, and cultural values."

Initially developed by the Secretary of the Interior to determine the appropriateness of proposed project work on registered properties within the Historic Preservation Fund grant-in-aid program, the *Standards for Rehabilitation* (the *Standards*) have been widely used over the years—particularly to determine if a rehabilitation qualifies as a Certified Rehabilitation for Federal tax purposes. In addition, the *Standards* have guided Federal agencies in carrying out their historic preservation responsibilities for properties in Federal ownership or control; and State and local officials in reviewing both Federal and nonfederal rehabilitation proposals. They have also been adopted by historic district and planning commissions across the country.

The intent of the *Standards* is to assist the long-term preservation of a property's significance through the preservation of historic materials and features. The *Standards* pertain to historic buildings of all materials, construction types, sizes, and occupancy and encompass the exterior and interior of the buildings. They also encompass related landscape features and the building's site and environment, as well as attached, adjacent, or related new construction. To be certified for Federal tax purposes, a rehabilitation project must be determined by the Secretary of the Interior to be consistent with the historic character of the structure(s), and where applicable, the district in which it is located. The Standards are to be applied to specific rehabilitation projects in a reasonable manner, taking into consideration economic and technical feasibility.

The ten Standards are:

1. A property shall be used for its historic purpose or be placed in a new use that requires minimal change to the defining characteristics of the building and its site and environment.

2. The historic character of a property shall be retained and preserved. The removal of historic materials or alteration of features and spaces that characterize a property shall be avoided.

3. Each property shall 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 architectural elements from other buildings, shall not be undertaken.

4. Most properties change over time; those changes that have acquired historic significance in their own right shall be retained and preserved.

5. Distinctive features, finishes, and construction techniques or examples of craftsmanship that characterize a property shall be preserved.

6. Deteriorated historic features shall be repaired rather than replaced. Where the severity of deterioration requires replacement of a distinctive feature, the new feature shall match the old in design, color, texture, and other visual qualities and, where possible, materials. Replacement of missing features shall be substantiated by documentary, physical, or pictorial evidence.

7. Chemical or physical treatments, such as sandblasting, that cause damage to historic materials shall not be used. The surface cleaning of structures, if appropriate, shall be undertaken using the gentlest means possible.

8. Significant archeological resources affected by a project shall be protected and preserved. If such resources must be disturbed, mitigation measures shall be undertaken.

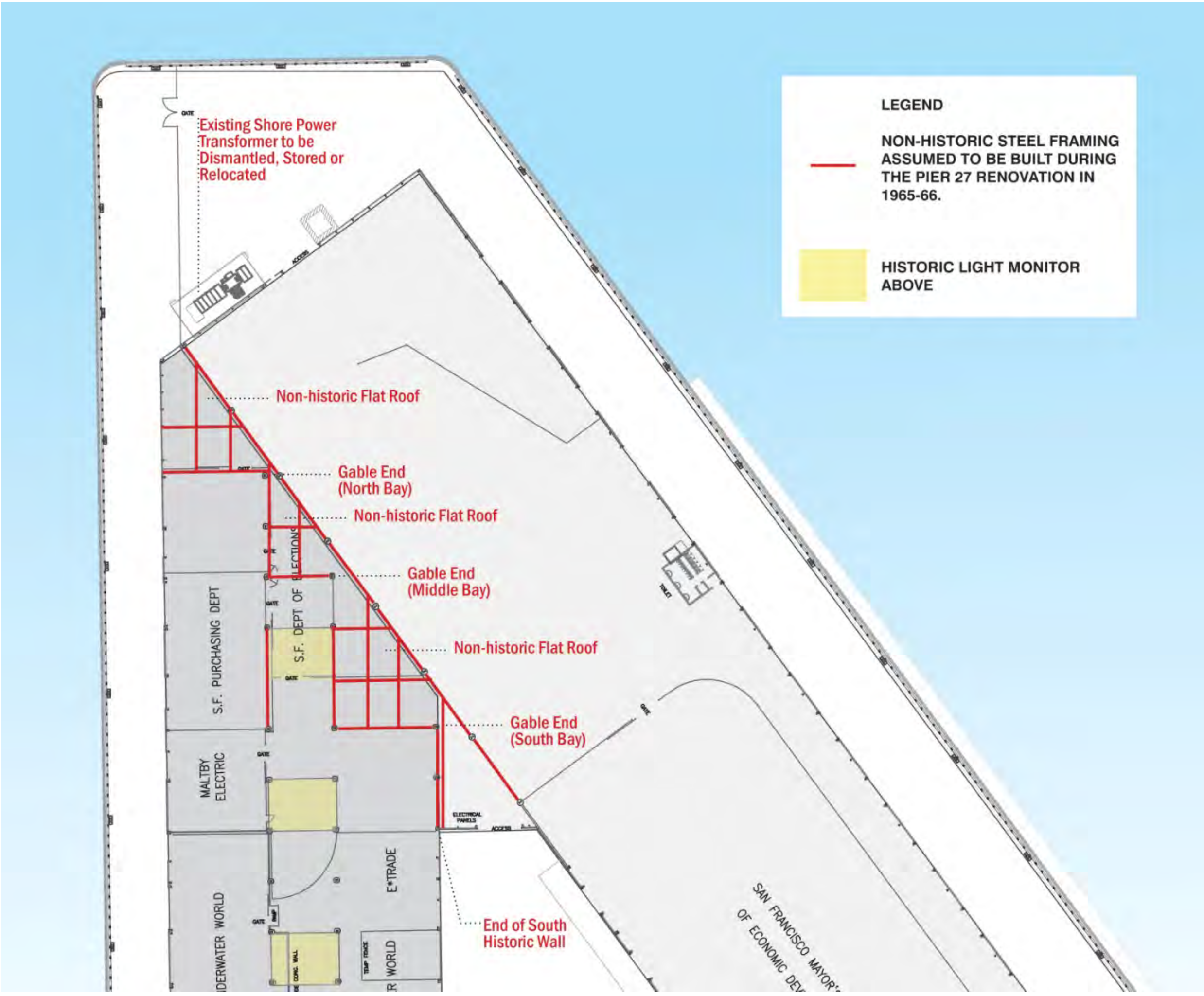
9. New additions, exterior alterations, or related new construction shall not destroy historic materials that characterize the property. The new work shall be differentiated from the old and shall be compatible with the massing, size, scale, and architectural features to protect the historic integrity of the property and its environment.

10. New additions and adjacent or related new construction shall be undertaken in such a manner that if removed in the future, the essential form and integrity of the historic property and its environment would be unimpaired.

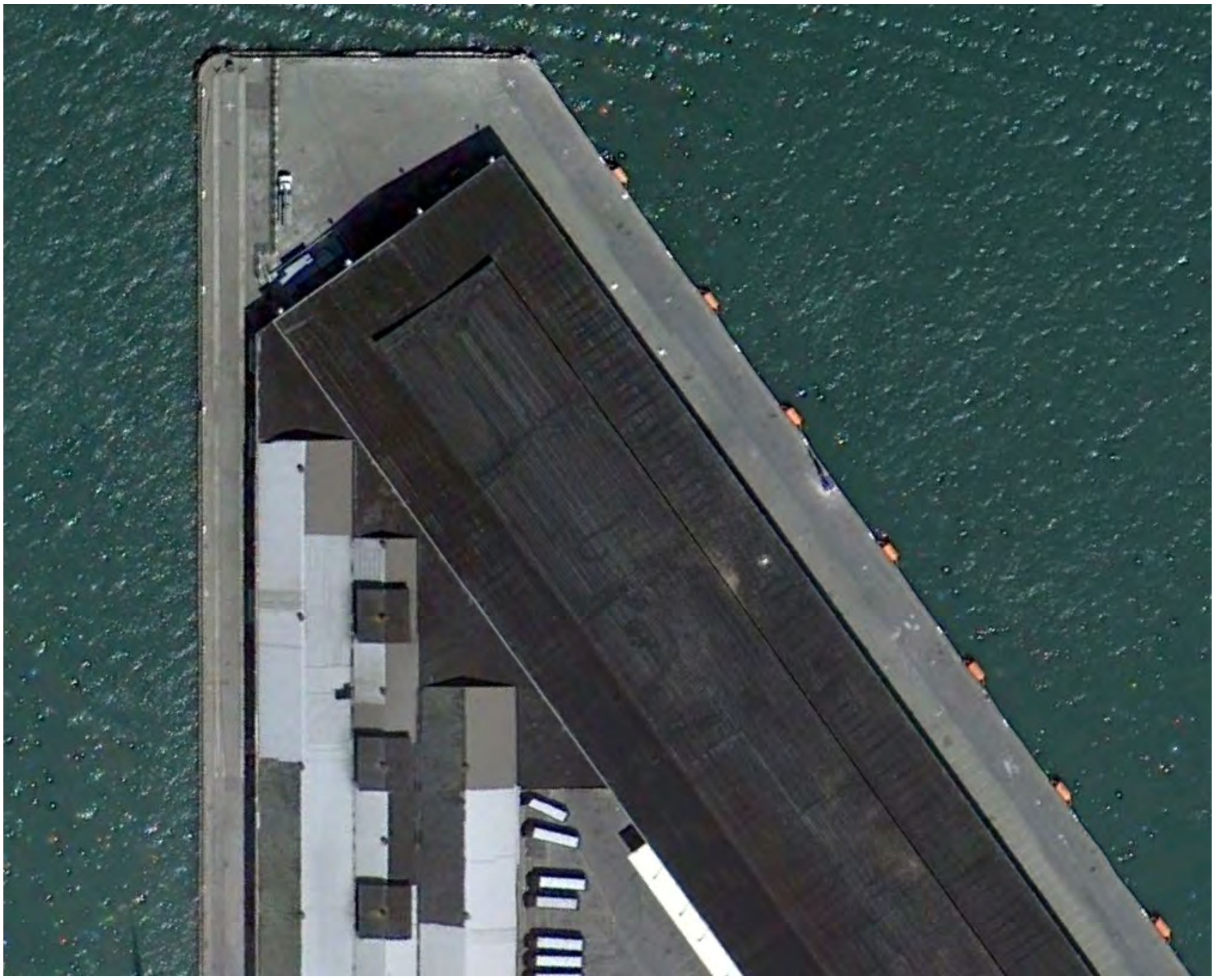
3. Construction Background

Pier 29 was the southernmost of a group of seven new piers (numbered 29 to 41) proposed in the early 1910s for San Francisco's northern waterfront. The substructure of Pier 29 was completed in November 1916. The Pier 29 shed was completed in July 1917, and the bulkhead building in 1918. The outshore end of the pier originally consisted of a reinforced concrete wall with three large arched windows, approximately 13 feet wide by 15 feet high.

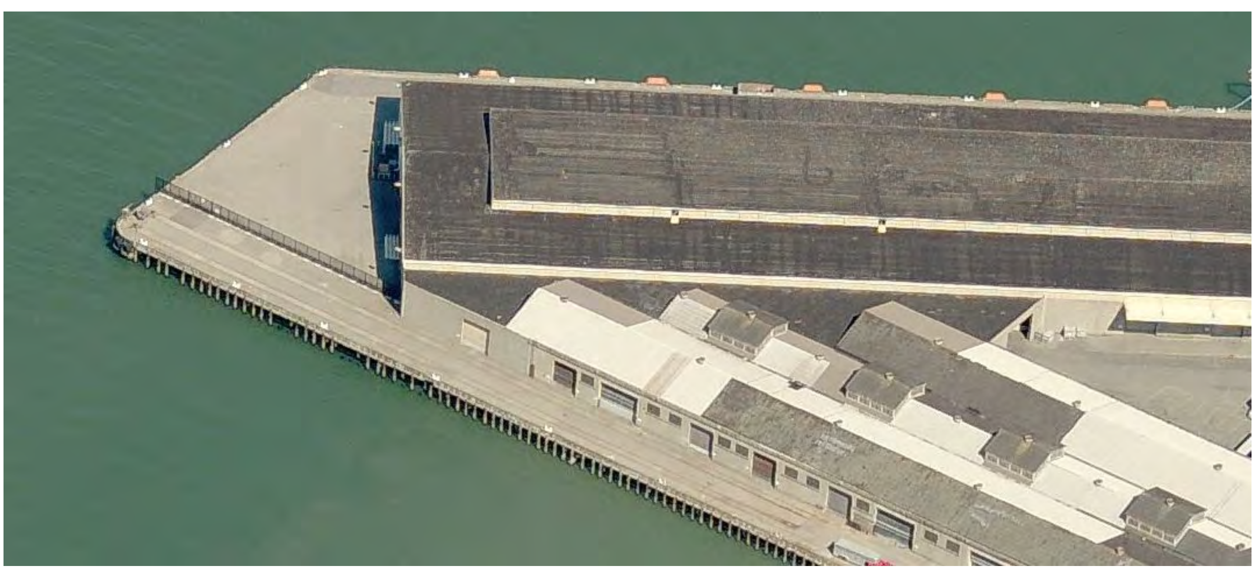
Pier 29 was significantly altered when Pier 27 was constructed in 1965. To enable the outshore end of Pier 29 to open directly into Pier 27, Pier 29 was "cut back" in a stepped fashion, and the reinforced concrete wall at the outshore end of Pier 29 and several bays along the south wall of the Pier 29 shed were removed. At the same time, Pier 29's substructure was extended to accommodate the end of Pier 27, and steel framing and flat roofs were added to the northern end of Pier 29 where it joined Pier 27. In addition, the area south of Pier 29 was filled in to support a triangular asphalt parking lot and driveway in the space between the two piers.



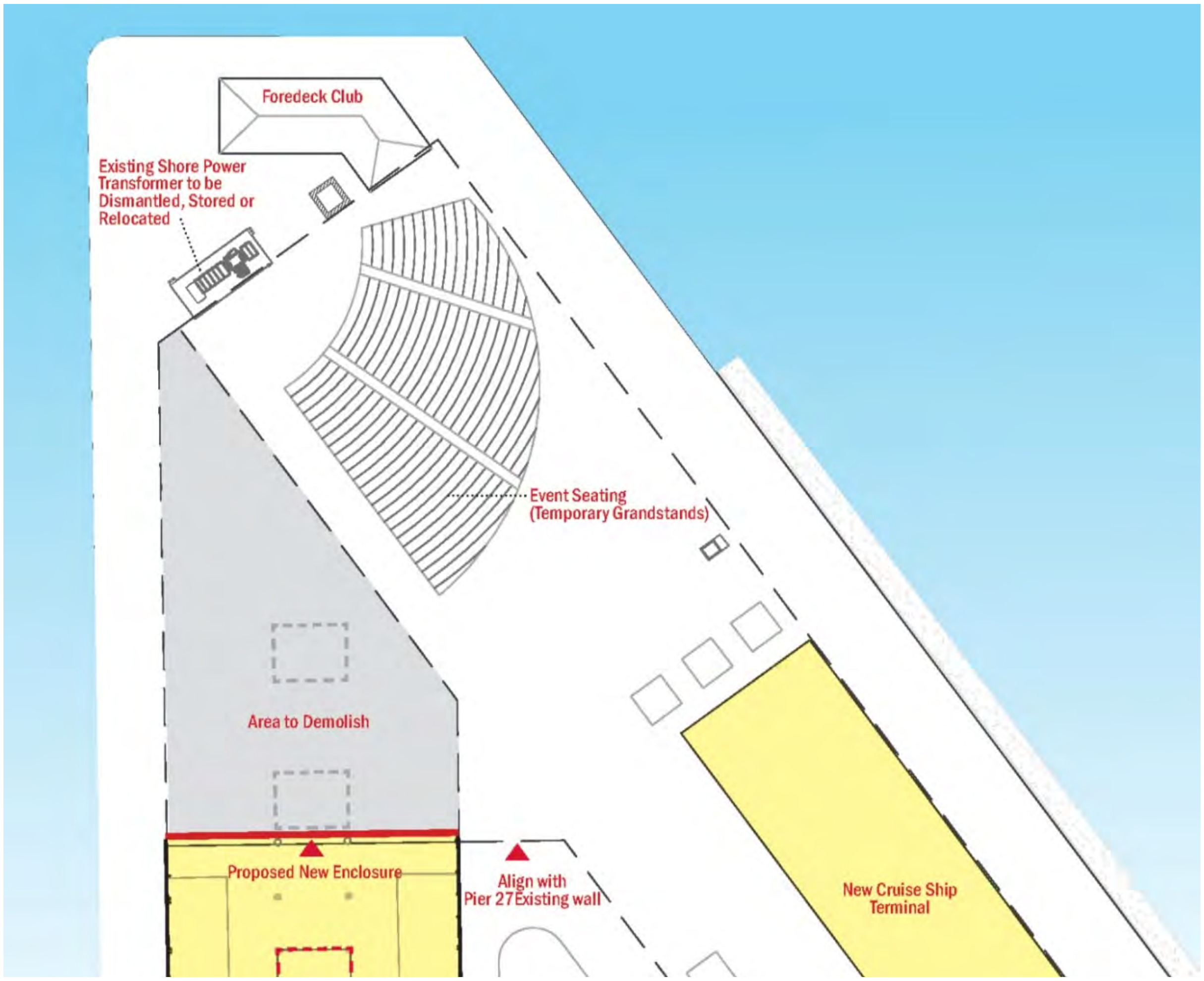
The shed at Pier 29 was clipped in the 1960s in order to connect it to the new Pier 27. Image courtesy AECOM.



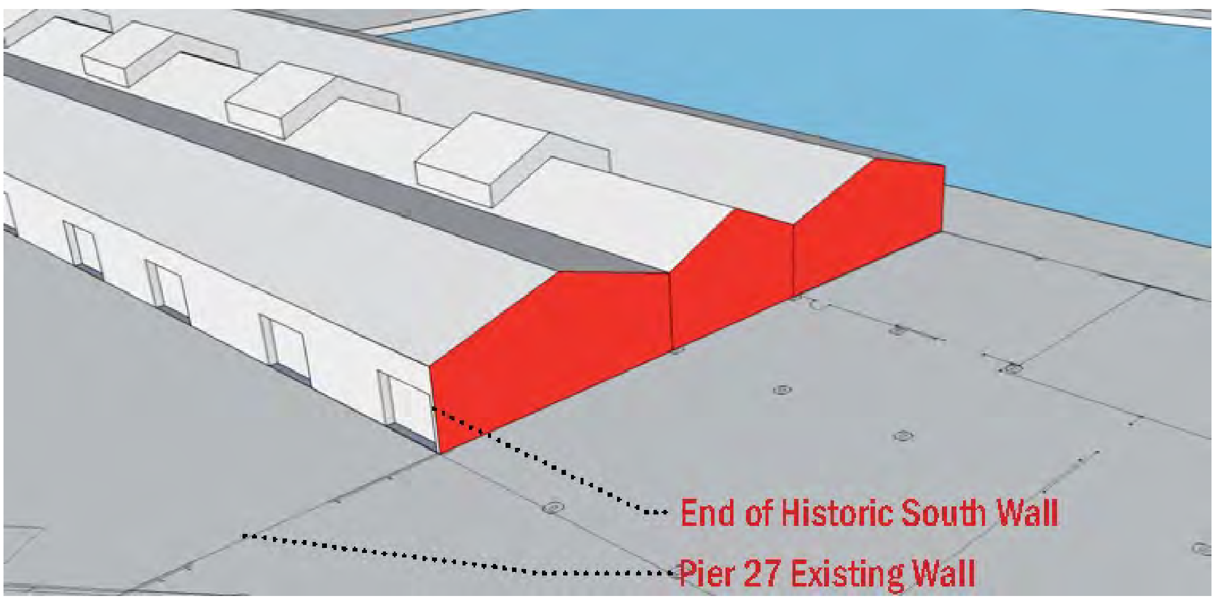
Aerial of project site. Image source: Google Earth.



Bird's-eye view of project site, looking southeast. Image source: Bing Maps.



America's Cup Improvements, Piers 27-29. Image courtesy AECOM.

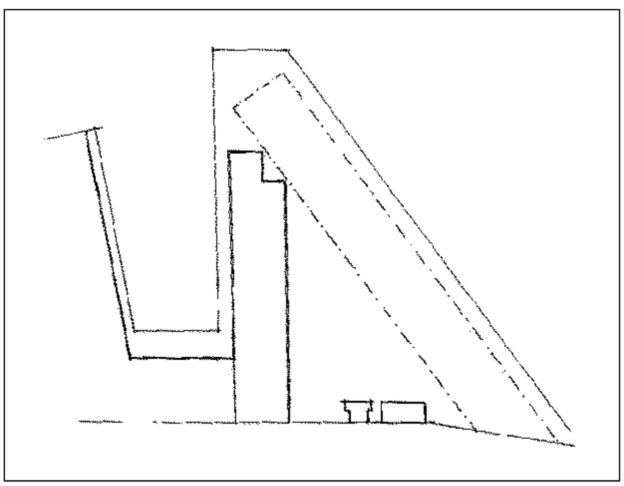


View looking west, showing proposed new Pier 29 enclosure wall. Image courtesy AECOM.

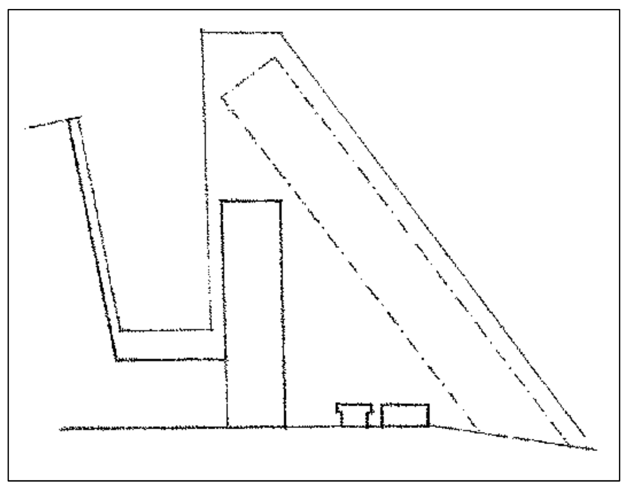
4. Project Description

The proposed project includes demolition of Pier 27 to accommodate a new cruise ship terminal and use of Pier 29 and the adjacent deck area for events related to the 2013 America's Cup. This new terminal will be considerably smaller than the existing shed at Pier 27 and, in particular, will no longer connect to Pier 29, allowing Pier 29 to be expressed as a freestanding structure. A Foredeck Club and a temporary grandstand to be used during the 2013 America's Cup are proposed for the outshore end of Pier 27-29. The outshore end of Pier 29 would be "cut back" to where the original structure is intact.

Several alternative treatments of Pier 29 were considered in the historic resource analysis that ARG completed for the Port in preparation for potential rehabilitation of Pier 29. As described in ARG's 1999 Historic Resources Report for Piers 27-31, there are two main options in spatially separating Piers 27 and 29. One option is to cut away the altered parts of Pier 29, leaving a stepped end containing only the original structure. The other option is to demolish the Pier 29 shed back to the line where the original structure is intact. (This line is approximately 220 feet inshore of the location of the original end wall.) The design team chose the latter option because, although it shortens the Pier 29 shed, it preserves its original rectangular shape and more faithfully preserves the profile of the building, which historically had an end wall at its outshore end.



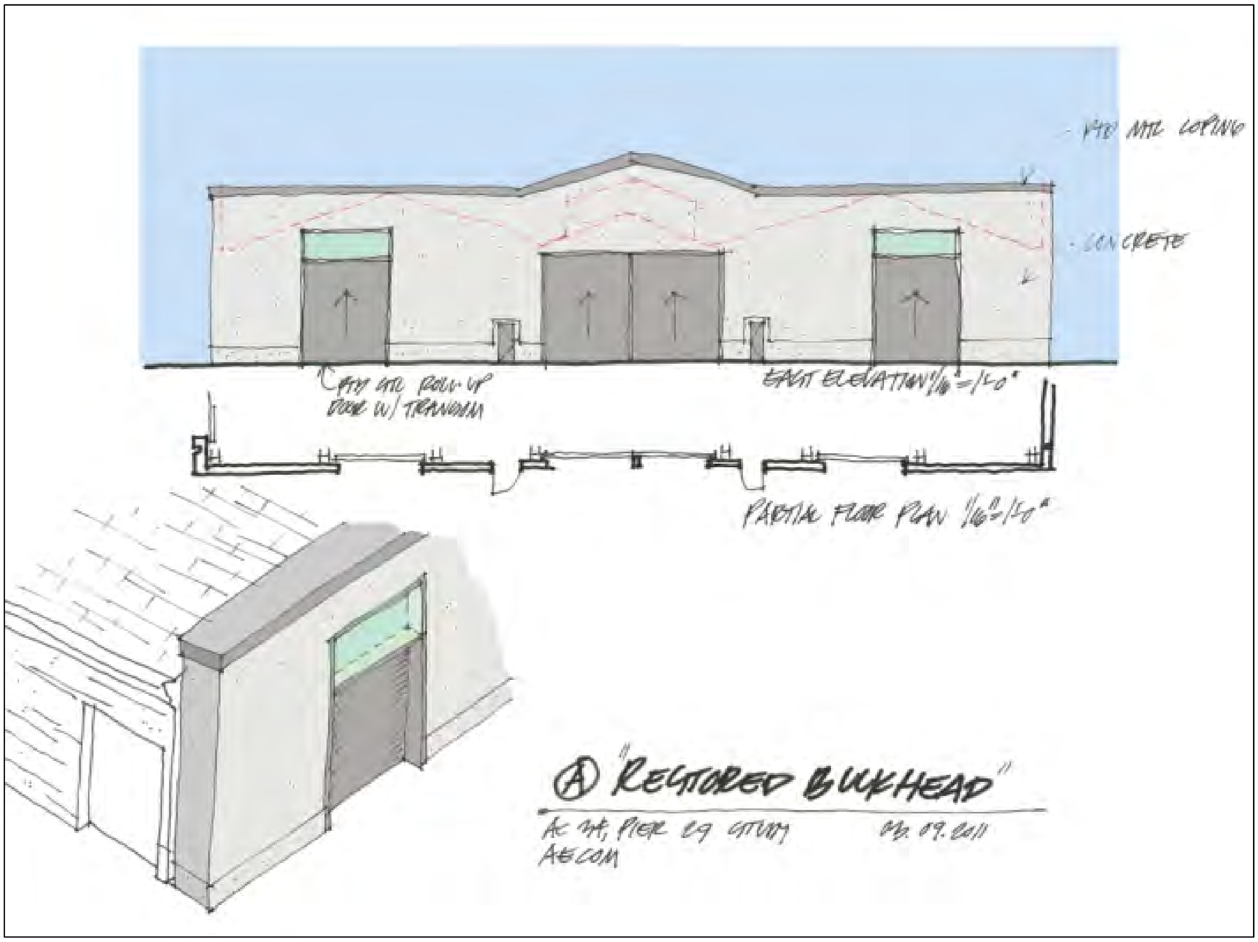
Stepped End Option



Flat End Option

Four alternative designs were considered for the design of Pier 29's new end wall for the America's Cup/cruise ship terminal project. Three of the alternatives were found to be inconsistent with the *Secretary's Standards*. We examine each of the alternatives below.

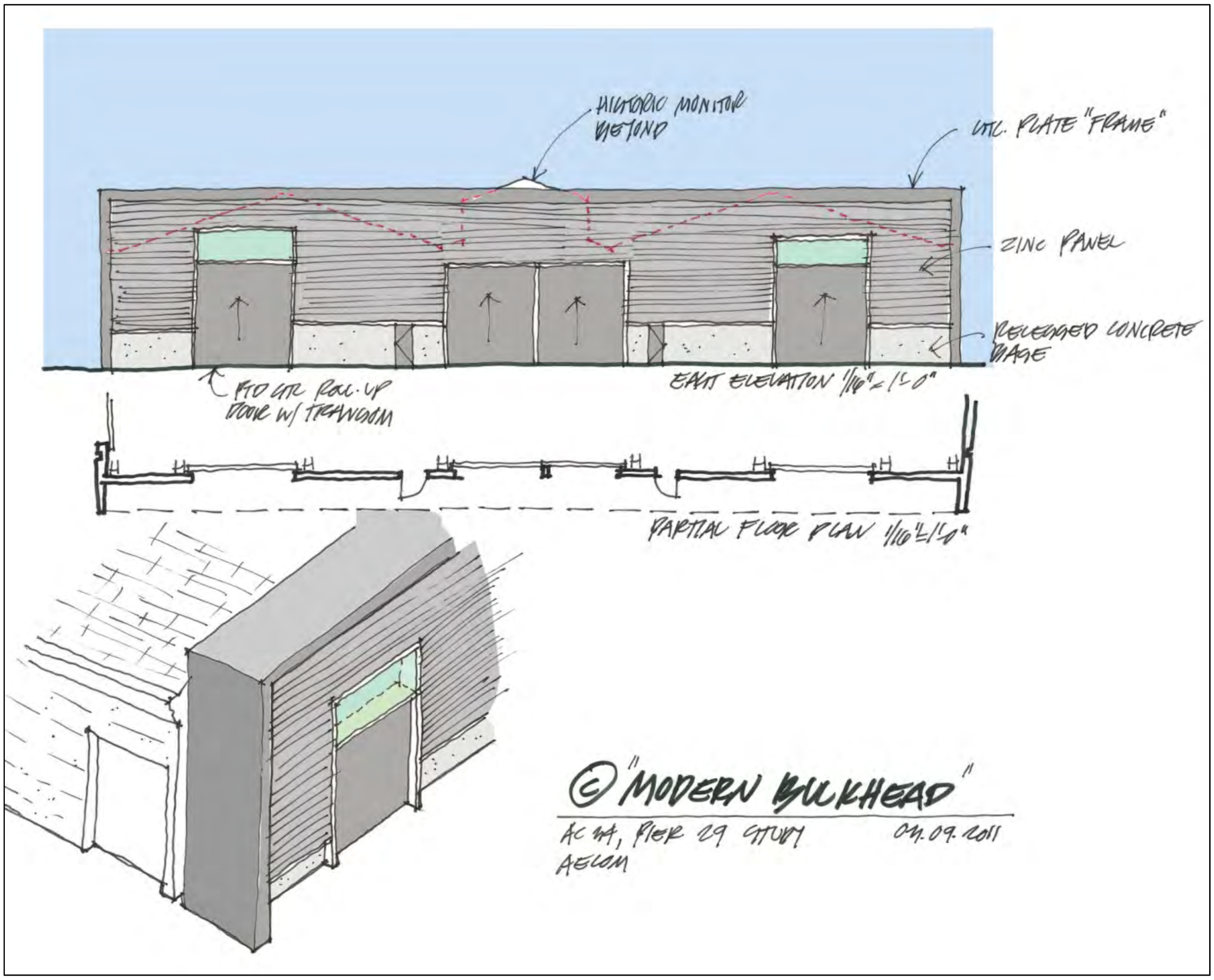
1. "Restored Bulkhead" Alternative



"Restored Bulkhead" alternative. Image courtesy AECOM.

The "Restored Bulkhead" alternative entailed construction of a concrete wall with the same single-gabled profile as the original end wall. Because the new wall's location would be more than 200 feet inshore of the location of the shed's original end wall, however, this option was considered historically misrepresentative.

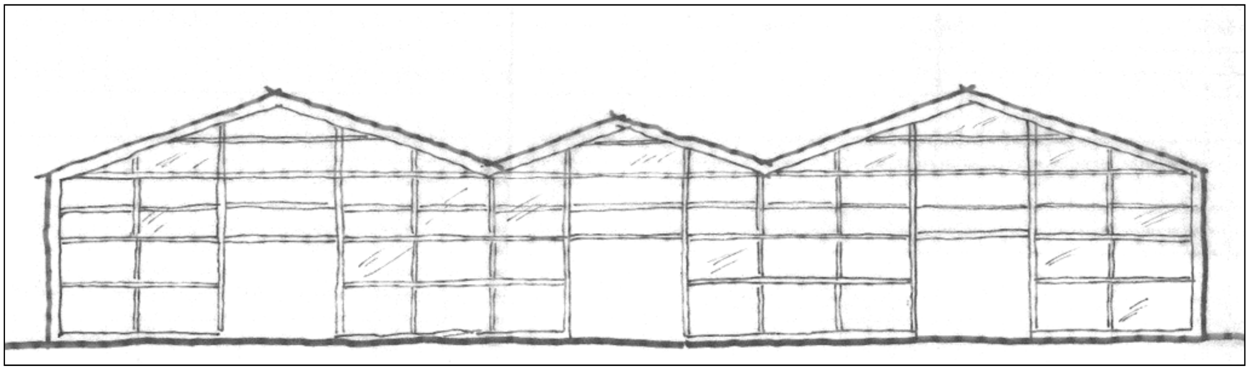
2. "Modern Bulkhead" Alternative



"Modern Bulkhead" alternative. Image courtesy AECOM.

The "Modern Bulkhead" alternative entailed construction of a rectangular end wall with no gable. Though such a wall would be clearly distinguishable from the rest of the historic building, its shape and appearance would be inconsistent with the character of similar pier structures along the San Francisco waterfront. Thus this alternative was also rejected.

3. "Glass and Metal End Wall" Alternative

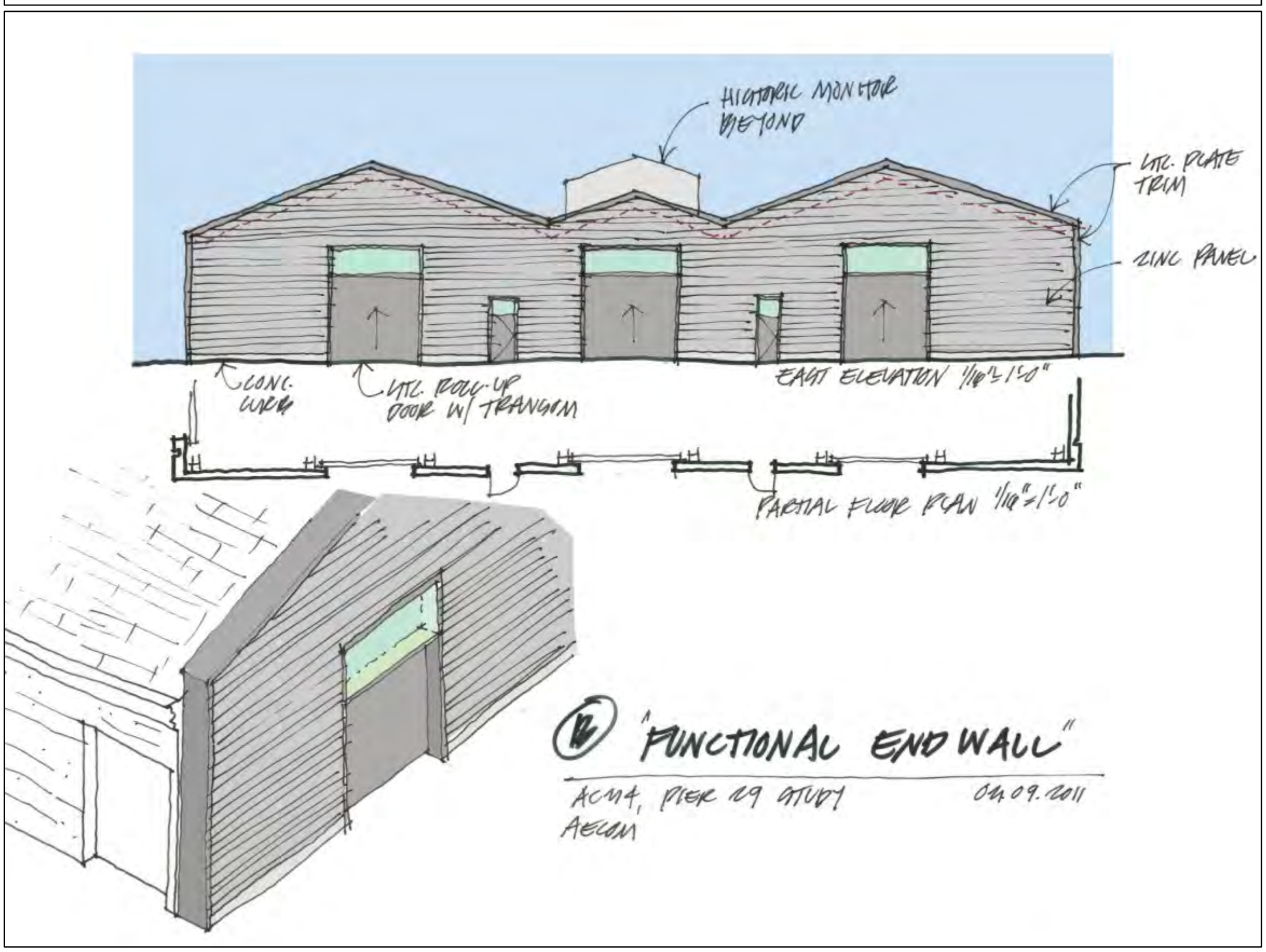


"Glass and Metal End Wall" alternative. Image courtesy AECOM.

