Dry Tortugas National Park

Dry Tortugas Light Station

Lighthouse and Oil House

Historic Structure Report

Prepared for

Dry Tortugas National Park

Southeast Region, National Park Service

by

Lord, Aeck & Sargent Architecture

2009

The historic structure report presented here exists in two formats. A traditional, printed version is available for study at the park, the Southeastern Regional Office of the NPS (SERO), and at a variety of other repositories. For more widespread access, the historic structure report also exists in a web-based format through ParkNet, the website of the National Park Service. Please visit www.nps.gov for more information.

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2009
Historic Structure Report
Dry Tortugas Light Station
Dry Tortugas National Park

LCS#: 091383 (Dry Tortugas Lighthouse)
LCS#: 091387 (Oil House)

Cover Image: Undated nineteenth century image of Dry Tortugas Light Station, National Archives and Records Administration, Record Group 26.

Dry Tortugas National Park
Dry Tortugas Light Station
Lighthouse and Oil House
Historic Structure Report
2010

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Appendix A

Draft National Register Nomination Form

Appendix B

Dry Tortugas Light Station Materials Analysis, Dry Tortugas, Florida, Building Conservation Associates, August, 2009.

Management Summary

The Dry Tortugas Lighthouse (also referred to as the Loggerhead Key Lighthouse) was constructed in 1858 to better mark the dangerous shoals of the Dry Tortugas after the lighthouse on Garden Key was determined inadequate for this purpose. It was constructed during a period of transition and significant growth within the Lighthouse Establishment. The Light Station is made up of several structures originally built to accommodate the light keepers, their families and the equipment and supplies necessary to maintain the Lighthouse and support habitation in this remote location. The Lighthouse has continuously served as an active aid to navigation from the time of its construction to the present.

The Light Station was manned by keepers or caretakers from its initial construction through the mid-1980s when the lamp or optic was automated, eliminating the need for continual occupation of the site. The decision to automate the lamp was made after the rotating mechanism of the existing second-order lens was damaged during repairs to the Lantern.

In 1992, legislation was passed to abolish Fort Jefferson National Monument (designated by Franklin Delano Roosevelt in 1935) and establish Dry Tortugas National Park (DRTO). As part of the Park's enabling legislation, Loggerhead Key, along with the resources of the Light Station (with the exception of the Lighthouse) were transferred from the United States Coast Guard (USCG) to the National Park



Figure 1. 2008 photograph of Dry Tortugas Light Station on approach to the main dock from the east.

Service (NPS). Under the Park Service's management, public visitation to the Key has been limited. However, a relatively constant presence has been maintained at the site through the NPS's Volunteer-In-Parks (VIP) program and various research initiatives.

In October 2008, Lord, Aeck & Sargent was contracted by the National Park Service to prepare a Historic Structure Report (HSR) for the resources of the Dry Tortugas Light Station. It was decided that three documents would be prepared, the first would address the Lighthouse and Oil House, the second, the Keeper's Residence and the last document would address the remaining resources of the Light Station. This document addresses the Dry Tortugas Lighthouse and Oil House.

During the first week of March 2009, a two member team from Lord, Aeck & Sargent (Rob Yallop and Glen Bennett) traveled to Loggerhead Key to undertake a physical inspection of the Light Station resources. In addition, Ms. Dorothy Krotzer of Building Conservation Associates Inc. also traveled to the site to collect mortar and paint samples for analysis (The results of this analysis are provided in Appendix B). Personnel from Lord, Aeck & Sargent spent a week on the island documenting the resources and collecting information to support preparation of the HSRs. A second brief visit was made to the site in June 2009.

Field notes, measurements, material sampling and photographs were collected for all of the structures as a means to record the existing conditions. With the exception of the mortar and paint sampling, no destructive testing was performed and no historic fabric was removed to facilitate the collection of information. All portions of the buildings were accessible with the exception of the Lighthouse galleries. A hurricane-proof plywood insert had been installed at the Watch Room level door, restricting access to the galleries. Exterior conditions of the Lantern and Watch Room were therefore observed from grade using binoculars.

Historic research included two trips to the National Archives and Records Administration in Washington D.C. and one visit to the Southeast Region National Archives and Records Office in Morrow, Georgia to review documents, drawings and photographs held primarily in Record Group 26. The files held in the National Park Service Southeast Regional Office and the archives of Everglades National Park were also reviewed. A visit was made to the USCG offices in Miami to review records pertaining to their management of the site. Numerous other secondary sources were consulted in preparation of the HSR.

Current agreements call for transfer of the Lighthouse to the National Park Service in the near future, pending the fulfillment of several requirements, including completion of this report. Upon official transfer of the Lighthouse, the structure will remain an active aid to navigation and the USCG will retain management and maintenance responsibilities for the optic and its associated equipment.

The Park's General Management Plan has addressed treatment and use of the Light Station resources through the establishment of a Historic Preservation/Adaptive Use (HP/AU) Management Zone in the center of Loggerhead Key. Without being specific, this management zone prescribes that the resources of the Light Station will be primarily reserved for interpretive and educational opportunities. The structures will also be adaptively used to accommodate critical functions such as housing for volunteers, staff, and research personnel and the storage of utility components and equipment.

Changes to the Lighthouse have been limited and the structure appears today much like it did after 1870 when the daymark was applied. This presents exciting opportunities for interpreting the architecture and history of the Lighthouse. By contrast, the Oil House has experienced extensive modifications to its original form and materials as its use has evolved over the years. As one might expect, the fabric of both structures has had to be constantly repaired and in some cases replaced as the marine environment and intensive storms that frequent this region have resulted in ongoing damage and deterioration. In addition, the limited manpower available and the remoteness of the site have made maintaining the resources a challenge.

The desire of the National Park Service to provide greater access to the resources of the Light Station presents additional challenges. Establishing visitor access to Loggerhead Key is the first issue that must be addressed through renewed concession agreements or other special arrangements.

The existing conditions of the Lighthouse do not present major obstacles to greater access but there are several issues that should be addressed before the structures can be fully occupied by the visiting public. These include increasing light levels in the stair tower and repairing broken stair treads and sections of handrail. The wedge shape of the stair treads and the physical dimensions of the upper landings will limit the number of visitors that can be safely accommodated in the Lighthouse at one time.

Visitor access to the Watch Room and Lantern is more problematic due to the limited physical size of these spaces and their access points. There is no landing at the Watch Room level and it is therefore necessary to guide oneself through a narrow hatch in the Watch Room floor while ascending the last few stairs which are set at a steep incline. Also, the Watch Room and Lantern gallery railings are deteriorated and do not currently meet the requirements of applicable codes. Therefore, public access to the Watch Room gallery should not be permitted until modifications are made to the railing that address safety concerns. Access to the Lantern gallery by the public is not practical as this level can only be reached by an exterior-mounted ladder that requires the climber to wear fall protection.

Access to the site by the physically disabled will require careful study of each leg of a potential trip to the site, beginning in Key West. The Lighthouse and Oil House have never been accessible structures. Implementing the changes required to fully comply with the requirements of the Architectural Barriers Act, the Rehabilitation Act and the Americans with Disabilities Act will not be possible without negatively impacting the historic character of these structures. Therefore the application of "minimum alternative access" as provided for in the procedures described in ADAAG 4.1.7 (2), and further discussed in 28 CFR 36.405 and ADAAG 4.1.7(3) should be applied. The types of responses appropriate under the "minimum alternative access" provisions could include such elements as accessible observation points on the ground to view building features, videos interpreting the experience of ascending the tower and viewing the surroundings from the Watch Room gallery, or scale models of the Lighthouse and Light Station resources available for viewing at a Visitor's Center or other accessible facility.

Summary of Recommendations

The following is a summary of the treatments recommended to preserve and rehabilitate the Dry Tortugas Lighthouse and Oil House and to prepare them for continued, and potentially more intensive, use. The recommendations have been organized into five "Work Packages" presented in the general order of priority and also in response to limits on the amount of cyclical maintenance funding that can be requested by the Park in a given year. Work Package 1 represents those deficiencies that need to be addressed in the short term to address critical condition problems and issues of life safety. Following completion of this initial phase of work, the packages are generally organized to address repairs to the Lighthouse from the top down. The timeline for conducting repairs assumes that the work will be completed over an approximately 10 year period.

Additionally, given the remoteness of the site and the significant costs associated with a potential contractor's General Conditions and scaffolding, it may not be practical to phase the interior or exterior masonry repair and repainting scopes to fit within the established funding limits. Therefore it may be necessary for the Park to request "line item" funding for Work Package s 3 and 5.

General

- Prepare an updated national register nomination for the Light Station resources.
- Limit public access to the Lighthouse to small groups of no more than 4-5 visitors.
- Explore the potential for reacquiring and installing the second-order bivalve lens.
-

Work Package 1 – Priority Treatments and Activities

Watch Room

- Expose and treat corroded anchors in masonry wall.

- If existing stucco finish requires widespread removal to accommodate repair of anchors, replace with a more compatible stucco finish system. If not, repair existing stucco as needed.
- Expose, remove corrosion and refinish I-beams and lintel supporting Watch Room level floor plate.

Lighthouse Stair Tower

- Repair broken sections of hand rail.
- Replace failed stair treads (2).
- Install lighting system to increase light levels in stair tower.

Masonry Repair

- Monitor vertical cracking below Watch Room level of Lighthouse.

Concrete Passageway

- Flood test roof of Passageway to confirm integrity.
- As a priority repair concrete spalling by exposing rebar, removing corrosion, refinishing and then patching concrete.
- Repaint interior and exterior of Passageway.

Work Package 2 – Lantern and Watch Room Level Repairs

- Complete Lantern roof repair project including replication of integral gutter system, vent ball and lightning rod.
- Repair Lantern floor plates by removing corrosion and reapplying an appropriate protective finish.
- Recast and replace corroded iron headers of Lantern structure.
- Repair corroded gallery railing.
- Remove exterior access ladder structure installed in 1978.

Watch Room

- Repair and make operable the circular, bronze ventilators in the Watch Room walls.
- Repair historic Watch Room-level door and reinstall. If repair is not feasible, install new door that matches the historic door in material and design.
- Repair Watch Room floor plates by removing corrosion and reapplying an appropriate protective finish.
- If visitor access to galleries is desired replace corroded gallery railings with code-compliant railing.
- Install a new smaller exterior ladder that is in keeping with the historic condition to provide access between the Watch Room and Lantern galleries.
- Remove corrosion and refinish lens pedestal components.
- Install new window and shutter assembly at Watch Room. Review design and monitor performance of unit over time to inform installation of remaining windows in tower.

Work Package 3 – Interior Masonry and Miscellaneous Repairs

Masonry Repair

- Abate lead-based paint and reapply interior finish.
- Quantify areas of mortar loss.
- At locations of critical mortar loss, conduct masonry repointing and repair of the Lighthouse interior.
- Repair vertical cracking with deep penetrating mortar.

Lighthouse Stair Tower

- Preserve Lighthouse entry door and install appropriate hardware to improve operability and security.

Work Package 4 – Repair and Rehabilitation of Oil House

Oil House Exterior

- Abate lead-based paint and reapply exterior finish on Oil House.
- Conduct minor masonry repairs.
- Remove existing windows and install new windows and shutters in Oil House.
- Install new roof on Oil House.
- Repair and preserve existing Oil House door.

Oil House Interior

- Contingent on its ultimate use, remove modern faux wood paneling on first floor and relocate electrical panels associated with photovoltaic system.
- Remove vinyl tile on second floor and install wood flooring.

West Addition

- Repoint and monitor horizontal crack in north and west walls.
- Install new window in west elevation.

South Addition

- Retain South Addition to house critical equipment but do not commit resources to its long term preservation.

Work Package 5 – Exterior Masonry Repair and Installation of New Windows

Masonry Repair

- Verify construction of tower walls.
- Explore options for ventilating internal voids if present.
- Quantify areas of critical mortar loss.
- At locations of critical mortar loss, conduct masonry repointing and repair of the Lighthouse exterior.
- Abate lead-based paint and reapply daymark on Lighthouse.

Windows

- Remove existing windows and install new windows and shutters in Lighthouse.

Administrative Data

Resource Names and Numbers

Building Name: Dry Tortugas Lighthouse
Structure No.: HS-21
List of Classified Structures (LCS) No.: 091383
Building Name: Dry Tortugas Light Station Oil House
Structure No: HS-23
List of Classified Structures (LCS) No.: 091387

Resource Location

The Dry Tortugas Lighthouse and Dry Tortugas Light Station Oil House are located on Loggerhead Key within Dry Tortugas National Park. Located 65 miles west of Key West Florida, Dry Tortugas National Park encompasses an area of approximately 100 square miles containing seven, small, sand and coral keys (islands) and the surrounding shoals and water. Loggerhead Key and Garden Key are the only inhabited keys within the Park. The Park's central cultural feature, Fort Jefferson, is located on Garden Key, approximately 2 ½ nautical miles east of Loggerhead Key. Access to the Park is by boat or seaplane. The visiting public generally travels to the Park on commercial ferries operated out of Key West. The primary public docking facilities and debarkation points are on Garden Key.

Loggerhead Key is the largest key in the Park measuring approximately 1 mile long and 700 yards across and containing approximately 35 acres. The lighthouse and oil house are among several historically significant buildings at the Dry Tortugas Light Station. The Light Station complex is located in the approximate geographic center of Loggerhead Key.

Location: Loggerhead Key, Dry Tortugas National Park
Coordinates: Latitude 24° 38' 00.021" N, Longitude 82° 55' 13.958" W
County: Monroe
State: Florida

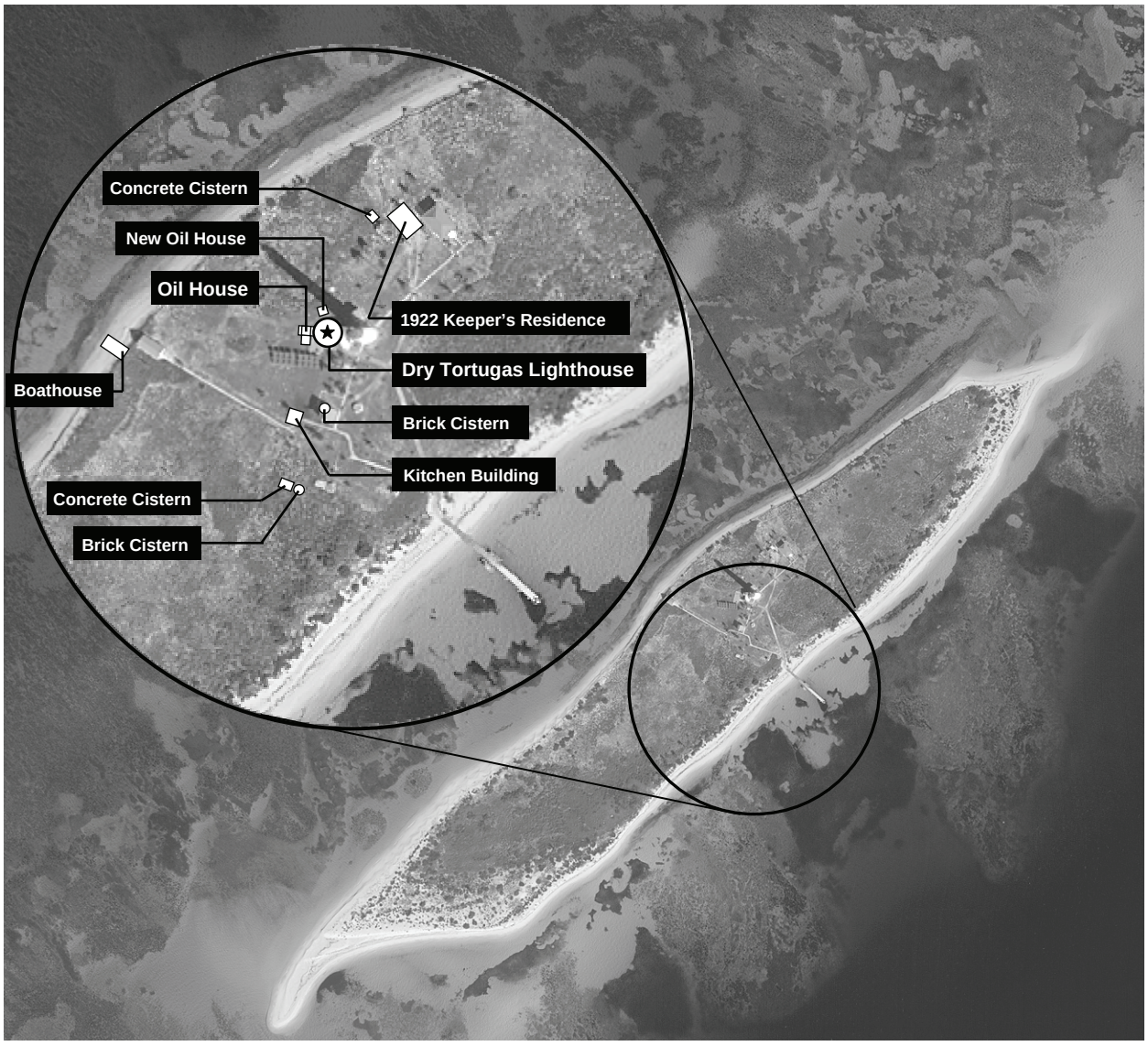
Lighthouse Data

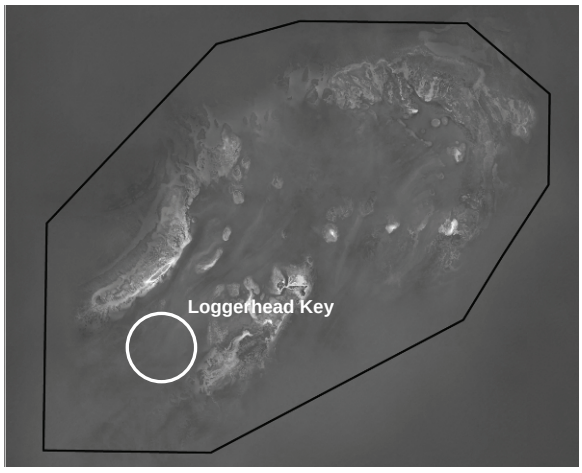
Active: Yes
Construction: First Order conical brick tower constructed 1858
Focal Plane: 151'
Range 20 miles
Original Light: Fixed, first-order Fresnel lens (Sautter & Company)
Current Light Single Flashing, White, 20s, VEGA VRB-25
Daymark: lower half painted white, upper half and lantern painted black
U.S. Coast Guard District: 7th

Cultural Resource Data

In 1984, a draft National Register nomination was prepared for the Dry Tortugas Light Station by National Park Service staff as part of a submission to the USCG, Department of Transportation. No further action was taken by the USCG regarding the nomination. The National Park Service subsequently conducted a review of the nomination in 1989 anticipating a potential transfer of the Light Station from the USCG. Based on this review, the nomination was updated in 1993 and submitted to the Acting Chief Historian of the National Park Service's Washington Support Office for a second review in 1995. No further action was taken with regard to the draft nomination.