Under this alternative, the new end wall of Pier 29 would consist of an exposed, metal-framed curtain wall or assembly in a grid layout, with individual cells of the grid in-filled with metal or glass panels. The wall would contain three rollup doors – centered beneath the three gables – and two person doors. The bottom course of the grid would consist of metal panels and the bay closest to Pier 27 would include metal panel up to the height of the rollup doors. Frame and metal panel colors would be complimentary to the trim colors of the pier shed. Panel sizes depicted in the above sketch represent the concept rather than actual sizes.

According to Standard 9 of the *Secretary's Standards*, new additions to a historic building need to be both differentiated from and compatible with the existing building. Like the "Modern Bulkhead" alternative, this alternative passes the differentiation test, as the extensive use of glass and metal panels in the new wall would clearly distinguish it from the existing building. The visual permeability of the proposed end wall, however, is incompatible with the character of the existing building and other similar pier structures along the San Francisco waterfront. With its extensive use of glass, the proposed end wall is markedly at odds with the building's historic outshore end, which was characterized by window and door openings set into an opaque wall. Nor does the proposed grid relate to any aspect of the design or ornamentation of the existing building. Thus the "Glass and Metal End Wall" alternative does not appear to be sufficiently compatible with the character of the existing building to satisfy the *Secretary's Standards*.

4. Preferred Alternative: "Functional End Wall"



The preferred alternative, "Functional End Wall." Images courtesy AECOM.

The preferred "Functional End Wall" alternative entails construction of a three-gabled end wall that matches the profile of the existing building. The wall would be clad in horizontal metal paneling and would have metal coping. Steel roll-up doors with transom would occupy each of the three bays, with pedestrian doors in between.

This alternative directly conveys the shape of the shed at the location of the cut. In addition, the rhythm of the roll-up doors and pedestrian entrances evokes the pattern of window and door openings of the original historic end wall, without duplicating it. The new wall would be separated from the existing walls of the shed by a shallow reveal, further distinguishing new construction from the existing pier shed.

5. Project Assessment

We conclude with a discussion of the proposed treatment of Pier 29 with reference to each of the *Secretary of the Interior's Standards for Rehabilitation*. As described below, the preferred "Functional End Wall" alternative appears to be consistent with the *Secretary's Standards*.

Standard 1. *A property shall be used for its historic purpose or be placed in a new use that requires minimal change to the defining characteristics of the building and its site and environment.*

Though it long supported a variety of maritime and light industrial uses, Pier 29 has more recently been used as a storage facility. As identified in the Historic Resource Evaluation completed by ARG in 1999 and updated in 2011, character-defining features of the Pier 29 shed include:

- reinforced concrete walls
- steel rolling doors
- door openings with clipped corners
- steel sash multi-light windows with ribbed wire glass
- wooden beams
- a series of three trussed roof gables
- a row of monitors in the central gable

The proposed project entails changes to these character-defining features only in the triangular area at the pier's outshore end, which was extensively altered in 1965 to accommodate Pier 27. Specifically, a portion of the northwestern wall of the shed containing three historic door openings (and two non-historic door openings) and seven historic windows will be removed, along with two historic roof monitors and associated roof trusses. Multiple instances of each of these features remain elsewhere in the inshore portion of the Pier 29 shed, which will remain intact. Given the altered state of the outshore end of Pier 29, the removal of these features would not compromise the defining characteristics of the building or its site and, in particular, Pier 29 would remain a contributor to the Embarcadero Historic District.

Standard 2. *The historic character of a property shall be retained and preserved. The removal of historic materials or alteration of features and spaces that characterize a property shall be avoided.*

See discussion under Standard 1. The extent and profile of the Pier 29 shed has been obscured by the demolition and envelopment that occurred in conjunction with the construction of Pier 27 in the 1960s. By removing Pier 27 and the altered outshore portion of Pier 29, the proposed project will enhance the historic character of the property by expressing the shed's historic freestanding profile and rectangular plan.

Standard 3. *Each property shall 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 architectural elements from other buildings, shall not be undertaken.*

The proposed alteration of Pier 29 does not introduce any conjectural features or other changes that would create a false sense of historic development.

Standard 4. *Most properties change over time; those changes that have acquired historic significance in their own right shall be retained and preserved.*

The proposed project does not entail removal of any historically significant alterations to the site, as the alterations to be removed are outside the Embarcadero Historic District's period of significance. Pier 27 is a non-contributing feature of the Embarcadero Historic District, as it was built outside the district's period of significance. Nor does Pier 27 appear to be eligible for listing on the National Register of Historic Places as an individual resource. The pier is less than 50 years old and does not possess sufficient architectural or historical significance to be a contributor to the historic district or an individually eligible resource. As a result, Pier 27 does not constitute a change to the site that has acquired significance in its own right. Moreover, by removing Pier 27, the shore power transformer, and the compromised outshore end of Pier 29, the proposed project removes non-historic elements from the site and returns Pier 29 to a freestanding building.

Standard 5. *Distinctive features, finishes, and construction techniques or examples of craftsmanship that characterize a property shall be preserved.*

See discussion under Standard 1. Distinctive features, finishes and construction techniques will be preserved throughout the intact portion of the Pier 29 shed.

Standard 6. *Deteriorated historic features shall be repaired rather than replaced. Where the severity of deterioration requires replacement of a distinctive feature, the new feature shall match the old in design, color, texture, and other visual qualities and, where possible, materials. Replacement of missing features shall be substantiated by documentary, physical, or pictorial evidence.*

The proposed project entails no replacement of historic features.

Standard 7. *Chemical or physical treatments, such as sandblasting, that cause damage to historic materials shall not be used. The surface cleaning of structures, if appropriate, shall be undertaken using the gentlest means possible.*

The proposed project entails no chemical or physical treatments of existing historic materials.

Standard 8. *Significant archeological resources affected by a project shall be protected and preserved. If such resources must be disturbed, mitigation measures shall be undertaken.*

Though an archeological evaluation is beyond the scope of this analysis, given the site's bayside location, it is not anticipated that the proposed project would affect any significant archeological resources.

Standard 9. *New additions, exterior alterations, or related new construction shall not destroy historic materials that characterize the property. The new work shall be differentiated from the old and shall be compatible with the massing, size, scale, and architectural features to protect the historic integrity of the property and its environment.*

See discussion under Standard 1. The proposed end wall for Pier 29 is designed to preserve the integrity of the historic property. The proposed wall conveys the three-gabled shape of the historic shed at the location of the cut. In addition, the rhythm of the proposed roll-up doors and pedestrian entrances evokes the window and door openings of the original reinforced concrete end wall, without duplicating those features. The new wall would be separated from the existing walls of the shed by a shallow reveal, distinguishing the new construction from the historic structure.

Standard 10. *New additions and adjacent or related new construction shall be undertaken in such a manner that if removed in the future, the essential form and integrity of the historic property and its environment would be unimpaired.*

The proposed America's Cup grandstand would be temporary and its future removal would not destroy any historic materials. While evaluation of the proposed design of the new Foredeck Club and Cruise Ship Terminal is beyond the scope of the present analysis, both will be situated more than 100 feet apart from the Pier 29 shed and are reversible, as they could be removed in the future without compromising the essential form and integrity of the historic pier.

6. National Park Service Preservation Briefs

The National Park Service has published a series of reference documents, known as Preservation Briefs, that provide guidance on preserving, rehabilitating and restoring historic buildings. The following NPS Preservation Briefs are particularly relevant to the proposed work at the Piers 27-29 project site and are attached to this report:

- *Preservation Brief 1: Cleaning and Waterproof Coating of Masonry Buildings*
- *Preservation Brief 9: The Repair of Historic Wooden Windows*
- *Preservation Brief 10: Exterior Paint Problems on Historic Woodwork*
- *Preservation Brief 13: The Repair and Thermal Upgrading of Historic Steel Windows*
- *Preservation Brief 15: Preservation of Historic Concrete: Problems and General Approaches*
- *Preservation Brief 38: Removing Graffiti from Historic Masonry*

Additional Preservation Briefs can be found at the National Park Service's Technical Preservation services website, http://www.cr.nps.gov/hps/TPS/briefs/presbhom.htm.

1 Preservation Briefs

Technical Preservation Services
National Park Service
U.S. Department of the Interior

Assessing Cleaning and Water-Repellent Treatments for Historic Masonry Buildings

Robert C. Mack, FAIA
Anne Grimmer

» Preparing for a Cleaning Project
» Understanding the Building Materials
» Cleaning Methods and Materials
» Planning a Cleaning Project
» Water-Repellent Coatings and Waterproof Coatings
» Summary

A NOTE TO OUR USERS: The web versions of the **Preservation Briefs** differ somewhat from the printed versions. Many illustrations are new, captions are simplified, illustrations are typically in color rather than black and white, and some complex charts have been omitted.

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.

Ninety years of accumulated dirt and pollutants are being removed from this historic theater using an appropriate chemical cleaner, applied in stages. Photo: Richard Wagner, AIA.

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. Although specifically intended for historic buildings, the information is applicable to all masonry buildings. This publication updates and expands *Preservation Briefs 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.

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.

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. 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

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. 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.

The decorative trim on this brick builing is architectural terra-cotta intended to simulate the limestone foundation. Photo: NPS files.

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. 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 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.

Any cleaning method should be tested before using it on historic masonry. Photo: NPS files.

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.

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 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.

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* 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.

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. 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. 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.


Low-to-medium-pressure steam (hot-pressurized water washing) is a gentle method of softening heavy soiling deposits and cleaning historic marble. Photo: NPS files.

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 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.

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 important of all, it is imperative 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. 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 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.

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.

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. 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.

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. 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.

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. 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.

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.

Poulticing to Remove Stains and Graffiti

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 (a solvent or other remover) to form a paste which is applied to the stain. The poultice is kept moist and left on the stain as long as necessary for it to draw the stain out of the masonry. As it dries, the paste absorbs the staining material so that it is not redeposited on the masonry surface.

The iron stain on this granite post may be removed by applying a commercial rust-removal product in a poultice. Photo: NPS files

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.

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. 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.

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.

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.

Sandblasting has permanently damaged this brick wall. Photo: NPS files

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. 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.

Ice particles, or pelletized dry ice (carbon dioxide or CO_2), are another medium used as an abrasive cleaner. 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 a 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. 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.

The lower floors of this historic brick and architectural terra-cotta building have been covered during chemical cleaning to protect pedestrians and vehicular traffic from potentially harmful overspray. Photo: NPS files.

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 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. 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. 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 water-borne 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.

This clear coating has failed and is pulling off pieces of the stone as it peels. Photo: NPS files

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 the 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.

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.

Most historic masonry buildings, unless they are painted, have survived for decades

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 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.


Improper cleaning methods may have been responsible for the formation of efflorescence on this brick. Photo: NPS files.

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 historic masonry surface, and they are not always effective. 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 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 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 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.

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.**

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.

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Home page logo: Approriate cleaning of historic masonry. Photo: NPS files.

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The Repair of Historic Wooden Windows

John H. Myers

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A NOTE TO OUR USERS: The web versions of the **Preservation Briefs** differ somewhat from the printed versions. Many illustrations are new, captions are simplified, illustrations are typically in color rather than black and white, and some complex charts have been omitted.

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. 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.

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.


Windows are frequently important visual focal points, especially on simple facades such as this mill building. Replacement of the multi-pane windows with larger panes could dramatically alter the appearance of the building. Photo: NPS files.

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.

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 proceed 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 runoff, 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.


Deterioration of poorly maintained windows usually begins on horizontal surfaces and at joints, where water can collect and saturate the wood. Photo: NPS files.

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. 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 endgrain 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 section 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.

This historic double-hung window has many layers of paint, some cracked and missing putty, slight separation at the joints, broken sash cords, and one cracked pane. Photo: NPS files.

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. Photo: NPS files.

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, 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.

Sash can be removed and repaired in a convenient work area. Paint is being removed from this sash with a hot air gun. Photo: NPS files.

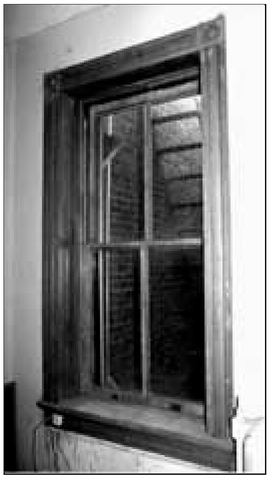
Paint removal should begin on the interior frames, being careful to remove the paint from the interior stop and the parting bead, particularly along the seam where these stops meet the jamb. This can be accomplished by running a utility knife along the length of the seam, breaking the paint bond. It 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. 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, the glass should be removed or protected from the sudden temperature change which can cause breakage. An 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.

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 weather-tight 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. 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.


Following the relatively simple repairs, the window is weathertight, like new in appearance, and serviceable for many years to come.Photo: NPS files.

The operations just discussed summarize the efforts necessary to restore a window with minor deterioration to "like new" condition. 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.

This illustrates a two-part expoxy 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: NPS files.

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 semirigid epoxies which saturate the porous decayed wood and then harden. The surface of the consolidated wood can then be filled with a semirigid epoxy patching compound, sanded and painted. Epoxy patching compounds can be used to build up 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. 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. More information on epoxies can be found in the publication "Epoxies for Wood Repairs in Historic Buildings," cited in the bibliography.

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.

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. 024016000951), 1978.

Rehab Right. Oakland, California: City of Oakland Planning Department, 1978 (pp. 7883).

"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.

Weeks, Kay D. and David W. Look, "Preservation Briefs: 10 Exterior Paint Problems on Historic Woodwork." Washington, DC: Technical Preservation Services, U.S. Department of the Interior, 1982.

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Home page logo: Historic six-over-six windows--preserved. Photo: NPS files.

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. Technical Preservation Services (TPS), Heritage Preservation Services Division, National Park Service prepares standards, guidelines, and other educational materials on responsible historic preservation treatments for a broad public.

KDW

10 Preservation Briefs
Technical Preservation Services
National Park Service
U.S. Department of the Interior

Exterior Paint Problems on Historic Woodwork

Kay D. Weeks and David W. Look, AIA

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» Treating Paint Problems
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A NOTE TO OUR USERS: The web versions of the **Preservation Briefs** differ somewhat from the printed versions. Many illustrations are new, captions are simplified, illustrations are typically in color rather than black and white, and some complex charts have been omitted.

A cautionary approach to paint removal is included in the guidelines to the *Secretary of the Interior Standards for Rehabilitation.* 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 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-based paint, 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


The paint on this exterior decorative feature is sound. Photo: NPS files.

Paint 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 reapplication every 5 to 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 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. 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 the protective and decorative paint finish was removed and an inappropriate clear finish applied, the exterior character of the building was altered. Photo: NPS files.

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 been identified the general approach should be to remove paint to the next sound layer using the gentlest means possible, then to repaint.*** 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.

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.

Re-painting 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 to 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.

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. 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 problem evidenced here by mossy growth and deteriorated wood must be resolved and the wood allowed to dry out before the wood is repainted. Photo: NPS files.

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 l/2 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.

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 l/2 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 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.)

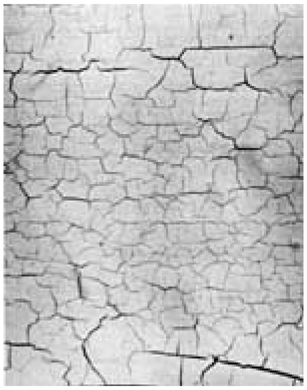
Discoloration due to color extractives in replacement wood can usually be cleaned with a solution of equal parts denatured alcohol and water. After the affected area has been rinsed and permitted to dry, a "stainblocking primer" especially developed for preventing this type of stain should be applied (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. 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.

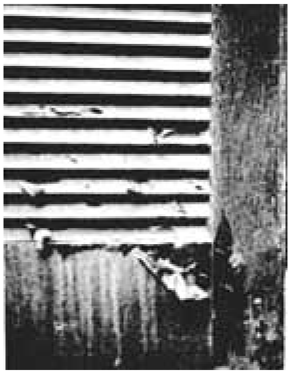


Crazing--or surface cracking--is an exterior surface condition which can be successfully treated by sanding and painting. Photo: Courtesy, National Decorating Products Assocation.

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.

Intercoat Peeling



Here, a latex top coat was applied directly over old oil paint, resulting in intercoat peeling. The latex was unable to adhere. If latex is used over oil, an oil-base primer should be applied first. Photo: Mary L. Oehrlein, AIA.

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 airborne 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. 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.

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 solventrich 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


Wrinkled layers can generally be removed by scraping and sanding as opposed to total paint removal. Photo: Courtesy, National Decorating Products Association.

Another error in application that can easily be avoided is wrinkling. 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.

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. 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.

Cracking / Alligatoring

Cause of Condition

Cracking and alligatoring are advanced stages of crazing. 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.

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 overriding 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.

Paint scrapers are commonly available in 1-5/16, 2-1/2, and 3-1/2 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.

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. The abrasive surface varies from about 3x7 inches to 4x9 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.

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. 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".)

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

CP5-55

Electric heat plate: The electric heat plate 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.

Electric heat gun: The electric heat gun (electric hot-air gun) looks like a hand-held hairdryer with a heavy-duty metal case. 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 buildup. (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.)

The nozzle on the electric heat gun permits hot air to be aimed into cavities on solid decorative surfaces, such as this carriage house door. After the paint has been sufficiently softened, it can be carefully removed with a scraper. Photo: NPS files.

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."

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, leadbase 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 homeowner 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

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General Paint Type Recommendations

Decorative features were painted with a traditional oil-based paint as a part of the rehabilitation. Photo: NPS files.

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 heavily 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.

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.

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Home page logo: Peeling paint on historic wood siding. Photo: ©John Leeke, 2002.

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The Repair and Thermal Upgrading of Historic Steel Windows

Sharon C. Park, AIA

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A NOTE TO OUR USERS: The web versions of the **Preservation Briefs** differ somewhat from the printed versions. Many illustrations are new, captions are simplified, illustrations are typically in color rather than black and white, and some complex charts have been omitted.

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, insensitively designed replacement windows may diminish--or destroy--the building's historic character.

This Brief identifies various types of historic steel

Maintaining historic steel windows for continued use is always recommended. Photo: NPS files.

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.

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 multi-story 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. 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. 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 by-product 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. 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,

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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.

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.

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.

A severely deteriorated frame, such as this, can be replaced in kind. Photo: Henry Chambers, AIA.

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 maintenance, 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.

Typical Rolled Steel Windows Available from 1890 to the Present

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.

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.

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.

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.

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.

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.

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.

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 oxyacetylene 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 deg. 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 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 anticorrosive 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.


The historic steel sash is shown in place, prior to its removal and replacement with inappropriate aluminum sash (see below). Photo: NPS files.

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 buildup 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 anticorrosive 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. Anticorrosive primers generally consist of oil-alkyd based paints rich in zinc or zinc chromate.(2) 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 blowdrier (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.


The historic steel sash (see photo above) was removed and replaced with modern aluminum sash, resulting in a negative visual impact on the building's historic character. Photo: NPS files.

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 re-align 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.

To complete the checklist for routine maintenance, cracked glass, deteriorated glazing compound, missing screws, and broken fasteners 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 anticorrosive 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 anticorrosive 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.

As part of the orderly removal of windows, each window should be numbered and the parts labeled. 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 labeled 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 anticorrosive 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 oxyacetylene 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.

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.(3)

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. 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 midpoint, 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 (27 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.

Appropriate Types of Weatherstripping for Metal Windows

SPRING-METAL comes in bronze, brass or stainless steel with an integral friction fit clip. The weatherstripping is applied after the repaired windows are painted to avoid galvanic corrosion. This type of thin weatherstripping is intended for windows in good condition.

VINYL STRIPS are scored and fold into a "V" configuration. Applied adhesive is necessary which will increase the thickness of the weatherstripping, making it inappropriate for some situations. The weatherstripping is generally applied to the window after painting.

Closed cell **FOAM TAPE** comes either with or without an adhesive backing. It is effective for windows with a gap of approximately 1/4" and is easy to install. However, this type of weatherstripping will need frequent replacement on windows in regular use. The metal section should be cleaned of all dirt and grease prior to its application.

SEALANT BEAD. This very effective type of weatherstripping involves the application of a clean bead of firm setting caulk on the primed frame with a polyethelene bond breaker tape on the operable sash. The window is then closed until the bead has set and takes the form of the gap. The sash is then opened and the tape is removed leaving the set caulk as the weatherstripping.

Thermal Glazing

Historic steel sash can be fitted with dual glazing to improve thermal efficiency. Photo: NPS files.

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. 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.

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. 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.

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 boxlike 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.

NOTES

(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 nonferrous metals, such as bronze, Monel, or aluminum, refer to *Metals in America's Historic Buildings* (see bibliography).

(2) Refer to Table IV. Types of Paint Used for Painting Metal in Metals in America's Historic Buildings, p. 139. (See bibliography).

(3) 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 reglazing 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).

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Washington, D. C. September, 1984

Home page logo: Metal casement window from "Hope's Metal Windows and Casements, 1818-1926." Photo: Courtesy, Hope's Windows, Inc.

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. Technical Preservation Services (TPS), Heritage Preservation Services Division, National Park Service prepares standards, guidelines, and other educational materials on responsible historic preservation treatments for a broad public.

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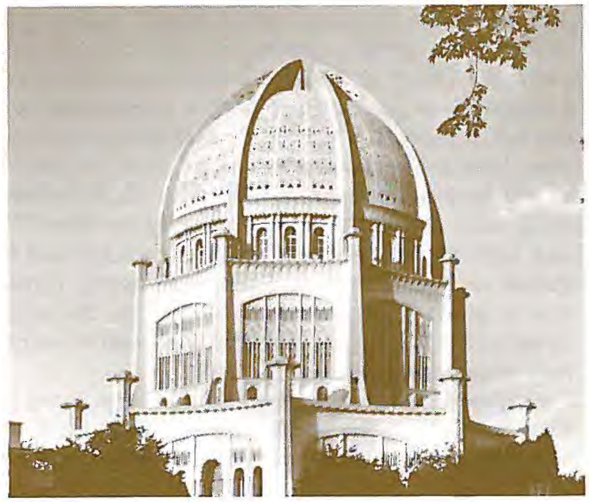
15 PRESERVATION BRIEFS



Preservation of Historic Concrete: Problems and General Approaches

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Rocky Mountain Regional Office, Division of Cultural Resources

The Secretary of the Interior's "Standards for Rehabilitation" require that deteriorated architectural features shall be repaired rather than replaced. When the severity of deterioration requires removal of historic material, its replacement should match the material being replaced in composition, design, color, texture, and other visual qualities.

"Concrete" is a name applied to any of a number of compositions consisting of sand, gravel, crushed stone, or other coarse material, bound together with various kinds of cementitious materials, such as lime or cements. When water is added, the mix undergoes a chemical reaction and hardens. An extraordinarily versatile building material, concrete is used for the utilitarian, the ornamental, and the monumental. While early proponents of modern concrete considered it to be permanent, it is, like all materials, subject to deterioration. This Brief surveys the principal problems posed by concrete deterioration, their likely causes, and approaches to their remedies. In almost every instance, remedial work should only be undertaken by qualified professionals. Faulty concrete repair can worsen structural problems and lead to further damage or safety hazards. Concrete repairs are not the province of do-it-yourselfers. Consequently, the corrective measures discussed here are included for general information purposes only; they do not provide "how to" advice.

HISTORICAL OVERVIEW

The Romans found that the mixture of lime putty with pozzolana, a fine volcanic ash, would harden under water. The result was possibly the first hydraulic cement. It 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, with the Spanish introducing a form of concrete to the New World in the first decades of the 16th century. It was used by both the Spanish and English in coastal areas stretching from Florida to South Carolina. Called "tapia," or "tabby," the substance was a creamy white, monolithic masonry material composed of lime, sand, and an aggregate of shells, gravel, or stone mixed with water. This mass of material was placed between wooden forms, tamped, and allowed to dry, the building arising in layers, about one foot at a time.

Despite its early use, concrete was slow in achieving widespread acceptance as a building material in the United States. In 1853, the second edition of Orson S. Fowler's *A Home for All* publicized the advantages of "gravel wall" construction to a wide audience, and poured gravel wall buildings appeared across the United States (see fig. 1). Seguin, Texas, 35 miles east

Fig. 1. Milton House, Milton, Wisconsin (1844). An early example of gravel wall construction with 12- to 15-inch thick monolithic concrete walls coated on the exterior with stucco. Photo: William B. Coney.

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402

of San Antonio, came to be called "The Mother of Concrete Cities" for some 90 concrete buildings made from local "lime water" and gravel (see fig. 2). 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 built at several western posts, such as the buildings that were constructed with 12- or 18-inch-thick walls at Fort Laramie, Wyoming between 1872 and 1885. By the 1880s sufficient experience had been gained with unreinforced concrete to permit construction of much larger buildings. The Ponce de Leon Hotel in St. Augustine, Florida, is a notable example from this period (see fig. 3).

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 reinforced concrete more practicable. The invention of the horizontal rotary kiln allowed production of a cheaper, more uniform and reliable cement, and led to the greatly increased acceptance of concrete after 1900.

During the early 20th century Ransome in Beverly, Massachusetts, Albert Kahn in Detroit, and Richard E. Schmidt in Chicago promoted concrete for utilitarian buildings with their "factory style," featuring an exposed concrete skeleton filled with expanses of glass. Thomas Edison's cast-in-place reinforced concrete homes in Union Township, New Jersey, proclaimed a similarly functional emphasis in residential construction (see fig. 4). From the 1920s onward, concrete began to be used with spectacular design results: in James J. Earley and Louis Bourgeois' exuberant, graceful Baha'i Temple in Wilmette, Illinois (see cover); and in Frank Lloyd Wright's masterpiece "Fallingwater" near Mill Run, Pennsylvania (see fig. 5). Eero Saarinen's soaring Terminal Building at Dulles International Airport outside Washington, D.C., exemplifies the masterful use of concrete achieved in the Modern era.

Fig. 2. Sebastopol House, Seguin, Texas (1856). This Greek Revival dwelling is one of the few remaining poured-in-place concrete structures in this Texas town noted for its construction of over 90 concrete buildings in the mid-nineteenth century. The high parapets surrounding the flat roof were lined and served as a water reservoir to cool the house. Photo: Texas Historical Commission.

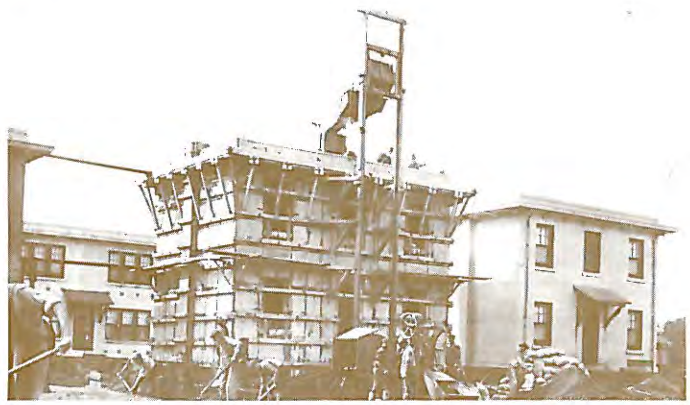

Fig. 4. Thomas A. Edison's Cast-in-Place Houses, Union Township, New Jersey (1909). This construction photo shows the formwork for the cast-in-place reinforced concrete houses built as low-cost housing using a standard 25- by 30-foot module. Photo: Edison National Historical Site.

Fig. 3. Ponce de Leon Hotel, St. Augustine, Florida (1885-87). An example of unreinforced concrete used on a grand scale, this Spanish Colonial Revival hotel was designed by Carrere and Hastings and commissioned by railroad magnate Henry Flagler. The building now serves as the main campus hall for Flagler College. Photo: Flagler College.

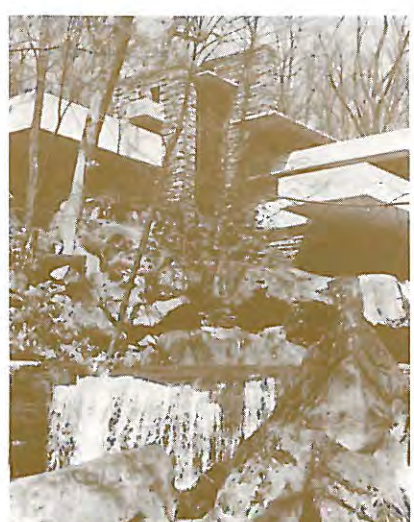

Fig. 5. "Fallingwater," near Mill Run, Pennsylvania (1936-37). This dramatic reinforced concrete residence by Frank Lloyd Wright is anchored into bedrock on the hillside and cantilevered over the stream. The great tensile strength of reinforced concrete made this type of construction possible. Photo: Paul Mayen.

Types of Concrete

Unreinforced concrete is a composite material containing aggregates (sand, gravel, crushed shell, or rock) held together by a cement combined with water to form a paste, and gets its name from the fact that it does not have any iron or steel reinforcing bars. It was the earliest form of concrete. The ingredients become a plastic mass that hardens as the concrete hydrates, or "cures." Unreinforced concrete, however, is relatively weak, and since the turn of the century has largely been replaced by reinforced concrete. *Reinforced concrete* is conrete strengthened by the inclusion of metal bars, which increase the tensile strength of concrete. Both unreinforced and reinforced concrete can be either cast in place or precast. *Cast-in-place* concrete is poured on-site into a previously erected formwork that is removed after the concrete has set. *Precast concrete* is molded off-site into building components. More recent developments in concrete technology include *post-tensioned concrete* and *pre-stressed concrete*, which feature greater strength and reduced cracking in reinforced structural elements.

Fig. 7. Battery Commander's Station, Ft. Washington, Maryland (1904). This reinforced concrete tower with a cantilevered balcony is showing serious deterioration. Water has penetrated the slab, causing freeze-thaw spalling around the posts and corrosion of the reinforcing bars. This internal corrosion is causing expansion inside the slab and creating major horizontal cracks in the concrete. Under the balcony can be seen the network of hardened white calcified deposits, which have exuded through cracks in the concrete as a result of alkali-aggregate reaction. Photo: Lee H. Nelson, FAIA.

CAUSES OF CONCRETE DETERIORATION

Deterioration in concrete can be caused by environmental factors, inferior materials, poor workmanship, inherent structural design defects, and inadequate maintenance (see figs. 6, 7, and 8).

Environmental factors are a principal source of concrete deterioration. Concrete absorbs moisture readily, and this is particularly troublesome in regions of recurrent freeze-thaw cycles. Freezing water produces expansive pressure in the cement paste or in nondurable aggregates. Carbon dioxide, another atmospheric component, can cause the concrete to deteriorate by reacting with the cement paste at the surface.

Materials and workmanship in the construction of early concrete buildings are potential sources of problems. For example, aggregates used in early concrete, such as cinders from burned coal and certain crushed brick, absorb water and produce a weak and porous concrete. Alkali-aggregate reactions within the concrete can result in cracking and white surface staining. Aggregates were not always properly graded by size to ensure an even distribution of elements from small to large. The use of aggregates with similarly sized particles normally produced a poorly consolidated and therefore weaker concrete.

Fig. 8. Meridian Hill, Washington, D.C. (1934). This reinforced concrete pier has lost much of its projecting molding partly from accidental impact and partly from spalling induced by freeze-thaw action. Evidence of moisture leaching out from the interior through cracks is seen as white deposits on the surface of this exposed aggregate concrete. Photo: Lee H. Nelson, FAIA.

Fig. 6. Battery Fortifications, Ft. Washington, Maryland (1891-97). This unreinforced concrete fortification exhibits several kinds of deterioration: the diagonal structural crack due to uneven settlement, the long horizontal crack at the cold joint, the spalling of the concrete surface coating, and vegetative growth. Photo: Sharon C. Park, AIA.

Early builders sometimes inadvertently compromised concrete by using seawater or beach sand in the mix or by using calcium chloride or a similar salt as an additive to make the concrete more "fireproof." A common practice, until recently, was to add salt to strengthen concrete or to lower the freezing point during cold-weather construction. These practices cause problems over the long term.

In addition, early concrete was not vibrated when poured into forms as it is today. More often it was tamped or rodded to consolidate it, and on floor slabs it was often rolled with increasingly heavier rollers filled with water. These practices tended to leave voids (areas of no concrete) at congested areas, such as at reinforcing bars at column heads and other critical structural locations. Areas of connecting voids seen when concrete forms are removed are known as "honeycombs" and can reduce the protective cover over the reinforcing bars.

Other problems caused by poor workmanship are not unknown today. If the first layer of concrete is allowed to harden before the next one is poured next to or on top of it, joints can form at the interface of the layers. In some cases, these "cold joints" visibly detract from the architecture, but are otherwise harmless. In other cases, "cold joints" can permit water to infiltrate, and subsequent free-thaw action can cause the joints to move. Dirt packed in the joints allows weeds to grow, further opening paths for water to enter. Inadequate curing can also lead to problems. If moisture leaves newly poured concrete too rapidly because of low humidity, excessive exposure to sun or wind, or use of too porous a substrate, the concrete will develop shrinkage cracks and will not reach its full potential strength.

Structural Design Defects in historic concrete structures can be an important cause of deterioration. For example, the amount of protective concrete cover around reinforcing bars was often insufficient. Another design problem in early concrete buildings is related to the absence of standards for expansion-contraction joints to prevent stresses caused by thermal movements, which may result in cracking.

Improper Maintenance of historic buildings can cause long-term deterioration of concrete. Water is a principal source of damage to historic concrete (as to almost every other material) and prolonged exposure to it can cause serious problems. Unrepaired roof and plumbing leaks, leaks through exterior cladding, and unchecked absorption of water from damp earth are potential sources of building problems. Deferred repair of cracks allowing water penetration and freeze-thaw attacks can even cause a structure to collapse. In some cases the application of waterproof surface coatings can aggravate moisture-related problems by trapping water vapor within the underlying material.

MAJOR SIGNS OF CONCRETE DETERIORATION

Cracking occurs over time in virtually all concrete. Cracks vary in depth, width, direction, pattern, location, and cause. Cracks can be either active or dormant (inactive). Active cracks widen, deepen, or migrate through the concrete. Dormant cracks remain unchanged. Some dormant cracks, such as those caused by shrinkage during the curing process, pose no danger, but if left unrepaired, they can provide convenient channels for moisture penetration, which normally causes further damage.

Structural cracks can result from temporary or continued overloads, uneven foundation settling, or original design inadequacies. Structural cracks are active if the overload is continued or if settlement is ongoing; they are dormant if the temporary overloads have been removed, or if differential settlement has stabilized. Thermally-induced cracks result from stresses produced by temperature changes. They frequently occur at the ends or corners of older concrete structures built without expansion joints capable of relieving such stresses. Random surface cracks (also called "map" cracks due to their resemblance to the lines on a road map) that deepen over time and exude a white gel that hardens on the surface are caused by an adverse reaction between the alkalis in a cement and some aggregates.

Since superficial repairs that do not eliminate underlying causes will only tend to aggravate problems, professional consultation is recommended in almost every instance where noticable cracking occurs.

Spalling is the loss of surface material in patches of varying size. It occurs when reinforcing bars corrode, thus creating high stresses within the concrete. As a result, chunks of concrete pop off from the surface. Similar damage can occur when water absorbed by porous aggregates freezes. Vapor-proof paints or sealants, which trap moisture beneath the surface of the impermeable barrier, also can cause spalling. Spalling may also result from the improper consolidation of concrete during construction. In this case, water-rich cement paste rises to the surface (a condition known as laitance). The surface weakness encourages scaling, which is spalling in thin layers.

Deflection is the bending or sagging of concrete beams, columns, joists, or slabs, and can seriously affect both the strength and structural soundness of concrete. It can be produced by overloading, by corrosion, by inadequate construction techniques (use of low-strength concrete or undersized reinforcing bars, for example), or by concrete creep (long-term shrinkage). Corrosion may cause deflection by weakening and ultimately destroying the bond between the rebar and the concrete, and finally by destroying the reinforcing bars themselves. Deflection of this type is preceded by significant cracking at the bottom of the beams or at column supports. Deflection in a structure without widespread cracking, spalling, or corrosion is frequently due to concrete creep.

Stains can be produced by alkali-aggregate reaction, which forms a white gel exuding through cracks and hardening as a white stain on the surface. Efflorescence is a white, powdery stain produced by the leaching of lime from Portland cement, or by the pre-World War II practice of adding lime to whiten the concrete. Discoloration can also result from metals inserted into the concrete, or from corrosion products dripping onto the surface.

Erosion is the weathering of the concrete surface by wind, rain, snow, and salt air or spray. Erosion can also be caused by the mechanical action of water channeled over concrete, by the lack of drip grooves in beltcourses and sills, and by inadequate drainage.

Corrosion, the rusting of reinforcing bars in concrete, can be a most serious problem. Normally, embedded reinforcing bars are protected against corrosion by being buried within the mass of the concrete and by the high alkalinity of the concrete itself. This protection, however, can be destroyed in two ways. First, by carbonation, which occurs when carbon dioxide in the air reacts chemically with cement paste at the surface and reduces the alkalinity of the concrete. Second, chloride ions from salts combine with moisture to produce an electrolyte that effectively corrodes the reinforcing bars. Chlorides may come from seawater additives in the original mix, or from prolonged contact with salt spray or de-icing salts. Regardless of the cause, corrosion of reinforcing bars produces rust, which occupies significantly more space than the original metal, and causes expansive forces within the concrete. Cracking and spalling are frequent results. In addition, the load-carrying capacity of the structure can be diminished by the loss of concrete, by the loss of bond between reinforcing bars and concrete, and by the decrease in thickness of the reinforcing bars themselves. Rust stains on the surface of the concrete are an indication that internal corrosion is taking place.

PLANNING FOR CONCRETE PRESERVATION

Whatever the causes of deterioration, careful analysis, supplemented by testing, is vital to the success of any historic concrete repair project. Undertaken by experienced engineers or architects, the basic steps in a program of testing and analysis are document review, field survey, testing, and analysis.

Document Review. While plans and specifications for older concrete buildings are rarely extant, they can be an invaluable aid, and every attempt should be made to find them. They may provide information on the intended composition of the concrete mix, or on the type and location of reinforcing bars. Old photographs, records of previous repairs, documents for buildings of the same basic construction or age, and news reports may also document original construction or changes over time.

Field Survey. A thorough visual examination can assist in locating and recording the type, extent, and severity of stress, deterioration, and damage.

Testing. Two types of testing, on-site and laboratory, can supplement the field condition survey as necessary. On-site, nondestructive testing may include use of a calibrated metal detector or sonic tests to locate the position, depth, and direction of reinforcing bars (see fig. 9). Voids can frequently be detected by "sounding" with a metal hammer. Chains about 30 inches long attached to a 2-foot-long crossbar, dragged over the slabs while listening for hollow reverberations, can locate areas of slabs that have delaminated. In order to find areas of walls that allow moisture to penetrate to the building interior, areas may be tested from the outside by spraying water at the walls and then inspecting the interior for water. If leaks are not readily apparent, sophisticated equipment is available to measure the water permeability of concrete walls.

If more detailed examinations are required, nondestructive instruments are available that can assist in determining the presence of voids or internal cracks, the location and size of rebars, and the strength of the concrete. Laboratory testing can be invaluable in determining the composition and characteristics of historic concrete and in formulating a compatible design mix

Fig. 9. Nondestructive sonic tests are one way of determining the location and soundness of internal reinforcing bars and the hardness of the concrete. There are a variety of other nondestructive tests provided by professional consultants that will help in the evaluation of the structural integrity of concrete prior to major repair work. Photo: Feld, Kaminetzky and Cohen and American Concrete Institute.

for repair materials (see fig. 10). These tests, however, are expensive. A well-equipped concrete laboratory can analyze concrete samples for strength, alkalinity, carbonation, porosity, alkali-aggregate reaction, presence of chlorides, and past compostion.

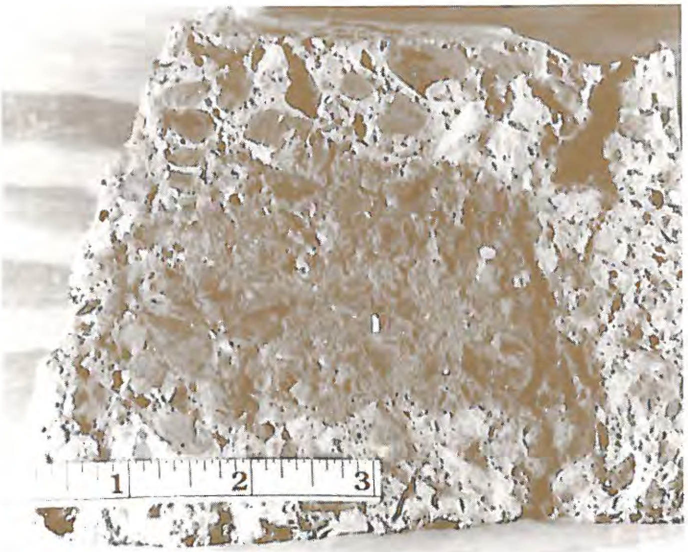

Fig. 10. Testing of actual samples of concrete in the lab may be necessary to determine the strength and condition of the concrete. In this sample, the surface, which is lighter than the sound concrete core, shows that carbonation has taken place. Carbonation reduces the alkalinity in concrete and may hasten corrosion of reinforcing bars close to the surface. Photo: Stella L. Marusin.

Analysis. Analysis is probably the most important step in the process of evaluation. As survey and test results are revised in conjunction with available documentation, the analysis should focus on determining the nature and causes of the concrete problems, on assessing both the short-term and long-term effects of the deterioration, and on formulating proper remedial measures.

CONCRETE REPAIR

Repairs should be undertaken only after the planning measures outlined above have been followed. Repair of historic concrete may consist of either patching the historic material or filling in with new material worked to match the historic material. If replacement is necessary, duplication of historic materials and detailing should be as exact as possible to assure a repair that is functionally and aesthetically acceptable (see fig. 11). The correction and elimination of concrete problems can be difficult, time-consuming, and costly. Yet the temptation to resort to temporary solutions should be avoided, since their failure can expose a building to further and more serious deterioration, and in some cases can mask underlying structural problems that could lead to serious safety hazards (see fig. 12).

Principal concrete repair treatments are discussed below. While they are presented separately here, in practice, preservation projects typically incorporate multiple treatments (see figs. 13a-i).

Fig. 11. Meridian Hill, Washington, D.C. (1934). It is important to match the visual qualities, such as color and texture, when repairs or replacement sections are undertaken. In this case, the new replacement step, located second from the left, matches the original pebble-finish surface of the adjacent historic steps. Photo: Sharon C. Park, AIA.

Fig. 12. Without proper preparation and correction of a pre-existing problem, repairs will fail. Insufficient concrete at the surface caused this patch around a reinforcing bar to fail within a year. In this case, a structural engineer should have assessed the need for this rod so close to the surface. Redundant rods are often cut out prior to patching. Photo: Alonzo White.

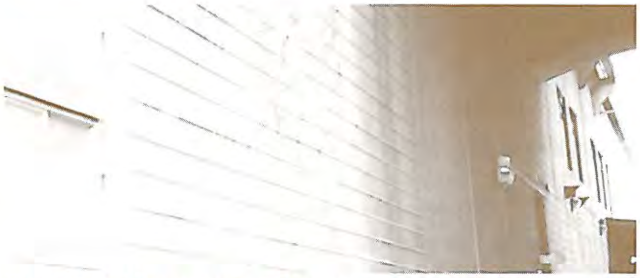

Fig. 13a. Buckling concrete under a painted surface indicates underlying deterioration. It is often difficult to assess the amount of deterioration until the area has been cleaned and examined closely.

Fig. 13b. Upon removal of the deteriorated surface, a pocket of poorly mixed concrete (mostly sand and gravel) was easily chiseled out. The reinforcing rods were in good condition.

Fig. 13c. Narrow cracks often need to be widened to receive concrete patches. Here a pneumatic chisel is being used.

Fig. 13d. Deteriorated or redundant reinforcing bars are removed after evaluation by a structural engineer. An acetylene torch is being used to cut out the bars.

Fig. 13e. A spalled area of concrete has been cleaned back to a sound surface, and is being coated with a bonding agent to increase adherence of the new concrete patch.

Fig. 13f. Workmen are applying patching concrete and using a trowel to form ridges to match the appearance of the historic concrete ridges that were originally created by the form boards.

Fig. 13g. A soft brush is used to smooth the patch and to blend it with the adjacent historic concrete.

Fig. 13h. This active crack at a window sill and in the foundation wall has been filled with a flexible sealant. This area was subsequently painted with a masonry paint compatible with the sealant.

Fig. 13i. Upon completion of all repairs, the building was painted. The finished repair of the deterioration seen in 13a and b is shown in this photograph. The patch matches the texture and detailing of the historic concrete.

Fig. 13a-i. Virginia Heating Plant, Arlington, Virginia (1941). This reinforced concrete building exhibits several serious problems, including cracking, spalling, and corrosion of reinforcing bars. As a result of careful planning and close supervision, successful repairs have been carried out. Photos: Alonzo White and Sharon C. Park, AIA.

Repair of Cracking. Hairline, nonstructural cracks that show no sign of worsening normally need not be repaired. Cracks larger than hairline cracks, but less than approximately one-sixteenth of an inch, can be repaired with a mix of cement and water. If the crack is wider than one-sixteenth of an inch, fine sand should be added to the mix to allow for greater compactibility, and to reduce shrinkage during drying. Field trials will determine whether the crack should be routed (widened and deepened) minimally before patching to allow sufficient penetration of the patching material. To ensure a long-term repair, the patching materials should be carefully selected to be compatible with the existing concrete as well as with subsequent surface treatments such as paint or stucco.

When it is desirable to reestablish the structural integrity of a concrete structure involving dormant cracks, epoxy injection repair should be considered. An epoxy injection repair is made by sealing the crack on both sides of a wall or a structural member with an epoxy mortar, leaving small holes, or "ports" to receive the epoxy resin. After the surface mortar has hardened, epoxy is pumped into the ports. Once the epoxy in the crack has hardened, the surface mortar can be ground off, but the repair may be visually noticeable. (It is possible to inject epoxy without leaving noticeable patches, but the procedure is much more complex.)

Other cracks are active, changing their width and length. Active structural cracks will move as loads are added or removed. Thermal cracks will move as temperatures fluctuate. Thus, expansion-contraction joints may have to be introduced before repair is undertaken. Active cracks should 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-filled cracks require considerable attention, or else they will detract from the appearance of the historic building.

Random (map) cracks throughout a structure are difficult to correct, and may be unrepairable. Repair, if undertaken, requires removing the cracked concrete. A compatible concrete patch to replace the removed concrete is then installed. For some buildings without significant historic finishes, an effective and economical repair material is probably a sprayed concrete coating, troweled or brushed smooth. Because the original concrete will ultimately contaminate new concrete, buildings with map cracks will present continuing maintenance problems.

Repair of Spalling. Repair of spalling entails removing the loose, deteriorated concrete and installing a compatible patch that dovetails into the existing sound concrete. In order to prevent future crack development after the spall has been patched and to ensure that the patch matches the historic concrete, great attention must be paid to the treatment of rebars, the preparation of the existing concrete substrate, the selection of compatible patch material, the development of good contact between patch and substrate, and the curing of the patch.

Once the deteriorated concrete in a spalled area has been removed, rust on the exposed rebars must be removed by wire brush or sandblasting. An epoxy coating applied immediately over the cleaned rebars will diminish the possiblity of further corrosion. As a general rule, if the rebars are so corroded that a structural engineer determines they should be replaced, new supplemental reinforcing bars will normally be required, assuming that the rebar is important to the strength of the concrete. If not, it is possible to cut away the rebar.

Proper preparation of the substrate will ensure a good bond between the patch and the existing concrete. If a large, clean break or other smooth surface is to be patched, the contact area should be roughened with a hammer and chisel. In all cases, the substrate should be kept moist with wet rags, sponges, or running water for at least an hour before placement of the patch. Bonding between the patch and substrate can be encouraged by scrubbing the substrate with cement paste, or by applying a liquid bonding agent to the surface of the substrate. Admixtures such as epoxy resins, latexes, and acrylics in the patch may also be used to increase bonding, but this may cause problems with color matching if the surfaces are to be left unpainted.

Compatible matching of patch material to the existing concrete is critical for both appearance and durability. In general, repair material should match the composition of the original material (as revealed by laboratory analysis) as closely as possible so that the properties of the two materials, such as coefficient of thermal expansion and strength, are compatible. Matching the color and texture of the existing concrete requires special care. Several test batches of patching material should be mixed by adding carefully selected mineral pigments that vary slightly in color. After the samples have cured, they can be compared to the historic concrete and the closest match selected.

Contact between the patch and the existing concrete can be enhanced through the use of anchors, preferably stainless-steel hooked pins, placed in holes drilled into the structure and secured in place with epoxy. Good compaction of the patch material will encourage the contact. Compaction is difficult when the patch is "laid-up" with a trowel without the use of forms; however, by building up thin layers of concrete, each layer can be worked with a trowel to achieve compaction. Board forms will be necessary for large patches. In cases where the existing concrete has a significant finish, care must be taken to pin the form to the existing concrete without marring the surface. The patch in the form can be consolidated by rodding or vibration.

Because formed concrete surfaces normally develop a sheen that does not match the surface texture of most historic concrete, the forms must be removed before the patch has fully set. The surface of the patch must then be finished to match the historic concrete. A brush or wet sponge is particularly useful in achieving matching textures. It may be difficult to match historic concrete surfaces that were textured, as a result of exposed aggregate for example, but it is important that these visual qualities be matched. Once the forms are removed, holes from the bolts must also be patched and finished to match adjacent surfaces.

Regardless of size, a patch containing cement binder (especially Portland cement) will tend to shrink during drying. Adequate curing of the patch may be achieved by keeping it wet for several days with damp burlap bags. It should be noted that although greater amounts of sand will reduce overall shrinkage, patches with a high sand content normally will not bond well to the substrate.

Repair of Deflection. Deflection can indicate significant structural problems and often requires the strengthening or replacement of structural members. Because deflection can lead to structural failure and serious safety hazards, its repair should be left to engineering professionals.

Repair of Erosion. Repair of eroded concrete will normally require replacing lost surface material with a compatible patching material (as outlined above) and then applying an appropriate finish to match the historic appearance. The elimination of water coursing over concrete surfaces should be accomplished to prevent further erosion. If necessary, drip grooves at the underside of overhanging edges of sills, beltcourses, cornices, and projecting slabs should be installed.

SUMMARY

Many early concrete buildings in the United States are threatened by deterioration. Effective protection and maintenance are the keys to the durability of concrete. Even when historic concrete structures are deteriorated, however, many can be saved through preservation projects involving sensitive repair (see figs. 14a-c), or replacement of deteriorated concrete with carefully selected matching material (see figs. 15a-c). Successful restoration of many historic concrete structures in America demonstrates that techniques and materials now available can extend the life of such structures for an indefinite period, thus preserving significant cultural resources.

Fig. 14a. Spalled concrete was most noticeable at locations of concentrated rebars. Deteriorated concrete, the 1960s stucco finish, and corrosion were removed by grit-blasting. Photo: Robert Bell.

Fig. 14b. Board screeds were attached to the building to recreate the sharp edges of the original detail. Photo: Robert Bell.

Fig. 14c. Once the repair work was complete, the entire building was sprayed with a concrete mixture consisting of pea-gravel, cement, and sand, which was then hand-troweled. Finally, the building was lightly grit-blasted to remove the cement paste and reproduce the exposed agregate finish. Photo: Harry J. Hunderman.

Fig. 14a-c. Unity Temple, Oak Park, Illinois (1906). Architect Frank Lloyd Wright used cast-in-place concrete with an exposed aggregate finish. However, reinforcing bars placed too close to the surface resulted in corrosion, cracking, and spalling. A superficial repair in the 1960s coated the surface with a concrete mix and Portland cement paint which produced a stucco-like finish and accelerated deterioration. Repair work was undertaken in 1971.

Fig. 15a. The spindle-type railings were deteriorated beyond repair. The concrete was cracked or broken and the center reinforcing rods were exposed and badly rusted.

Fig. 15b. Deteriorated spindles were removed. The original 1914 molds were still available and used in casting new concrete spindles, but had they not been available, new molds could have been made to match the originals.

Fig. 15c. The new concrete spindles have been installed. This sensitive renovation reused the historic concrete cap railing and stone piers, as they were still in sound condition.

Fig. 15a-c. Columbia River Highway, Oregon. This historic highway overlooking the Columbia River Gorge was constructed from 1913 to 1922 and contains a number of significant concrete bridges. These photos illustrate the sensitive replacement of the concrete spindle-type balusters on the Young Creek (Shepperd's Dell) Bridge of 1914. Photos: James Norman, Oregon Department of Transportation.

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Cover: Baha'i Temple, Wilmette, Illinois (1933). Photo: William B. Coney.

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38 Preservation Briefs

Technical Preservation Services
National Park Service
U.S. Department of the Interior

Removing Graffiti from Historic Masonry

Martin E. Weaver

» Identifying the Graffiti and the Masonry
» Graffiti Removal Methods and Materials
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A NOTE TO OUR USERS: The web versions of the **Preservation Briefs** differ somewhat from the printed versions. Many illustrations are new, captions are simplified, illustrations are typically in color rather than black and white, and some complex charts have been omitted.

Removing graffiti as soon as it appears is the key to its elimination--*and* recurrence. Thus, the intent of this Preservation Brief is to help owners and managers of historic masonry structures find the best way to remove exterior, surface-applied graffiti* quickly, effectively, and safely. The Brief will discuss the variety of materials used to apply graffiti, and offer guidance on how to remove graffiti from all types of historic masonry without harming either the surface or the substrate. Suggestions will also be given regarding the use of physical barriers to protect masonry surfaces from graffiti, and the application of barrier coatings to facilitate graffiti removal. Building managers and owners of historic properties will be advised on the importance of being prepared for rapid graffiti removal by testing different cleaning techniques in advance in order to select the most appropriate and sensitive cleaning technique. Health and safety and environmental concerns are addressed, as well as regulatory matters. Removing graffiti without causing damage to historic masonry is a job for trained maintenance crews, and in some cases, professional conservators, and generally should not be attempted by untrained workers, property owners or building managers. Although the focus of this Preservation Brief is on *historic* masonry, the same guidance may be applied equally to removing graffiti from non-historic masonry.

Identifying the Graffiti and the Masonry

Successful graffiti removal from historic masonry depends on achieving a balance between breaking the bond between the graffiti and the masonry surface without damaging the masonry.

This generally requires knowledge both of the materials used to make the graffiti and the masonry on which the graffiti has been executed, as well as knowledge of cleaning methods and materials. Without this, masonry surfaces can be badly disfigured or damaged during graffiti removal.

*The word *graffito* (*graffiti*, plural) -- is derived from the old Italian diminutive of *graffio*-to scratch, and the Latin *graphire*-to write. *Graffiti* in contemporary usage has come to mean an inscription, drawings, or markings. Except in very formal or technical applications, *graffiti* is generally considered a "mass" noun and paired with a singular verb.

Inappropriate abrasive blasting to remove the graffiti has permanently etched the graffiti into the stone. Photo: NPS files.

Graffiti. Most graffiti is made with spray paints. Although a number of solvents and paint strippers are capable of dissolving or breaking down these paints, some may permanently discolor or stain the masonry surface if not used correctly. As a result, the remaining paint may become more difficult, or even impossible, to remove. Poorly thought-out and generally hasty attempts to remove graffiti using harsh chemicals or abrasives can also cause permanent damage to the masonry that may be worse than the graffiti.

The ability to identify the graffiti material is an important step in successful removal. Numerous kinds of spray paint (polyurethanes, lacquers, and enamels), and brush-applied paints (oils and synthetic resins such as vinyls, acrylics, acetates, methacrylates, or alkyds), as well as permanent felt markers are the materials most often used to make graffiti. But other materials are also used for graffiti, including water-soluble felt markers, ballpoint pens, chalk, graphite and colored pencils, pastels, wax and oil crayons, liquid shoe polish, and lipstick. The range of materials adopted by graffitists continues to expand.

Paints are composed of pigments that provide color and hiding power; binder that holds the pigments together and to the substrate; and a solvent that allows the pigment/binder mixture to flow. Some spray paints and markers may contain dyes instead of pigments. Paints are applied wet. Generally, as the solvent evaporates, the binder solidifies. The greater the solvent content of the paint, the greater the flow rate, and thus, the greater the ability of the paint to penetrate into masonry pores.

The two primary components contained in most graffiti materials--pigment or dye, and binder--may simply remain on the masonry surface, or penetrate into the masonry to varying depths depending on a number of factors, including the surface tension of the substrate and viscosity of the solvent or vehicle. Thus, even the total removal of the pigment or the binder may leave residues of the other component actually in, or below, the surface of the stone. Residual stains, or graffiti "ghosts," such as those from any kind of red paint or the fine black pigments used in spray paints, may be particularly difficult to remove. With painted graffiti, it is helpful to establish how long it has been on the surface. For most paints that have been on the surface for several weeks or months, hardening processes are likely to be complete or well-advanced; the solubility of the paint is proportionately reduced and it will be more difficult to remove.

Masonry. The historic masonry substrate must also be identified. As used here, the term *masonry* encompasses all types of natural stones; manufactured clay materials, including brick and terra cotta; and cementitious materials, such as cast stone, concrete and mortar. The common factor among masonry materials is that they are porous, to a greater or lesser extent, and sensitive to abrasion. After identifying the masonry, its condition, including fragility, porosity and permeability, must also be assessed prior to beginning graffiti removal. For example, a smooth, newly-polished granite surface is comparatively easy to clean because it is relatively impermeable and paint vehicles tend to stay on the surface rather than penetrate into microscopic pores. A very smooth, polished surface also has no pits or crevices that will retain particles of pigment or binder. In contrast, weathered marble or limestone may be extremely porous and permeable, with a rough surface on which particles of pigment can easily lodge. The fragility of such a surface can make it impossible to clean the surface even with a bristle brush without risking severe surface loss. A difference in surface texture or finish may also be the reason that a particular cleaning agent will work in one situation but not another.


Spray painted graffiti defaces this historic brick building. Photo: NPS files.

Some types of masonry may react adversely to contact with the various cleaning agents required to break or dissolve the bond between the graffiti and the masonry surface. Thus, for purposes of cleaning, masonry types are often categorized according to whether they are acid-sensitive, non-acid sensitive, or alkali-sensitive. *Acid-sensitive* stones consisting of carbonate materials may be damaged or even destroyed by contact with acids. Although, in many instances, acidic cleaning compounds are not effective for graffiti removal and generally should not be used for this purpose, it is useful to know that some acid-sensitive materials include: stones such as limestone, marble, travertine, calcareous sandstones and shales; most polished stones; and glazed architectural terra cotta and glazed brick. *Non-acid sensitive* masonry materials include slate, granite, unglazed architectural terra cotta and unglazed brick. *Alkali-sensitive* stones may contain silicates, or ferrous, soluble iron compounds that can react with alkalis or water to form severe staining. *Alkali-sensitive* stones include some granites, Indiana limestone, and many types of sandstone, especially those that are green or grey in color. Glazed and polished surfaces tend to be damaged by both strong acids and strong alkalis.

Graffiti Removal Methods and Materials

A variety of treatments are available from which to choose the most appropriate method of graffiti removal that will not damage the surface of historic masonry. Removal techniques, which are chosen according to the type of graffiti and the masonry, range from simply erasing pencilled graffiti with soft erasers, or removing chalked graffiti with soft brushes, to poulticing with water (with or without detergents), poulticing with organic solvents or alkali-based paint removers, or applying bleach to remove painted graffiti. In very limited situations, it may mean using very delicate and controlled abrasive means. Successful graffiti removal often requires a combination of cleaning materials and methods.


A poultice is ofen the preferred method of graffiti removal.

Poulticing

Photo: NPS files.

The most effective method of removing graffiti from masonry usually involves the use of a poultice. A poultice consists of an absorbent material or powder-inert clays such as kaolin or sepiolite, diatomaceous earth (fuller's earth); or cellulose products such as fluff pulp cellulose or shredded paper-mixed with a cleaning solution (a liquid reagent such as water, organic solvent, paint stripper or bleach) to form a paste or slurry. The purpose of a poultice is twofold: it enables a cleaning solution to be kept in contact with the stained area as long as possible, while allowing the cleaning solution to pull the staining material out of the substrate via the poultice without redepositing it in, or restaining, the masonry. A poultice is often covered with a plastic sheet to retard evaporation. With some extremely porous types of stone, such as marble, although a poultice may remove a stain from one side of the stone, stains can pass completely through the stone and be redeposited on the other side of the masonry slab. Thus, caution should always be exercised in stain and graffiti removal.


Painting over graffiti on stone is not a recommended maintenance treatment. Photo: NPS files.

Water and Detergent. Graffiti removal from historic masonry should always begin with the gentlest means possible. In some instances, this means low-pressure water washing. Fresh graffiti-one or two days old-made with water-soluble markers may sometimes be removed with water, possibly aided by a neutral or non-ionic detergent. (Non-ionic detergents which do not ionize in solution, do not deposit a solid, visible residue.) Ammonia can also be effective in removing fresh graffiti. Any detergent should be approached with caution and tested before using because most commercial laundry detergents are not neutral and contain substances which may leave undesirable residues on masonry materials. Usually, the water and detergent should be mixed with an absorbent material and applied in the form of a poultice. Although water washing is often likely to be the gentlest cleaning method for historic masonry, it may not be as effective for removing graffiti because many graffiti materials are not soluble in water.

Organic Solvents and Paint Removers. Most graffiti can be removed without damaging the masonry with proprietary graffiti-removal products and commercial paint strippers containing organic solvents. But, these products should always be tested and used in accordance with manufacturer's instructions included in the product literature. Normally, solvents should be used in a poultice form to prevent them from penetrating into the substrate, and permanently discoloring or staining the masonry. A number of paint-removers are manufactured as thick gels or pastes that cling to the surface, and some commercial paint-removal products include a tough fiber-reinforced paper or cloth backing that retards evaporation and also facilitates neat and clean removal of the used stripper. The advantage of using organic solvents is that they evaporate completely, leaving no residual material in the masonry. However, organic solvents may present a severe health hazard, and workers using them must wear adequate protection. "Off-the-shelf" aerosol graffiti removers generally should not be used because the dissolved paint being removed may run down the wall "staining" a previously clean area; or pigments may also be redistributed by the rinsing and scrubbing recommended by the product manufacturer.

Alkaline Compounds. Alkaline compounds may be used to remove some oils and greases, and waxes from *non-alkali sensitive* masonry. Like organic solvents, alkaline compounds should generally be used in conjunction with a poultice when removing graffiti. The use of alkaline compounds should always be followed by a weak acid wash and a water rinse in order to neutralize-or remove-all the alkaline residues from the masonry. Strong alkalies (pH13-14), such as sodium hydroxide-based paint removers (caustic soda or lye), generally should not be used as they can cause efflorescence and staining on masonry surfaces, if not properly neutralized. Potassium and other hydroxide paint removers may react with iron compounds in some masonry, particularly Indiana limestone, to form dark brown (rust-colored), or black ferric hydroxide stains, which are very difficult to remove.

Bleaches. Alkali-based bleaches such as calcium hypochlorite can sometimes be used very successfully in a poultice to bleach or decolorize certain dyes contained in some paints and inks that cannot readily be removed by other means.


Damaging graffiti removal methods have scarred the marble. Photo: NPS files.

Mechanical or Abrasive Methods. Mechanical treatments include dry or wet blasting, using abrasive grits, such as sand, dolomite powder, aluminum oxide, ground-walnut shells, sodium bicarbonate (baking soda), and others; high-pressure water washing; and mechanical sanding or grinding. All of these abrasive methods will cause damage to masonry and, in most instances, should never be considered as a method of removing graffiti from historic masonry. Abrasive methods used mistakenly by untrained workers to remove graffiti usually result in etching the outline of the graffiti permanently into the masonry. Some historic masonry materials can be easily damaged by pressure washing even at low or moderate pressures (100-400 psi). Occasionally, however, under very controlled circumstances, a *micro-abrasive* technique may be appropriate for removing graffiti from delicate masonry surfaces, if used at low pressures of 35-40 psi with fine abrasives.

This treatment, which must be done very slowly and carefully to avoid damaging the masonry, should be tested first, and undertaken only by a professional conservator. Another exception, even though it is not strictly an abrasive treatment, is using a razor blade as a first step to remove spray paint or felt-tip marker from polished granite. However, this too, should be undertaken only by a *professional conservator*, and only on *polished granite*, which is very hard and generally impervious to scratches.

Laser Cleaning. Although not in general use as a cleaning technique, laser technology offers great promise in the future as a non-damaging method of graffiti removal.

Testing

Before selecting a removal method, all cleaning materials and techniques for removing graffiti from a historic masonry building should be tested on mock-ups or areas of the resource that are not highly visible, but which are representative of typical conditions. Visual observation should be supplemented by the use of a magnifying glass, and spot tests should be carried out with various solvents to help identify the specific graffiti medium, which will aid in its removal. More complex testing using laboratory equipment and more scientific analytical processes may sometimes be necessary in complex situations. Sample areas that represent the desired degree of "cleanliness" should be approved in writing by client, architect, conservator or other appropriate authority. The materials and all the other data necessary to reproduce the desired cleaning results should be meticulously recorded and the accepted sample area preserved for reference until the end of the job. The existence of a "clean" sample for comparison and a signed agreement can avoid unpleasant surprises, misunderstandings, and perhaps legal actions.

When a type of graffiti appears for the first time that was executed with a material not immediately recognizable and for which no countermeasures have been developed, tests may need to be carried out by an architectural conservator to identify the material and to determine effective removal treatments. Agencies with large inventories of graffiti-prone buildings and structures should watch for graffiti made with new materials and experiment with different cleaning methods in order to be prepared when it appears. Such early action can save large sums of money in the long term. (See "Development of a Treatment Plan.")

Health and Safety Considerations

Most of the chemicals used for graffiti removal are dangerous to workers, as well as to others who may be in the vicinity. Organic solvents are toxic by ingestion, inhalation, and skin contact. Material Safety Data Sheets (MSDS), available from the product manufacturer for all paint-removal products, should always be consulted and followed. Identification of hazardous components and checking with chemical reference works will help assure that the least hazardous, but most effective, products are selected.

Generally speaking, it is a sensible policy to carry out all graffiti removal in well-ventilated conditions. Some solvents can be used only outdoors, and sometimes forced ventilation may be necessary even there, requiring workers to use air-fed respiratory equipment to avoid wind-blown fumes. Smoking, eating or drinking must not be allowed when cleaning is in progress.

Some materials used for graffiti removal are so corrosive that accidental contact can cause serious, permanent scarring and painful injuries. Wearing appropriate protective clothing must be strictly enforced. Mandatory personal protective equipment (PPE) normally includes face shields or safety glasses; long, chemical-resistant gloves; face masks with respirators for organic solvents; and possibly, full protective clothing with an independent air supply.

All smoking and open flames should be rigorously excluded from work areas; many solvents are flammable or highly explosive in vapor or liquid form when mixed with air. Solvent residue, used swabs, cloths, overalls and all other solvent-contaminated items should be safely and legally disposed of, or properly stored-even overnight-away from potential sources of fire. Electrical equipment may require explosion-proof fittings when used with certain solvents.

When electric pumps and pressure-spraying equipment are used, it is especially important that all necessary precautions be taken to avoid electric shock. Water sprays and puddles on the ground present a potentially dangerous situation, if they come into contact with temporary wiring at worksites where graffiti is being removed. Such hazards must be carefully monitored and controlled.

As with any construction project, attention should always be directed toward the general safety of the workers and passers-by, but also toward possible damage to the resource itself that might result from careless placement of ladders, or scaffolding. Chemicals used for masonry cleaning can also damage adjacent metals, glass, and painted surfaces, as well as vegetation. Product manufacturers' instructions should always be closely followed to avoid such inadvertent "collateral" damage.

Environmental Considerations

To protect against environmental contamination, including the formation of unwanted ozone at ground level and damage to the ozone layer in the earth's outer atmosphere, legislation has been enacted in some states making it illegal to use even moderate quantities of some solvents--*volatile organic compounds (VOCs)* contained in paint removers. In response to this legislation, many new products are being developed that do not contain VOCs.

After completing graffiti removal, the disposal of chemical products and rinsing effluent must be taken into account. Arrangement for disposal of the cleaning waste should be made *prior* to beginning graffiti removal, especially if it is a project of considerable size. In many places it is illegal to discharge solvents and/or paint residues into sewers or storm drains. The owner or manager of a historic property, or in some cases the individual or firm doing the cleaning or graffiti removal, is responsible for being informed of, and complying with, relevant laws and regulations. Under provisions of the National Historic Preservation Act of 1966, as amended, approval may be required from a state or federal preservation agency before any work can be undertaken on buildings or structures listed in or eligible for listing in the National Register of Historic Places, if such a project involves federal funding or licensing. Many state and local historic district commissions and review boards have their own regulations that require approval for cleaning or graffiti removal work that is undertaken on landmarks or properties in locally designated historic districts.

Barrier Coatings

Anti-graffiti or barrier coatings are intended to facilitate the removal of graffiti from porous as well as non-porous surfaces. These coatings are most commonly transparent, but may also be pigmented. They are available in a variety of formulations designed to serve different needs. The use of barrier coatings to protect graffiti-prone historic masonry surfaces may seem to be an easy preventive solution to a persistent graffiti problem. However, for the most part, these coatings are not the panacea that some advertising might suggest. Some of them simply do not work, and others may cause physical or aesthetic changes or damage to the masonry.

Transparent Coatings. Transparent coatings serve as a barrier between the masonry surface and graffiti, preventing graffiti from penetrating into the masonry. They are also intended to make graffiti removal easier since most graffiti does not adhere well to them. Generally, graffiti applied over transparent barrier coatings can be removed with low-pressure water and a detergent, or with a solvent.

There are basically two kinds of transparent barrier coatings: temporary and permanent. Temporary, or "sacrificial" coatings are removed when graffiti is removed and then must be reapplied. Permanent transparent barrier coatings are more resistant to the water or solvents used to remove graffiti, and remain on the masonry surface when graffiti is removed (although this type of coating also must usually be reapplied after several cleanings). A third type of transparent barrier coating combines temporary and permanent coatings, based on a two-part system.

A water-based acrylic sealer is first applied to the masonry surface, after which a sacrificial layer consisting of a polyethylene wax emulsion or dispersion coat is applied over the sealer. When graffiti is removed, the sealer coat remains on the masonry, but the sacrificial coat dissolves and is removed with the graffiti, and thus must be reapplied. (With this two-part system, even the first coat will eventually wear off after multiple cleanings, and must also be reapplied.)

The difference in color between the bottom and the top of the stone spandrel is the only clue to the presence of a clear barrier coating. Photo: NPS files.

Unfortunately, in application, there are a number of negative aspects of transparent barrier coatings that generally prevent their being recommended for use on historic masonry. First, clear coatings may alter the color of the masonry surface and add a gloss that may be highly visible, or apparent only in certain lighting conditions or when it rains. Second, clear coatings may reduce the water-vapor permeability of the masonry, thereby contributing to possible water-related deterioration. Third, the coating may discolor and change over time. Exposure to ultra-violet light can cause a coating to yellow; dirt build-up may darken the treated surface; and some coatings acquire a sheen when rubbed or brushed against. Such changes are especially noticeable when only a portion of the building has been coated. Furthermore, if coatings are not maintained on a regular basis, usually through periodic removal and reapplication, many coatings tend to fail. What often results is an uneven, "patchy" look to the masonry that can have a very negative impact on the character of the historic building.

Despite these potential drawbacks, there may be some instances in which the graffiti problem or frequency of occurrence is so severe that application of a transparent barrier coating on historic masonry may be worth considering. Some water-base polysaccharide coatings, and silicone and silicone-base coatings have been used with success on masonry structures. They are essentially invisible, and do not change the natural appearance of the masonry. Although less durable than solvent-borne coatings, they are water-vapor permeable (breathable), and may be reapplied to the masonry surface immediately after removing graffiti, while the surface is still damp.

However, extreme caution must be exercised before applying a transparent barrier coating. Experimental test applications should always be tried first on discrete areas that are not highly visible, and the treated areas evaluated over a period of time. Laboratory test results on the performance of coatings applied to samples of like masonry types may be useful to some extent. But because the tests are carried out in a controlled environment, they may not be as accurate or reliable as tests actually carried out on-site where the factors of weather and pollution are the same as those at the location where the coating will be used. If circumstances warrant, and the use of a barrier coating is determined necessary, an architectural conservator should evaluate the test performance of a variety of coatings before selecting one to be applied to historic masonry. Because of the potential for disfigurement, owners of landmark-designated buildings are required by some preservation review boards and landmark commissions to obtain approval before they apply a barrier coating.