Dry Tortugas National Park was established in 1992 by Public Law 102-525 to "preserve and protect for the education, inspiration, and enjoyment of present and future generations nationally significant natural, historic, scenic, marine, and scientific values in South Florida." Under [36 CFR 60.1(b) (1)], historic units of the National Park System are automatically given National Register of Historic Places status by virtue of their incorporation into the park system. Thus, the Dry Tortugas Light Station was listed on the National Register of Historic Places as part of Dry Tortugas National Park.





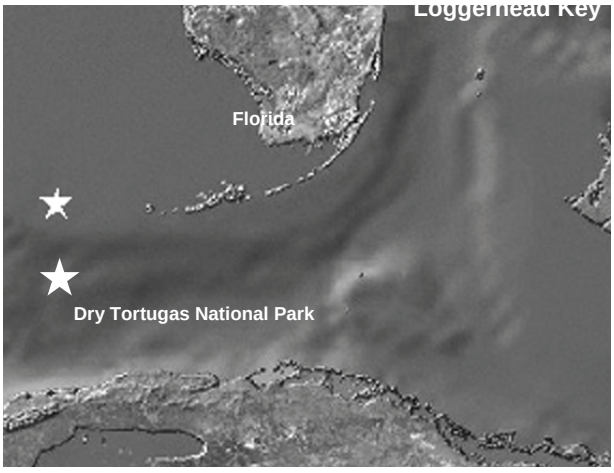


Figure 2. Maps showing location of Dry Tortugas National Park, Loggerhead Key and the individual structures of the Dry Tortugas Light Station.

Significance

The draft national register nomination proposes a broad period of significance for the property spanning from its initial construction date through to the "present," or 1995, the year the draft nomination was submitted to the Washington Support Office. This approach suggests the Lighthouse derives its primary significance from its function as an aid to navigation and is inclusive of the entire period it has been active. This approach acknowledges all epochs of the Light Station's history including the National Park Service's management of the site.

Specifically, the draft nomination provides the following statement about the Light Station's significance.

> The light station is significant primarily for its role in facilitating America's ocean-borne commerce and as a notable example of the kind of civilian public works project undertaken by Army engineers prior to the Civil War. While the lighthouse is clearly the most important structure within the boundaries of the nominated area, there were several ancillary structures built at the same time as the lighthouse, and also from the 1920s, a period in which the station was extensively modernized.

It is recommended that the draft national register nomination be updated based on the research collected in preparing the HSRs and resubmitted for formal acceptance.

Related Studies

Hellman, Robert and David M. Brewer. *Archeological Survey of Loggerhead Key, Dry Tortugas National Park*. Southeast Archeology Center (SEAC), National Park Service, 2003.

Kenneth Smith Architects Inc., and Bender & Associates, Architects P.A. for the State of Florida Department of State, Division of Historical Resources and Department of Community Affairs, Florida Coastal Management Program. *Florida Lighthouse Study* 2002

National Park Service *Draft National Register of Historic Places Registration Form* 1993

National Park Service. *General Management Plan Amendment, Dry Tortugas National Park.* 2002

National Park Service National Register Programs Division, Preservation Services Branch for the Department of Transportation, United States Coast Guard, Seventh District, *Rehabilitation Report and National Register Nomination for the United States Coast Guard Light Station, Dry Tortugas Lighthouse, Loggerhead Key Florida*. October 1984

Lights on the Florida Reef

The fixed *white* light of Fowey Rocks,
And Carysfort's *white flash*,
Both may be seen from the middle
Of a twenty-three mile dash.
Alligator Reef's *red, white* and *white*
Lies thirty miles away.
Log thirty more, Sombrero *white*
Points to Honda Bay.
Then comes the Shoals American,
White flashing through the night.
Just fifteen miles from *white* Key West,
Twenty from Sand Key's *twinkling white*.
The Marquesas are unlighted;
But on Rebecca's Shoal,
A *white* and *red* is sighted,
Warning from wreck and dole.
Sixteen miles to Dry Tortugas
With a *white* light on the fort,
Three more to the *flash* of Loggerhead,
And all's clear to a western port.

Kirk Monroe

Historical Background and Context

The historical background of the Dry Tortugas Light Station is documented by historians, Love Dean in *Lighthouses of the Florida Keys* and Neil Hurley in *Lighthouses of the Dry Tortugas: An Illustrated History*. These along with Russ Holland's *America's Lighthouses: Their Illustrated History since 1716* and Edwin C. Bearss' *Shipwreck Study-The Dry Tortugas* contributed to the development of the historical background and context. The following narrative draws upon these histories and references them when cited. The historical background also relies on the "clipping files" and other primary sources related to the Dry Tortugas Light Station found in National Archives Record Group 26.

Discovery and Early Exploration

Juan Ponce de Leon is credited with the discovery in 1513 of 11 sand and coral islands located at the southwestern tip of the Florida Keys. Because sea turtles were in abundance, he named the islands "Las Tortugas," meaning *the turtles*. At the time of Ponce de Leon's discovery, hundreds of turtles were present on the shores of these islands along with pelicans and the now-extinct Caribbean monk seal.[1] Several accounts describe Ponce de Leon's crews capturing over a hundred turtles in one night - turtles were a significant source of food for mariners.

The first recorded shipwreck in the area occurred in 1622 when the *Nuestra Senora del Rosario* ran aground on one of the keys of the Tortugas. The survivors and their rescuers reportedly camped on the island that would later be named Loggerhead Key.[2]

Florida was under Spanish rule from 1513 until 1763, when it was ceded to Britain. While under British rule, Las Tortugas were surveyed by T. Jefferys in 1763, by Bernard Romans in 1766, and by George Gauld in the 1770s. Gauld's maps, published in 1773, were used widely for navigation of the gulf coast off British West Florida. Due to the lack of fresh drinking water, or possibly "in contradiction to the vast tract of wet reef which at low water nearly reaches the surface," Las Tortugas eventually became known as the *Dry* Tortugas. On his charts, Gauld named the individual islands that made up the Dry Tortugas including Loggerhead "Turtle" Key.[3]

In 1783, following its participation in the American Revolution, Spain regained Florida, and maintained it as a colony until 1821. Spain encouraged settlement of the region through land grants, but Florida remained sparsely populated well into the nineteenth century. By 1845 when Florida became a state it had only 60,000 residents.

Given their location at the intersection of the Gulf of Mexico and the Atlantic Ocean where the swift Gulf Stream current flows though the Straits of Florida, the Dry Tortugas witnessed considerable shipping traffic. Westward expansion in the United States led to an increase in the transport of goods from the interior of the continent to the urban centers along the east coast. After passing through the open waters of the gulf, most ships heading east avoided the Dry Tortugas by taking a

[1] Bearss, Edwin C., *Shipwreck Study-The Dry Tortugas*, Washington, DC: Eastern Service Center-Office of History and Architecture, United States Department of the Interior, National Park Service, April 15, 1971,1.

[2] Hellmann, Robert and David M. Brewer, Archaeological Survey of Loggerhead Key, Dry Tortugas National Park,SEAC Accession No. 1341, 2003.

[3] Dean, Love, *Lighthouses of the Florida Keys,* Inc., Sarasota, Florida: Pineapple Press, 1998, 75.



Figure 3. Map produced in 1838 based on Gauld's earlier 1773 survey of the Dry Tortugas. Note the map identifies Loggerhead "Turtle" Key.

southerly route and navigating along the Cuban coastline. Stormy weather or a captain's inexperience could result in ships veering off course and foundering in the shallow reefs of the Keys. Not only did mariners have to be mindful of the hazardous sailing conditions, but they also had to keep a vigilant watch for pirates cruising these same waters in search of vessels they could exploit.

Salvaging, or wrecking as it was also known, became a lucrative business in the Florida Keys. Dozens of vessels and hundreds of men were active in the trade which became highly organized and regulated. Wreckers had to hold a license issued by the Federal Court to legitimately take part in salvaging activities. During the nineteenth century, the Keys claimed hundreds of ships carrying millions of dollars of cargo which was eventually salvaged and liquidated in the auction houses of Key West. In the Dry Tortugas, the natural harbor at Garden Key provided safe anchorage for the wreckers from where they could observe the surrounding keys and quickly respond to any ship running aground or needing assistance.[4]

Aids to Navigation in the Dry Tortugas

On August 7, 1789, the new Congress of the United States, with its ninth act, assumed responsibility for managing the nation's lighthouses and navigational aids. Prior to this, each state sited, built, and managed lighthouses as needed. The U.S. Lighthouse Establishment was the body created by the government to oversee the construction and operation of the lighthouses. Initially, Secretary of the Treasury, Alexander Hamilton, directly appointed keepers and negotiated construction contracts. Even President Washington signed and approved lighthouse contracts during the first years of his presidency. In 1792 oversight of the lighthouses was passed to the Secretary of Revenue, and then back to the Secretary of Treasury in 1820 when Stephen Pleasonton became the Fifth Auditor of the Treasury.

During the early part of the nineteenth century, after the U.S. acquisition of the Louisiana Territory, shipping through the Florida Straits increased. Lieutenant Commander Matthew C. Perry was assigned to survey the Keys in 1821, after portions of Florida became a U.S. territory. Perry noted the difficult sailing conditions and reported to Congress that four light stations would be necessary to alleviate nautical risk within the Florida Keys. These included Southwest Key, Sand Key, Key Largo and Cape Florida. Congress responded with a recommendation to build lighthouses at Key West, Cape Florida and the Dry Tortugas. In the Dry Tortugas, Garden Key was selected as the most suitable location for a lighthouse. Construction of the

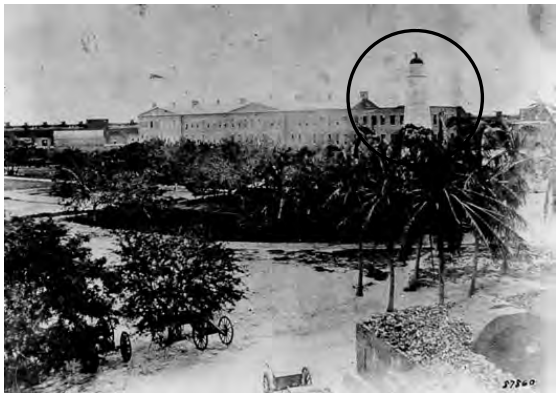


Figure 4. Undated nineteenth century view of Garden Key lighthouse within the parade ground of Fort Jefferson.

Garden Key lighthouse began in August of 1824 and continued until the lamp was lit on July 4, 1826. The focal plane of the light was 70 feet above sea level and the lantern was fitted with 23 lamps and 14-inch reflectors.[5]

Despite construction of a lighthouse on Garden Key, over the next two decades, mariners continued to complain about the inadequacy of navigational aids in the Dry Tortugas. The new light was not only difficult to see in the hazy conditions of the gulf, its location six miles from the outer southwest edge of the reefs, and another eight miles from the northeastern shoals, meant that ships would find themselves in dangerous waters before the light was visible. The light constructed on Garden Key was simply not tall enough to adequately mark the hazards of the Dry Tortugas.

[4] Ibid., 78

[5] Ibid., 77.



Figure 5. Captain Horatio G. Wright.

Numerous ship wrecks, including the *Concord* and *Florence* in 1831 and the *America* in 1836, were blamed on the poor visibility of the Garden Key lighthouse. In an 1836 interview with the *Key West Inquirer*, John Thompson, assistant light keeper at Garden Key, described the need for two additional lighthouses in the Dry Tortugas—one on the easternmost and the other on the westernmost keys.[6] The newspaper endorsed Thompson's position.

Others voiced their opinion directly to the Lighthouse Board. William Whitehead, the Collector of Customs at Key West, wrote to Stephen Pleasonton in1836:

> Should it not be thought advisable to have all the appropriations made in one year, I would designate as being worthy of attention first the two light houses recommended for the Tortugas in place of the one now there. Many vessels have grounded there during the last year in consequences of inadequacy of the present light which I have every reason to believe does not arise from any neglect of those in charge.[7]

Meanwhile, in 1842, twenty-six year old Captain Horatio Gouvenor Wright was selected and charged with leading the construction of a massive fortification planned for Garden Key. Fllowing conflicts with Spain and England regarding border disputes, President Tyler and Congress were persuaded to set aside four million dollars for military installations at Key West, Key Biscayne and the Dry Tortugas. In June 1844, President Tyler signed appropriations for the initial phase of construction of the fortification that would later be named Fort Jefferson. With the capacity to house 1,500 men, arm three tiers with 450 weapons, and to stand 50 feet off the water, Fort Jefferson was designed to be the largest "Third System" fort in America. The walls of the proposed fort were to be laid out in a manner that would encompass the existing Garden Key lighthouse and keeper's dwelling.

Shipping activity in the Dry Tortugas escalated to an unprecedented level as supplies of men and material were sent to Garden Key. Complaints about the light continued until Pleasonton finally ordered several reconnaissance trips by his staff to assess the conditions. Adam Gordon, Lighthouse Superintendent at Key West, along with Captains William H. Chase and George Dutton of the Army Corps of Engineers, were sent to the Dry Tortugas to evaluate the light on Garden Key. They agreed the light was too low and dim to provide adequate aid to navigation and recommended that the light be relocated to Loggerhead Key. In the interim, Winslow Lewis was sent to inspect the lighthouse to see if anything could be done to improve its effectiveness. Lewis made minor adjustments to the lamp, but these proved to be ineffective and complaints continued.

Lighthouse Illumination

American lighthouses of the nineteenth century, including the one at Garden Key, were lit primarily with Argand oil lamps. In

[6] Bearss, 14.

[7] Hurley, Neil E. *Lighthouses of the Tortugas, An Illustrated History*, Alexandria, Virginia: Historic Lighthouse Publishers, 1990, 18.

1781, Amie Argand developed a ring-shaped wick that allowed air to flow through and around the flame and thus produce a brighter, cleaner fire. The same Winslow Lewis that was sent to make adjustments to the Garden Key light had developed and promoted a silver metallic, parabolic reflector assembly to be used with the Argand lamp. Lewis had successfully lobbied the Collector of Customs in Boston, Congress, and members of the Lighthouse Establishment, and his apparatus became the standard used in American lighthouses during first quarter of the nineteenth century. Lewis was paid $60,000 for a patent to the system, and most lighthouses were fitted with his apparatus by 1815.[8] Lewis' system was an improvement on the various wicks and fuels previously used, but the Fresnel lens was concurrently being developed and would eventually surpass the Argand lamp and Lewis'parabolic reflector system in light quality and intensity.

Developed by Augustin Fresnel, a French physicist, the Fresnel lens resembled a large glass beehive surrounding a single lamp. Asked by the French Commission on Lighthouses in 1819 to help improve the illumination system, Fresnel worked with Claude Mathieu, his two brothers—Lenor and Fulgence, and Monsieur Talbouret to develop the new lamp technology. He also worked with Francois Soleil, Sr., a Parisian optician and glass manufacturer.