Pigmented Coatings. A pigmented barrier coating may be used on masonry as a *permanent*, preventive barrier coating, or as a *temporary* means of concealing graffiti until it can be removed.

This formerly clear barrier coating is very shiny and has discolored as it has aged. Photo: NPS files.

Like a transparent barrier coating, a pigmented barrier coating facilitates the removal of graffiti because graffiti does not adhere well to it. Pigmented barrier coatings that are water-vapor permeable may sometimes be used as a *permanent* barrier coating on non-historic masonry where there is frequent recurrence of graffiti, and when constant surveillance is not possible. Although there are some instances in which pigmented barrier coatings may be appropriate on painted historic masonry, they are **not** recommended for unpainted historic masonry because they will change the appearance of the masonry. There is also another kind of pigmented coating that is specially formulated to be used as a *temporary* measure to conceal graffiti that cannot be removed right away. This temporary, vapor-permeable paint is removed when the graffiti is removed.

Pigmented coatings are also not generally recommended as a permanent measure to cover up graffiti. Some graffiti materials, particularly felt markers, bleed through the coating; and repeated applications of the coating or paint can result in a heavy paint build-up on a masonry surface. Another disadvantage of using paint or a pigmented coating to hide graffiti is that it usually appears as an obvious patch on unpainted masonry and tends to attract more graffiti unless the paint can be applied in a discrete, and well-defined area. If incompatible with either the masonry or the graffiti, such a coating may peel off the masonry surface in an unsightly manner. Like transparent coatings, pigmented coatings may be difficult or impossible to remove completely once their performance or appearance is no longer satisfactory.

Preventing and Controlling Graffiti

Experience shows that prompt removal of graffiti is one of the most effective measures against its recurrence. Graffiti that is not removed quickly tends to attract more graffiti. Often motivated by a need to have their work seen, graffitists tend to be discouraged from repeating their efforts in a location where their work is quickly removed.

Apart from removal, effective graffiti-prevention measures can be considered under two headings. The first consists of physical measures involving maintenance, lighting, security and the erection of barriers on or around the property itself. The second focuses on community awareness programs that include neighborhood patrols, community service programs and educational programs in the schools.

Maintenance and Security. Neglect invites vandalism, whereas a well-maintained property encourages civic pride. Thus, careful attention should be given to establishing regular maintenance programs which do not allow properties to reach a point of obvious deterioration or abandonment. Cyclical maintenance also makes good sense economically.

Graffiti is less likely to occur if graffitists can be clearly seen. It is often recommended that accessible, graffiti-prone areas be illuminated with floodlighting or spotlights. Graffiti may also be reduced or prevented by the presence of security guards, park rangers or police officers, or by the visible presence of surveillance cameras. Publicity about arrests and punitive measures against the graffitists, and the general vigilance of the security system may also reduce graffiti.

If they are historically appropriate and compatible with the historic property, soft barriers in the form of low, possibly thorny, shrubs and bushes or other forms of landscaping and planting may be effective deterrents. Such plantings can make it difficult to reach the property by any route other than the approved secure one. Hard barriers provided by fences and transparent screens or shields, such as clear acrylic or other polycarbonate sheets, may also afford some degree of protection. But these can have a negative aesthetic impact on the property's appearance, particularly if the barriers themselves become disfigured by graffiti.

Community Awareness. Community action and education often play an important role in a successful anti-graffiti program. Neighborhood watches can effectively deter graffitists, and can help police and other security agencies in the detection and prevention of graffiti. Intensive public campaigns against graffiti, including presentations in schools, developing programs to foster community pride, and sentencing offenders to remove graffiti in their own community can also be useful. Publicity concerning arrests of graffitists can be a useful preventive tool. (But, on the other hand, frequent newspaper coverage of graffiti outbreaks or even of new community efforts at deterring graffiti can sometimes have the opposite effect by challenging the "creativity" of graffitists.) Community groups trained in proper cleaning techniques can also assist property owners in prompt and non-damaging graffiti removal.

Summary

Although rapid graffiti removal is the most effective weapon in eliminating graffiti and preventing its recurrence in the same location, hasty, untested removal attempts can disfigure and cause harm to historic masonry. Thus, it is important that the owner or manager of a historic masonry building or structure be prepared with a plan to ensure the prompt removal of graffiti when it occurs. Regularly scheduled maintenance and cleaning programs to eliminate graffiti from historic masonry properties may be assisted by the installation of physical barriers, security systems and lighting, as well as increased community involvement. Successful graffiti removal from historic masonry requires knowledge of a variety of cleaning methods and materials, and an awareness that what works to remove graffiti from one kind of masonry surface may not remove it from another. By testing different cleaning methods in advance, treatment plans will be available, when needed, to provide guidance for safe and sensitive graffiti removal from historic masonry.

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Development of a Treatment Plan.

For managers or owners of historic masonry buildings, or agencies responsible for large inventories of graffiti-prone properties, including parks, highway and railroad bridges and viaducts, bus, train and subway stations, and cemeteries, the development of a treatment plan may be the first step toward an effective graffiti-removal program. It is becoming increasingly common for large or important historic properties to have regular maintenance and disaster plans that include graffiti removal.

When feasible, a separate treatment plan should be prepared for each structure. However, if this is not possible, it is advisable to prepare a variety of treatment plans for specific masonry types. Plans should be prepared to cover all types of masonry that fall under one jurisdiction, management or ownership that are potential targets for graffiti.

Guidance contained in treatment plans should be based on the results of carefully controlled testing to remove a wide variety of common graffiti materials safely, and without damaging the various types of masonry. Individual treatment plans should address all parts of the building or structure that could be disfigured by graffiti, and any features too fragile to be cleaned by anyone other than a conservator should be noted on the plan.

A treatment plan is essentially a cleaning specification, but it should also include information on the following:

- the types and conditions of masonry likely to be targeted by graffiti;
- methods, materials and techniques known to work most successfully in the removal of specific types of graffiti from the surface of each type of masonry;
- sources for materials;
- a list of contractors with expertise in graffiti removal, including names, telephone numbers, information on emergency access to the property, and storage location of materials;
- graffiti-removal methods which may be harmful to the masonry surface;
- contractors or consultants who are **not acceptable** and should not be considered for graffiti removal;
- scaffolding, pumps, or safety equipment that might be required, where it is available, and costs involved; and
- health and safety concerns regarding specific removal treatments, product literature and Material Safety Data Sheets (MSDS).

Criteria to Consider Before Selecting a Barrier Coating as the Primary Protective Means of Combating Graffiti

What to look for in a Barrier Coating:

- Water-vapor permeable, or "breathable".
- "Invisible" without gloss or sheen, when applied to masonry.
- No change in appearance from uncoated areas when masonry is wet.
- Does not discolor or attract dirt.
- Weathers evenly.

Questions to Ask:

- Will the coating last long enough to offset its cost?
- Will the application and reapplication of the coating be cost effective?
- Will the coating be effective against more than one type of graffiti?
- Can the coating be completely and thoroughly removed, so that, if necessary, paint, or another coating will adhere to the masonry surface?
- Will the building ever need to be repointed or patched? A barrier coating may make this difficult or even impossible.

Before Application:

- Seek advice of an architectural conservator.
- Test coating on an inconspicuous area of masonry, or study the success/failure of the coating in other locations where it has been used.

Tips for Successful Graffiti Removal

- It is important to pre-wet the masonry surface when using an alkaline paint remover; it is also advisable to pre-wet the masonry surrounding a graffitied area to dilute the effect of any cleaning agents that might be inadvertently splashed or spilled on the unsoiled surface. **Do not wet the area to be cleaned if the cleaning agent is solvent-based or incompatible with water.**

- Always rinse the cleaning agent off the masonry surface starting at the bottom and moving up. This prevents the cleaning agent from running down and staining a lower surface.

- Air temperature can be a factor in graffiti removal. Most paint removers do not work when the air temperature is either very cold or very hot. This may sometimes explain why a method that worked in one instance may not be effective again in another, similar situation.

- Variations within the same type of stone, such as bedding planes, density, finish, or degree of weathering, may explain why some areas of the same stone sometimes clean better that others.

- Even if advance testing has been done and a treatment plan exists, at least some on-the-spot testing will probably be necessary.

- Mortar joints react differently from masonry units, and may require a different cleaning material and/or method to be cleaned effectively.

- Graffiti removal may result in an obviously "clean" spot. Always clean the entire masonry unit that is bounded by mortar joints (but not the joints themselves, unless necessary). The prominence of the clean spot may be minimized by fanning the cleaning out from the spot, and "feathering" it by gradually reducing the strength or thoroughness of the cleaning.

- If it is not possible to completely remove all traces of graffiti without removing some of the masonry surface, it may be preferable to leave the masonry alone. Some graffiti ghosts become less noticeable with time due to fading of the dyes used in paints and markers. Sometimes it may be possible to conceal more obvious graffiti ghosts with carefully-matched paint.

- After graffiti removal, the masonry surface should always be tested with Ph strips to make sure all the cleaning materials have been completely removed. Non-staining Ph strips, available from chemical supply companies, will indicate whether acids or alkalis remain on the masonry surface.

- Although alkaline paint removers are sometimes ineffective on modern formulations of aerosol paints, they can work well in removing multi-layered graffiti because they last longer.

- What removes graffiti in one instance may not always work again even in what appears to be an identical situation.

- More than one cleaning material and technique may be required to clean a heavily graffitied area if different materials were used to make the graffiti. For example, shapes are often outlined with broad-tipped felt markers and then filled in with spray paint.

- Effective graffiti removal often depends on trial-and-error testing, as well as a knowledge of masonry materials, graffiti materials and cleaning techniques.

Acknowledgements

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Washington, DC. October, 1995

Home page logo: Poultice to remove pig graffiti. Photo: NPS files.

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. Technical Preservation Services (TPS), Heritage Preservation Services Division, National Park Service prepares standards, guidelines, and other educational materials on responsible historic preservation treatments for a broad public.

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APPENDIX CP-6
Historical Resources Report Piers 27, 29 and 31, San Francisco, California

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Draft Historical Resources Report

Piers 27, 29 and 31

San Francisco, California

prepared for

The Port of San Francisco

San Francisco, California

prepared by

Architectural Resources Group

San Francisco, California

September 30, 1999

Updated March 25, 2011

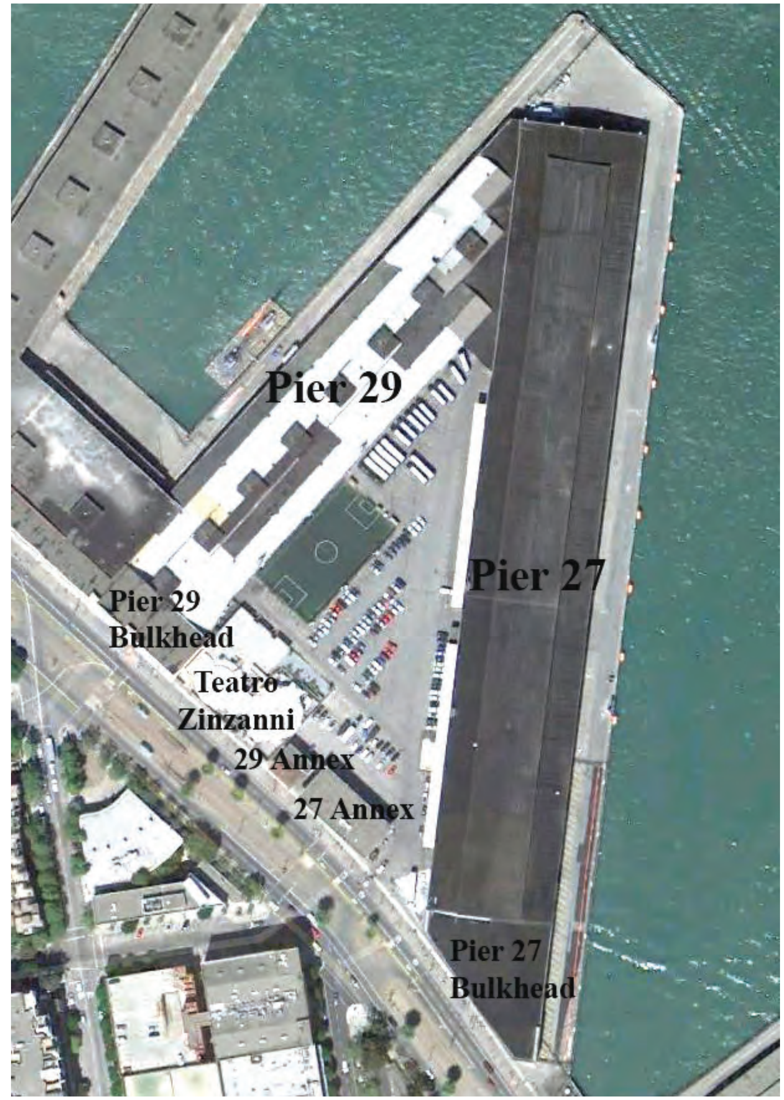
CP6-4

1. Introduction

In July 1999 the Port of San Francisco retained Architectural Resources Group (ARG) to prepare an historic resource report for Piers 27, 29, and 31. For each historic building or structure within the 1999 project area, ARG staff members developed an historical overview, a building description, a conditions analysis, a list of character-defining features, a description of known additions or alterations, and a summary of historic significance.

In advance of modifications to Piers 27 and 29 proposed by AECOM, the Port of San Francisco requested that ARG update the portions of its 1999 report related to the Piers 27-29 complex in order to complement the Port's environmental review process. ARG also completed an assessment of the consistency of the proposed changes with the *Secretary of the Interior's Standards for Rehabilitation*. That assessment is attached as an appendix.

ARG staff members visited and photographed the project site in March 2011 and revised the original report to ensure that it incorporates any significant changes made to the site since



1999. ARG staff members also revised the historical information in the report to ensure it is fully consistent with the extensive documentation that was compiled in support of the Port of San Francisco Embarcadero Historic District's addition to the National Register of Historic Places in 2006. Piers 27 and 29, along with associated ancillary buildings, are located within the boundaries of the Embarcadero Historic District, though, as described below, only Pier 29 and the Pier 29 Annex have been deemed contributors to that district.

For the purposes of this report, a pier is defined as the entire structure (including the pilings and deck) extending from below the surface of the water up to and including any remaining train tracks and the main floor plane. A shed is defined as the building covering the length of the pier, commonly used for storage and transfer of goods. A bulkhead is defined as the building at the Embarcadero entrance of the pier that is separate from (though typically attached to) the shed. More architecturally embellished than the sheds, bulkhead buildings were built to provide a formal entrance to the piers, as well as to house additional storage and office spaces for maritime businesses. A bulkhead connector is a rectangular building that connects two bulkheads but does not have an associated pier or shed.

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View south along the Embarcadero from Pier 37, late 1930s. Photo Source: San Francisco Public Library

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2. San Francisco's Northern Waterfront

Constructed in the 1890s, the first Pier 27 was one of the oldest piers on San Francisco's northern waterfront until it was demolished in the 1960s. Located at the site of the former Lombard Street Wharf, the first Pier 27 was a freight shed, used largely for storage of potatoes and onions shipped from California's Central Valley. Until Piers 29-41 were built in the 1910s, the waterfront immediately north of Pier 27 was developed with a series of small slips for freight steamships. San Francisco Sanborn Maps dating to the early 1900s recorded several freight sheds and cattle corrals along this section of the seawall. Following tradition, this group of piers have odd numbers, as do all the piers north of the Ferry Building, while south of the Ferry Building the piers are assigned even numbers.

Today, piers 29-35 show the influence of both the City Beautiful movement in San Francisco and the Port's need to create utilitarian marine architecture to transfer goods between ship and shore. (Piers 37, 39 and 41 have since been altered and no longer contribute to the port's historical significance.) These piers are a result of the beautification effort undertaken to prepare San Francisco for the 1915 Panama-Pacific International Exhibition to celebrate the opening of the Panama Canal. With the opening of the canal in 1914, the Port of San Francisco was expected to become a world leader in maritime commerce. The city attained this distinction by the mid- to late 1920s, when an inter-coastal rate led to low cargo taxes fueling maritime commerce at the Port of San Francisco. By the early-1930s the monumental bulkheads, which had been constructed since 1915, formed a grand and consistent façade along San Francisco's Embarcadero. The bulkheads reflect the State Board of Harbor Commissioner's desire to express the economic importance and stability of San Francisco's waterfront industries in the reconstruction of an earthquake-shaken city, as well as their City Beautiful-inspired design concept for the Embarcadero.

Piers 29-35 form an intact grouping of bulkhead façades, similar to that of Piers 1-5 closer to the Ferry Building. Pier 35 is 200 feet wide and approximately 900 feet long, and was completed in 1916. The Pier 29 bulkhead was completed in 1917. Piers 31 and 33 were built in 1918 and were of identical size: 800 feet long by 150 feet wide. The two piers, sheds, and bulkhead buildings were designed by architects Oliver Jones

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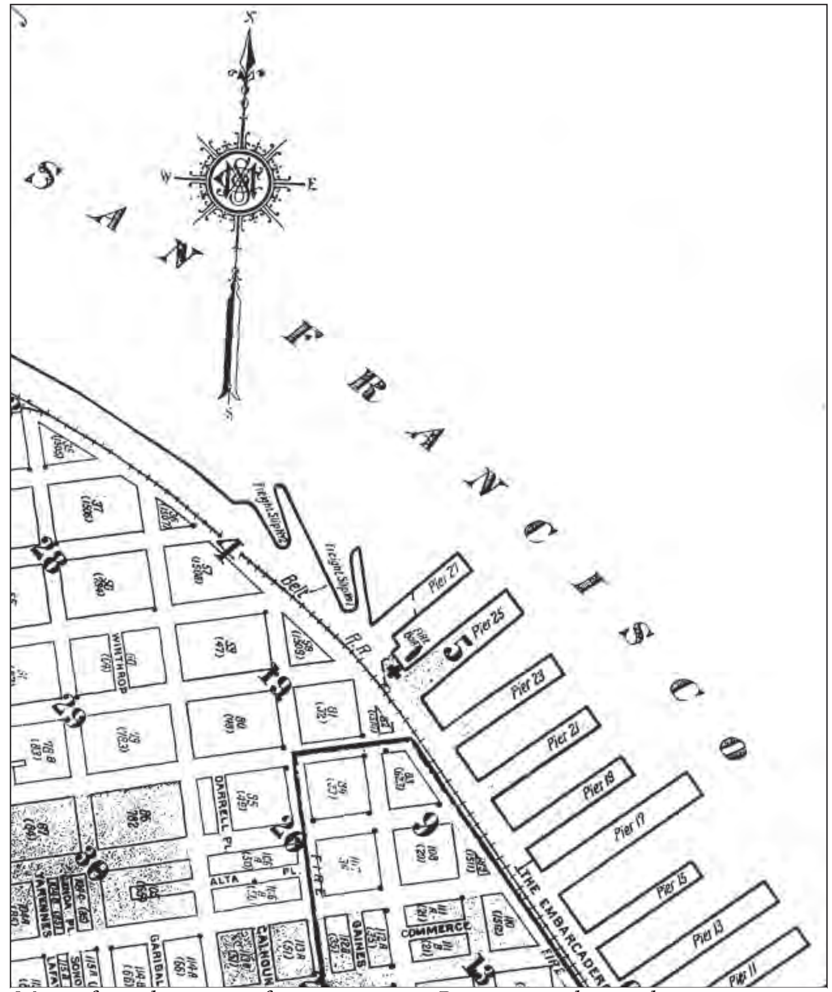
and A. A. Pyle. Their sheds are of similar design, with a row of flat-topped monitor lights down the center. The bulkhead buildings use identical features, albeit in a slightly different configuration, as the Pier 33 bulkhead is slightly more shallow than that of Pier 31. While these piers and bulkheads were not completed by the opening of the 1915 exposition, they had been planned and were under construction as part of the improvements to the waterfront. The Pier 29-35 bulkhead buildings and connector are strong examples of San Francisco's traditional Neoclassical waterfront of the 1910s, and clearly signify the importance of the Port within the city's history.

The San Francisco City Directories through the early 1960s list Piers 29 and 31 as a single entity. By the 1930s and up through 1960, Lukenbach Steamship Company was the major tenant at Piers 29-31. In the 1950s and '60s Lukenbach shared these two piers with Coastwise Lines' Stevedores, Pacific Stevedoring and Ballasting Company, and the West Coast Terminals Company. (Stevedores loaded and unloaded cargo at the piers.)



Map of northern waterfront in 1915. Pier 27 is the northernmost pier, and the Belt Line Railroad is a dominant feature along the Embarcadero. Source: Sanborn Fire Insurance Company, 1915.

3. Pier 27

Historical Overview

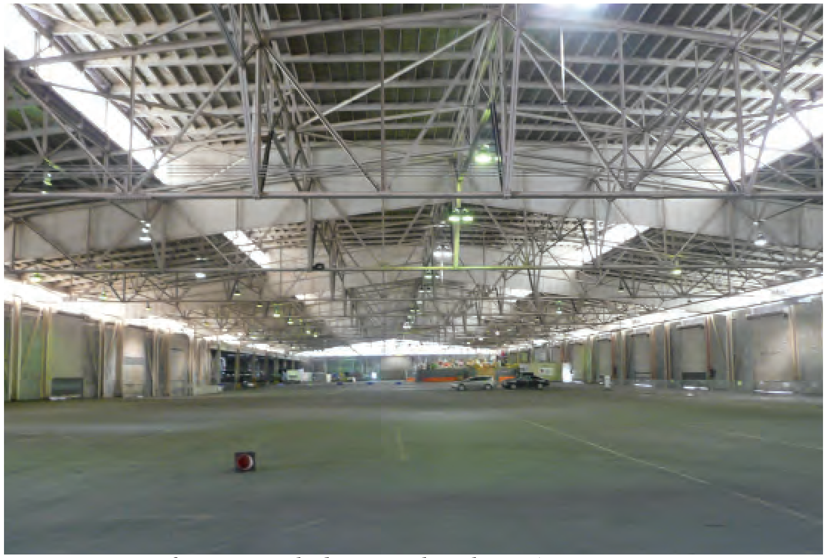
The current pier and shed at Pier 27 were built in 1965-67. This single, long shed replaced Piers 25 and 27, which dated from the early 1900s and the late 1800s, respectively. The original Pier 27 was known as the "Potato Pier," as it was the primary transport and storage location for potatoes grown in California's Central Valley.

The current pier and shed appear to have been designed purely for efficiency, with little attention given to employing a design that was compatible with that of the neighboring Neoclassical bulkheads. This concrete shed/bulkhead has the simple ornamentation and was relatively inexpensive to build. As explained in the National Register nomination for the Embarcadero Historic District, the Port considered Pier 27 an embodiment of "all the engineering achievements for the modern age of shipping, providing facilities for the swift and efficient loading and discharge of ships, trucks and trailers, and railroad cars" (Corbett, 7-200).

View of Pier 27, Embarcadero façade. Photo Source: ARG

Description

Pier 27 projects approximately due north from the Embarcadero, roughly at a 45 degree angle to the rest of the piers on the northern waterfront. It intersects the end of the historic Pier 29 shed, forming a triangular apron between the two piers and the Embarcadero. This open space is currently asphalted and used for parking and truck access to the pier sheds. The substructure of Pier 29, constructed in 1965, consists of pre-stressed concrete pilings and a reinforced concrete deck.


Interior view of Pier 27, looking north. Photo Source: ARG

The façade of the Pier 27 bulkhead, built in 1965-66, represents a departure from the City Beautiful inspired bulkheads constructed in the 1910s. Pier 27 has an approximately four-foot-high base of exposed aggregate with unpainted reinforced concrete above. A heavy cornice of exposed concrete projects approximately one foot beyond the main façade. The west (Embarcadero) side has no penetrations, except for a large steel rolling door. A flag pole is present at the north end of this façade.

The pier shed, which dates from 1966-1967, is also of reinforced concrete. Filtered natural light penetrates the interior through a continuous row of corrugated translucent plastic just below the roof line. Along the north side of the pier are several metal rolling doors and a raised loading dock. The western end of the shed is occupied by the offices and the garage for Bauer's Limousine Company. The remainder of the shed is used as storage for a number of different businesses.

Historic Status

Pier 27 is a non-contributor to the Embarcadero Historic District, as it was built outside the district's period of significance. Nor does Pier 27 appear to be eligible for listing on the National Register of Historic Places as an individual resource. This massive concrete pier is less than 50 years old, and does not possess sufficient architectural or historical significance to be an individually eligible resource.

4. Pier 27 Annex

Historical Overview

The Pier 27 Annex, also known as the Pier 29 Office Building, was designed by the office of the Chief Engineer of the Port of San Francisco, and constructed in 1962. It was built before the new Pier 27 was constructed, and provided additional office space for the Port. It is now leased to a number of small tenants, including several cruise ship lines and other businesses with a relationship to the waterfront.

Description

The Pier 27 Annex is two stories high with a cement plaster exterior and decorative redwood mullions stretching the full height of the façades. A large cornice with ribbed aluminum facia projects approximately five feet out from the façade. The first floor is raised several feet off the ground plane, and the two entry doors on the Embarcadero side are accessed via several concrete steps. Windows on the first and second floors are four rectangular panes high, arranged between the redwood mullions. A flagpole is attached behind the cornice line and centered over the main entrance door. Multiple tenants have mounted signs between the first and second floor windows.

Pier 27 Annex, Embarcadero Façade. Photo Source: ARG

Historic Status

The Pier 27 Annex is a non-contributor to the Embarcadero Historic District, as it was built outside the district's period of significance. Nor does the Pier 27 Annex appear to be eligible for listing on the National Register of Historic Places as an individual resource. While nearly 50 years old, this building does not possess sufficient architectural or historical significance to be individually eligible.

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5. Pier 29 Annex

Historical Overview

This two-story Mission and Prairie-style office building was designed by State Engineer Nathaniel Ellery. It was completed in July 1909, prior to the construction of bulkhead buildings on the inshore ends of San Francisco's piers. Originally constructed on a site just north of Pier 3 as the headquarters for the California Transportation Company, the building was moved to its current location between Piers 27 and 29 in 1918. The 1915 Sanborn Map of the area indicates that the building was one of an identical pair constructed at Pier 3. The other building remained in place until at least 1927, and was probably removed when construction began on Pier 1 in 1929 (Corbett, 7-117).

The Pier 29 Annex, Embarcadero façade,with the newer Pier 27 Annex at the far right. Photo Source: ARG

Following relocation, the Pier 29 Annex served as the Belt Line Railroad Superintendent's office, conveniently located directly across the Embarcadero from the Belt Line Railroad Round House complex. Historic photographs and Sanborn Maps indicate that building was rotated 90 degrees when relocated, so that the longer, more ornate façade now faces the Embarcadero. At its original Pier 3 location, the building faced south, towards the Ferry Building. Alterations were completed in December 1919, and the building was occupied by September of that year. The superintendent's offices and record room were located on the second floor, wile the dispatcher's office and crew locker rooms were on the first floor. The main offices of the Belt Line Railroad were located just a few blocks away, on the second floor of the Ferry Building. The superin-

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The Belt Line Railroad Building being moved into place at its new location next to Pier 29 (left), in 1919. Photo Source: Port of San Francisco and San Francisco Maratime National Historic Park, San Francisco Chronicle Collection.

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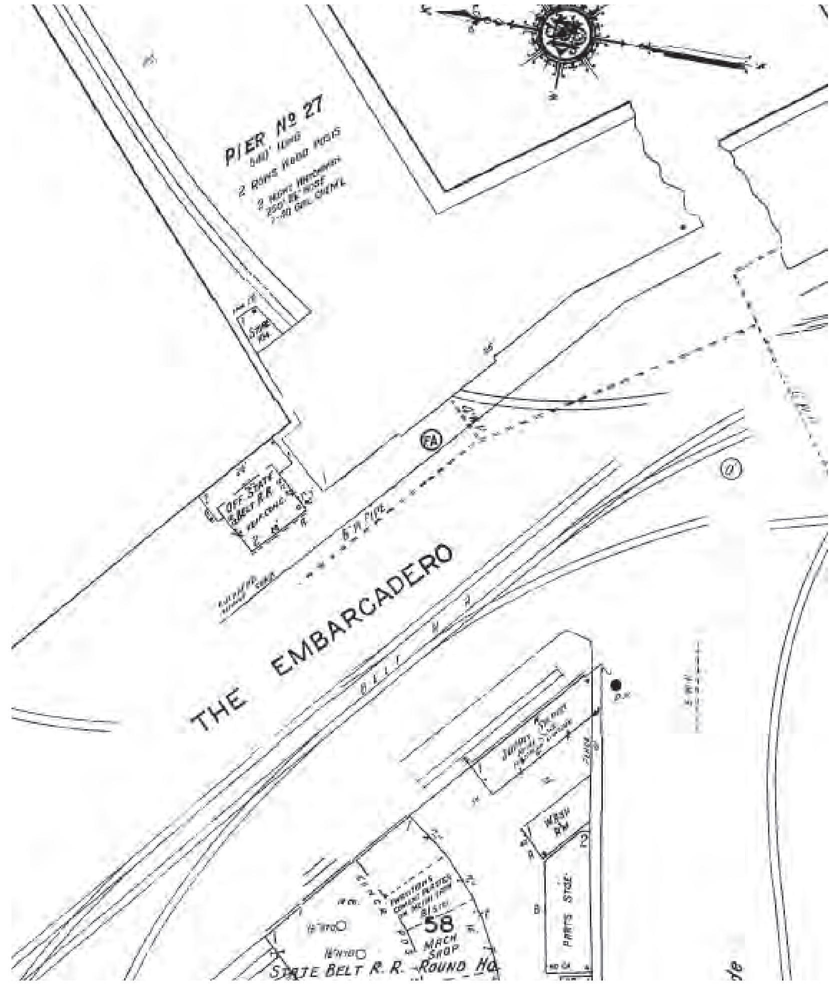
tendent, Fred E. Stewart, wrote in his report in the Report of Board of State Harbor Commissioners in 1920:

> Ample accommodations are provided for the Superintendent and clerical staff, while the record room and filing systems for classifying records render all data instantly available. Office equipment of the approved modern pattern is installed, and the conveniences provided for the yardmasters and switching force are decidedly in advance of similar institutions elsewhere. The permanent character of the building, amply lighted, heated, and ventilated; the locker-rooms, shower baths for switchmen's use, and other advantages, contribute to the maintenance of a permanent working force (*Report of the Board of State Harbor Commissioners*, 1920, 21-2).

The Belt Line Railroad occupied this building until 1973, when the state sold the defunct and outdated operation to Kyle Railways for one dollar. The railroad was closed permanently in 1993, when the city began a program of improvements to the waterfront district. Since 1973, the Port of San Francisco has leased the building to various tenants.



This 1949 map shows the Pier 29 Annex in its current site next to the original Pier 27. The Belt Line Round House is visible across the Embarcadero. Map Source: Sanborn Fire Insurance Company, 1949

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Description

The Pier 29 Annex is a two-story Mission Revival- and Prairie-style office building with a smooth stucco façade and red tile hipped roof. A two-story Modern-style addition with a flat roof is adjacent to the building's east side. The original building and addition are built of reinforced concrete. The low-hipped roof has open eaves with decoratively carved rafter tails. The façade is ornamented with simple geometric brick and tile work located between the first and second floor windows on the north and west walls. Second floor windows consist of fixed single-paned wood windows framed by oversized wooden colonnettes. The first floor double-hung windows have simple wood frames and brick lintels. Windows on the south side of the first floor are double-hung with low, pointed arches. All windows on the original building are deep-set in the façade.

The rear façade of the addition has three-paned casement windows on the second floor, and an asymmetrical arrangement of two pairs of casement windows at the north end and three small, high single-paned windows to the south. These small windows once ventilated the shower rooms mentioned by the superintendent of the Belt Line Railroad in his report to the Harbor Commissioners.

The first floor interior of the original building remains largely intact. The front office has patterned tile floors and dark wood paneling. A stairway along the north wall of the building retains its original wood treads, and a round window with square diamond panes at the top landing. The second floor has been subdivided into multiple room configurations in recent years, although some original doors and interior walls remain.

Character-Defining Features

Character-defining features of the Belt Line Railroad building include its stuccoed façade, brick and tile exterior ornamentation, red tile roof, extended rafter tails with decorative and carved ends, wooden window casings, and decorative colonnettes.

The original interior is well-preserved at the front ground floor offices. Character-defining features in this space include the tile floor, as well as the decorative woodwork and paneling. There are some original doors and windows at the second floor that give the space some historic character.

Additions / Alterations

The Pier 29 Annex has a two-story rear addition, completed in 1919 following the building's 1918 relocation. Further additions include an exterior stair to the second floor on the south side and a transformer shed under the stair. There is a new exterior door at the first floor, south side, and it appears that the original windows have been replaced with single-paned windows on the second floor. A first-story window at the north façade addition has been sealed off, and a shelter built over the adjacent doorway.

Historic Status

The Pier 29 Annex is listed on the National Register of Historic Places as a contributor to the Port of San Francisco Embarcadero Historic District. It is significant for its historical association with San Francisco's Belt Line Railroad and with the overall development of the Port. Built of permanent materials and given a decorative architectural treatment, the Pier 29 Annex is unusual among freestanding bulkhead office buildings built in San Francisco in the early twentieth century (Corbett, 7-117).

6. Pier 29

Historical Overview

Pier 29 was the southernmost of a group of seven new piers (numbered 29 to 41) proposed in the early 1910s for San Francisco's northern waterfront. Unlike the existing piers, these new piers would not be perpendicular to the seawall, but would incline northward, to allow for longer piers while maintaining the established pierhead line distance of 800 feet. Each of these piers was to have a bulkhead with Neoclassical façade. Work on Piers 35, 37, 39 and 41 began 1913-1914, followed by the construction of Pier 29 in 1915 (Corbett, 7-114).

Until the Pier 29 substructure was constructed, Pier 27 was the northernmost harbor pier, and the Pier 29 site was used as a small freight slip, with a rail spur connection to the Belt Line Railroad. The Pier 29 shed was completed in 1917, and the bulkhead and bulkhead connector to neighboring Pier 31 in 1918. The opening of the Panama Canal in 1914 caused a significant increase in trade and physical expansion for San Francisco's already thriving port. Pier 29 was one of several new piers built during the Port's expansion after the opening of the canal.

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In an effort to make piers and boat slips more durable and less susceptible to decay than the earlier wooden piles, Pier 29 was built on concrete piles. A 1915 article in *The Architect and Engineer* reported:

> Observations at the northern portion of the [water]front disclosed the fact that there was a strong tidal current at this point, which might endanger wooden pile structures and it was decided to build the three most exposed piers of the seven contemplated for this section of concrete, to act as breakwaters and to deflect the current eastward away from the shore. For this reason piers 29, 35 and 39 have been designed as reinforced concrete piers, piers 29 and 39 as concrete cylinder piers, resting on wooden piles below the mud line . . . (Oswald Speir, "Recent Work of the California State Engineering Department" *The Architect and Engineer* 43, October 1915, 64-76).

The Pier 29 bulkhead façade. Photo Source: ARG

The Lukenbach Steamship Company occupied Piers 29 and 31 by 1935 and continued to do so through 1960. San Francisco city directories list Luke's Lunch as the sole tenant in the 1960s until the small restaurant was removed in 1973. The pier is now occupied by a variety of tenants, including storage for the City of San Francisco.

Description

The Pier 29 substructure was designed by architect G. A. Wood in 1915 and the pier was completed in November 1916. The pier, approximately 200 feet wide and 800 feet long, is supported by concrete piles and has a reinforced concrete deck. Spurs of the Belt Line Railroad extended along both sides of the pier. On the north side, the tracks were depressed in the pier surface, while at the southern spur they were flush. The depressed tracks allowed trains to unload trade goods at the level of the

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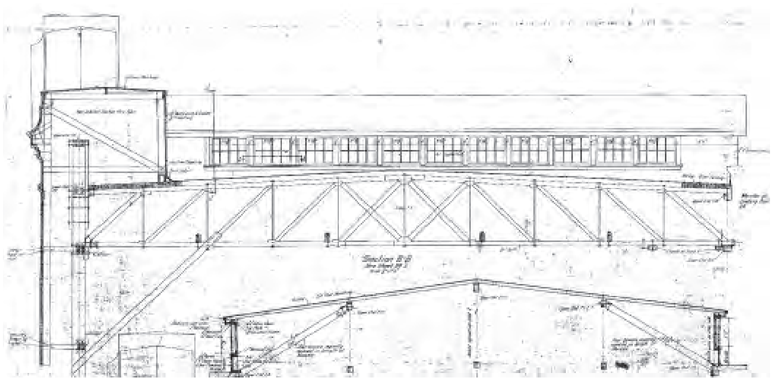
Natural light pours in through Pier 29's roof monitors and side windows. Photo Source: ARG

pier deck. The Port originally provided sand boxes with a mix of sand and pea gravel at the end of each track spur to prevent runaway trains from falling into the bay.

The Pier 29 shed was completed in July 1917, based on the plans completed by Oliver W. Jones and approved by Chief Engineer Frank White. When constructed, the shed was 160 feet wide and 762 feet long (*Report of the Board of State Harbor Commissioners*, 1918, 41). It has a combination timber and steel frame, concrete walls, steel rolling doors, and a corrugated iron roof. The shed was built fully wired with an up-to-date electrical system—a new feature for San Francisco's piers—and boasted "high-efficiency nitrogen lamps" (*Report of the Board of State Harbor Commissioners*, 1918, 44). The decorative cornice on the shed was originally galvanized iron, painted to match the concrete walls below. On the interior, the transit shed is divided into three aisles, with the roof over each aisle rising to a gable. Eight gabled monitors that are square in plan rise at periodic intervals from the gabled roof over the central aisle. The roof material is wood and is supported by a mixed structural system of wood and steel trusses. The transverse trusses are wood, and are supported by square wooden posts, while the longitudinal trusses are steel. Windows in the monitors are wood.

The outshore end of the pier originally consisted of a reinforced concrete wall with three large arched windows, approximately 13 feet wide by 15 feet high. The rise of the arch was only nine inches. There are a high row of windows running down both sides of the shed. All windows are steel sash with ribbed wire glass. The standard pane is 12 by 18 inches. The rhythm of the shed walls is set by a regular row of truck entryways with steel rolling doors. The original openings were 16 feet wide by 18 feet, two inches tall. The top corners are cut in, a simple detail that adds a bit of elegance to a utilitarian structure. Inside the pier, concrete wheel guards protect the base of each central column from damage due to heavy truck traffic.

The Pier 29 bulkhead building, completed in 1918, is made of a reinforced concrete base with a timber frame covered in metal lath and concrete plaster. The bulkhead was designed by A.A. Pyle under the supervision of Chief Engineer Frank White. The Pier 29 bulkhead building was built in conjunction with the Pier 31 bulkhead and the eleven-bay connector between them.



Section of the Pier 29 bulkhead, as designed by A. A. Pyle. Drawing Source: Port of San Francisco

Piers 29-31 during World War I. Note trains in foreground and Navy ships in Bay. Photo Source: San Francisco Public Library

Unlike most San Francisco bulkheads, which are only one bay deep, the Pier 29 bulkhead is two bays deep. The bulkhead has a central monumental arched entrance with a rusticated keystone and voussoirs. The arch is filled with a roll-up metal door. The bulkhead extends two and a half bays to the south and three and a half to the north. (There were originally four and a half, but one was destroyed when a second truck entrance was added.) The façade is cement plaster scored to resemble ashlar and molded in places to form rusticated pilasters. Windows are wood sash with 10-over-25 glazing on the ground story and 6-over-6 on the second story. The cornice line has dentil molding and string-course detailing. A back-lit decorative box at the base of the north leg of the arch identifies the pier number.

Character-Defining Features

Character-defining features of the bulkhead include its monumental arched entrance; dentil molding and string-courses at the base of the cornice; rusticated pilasters, quoins, voussoirs, and keystones; concrete plaster finish scored to resemble ashlar; a rolling steel door; 10-over-25 and 6-over-6 glazing patterns; the flagpole mounted on the roof above the arch; cast iron letters identifying the pier number above the arch; and the backlit address box at the base of one leg of the arch.

Character-defining features of the shed include reinforced concrete walls, steel rolling doors, door openings with clipped corners, steel sash multi-light windows with ribbed wire glass, wooden beams, and a series of three roof gables with a row of monitors in the central gable. The roof trusses that help create the large interior volume are also character-defining features of the shed. Though not visible to the general public,

North wall, Pier 29 shed, looking northeast. Photo Source: ARG

the pier structure is defined by cylindrical concrete pilings. Its reinforced concrete deck is characteristic of piers built in the 1910s.

Condition

The Pier 29 bulkhead maintains a high degree of integrity, but the shed and pier have been altered significantly over the years. The construction of Pier 27 eliminated several bays at the outer end of the shed. Cast-in-place reinforced concrete walls form the enclosure of the pier shed. Corroding rebar is exposed on both the interior and exterior of the building and there is a significant amount of grime and efflorescence on both surfaces. Inappropriate attempts at patching – using mixtures with a high gray Portland-cement content – are visible on the exterior. The concrete plaster of the bulkhead façade shows spalling and cracking. Patching materials of varying colors and textures have been added over the years.

Some glass panes in the side windows and monitors have been replaced with wired glass of a different color and type than the original. The interiors of the monitor lights were originally painted with lead-based white paint which is now peeling and flaking off in significant amounts, visible in small piles on the floor. Corrugated metal fire baffles in the rafters are damaged, rusting, or appear to be slipping in places.

Additions / Alterations

The construction of Pier 27 in 1965 caused the most significant alterations to Pier 29. To enable the outshore end of Pier 29 to open directly into Pier 27, the reinforced concrete wall at the outshore end of Pier 29 and several bays along the south wall of the Pier 29 shed were removed. At the same time, Pier 29's substructure was extended to accommodate the end of

Cracking, spalling and off-color patches are visible on the exterior plaster, as is deterioration of the Pier 29 sign. Photo Source: ARG

Multi-light wood windows, Pier 29 bulkhead building. Photo Source: ARG

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Pier 27, and steel framing was added to the northern end of Pier 29 where it joined Pier 27. In addition, the area south of Pier 29 was filled in to support a triangular asphalt parking lot and driveway in the space between the two piers.

A triangular addition accommodating a small restaurant, Luke's Lunch, was located at the southern corner of Pier 29, squeezed between the bulkhead and the curve of the Belt Line train track extension. The precise date of its addition is not known, but Luke's was in operation through 1968. Luke's Lunch changed its name to Sam's Lunch in 1969, and changed again to Joe's Lunch before finally closing altogether in 1972. The Peer Inn tavern was located just inside the bulkhead at this corner until the pier's renovation in 1962.

More recent alterations include the widening of several truck entryways in the pier shed. These have interrupted the original rhythm of the shed façades, removing the simple original corner details, and have been finished with a light gray cement which does not match the original. On the bulkhead, two pedestrian doors have been cut into windows on the Embarcadero façade. The rails along the south side of the shed have been paved over and are no longer visible.

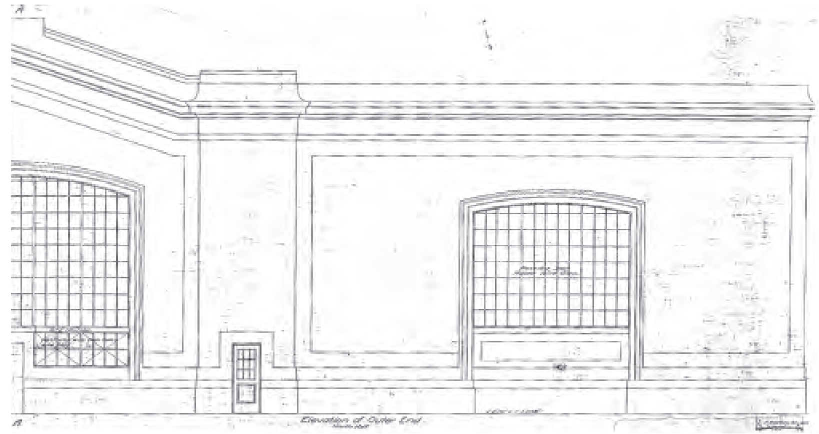
Pier 29 shed, south side. Alterations include widening of doors and lighting fixtures mounted on the roof. Photo Source: ARG

Intersection of Piers 27 (right) and 29 (left). Source: ARG

While still used as a parking lot, the large triangular area at the center of the Pier 27-29 complex also hosts an artificial turf soccer field, as well as two temporary tent structures and associated sheds used by Teatro Zinzanni. Floodlights on large metal frames have been mounted on the roof of the Pier 29 shed to light the parking lot and soccer field at night.

The pier structure (below the deck) has been repaired several times over the years. In 1947, gunite was applied to spalled concrete slabs, beams and girders. In 1962 the Port Department of Engineering applied gunite and steel reinforcing to repair concrete framing and pile cylinders along the north side of the pier. In 1995, the Department of Engineering repaired several cracked piles, beams, and girders damaged in the 1989 earthquake.

Two bays at the center of the façade of the Pier 29-31 connector were altered in 1962. The northernmost of these bays, which was originally a large rectangular opening for a rail spur, was enlarged further, removing most of two flanking decorative pilasters. The wall, fenestration, and pilasters of the adjacent bay on the south were replaced by a similarly large rectangular opening (Corbett, 7-115.)



Partial elevation of the outshore façade of Pier 29, as drawn by Oliver Jones. Drawing Source: Port of San Francisco

Historic Status

Pier 29 is listed on the National Register of Historic Places as a contributor to the Port of San Francisco Embarcadero Historic District.

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APPENDIX CP-7
Northeast Wharf Plaza, Pier 27: Assessment of Project Consistency with *Secretary's Standards* and Performance Criteria

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ARCHITECTURAL RESOURCES GROUP, INC.
Architects, Planners & Conservators

MEMORANDUM

To: Mark Paez
Preservation Planner
Port of San Francisco
Pier 1, The Embarcadero
San Francisco, CA 94111

Project: International Cruise Terminal & Northeast Wharf Plaza, Pier 27
San Francisco, CA

Project #: 11065

Date: Revised, November 22, 2011

Phone: 415-705-8674

Via: e-mail

Re: **Northeast Wharf Plaza, Pier 27**
Assessment of Project Consistency with *Secretary's Standards* and Performance Criteria

1. Introduction

The present memorandum is one of several that have been prepared by Architectural Resources Group for the Port of San Francisco that involve the assessment of historical resources and proposed projects at Piers 27-29:

- At the Port's request, ARG completed a Historic Resources Report for Piers 27, 29 and 31 in September 1999. For each structure on-site, the report included an historical overview, a building description, a conditions analysis, a list of character-defining features and a description of additions and alterations. At the Port's request, ARG reviewed and updated the 1999 Historic Resources Report in March 2011. That revised report describes the resources within the Plaza/Terminal project area and is the basis for the historic narrative supporting the present memorandum.

- In June 2011, Architectural Resources Group (ARG) reviewed the Performance Criteria that the Port prepared for the development of the Northeast Wharf Plaza at Pier 27 for consistency with the *Secretary of the Interior's Standards for Rehabilitation*. The Port has since revised the Performance Criteria (primarily in response to several suggestions made in ARG's June report) and developed a proposed design for the plaza. The present November 2011 ARG memorandum evaluates the Port's proposed plaza design for consistency with both the Performance Criteria and the *Secretary of the Interior's Standards for Rehabilitation*.

- In conjunction with the assessment of the proposed design of the Northeast Wharf Plaza, ARG completed a separate memorandum in June 2011 evaluating the proposed design of the International Cruise Terminal for consistency with the *Secretary's Standards*.

2. Project Description
The Northeast Wharf Plaza is being developed in conjunction with a new International Cruise Terminal planned for the Pier 27 site. Generally, development of the Northeast Wharf Plaza entails:

- Removal of the Pier 27 Annex and the adjacent temporary tent structures and prefabricated buildings that house Teatro Zinzanni.

- Retention of the Pier 29 Annex (Belt Line Railroad Building), including the rear addition.

- Creation of triangular open space generally in place of the existing Pier 27 bulkhead. This open space, approximately 52,000 square feet in size, consists of a lawn with a curved path along the Embarcadero and a few trees in the lawn's western portion. The trees would be in individual planters.

- Creation of an approximately 7,000-square-foot open space behind the Belt Line Railroad Building that extends easterly towards the new Cruise Terminal. This open space will consist of four rows of trees in defined planting areas set amidst an open lawn.

- The remaining area of the Plaza, approximately 35,000 square feet, will be covered in cast-in-place architectural concrete paving.

An existing conditions aerial photograph and a site plan of the proposed Northeast Wharf Plaza are included below at the end of this report.

3. Historical Background
The Plaza/Terminal project area is located within the Port of San Francisco Embarcadero Historic District. The current historic status of the project area and the structures within it is summarized below.

Port of San Francisco Embarcadero Historic District
The Port of San Francisco Embarcadero Historic District, which was added to the National Register of Historic Places in May 2006, includes an approximately three-mile curving stretch of San Francisco's northeastern waterfront from Pier 45 at Fisherman's Wharf, south to Pier 48 at China Basin. The district includes pier structures, other waterfront structures such as the Ferry Building, as well as the waterside portion of the Embarcadero corridor including the Seawall, Herb Caen Way/Embarcadero Promenade and the Bulkhead Wharf. Most of the district resources were constructed between 1908 and 1938, though the construction of the seawall and Ferry Building dates from the 1890s.

Pier 27
Pier 27 is a non-contributor to the Port of San Francisco Embarcadero Historic District because it was built outside the district's period of significance. The current pier and shed at Pier 27 were constructed 1965-1967, replacing two wooden piers: Piers 25 & 27. Pier 25, which dated from the early 1900s, along with its Neoclassical style bulkhead building, constructed in 1920, were demolished in 1965 in

preparation for the construction of the current Pier 27 pier and shed. The former Pier 27 was removed in 1948.

Pier 27 Annex
The Pier 27 Annex (also known as the Pier 29 Office Building) is a non-contributor to the district because it was built outside the district's period of significance. This building appears to have been constructed in 1962. Conflicting Port records indicate the building was associated with both Pier 27 and Pier 29. Built as offices, it remains in office use. There remains some uncertainty whether any portion of the former Pier 27 Bulkhead is a part of this structure.

Pier 29 Annex
The Pier 29 Annex (Belt Line Railroad Building) is a contributor to the Port of San Francisco Embarcadero Historic District. The building was originally constructed in 1909 near what is now Pier 3. Constructed as one of a pair of buildings, this Mission Style office building with Craftsman and Prairie style features was moved to its current site in 1918. Immediately following relocation, a rear addition was added to the building. This addition is constructed of concrete block and finished to match the principal building. Beginning in 1919, the building served as offices and employee facilities in support of the Belt Line Railroad Engine House located directly across from the site, on the south side of the Embarcadero at Seawall Lot 319. The property was transferred to Kyle Railroads and then to the Port of San Francisco. Since 1973 the Port of San Francisco has leased the building to various tenants.

Pier 29
Pier 29 is a contributor to the Port of San Francisco Embarcadero Historic District. The substructure, transit shed and bulkhead building at Pier 29 were completed in 1916, 1917 and 1918, respectively.

Teatro Zinzanni
Teatro Zinzanni consists of two temporary tent structures along the Embarcadero that are accompanied by four prefabricated temporary buildings located immediately north of the tent structures. Installed on the site in March 2000 (well outside the district's period of significance) the structures are not contributors to the district. Because of their temporary nature, the tent structures and ancillary portable buildings were not evaluated nor included as non-contributing structures in the Port of San Francisco Embarcadero Historic District nomination.

4. The Secretary of the Interior's Standards for Rehabilitation
The Secretary of the Interior is responsible for establishing standards for all programs under Departmental authority and for advising Federal agencies on the preservation of historic properties listed in or eligible for listing in the National Register of Historic Places. The *Standards for Rehabilitation* (codified in 36 CFR 67 for use in the Federal Historic Preservation Tax Incentives program) address the most prevalent treatment. "Rehabilitation" is defined as "the process of returning a property to a state of utility, through repair or alteration, which makes possible an efficient contemporary use while preserving those portions and features of the property which are significant to its historic, architectural, and cultural values."

Initially developed by the Secretary of the Interior to determine the appropriateness of proposed project work on registered properties within the Historic Preservation Fund grant-in-aid program, the *Standards for Rehabilitation* (the *Standards*) have been widely used over the years—particularly to determine if a rehabilitation qualifies as a Certified Rehabilitation for Federal tax purposes. In addition, the *Standards* have guided Federal agencies in carrying out their historic preservation responsibilities for properties in Federal ownership or control; and State and local officials in reviewing both Federal and nonfederal rehabilitation proposals. They have also been adopted by historic district and planning commissions across the country.

The intent of the *Standards* is to assist the long-term preservation of a property's significance through the preservation of historic materials and features. The *Standards* pertain to historic buildings of all materials, construction types, sizes, and occupancy and encompass the exterior and interior of the buildings. They also encompass related landscape features and the building's site and environment, as well as attached, adjacent, or related new construction. To be certified for Federal tax purposes, a rehabilitation project must be determined by the Secretary of the Interior to be consistent with the historic character of the structure(s), and where applicable, the district in which it is located. The Standards are to be applied to specific rehabilitation projects in a reasonable manner, taking into consideration economic and technical feasibility.

5. The Port's Northeast Wharf Plaza Performance Criteria

The Port of San Francisco has developed a set of performance criteria for the Northeast Wharf Plaza that are intended to ensure that the new park be designed in a manner that recognizes the Historic District setting of the project and is compatible with it. In essence, the Performance Criteria apply the *Secretary's Standards* to the specific context of the Plaza project site. In their entirety, the performance criteria are as follows:

> To mitigate the project's potential impacts of the Northeast Wharf Plaza on Pier 29, Belt Railroad Office Building, Pier 23 Restaurant, and the Embarcadero Historic District, the following performance criteria have been defined to produce a plaza design that maintains the character and integrity of the District and to achieve consistency with the *Secretary's Standards*, and the Port shall comply with these criteria:
>
> *a)* *Plaza Relationship to Embarcadero Historic District*. Plaza structures and public spaces should be consistent with the Secretary's Standards with respect to the character-defining features and be compatible with the Embarcadero Historic District by recognizing the bulkhead, pier, and apron zones, with improvements within those zones being compatible with the architectural character of the Embarcadero Historic District.
>
> *b)* *Structures at Northeast Wharf Plaza*. Structures near the Northeast Wharf Plaza should be designed to be consistent with the *Secretary's Standards* and compatible with the historic character of bulkhead buildings through the following:
>
> - To feature the Belt Line Railroad Building and recognize its unique waterfront placement as a freestanding structure located on the bulkhead wharf fronting on the Embarcadero Promenade and rehabilitated consistent with the *Secretary's Standards*, new structures should be set back from the Embarcadero Promenade at least 30 feet and provide visual separation from the Belt Line Railroad Building accomplished by separating the new structures from the Belt Line Railroad Building by at least 40 feet.

- As part of the design process the Port shall assess the historic integrity of the rear addition of the Belt Line Railroad Building and determine whether it retains sufficient integrity to be considered an integral part of its contributing resource status. Should the addition be determined integral to the contributing resource its treatment shall be consistent with the *Secretary's Standards*.

- To acknowledge and strengthen the Cruise Terminal as the dominant maritime use of the pier, new structures should be located to respect the sight line from the Embarcadero Promenade to the terminal, and sited to follow the geometry established by the cruise terminal structure (instead of being parallel to the Embarcadero Promenade).

- Major new buildings/structures that are located on the bulkhead wharf should acknowledge the monumental scale and civic character of the historic bulkhead buildings. New buildings/structures should have substantial height, massing and forms which may be accomplished with tall ground floor heights, walls with large sections of solid and void, strong cornice features, and prominent entries. This may be accomplished with a symmetrical façade to the front of the new structures that features a wide central storefront with doors and windows to the base, and flanked with solid sections that have fewer or smaller amounts of glazing.

- New structures within the Plaza shall be designed to support the historic setting of the Embarcadero Historic District including Pier 23, 29 and the Belt Line Railroad Building and shall be compatible but not mimic these historic resources in order to avoid creating a false sense of historical development.

- To architecturally complement the Belt Railroad and bulkhead buildings, new structures should be finished in industrial materials characteristic of the Embarcadero Historic District such as concrete, stucco or metal siding and steel sash windows.

c) *Plantings at Northeast Wharf Plaza.* To recognize the Belt Railroad Office Building's historic placement as a freestanding structure within a working maritime environment and the industrial character of the Embarcadero Historic District, significant plantings should be setback at least 20 feet from the Belt Line Railroad Building. Lawn areas in the Plaza should be in raised planters that appear as an additive feature over the pier deck. Other plantings in the Plaza should serve to delineate space and should be limited to trees or plants in clearly defined planters or within the pier deck in a manner that continues to allow the site to be expressed as a pier deck.

d) *Evaluation for Consistency with Performance Criteria.* Prior to issuance of Port Building or Encroachment Permits, Port staff shall consult with the Planning Department to review and determine consistency of the preferred design for the Northeast Wharf Plaza with the above performance criteria, as determined by the Port of San Francisco preservation staff and the Planning Department preservation staff. This would include preparation of a Historic Resource Evaluation Report by a qualified historic preservation professional to assess the project's consistency with these performance criteria.

6. Project Assessment
In ARG's professional opinion, the proposed design of the Northeast Wharf Plaza is consistent with both the *Secretary of the Interior's Standards for Rehabilitation* and the Port's Northeast Wharf Plaza Performance Criteria. The discussion of the proposed design, which is based on the site plan included at the end of this document, is organized with reference to each of the ten *Standards*.

Standard 1. *A property shall be used for its historic purpose or be placed in a new use that requires minimal change to the defining characteristics of the building and its site and environment.*

The proposed design of the Northeast Wharf Plaza appears to retain the character of the waterfront historic district. The Plaza, designed as an open park space, provides for public access to the Cruise Terminal and expands views and vistas to the open water. The Plaza retains the physical character of the pier deck through the use of non-intensive landscape features clearly delineated as an added layer and distinguished from the pier structure. The Belt Line Railroad Building's use will likely remain an office function or support building for the proposed plaza.

The proposed maritime use of the Piers 27-29 site is consistent with the Port's Public Trust mandate as set forth in the San Francisco Bay Conservation and Development Commission (BCDC) San Francisco Waterfront Special Area Plan and the Port's Waterfront Land Use Plan. The continued maritime use of the Historic District is also important because it is a form of the historic use and function as an ocean and inland cargo and passenger transportation port.

Standard 2. *The historic character of a property shall be retained and preserved. The removal of historic materials or alteration of features and spaces that characterize a property shall be avoided.*

The proposed design for the Northeast Wharf Plaza entails no removal of historic materials. The Belt Line Railroad Building, which is the only contributing building to the Embarcadero Historic District within the Plaza boundary, will be preserved in place. In fact, the design of the Plaza will enhance the building's prominence by removing the non-contributing buildings and structures (including Pier 27, the Pier 27 Annex and the Teatro Zinzanni structures) that have altered the historic setting and that currently surround the building. Proposed landscaping will be set back at least 30 feet from the Belt Line Railroad Building, preserving the building's identity as a freestanding structure situated within a working maritime environment. This landscaped area includes a possible future restroom building. This building would be located more than 40 feet from the Belt Line Railroad Building, and would be located behind the building, minimizing its visibility from the Embarcadero Promenade.

Standard 3. *Each property shall 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 architectural elements from other buildings, shall not be undertaken.*

The proposed design of Northeast Wharf Plaza does not include the use of conjectural features or architectural elements that would create a false sense of historical development. The new Plaza will be distinct from Pier 29 and the Belt Line Railroad Building. In particular, the proposed lawn areas will be set in raised planters of clearly contemporary vintage.

Standard 4. *Most properties change over time; those changes that have acquired historic significance in their own right shall be retained and preserved.*

The proposed design of the Northeast Wharf Plaza includes demolition of the following structures, none of which appears to possess historical significance:

Pier 27: Pier 27 is a non-contributing feature of the Embarcadero Historic District, as it was built outside the district's period of significance. Nor does Pier 27 appear to be eligible for listing on the National Register of Historic Places as an individual resource. The pier is less than 50 years old and does not possess sufficient architectural or historical significance to be a contributor to the historic district or an individually eligible resource. As a result, Pier 27 does not constitute a change to the site that has acquired significance in its own right. Therefore removal of this non-contributor is consistent with the *Secretary's Standards*.

Pier 27 Annex (also known as the Pier 29 Office Building): The Pier 27 Annex does not possess sufficient architectural or historical significance to be a contributor to the historic district or an individually eligible resource.

Teatro Zinzanni: The group of tents and temporary structures on-site that are affiliated with Teatro Zinzanni are less than 50 years of age and do not possess sufficient architectural or historical significance to be contributors to the historic district or individually eligible resources.

Standard 5. *Distinctive features, finishes, and construction techniques or examples of craftsmanship that characterize a property shall be preserved.*

The proposed design for the Northeast Wharf Plaza includes no removal of any distinctive features, finishes, construction techniques or examples of craftsmanship that characterize the Embarcadero Historic District or any contributors thereto.

Standard 6. *Deteriorated historic features shall be repaired rather than replaced. Where the severity of deterioration requires replacement of a distinctive feature, the new feature shall match the old in design, color, texture, and other visual qualities and, where possible, materials. Replacement of missing features shall be substantiated by documentary, physical, or pictorial evidence.*

The proposed Plaza design includes no specific changes to the exterior of the Belt Line Railroad Building. Future work on the building would be subject to the Performance Criteria identified above, which stipulate that any rehabilitation of resources that contribute to the Embarcadero Historic District shall be conducted in compliance with the *Secretary of the Interior's Standards for Rehabilitation*.

Standard 7. *Chemical or physical treatments, such as sandblasting, that cause damage to historic materials shall not be used. The surface cleaning of structures, if appropriate, shall be undertaken using the gentlest means possible.*

No chemical or physical treatments of existing historic materials are specified in the proposed design for the Northeast Wharf Plaza.

Standard 8. *Significant archeological resources affected by a project shall be protected and preserved. If such resources must be disturbed, mitigation measures shall be undertaken.*

Though an archeological evaluation is beyond the scope of this analysis, given that the proposed Northeast Wharf Plaza would use the existing pier and bulkhead wharf deck and substructure, it is not anticipated that the project would affect any significant archeological resources.

Standard 9. *New additions, exterior alterations, or related new construction shall not destroy historic materials that characterize the property. The new work shall be differentiated from the old and shall be compatible with the massing, size, scale, and architectural features to protect the historic integrity of the property and its environment.*

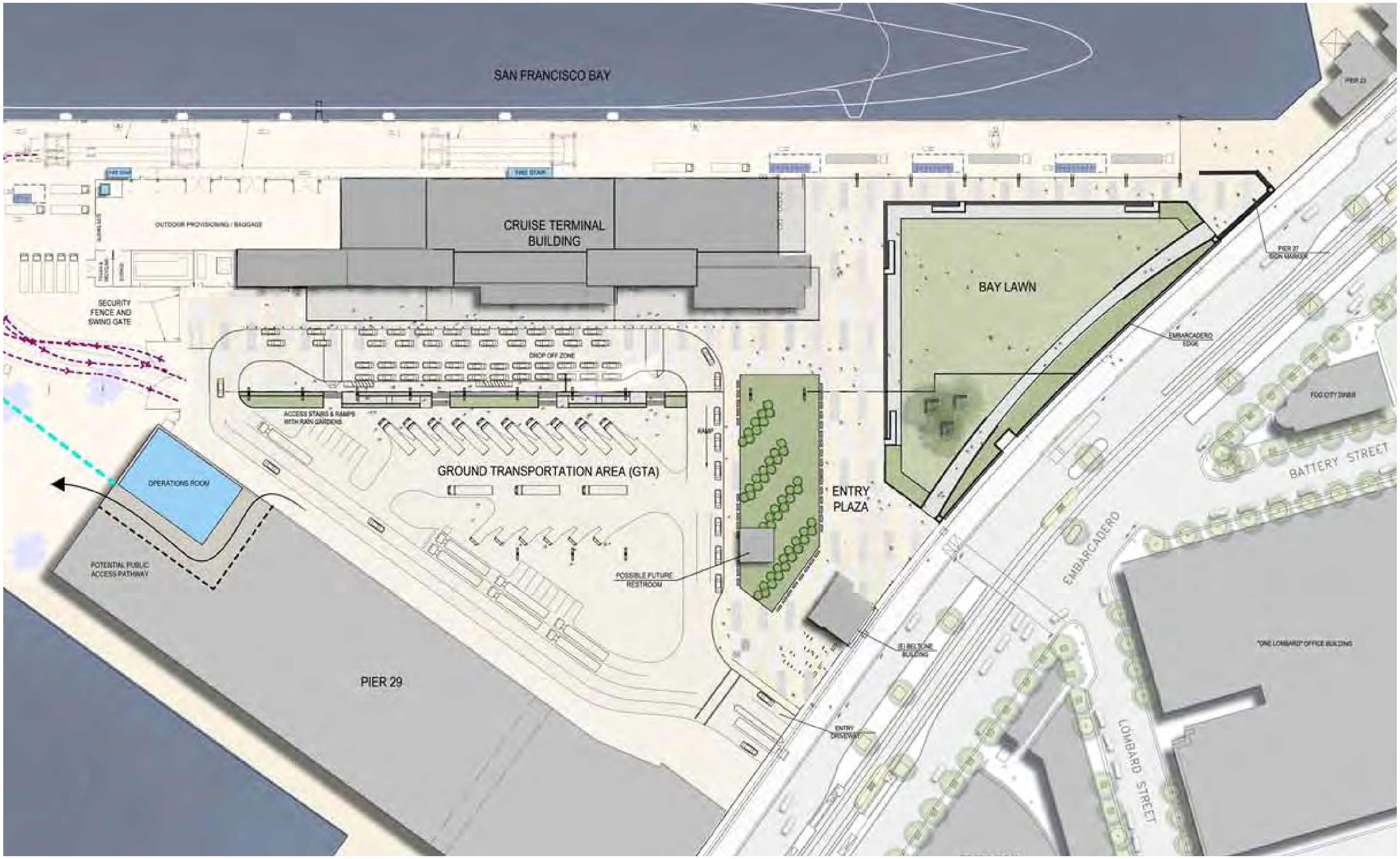
As described above, the proposed Plaza design, including installation of concrete paving, two lawn areas with planters, and a potential future restroom building, does not include the removal of any historic materials or features. Nor does it include the addition of any architectural elements that would create a false sense of historical development. The proposed features will be clearly delineated as an added layer that is distinguished from the pier structure and the surrounding Embarcadero Historic District. The proposed lawns and paved area reinforce the open feel and large scale of the wharf area. The lawns have also been designed to preserve the sight lines from the Embarcadero Promenade to the new cruise terminal, in keeping with the Port's Performance Criteria.

If constructed in the future, the restroom building would be subject to the Port's Performance Criteria, which stipulate that the design of new structures needs to be complementary to the surrounding historic district while differentiated from it.

Standard 10. *New additions and adjacent or related new construction shall be undertaken in such a manner that if removed in the future, the essential form and integrity of the historic property and its environment would be unimpaired.*

The proposed Northeast Wharf Plaza is not physically connected to contributing buildings or character-defining features of the Embarcadero Historic District. As a result, the Plaza could be removed in the future without adversely affecting the integrity of the historic district or the integrity of any district contributors.

Aerial view of project site existing conditions, looking east. (Aerial source: www.bing.com)



Site Plan of proposed Northeast Wharf Plaza (Source: Port of San Francisco dated November 18, 2011).

APPENDIX AQ

Supplemental Air Quality Supporting Information

AQ-2A: Updated Health Risk Assessment Results for AC34 Project Variant

AQ-3A: Updated Air Quality Calculations Sheets for the Final EIR

AQ-4: Cruise Ship Vessel Activity and Emission Inventory Methodology, James R. Herman Cruise Terminal and Northeast Wharf Plaza Project

AQ-5: Fuel Assumptions for Marine Vessels Operating at AC34

AQ-6: Shoreside Power at BAE Systems Facility, Pier 70

APPENDIX AQ-2A
Updated Health Risk Assessment Results for AC34 Project Variant (Environ, November 2011)

Replacement pages for Appendix AQ-2 in Draft EIR.