The design intent of the Fresnel lens was to refract all of the light emitted from the source into one concentrated horizontal beam. By compounding the light beams in the lens a stronger and brighter signal was produced. By 1821, Fresnel's design was refined into an assembly of eight panels of concentric circular lenses with catadioptric prisms at the top and bottom of the panels. The lenses were made with triangular shaped glass that concentrated the light into a narrow horizontal beam. In 1824, the first fixed Fresnel lens was constructed along with separate flash panels that were made to revolve around the light and produce two or four flashes per revolution. The flashes helped to distinguish the lights

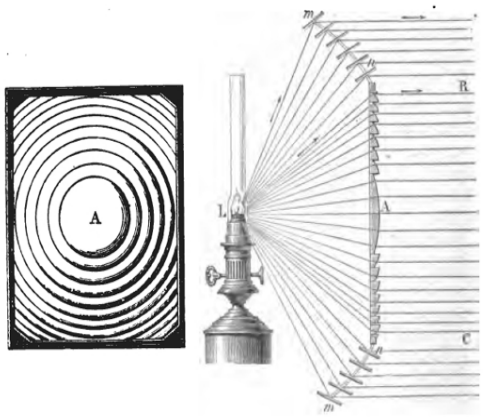


Figure 6. Schematic showing how the Fresnel lens concentrated light from a single source into a horizontal beam.

from stars or other lighthouses. This new Fresnel technology produced a bright, narrow sheet of concentrated light emitting from the lighthouse, which could be manipulated multiple ways for signaling sailors.[9]

Under Pleasonton's guidance, the lighthouse system grew from 55 lighthouses in 1820, to 331 in 1852. Despite development of the French Fresnel lens and its widespread use in Europe, Pleasonton continued to favor the Argand lamps and parabolic reflector system. His reason for not using the newer Fresnel technology, he said, was based on budgetary considerations. It has also been suggested that Pleasonton's personal friendship with Winslow Lewis translated into a loyalty to Lewis' seemingly inferior system. Pleasonton's resistance to adopt the Fresnel technology resulted in mounting criticism of the Treasury Department's management of the lighthouse system. Eventually this led Congress to direct the Secretary of the Treasury to investigate the Lighthouse Establishment. Ultimately the decision was made to:

> discharge all the administrative duties of said office relating to the construction, illumination, inspection, and superintendence of light-houses, light vessels, beacons, buoys, seamarks, and their appendages, and embracing the security of foundations of works already existing, procuring illuminating and other apparatus, supplies, and materials of all

[8] Holland, Francis Ross, *America's Lighthouses: Their Illustrated History Since 1716*, Brattleboro, Vermont: Stephen Greene Press, 1972,15.

[9] Ibid., p. 18.

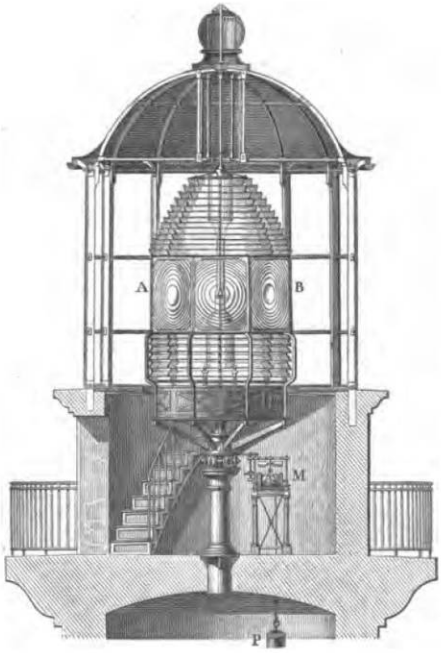


Figure 7. Section through a typical first-order lantern equipped with a Fresnel lens.

> kinds for building and for rebuilding when necessary, and keeping in good repair, the light-houses, light-vessels, beacons, and buoys of the United States.[10]

An outcome of the investigation was the creation of the U.S. Lighthouse Board. This newly formed body would be made up of four high ranking military officers, two from the Navy and two from the Army along with two civilians of "high scientific attainments." The Board would also divide the country into eight districts, expand inspection and engineering services, set up a central supply depot, begin publishing an annual "Light List", and encourage the use of new technology such as the Fresnel lens.

A New Light in the Dry Tortugas

The Seventh District established by the Lighthouse Board included the Dry Tortugas, extending "from Cape Carnaveral [sic] light-house, Florida, to include Cedar Keys, Florida." The office of the Superintendent of the Seventh District was located at Key West.[11]

The newly formed Board began immediately equipping existing and new lighthouses with Fresnel lenses. In the Dry Tortugas, the focus of the Board was to respond to decades of complaints by providing additional navigational aids including the construction of a new lighthouse on Loggerhead Key. Additionally, the light on Garden Key was slated for retooling including the installation of a fourth-order Fresnel lens to service the immediate harbor traffic. The new lighthouse proposed for Loggerhead Key was to be equipped with a first-order lens—the largest lamp available.

In 1855 Lieutenant T.A. Jenkins, United States Secretary of the Lighthouse Board, requested that Capitan H.G. Wright, overseer of construction at Fort Jefferson, submit a preliminary sketch and estimate for the new lighthouse. Wright provided a response to Jenkins on September 23rd, but it appears there was some confusion about the final location of the lighthouse, as his preliminary sketches, estimates, and letter are prepared for a project on Garden Key.

> It is proposed to first lay a grillage, as shown on the sketch, the top of which shall be on a level of those in the bastion of the fort….I cannot make any satisfactory estimate for the keeper's dwelling, as I do not know what allowance of room for each person is authorized by the board, therefore none is submitted. There is now a wooden house, built for the keeper in 1847, which contains two lower rooms, with hall, two half attic rooms and a detached kitchen, which if sufficiently capacious, will answer the purpose for some years to come…The privy should be built over a vault communicating with the sewers of the work, the cost of vault which will be not far from $100.[12]

[10] *Light-house Appropriations Bill. Statutes at Large of the United States of America 1789-1873*, 32nd Congress, 1st sess., vol.10, August 1852, 119.

[11] *Organization and Duties of the Lighthouse Board: Regulations, Instructions, Circulars, and General Orders*, Washington DC: Government Printing Office,1871, 53.

[12] Dry Tortugas Light Station Clipping File, Appendix no. 17, H.G. Wright, Capitan of Engineers, Fort Jefferson, FL, to Lieutenant T.A. Jenkins, U.S.N., Secretary, Light-house Board, Washington, D.C., September 23, 1855, Record Group 26, NA.

Ultimately the location for the new lighthouse was resolved and on August 18, 1856, Congress appropriated "for rebuilding the light-house, on a proper site, at Dry Tortugas and fitting it with first-order apparatus, thirty-five thousand dollars."[13]

In the same year, Wright was replaced by Captain Daniel P. Woodbury of New Hampshire. Woodbury who would now oversee construction of the fort and the lighthouse made several design changes to Wright's original proposal. According to Love Dean, Woodbury modified the dimensions of the tower, construction of the steps, masonry detailing and connection details between the lantern and the tower. He also configured the brick to corbel out below the Watch Room, forming the floor of the galley above.[14]

Construction of the lighthouse on Loggerhead Key began in 1857 and within a year the tower was complete. The first-order Fresnel lens was manufactured by the L. Sautter & Company. During the conversion to Fresnel lenses, the U.S. Lighthouse Board generally divided their purchases equally between the two primary lens manufacturers; L. Sautter & Company and Henry LePaute.

In 1852, Louis Sautter bought the business started by Francois Soleil, Sr., with whom Fresnel worked to develop the Fresnel lens. Soleil's business passed to his son-in-law, Jean Jacques Francois and onto his son-in-law, Theodore Letrouneau before it finally left the Soleil descendants. Sautter & Company shipped their first lens to America in 1853 for the lighthouse at Alcatraz Island.

Sautter continued working with the glass manufacturer St. Gobain in Paris to make bigger and better glass pieces. Through acquisition and mergers, the company evolved to include electrical generators and searchlights. The company's lights were used to illuminate the Champs-Élysées and the Arc de Triomphe in the late nineteenth century.[15]

By 1858 the lighthouse and buildings of the Dry Tortugas light station were complete. The station consisted of several structures sited in the middle of Loggerhead Key including the 150- foot brick lighthouse, a detached two story oil house, a two-story keepers' dwelling, a separate two-story kitchen, and two brick cisterns and several privies. A boathouse would not be constructed until 1871.

Keepers and their Duties

Benjamin Kerr was the first keeper assigned to the light station on Loggerhead Key. He was transferred from Garden Key in 1858 with a salary of $600 a year and brought with him, Henrietta his wife, and seven children. Kerr was employed at the Dry Tortugas light station until 1861, when he was replaced by James P. Lightbourn. Besides being named the first keeper of the Dry Tortugas Lighthouse, Kerr's notoriety stems from an incident in which both of his assistant keepers allied with his wife and one daughter to "make an attempt on his life."[16] According to G. Phillips who was stationed at Fort Jefferson at the time, Kerr and one of his daughters arrived at Garden Key in a small boat, after having escaped from Loggerhead Key. Kerr and his wife apparently reconciled and managed to finish their assignment with no further incidents.

The *Organization and Duties of the Lighthouse Board* set forth the requirements for lighthouse keepers. A few of the fundamental requirements established by the Board are listed below:

> LIV. Keepers were required to be over 18 and be able to read and write, and be in every respect competent to discharge the duties of the keeper….
> LV. Men of intemperate habits and those who are otherwise mentally or physically incapable of performing the duties of the light keepers, must not be nominated for appointment by superintendents of lights.
> LVII. Women and servants must not be employed in the management of lights, except by the special authority of the Department.[17]

[13] *Light-house and Appropriation Bill, Statutes at Large of the United States of America 1789-1873,* 34th Congress, 1st sess., August 1856, vol.11, 99.
[14] Dean, 84.
[15] Tag, Thomas, *The Sautter Lens Works Producers of the Fresnel Lens*, U.S. Lighthouse Society's, *The Keeper's Log*, Summer, 2005, www.uslhs.org.
[16] Dean, 87.
[17] *Organization and Duties of the Lighthouse Baord,* 60.

Pay was established at the keeper's appointment and was begun when they entered their duties. The keepers were permitted to select their assistants, but keepers' families were allowed to be nominated only in "rare and exceptional cases."[18] The keeper's duties included keeping all aspects of the light station clean and in good working order, lighting and maintaining lamps, painting and maintaining all finishes both inside and out of all buildings, and maintaining clothing and accessories necessary to service and protect the light. Other duties included providing reports to the district office, maintaining safe and dry places for cleaning supplies, and logging in and out supply deliveries. [19]

As one might expect, life on Loggerhead Key was particularly isolated. With a few exceptions, keepers remained at the light station for short durations. There were 10 keepers assigned to the Dry Tortugas station between 1858 and 1912.

During the 1860s, rations for each lighthouse keeper and assistant keeper, in addition to their salary, included:

> 40 pounds of salt pork, 52 pounds of salt beef, 100 pounds of flour, or 80 pounds of ship biscuit, 11 ½ pounds of brown sugar, 6 pounds of coffee, or 1 ½ pound tea, 5 pounds rice and 2 gallons beans or peas per quarter[20]

A break in the monotony came for the keepers and their families when on occasion they would be invited to socialize with the families of officers stationed at Fort Jefferson. Alternately at times the lighthouse keeper would host parties on Loggerhead Key, usually in conjunction with turtle turning expeditions. "Turtle turning" involved turning large turtles on their backs, thereby rendering them helpless and unable to escape. The turtle turning parties were often accompanied by the sharing of food, music, and dancing.

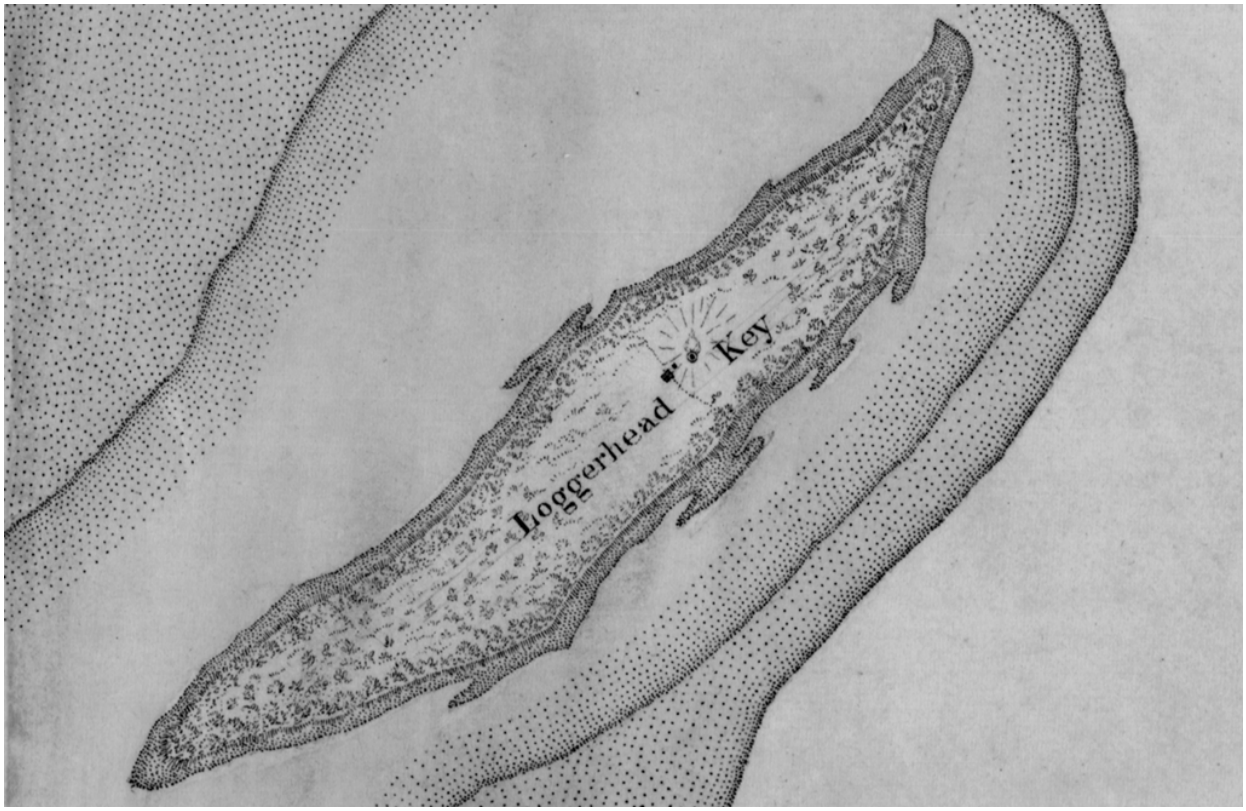
Later during the twentieth century, keepers were restricted to living on the island without their families. In a 1938 letter from the Superintendent of Lighthouses to the Commissioner of Lighthouses, the Superintendent advocates for familial visits for keepers during the summer months. Responding to a proposed change in policy that would eliminate this privilege, the letter emphasizes the remote and isolated conditions at the station:

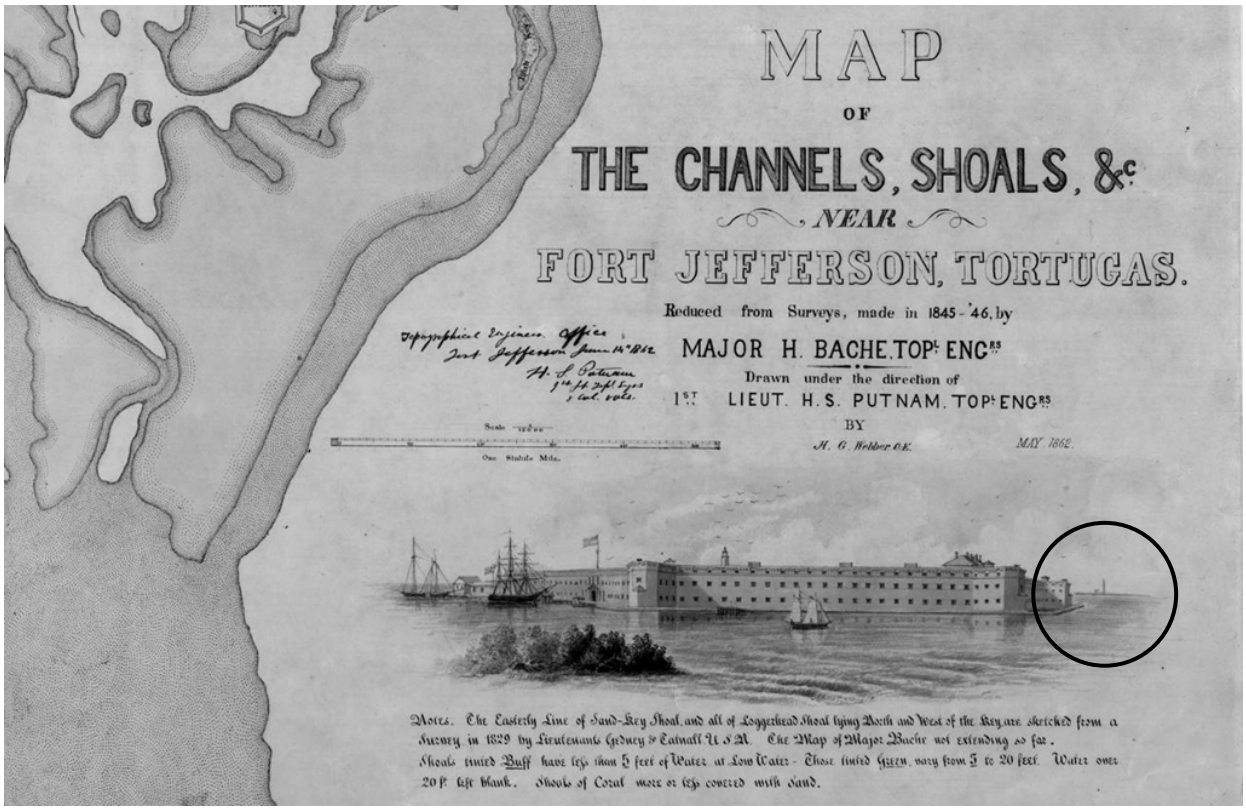
> Dry Tortugas Light station, Fla., is possibly one of the most isolated as well as attractive and efficient stations in the Service… There is no intention to make the station a resort; it is a condition that has existed for many years with nothing but beneficial results to the keepers and their families and this office believes that the best interest of the Service is being conserved in making no changes. With unrestricted privileges of this nature being enjoyed by the Carnegie Institutions Biological Station on the same reservation together with the other reasons it is recommended that no changes or restrictions in this respect be made….In reference to inquiry as to whether or not they be quartered in the station buildings, Bureau is advise that such is the case and the keepers and their families are perfectly satisfied to subject themselves to the slight inconvenience for the pleasure and privilege of having these relatives and friends with them as requested. It has been the experience of this office that these keepers feel that these dwellings are their homes, for which they pay more rent than they are worth, in addition to having to maintain homes elsewhere.[21]

Even into the 1980s, lighthouse keepers with the Coast Guard reinforced the lonesome and isolated nature of their duties. Most assignments for unwed officers were for six weeks with three weeks on shore and assignments for married officers were typically four weeks with two weeks on shore. "The biggest complaint was the absence of women and having to cook for each other."[22]

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[18] Ibid.
[19] Ibid., 88-89.
[20] U.S. Lighthouse Board, *Registers of Lighthouse Keepers, 1845-1912*, National Archives Southeast Region, Morrow, Georgia.
[21] Superintendent of Lighthouses to Commissioner of Lighthouses, 08 June 1938, Record Group 26, NA, Washington, DC.
[22] Hurley, 59.





Figures 8 and 9. Portions of an 1862 map of Dry Tortugas showing the first depictions of the light station. Loggerhead Key is shown in plan (above) and the lighthouse can be seen in elevation beyond Fort Jefferson within the cartouche (below).

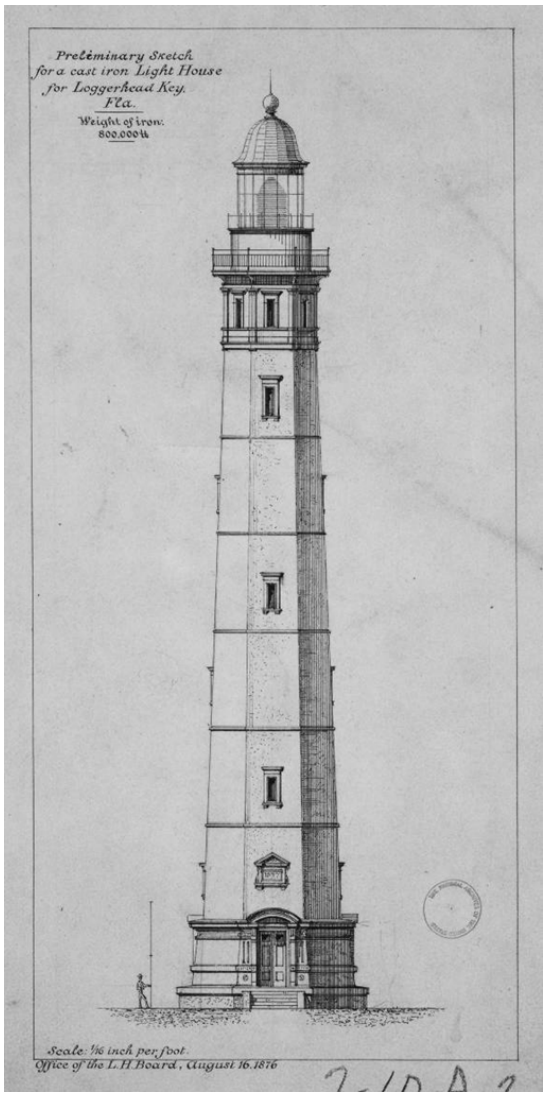


Figure 10. Elevation of iron tower proposed to replace storm-damaged masonry tower

War and Disease

Florida seceded from the Union on January 10, 1861, but the Dry Tortugas remained under the command of Union forces throughout the War. The Union successfully blockaded St. Augustine, Jacksonville, Key West and Pensacola. Still, some smaller vessels were able to smuggle goods such as cattle, crops and salt to Confederate sympathizers. While most of the battles of the Civil War took place in other states, approximately 16,000 Floridians left home to fight in the war. The battles of Olustee (near Tampa Bay) and Natural Bridge (near Tallahassee) were both won by the Confederates and Tallahassee was the only state capital in the Confederacy not seized by Union Troops. [23]

During the War, the 47th Regiment of the Pennsylvania Veteran Volunteers were stationed at Fort Jefferson and by 1865 nearly two thousand people were living on Garden Key. The installation was used primarily as a military outpost and prison during the war and was never fired upon or fired a shot in conflict.

A yellow fever outbreak in 1867 resulted in the Light Station falling into disrepair for several years. During the period between 1867 and 1871 Loggerhead Key was used as quarantine station for military personnel, which strained resources and impeded maintenance of the buildings. By 1871 the outbreak had subsided and various maintenance projects were again underway.

A second outbreak of yellow fever affected the Dry Tortugas in September of 1873, requiring all healthy soldiers on Garden Key to once again be relocated to Loggerhead Key. During the outbreak, thirty people were infected resulting in 12 casualties. The healthy were still on Loggerhead Key when the hurricane of 1873 hit the island.

The Hurricane of 1873

The hurricane that struck the Dry Tortugas on October 6, 1873, initially formed near the Leeward Islands, drifted west towards the Yucatan Peninsula, then backtracked through the lower Gulf of Mexico, before it curved northward and passed over the towns of Punta Rassa and Melbourne on the east coast of Florida. Although the track of the hurricane took the eye north of the Dry Tortugas, it delivered a damaging blow to the Light Station.

The initial evaluation of the storm-damaged Light Station was bleak. The Lighthouse was reported to be in dangerous condition and it was initially recommended that the entire tower would need to be rebuilt.

[23] Florida Center for Instructional Technology, College of Education, *Florida's Role in the Civil War: "Supplier of the Confederacy"*, University of South Florida, 2009 http://fcit.usf.edu/Florida/lessons/cvl_war/cvl_war1.htm.



Figure 11. Undated nineteenth-century view of the Dry Tortugas light station looking northeast.

Because Loggerhead Key was still under a yellow fever quarantine and contact with the island was limited, only temporary repairs could be made following the storm.

> The walk in front of the keeper's dwelling has been cemented and the water-conductors to the cisterns repaired. The cisterns have been cleaned and repaired, and wooden shutters for the tower-windows have been made, painted and hung. It is proposed, during the coming season, to make careful examination with a view to determining on plans for the foundation of a new tower.[24]

Congress appropriated $75,000 for repairs to the Lighthouse and plans were prepared for a new structure. In contrast to the existing masonry tower, the design of the replacement structure would be entirely of cast iron.

By 1875 the upper portion of the lighthouse had been extensively repaired, anchors were extended down through the lighthouse walls to secure the lantern and the tower received its distinctive daymark. The upper portion of the tower was painted black and the lower portion was painted white. The black color was supposed to help dampen reflections, contrast with the white clouds and show a distinct color pattern for sailors.[25]

The work was completed just as a second hurricane swept through the Dry Tortguas. The repairs held and were closely monitored during the ensuing years. Ultimately it was decided that a new lighthouse would not be necessary.

During this same period, discussions were held about the inadequacies of the Garden Key Lighthouse and its placement within the parade ground of Fort Jefferson. After another hurricane damaged the Garden Key Lighthouse, plans were made to replace it with an iron structure to be located on top of bastion C of the Fort. The original Garden KeyLighthouse was demolished and on April 5, 1876, the new cast iron light tower was lit.[26]

[24] Ibid.

[25] Hurley, 39.

[26] Hurley, 41. The choice to construct the new tower out of iron was a strategic military decision. If the fort came under attack, a brick tower was considered more dangerous because of the heavy shrapnel produced if hit by shells.

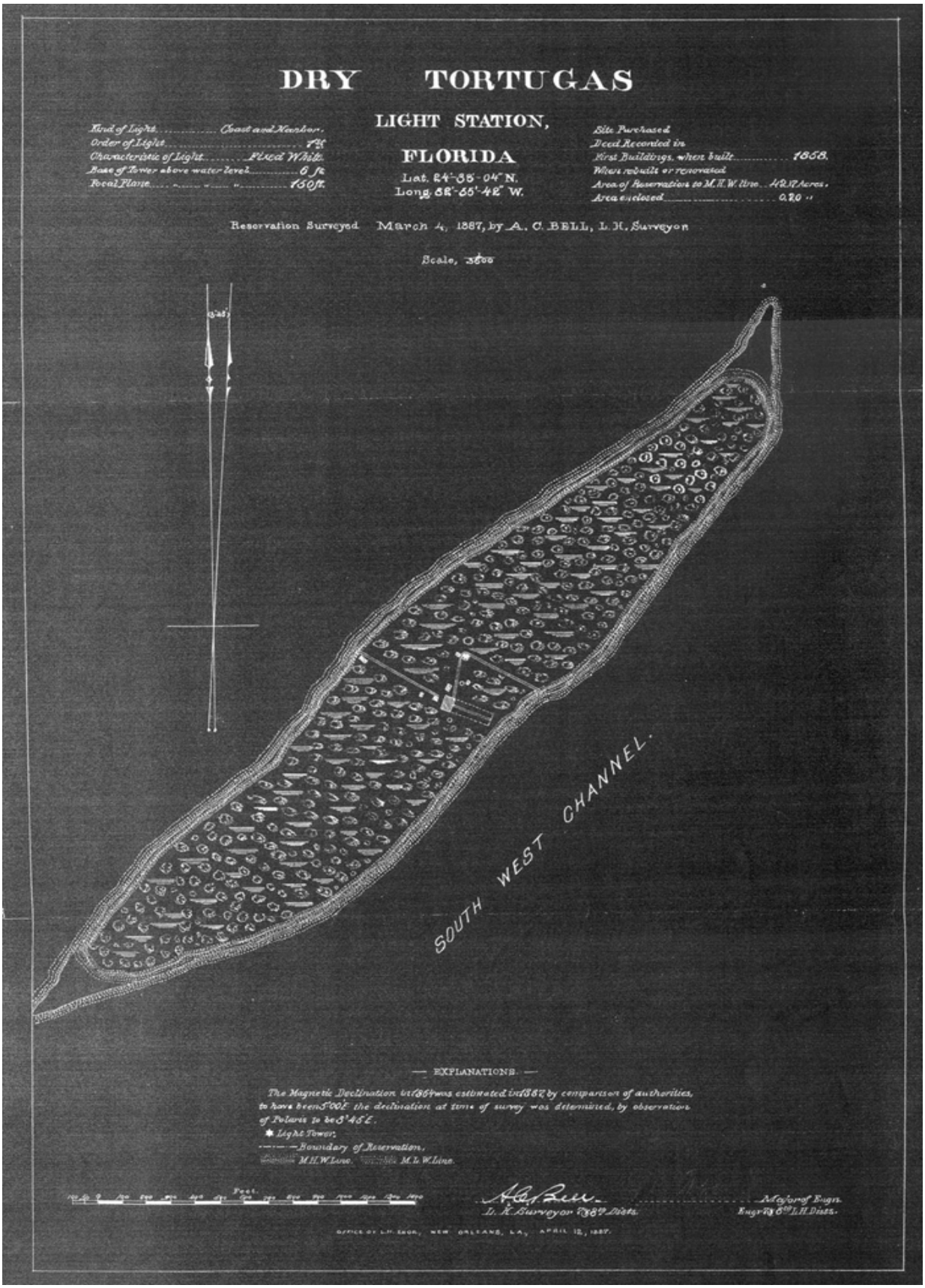


Figure 12. 1887 survey of Dry Tortugas Light Station by A. C. Bell.

Late Nineteenth-Century Development

Through the late 1870s, minor repairs were made to several of the Station's structures, and in 1880, a new boathouse was built. From 1888 to 1910, Prussian George Billberry served as keeper of the Light Station. During his service, many repairs and upgrades were made to the Station buildings. From 1880 through the 1890s, mineral lamps—otherwise known as Luchaire incandescent oil vapor lamps (i.o.v.)—became the method of illumination. New glass was installed in the lantern, wash houses were built, structures were painted and whitewashed, wire fence was installed, and on "April 30, 1893, the characteristic of the Loggerhead Key light was changed from fixed white to fixed white with a fixed red sector."[27] The implementation of red sector lighting was a navigational advancement for its time. A red pane of glass was installed on the side or sides of the lantern where the reefs or shoals were particularly dangerous. Shipmen knew not to navigate directly into the red light for this would signal imminently dangerous waters.

For most of the 1890s, once again Loggerhead and Garden keys were used as quarantine stations, this time for those suspected of being infected with small pox. Despite an order in 1893 from the War Department to discontinue the quarantine stations, the two keys would serve this purpose until 1900.

The Spanish American War

In 1898, the United States entered into war with Spain over the liberation of Cuba. The Dry Tortugas served as a harbor and staging area for ships in the area. The most notable incident of the war occurred with the *U.S.S. Maine*. On January 24, 1898, the ship sailed to Havana and a few weeks later it suffered a massive explosion that killed 260 of its 350 sailors and sank the battleship. At the time, the explosion was blamed on an underwater Spanish mine, and as a result, the U.S. declared war against Spain on April 21. The war cry "Remember the Maine!" stems from this incident. The war was relatively short-lived and a treaty ending the conflict was signed in December 1898.

In 1976, a Navy panel came to the conclusion that the blast on the *Maine* was the result of an onboard fire in the coal storage area. It is possible that the fire may have originated while the ship was in the harbor at Garden Key.

Bureau of Lighthouses

With the turn of the century, came a change in the management of the Lighthouse Board. In 1903, the Board was moved from the Treasury Department to the Department of Commerce. In 1910, it officially became known as the Bureau of Lighthouses. Congress intended to accomplish several objectives with this reorganization. First, it sought to demilitarize the lighthouse service. Both the Army and the Navy were not allowed a prominent role on the Board, the goal being to shed a civilian light on a primarily civilian service. Secondly, the reorganization allowed for an increase in districts to accommodate the growing number of light stations. In 1910, George R. Putnam was selected to lead the new Bureau of Lighthouses. Serving for 25 year, Putnam's most notable contributions include the introduction of radio beacons as an added means of navigation, electrification of many light stations and a retirement system for field employees.[28]

The Carnegie Institution Marine Biology Laboratory

In 1904, a portion of the northern end of Loggerhead Key was granted through a revocable lease, to the Carnegie Institute for the establishment of a research laboratory to study marine life in the Atlantic. The Institute declared in their 1904 Year Book the establishment of the Marine Biological Laboratory at the Dry Tortugas, under the direction of Alfred G. Mayor.

Mayor was a Harvard educated biologist who initially studied butterfly pigmentation. However, due to a serious eye inflammation he was forced to pursue research that relied

[27] Hurley, 45.

[28] Holland, 38.



Figure 13. Undated view of the Carnegie Institute's Marine Biology Research Laboratory with the Dry Tortugas lighthouse in the distance.

less on work with a microscope. Jellyfish offered the perfect specimen for him to study work on the species. The Dry Tortugas offered an ideal location for collecting and observing jellyfish among other tropical plants and marine life.

The laboratory complex was constructed between 1904 and 1906 and was comprised of:

> a main laboratory building and sleeping porch, a detached lab, a kitchen, a windmill for pumping salt water and air to aquariums, a dock, a shipways, two small outhouses and a cistern. The labs and outhouses were built in New York and shipped to Loggerhead for assembly, while the rest of the buildings were built on site. About 50 palm trees were planted around the lab to shade the buildings and provide hurricane protection. All the buildings, chemicals, lab glassware and furniture cost only $4,800. The lab's research vessel was a 57-foot-long ketch, with a 20 horsepower auxiliary engine.[29]

and he subsequently published a three volume

A vast and diverse program of research was conducted at the laboratory. Some of the most notable accomplishments include groundbreaking research on coral reefs and mangrove communities, the establishment in 1908, of the Dry Tortugas as a wildlife refuge for the sooty tern, and the first underwater photographs—both black and white and color were taken there.

Although the Institute viewed Mayor as a promising individual, his selection of Loggerhead Key for the research laboratory was seen as a poor choice. It was too remote and difficult to access and receive support from the mainland. In addition, working around hurricane season left for a brief research period from May until July each year.

[29] Hurley, 48. Carnegie Institute Yearbooks.

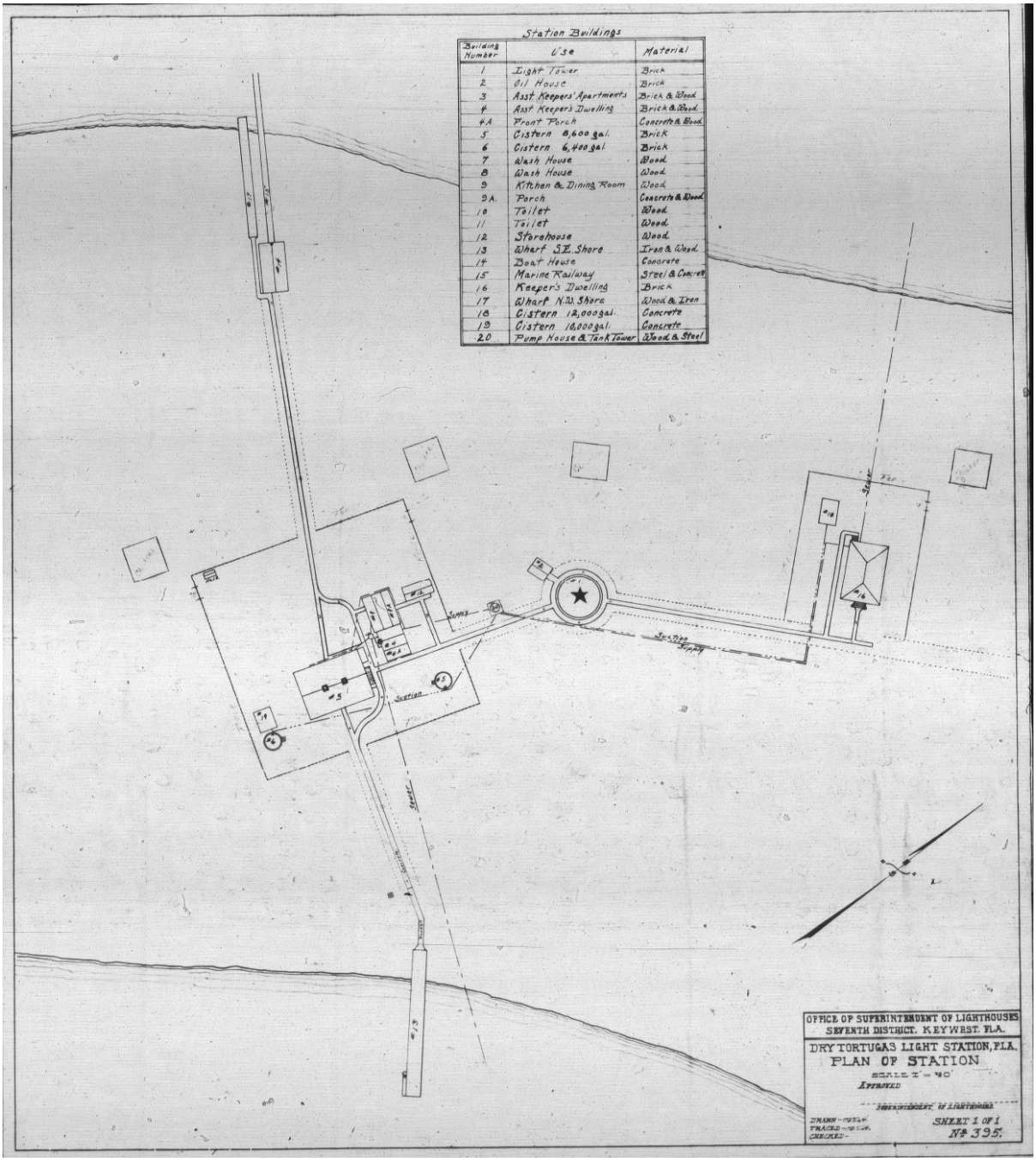


Figure 14. Ca. 1925 Plan of the Dry Tortugas Light Station.

Mayor had some aspirations to relocate the lab to Jamaica to create a truly international biological station, but he suffered from tuberculosis and in June of 1922, his body was found face down on the shore of Loggerhead Key. He was 54 years old. The coroner ruled

> that Mayor died of "heart-failure and general debility contingent upon his tubercular condition."[30] A plaque erected in his honor in

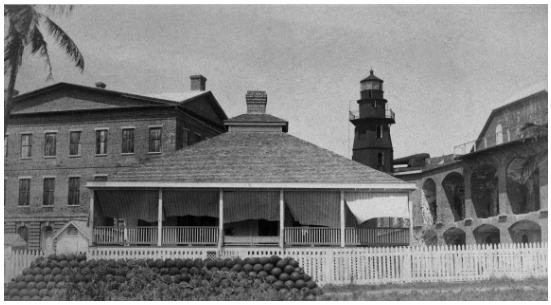


Figure 15. Undated view of the Garden Key Keeper's Residence with the iron lighthouse on bastion C in the distance.



Figure 16. View of Dry Tortugas Keeper's Residence shortly after completion.

1929 stands near the site of the former laboratory complex.

The Carnegie lab survived through the Great Depression and several hurricanes until 1939, when Carnegie President Vannevar Bush closed the laboratory. Reduced funding and a shift in philosophical focus from macro-biology to microbiology have been reasons stated for the closure.[31] During the thirty-five years of laboratory operation, more than 140 scientists visited and conducted research on, and in the waters surrounding Loggerhead Key.

Early Twentieth Century Modernization

The early part of the twentieth century not only included the restructuring of national lighthouse management and the birth of modern marine biology with the establishment of the Carnegie laboratory, but also ushered in modern technological advances at the Light Station. Radio beacons, electricity, concrete cisterns, a new lens and multiple construction projects were completed during this period.

Two significant hurricanes during the 1910s, once again, caused serious damage to the Light Station and the laboratory complex. The hurricane of October 10, 1910, (hurricanes were not named until the 1950s) damaged the wharf, shattered panes of glass in the tower, and severely damaged the dormitory and blew the roof off the main building at the Carnegie laboratory complex. The machine shop was moved off its foundations nearly five feet. On September 8, 1916, Congress allotted $2,800 and;

> a wrought-iron pile wharf with cast-iron caps and wooden girders, stringers, and decking was erected in place of the old wharf, which was destroyed. All work was completed in May, 1917. Amount expended to June 30, 1917, $2,631.19.[32]

As a result of damage sustained in the 1910 hurricane, the original first-order lens was replaced with a second-order lens.

A second hurricane hit the island on September 10, 1919, severely damaging the laboratory by washing away snail breeding cages and resulting in damage to all the buildings.

Fort Jefferson experienced a massive fire in 1912 that destroyed the Garden Key light keeper's dwelling, as well as the fort's barracks, kitchen and latrine. The keeper's house was not rebuilt and some years later the harbor light was deemed unnecessary for navigational purposes and decommissioned. In 1921, the lighthouse on Loggerhead Key became the primary navigational beacon in the Dry Tortugas.

Following the decommissioning of the light on Garden Key, the Bureau of Lighthouses took several steps to upgrade and modernize the Light Station on Loggerhead Key. In 1922, a new dwelling for the primary keeper was constructed and two new concrete cisterns

[30] Calder, Dale R. and Lester D. Stephens. *Seafaring Scientist: Alfred Goldsborough Mayor, Pioneer in Marine Biology*, Columbia, South Carolina: University of South Carolina Press, 147.
[31] Hurley, 49.

[32] Ibid.

installed. Five years later when the original Oil House was converted to a radio beacon equipment room, it was connected to the tower by a reinforced concrete passageway. The marine radio beacon was installed in 1926 to assist ship traffic and provide basic communication. The new technology offered a means of communicating with mariners about weather, operations, and navigational issues. The marine radio beacons were able to transmit communications to ships in storms when the lighthouse was difficult to see.

The introduction of electricity to the island was another technological advancement that changed the way the Lighthouse and Light Station operated. Powered by generators, housed in a frame addition constructed on the south elevation of the former Oil House, the new electric light installed in the Lighthouse in 1931 had 3,000,000 candle-power, making the Dry Tortugas light the brightest in America. Several mariners reported that they could see the light up to 52 miles away. Before electrification, the Lighthouse had a range of approximately 19 miles. The existing incandescent oil vapor lamp was kept as a secondary system.

In 1935 Fort Jefferson was designated a National Monument by President Franklin Roosevelt and was transferred to the National Park Service.

The U.S. Coast Guard

In 1939, the duties of the Bureau of Lighthouse were amalgamated into the operation of the United States Coast Guard. Light keepers were given the choice of becoming petty officers or remaining as civilian employees. During World War II keepers were utilized as lookouts for German U-Boats in the Florida Straits. The threat of attack by enemy U-boats was real as twenty-four American ships were sunk by German submarines during the war. Coast Guard keepers also took part in beach patrols and at times had to rescue or recover victims of U-boat attacks.

During the war, there was some debate as to whether the lighthouse lights should be extinguished or dimmed. Exposing ships to enemies was considered less of a danger than running aground, so the Coast Guard implemented "dim-out" policies in which the intensity of the lamps was turned down.[33]



Figure 17. Image taken from the top of the tower showing the burned remains of the original keeper's dwelling.

In March of 1945 a fire destroyed the original 1858 keeper's dwelling and damaged the adjacent kitchen building. As a result, the keeper's dwelling had to be demolished to its foundations. A second fire in 1964 destroyed several of the abandoned Carnegie laboratory structures.

Under management of the USCG the Dry Tortugas Light Station remained manned with a crew of from two, to as many as twelve personnel. From the mid-twentieth century to the 1990s, numerous projects were planned and implemented at the Station beyond the required routine maintenance and minor repairs that took up much of the time of those stationed on the island. A majority of the projects centered on upgrading and repairing the various systems that were critical to habitation of the island such as those that provided potable water, sanitary systems, and generation of electrical power. In 1967, extensive improvements were made to the

[33] Hurley, 57.

tower including sandblasting the exterior and repainting the daymark.

Projects in the 1970s focused on the installation of fuel and water tanks, upgrading electrical service and providing fire protection in the 1922 Keeper's Residence or "barracks building" as it was referred to during this period. In 1975 during the construction of a new wharf on the eastern shore, a Seaman Apprentice, William H. Graves, was tragically killed. A small monument dedicated to Seaman Graves is located near the site of the accident.

In 1984, the USCG commissioned National Park Service personnel to prepare a rehabilitation report and national register nomination for the Dry Tortugas Light Station property. This project was undertaken to document the history of the Light Station and to make recommendations for the appropriate repair of the historic lighthouse and support structures in advance of a planned automation and modernization program. The document included recommendations focused on repairs to the Lighthouse as well as both mortar and paint analysis.

The following year an extensive program of repairs was completed on the Lighthouse, and in 1986, the USCG decommissioned the existing second-order bi-valve lens after aggregate from sand-blasting operations contaminated the mecury float mechanism. As a result the lens was no longer able to rotate and was replaced with an automated 24" Directional Code Beacon (DCB-24). The new lamp was programmed to create a flashing light every 20 seconds that could be seen up to 24 miles away. The bivalve lens was removed and placed on display at the National Aids to Navigation School in Yorktown, Virginia where it remains today.[34]

The National Park Service

Following automation of the Lighthouse optic in 1986 the USCG continued to be challenged by mounting deferred maintenance and limited funding for repair or capital improvements. In an effort to reduce their burden, consideration was given to demolishing several non-essential structures including the boat house and original kitchen building. In addition, advancements in the Long Range Navigation (LORAN) system and GPS (Global Positioning System) technology, as well as the expanded use of Satellite Navigation (SATNAV) resulted in diminishing reliance by mariners on visual aids such as lighthouses and beacons.

About the same time, the National Park Service, and at least two other groups, expressed interest in taking over management of Loggerhead Key and the Light Station property from the USCG. The other groups vying for the property included the Key West Ports and Transportation Authority who was interested in establishing a marine hatchery and science camp on the island, and the Key West Art and Historical Society who expressed an interest in managing the lighthouse, but had not submitted a formal proposal.

In 1991, the Coast Guard determined that the National Park Service presented the most viable proposal and several meetings were held between the two entities to evaluate the condition of the existing resources and to discuss the logistics of a transfer. Negotiations focused on resolution of several utility issues regarding the electrical generators and septic system and also a requirement for the USCG to remove all hazardous materials from the island as a condition of transfer. Despite their desire to divest themselves of the Light Station completely, the USCG would continue to maintain the light as an active aid to navigation and provide logistical support to the Park Service as part of the agreement. Transfer of the light station also provided opportunity for the USCG to eliminate permanent staff on the island and limit its obligation to routine site visits to maintain the optic. Establishment of Dry Tortugas National Park the following year provided the ideal mechanism for formally transferring Loggerhead Key and the Light Station to the National Park Service.

Dry Tortugas National Park was created in 1992 to "preserve and protect for the education, inspiration, and enjoyment of present and future generations nationally significant natural, historic, scenic, marine and scientific values in South Florida." The Park

[34] Dean, 99.



Figure 18. Chug used by Cuban refugees to land at Loggerhead Key in 2008.

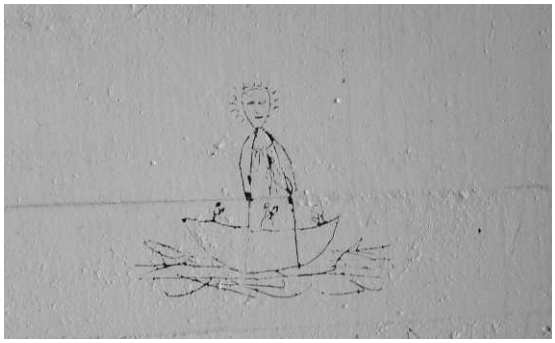


Figure 19. Graffiti left by Cuban refugees on wall of Boathouse.

the Light Station resources being listed on the National Register of Historic Places.

Through its Volunteers-In-Parks (VIP) program, the Park Service has been able to maintain a consistent presence on Loggerhead Key for much of the last two decades. The volunteers, who stay on the island for one to several months at a time, are housed in the former kitchen building and perform limited repair and maintenance of the resources. More importantly their presence provides a level of security for the island that serves as a deterrent to those that may seek to damage or cause harm to cultural or natural resources.

Since the National Park Service assumed management of the Light Station they have had the additional challenge of dealing with Cuban refugees making landfall at Loggerhead Key. The Dry Tortugas have become a primary landing point for the refugees due to their proximity to Cuba and remote location.

boundaries established at the time encompassed all of the seven small islands that make up the Dry Tortugas as well as the coral reefs, shoals and waters within an approximately 100 square-mile area. As part of the enabling legislation for the Park, the USCG lands, including all of Loggerhead Key were formally transferred from the USCG to the National Park Service. The establishment of Dry Tortugas National Park also resulted in

Since adoption of the "wet foot/dry foot" policy in the mid-1990s, the influx of refugees has been steady. The wet foot/dry foot policy generally states that if a refugee is able to make landfall on U.S. soil they will be allowed to stay and can pursue citizenship, on the other hand, if they are intercepted in the waters between Cuba and the United States, they will be sent back to Cuba or to a third country.

Generally arriving at night, during periods of calm weather, the refugees cross the open waters between the two countries in make-shift boats referred to as "chugs." These chugs accumulate on the keys and intermittently have to be removed to the mainland for disposal.

After the Mariel Boatlift in 1980, the numbers of Cuban refugees attempting to enter the United States peaked again in 1994 and 2005. Refugees that make landfall within the Park are temporarily detained by the National Park Service until USCG officials can transfer them to the mainland for processing. Historic



Figure 20. Aerial view of Loggerhead Key showing density of Australian Pine growth prior to de-vegetation project.

resources, primarily the Boathouse on Loggerhead Key and the casemates within Fort Jefferson on Garden Key, are occasionally used to temporarily house landed refugees. In recent years the USCG has increased its patrols in the waters around the Park reducing the number of refugees making landfall on the Keys.