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Cancer Risk Significance Exceedances
Recreational and Residential Receptors
Operations of AC34

UTMx	UTMy	Cancer Risk (in a million)	Emission Type	Category
554,592.10	4,178,083.40	10.1	Operations	AC34
554,637.80	4,178,084.70	14.7	Operations	AC34
554,590.90	4,178,129.10	14.1	Operations	AC34
554,636.60	4,178,130.30	19.2	Operations	AC34
554,682.30	4,178,131.60	22.3	Operations	AC34
554,728.00	4,178,132.80	24.0	Operations	AC34
554,773.70	4,178,134.00	24.3	Operations	AC34
554,819.30	4,178,135.20	24.0	Operations	AC34
554,865.00	4,178,136.40	22.8	Operations	AC34
554,910.70	4,178,137.70	20.0	Operations	AC34
554,589.70	4,178,174.80	14.8	Operations	AC34
554,635.40	4,178,176.00	20.3	Operations	AC34
554,681.10	4,178,177.30	23.9	Operations	AC34
554,726.70	4,178,178.50	25.9	Operations	AC34
554,772.40	4,178,179.70	26.5	Operations	AC34
554,818.10	4,178,180.90	26.3	Operations	AC34
554,863.80	4,178,182.10	25.3	Operations	AC34
554,588.50	4,178,220.50	14.1	Operations	AC34
554,634.10	4,178,221.70	19.5	Operations	AC34
554,679.80	4,178,222.90	22.9	Operations	AC34
554,725.50	4,178,224.20	25.0	Operations	AC34
554,771.20	4,178,225.40	25.8	Operations	AC34
554,816.90	4,178,226.60	25.7	Operations	AC34
554,587.20	4,178,266.20	11.6	Operations	AC34
554,632.90	4,178,267.40	16.1	Operations	AC34
554,678.60	4,178,268.60	19.1	Operations	AC34
554,724.30	4,178,269.90	21.1	Operations	AC34
554,770.00	4,178,271.10	22.4	Operations	AC34
554,677.40	4,178,314.30	11.9	Operations	AC34
554,723.10	4,178,315.50	14.1	Operations	AC34
554,337.30	4,180,774.30	11.4	Operations	AC34
554,383.00	4,180,775.50	13.3	Operations	AC34
554,428.70	4,180,776.70	13.0	Operations	AC34
554,244.70	4,180,817.50	12.4	Operations	AC34
554,290.40	4,180,818.80	14.3	Operations	AC34
554,336.10	4,180,820.00	15.8	Operations	AC34
554,381.80	4,180,821.20	16.1	Operations	AC34
554,427.50	4,180,822.40	15.1	Operations	AC34
553,969.40	4,180,855.90	12.1	Operations	AC34
554,015.00	4,180,857.10	13.7	Operations	AC34
554,060.70	4,180,858.30	14.6	Operations	AC34

UTMx	UTMy	Cancer Risk (in a million)	Emission Type	Category
554,106.40	4,180,859.60	15.3	Operations	AC34
554,152.10	4,180,860.80	15.6	Operations	AC34
554,197.80	4,180,862.00	16.0	Operations	AC34
554,243.50	4,180,863.20	16.6	Operations	AC34
554,289.20	4,180,864.40	17.6	Operations	AC34
554,334.90	4,180,865.70	17.9	Operations	AC34
554,380.60	4,180,866.90	17.3	Operations	AC34
554,426.30	4,180,868.10	15.8	Operations	AC34
553,968.10	4,180,901.60	12.7	Operations	AC34
554,013.80	4,180,902.80	15.0	Operations	AC34
554,059.50	4,180,904.00	16.0	Operations	AC34
554,105.20	4,180,905.20	16.7	Operations	AC34
554,150.90	4,180,906.50	17.4	Operations	AC34
554,196.60	4,180,907.70	17.6	Operations	AC34
554,242.30	4,180,908.90	17.6	Operations	AC34
554,288.00	4,180,910.10	18.1	Operations	AC34
554,333.70	4,180,911.40	17.9	Operations	AC34
554,379.30	4,180,912.60	17.1	Operations	AC34
554,425.00	4,180,913.80	15.3	Operations	AC34
553,966.90	4,180,947.30	11.6	Operations	AC34
554,012.60	4,180,948.50	13.2	Operations	AC34
554,058.30	4,180,949.70	13.5	Operations	AC34
554,104.00	4,180,950.90	13.7	Operations	AC34
554,149.70	4,180,952.20	15.2	Operations	AC34
554,195.40	4,180,953.40	15.5	Operations	AC34
554,241.10	4,180,954.60	15.5	Operations	AC34
554,286.70	4,180,955.80	15.6	Operations	AC34
554,332.40	4,180,957.00	15.2	Operations	AC34
554,378.10	4,180,958.30	14.3	Operations	AC34
554,423.80	4,180,959.50	13.4	Operations	AC34
553,965.00	4,182,730.40	13.2	Operations	AC34
553,066.30	4,183,849.50	13.8	Operations	AC34
553,112.00	4,183,850.70	11.9	Operations	AC34
552,973.70	4,183,892.70	10.6	Operations	AC34
553,110.80	4,183,896.40	16.8	Operations	AC34
553,156.50	4,183,897.60	14.4	Operations	AC34
552,881.10	4,183,936.00	10.3	Operations	AC34
552,926.80	4,183,937.20	10.6	Operations	AC34
552,972.50	4,183,938.40	11.2	Operations	AC34
553,018.20	4,183,939.60	12.6	Operations	AC34
553,201.00	4,183,944.50	15.5	Operations	AC34
552,788.50	4,183,979.20	11.6	Operations	AC34
552,834.20	4,183,980.40	13.5	Operations	AC34
552,879.90	4,183,981.70	14.3	Operations	AC34
552,925.60	4,183,982.90	14.2	Operations	AC34

UTMx	UTMy	Cancer Risk (in a million)	Emission Type	Category
552,971.30	4,183,984.10	13.8	Operations	AC34
553,017.00	4,183,985.30	13.8	Operations	AC34
553,062.70	4,183,986.50	14.3	Operations	AC34
553,108.40	4,183,987.80	15.5	Operations	AC34
552,741.60	4,184,023.70	11.4	Operations	AC34
552,787.30	4,184,024.90	15.2	Operations	AC34
552,833.00	4,184,026.10	19.4	Operations	AC34
552,924.40	4,184,028.60	22.7	Operations	AC34
552,970.10	4,184,029.80	19.9	Operations	AC34
553,015.80	4,184,031.00	17.8	Operations	AC34
553,061.50	4,184,032.20	16.5	Operations	AC34
553,107.10	4,184,033.50	15.9	Operations	AC34
552,694.70	4,184,068.20	10.1	Operations	AC34
552,740.40	4,184,069.40	13.0	Operations	AC34
552,786.10	4,184,070.60	19.6	Operations	AC34
552,831.80	4,184,071.80	27.7	Operations	AC34
552,877.50	4,184,073.00	36.5	Operations	AC34
553,014.50	4,184,076.70	25.7	Operations	AC34
553,060.20	4,184,077.90	21.4	Operations	AC34
553,105.90	4,184,079.10	18.8	Operations	AC34
552,693.50	4,184,113.80	10.7	Operations	AC34
552,739.20	4,184,115.10	16.0	Operations	AC34
552,784.90	4,184,116.30	24.2	Operations	AC34
552,830.60	4,184,117.50	40.1	Operations	AC34
552,876.30	4,184,118.70	46.4	Operations	AC34
552,921.90	4,184,120.00	48.1	Operations	AC34
553,059.00	4,184,123.60	29.6	Operations	AC34
552,692.30	4,184,159.50	12.2	Operations	AC34
552,738.00	4,184,160.80	20.5	Operations	AC34
552,783.60	4,184,162.00	32.3	Operations	AC34
552,829.30	4,184,163.20	48.3	Operations	AC34
552,966.40	4,184,166.90	52.8	Operations	AC34
553,012.10	4,184,168.10	48.1	Operations	AC34
552,691.00	4,184,205.20	12.1	Operations	AC34
552,736.70	4,184,206.50	24.6	Operations	AC34
552,828.10	4,184,208.90	51.6	Operations	AC34
552,873.80	4,184,210.10	59.9	Operations	AC34
553,010.90	4,184,213.80	51.5	Operations	AC34
552,735.50	4,184,252.10	22.7	Operations	AC34
552,872.60	4,184,255.80	58.0	Operations	AC34
552,918.30	4,184,257.00	62.6	Operations	AC34
552,734.30	4,184,297.80	19.0	Operations	AC34
552,733.10	4,184,343.50	15.6	Operations	AC34
552,731.90	4,184,389.20	13.3	Operations	AC34
552,730.60	4,184,434.90	12.8	Operations	AC34

UTMx	UTMy	Cancer Risk (in a million)	Emission Type	Category
552,546.60	4,184,475.70	11.4	Operations	AC34
552,592.30	4,184,476.90	15.6	Operations	AC34
552,638.00	4,184,478.10	13.8	Operations	AC34
552,729.40	4,184,480.60	14.0	Operations	AC34
552,636.80	4,184,523.80	28.4	Operations	AC34
552,682.50	4,184,525.10	19.2	Operations	AC34
552,728.20	4,184,526.30	17.7	Operations	AC34
552,544.20	4,184,567.10	12.7	Operations	AC34
552,681.30	4,184,570.80	31.9	Operations	AC34
552,727.00	4,184,572.00	25.5	Operations	AC34
552,772.70	4,184,573.20	30.1	Operations	AC34
550,121.40	4,184,548.10	10.1	Operations	AC34
552,543.00	4,184,612.80	10.6	Operations	AC34
552,725.70	4,184,617.70	36.2	Operations	AC34
550,120.20	4,184,593.70	10.2	Operations	AC34
550,165.90	4,184,595.00	10.1	Operations	AC34
552,587.50	4,184,659.70	11.4	Operations	AC34
550,164.70	4,184,640.70	10.6	Operations	AC34
550,163.40	4,184,686.30	10.2	Operations	AC34

APPENDIX AQ-3A
Updated Air Quality Calculations Sheets for the Final EIR

Replacement pages for pages AQ.3-57 to AQ.3-66.

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Table X-X. 2012 Emission Factors for AC34 Race Operation

Activities/ Components	HP / Truck Type	Fuel Type	Source of EF [1]	EF Unit	ROGexh-D	ROGexh-G	ROGevp	CO	NOx	SOx	PM10	DPM	PM2.5	PMtire	PMbrk	CO2	CH4	N2O
On-Water Sources																		
spect_boats - main	1000	D	BPC	g/hp-hr	1.10	0.00	0.00	3.51	13.82	N/A [3]	0.55	0.55	0.53	0.00	0.00	0.00	0.00	0.00
spect_boats - aux	94	D	BPC	g/hp-hr	2.01	0.00	0.00	5.44	13.16	N/A [3]	0.68	0.68	0.66	0.00	0.00	0.00	0.00	0.00
race_vessels - gas	279	G	OFFROAD	g/hp-hr	0.00	9.96	13.89	273.47	7.83	0.01	0.10	0.00	0.09	0.00	0.00	1071.96	0.54	0.48
race_vessels - dsl	722	D	HCR / OFFROAD [2]	g/hp-hr	0.68	0.00	0.00	3.73	5.10	0.02	0.15	0.15	0.14	0.00	0.00	1767.90	0.88	0.00
assist_tug - main	1500	D	BPC	g/hp-hr	1.24	0.00	0.00	3.72	14.22	N/A [3]	0.59	0.59	0.57	0.00	0.00	0.00	0.00	0.00
assist_tug - aux	111	D	BPC	g/hp-hr	2.10	0.00	0.00	5.59	13.47	N/A [3]	0.72	0.72	0.70	0.00	0.00	0.00	0.00	0.00
assist_tug_alcatraz - main	1500	D	BPC	g/hp-hr	1.24	0.00	0.00	3.72	14.22	N/A [3]	0.59	0.59	0.57	0.00	0.00	0.00	0.00	0.00
assist_tug_alcatraz - aux	111	D	BPC	g/hp-hr	2.10	0.00	0.00	5.59	13.47	N/A [3]	0.72	0.72	0.70	0.00	0.00	0.00	0.00	0.00
motor_craft - gas	101	G	OFFROAD	g/hp-hr	0.00	43.21	19.67	168.59	7.36	0.02	5.78	0.00	5.32	0.00	0.00	1116.62	2.66	0.40
motor_craft - dsl	196	D	HCR / OFFROAD [2]	g/hp-hr	0.68	0.00	0.00	3.73	5.10	0.02	0.15	0.15	0.14	0.00	0.00	1766.66	0.88	0.00
sailboats - gas	12.6	G	OFFROAD	g/hp-hr	0.00	48.89	342.08	259.42	8.20	0.02	5.37	0.00	4.94	0.00	0.00	1146.13	2.98	0.94
sailboats - dsl	37	D	OFFROAD	g/hp-hr	3.37	0.00	0.00	5.07	11.51	0.01	0.29	0.28	0.27	0.00	0.00	613.26	0.30	0.00
priv_lgvessels - main	3300	D	BPC	g/hp-hr	1.10	0.00	0.00	3.51	13.82	N/A [3]	0.55	0.55	0.53	0.00	0.00	0.00	0.00	0.00
priv_lgvessels - aux	94	D	BPC	g/hp-hr	2.01	0.00	0.00	5.44	13.16	N/A [3]	0.68	0.68	0.66	0.00	0.00	0.00	0.00	0.00
Off-Road Equipment																		
Generator 60kw/500A	105	D	OFFROAD	g/hp-hr	1.02	0.00	0.00	3.60	5.85	0.01	0.46	0.46	0.42	0.00	0.00	568.30	0.08	0.00
Generator-144KW/1200 AMps	252	D	OFFROAD	g/hp-hr	0.38	0.00	0.00	1.28	4.32	0.01	0.13	0.13	0.12	0.00	0.00	568.30	0.03	0.00
Generator Twin Pack400Twin	1072	D	OFFROAD	g/hp-hr	0.39	0.00	0.00	1.28	4.44	0.01	0.13	0.13	0.12	0.00	0.00	568.30	0.03	0.00
19' Scissor Lift [4]	N/A	E	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
32' scissor lift [4]	N/A	E	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
43' Scissor Lift [4]	N/A	E	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
60' Boomlift	83	D	OFFROAD	g/hp-hr	1.04	0.00	0.00	3.99	5.45	0.01	0.50	0.50	0.46	0.00	0.00	568.30	0.08	0.00
5k Warehouse (forklift)	41	D	OFFROAD	g/hp-hr	2.31	0.00	0.00	6.48	5.75	0.01	0.52	0.52	0.48	0.00	0.00	568.30	0.18	0.00
10k Reach forklift	99	D	OFFROAD	g/hp-hr	1.04	0.00	0.00	3.99	5.45	0.01	0.50	0.50	0.46	0.00	0.00	568.30	0.08	0.00
Event 4000w Light Tower	12	D	OFFROAD	g/hp-hr	1.02	0.00	0.00	3.87	5.87	0.01	0.34	0.34	0.31	0.00	0.00	568.30	0.08	0.00
boat_lifts	200	D	OFFROAD	g/hp-hr	0.66	0.00	0.00	1.57	5.43	0.01	0.20	0.20	0.18	0.00	0.00	568.30	0.05	0.00
On-Road Trucks																		
6' Gas Flatbed - idle	LHD2	G	EMFAC	g/hr	0.00	21.85	0.00	138.68	1.48	0.05	0.00	0.00	0.00	0.00	0.00	4776.90	0.00	0.00
6' Gas Flatbed - 5mph	LHD2	G	EMFAC	g/mi	0.00	1.19	1.28	12.70	0.62	0.02	0.05	0.00	0.04	0.00	0.01	2513.51	0.00	0.00
Pickup Truck - idle	LHD2	G	EMFAC	g/hr	0.00	21.85	0.00	138.68	1.48	0.05	0.00	0.00	0.00	0.00	0.00	4776.90	0.00	0.00
Pickup Truck - 5mph	LHD2	G	EMFAC	g/mi	0.00	1.19	1.28	12.70	0.62	0.02	0.05	0.00	0.04	0.00	0.01	2513.51	0.00	0.00
26' Bobtail Truck - idle	HHD	D	EMFAC	g/hr	11.46	0.00	0.00	49.27	112.64	0.06	1.50	1.50	1.38	0.00	0.00	6541.72	0.00	0.00
26' Bobtail Truck - 5mph	HHD	D	EMFAC	g/mi	8.61	0.00	0.00	14.10	30.55	0.04	1.76	1.76	1.62	0.01	0.01	3845.36	0.00	0.00
On-Road Spectator Traffic																		
Private Auto	LDA	G	EMFAC	g/mi	0.00	0.06	0.03	1.88	0.19	0.00	0.01	0.00	0.01	0.00	0.01	371.03	0.00	0.00

Notes:

1. BPC: San Francisco Bay Area Seaports Air Emissions Inventory, 2005; OFFROAD: ARB OFFROAD 2007 Model; EMFAC: ARB EMFAC v2.3 Model; HCR: 2007 ARB Harbor Craft Rule
2. Diesel Race Support Vessel and Diesel Small Private Motor Craft Emissions Factors for ROG, CO, NOx, and PM are sourced from the 2007 ARB Harbor Craft Rule while other pollutant EFs are sourced from the ARB OFFROAD 2007 mode
3. SOx emissions for diesel marine sources are calculated based on fuel consumption
4. Emissions from off-road equipment powered by electricity are not quantified in this analysis

Table X-X. 2013 Emission Factors for AC34 Race Operation

Activities/ Components	HP / Truck Type	Fuel Type	Source of EF [1]	EF Unit	ROGexh-D	ROGexh-G	ROGevp	CO	NOx	SOx	PM10	DPM	PM2.5	PMtire	PMbrk	CO2	CH4	N2O
On-Water Sources																		
spect_boats - main	1000	D	BPC	g/hp-hr	1.10	0.00	0.00	3.51	13.82	N/A [3]	0.55	0.55	0.53	0.00	0.00	0.00	0.00	0.00
spect_boats - aux	94	D	BPC	g/hp-hr	2.01	0.00	0.00	5.44	13.16	N/A [3]	0.68	0.68	0.66	0.00	0.00	0.00	0.00	0.00
race_vessels - gas	287	G	OFFROAD	g/hp-hr	0.00	9.94	14.23	272.76	7.81	0.01	0.10	0.00	0.09	0.00	0.00	1068.14	0.54	0.48
race_vessels - dsl	722	D	HCR / OFFROAD [2]	g/hp-hr	0.68	0.00	0.00	3.73	5.10	0.02	0.15	0.15	0.14	0.00	0.00	1771.91	0.88	0.00
assist_tug - main	1500	D	BPC	g/hp-hr	1.24	0.00	0.00	3.72	14.22	N/A [3]	0.59	0.59	0.57	0.00	0.00	0.00	0.00	0.00
assist_tug - aux	111	D	BPC	g/hp-hr	2.10	0.00	0.00	5.59	13.47	N/A [3]	0.72	0.72	0.70	0.00	0.00	0.00	0.00	0.00
assist_tug_alcatraz - main	1500	D	BPC	g/hp-hr	1.24	0.00	0.00	3.72	14.22	N/A [3]	0.59	0.59	0.57	0.00	0.00	0.00	0.00	0.00
assist_tug_alcatraz - aux	111	D	BPC	g/hp-hr	2.10	0.00	0.00	5.59	13.47	N/A [3]	0.72	0.72	0.70	0.00	0.00	0.00	0.00	0.00
motor_craft - gas	100	G	OFFROAD	g/hp-hr	0.00	40.26	19.37	162.75	7.23	0.02	5.84	0.00	5.37	0.00	0.00	1127.49	2.48	0.39
motor_craft - dsl	196	D	HCR / OFFROAD [2]	g/hp-hr	0.68	0.00	0.00	3.73	5.10	0.02	0.15	0.15	0.14	0.00	0.00	1768.76	0.88	0.00
sailboats - gas	12.6	G	OFFROAD	g/hp-hr	0.00	46.23	341.95	257.13	8.27	0.02	5.40	0.00	4.97	0.00	0.00	1151.23	2.82	0.94
sailboats - dsl	37	D	OFFROAD	g/hp-hr	3.39	0.00	0.00	5.10	11.59	0.01	0.29	0.28	0.27	0.00	0.00	616.86	0.31	0.00
priv_lgvessels - main	3300	D	BPC	g/hp-hr	1.10	0.00	0.00	3.51	13.82	N/A [3]	0.55	0.55	0.53	0.00	0.00	0.00	0.00	0.00
priv_lgvessels - aux	94	D	BPC	g/hp-hr	2.01	0.00	0.00	5.44	13.16	N/A [3]	0.68	0.68	0.66	0.00	0.00	0.00	0.00	0.00
Off-Road Equipment																		
Generator 60kw/500A	105	D	OFFROAD	g/hp-hr	0.93	0.00	0.00	3.57	5.48	0.01	0.42	0.42	0.39	0.00	0.00	568.30	0.07	0.00
Generator-144KW/1200 AMps	252	D	OFFROAD	g/hp-hr	0.36	0.00	0.00	1.21	3.99	0.01	0.11	0.11	0.11	0.00	0.00	568.30	0.03	0.00
Generator Twin Pack400Twin	1072	D	OFFROAD	g/hp-hr	0.37	0.00	0.00	1.21	4.11	0.01	0.12	0.12	0.11	0.00	0.00	568.30	0.03	0.00
19' Scissor Lift [4]	N/A	E	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
32' scissor lift [4]	N/A	E	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
43' Scissor Lift [4]	N/A	E	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
60' Boomlift	83	D	OFFROAD	g/hp-hr	0.93	0.00	0.00	3.95	5.04	0.01	0.43	0.43	0.40	0.00	0.00	568.30	0.07	0.00
5k Warehouse (forklift)	41	D	OFFROAD	g/hp-hr	2.00	0.00	0.00	6.25	5.53	0.01	0.46	0.46	0.43	0.00	0.00	568.30	0.15	0.00
10k Reach forklift	99	D	OFFROAD	g/hp-hr	0.93	0.00	0.00	3.95	5.04	0.01	0.43	0.43	0.40	0.00	0.00	568.30	0.07	0.00
Event 4000w Light Tower	12	D	OFFROAD	g/hp-hr	0.97	0.00	0.00	3.80	5.62	0.01	0.32	0.32	0.29	0.00	0.00	568.30	0.07	0.00
boat_lifts	200	D	OFFROAD	g/hp-hr	0.62	0.00	0.00	1.49	5.04	0.01	0.18	0.18	0.16	0.00	0.00	568.30	0.05	0.00
On-Road Trucks																		
6' Gas Flatbed - idle	LHD2	G	EMFAC	g/hr	0.00	21.73	0.00	137.87	1.46	0.05	0.00	0.00	0.00	0.00	0.00	4776.90	0.00	0.00
6' Gas Flatbed - 5mph	LHD2	G	EMFAC	g/mi	0.00	1.04	1.20	11.05	0.56	0.02	0.05	0.00	0.04	0.00	0.01	2513.51	0.00	0.00
Pickup Truck - idle	LHD2	G	EMFAC	g/hr	0.00	21.73	0.00	137.87	1.46	0.05	0.00	0.00	0.00	0.00	0.00	4776.90	0.00	0.00
Pickup Truck - 5mph	LHD2	G	EMFAC	g/mi	0.00	1.04	1.20	11.05	0.56	0.02	0.05	0.00	0.04	0.00	0.01	2513.51	0.00	0.00
26' Bobtail Truck - idle	HHD	D	EMFAC	g/hr	10.96	0.00	0.00	48.55	113.98	0.06	1.35	1.35	1.24	0.00	0.00	6541.71	0.00	0.00
26' Bobtail Truck - 5mph	HHD	D	EMFAC	g/mi	7.81	0.00	0.00	12.93	27.24	0.04	1.50	1.50	1.38	0.01	0.01	3845.36	0.00	0.00
On-Road Spectator Traffic																		
Private Auto	LDA	G	EMFAC	g/mi	0.00	0.04	0.03	1.60	0.16	0.00	0.01	0.00	0.01	0.00	0.01	369.93	0.00	0.00

Notes:

1. BPC: San Francisco Bay Area Seaports Air Emissions Inventory, 2005; OFFROAD: ARB OFFROAD 2007 Model; EMFAC: ARB EMFAC v2.3 Model; HCR: 2007 ARB Harbor Craft Rule
2. Diesel Race Support Vessel and Diesel Small Private Motor Craft Emissions Factors for ROG, CO, NOx, and PM are sourced from the 2007 ARB Harbor Craft Rule while other pollutant EFs are sourced from the ARB OFFROAD 2007 mode
3. SOx emissions for diesel marine sources are calculated based on fuel consumption
4. Emissions from off-road equipment powered by electricity are not quantified in this analysis

On-Water Sources

Table X-X. 2012 AC34 On-Water Source Activity Data Summary

Location	Activity/Component	HP	LF	Fuel Type	Hours/Day/ Unit	# Days	# Units
AC Village: Marina Green	spect_boats - main	1000	42%	D	6	20	7
	spect_boats - aux	94	43%	D	6	20	7
	race_vessels - gas	279	21%	G	6	20	8
	race_vessels - dsl	722	23%	D	6	20	2
Alcatraz	assist_tug_alcatraz - main	1500	50%	D	1	2	3
	assist_tug_alcatraz - aux	111	31%	D	1	2	3
Barge Helipad& Regional Airports	assist_tug - main	1500	50%	D	1	2	1
	assist_tug - aux	111	31%	D	1	2	1
Fort Mason	race_vessels - gas	279	21%	G	6	20	4
	race_vessels - dsl	722	23%	D	6	20	1
Pier 30-32	race_vessels - gas	279	21%	G	6	20	40
	race_vessels - dsl	722	23%	D	6	20	10
Pier 80	race_vessels - gas	279	21%	G	6	20	4
	race_vessels - dsl	722	23%	D	6	20	1
Spectator Boats	motor_craft - gas	101	21%	G	4	20	30
	sailboats - gas	13	23%	G	2	20	84
	sailboats - dsl	37	23%	D	2	20	42

Table X-X. 2013 AC34 On-Water Source Activity Data Summary

Location	Activity/Component	HP	LF	Fuel Type	Hours/Day/ Unit	# Days	# Units
Alcatraz	assist_tug_alcatraz - main	1500	50%	D	1	2	3
	assist_tug_alcatraz - aux	111	31%	D	1	2	3
Barge Helipad& Regional Airports	assist_tug - main	1500	50%	D	1	2	1
	assist_tug - aux	111	31%	D	1	2	1
Fort Mason	race_vessels - gas	287	21%	G	6	50	4
	race_vessels - dsl	722	23%	D	6	50	1
	priv_lgvessels - main	3300	0.14	D	4	50	1
	priv_lgvessels - aux	94	0.43	D	8	50	1
Pier 9	priv_lgvessels - main	3300	14%	D	4	50	2
	priv_lgvessels - aux	94	43%	D	8	50	2
Piers 14-22.5 Open Water Basin	spect_boats - main	1000	0.42	D	6	50	2
	spect_boats - aux	94	0.43	D	6	50	2
	priv_lgvessels - main	3300	0.14	D	4	50	10
	priv_lgvessels - aux	94	0.43	D	8	50	10
Pier 19 and 19½	spect_boats - main	1000	42%	D	6	50	1
	spect_boats - aux	94	43%	D	6	50	1
	race_vessels - gas	287	21%	G	6	50	17
	race_vessels - dsl	722	23%	D	6	50	3
Pier 26 and 28	race_vessels - gas	287	21%	G	6	50	17
	race_vessels - dsl	722	23%	D	6	50	3
Pier 23	spect_boats - main	1000	42%	D	6	50	2
	spect_boats - aux	94	43%	D	6	50	2
	race_vessels - gas	287	21%	G	6	50	26
	race_vessels - dsl	722	23%	D	6	50	4
Pier 30-32	race_vessels - gas	287	21%	G	6	50	34
	race_vessels - dsl	722	23%	D	6	50	6
Pier 80	race_vessels - gas	287	21%	G	6	50	4
	race_vessels - dsl	722	23%	D	6	50	1
Piers 27-29 and Pier 29½	spect_boats - main	1000	42%	D	6	50	3
	spect_boats - aux	94	43%	D	6	50	3
	race_vessels - gas	287	21%	G	6	50	4
	race_vessels - dsl	722	23%	D	6	50	1
	priv_lgvessels - main	3300	14%	D	4	50	20
	priv_lgvessels - aux	94	43%	D	8	50	20
Spectator Boats	motor_craft - gas	100	22%	G	4	50	44
	sailboats - gas	13	23%	G	2	50	122
	sailboats - dsl	37	23%	D	2	50	63

In-Air Sources

Table X-X. 2012 AC34 In-Air Sources Activity Data Summary

Location	Activity/Component	HP	Fuel Type	Hours/Day/ Unit	# Days	# Units
Barge Helipad& Regional Airports	helicopter	400	Jet	6	20	2
	helicopter	320	G	6	20	1

Table X-X. 2013 AC34 In-Air Sources Activity Data Summary

Location	Activity/Component	HP	Fuel Type	Hours/Day/ Unit	# Days	# Units
Barge Helipad& Regional Airports	helicopter	400	Jet	6	50	2
	helicopter	320	G	6	50	1

Off-Road Sources

Table X-X. 2012 AC34 Off-Road Sources Activity Data Summary

Location	Activity/Component	HP	LF	Hours/Day/ Unit	Fuel Type	# Days	# Units
AC Village: Marina Green	Generator 60kw/500A	105	50%	10	D	18	1
	Generator Twin Pack400Twin	1072	50%	10	D	18	2
	32' scissor lift	0	0%	0	E	12	1
	5k Warehouse (forklift)	41	20%	2	D	12	3
	10k Reach forklift	99	20%	2	D	10	1
	Event 4000w Light Tower	12	50%	2	D	44	2
AC34 Live Sites	Generator 60kw/500A	105	50%	10	D	1	1
	Generator-144KW/1200 AMps	252	50%	10	D	18	1
	Generator Twin Pack400Twin	1072	50%	10	D	18	1
Alcatraz	Generator 60kw/500A	105	50%	10	D	2	1
	Generator Twin Pack400Twin	1072	50%	10	D	2	1
	19' Scissor Lift	0	0%	0	E	18	1
	5k Warehouse (forklift)	41	20%	2	D	18	2
	10k Reach forklift	99	20%	2	D	18	1
	Event 4000w Light Tower	12	50%	2	D	18	2
Cavallo Point	Generator 60kw/500A	105	50%	10	D	18	1
	Generator Twin Pack400Twin	1072	50%	10	D	18	2
	32' scissor lift	0	0%	0	E	12	1
	5k Warehouse (forklift)	41	20%	2	D	12	3
	10k Reach forklift	99	20%	2	D	10	1
	Event 4000w Light Tower	12	50%	2	D	38	2
Crissy Field	Generator 60kw/500A	105	50%	10	D	1	1
	Generator-144KW/1200 AMps	252	50%	10	D	18	1
	Generator Twin Pack400Twin	1072	50%	10	D	18	1
	19' Scissor Lift	0	0%	0	E	12	2
	60' Boomlift	83	20%	2	D	10	1
	5k Warehouse (forklift)	41	20%	2	D	12	2
	10k Reach forklift	99	20%	2	D	12	2
	Event 4000w Light Tower	12	50%	2	D	44	2
Fort Mason	Generator 60kw/500A	105	50%	10	D	1	1
	Generator-144KW/1200 AMps	252	50%	10	D	18	1
	Generator Twin Pack400Twin	1072	50%	10	D	18	1
	19' Scissor Lift	0	0%	0	E	15	2
	32' scissor lift	0	0%	0	E	15	2
	5k Warehouse (forklift)	41	20%	2	D	12	2
Pier 30-32	boat_lifts	200	29%	24	D	80	2
Pier 32-36 Open Water Basin	boat_lifts	200	29%	24	D	80	2
Pier 80	boat_lifts	200	29%	24	D	80	2

Table X-X. 2013 AC34 Off-Road Sources Activity Data Summary

Location	Activity/Component	HP	LF	Hours/Day/ Unit	Fuel Type	# Days	# Units
AC Village: Marina Green	Generator 60kw/500A	105	50%	10	D	21	1
	Generator-144KW/1200 AMps	252	50%	10	D	50	2
	Generator Twin Pack400Twin	1072	50%	10	D	50	2
	32' scissor lift	0	0%	0	E	18	1
	5k Warehouse (forklift)	41	20%	2	D	25	3
	10k Reach forklift	99	20%	2	D	21	1
	Event 4000w Light Tower	12	50%	2	D	71	2
AC34 Live Sites	Generator-144KW/1200 AMps	252	50%	10	D	50	2
Alcatraz	Generator 60kw/500A	105	50%	10	D	26	1
	Generator Twin Pack400Twin	1072	50%	10	D	26	1
	19' Scissor Lift	0	0%	0	E	18	1
	5k Warehouse (forklift)	41	20%	2	D	18	2
	10k Reach forklift	99	20%	2	D	18	1
	Event 4000w Light Tower	12	50%	2	D	26	2
Cavallo Point	Generator 60kw/500A	105	50%	10	D	50	1
	Generator Twin Pack400Twin	1072	50%	10	D	50	2
	32' scissor lift	0	0%	0	E	12	1
	5k Warehouse (forklift)	41	20%	2	D	12	3
	10k Reach forklift	99	20%	2	D	12	1
	Event 4000w Light Tower	12	50%	2	D	62	2
Crissy Field	Generator-144KW/1200 AMps	252	50%	10	D	50	2
	19' Scissor Lift	0	0%	0	E	21	2
	60' Boomlift	83	20%	2	D	21	1
	5k Warehouse (forklift)	41	20%	2	D	21	2
	10k Reach forklift	99	20%	2	D	21	2
	Event 4000w Light Tower	12	50%	2	D	71	2
Fort Mason	Generator-144KW/1200 AMps	252	50%	10	D	50	2
	19' Scissor Lift	0	0%	0	E	18	2
	32' scissor lift	0	0%	0	E	18	2
	5k Warehouse (forklift)	41	20%	2	D	18	2
Pier 19 and 19½	Generator-144KW/1200 AMps	252	50%	10	D	50	2
	Generator Twin Pack400Twin	1072	50%	10	D	50	2
	32' scissor lift	0	0%	0	E	81	2
	43' Scissor Lift	0	0%	0	E	81	2
	5k Warehouse (forklift)	41	20%	2	D	81	2
	10k Reach forklift	99	20%	2	D	81	1
Pier 23	Generator-144KW/1200 AMps	252	50%	10	D	50	2
	Generator Twin Pack400Twin	1072	50%	10	D	50	2
	32' scissor lift	0	0%	0	E	81	2
	43' Scissor Lift	0	0%	0	E	81	2
	5k Warehouse (forklift)	41	20%	2	D	81	2
	10k Reach forklift	99	20%	2	D	81	1
Pier 30-32	Generator 60kw/500A	105	50%	10	D	50	1
	Generator-144KW/1200 AMps	252	50%	10	D	50	1
	Generator Twin Pack400Twin	1072	50%	10	D	50	2
	19' Scissor Lift	0	0%	0	E	81	2
	32' scissor lift	0	0%	0	E	81	2
	43' Scissor Lift	0	0%	0	E	81	2
	60' Boomlift	83	20%	2	D	81	1
	5k Warehouse (forklift)	41	20%	2	D	81	8
	10k Reach forklift	99	20%	2	D	81	4
	Event 4000w Light Tower	12	50%	2	D	131	4
	boat_lifts	200	29%	24	D	90	3
Pier 80	boat_lifts	200	29%	24	D	90	3

Piers 27-29 and Pier 29½	Generator-144KW/1200 AMps	252	50%	10	D	50	6
	Generator Twin Pack400Twin	1072	50%	10	D	50	6
	19' Scissor Lift	0	0%	0	E	81	2
	32' scissor lift	0	0%	0	E	81	2
	43' Scissor Lift	0	0%	0	E	81	2
	60' Boomlift	83	20%	2	D	81	1
	5k Warehouse (forklift)	41	20%	2	D	81	5
	10k Reach forklift	99	20%	2	D	81	1
	Event 4000w Light Tower	12	50%	2	D	131	2

On-Road Trucks

Table X-X. 2012 AC34 On-Road Sources Activity Data Summary

Location	Activity/Component	HP	Fuel Type	Hours/Trip	Miles/Trip	# Days	# Trips
AC Village: Marina Green	6' Gas Flatbed - idle	12	G	0.17	N/A	30	2
	6' Gas Flatbed - 5mph	12	G	N/A	0.25	30	2
	26' Bobtail Truck - idle	450	D	0.17	N/A	1	300
	26' Bobtail Truck - 5mph	450	D	N/A	0.25	1	300
Alcatraz	6' Gas Flatbed - idle	12	G	0.17	N/A	18	3
	6' Gas Flatbed - 5mph	12	G	N/A	0.25	18	3
	Pickup Truck - idle	250	G	0.17	N/A	18	2
	Pickup Truck - 5mph	250	G	N/A	0.25	18	2
	26' Bobtail Truck - idle	450	D	0.17	N/A	18	10
	26' Bobtail Truck - 5mph	450	D	N/A	0.25	18	10
Cavallo Point	6' Gas Flatbed - idle	12	G	0.17	N/A	30	2
	6' Gas Flatbed - 5mph	12	G	N/A	0.25	30	2
	26' Bobtail Truck - idle	450	D	0.17	N/A	1	300
	26' Bobtail Truck - 5mph	450	D	N/A	0.25	1	300
Crissy Field	6' Gas Flatbed - idle	12	G	0.17	N/A	30	2
	6' Gas Flatbed - 5mph	12	G	N/A	0.25	30	2
	Pickup Truck - idle	250	G	0.17	N/A	30	2
	Pickup Truck - 5mph	250	G	N/A	0.25	30	2
	26' Bobtail Truck - idle	450	D	0.17	N/A	1	300
	26' Bobtail Truck - 5mph	450	D	N/A	0.25	1	300
Fort Mason	6' Gas Flatbed - idle	12	G	0.17	N/A	30	1
	6' Gas Flatbed - 5mph	12	G	N/A	0.25	30	1
	26' Bobtail Truck - idle	450	D	0.17	N/A	1	75
	26' Bobtail Truck - 5mph	450	D	N/A	0.25	1	75

Table X-X. 2013 AC34 On-Road Sources Activity Data Summary

Location	Activity/Component	HP	Fuel Type	Hours/Day/ Unit	Miles/Trip/ Units	# Days	# Units
AC Village: Marina Green	6' Gas Flatbed - idle	12	G	0.17	N/A	71	2
	6' Gas Flatbed - 5mph	12	G	N/A	0.25	71	2
	26' Bobtail Truck - idle	450	D	0.17	N/A	1	500
	26' Bobtail Truck - 5mph	450	D	N/A	0.25	1	500
Alcatraz	6' Gas Flatbed - idle	12	G	0.17	N/A	18	3
	6' Gas Flatbed - 5mph	12	G	N/A	0.25	18	3
	Pickup Truck - idle	250	G	0.17	N/A	18	2
	Pickup Truck - 5mph	250	G	N/A	0.25	18	2
	26' Bobtail Truck - idle	450	D	0.17	N/A	1	200
	26' Bobtail Truck - 5mph	450	D	N/A	0.25	1	200
Cavallo Point	6' Gas Flatbed - idle	12	G	0.17	N/A	12	2
	6' Gas Flatbed - 5mph	12	G	N/A	0.25	12	2
	26' Bobtail Truck - idle	450	D	0.17	N/A	1	300
	26' Bobtail Truck - 5mph	450	D	N/A	0.25	1	300
Crissy Field	6' Gas Flatbed - idle	12	G	0.17	N/A	21	2
	6' Gas Flatbed - 5mph	12	G	N/A	0.25	21	2
	Pickup Truck - idle	250	G	0.17	N/A	21	2
	Pickup Truck - 5mph	250	G	N/A	0.25	21	2
	26' Bobtail Truck - idle	450	D	0.17	N/A	1	500
	26' Bobtail Truck - 5mph	450	D	N/A	0.25	1	500

Fort Mason	6' Gas Flatbed - idle	12	G	0.17	N/A	18	1
	6' Gas Flatbed - 5mph	12	G	N/A	0.25	18	1
	26' Bobtail Truck - idle	450	D	0.17	N/A	1	150
	26' Bobtail Truck - 5mph	450	D	N/A	0.25	1	150
Pier 19 and 19½	6' Gas Flatbed - idle	12	G	0.17	N/A	81	4
	6' Gas Flatbed - 5mph	12	G	N/A	0.25	81	4
	26' Bobtail Truck - idle	450	D	0.17	N/A	1	300
	26' Bobtail Truck - 5mph	450	D	N/A	0.25	1	300
Pier 23	6' Gas Flatbed - idle	12	G	0.17	N/A	81	4
	6' Gas Flatbed - 5mph	12	G	N/A	0.25	81	4
	26' Bobtail Truck - idle	450	D	0.17	N/A	1	300
	26' Bobtail Truck - 5mph	450	D	N/A	0.25	1	300
Pier 30-32	6' Gas Flatbed - idle	12	G	0.17	N/A	81	8
	6' Gas Flatbed - 5mph	12	G	N/A	0.25	81	8
	26' Bobtail Truck - idle	450	D	0.17	N/A	1	600
	26' Bobtail Truck - 5mph	450	D	N/A	0.25	1	600
Piers 27-29 and Pier 29½	6' Gas Flatbed - idle	12	G	0.17	N/A	81	3
	6' Gas Flatbed - 5mph	12	G	N/A	0.25	81	3
	26' Bobtail Truck - idle	450	D	0.17	N/A	1	600
	26' Bobtail Truck - 5mph	450	D	N/A	0.25	1	600