The National Park Service has also recently completed an extensive landscape restoration program to remove the Australian Pine and other exotic plants from Loggerhead Key. These invasive species were introduced by Carnegie Institute personnel during the first quarter of the twentieth century dramatically changing the landscape character of the island. The program has been successful in removing the trees and returning the island to its pre-Carnegie appearance.

With the exception of the Lighthouse which continues to function as an active aid to navigation, the resources of the Dry Tortugas Light Station are primarily used for housing and also to shelter critical components of the island's utility systems. Volunteers from the VIP program occupy the former original kitchen building for most of the year and the 1922 Keeper's Residence is reserved for intermittent use by National Park Service personnel, researchers or contractors. The USCG also maintains a room in the Keeper's Residence for its use during routine visits to service the light. Visitation to the Park is limited by the Park's General Management Plan Amendment which currently limits the numbers of visitors allowed on the island to 24. It also establishes permissible activities allowed on the island which include hiking, picnicking and exploring. The GMPA currently restricts access to the Lighthouse and Light Station buildings by the visiting public until such time as they can be "made safe" for this level of use.

Chronology of Development and Use

Design and Construction

Construction of the lighthouse on Loggerhead Key was a priority for the Lighthouse Board; in fact, in 1852, the agency "listed projects to improve the Dry Tortugas light as number three in the nation in terms of importance."[35]

Initial planning for the new lighthouse began in 1855 when T. A. Jenkins, U.S.N., Secretary of the Light-House Board requested H.G. Wright, Chief Engineer in charge of construction at Fort Jefferson develop an estimate for the proposed project. Wright's proposal provides unique insight into the planning and consideration that went into designing a new lighthouse in the mid-nineteenth century. By his request, it is certain Jenkins sought to take advantage of Wright's construction expertise and experience working in the Dry Tortugas to gain an understanding of the challenges and potential costs that would be associated with constructing the new lighthouse. Based on Wright's response , it appears that Jenkins' instructions were vague causing Wright to make a number of assumptions in order to develop the design estimate. It is also clear that although Wright gave the exercise considerable thought, he was not entirely comfortable engineering a lighthouse structure.

The following excerpts are taken from Wright's proposal letter.

> Your instructions indicated the height without fixing the other important dimensions. This has perplexed me very much, as I do not know and have no means of ascertaining what experience has shown to be suitable in regard to convenience and stability for the upper and lower diameters, and the thickness of the walls for a tower so much higher than our ordinary structures. But should any of the dimensions I have assumed not meet the approval of the board, the estimates may be readily modified to suit the necessary changes, as an analysis of the costs of the principal items of masonry is appended.[36]

Wright goes on to provide considerable detail about how he proposes to construct the lighthouse foundation and the ability of the sandy soils to support the weight of the structure.

> A sufficient foundation being important to the stability of the tower, I have endeavored to make one that shall fulfill all the necessary conditions. It is proposed to first lay grillage, as shown on the sketch, the top of which shall be on a level of those in the bastions of the form, and being always under water is secured from decay. On this rests the foundation three feet high, with a batter of two feet on each side. The outlines of the grillage and foundation are made polygonal, instead of circular, for convenience of setting the curbing for the concrete. With such a foundation the pressure on the bed will be, for project No.1, a little over 36 cubic feet to the square foot, a pressure shown by experiments made here to be admissible, as the settlement under nearly twice the weight, at a point not far distant from the probable location of the tower, did not exceed three-fourths of an inch. If the grillage is not used, an additional and equivalent spread must be given to the masonry of the foundation, which must go down to the water to secure it from being undermined by rats and crabs.[37]

[35] Hurley, Neil E. *Lighthouses of the Tortugas, An Illustrated History*, Alexandria, Virginia: Historic Lighthouse Publishers, 1990, 30.

[36] Dry Tortugas Light Station Clipping File, Appendix no. 17, H.G. Wright, Capitan of Engineers, Fort Jefferson, FL to Lieutenant T.A. Jenkins, U.S.N., Secretary, Light-house Board, Washington, DC, 23 September 1855, Record Group 26, NA.

[37] Ibid.

He also discusses the proposed wall construction including formulation of the mortar and brick selection.

> There being nothing in your instructions relative to the kind of materials to be used for the masonry, I have assumed the foundations of the tower to be entirely concrete, and the walls for concrete faced inside and out with hard burned Pensacola or Mobile bricks, the facing being employed as better resisting the action of the sea air than the concrete. The bond assumed for this facing is the same as is now used on the fort, and is represented in the sketch.
>
> I am disposed to believe that the mortar for both brickwork and concrete should be made of cement and sand without any admixture of lime, and in the proportion of two parts of the latter to one of the former in powder. The voids in the sand being about one-third, and the shrinkage of the cement about one quarter when reduced to a paste, the latter will a little more than suffice to fill the voids of the former when mixed in the above proportions. Experience here has shown that lime mortar does not fully resist the action of the atmosphere, and therefore should not be relied upon…[38]

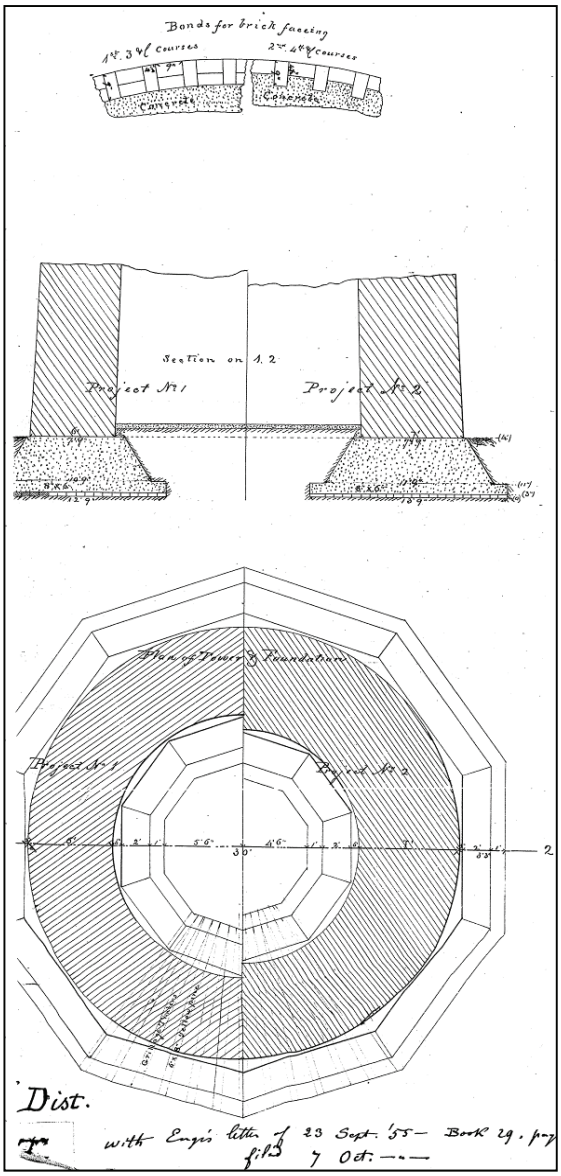


Figure 21. Portion of sketch from Wright's 1855 proposal showing the foundation and wall construction of the proposed lighthouse.

The proposal also discusses at the superiority of Pensacola or Mobile brick over bricks supplied from the north. Despite their higher freight costs, Wright favored the Pensacola and Mobile bricks because they withstood the harsh elements of the region better than the northern bricks. A lesson learned during construction of Fort Jefferson. Wright proposed that the northern brick could be used in all unexposed areas as a cost savings measure.

The potential cost impact of having to elevate materials to the top of the tower was also considered by Wright.

> An important item of cost, and one not easily estimated for with accuracy is raising the materials for so high a tower. When the ordinary means of hodding them [carrying materials with a hod or wooden contraption that is strapped over the worker's shoulders] is employed, it is known that the cost increases rapidly after the structure is carried above a medium elevation. For this work to be hoisted, but this process will be a slow one, owing to the want of room for more than a single derrick, and will probably be found inadequate unless steam is employed. There is a small steam engine now in use here which may be available for this purpose…[39]

The effects of hurricane wind loads also influenced Wright's design assumptions.

> The arm lever, on which the weight of the tower acts against any force overturning it

[38] Ibid.
[39] Ibid.

> about its base, is taken at 14 feet, or one foot less than the radius of the base. The pressure of wind in the strongest hurricanes has been taken at 50 pounds per square foot, and as the tower is conical, the pressure against it is less than it would be against a plane surface equal to the central section, and has been assumed at two-thirds of 50 or 33 1/3 pounds to the square foot of this section. The central section of the tower and Lantern is taken at 160 x 30 x 15/2, which is probably in excess and the leverage at 71.1 feet, or the distance of the centre of gravity of the section above its lower base.

Because Wright was not well-versed in lighthouse construction and was provided little dimensional information from Jenkins, he developed two variations of his design and two separate cost estimates. He refers to these in his proposal as Project No. 1 and Project No. 2. The only difference between the scenarios was the thickness of the tower walls. The costs varied only slightly with Project No. 1 totaling $34,464.80 and Project No. 2 coming in at $35,806. 25.[40]

Both scenarios included costs for excavation and embankment, lumber for grillage, concrete for the foundation, brick masonry and concrete for the tower walls, costs for raising the materials, derricks, lumber for the upper floors and landings, 10 windows, sills, and lintels, one door frame, sills and lintels, ladders, landings and costs for storing materials.

In both cases Wright included the cost for a cast-iron stairway, a $10,000 allowance for the first-order Fresnel lens and a 10% contingency for unforeseen conditions. Relying on the accuracy of Wright's computations, Congress appropriated $35,000 in 1856 for construction of the new lighthouse.

The same year the project received its funding Wright was replaced at Fort Jefferson by Captain Daniel P. Woodbury.[41] After nearly nine years of supervising construction at Fort Jefferson, Wright requested a transfer to escape the heat in favor of a "more temperate climate."[42]He was reassigned as the assistant to the Chief Engineer in Washington, D.C. He would later command the 6th Army Corps during the last years of the Civil War and then supervise completion of the Washington Monument.

From the beginning, Woodbury was not happy with his assignment to Fort Jefferson. He did not like the remote location or the tropical climate. He was continually asking for assistants to help him with his work and trying to arrange for transfers. General Totten, who had assigned Woodbury to Fort Jefferson, insisted he remain in the Dry Tortugas. Informed of his increased duties to oversee construction of the lighthouse at Loggerhead Key in the fall of 1856, Woodbury again asked for assistance and finally arranged for a local draftsperson to help him for four dollars a day.[43]

It is said that Woodbury made several design changes to Wright's initial proposal including modifying the dimensions of the tower and changing the construction of the steps from cast-iron to stone. Woodbury is also attributed with eliminating the use of iron brackets to support the galleries in favor of corbelled masonry. This design approach may have been employed in response to the harsh environment of the region and its known detrimental effects on metals, or more likely, was influenced by Woodbury and the skills of his available labor force.

The original architectural plans for the Lighthouse were developed in 1857 by the engineers of the Seventh District. The plans consist of a single drawing that includes a plan of Loggerhead Key as well as plans and sections for the proposed Lighthouse and Keeper's Dwelling (Figure 21). A second undated drawing, which is referred to in correspondence from the 1920s as an "original drawing of Dry Tortugas light tower" shows the lighthouse in plan, section and elevation (Figure 22).

Construction of the Lighthouse began in 1857 and within a year the tower was complete. The first-order Fresnel lens, manufactured by the L. Sautter & Company was ordered and installed in the Lantern. The receipt sent to Captain Woodbury on April 16, 1857 contains an itemized list of components for the lens that tallies $41,467.02 (presumably, the units are

[40] Ibid.
[41] Bearss, Edwin C., *Historic Structure Report – Historical Data Section Fort Jefferson 1846-1898*, Fort Jefferson National Monument, Monroe County, Florida, 1983,141.
[42] Ibid., 55-56.
[43] Ibid., 143.

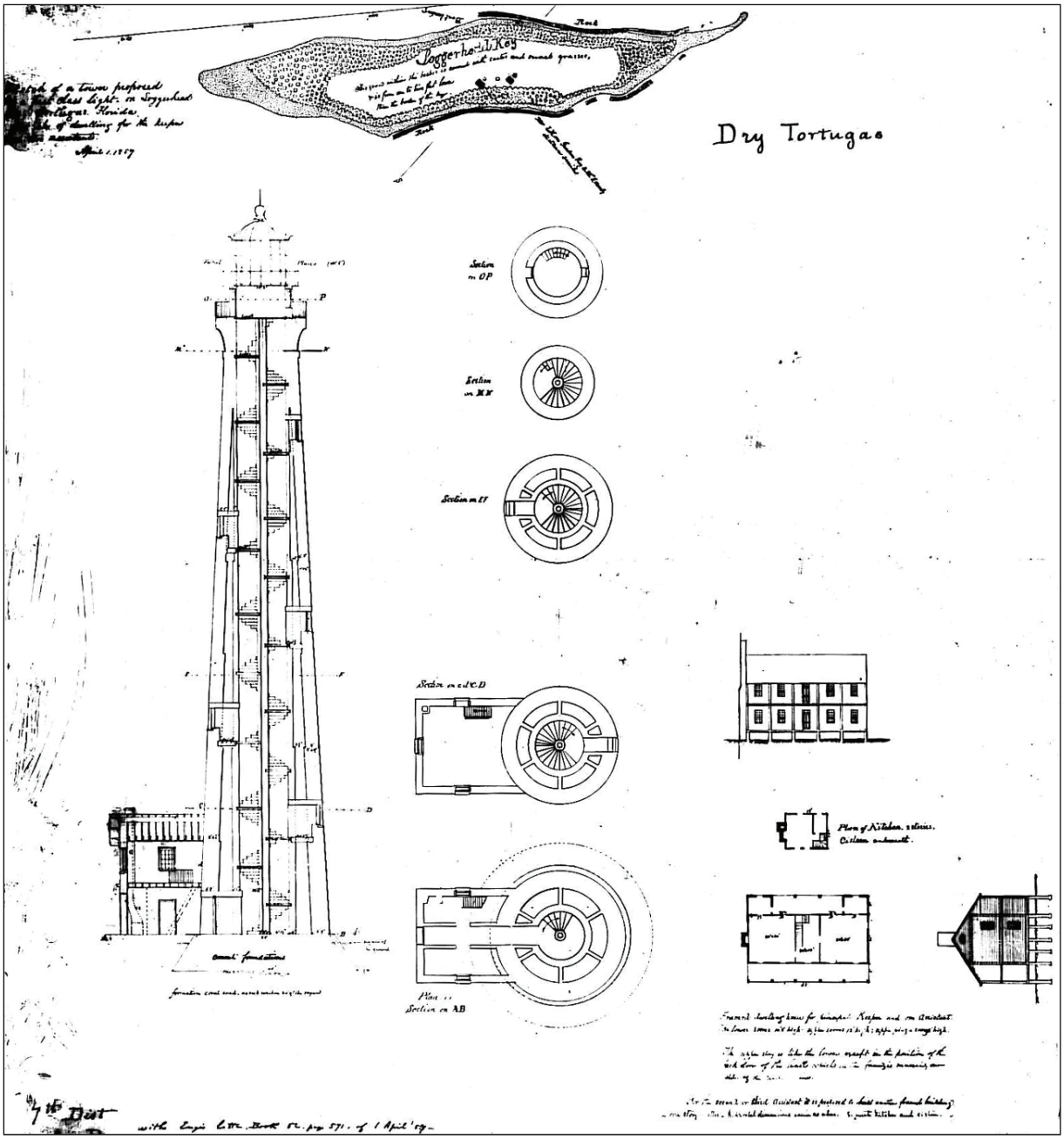


Figure 22. Architectural plans for Dry Tortugas Lighthouse and Keeper's Residence prepared in April 1857.

French francs as Wright had only set aside a $10,000 allowance in his proposal).

The Lighthouse was generally constructed according to the original plans with the exception of the oil house which is shown on the drawings attached to the base of the tower, but was constructed as a free-standing building. The reasons for this change could not be determined from the available historic documentation.