On-Road Spectator Traffic

Table X-X. 2012 AC34 On-Road Spectator Traffic Activity Data Summary

Location	Activity/Component	Fuel Type	Miles/Trip	# Days	Trips/Day
San Francisco Origin	Light Duty Passenger Cars	G	5	20	1,995
East Bay Origin	Light Duty Passenger Cars	G	11.5	20	9,452
North Bay Origin	Light Duty Passenger Cars	G	54.2	20	5,864
South Bay Origin	Light Duty Passenger Cars	G	50	20	10,165
Out fo Region Origin	Light Duty Passenger Cars	G	62.4	20	1,282

Table X-X. 2013 AC34 On-Road Spectator Traffic Activity Data Summary

Location	Activity/Component	Fuel Type	Miles/Trip	# Days	Trips/Day
San Francisco Origin	Light Duty Passenger Cars	G	5	50	2,132
East Bay Origin	Light Duty Passenger Cars	G	11.5	50	10,051
North Bay Origin	Light Duty Passenger Cars	G	54.2	50	6,451
South Bay Origin	Light Duty Passenger Cars	G	50	50	10,846
Out fo Region Origin	Light Duty Passenger Cars	G	62.4	50	1,325

In-Air Sources

Table X-X. 2012 AC34 Operation In-Air Sources Emissions [lb/yr]

Location	ROG	CO	NOx	SOx	PM10	DPM	PM2.5	PMtire	PMbrk	CO2	CH4	N2O
Barge Helipad & Regional Airports	556	21,936	400.63	95.93	0.00	0.00	0.00	0.00	0.00	234,258	0.00	0.00

Table X-X. 2013 AC34 Operation In-Air Sources Emissions [lb/yr]

Location	ROG	CO	NOx	SOx	PM10	DPM	PM2.5	PMtire	PMbrk	CO2	CH4	N2O
Barge Helipad & Regional Airports	1,384	54,674	999	239.04	0.00	0.00	0.00	0.00	0.00	583,726	0.00	0.00

Off-Road Equipment

Table X-X. 2012 AC34 Operation Off-Road Equipment Emissions [lb/yr]

Location	ROG	CO	NOx	SOx	PM10	DPM	PM2.5	PMtire	PMbrk	CO2	CH4	N2O
AC Village: Marina Green	193.78	633	2,020	2.58	65.42	65.42	60.19	0.00	0.00	254,050	14.87	0.00
AC34 Live Sites	103.33	336.35	1,158	1.49	33.77	33.77	31.07	0.00	0.00	148,709	7.93	0.00
Alcatraz	17.20	56.60	139.21	0.18	5.85	5.85	5.38	0.00	0.00	16,802	1.32	0.00
Cavallo Point	193.46	632	2,019	2.58	65.32	65.32	60.09	0.00	0.00	253,871	14.84	0.00
Crissy Field	110.64	362.28	1,192	1.54	36.43	36.43	33.51	0.00	0.00	152,132	8.49	0.00
Fort Mason	105.35	342.00	1,163	1.50	34.23	34.23	31.49	0.00	0.00	149,205	8.08	0.00
Pier 30-32	320.68	767	2,648	3.12	95.99	95.99	88.31	0.00	0.00	277,247	24.60	0.00
Pier 32-36 Open Water Basin	320.68	767	2,648	3.12	95.99	95.99	88.31	0.00	0.00	277,247	24.60	0.00
Pier 80	320.68	767	2,648	3.12	95.99	95.99	88.31	0.00	0.00	277,247	24.60	0.00

Table X-X. 2013 AC34 Operation Off-Road Equipment Emissions [lb/yr]

Location	ROG	CO	NOx	SOx	PM10	DPM	PM2.5	PMtire	PMbrk	CO2	CH4	N2O
AC Village: Marina Green	562	1,877	6,096	8.46	182.08	182.08	167.51	0.00	0.00	840,952	43.11	0.00
AC34 Live Sites	97.92	333.65	1,099	1.54	31.63	31.63	29.10	0.00	0.00	156,556	7.51	0.00
Alcatraz	145.25	495.09	1,440	1.97	50.00	50.00	46.00	0.00	0.00	192,532	11.14	0.00
Cavallo Point	491.10	1,649	5,165	7.12	163.42	163.42	150.35	0.00	0.00	701,790	37.67	0.00
Crissy Field	109.43	378.02	1,155	1.62	35.79	35.79	32.93	0.00	0.00	162,513	8.39	0.00
Fort Mason	100.53	341.83	1,106	1.55	32.23	32.23	29.66	0.00	0.00	157,299	7.71	0.00
Pier 19 and 19½	547	1,818	5,987	8.32	174.42	174.42	160.47	0.00	0.00	829,925	41.97	0.00
Pier 23	547	1,818	5,987	8.32	174.42	174.42	160.47	0.00	0.00	829,925	41.97	0.00
Pier 30-32	1,136	3,356	10,214	13.64	353.75	353.75	325.45	0.00	0.00	1,285,471	87.15	0.00
Pier 80	510	1,230	4,150	5.26	146.38	146.38	134.67	0.00	0.00	467,854	39.16	0.00
Piers 27-29 and Pier 29½	1,634	5,429	17,943	24.95	521	521	478.87	0.00	0.00	2,487,316	125.39	0.00

On-Road Trucks

Table X-X. 2012 AC34 Operation On-Road Trucks Emissions [lb/yr]

Location	ROG	CO	NOx	SOx	PM10	DPM	PM2.5	PMtire	PMbrk	CO2	CH4	N2O
AC Village: Marina Green	3.25	11.24	17.52	0.01	0.46	0.46	0.42	0.00	0.00	1,546	0.00	0.00
Alcatraz	2.46	9.87	10.56	0.01	0.28	0.27	0.25	0.00	0.00	1,097	0.00	0.00
Cavallo Point	3.25	11.24	17.52	0.01	0.46	0.46	0.42	0.00	0.00	1,546	0.00	0.00
Crissy Field	3.81	14.72	17.58	0.02	0.46	0.46	0.42	0.00	0.00	1,734	0.00	0.00
Fort Mason	0.95	3.68	4.39	0.00	0.11	0.11	0.11	0.00	0.00	433.50	0.00	0.00

Table X-X. 2013 AC34 Operation On-Road Trucks Emissions [lb/yr]

Location	ROG	CO	NOx	SOx	PM10	DPM	PM2.5	PMtire	PMbrk	CO2	CH4	N2O
AC Village: Marina Green	5.48	20.54	28.57	0.03	0.66	0.66	0.61	0.00	0.00	2,708	0.00	0.00
Alcatraz	2.50	10.10	11.46	0.01	0.27	0.26	0.25	0.00	0.00	1,187	0.00	0.00
Cavallo Point	2.72	8.85	17.09	0.01	0.40	0.40	0.37	0.00	0.00	1,432	0.00	0.00
Crissy Field	4.94	17.25	28.52	0.02	0.66	0.66	0.61	0.00	0.00	2,526	0.00	0.00
Fort Mason	1.42	4.77	8.55	0.01	0.20	0.20	0.18	0.00	0.00	735	0.00	0.00
Pier 19 and 19½	5.49	25.88	17.34	0.02	0.40	0.40	0.37	0.00	0.00	2,375	0.00	0.00
Pier 23	5.49	25.88	17.34	0.02	0.40	0.40	0.37	0.00	0.00	2,375	0.00	0.00
Pier 30-32	10.97	51.76	34.69	0.05	0.81	0.79	0.74	0.00	0.01	4,749	0.00	0.00
Piers 27-29 and Pier 29½	7.24	28.77	34.35	0.03	0.80	0.79	0.73	0.00	0.00	3,477	0.00	0.00

On-Water Sources

Table X-X. 2012 AC34 Operation On-Water Sources Emissions [lb/yr]

Location	ROG	CO	NOx	SOx	PM10	DPM	PM2.5	PMtire	PMbrk	CO2	CH4	N2O
AC Village: Marina Green	4,066	37,898	13,177	8.03	504	490.54	487.42	0.00	0.00	292,619	146.18	60.61
Alcatraz	13.22	39.46	147.22	0.06	6.16	6.16	5.98	0.00	0.00	0.00	0.00	0.00
Barge Helipad & Regional Airports	4.41	13.15	49.07	0.02	2.05	2.05	1.99	0.00	0.00	0.00	0.00	0.00
Fort Mason	1,532	17,382	720	1.66	13.14	6.49	12.09	0.00	0.00	146,309	73.09	30.31
Pier 30-32	15,316	173,819	7,204	16.65	131.41	64.87	120.90	0.00	0.00	1,463,093	731	303.06
Pier 80	1,532	17,382	720	1.66	13.14	6.49	12.09	0.00	0.00	146,309	73.09	30.31
Spectator Vessels	15,789	25,057	1,387	2.67	786	8.96	723	0.00	0.00	172,063	378.33	65.97

Table X-X. 2013 AC34 Operation On-Water Sources Emissions [lb/yr]

Location	ROG	CO	NOx	SOx	PM10	DPM	PM2.5	PMtire	PMbrk	CO2	CH4	N2O
Alcatraz	13.22	39.46	147.22	0.06	6.16	6.16	5.98	0.00	0.00	0.00	0.00	0.00
Barge Helipad & Regional Airports	4.41	13.15	49.07	0.02	2.05	2.05	1.99	0.00	0.00	0.00	0.00	0.00
Piers 14-22.5 Open Water Basin	3,665	11,321	41,233	16.56	1,701	1,701	1,650	0.00	0.00	0.00	0.00	0.00
Fort Mason	4,288	45,532	5,120	5.53	169.28	152.22	162.54	0.00	0.00	370,634	185.33	77.80
Pier 9	590	1,816	6,570	2.64	272.01	272.01	263.85	0.00	0.00	0.00	0.00	0.00
Pier 19 and 19½	17,233	190,253	11,280	16.81	291.08	219.21	276.32	0.00	0.00	1,328,304	665	330.67
Pier 23	26,480	291,257	18,889	25.20	516	405.99	491.41	0.00	0.00	1,915,339	960	506

Table X-X. 2013 AC34 Operation On-Water Sources Emissions [lb/yr] (continued)

Location	ROG	CO	NOx	SOx	PM10	DPM	PM2.5	PMtire	PMbrk	CO2	CH4	N2O
Pier 26 and 28	16,875	189,133	7,088	15.13	120.52	48.66	110.88	0.00	0.00	1,328,304	665	330.67
Pier 30-32	33,749	378,267	14,176	30.27	241.04	97.31	221.76	0.00	0.00	2,656,607	1,330	661
Pier 80	3,993	44,624	1,835	4.21	33.28	16.22	30.61	0.00	0.00	370,634	185.33	77.80
Piers 27-29 and Pier 29½	10,965	66,147	80,109	35.65	3,265	3,248	3,165	0.00	0.00	370,634	185.33	77.80
Spectator Vessels	56,044	89,122	5,071	9.88	2,910	33.97	2,677	0.00	0.00	637,394	1,297	239.63

On-Road Spectator Traffic

Table X-X. 2012 AC34 Operation On-Road Spectator Traffic Emissions [lb/yr]

Location	ROG	CO	NOx	SOx	PM10	DPM	PM2.5	PMtire	PMbrk	CO2	CH4	N2O
San Francisco	40.12	825	81.46	1.57	4.56	0.00	4.13	0.88	2.20	163,157	0.00	0.00
East Bay	437.29	8,992	888	17.15	49.74	0.00	45.01	9.59	23.96	1,778,304	0.00	0.00
North Bay	1,279	26,291	2,596	50.14	145.44	0.00	131.59	28.03	70.07	5,199,361	0.00	0.00
South Bay	2,045	42,044	4,151	80.19	232.58	0.00	210.44	44.82	112.05	8,314,783	0.00	0.00
Out of Region	321.86	6,618	653	12.62	36.61	0.00	33.13	7.06	17.64	1,308,868	0.00	0.00

Table X-X. 2013 AC34 Operation On-Road Spectator Traffic Emissions [lb/yr]

Location	ROG	CO	NOx	SOx	PM10	DPM	PM2.5	PMtire	PMbrk	CO2	CH4	N2O
San Francisco	88.94	1,876	188.08	4.20	12.15	0.00	11.00	2.35	5.88	434,722	0.00	0.00
East Bay	964	20,338	2,039	45.53	131.76	0.00	119.26	25.48	63.71	4,713,564	0.00	0.00
North Bay	2,917	61,523	6,169	137.73	398.59	0.00	360.76	77.09	192.72	14,258,542	0.00	0.00
South Bay	4,524	95,418	9,567	213.61	618	0.00	560	119.56	298.89	22,114,176	0.00	0.00
Out of Region	690	14,544	1,458	32.56	94.23	0.00	85.29	18.22	45.56	3,370,804	0.00	0.00

APPENDIX AQ-4
Cruise Ship Vessel Activity and Emission Inventory Methodology, James R. Herman Cruise Terminal and Northeast Wharf Plaza Project

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ENVIRON

November 23, 2011

MEMORANDUM

To: Chris Sanchez, ESA

From: Elizabeth Miesner
Michael Keinath
Chris Lindjhem
Till Stoekenius

Re: Cruise Ship Vessel Activity and Emission Inventory Methodology
James R. Herman Cruise Terminal and Northeast Wharf Plaza Project

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This section documents the emission estimation methods and results for large deep-draft ocean-going vessels (OGV) calling at Port of San Francisco (POSF) cruise terminals in 2011 and future year scenarios. ENVIRON followed the United States Environmental Protection Agency (EPA) guidance for best practices (ICF Consulting 2009) with updates for consistency with the latest California Air Resources Board (ARB) OGV emission inventory (ARB 2011a). The basic activity data were provided in the Port of San Francisco's 2005 emission inventory. (BPC 2010)

The cruise ships may be designed to use propulsion engines for movements and auxiliary engines for electrical power, or more often use a diesel-electric design where all diesel or gas turbine engines drive an electrical generator that supplies power for propulsion and auxiliary loads. The methodology used for estimating emissions was to multiply appropriate emission factors with the engine operating hours and load factor. Each vessel has unique characteristics of speed, engine type and power that affect the estimate of engine operating hours and load for each vessel call.

The activity for the ship calls used in this analysis is outlined in Table 1. Each link (a segment of the ship travel) is a specific operating mode for ship movements. For some links, a reduced speed limit of 13.5 knots was used rather than 15 knots as in the Bay Planning Coalition (BPC 2010) inventory as 15 knots is the maximum speed allowed along these links; using an average speed of 13.5 knots accounts for some vessels operating below the absolute maximum allowable speed limit.

Table 1. Ocean Going Vessels – Transit link descriptions

Transit into Port				
Direction	**Link Start**	**Link End**	**Distance (nautical miles)**	**Speed (knot)**
In – From Asia or Northern Ports	November Buoy	Pilot Boards	7.2	Cruise
In – From Hawaii	Whiskey Buoy	Pilot Boards	6.5	Cruise
In – From Southern Ports	Sierra Buoy	Pilot Boards	5.8	Cruise

Table 1. Ocean Going Vessels – Transit link descriptions				
Transit into Port				
Direction	**Link Start**	**Link End**	**Distance (nautical miles)**	**Speed (knot)**
In – All	Pilot Boards	Pilot Buoy	1.7[1]	10
In – All	Sea Buoy	Golden Gate	8.7	13.5
In – All	Golden Gate	North of Pier 45	2.9	13.5
In – All	North of Pier 45	Pier 35	0.6	7
In – All (when Pier 27 in operation)	Pier 35	Pier 27	0.45	7
Maneuvering Modes				
Direction	**Link Start**	**Link End**	**Distance (nautical miles)**	**Speed (knot)**
In	At Pier	At Pier	0.25	0.16
Out	At Pier	At Pier	0.25	0.16
Transit out of Port				
Direction	**Link Start**	**Link End**	**Distance (nautical miles)**	**Speed (knot)**
Out – All (when Pier 27 in operation)	Pier 27	Pier 35	0.45	7
Out – All	Pier 35	North of Pier 45	0.6	7
Out – All	North of Pier 45	Golden Gate	2.9	13.5
Out – All	Golden Gate	Sea Buoy	8.9	13.5
Out – All	Sea Buoy	Pilot Departs	1.7[1]	10
Out – To Asia or Northern Ports	Pilot Departs	November Buoy	5.9	Cruise
Out – To Hawaii	Pilot Departs	Whiskey Buoy	6.6	Cruise
Out – To Southern Ports	Pilot Departs	Sierra Buoy	7.1	Cruise

Notes:
[1] Assumes 10 minutes at slower speed for the pilot to board and depart safely. Distance in this mode was subtracted from the cruise mode. Distances were measured from east of Sea Buoy.

Propulsion Power and Load

Propulsion power and vessel speed were derived from the Lloyds (2009) database, which provides design features for each vessel. Similar to the ARB OGV emissions inventory (ARB 2011a), Lloyds' Main Engine Power and Vessel Speed data were used directly to obtain estimates of maximum engine power and vessel speed.

Load factors for the propulsion power over any given link were determined from the Stokes Law cubic relationship for speed vs. load. The proportional relationship of load to the vessel speed can be expressed as in the following equation, where the 100% load factor would correspond to the vessel operating at its maximum speed.

$$\text{Load Factor} = (\text{Vessel Speed}/\text{Vessel Maximum Speed})^3$$

Consistent with the ARB OGV emissions inventory, the cruise speed of an OGV was estimated to be 0.937 of the vessel maximum speed. Thus, the load factor at the cruise speed was calculated to be 0.823 during cruise conditions. For other vessel speed conditions, the propulsion load factor is reduced according to the link vessel operation speed and the vessel maximum speed for each of those links provided by the Lloyds database.

Most cruise ships have a diesel (or gas turbine) electric design in which there is no distinction between propulsion and auxiliary loads and power is supplied to a central electrical grid by numerous engines or gas turbines. To estimate the engine loads, the total load (propulsion load plus auxiliary load) at cruise speed was assumed to be 82.3% of total installed power (defined as the total rated power of all engines on board). Of this 82.3% total load,16% is assumed to be the auxiliary load (as described below and in ARB 2011a) and the remaining 66.3% is the propulsion load at cruise speed. The propulsion load is adjusted for speeds below cruise speed via the above formula for lower speed portions of each call as listed in Table 1.

Auxiliary Power and Load

As described in the Port of Oakland Emission Inventory study (ENVIRON 2008), the auxiliary power was primarily derived from auxiliary generator capacity taken from the Lloyds database and supplemented by other available data and estimates.

ENVIRON used the same auxiliary engine load factor as the ARB OGV emissions inventory (ARB 2011a) for auxiliary power of 0.16 (Table 2), and related it to the total installed power. During transiting (at cruise or reduced speed and maneuvering) for electric vessel designs, the hotelling load was added to the propulsion power demand as estimated above. For other vessel designs, the propulsion and auxiliary engines were treated independently.

Table 2. Ocean Going Vessels – Auxiliary engine load factor assumptions

Ship Type	Engine Load Factor –Hoteling
Cruise	0.16

Source:ARB. 2011

Emission Rates

Emission rates (or factors) used in this analysis come from the ARB OGV emission inventory (ARB 2011a) for diesel engines and the EPA guidance for best practices (ICF 2009) for gas turbines and are listed in Table 3. For the few non-electric geared-drive vessels, low load adjustment factors provided by ARB were applied to the propulsion engine emission factors as described in the Port of Oakland emission inventory report (ENVIRON 2008).

Table 3. Emission factors for OGV engines

Engine Type	Pollutant	Fuel	Emission Factor (g/kW-hr)
4-Stroke	CO	MGO 0.1	1.1
4-Stroke	CO_2	MGO 0.1	645
4-Stroke	NOx	MGO 0.1	13.2
4-Stroke	PM_{10}	MGO 0.1	0.25
4-Stroke	ROG	MGO 0.1	0.65
4-Stroke	SOx	MGO 0.1	0.4
4-Stroke	CO	MGO 0.5	1.1
4-Stroke	CO_2	MGO 0.5	645
4-Stroke	NOx	MGO 0.5	13.2
4-Stroke	PM_{10}	MGO 0.5	0.38
4-Stroke	ROG	MGO 0.5	0.65
4-Stroke	SOx	MGO 0.5	2.08
Gas Turbine	CO	Gas Oil	0.2
Gas Turbine	CO_2	Gas Oil	970
Gas Turbine	NOx	Gas Oil	2
Gas Turbine	PM_{10}	Gas Oil	0.13
Gas Turbine	$PM_{2.5}$	Gas Oil	0
Gas Turbine	ROG	Gas Oil	0.08347
Gas Turbine	SOx	Gas Oil	0

Abbreviations:

CO: carbon monoxide
CO_2: carbon dioxide
g/kW-hr: grams per kilowatt-hour
MGO: marine gas oil
NOx: oxides of nitrogen
PM_{10}: particulate matter, diameter less than 10 microns
$PM_{2.5}$: particulate matter, diameter less than 2.5 microns
ROG: reactive organic gases
SOx: sulfur oxides

Vessel Activity and Characteristics

The vessels call at the Port of San Francisco varies over the years. Table 4 shows the most recent number of port calls from 2001 to 2010. Based on these data, the nominal maximum number of port calls of 80 per year was used in the emission analyses for the baseline and further year scenarios.

Table 4. Number of vessel calls from 2001 to 2010 for Port of San Francisco	
Year	**Cruise Port Calls**
2001	41
2002	42
2003	80
2004	84
2005	84
2006	81
2007	60
2008	59
2009	62
2010	41

For vessel characteristics, in terms of cruise speed, type (i.e., electric or standard design) and installed engine power and type (i.e., diesel or gas turbine), the 2011 vessel data from the Lloyds database (see Table 5) were used to better represent the vessel fleet characteristics of the baseline and future year scenarios. The average berthing time was estimated to be 15.12 hours per call based on 2011 calls and expected calls.

Note that the Carnival Splendor call in February 2011 was excluded in the calculation of the average berthing time of 15.12 hours as it was in San Francisco for repairs. The 124 hours at berth for the Carnival Splendor call represented an unusual one-time event as it was much longer than the next longest call at 41 hours.

Table 6 shows the future year scenarios used for this analysis presented in the Draft Environmental Impact Report (DEIR) and the Final Environmental Impact Report (FEIR). The number of vessel calls was assumed to be 80 per year, as in the base year. Based on the historical data, this analysis assumed five (5) calls, out of the 80 calls per year, are exempted from the shorepower requirements as these calls are assumed to be made by cruise lines that would not call the California ports more than the shorepower rule threshold of five California port calls per year. Also, newer model and larger ships are expected to call at the new terminal in future years. Thus, the three latest model vessels calling in 2011, which were newer model and larger vessels, were used to represent the future fleet.

In addition, the California low sulfur fuels and shorepower requirements were included in the scenario development as shown for both the analysis. However, the future year analyses did not include the shoreside power requirements during the construction of the cruise terminal shell in 2012 or occupancy of the cruise terminal for the 34th Americas Cup event (AC34) in 2013, as shoreside power would not be available during those periods.

Table 5. 2011 Scheduled cruise ship calls and vessel characteristics

IMO Number	Calls	Propulsion Power (kW)	Vessel Name	Engine	Engine Type	Engine (rpm)	Speed (knots)	Engine Type	Auxiliary Power (kW)	Time at Berth (hrs)	Shorepower Use[a] (# of calls)
9141807	1	12,320	Deutschland	4-Stroke	Medium	514	20	Motor Diesel	7,720	41	0
9247144	1	N/A	Seven Seas Voyager	Electric	Medium	514	20	Diesel-Electric	23,760	32	0
9226906	2	N/A	Arcadia	Electric	Medium	514	22	Diesel-Electric	63,360	24	0
9333163	1	N/A	Carnival Splendor	Electric	Medium	514	22	Diesel-Electric	75,600	124[b]	0
9438066	1	N/A	Marina	Electric	Medium	514	19.5	Diesel-Electric	42,000	28	0
9169524	1	N/A	Aurora	Electric	Medium	514	24	Diesel-Electric	56,000	10	0
9183855	1	N/A	Europa	Electric	Medium	514	21	Diesel-Electric	21,600	20	0
9066667	14	N/A	Crystal Symphony	Electric	Medium	514	21	Diesel-Electric	36,330	14.1	0
9126819	1	N/A	Disney Wonder	Electric	Medium	514	21.5	Diesel-Electric	57,670	31.5	0
9342281	2	N/A	Norwegian Pearl	Electric	Medium	514	25	Diesel-Electric	72,080	9.5	0
9189419	2	N/A	Celebrity Millennium	Turbine	Gas	N/A	24	Gas Turbine	50,000	31	0
9228186	4	N/A	Sapphire Princess	Electric	Medium	514	23	Combined	60,700	13.5	3
9150913	14	N/A	Sea Princess	Electric	Medium	514	19.5	Diesel-Electric	46,080	9	8
9156474	4	N/A	Regatta	Electric	Medium	514	18	Diesel-Electric	18,600	10.5	0
9064126	2	15,536	Seven Seas Navigator	4-Stroke	Medium	600	17.5	Motor Diesel	6,600	10	0

[a] As provided by the Port of San Francisco in April 12, 2011 DRAFT 2011 Cruise Calls Using Shoreside Power at Pier 27 (Attachment A)

[b] Extraordinary due to drydock repairs.

AQ.4-8

Table 5. 2011 Scheduled cruise ship calls and vessel characteristics

IMO Number	Calls	Propulsion Power (kW)	Vessel Name	Engine	Engine Type	Engine (rpm)	Speed (knots)	Engine Type	Auxiliary Power (kW)	Time at Berth (hrs)	Shorepower Use[a] (# of calls)
9230402	1	N/A	Island Princess	Electric	Medium	514	24	Combined	62,683	9	1
9072446	2	29,250	Celebrity Century	4-Stroke	Medium	514	21.5	Motor Diesel	26,800	30	0
9195195	1	N/A	Radiance Of The Seas	Turbine	Gas	N/A	24	Gas Turbine	57,500	10	0
9229659	2	N/A	Coral Princess	Electric	Medium	514	21.5	Combined	62,683	8	1
8806204	1	N/A	Asuka II	Electric	Medium	514	22	Diesel-Electric	34,560	11	0
9189421	1	N/A	Celebrity Infinity	Turbine	Gas	N/A	24	Gas Turbine	70,742	24.5	0
9195157	1	N/A	Norwegian Star	Electric	Medium	514	24.6	Diesel-Electric	58,800	12	0
8708672	1	5,038	Orion II	4-Stroke	Medium	514	20	Motor Diesel	4,200	34	0
Total Number of Shoreside Power Calls											13
Average time at berth (without Carnival Splendor dry dock repairs)										15.12	

Abbreviations:
- hrs: hours
- IMO: International Marine Organization
- knots: nautical miles per hour
- kW: kilowatt
- N/A: not applicable
- rpm: revolutions per minute

AQ.4-9

Table 6. Future year scenarios

Year	Total Calls	DEIR Fuel	FEIR Fuel	Fleet Characteristics	DEIR Shorepower Use (Build Scenario)	FEIR Shorepower Use (Build Scenario)
2011	80	0.5% sulfur MGO	0.5% sulfur MGO	2011 - 61 scheduled calls (scaled to 80 calls for analysis)	Estimated 17 calls (expected 13 of 61 total calls will use shorepower in 2011, when scaled to 80 calls results in 17 calls using shorepower in 2011)	40 Calls
2012	80	0.1% sulfur MGO	0.5% sulfur MGO[c]	Same as 2011;	No shorepower use due to construction of cruise terminal shell	Same as 2011
2013	80	0.1% sulfur MGO	Same as 2012	Same as 2011	No shorepower use due to occupancy of cruise terminal by AC34 activities	Same as 2011

AQ.4-10

[c] Since the time of the DEIR, there has been a change of the Fuel Sulfur and Other Operational Requirements for Ocean-Going Vessels within California Waters and 24 nautical miles from the coast, so that 0.1% sulfur fuel is not required until 2014 (ARB 2011b). http://www.arb.ca.gov/ports/marinevess/documents/marinenote2011_2.pdf

Table 6. Future year scenarios

Year	Total Calls	DEIR Fuel	FEIR Fuel	Fleet Characteristics	DEIR Shorepower Use (Build Scenario)	FEIR Shorepower Use (Build Scenario)
2014 - 2016	80	0.1% sulfur MGO	0.1% sulfur MGO	Adjusted Berthing Time 15.12 hours for all future year scenarios Three representative vessels (Build Year, Total Power): 1) 27 calls, Carnival Splendor(2005, 75,600 kW) 2) 26 calls, Oceania Marina(2009, 42,000 kW) 3) 27 calls, Norwegian Pearl(2005, 72,080 kW)	38 calls (50% of 75 calls):[d] 1) 13 calls, Carnival Splendor 2) 12 calls, Oceania Marina 3) 13 calls, Norwegian Pearl NOTE: For "Shed Variant" – in 2014 no shorepower use is assumed due to construction of cruise terminal. For 2015 & 2016, shorepower assumptions as listed above.	40 calls: 4) 14 calls, Carnival Splendor 5) 13 calls, Oceania Marina 6) 13 calls, Norwegian Pearl NOTE: For "Shed Variant" – in 2014 no shorepower use is assumed due to construction of cruise terminal. For 2015 & 2016, shorepower assumptions as listed above.

AQ.4-11

[d] The ARB At-Berth Ocean-Going Vessel Regulation ("Shorepower Rule") requires at least 50% shorepower use in 2014, 70% in 2017 and 80% in 2020. Before 2014, shorepower use is required for equipped ships if compatible with available port equipment. Five calls were assumed to be exempted from the 80 calls as in 2011 there are 4 of 61 calls which are single calls from cruise lines which are not expected to call at other California ports (Hapag-Lloyd, NYK, TF Marine, and V. Ships). Five calls of 80 is scaled from the 4 of 61 in 2011. Other cruise lines in 2011 were Carnival (only 1 call at POSF in 2011, however, this is a large company with calls at other ports in California), Celebrity (5 calls), Crystal (14), Disney (1 call, but expect more elsewhere), NCL (3 calls, but expect more elsewhere), Oceania (5 calls), P&O (3 calls, but expect more elsewhere), Princess (21), Regent 7 Seas (3 calls, but expect more elsewhere), Royal Caribbean (1 call, but expect more elsewhere). All of these cruise lines would not be exempted from the ARB Shorepower Rule.

AQ.4-12

Table 6. Future year scenarios

Year	Total Calls	DEIR Fuel	FEIR Fuel	Fleet Characteristics	DEIR Shorepower Use (Build Scenario)	FEIR Shorepower Use (Build Scenario)
2017 – 2019	80	0.1% sulfur MGO	0.1% sulfur MGO	Same as 2014 - 2016	53 calls (70% of 75 calls):[e] 1) 18 calls, Carnival Splendor 2) 17 calls, Oceania Marina 3) 18 calls, Norwegian Pearl	Same as DEIR (All calls to Pier 27)
2020 onward	80	0.1% sulfur MGO	0.1% sulfur MGO	Same as 2014 - 2016	60 calls (80% of 75 calls):[f] 1) 20 calls, Carnival Splendor 2) 20 calls, Oceania Marina 3) 20 calls, Norwegian Pearl	Same as DEIR (All calls to Pier 27)

Abbreviations:
DEIR: Draft Environmental Impact Report
FEIR: Final Environmental Impact Report
MGO: marine gas oil
POSF: Port of San Francisco

[e] Ibid.
[f] Ibid.

References

Air Resources Board (ARB). 2011a. "Emissions Estimation Methodology for Ocean-Going Vessels," California Air Resources Board, May 2011. Available at http://www.arb.ca.gov/regact/2011/ogv11/ogv11appd.pdf

ARB. 2011b. "Marine Notice 2011-2: Changes to the Regulation on Fuel Sulfur and Other Operational Requirements for Ocean-Going Vessels within California Waters and 24 Nautical Miles of the California Baseline" California Air Resources Board, November 2011. Available at http://www.arb.ca.gov/ports/marinevess/documents/marinenote2011_2.pdf

Bay Planning Coalition (BPC). 2010. "SF Bay Seaports Air Emission Inventory, Port of San Francisco 2005 Emission Inventory," Prepared for the Bay Planning Coalition, June 2010.

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Lloyds. 2009. "PC Register of Ships, September 2009" Fairplay, Limited, 2009. September, 2009.

Attachment:

Attachment A: Port of San Francisco in April 12, 2011 DRAFT 2011 Cruise Calls Using Shoreside Power at Pier 27

Attachment A

Port of San Francisco in April 12, 2011
DRAFT 2011 Cruise Calls Using Shoreside Power at Pier 27

AQ.4-15

2011 Cruise Calls Using Shoreside Power
Port of San Francisco Pier 27
(April 12, 2011 Draft)

Date	Ship	Arrive	Depart	Pier/Side-To	Tugs Required	Power Req'd
May 14 (Saturday)	Island Princess	7:00(6:30?)AM	4:00(5:00?)PM	Pier 27 (SST or PST?)	3 - Class A Tugs	8.5 MW @11.0 kV
May 30 (Monday)	Sea Princess	7:00AM	4:00PM	Pier 27 stern-in (PST)	2 - Class A Tugs	9.0 MW @6.6 kV
June 29 (Wednesday)	Sea Princess	7:00AM	4:00PM	Pier 27 stern-in (PST)	2 - Class A Tugs	9.0 MW @6.6 kV
July 9 (Saturday)	Sea Princess	7:00AM	4:00PM	Pier 27 stern-in (PST)	2 - Class A Tugs	9.0 MW @6.6 kV
July 29 (Friday)	Sea Princess	7:00AM	4:00PM	Pier 27 stern-in (PST)	2 - Class A Tugs	9.0 MW @6.6 kV
August 8 (Monday)	Sea Princess	7:00AM	4:00PM	Pier 27 stern-in (PST)	2 - Class A Tugs	9.0 MW @6.6 kV
August 28 (Sunday)	Sea Princess	7:00AM	4:00PM	Pier 27 stern-in (PST)	2 - Class A Tugs	9.0 MW @6.6 kV
Sept. 7 (Wednesday)	Sea Princess	7:00AM	4:00PM	Pier 27 stern-in (PST)	2 - Class A Tugs	9.0 MW @6.6 kV
Sept. 17 (Saturday)	Sea Princess	7:00AM	4:00PM	Pier 27 stern-in (PST)	2 - Class A Tugs	9.0 MW @6.6 kV
Sept. 22 (Thursday)	Sapphire Princess	8:00AM	10:00PM	Pier 27 stern-in (PST)	2 - Class A Tugs	10.5 MW @11.0 kV
Sept. 26 (Monday)	Coral Princess	10:00AM	5:00PM	Pier 27 stern-in (PST)	2 - Class A Tugs	? ? ? ?
Sept. 27 Tuesday)	Sapphire Princess	7:00AM	10:00PM	Pier 27 stern-in (PST)	2 - Class A Tugs	10.5 MW @11.0 kV
October 4 (Tuesday)	Sapphire Princess	7:00AM	10:00PM	Pier 27 stern-in (PST)	2 - Class A Tugs	10.5 MW @11.0 kV

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APPENDIX AQ-5
Fuel Assumptions for Marine Vessels Operating at AC34

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ENVIRON

November 23, 2011

MEMORANDUM

To: Chris Sanchez, ESA

From: Michael Keinath
Till Stoeckenius
Elizabeth Miesner

Re: Fuel assumptions for marine vessels operating at AC-34

Estimates of marine vessel operational emissions associated with the 34th Americas Cup event (AC-34) were based on various assumptions regarding vessel characteristics and activities provided to ENVIRON or obtained from other similar studies. This memorandum summarizes assumptions about fuel properties for all marine sources that contribute to emissions from the AC-34 events. As shown in Table 1, there are six types of vessels operating during the race. Race-sponsored spectator boats, assist tugs for helipad barge, assist tugs for transporting equipment/trucks to Alcatraz, and large, private spectator yachts were all assumed to run on United States Environmental Protection Agency (EPA) on-road diesel at 255 parts per million (ppm) sulfur content, which is based on emissions estimates for excursion boats and tugs in the San Francisco Bay Area Seaports Air Emissions Inventory.

In preparation of the Draft Environmental Impact Report (DEIR), there was limited information about the race support vessels except that they run on gasoline, and thus they were modeled using OFFROAD assuming the use of gasoline-fueled pleasure craft outboard engines. Also, since there was no information on fuel type for small, private spectator boats, the OFFROAD model was run for the San Francisco Bay Area Air Basin and the ratios for gasoline-and diesel-fueled boats were obtained. Note that the OFFROAD model is developed by the California Air Resources Board (ARB) for estimating emissions from off-road equipment specifically operating in California. Therefore the diesel fuel used is assumed to be 15% ppm sulfur content or lower Ultra-low Sulfur Diesel (ULSD) as required under California regulations.

Table 1. Marine vessels fuel assumptions as presented in the DEIR.

#	Vessel Type	Engine	Ref[1]	Fuel	Notes
1	Race-sponsored Spectator Boats	Main	BPC	EPA on-road diesel at 255ppm S	Modeled as excursion boats
		Auxiliary	BPC	EPA on-road diesel at 255ppm S	
2	Race Support Vessels	Main	OFFROAD	Gasoline	Modeled as 175HP outboard engine for pleasure crafts
3	Assist Tug for Helipad Barge	Main	BPC	EPA on-road diesel at 255ppm S	Modeled as tug boats
		Auxiliary	BPC	EPA on-road diesel at 255ppm S	

[1] BPC refers to the Bay Planning Coalition San Francisco Bay Seaports emissions inventory; OFFROAD refers to California Air Resources Board off-road emissions model.

Table 1. Marine vessels fuel assumptions as presented in the DEIR.					
#	Vessel Type	Engine	Ref[1]	Fuel	Notes
4	Assist Tug for transporting equipment / trucks to Alcatraz	Main	BPC	EPA on-road diesel at 255ppm S	Modeled as tug boats
		Auxiliary	BPC	EPA on-road diesel at 255ppm S	
5	Private Spectator Vessels - Small Local Vessels	Main (spark ignition)	OFFROAD	Gasoline	Vessel characteristics and EF are population weighted averages of pleasure crafts in SF Bay Area
		Main (compression ignition)	OFFROAD	CA ULSD	Vessel characteristics and EF are population weighted averages of pleasure crafts in SF Bay Area
6	Private Spectator Vessels - Large Yachts	Main	BPC	EPA on-road diesel at 255ppm S	Modeled as excursion boats
		Auxiliary	BPC	EPA on-road diesel at 255ppm S	

After the release of the DEIR, several changes were made to the marine vessels emissions estimates, including the fuel assumption for race support vessels. More detailed information was provided on the number of gasoline-fueled and diesel-fueled engines (instead of the all-gasoline-fueled assumption) and emissions were remodeled, as summarized in Table 2.

Table 2. Modification on fuel assumptions in the FEIR.					
#	Vessel Type	Engine	Ref	Fuel	Notes
2	Race Support Vessels	Main (spark ignition)	OFFROAD	Gasoline	Modeled as MY 2010, 4-stroke outboard engines
		Main (compression ignition)	OFFROAD	CA diesel	Modeled as MY 2010, inboard engines

APPENDIX AQ-6
Shoreside Power at BAE Systems Facility, Pier 70

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ENVIRON

November 23, 2011

MEMORANDUM

To: Chris Sanchez, ESA

From: Chris Lindjhem
Till Stoekenius
Michael Keinath
Lit Chan

Cc: Brad Benson, Port of San Francisco

Re: Shoreside Power at BAE Systems Facility, Pier 70

ENVIRON was asked by the Port of San Francisco (POSF) to calculate the potential emissions reductions by using shore power for ships undergoing maintenance at the BAE Systems Facility at Pier 70 in San Francisco. For conservative estimates, this analysis was performed based on the low-end projected annual usage information of the BAE Systems facility from 2012 through 2017 provided by Brad Benson of the POSF (see Attachment A.) The major differences between the low-end and high-end projected annual usage estimates are the number of days and vessels at the BAE Systems Facility for the T-AKE vessels. Depending on the scenario year, the ratio between the high-end and low-end estimates is between 1 to 2.5 with an average of 1.75 over the six year period.

The BAE Systems Facility has scheduled maintenance for several T-AKE military support vessels and cruise ships over the next six years, which is the period of BAE Systems Facility's current lease. These vessels are scheduled to be laid-up for multiple days within the dry dock or at nearby piers with the minimum total days of each type shown in Table 1. During this period there may be other vessels brought in for unscheduled maintenance, such as occurred in 2011 with the Carnival Splendor. The first of the T-AKE vessels is due for maintenance in 2011. For this analysis, the connect/disconnect time was subtracted from the time available for shorepower using the dry dock connect/disconnect time of 16 hours (8 hours each in and out), and 4 hours at the pier for the T-AKE vessels expected to be stationed at both the dry dock and pier for the same maintenance event, except one T-AKE vessel in 2013 that is not anticipated to be on the dry dock.

Table 1. Scheduled Maintenance (low-end projection estimates[1])

Ship Type	T-AKE Vessels			Cruise Ship		
Year	Number of Vessels	Total Days at Facility (for all vessels)	Total Connect/Disconnect Time (hours)	Number of Vessels	Total Days at Facility (for all vessels)	Total Connect or Disconnect Time (hours)
2012	2	110	40	3	36	48
2013	3	152	44[2]	3	28	48

Table 1. Scheduled Maintenance (low-end projection estimates[1])						
Ship Type	**T-AKE Vessels**			**Cruise Ship**		
Year	**Number of Vessels**	**Total Days at Facility (for all vessels)**	**Total Connect/Disconnect Time (hours)**	**Number of Vessels**	**Total Days at Facility (for all vessels)**	**Total Connect or Disconnect Time (hours)**
2014	2	97	40	4	44	64
2015	0	0	0	1	12	16
2016	1	55	20	3	27	48
2017	3	165	60	3	30	48

Notes:
[1] Low-end projection estimates are based on the lowest number of days and vessels for the T-AKE vessels at the BAE Systems Facility.
[2] One of the T-AKE vessels is not anticipated to be on the dry dock.

While at the BAE Systems Facility, both the T-AKE vessels and cruise ships require auxiliary loads to maintain ship functions such as HVAC and other crew support systems. These auxiliary loads are currently supplied by the on-board diesel generators. The T-AKE vessels have diesel-electric designs powered by four MAN 48/60 engines that have a total installed power of 35,700 kW. The cruise ships vary in size, but most, if not all, would have higher installed power than the T-AKE vessels and primarily use MAN 48/60 or Wartsila 46 medium-speed engines with typical rated speeds of 514 rpm.

For the purposes of this analysis, POSF indicated the load while in dry dock was assumed to be 4,000 kW for cruise ships, which is less than 10% of the typical nearly 50,000 kW minimal installed engine capacity on cruise ships, and less than the 16% load that the California Air Resources Board (ARB)'s estimates for passenger vessels during normal commercial port calls in emission inventory calculations (ARB 2011a), and a minimum of 3,500 kW for T-AKE vessels (as shown in Attachment A).

Under the ARB Ocean-Going Vessel (OGV) Fuel Rule (as amended September 16, 2011 [ARB 2011b]), 0.5% sulfur fuel will be required while operating within California waters in 2012 and 2013 and 0.1% sulfur fuel will be required starting in 2014. Emission factors for T-AKE vessels and cruise ships while operating on these fuels are shown in Table 2 (ARB 2011a). The NOx emission factor reflects the Tier 1 NOx limit under international standards for engines with rated speeds of 514 rpm which is applicable to vessels built after 2000 and major conversions of older engines (Tier 2 standards apply to vessels built after 2010 and vessels scheduled for maintenance during the next six years do not include new vessels) (MARPOL 2008).

Table 2. Emission factors for large medium speed marine diesel engines								
Year	**Fuel Sulfur Content**	**Emission Factors (g/kWh)**						
		ROG	**NOx**	**PM[1]**	**CO**	**SOx**	**CO_2**	**BSFC**
2012-2013	0.50%	0.65	12.9	0.38	1.1	2.08	645	203

Table 2. Emission factors for large medium speed marine diesel engines								
Year	Fuel Sulfur Content	Emission Factors (g/kWh)						
		ROG	NOx	PM[1]	CO	SOx	CO_2	BSFC
2014+	0.10%	0.65	12.9	0.25	1.1	0.40	645	203

Notes:
[1] As all PM is assumed to be diesel particulate matter.

Using the low-end projected maintenance schedule for the BAE Systems Facility shown in Table 1, ENVIRON estimated the potential emission reduction estimates using shore power for these vessels while they are undergoing maintenance. The potential emission reduction estimates are shown in Table 3. Note that the analysis assumed all vessels have the ability to use shore power and this assumption is reasonable as most military vessels and cruise ships are generally equipped or will be equipped with shore power capability. Even if some vessels that may not be equipped for shore power, the shore power project could include funding for the necessary onboard modifications to equip these vessels with shore power capability. Potential emission reduction estimates from this analysis is very conservative as it is based on the low-end projected usage information and that the actual generator loads while in dry dock may be higher than the estimates used in this analysis (i.e. 4,000 kW for cruise ships and 3,500 kW for T-AKE vessels).

Table 3. Potential Emissions reduction Estimates of Using Shore Power for the project						
Year	Emissions Reductions Estimates (tpy)					
	ROG	NOx	PM	CO	SOx	CO_2
2012	8.86	176	5.18	15	28	8,791
2013	10.83	215	6.33	18	35	10,743
2014	8.58	170	3.30	15	5	8,515
2015	0.78	15	0.30	1	0	774
2016	4.98	99	1.92	8	3	4,941
2017	11.71	232	4.50	20	7	11,616

Notes:
tpy – tons per year

Abbreviations

ARB – Air Resources Board

BSFC – Brake-specific fuel consumption

CO – carbon monoxide

CO_2 – carbon dioxide

NOx – oxides of nitrogen

OGV – Ocean-Going Vessel

PM – particulate matter

POSF – Port of San Francisco

ROG – reactive organic gases

SOx – oxides of sulfur

tpy – tons per year

References:

Air Resources Board (ARB). 2011a. "Appendix D Emissions Estimation Methodology for Ocean-Going Vessels," Staff Report: Initial Statement of Reasons (ISOR), May 2011, http://www.arb.ca.gov/regact/2011/ogv11/ogv11.htm

ARB. 2011b. "Final Regulation Order, Fuel Sulfur And Other Operational Requirements For Ocean-Going Vessels Within California Waters And 24 Nautical Miles Of The California Baseline," September 16, 2011, http://www.arb.ca.gov/regact/2011/ogv11/ogvfro17.pdf

MARPOL Annex VI. 2008. "Amendments to the Annex of the Protocol of 1997 to Amend the International Convention for the Prevention of Pollution from Ships, 1973, As Modified by the Protocol of 1978 Relating Thereto (Revised Marpol Annex Vi)," Resolution Mepc.176(58), Adopted on 10 October 2008, http://www.imo.org/OurWork/Environment/PollutionPrevention/AirPollution/Documents/23-Add-1.pdf

Attachments:

Attachment A: BAE SF Ship Repair Estimated Shorepower Usage
(Low estimate based on T-AKE & Cruise Ship work)

Attachment A

BAE SF Ship Repair Estimated Shorepower Usage
(Low estimate based on T-AKE & Cruise Ship work)

AQ.6-8

BAE SF Ship Repair Estimated Shorepower Usage (Low estimate based on T-AKE & Cruise Ship work)

Year	T-AKE (Days)	Cruise Ships (Days)	hours of work per day	Power Requirement: T-AKE Load kW	Power Requirement: Cruise Ship Load kW	Total Annual Power Usage: T-AKE (kWhr)	Total Annual Power Usage: Cruise Ships (kWhr)	Total Annual Power Usage: Combined (kWhr)
2012	110	36	24	3500	4000	9,240,000	3,456,000	12,696,000
2013	152	28	24	3500	4000	12,768,000	2,688,000	15,456,000
2014	97	44	24	3500	4000	8,148,000	4,224,000	12,372,000
2015	0	12	24	3500	4000	0	1,152,000	1,152,000
2016	55	27	24	3500	4000	4,620,000	2,592,000	7,212,000
2017	165	30	24	3500	4000	13,860,000	2,880,000	16,740,000
Six Year Total	579	177		--	--	48,636,000	16,992,000	65,628,000
Average	97	30		--	--	8,106,000	2,832,000	10,938,000
High	165	44		--	--	13,860,000	4,224,000	16,740,000
Low	0	12		--	--	0	1,152,000	1,152,000

*** Estimates of power consumption are only based on T-AKE and Cruise Ship availabilities, and assume lowest expected award rate of T-AKE contracts.**

APPENDIX TR

Supplemental Transportation Technical Appendix

TR-5A. Addendum to Appendix TR-5

TR-7A. Appendix TR-7 Replacement Pages

APPENDIX TR-5A
Addendum to Appendix TR-5

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Addendum to Appendix TR-5

AC34 - Regional Transit - Ridership and Capacity Assumptions							
Saturday Midday Peak Hour - Inbound into San Francisco							
		Existing	**Existing**	**Existing**	**Future**	**Capacity**	
BART		**Ridership**	**Capacity**	**Utilization**	**Capacity**	**Increase**	**People Plan Notes**
East Bay		3,900	8,064	48%	16,128	100%	Operate w/ 9/10-car long trains
South Bay		2,340	8,547	27%	17,094	100%	Operate w/ 9/10-car long trains
		6,240	16,611	38%	33,222	100%	
AC Transit							
11:22 arrival	F	19	40	48%	116	190%	Replace w/ artics (58 pax) at
11:52 arrival	F	37	40	93%	116	190%	15-min headways
11:20 arrival	NL	15	40	38%	58	45%	Replace w/ artics (58 pax) with
11:50 arrival	NL	21	40	53%	58	45%	same headway
11:44 arrival	O	25	40	63%	116	190%	Replace w/ artics; 30-min head.
		117	200	59%	464	132%	
SamTrans							
12:09 arrival	KX	32	40	80%	80	100%	One new service
Caltrain							
12:35 arrival	429	543	650	84%	1,300	100%	One new train
Golden Gate Ferries							
12:45	Sausalito	50	715	7%	1,115	56%	One new 400-pax ferry service
11:40	Larkspur	143	715	20%	1,115	56%	One new 400-pax ferry service
		193	1,430	13%	2,230	56%	
Golden Gate Buses							
11:56	10 from Marin City	13	41	32%	41	0%	
11:00	70 from San Rafael	11	41	27%	41	0%	
11:26	70 from San Rafael	11	41	27%	41	0%	
11:30	80 from San Rafael	13	41	32%	41	0%	
11:45	101 from San Rafae	14	41	34%	41	0%	
	93-Short	0	0	N/A	224	N/A	40- & 72-pax; 15-min headways
	4-Short Marin City	0	0	N/A	80	N/A	40-pax at 30-min headways
		62	205	30%	509	148%	
WETA Services							
10:40	Alameda & Oakland	263	388	68%	1,164	200%	Two new ferry services
11:00	Vallejo	297	300	99%	300	0%	
	Oyster Point	0	0	N/A	400	N/A	One new 400-pax ferry service
		560	688	81%	1,864	171%	
Blue & Gold							
11:30	Sausalito	293	650	45%	650	0%	
12:45	Tiburon	205	500	41%	500	0%	
		498	1,150	43%	1,150	0%	
	East Bay	4,577	8,952	51%	18,056	102%	
	North Bay	753	2,785	27%	3,889	40%	
	South Bay	2,915	9,237	32%	18,874	104%	
		8,245	20,974	39%	40,819	95%	
SOURCES:							
AC Transit - "SATURDAY_TRP_1010-1012-1103.xls" received via Monica P, from Robert							
Del Rosario, AC Transit, email on May 25, 2011							
GGT - "final_nb_sb_summary.xls" and "march_2011_all_ferry.xls"							
received via Monica P, from Joshua Widman, GGT, email on May 24, 2011							
BART - "Avg Train LoadsSatApr2011.pdf"							
received via Monica P, from Thomas Tumola, BART, email on May 27, 2011							
SamTrans - received via Monica P, from Donald Esse, SamTrans email on June 3, 2011							
Ferries -							
WETA - "AC34 Regional Weekend Data 5-25-11 WETA.rev.xlsx" received from Chad Mason							
email on June 2, 2011							
Blue & Gold - received via Monica P, from Patrick Murphy, B&G Flee, email on June 2, 2011							
Caltrain - received via Monica P, from Donals Esse, SamTrans, email on June 3, 2011							
Future Capacity - Appendix B, Draft People Plan, September 30, 2011							

Addendum to Appendix TR-5

34th America's Cup Transit Analysis

WEEKDAY PM PEAK RACE DAY

Outbound	EXISTING			EXISTING PLUS AC34 2012 [a]				EXISTING PLUS AC34 2013 [b]			
	Capacity	Ridership	Percent Utilization	Peak Hour AC34 Riders	Ridership	Percent Utilization	Passenger Shortfall	Peak Hour AC34 Riders	Ridership	Percent Utilization	Passenger Shortfall
SAN FRANCISCO											
Presidio/Crissy/Marina	2,891	1,820	63%	2,425	4,245	147%	1,354	1,758	3,578	124%	687
Fisherman's Wharf	4,049	3,309	82%	280	3,589	89%	0	312	3,621	89%	0
The Embarcadero	13,737	10,796	79%	93	10,889	79%	0	308	11,104	81%	0
Treasure Island	252	116	46%	9	125	50%	0	10	126	50%	0
Total	**20,929**	**16,041**	**77%**	**2,807**	**18,848**	**90%**	**1,354**	**2,387**	**18,428**	**88%**	**687**
EAST BAY											
BART	24,150	20,067	83%	997	21,064	87%	0	1,074	21,141	88%	0
AC Transit	4,193	2,517	60%	151	2,668	64%	0	163	2,680	64%	0
Ferries	1,519	702	46%	51	753	50%	0	53	755	50%	0
Total	**29,862**	**23,286**	**78%**	**1,198**	**24,484**	**82%**	**0**	**1,291**	**24,576**	**82%**	**0**
NORTH BAY											
Buses	2,205	1,397	63%	108	1,505	68%	0	117	1,514	69%	0
Ferries	1,706	906	53%	79	985	58%	0	85	991	58%	0
Total	**3,911**	**2,303**	**59%**	**187**	**2,490**	**64%**	**0**	**201**	**2,504**	**64%**	**0**
SOUTH BAY											
BART	16,800	10,202	61%	876	11,078	66%	0	945	11,147	66%	0
Caltrain	3,250	1,986	61%	170	2,156	66%	0	183	2,169	67%	0
SamTrans	940	575	61%	49	624	66%	0	53	628	67%	0
Total	**20,990**	**12,763**	**61%**	**1,096**	**13,858**	**66%**	**0**	**1,181**	**13,945**	**66%**	**0**

SATURDAY MIDDAY PEAK RACE DAY

Inbound	EXISTING			EXISTING PLUS AC34 2012 [a]				EXISTING PLUS AC34 2013 [b]			
	Capacity	Ridership	Percent Utilization	Peak Hour AC34 Riders	Ridership	Percent Utilization	Passenger Shortfall	Peak Hour AC34 Riders	Ridership	Percent Utilization	Passenger Shortfall
SAN FRANCISCO											
Presidio/Crissy/Marina	2,738	1,827	67%	15,320	17,147	626%	14,409	16,103	17,930	655%	15,192
Fisherman's Wharf	3,119	2,339	75%	1,677	4,016	129%	897	2,796	5,135	165%	2,016
The Embarcadero	8,494	5,247	62%	388	5,635	66%	0	2,744	7,991	94%	0
Treasure Island	189	84	44%	47	131	69%	0	102	186	98%	0
Total	**14,540**	**9,497**	**65%**	**17,433**	**26,930**	**185%**	**15,307**	**21,745**	**31,242**	**215%**	**17,208**
EAST BAY											
BART	8,064	3,900	48%	6,252	10,152	63%	0	10,747	14,632	91%	0
AC Transit	200	117	59%	178	295	64%	0	312	429	92%	0
Ferries	688	560	81%	639	1,199	82%	0	1,084	1,644	112%	956
Total	**8,952**	**4,577**	**51%**	**7,069**	**11,646**	**64%**	**0**	**12,142**	**16,704**	**93%**	**956**
NORTH BAY											
Buses	205	62	30%	350	412	81%	0	615	677	133%	472
Ferries	2,580	691	27%	2,550	3,241	96%	0	4,365	5,056	150%	2,476
Total	**2,785**	**753**	**27%**	**2,899**	**3,652**	**94%**	**0**	**4,980**	**5,733**	**147%**	**2,948**
SOUTH BAY											
BART	8,547	2,340	27%	6,723	9,063	53%	0	11,554	13,865	81%	0
Caltrain/Ferries	650	543	84%	775	1,318	78%	0	1,340	1,883	111%	1,233
SamTrans	40	32	80%	44	76	95%	0	73	105	131%	65
Total	**9,237**	**2,915**	**32%**	**7,541**	**10,456**	**55%**	**0**	**12,953**	**15,853**	**84%**	**1,298**

[a] Total weekday landside attendance = 40,400 visitors; total weekend landside attendance = 184,300 visitors
[b] Total weekday landside attendance = 43,700 visitors; total weekend landside attendance = 316,000 visitors

APPENDIX TR-7A
Appendix TR-7 Replacement Pages

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TR7A-3

PUBLIC OFF-STREET PARKING AVAILABLE BY STUDY AREA

Type		GGB/ Crissy Field A	Marina B	Fort Mason/ Aquatic P/ West FW C	East FW D	Emb from Bay to Ferry B E	Emb from Ferry B to China Basin F	Total
CPO	Customer parking only	695	236	411	889	30	918	3,179
FPA	Free, publicly available	1,252	615	301				2,168
PHO	Permit holders only		192	161	286	325	1,377	2,341
PPA	Paid, publicly available	909	152	1,107	5,432	8,127	11,509	27,236
Total		**2,856**	**1,195**	**1,980**	**6,607**	**8,482**	**13,804**	**34,924**
Subtotal publicly available		2,161	767	1,408	5,432	8,127	11,509	29,404
Average Weekday Midday Utilization				83%	83%	89%	52%	
Average Weekend Midday Utilization				88%	87%	33%	22%	

Source: San Francisco Municipal Transportation Agency, Presidio Trust

TR7A-4

PUBLIC OFF-STREET PARKING AVAILABLE BY STUDY AREA

Number	SFMTA Name	SFMTA Description	SFMTA Address	SFMTA Category	SFMTA Type	SFMTA Capacity	Utilization Weekday Midday	Utilization Weekend Midday	Utilization Summary by Area Weekday	Utilization Summary by Area Weekend	CRUISE TERMINAL Weekday Midday Utilization		CRUISE TERMINAL Weekend Midday Utilization	
											1,132	**83%**	**484**	**46%**
A6	*Presidio*	*Letterman Gym/Pool*	1155 Gorgas Ave	FPA	L	98								
A7	*Presidio*	*Letterman Gym/Pool*	215 Gorgas Ave	FPA	L	96								
A8	Dirt Lot	*Aircraft Hangars*	848 P-Mason St	FPA	L	26								
A9	Palace of Fine Arts	Closed for Doyle Dr Reconst.	51 Palace of Fine Arts	FPA	L	276								
A10	Stillwell Hall	*SF Gymnastics*	874 P-Mason St	FPA	L	31								
A11	Presidio	*Closed for Doyle Dr Reconst.*	298 Gorgas Ave	FPA	L	44								
A12	Palace of Fine Arts		2199 Jefferson St	FPA	L	116								
A13	Crissy Field	*East Beach*	99 Zanowitz St	FPA	L	280								
A14	*Crissy Field*	*West Bluff*	p-Hamilton St	FPA	L	150								
A15	Presidio	*Battery East*	974 P-Lincoln Blvd	FPA	L	70								
A16		*Fort Point*	Marine Dr	FPA	L	65								
A17	ILM	Lucas Arts	1115 Gorgas Ave	PPA	G	419								
A18	Presidio		1060 Torney Ave	PPA	L	26								
A19	Presidio		10 Edie Rd	PPA	L	29								
A20	Presidio Headquarters	*Bldgs 215 and 220*	10 French Ct	PPA	L	*105*								
N/A	*Presidio*	*Bldgs 210 and 211*	*Lincoln Blvd*	*PPA*	*L*	19								
N/A	*Presidio*	*Bldgs 222 to 229*	*Halleck St*	*PPA*	*L*	66								
A21	Golden Gate Bridge (employees only M-F)		25 Battery Cranston	PPA	L	164								
A22	Golden Gate Bridge	*Toll Plaza*	3 Transit Facility	PPA	L	81								
A06	Presidio	*Letterman Gym/Pool*	1155 Gorgas Ave	FPA	L	98								
B9	Marina Green Main		370 Marina Blvd	FPA	L	468								
B10	Yacht Harbor		41 Yacht Rd	FPA	L	147								
B14	Pierce and Lombard		3252 Pierce Street	PPA	L	116	N/A	N/A						
B15	Pacific Park Mgmt	Chestnut Street Ltd	2055 CHESTNUT ST	PPA	L	36								
C9	Ft Mason overflow		50 Marina Blvd	FPA	L	97			**83%**	**88%**				
C10	Marina Green Triangle		150 Marina Blvd	FPA	L	204								
C13	Sangiacomo Family LTd Partners	Marina Cove Residential	1550 BAY ST	PPA	G	176								
C14	No name but active lot	Monthly only	2927 Larkin ST	PPA	G	94								
C15	ACE Parking	Ghirardelli	900 NORTH POINT ST	PPA	G	280	83%	90%						
C16	ProPark	Beach & Hyde Garage	655 BEACH ST	PPA	G	120	N/A	84%						
C17	Fort Mason		3698 Laguna St	PPA	L	437								
D21	Parc Telegraph Parking		1603 MONTGOMERY ST	PPA	G	60	86%	N/A	**83%**	**87%**	59	86%		
D22	ACE Parking		55 FRANCISCO ST	PPA	G	400	88%	closed			216	88%		
D23	City Park		80 Francisco St	PPA	G	526	76%	47%			318	76%	197	47%
D24	Impark	Safeway/Walgreen's	350 BAY ST	PPA	G	353	N/A	87%						
D25	North Point Investors	Impark	2310 POWELL ST	PPA	G	284								
D26	Impark		2210 STOCKTON ST	PPA	G	150	N/A	84%						
D27	Cost Plus	City Park	455 North Point St	PPA	G	110	N/A	84%						
D28	Tuscan Inn		425 NORTH POINT ST	PPA	G	64								
D29	Sheraton Fisherman's Wharf, City park	Sheraton Hotel FW	2500 MASON ST	PPA	G	256	N/A	88%						
D30	Hilton		590 BAY ST	CPO	G	150	N/A	84%						
D30	Impark	**2210 Stockton**	2291 STOCKTON ST	PPA	G	200	N/A	88%						
D31	ACE Parking	Anchorage Garage	500 BEACH ST	PPA	G	575	N/A	84%						
D32	Savoy Corporation		2720 TAYLOR ST	PPA	G	50		100%						
D33	Impark	350 Bush St Pkng **(The Whar**	350 BEACH ST	PPA	G	241	N/A	88%						
D34	AMPCO	Pier 39 Parking	2550 POWELL ST	PPA	G	980	N/A	100%						
D35	US Parking	SF Clean Green	601 Bay St	PPA	L	29								
D36	Central Parking System	**SWL 314**	2 BAY ST	PPA	L	120	101%	100%			108	101%	107	100%
D37	City Park	Cost Plus	450 NORTH POINT ST	PPA	L	66	N/A	84%						

TR7A-5

PUBLIC OFF-STREET PARKING AVAILABLE BY STUDY AREA

Number	SFMTA Name	SFMTA Description	SFMTA Address	SFMTA Category	SFMTA Type	SFMTA Capacity	Utilization Weekday Midday	Utilization Weekend Midday	Utilization Summary by Area Weekday	Utilization Summary by Area Weekend	CRUISE TERMINAL Weekday Midday Utilization		CRUISE TERMINAL Weekend Midday Utilization	
D38	Nunzio corporation	Aliotos Parking	423 BEACH ST	PPA	L	23	N/A	100%						
D39	Academy of Art	Super Parking	2300 STOCKTON ST	PPA	L	200	N/A	88%						
D40	City Park	Longshoremen Union Hall	25 BEACH ST	PPA	L	65	N/A	88%						
D41	Wharf Properties Inc	Fishermans Wharf Parking	273 JEFFERSON ST	PPA	L	210	N/A	87%						
D42	City Parking Inc Richard B Stein	Fisherman Wharf Parking	160 JEFFERSON ST	PPA	L	250	N/A	100%						
D43	Central Parking System	Pier 43 1/2	1735 The Embarcadero	PPA	L	220	N/A	88%						
E5	City Park	Shell Building	100 Bush St	PPA	G	130	100%	N/A	**89%**	**33%**				
E6	City Park		1 Front St	PPA	G	340								
E7	AMPCO		388 MARKET ST	PPA	G	100	100%	N/A						
E8	Standard Parking		235 PINE ST	PPA	G	100	100%	N/A						
E9	Standard Parking		100 PINE ST	PPA	G	150	100%	N/A						
E10	AMPCO		345 CALIFORNIA ST	PPA	G	180								
E11	AMPCO		255 CALIFORNIA ST	PPA	G	65								
E12	AMPCO		201 CALIFORNIA ST	PPA	G	55	100%	N/A						
E13	101 California Venture	Hines	101 CALIFORNIA ST	PPA	G	250	100%	N/A						
E14	Central Parking System		1 CALIFORNIA ST	PPA	G	160	95%	N/A						
E15	Standard Parking		300 CALIFORNIA ST	PPA	G	60								
E16	ACE Parking		150 CALIFORNIA ST	PPA	G	35								
E17	City Park	Embarcadero West	350 SANSOME ST	PPA	G	201	98%	N/A						
E18	AMPCO		50 CALIFORNIA ST	PPA	G	141	92%	N/A						
E19	AMPCO	Embarcadero 1	350 Sacramento St	PPA	G	563	85%	19%						
E20	AMPCO	Embarcadero 2	250 Sacramento St	PPA	G	671	92%	14%						
E21	AMPCO	Embarcadero 3	150 Sacramento St	PPA	G	664	86%	15%						
E22	AMPCO	Embarcadero 4	51 Clay St	PPA	G	220	85%	28%						
E23	Golden Gateway		250 Clay Street	PPA	G	1,095	89%	52%						
E24	AMPCO		750 BATTERY St	PPA	G	72	92%	closed						
E25	City Park	**Golen Gateway Commons**	750 Front St	PPA	G	330	93%	closed						
E26	Liberty Park		900 SANSOME ST	PPA	G	140	91%	closed						
E27	California Parking		847 Front St	PPA	G	85	84%	closed						
E28	California Parking	California Parking	768 SANSOME ST	PPA	L	130	79%	24%						
E29	Central Parking System	**370 Pacific**	350 PACIFIC AVE	PPA	L	55	62%	12%						
E30	Hornblower	Hornblower Yachts Inc	40 Pier Three	PPA	L	180	84%	25%						
E31	City Park		240 PACIFIC AVE	PPA	L	29								
E32	Pacific Park Mgmt Inc	**50 Broad**	90 BROADWAY	PPA	L	160	98%	67%						
E33	Central Parking System	**SWL 323+750 Davies**	50 BROADWAY	PPA	L	270	67%	23%						
E34	Central Parking System		850 Front St	PPA	L	120	91%	33%						
E35	ACE Parking	**SWL 314**	501 The Embarcadero	PPA	L	77	85%	100%						
E36	Central Parking System	**SWL 321**	1062 Front St	PPA	L	150	99%	27%			218	99%	59	27%
E37	Central Parking System		40 Pier Fifteen	PPA	L	80								
E38	Central Parking System		40 Pier Twentythree	PPA	L	140	39%	45%			32	39%	37	45%
E39	Central Parking System		40 Pier Twentyseven	PPA	L	400	82%	38%			180	82%	84	38%
E40	EOP 188 The Embarcadero LLC	188 The Embarcadero Assoc	188 The Embarcadero	PPA	N/A	30								
E41	AMPCO		250 The Embarcadero	PPA	N/A	400								
E42	Unknown	Unknown	960 Sansome St	PPA	N/A	24								
E43	West Coast Parking Inc		735 DAVIS ST	PPA	N/A	75	86%	56%						

PUBLIC OFF-STREET PARKING AVAILABLE BY STUDY AREA

Number	SFMTA Name	SFMTA Description	SFMTA Address	SFMTA Category	SFMTA Type	SFMTA Capacity	Utilization Weekday Midday	Utilization Weekend Midday	Utilization Summary by Area Weekday	Utilization Summary by Area Weekend	CRUISE TERMINAL Weekday Midday Utilization	CRUISE TERMINAL Weekend Midday Utilization
F22	Port Anthority leases to Impark	Pier 48 Sheds A & B	40 Pier Fortyeight	PPA	G	400	closed	closed	**52%**	**22%**		
F23	ACE Parking	China Basin	185 BERRY ST	PPA	G	268	85%	closed				
F24	Standard Parking	250 King St **(Beacon Bldg.)**	215 Townsend St	PPA	G	750	56%	61%				
F25	ACE Parking		153 TOWNSEND ST	PPA	G	371	78%	closed				
F26	Tower Valet Parking	Game day = $40	250 BRANNAN ST	PPA	G	170	63%	closed				
F27	Main & Harrison LLC	**400 Spear**	401 MAIN ST	PPA	G	300	97%	closed				
F28	AMPCO	for 1 Harrison	439 Spear St	PPA	G	235						
F29	ACE Parking		405 HOWARD ST	PPA	G	160						
F30	Charles Schwab		215 Fremont St	PPA	G	40						
F31	AMPCO		400 Howard St	PPA	G	200						
F32	City Park		199 FREMONT ST	PPA	G	118						
F33	US Parking		10 NATOMA ST	PPA	G	110						
F34	ProPark		345 SPEAR ST	PPA	G	400						
F35	AMPCO		50 FREMONT ST	PPA	G	230						
F36	AMPCO		455 MARKET ST	PPA	G	120						
F37	AMPCO		120 HOWARD ST	PPA	G	83						
F38	AMPCO		201 SPEAR ST	PPA	G	90						
F39	AMPCO		425 MARKET ST	PPA	G	126						
F40	ACE Parking		75 HOWARD ST	PPA	G	515						
F41	Douglas Parking		160 SPEAR ST	PPA	G	37						
F42	AMPCO		50 BEALE St	PPA	G	90						
F43	Pacific Spear Corp		150 SPEAR ST	PPA	G	15						
F44	ACE Parking		333 MARKET ST	PPA	G	120						
F45	Standard Parking		121 SPEAR ST	PPA	G	450						
F46	Hewitt ML Zhou X Motzek RH	Standard Parking	155 STEUART ST	PPA	G	15						
F47	CA 90 Spear Ltd Partnership		60 SPEAR ST	PPA	G	11						
F48	ACE Parking		1 MARKET ST	PPA	G	160						
F49	Impark	Lot D	1050 03rd St	PPA	L	150						
F50	Impark	Lot A	1099 03rd St	PPA	L	2,501	36%	21%				
F51	Stewart Douglas		144 KING ST	PPA	L	30						
F52	SF Redevelopment Agency	SFRA	40 Pier Forty	PPA	L	280						
F53	Phoenix Industries	Game day parking $40	599 02nd ST	PPA	L	40						
F54	US Parking		270 BRANNAN ST	PPA	L	70	95%	25%				
F55	Impark	Pier 30/32	40 Pier Thirty	PPA	L	998	27%	7%				
F56	Impark		55 BRYANT ST	PPA	L	293	100%	29%				
F57	US Parking		250 MAIN ST	PPA	L	440						
F58	Impark		100 FOLSOM ST	PPA	L	48						
F59	Ace Parking		199 BEALE ST	PPA	L	81						
F60	Place 2 Park LLC		235 MAIN ST	PPA	L	260						
F61	Place 2 Park LLC		191 BEALE ST	PPA	L	230						
F62	AMPCO		123 MISSION ST	PPA	L	84						
F63	ACE Parking	Ferry Building	100 The Embarcadero	PPA	L	100						
F64	Delancey St Foundation	Delancey St Restaurant	600 The EMBARCADERO	PPA	N/A	50						
F65	Sudike Solomon/Abdi Kumsa	Cross Park	1 MISSION ST	PPA	N/A	270						

TR7A-6

34th America's Cup

ESTIMATED PARKING TURNOVER

	In	Out	Accum.
08:00	0	0	0
09:00	5	0	5
10:00	15	0	20
11:00	25	0	45
12:00	20	5	60
1:00	10	5	65
2:00	10	5	70
3:00	5	5	70
4:00	5	10	65
5:00	5	15	55
6:00	0	15	40
7:00	0	15	25
8:00	0	15	10
9:00	0	10	0
10:00	0	0	0
	100	100	

Turnover

100	vehicles
70	spaces used total
1.43	**each space turns over 1.4 times**

Sources
BART Giants Parade and Fleetweek ridership patterns
Adjusted based on AC34 projected schedule, ridership, and professional judgement

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