The simple, two-story, gable-roofed Oil House was constructed approximately 12' west of the Lighthouse. The building was constructed with load-bearing masonry walls, wood joists supporting the second floor and wood rafters. Although the original architectural plans show the roof with wide overhangs supported by brackets, the earliest images of the Light Station show only a simple eave configuration. It is

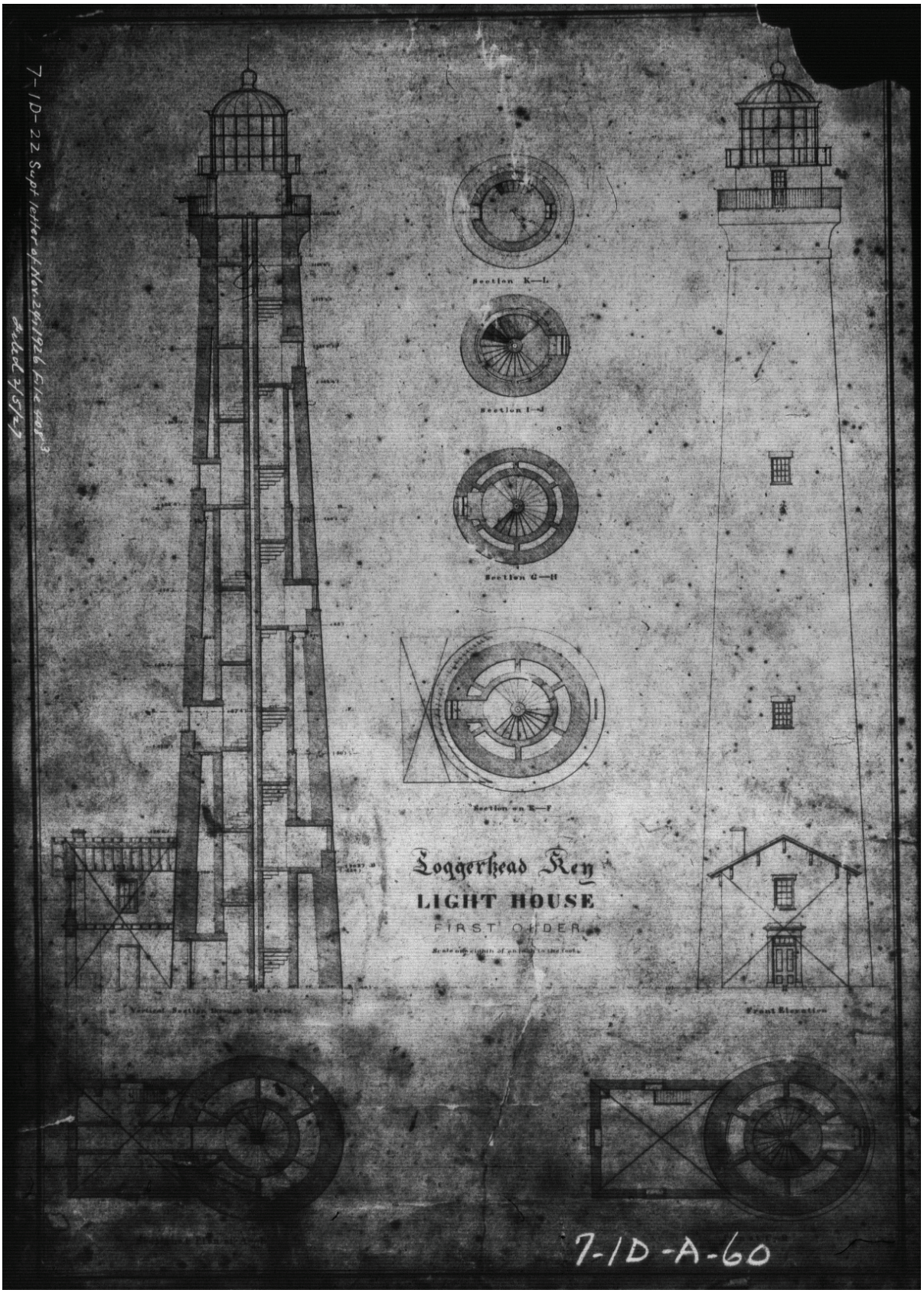


Figure 23. Drawing described as "original" plans for Dry Tortugas Lighthouse (Note the "X" through the attached Oil House).

possible that the roof was replaced and the overhangs eliminated following the 1873 hurricane.

The drawing also shows the first floor of the Oil House divided into three narrow rooms which was a typical plan configuration found in similar structures from the period. The building contained a fireplace in the southeast corner of the first floor and the windows are shown as eight-over-eight double-hung units. The first floor of the Oil House was used for the storage of oil while the second floor likely functioned as a work room. Correspondence from the 1920s describes the first floor room as containing eight 250 gallon steel kerosene storage tanks. Although it is not recorded, sperm oil was most likely the type of oil that was burned in the Dry Tortugas light when it was first constructed.

Early Repairs and Maintenance

Descriptions of repairs made to the Light Station between 1858 and the turn of the century are synthesized in the clipping files for the Dry Tortugas Light Station. These files contain excerpts taken from the Annual Reports of the Lighthouse Board for each lighthouse.

In 1861 minor repairs were made to the Lighthouse including the replacement of the tower windows. Several years later in 1867 more improvements were made when "new wick rings [were] provided, new supply tubes put on burners, burners packed, and curtain hooks put up into Lantern."[44]

Descriptions of improvements conducted in the late 1860s are as follows:

> 1868—The old and rusty lightning conductor has been replaced by a new one of copper with horn insulators; supply pipes of burners repaired; eight panes of glass set in the lantern. This tower also shows the effects of the heavy rains in this climate. Much of the mortar on the south and southwest sides is washed out, in some places to the depth of nearly half an inch. These walls should be repointed with cement. The plastering of the oil room and kitchen has fallen down and needs repairs. A suitable enclosure fence is recommended."
>
> 1869—The necessarily rigid quarantine kept up at Fort Jefferson, Dry Tortugas, has prevented the needed repairs on the tower at the station from being made during the past summer. The tower requires to be repointed, and painted with alternate white and black bands from the base to the lantern, to render it a better day-mark. These repairs will be made during the autumn. The illuminating apparatus is in good order and condition." [45]

In the early 1870s improvements to the light station included the construction of a boathouse and the application of the daymark. The interior of the Lighthouse was also" whitewashed" at this time.

Hurricane Damage and Repairs

The hurricane of October 6, 1873 caused severe damaged to the light station. In particular the force of the storm displaced the Lantern and lens apparatus of the Lighthouse and damaged the masonry at the top of the tower. The Lighthouse was described as being in "dangerous condition" after the storm and preliminary recommendations called for the structure to be demolished and rebuilt.

Several sources describe the damage caused by the hurricane. A letter prepared five days after the storm by the Seventh District Lighthouse Inspector to Prof. Joseph Henry, Chairman of the Lighthouse Board reads:

> Sir,
>
> I have the honor to submit for your information the following abstract of Inspections made since the hurricane of the 6th …At Dry Tortugas Station No. 365 Loggerhead Key. Joints of masonry at top of tower broken. Illuminating Apparatus turned from right to left 27 inches, pedestal and all. Lightning conductor loose, all the insulators are gone up to top of tower. Three panes of glass broken in Lantern. Ventilators in watch room out of order, won't work. Lock to tower door broken. Oil room door blown down. Dwelling and outbuildings badly shaken and a great deal of shingling blown away. Tin gutters torn off. Gutters to cistern blown away and destroyed. Our cistern burst above ground. Plastering on ceilings and walls of dwelling, and oil room fallen off. Fences all down. Tower and dwelling are very much in need

[44] Dry Tortugas Light Station Clipping File.

[45] Ibid.

> of whitewash. Boat houses blown completely away two of the front Standiaous[sic.] of dwelling were rotted. [46]

The same inspector later elaborated further on the damage to the Lantern and described the conditions faced by the keepers during the storm.

> I do not think that the efficiency of the light is impaired to the extent as to require it to be replaced. At the top of the tower the joints of masonry are broken, another of equal intensity would place the keepers who had to be in the tower, in a very perilous position. When the lamp was lighted on the evening of the 6th the two Ass't Keepers had to keep be of the apparatus, to steady it sufficiently to enable the Principal Keeper to light the lamp and the tower swayed to and fro, so much as to swash the oil out of the lamp (a mechanical---). Three panes of plate glass were broken in the lantern, one of them completely…

Because the Lantern had been displaced by the high winds, iron anchors were extended down through the Watch Room walls to better secure the Lantern to the masonry tower. In order to maintain the structural integrity of the tower, the repairs were made by removing thin columns of masonry, installing the anchors and replacing each section before moving on to the next. Despite these repairs, three years later, keepers continued to report that the Lantern would vibrate significantly in high winds. Post-storm repairs also included the fabrication and installation of shutters on the tower windows.

On March 3, 1875 Congress appropriated $75,000 for a new lighthouse to replace the storm-damaged tower. This figure was one-half of the initial estimate developed by the Lighthouse Board inspectors. The repairs were monitored during the next several years, and although plans were prepared for a new cast-iron tower, it was ultimately decided that reconstruction would not be necessary.

In September of 1875 a second hurricane hit the Dry Tortugas and caused damage to the Light Station. Many doors and windows were damaged, the lightning rod on the tower was broken, gutters were destroyed and the masonry Lighthouse was "severely shaken."[47]

Over the next decade improvements were limited to routine maintenance such as whitewashing the interior and exterior of the tower, refastening window frames, intermittent repair of Lantern glazing, and the installation of a new iron cone, damper pipe and oil lamps in the Lantern.

Changes to the Light

On April 30, 1893, "the characteristic of this light was changed from fixed white to fixed white with a fixed red sector."[48] This change was implemented by adding sheets of red glass to the lantern that aligned with navigational hazards.



Figure 24. Ca. 1892 image of the Light Station looking southwest.

[18]United States Lighthouse Board, List of General Correspondence, 1791-1900, National Archives and Records Administration, Washington, DC. Record Group 26. NC-31. Series 38.

[47] Ibid.
[48] Dry Tortugas Light Station Clipping File.

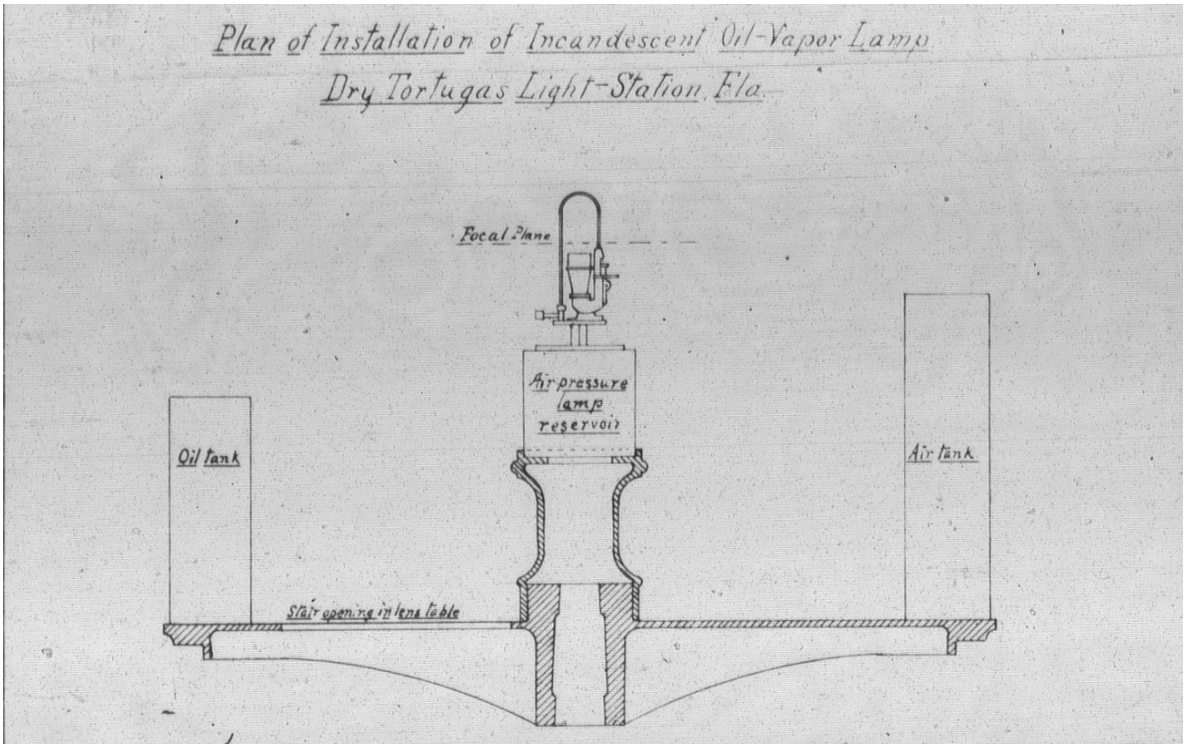


Figure 25. Section through lamp and lens platform prepared in 1911 showing new incandescent oil-vapor lamp.

Repairs to the lighthouse continued.

> The iron work of the tower was thoroughly scraped, scaled, and given two coats of paint from the top of the dome to the bottom of the tower. New storm doors were made and put in; five windows were fitted with new frames and storm windows. The watchroom [sic.] was ceiled and painted. . . .[49]

In 1910-1911 the original first-order lens was replaced with a second-order bivalve lens manufactured by the French rival to Sautter, Henry Lepaute. The new lens was given the designation "USLH 213."[50]

Replacement of the lens required extensive work within the Lantern and Watch Room, including the installation of a new lens platform, pedestal and Watch Room floor plate. Essentially all of the apparatus currently present within the Watch Room and Lantern was installed during the 1911 lens replacement. Also at this time, the existing lamp was replaced with an incandescent oil-vapor lamp (i.o.v.).

The bivalve lens, also known as a "clam shell lens" was accompanied by clockworks that drove the rotation of the lens. Like a mechanical clock the lens was rotated by the falling of weights set within the hollow column at the center of the tower. The lens pedestal sat in a 10" deep pool of mercury designed to eliminate friction in the rotation of the apparatus.

Despite a downgrade in size, the new second-order lens provided a brighter light with increased range. Correspondence from the period states "the candle power of the flash of the present second-order light is about 220 times as great as that of the former first-order fixed light and the luminous range for clear weather has been more than doubled by the change in the light."[51]

Following installation of the new lens mariners complained that the interval between flashes was too long. It was requested that the flashes be increased from one every forty seconds to one every ten seconds. In order to make this adjustment, modifications were made to the

[49] Ibid.
[50] Hurley, 50.
[51] Department of Commerce, Recommendation as Aids to Navigation, 10 March 1911, RG 26, NA.

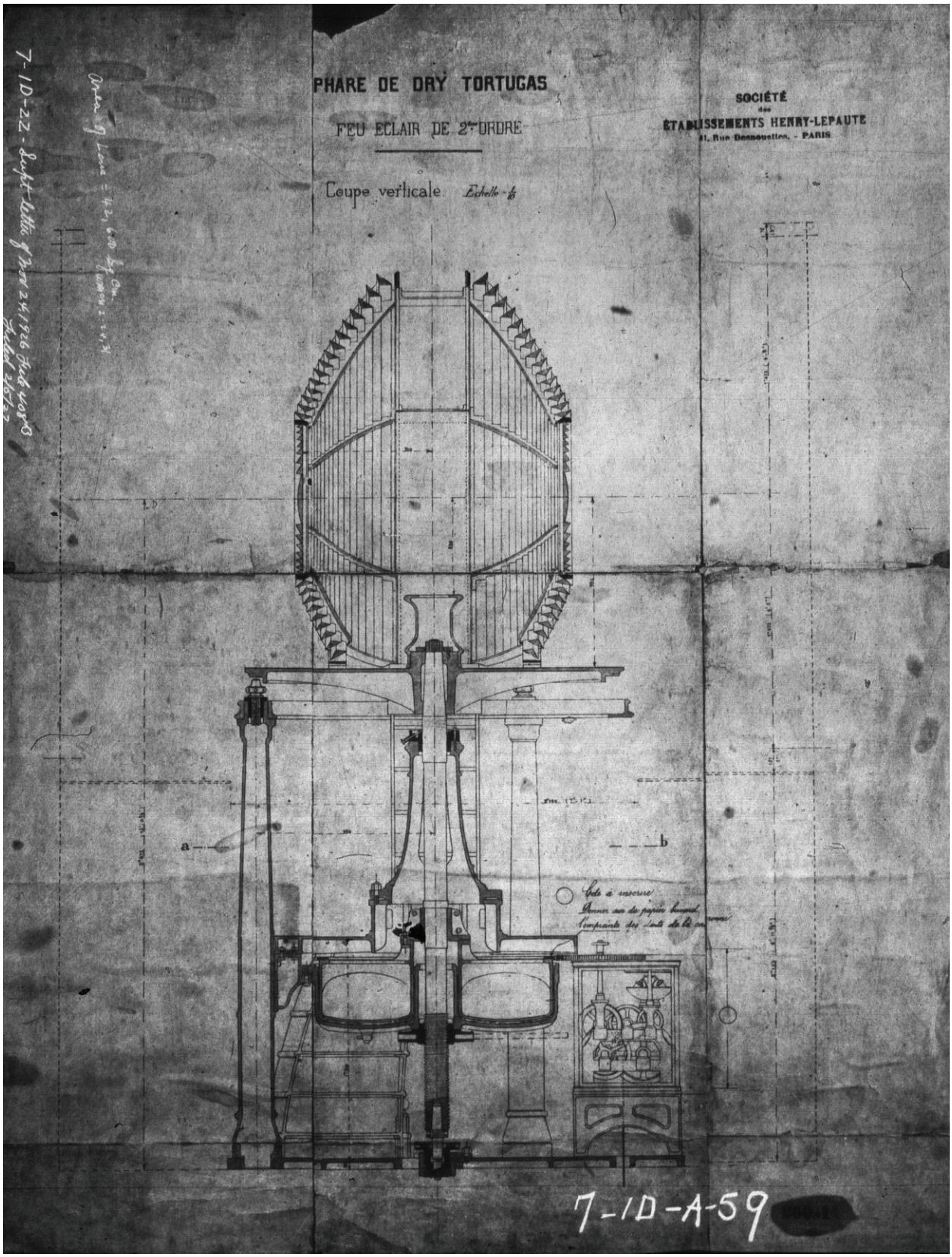


Figure 26. Ca. 1910-1911 drawing of the second-order lens and associated apparatus prepared by the Societe des Etablissements Henry-LePaute of Paris.

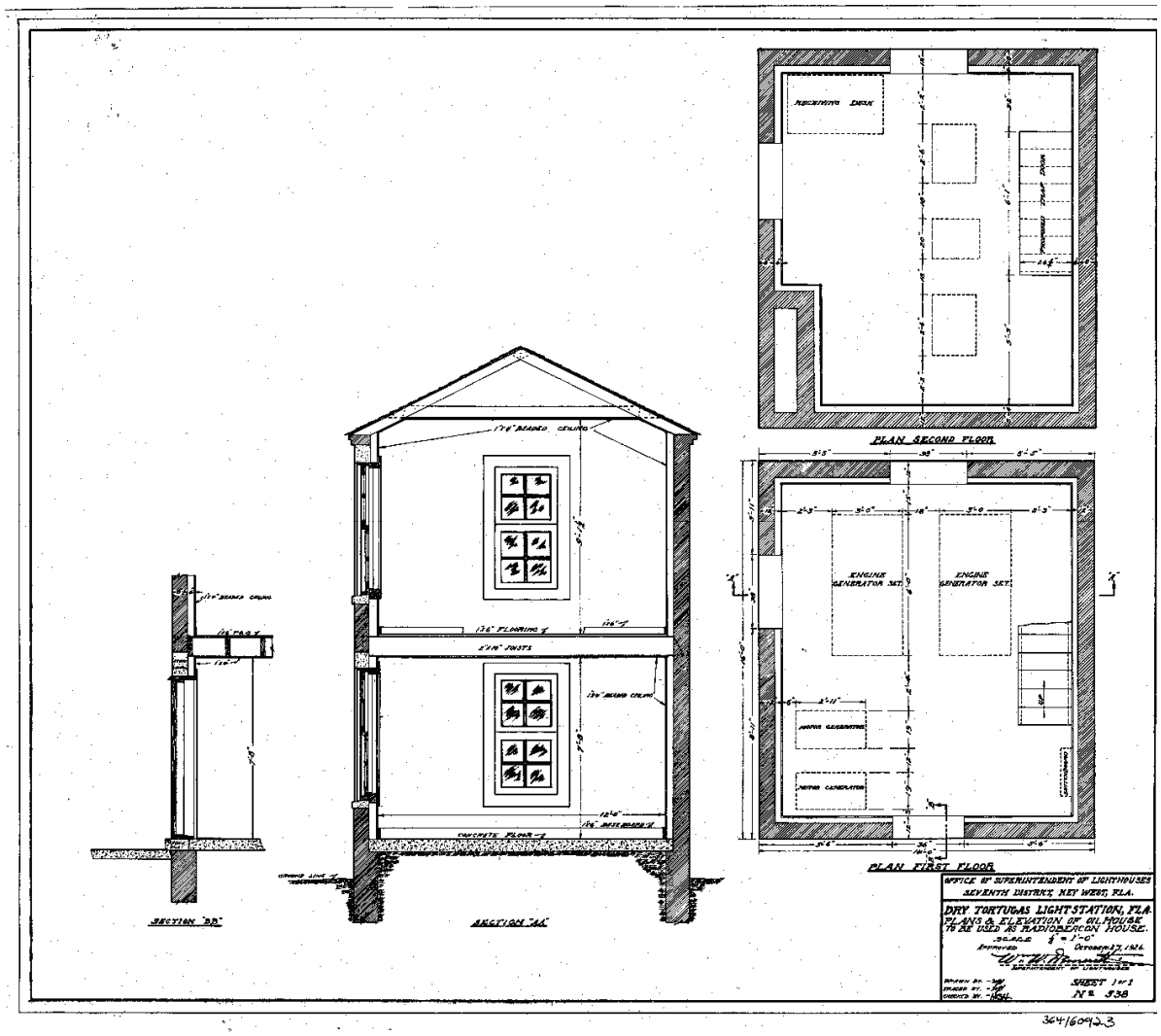


Figure 27. 1926 drawing prepared for the conversion of the Oil House to a Radio Beacon House.

routing of the clockwork cord. Originally fed through the center of the Watch Room floor plate, the cord was re-fed through a slot that had to be made in the side of the newel. The newly installed system required the keeper to wind the mechanism every 16 hours.

Modernization of the 1920s

In July of 1922 the Superintendent of Lighthouses requested that parallel copper screens be installed in the Lantern. These vertical curtains were designed to reduce the intensity of reflected eccentric rays "without diminishing the brilliancy of the primary rays."[52]

A purchase order from the Superintendent of Lighthouses, W.W.Demeritt, describes that the copper screens would be aligned with the center of the bulls eye on each side of the clamshell lens. The project was estimated to cost $170.00. J.S. Conway, the Commissioner of the Lighthouses approved the request with the requirement that a trial run be conducted prior to installation.

Also in 1922, H.B. Haskins, the Assistant Superintendent of Lighthouses made a request to install a four button, five phone interconnecting telephone system at the station. The intent was to provide a means for a keeper located at the top of the tower to communicate with the other keepers in the structures below. This system would be most useful during the

[52] Department of Commerce, Recommendation as Aids to Navigation, 18 July 1922 RG 26, NA.

many "storms which menace the station." Funding for the project was approved by the Commissioner of the Bureau of Lighthouse and the system was installed.

In the mid-1920s plans were made to change the function of the Oil House from storing oil and materials to housing radio beacon equipment. This relatively new technology provided a means for vessels to determine their location during inclement weather when the light was not visible, and to communicate with the light keepers. The radio beacon was to be operated for "30 minutes every 6 hours during ordinary weather and continuously during hurricane weather."[53]

Drawings for the conversion of the Oil House were prepared in October 1926 and show the first floor being used to house generators and the second floor reserved for the radio receiving equipment. Modifications made to the building to accommodate the new function include the installation of bead-board wall and ceiling finishes, and new flooring and base-boards. The windows shown in the 1926 drawing are four-over-four double hung units. The drawings do not state whether these were existing or to be installed as part of the repurposing of the structure. Because the station still required a space to store oil and materials, a new one-story concrete oil house was constructed just to the north of the original structure.

The following year, the new radio beacon house was connected to the tower by a concrete passageway. The passageway was constructed to protect the keeper when passing between the buildings during stormy weather. The passageway was constructed with 8" reinforced concrete walls and a concrete roof slab with flanking parapets. Two aligned doorways adjacent to the tower provide access through the passageway. The passageway was also intended to keep the doors of the tower from blowing open during driving winds. Should the door to the tower be left open or torn off, loss in pressure within the tower could potentially cause a vacuum that would pull the glass in the Lantern Room in and out, subsequently blowing out the light.[54] The passageway was estimated in November of 1926 to cost $315.00 in material and $478.63 in labor.[55]

By the fall of 1929, the Superintendent of Lighthouses requested the repair and refurbishment of the clockworks. A requisition from October 31, 1929 states that the Mallory S.S. Co. would supply the new components.

A year later, a request was made to convert the main lamp of the Lighthouse from incandescent oil vapor to electric lights. After much correspondence between the manufacturers and the Department of Commerce about how to light the tower, a group of inspectors and engineers were assembled on Fort Jefferson on the evening of October 8,1931 to test several bulb configurations. The original 55 mm Type A IOV was tested against 3-250 Watt frosted bulbs placed 1-7/8" apart, 2- 250 Watt frosted bulbs placed in a similar configuration and 1-500 Watt G-40 frosted bulb. The testing team had photometers, timers, and obscuring screens at Fort Jefferson to measure the light levels from across the 2-1/2 mile distance to Loggerhead Key. The 500 Watt bulb was chosen as the best lamp for the tower.[56] According to several accounts, the Dry Tortugas Lighthouse became "the most powerful in the United States in 1931 when a three-million-candlepower electric light was switched on, about 250 times the intensity of the kerosene lamps it replaced."[57]

Requests in 1933 included funding to repair the Lantern gallery and install an electric drive and alarm for the lens. Converting the lens to an electric drive would alleviate the keeper from having to climb the tower twice each evening to wind the clockworks.

Repairs to the iron work of the Lantern Room, including the replacement of 16 gallery plates were also conducted this same year. In order to replace the iron floor plates, several courses of brick at the top of the Watch Room walls had to be removed. As part of the same program of improvements a window was added to the east elevation of the radio beacon house (former Oil House) to provide additional ventilation. Storm shutters for all of the dwellings were also installed. H.D. King, Deputy Commissioner of

[53] Ibid., October 1926.
[54] Ibid., 10 November 1926.
[55] Ibid.
[56] Ibid., October 13, 1931.
[57] Cipra, p.29.

the Bureau of Lighthouses approved $3,000 for the improvements.

This repair package was funded by the National Industrial Recovery Act (NIRA) of June 16, 1933.[58] NIRA was a pivotal act that sought to restructure the industrial economy, promote fair competition, establish boundaries for worker's rights and lay the groundwork for President Franklin D. Roosevelt's New Deal program. The NIRA program was in place for two years until it was deemed unconstitutional and discontinued.

Prior to 1939, a reinforced concrete addition was constructed on the rear elevation of the former Oil House to house batteries. The drawings for the project are undated but show an 11' x 11' one room extension with 8" reinforced concrete walls. The addition has a continuous concrete foundation with a 2'-0" wide footing. The floor is a 5" concrete slab on fill. Two, 2' x 6' windows are located on the north and south elevations. The drawings call for the original window in the west elevation of the radio beacon house to be replaced by a door and the window salvaged and installed in the west elevation of the addition.

Coast Guard Era Modifications

In 1939 the US Coast Guard assumed management of the Light Station from the Lighthouse Board. Construction and maintenance projects were limited during the early 1940s—presumably due to resources being diverted to the war effort.



Figure 28. Image of wood-frame addition to Oil House constructed between 1943 and 1951.

Between 1943 and 1951 a second addition was constructed on the former Oil House. An undated image shows the addition as a wood frame gable roof structure extending perpendicularly from the south wall of the building. The addition contains a central doorway with flanking six-over-six, double-hung wood windows on its east elevation and two similar windows on the south elevation. The building is clad with wide board siding and has a shingle roof. It is likely the building was constructed to house generators as the former Oil House is consistently labeled as "Gen. & R.B. Bldg." on subsequent site plans of the Station. Construction of the addition's gable roof required modification of the original second floor window opening.

The wood frame addition was removed in 1969 when a new much larger generator and radio beacon building was constructed just to the west of the former oil house. This metal building remained in service until the 1980s when it was demolished.

In 1967 the USCG conducted extensive repairs to the Lighthouse. The exterior of the tower was sand-blasted to remove the existing paint, deteriorated mortar joints were repointed and the daymark was reapplied. Repainting included the application of a white prime coat over the entire surface of the tower followed by coats of black and white paint. The painting and masonry repairs were conducted from a bucket suspended from the Lantern level. On the interior, a new handrail was installed in the stair tower.

The exterior of the Watch Room was also extensively repaired. The stucco finish of the interior and exterior Watch Room level walls was removed and a new multi-coat stucco system was applied. The mortar floor surface of the Watch Room gallery was completely removed and replaced and an 8" wide stainless steel tension ring was installed to secure the masonry at this level.

The metal work of the Lantern, including the galleries and copper dome roof, were also sand-blasted and repainted. Other repairs at the Lantern level included the scaling and cleaning of corroded metal and repair of the dome roof soffit and integral gutter.

[58] Ibid., July 31, 1933.



Figure 29. Image taken in 1982 during repairs and improvements to the Oil House conducted by the crew of the CGC *White Sumac*.

The tower windows were also replaced at this time with three-pane, aluminum, awning windows. Because the new windows would not completely fill the original rough opening, a two-inch concrete sill was fashioned to make up the difference.

In 1982 the crew of the CGC *White Sumac* was engaged to construct an addition to the former Oil House and complete various repairs to the Lighthouse and other buildings of the Light Station. As part of this work, the interior of the Lighthouse was "water-blasted" to remove peeling and flaking paint and partially repainted.

New "heavy-duty type windows capable of withstanding high winds and foul weather" were installed in the tower. These are likely the same bronze aluminum units that are present today. The existing windows that were removed at the time were described as "aluminum framed, light weight windows suitable for a house trailer."The former Oil House was re-roofed and a "drop ceiling" and paneling were installed on the second floor. New lights were also installed in the building. The concrete block "generator room" was constructed on the foundation of the previous frame addition.

Three years later in 1985, additional repairs were made to the Lighthouse. Included in the scope of repairs was the re-pointing of the exterior masonry and repair of the Watch Room level stucco walls, replacement of glass panes in the Lantern Room, replacement of the Lantern and Watch Room gallery railings, painting of the copper roof and other minor repairs.

The following year, after an incident that resulted in the mercury spilling from the float drum, a decision was made to decommission the second-order lens and install an automated



Figure 30. Image taken in early 2009 during repair of the Lantern roof.

navigational beacon. The second-order lens was removed from the Lantern and placed on display at the National Aids to Navigation School in Yorktown, Virginia. A new 24" Directional Code Beacon (DCB-24) was installed and powered by solar panels mounted to the wall of the Watch Room gallery. The new lamp created a flashing light every 20 seconds that could be seen up to 24 miles away.[59] The DCB-24 was replaced in 1996 with a new marine rotating beacon (VRB-25).

Recent Alternations by the National Park Service

Given that the Lighthouse has remained an active aid to navigation since the transfer of the light station property, the USCG has continued to conduct routine maintenance and minor repairs to the Lighthouse and Oil House. Through its VIP program the National Park Service has also committed resources to the maintenance of these buildings and have completed at least two significant repair projects.

In 2005, the National Park Service replaced the doors in the concrete passageway as well as the windows in the west addition of the original Oil House. The designers of the project used historic photographs to replicate the detail of the original doors and windows. The door openings in the passageway were widened slightly as part of this improvement project.

During the approximately 25 years between 1985 and 2009 the Lighthouse Lantern structure and roof had deteriorated significantly to the point that the structure was open to the weather for an extended period of time. This prompted a recent emergency stabilization effort by the National Park Service to replace the copper roof and Lantern glazing, and scale and paint the iron elements of the Lantern structure.

The project began with removal of the deteriorated roof panels followed by removal of the vent ball and lightning rod which were placed in storage at the Everglades National Park collections facility. Due to the limited funding available only a partial restoration of the roof could be accomplished. The dome of the roof was replaced, but reconstruction of the integral gutter system and replication of the vent ball and reinstallation of the lighting rod could not be completed. The new copper panels were attached to the existing iron skeleton with stainless steel clips and a roof access hatch was added. The Lantern glass was replaced with 7/16" tempered hurricane glazing and the iron frame was scaled and painted. The project was completed in early 2009.

[59] Dean, p. 99.

Dry Tortugas Light Station Chronology

1825	**Lighthouse constructed on Garden Key, Dry Tortugas**
1837	Recognition that additional aids to navigation are needed in the Dry Tortugas.
1838	Vessel *America* wrecks near Garden Key, Dry Tortugas.
1838	Recommendation to increase height of Garden Key Lighthouse.
1846	Construction of fortification commences on Garden Key.
1849	Collector at Key West, S. R. Mallory makes recommendation for establishment of a light on Loggerhead Key.
1851	Congress directs Treasury to establish a board to investigate the Lighthouse Service.
1852	**Congress establishes the Lighthouse Board. Florida, including the Dry Tortugas is assigned to the 7th District.**
1853	Letter from Lieutenant George G. Meade, Corps of Topographical Engineers to Lighthouse Board October 26, 1853: "A day beacon is wanted on one of the outer shoals of the Tortugas, which is at such a distance from the light on Garden Key, that navigators should have their attention called to it before getting to near."
Sept. 25, 1855	At the request of the Light House Board, Captain Horatio Wright, Captain of Engineers overseeing construction of the fortification on Garden Key, submits a letter of description, estimate and preliminary sketch of a proposed 150' lighthouse for the Dry Tortugas (the letter reveals some confusion between Wright and the Light House Board over the location of the proposed lighthouse).
1856 – August 18tn	**Congress appropriates $35,000 for first order lens and lighthouse at Dry Tortugas (Loggerhead Key). Captain Daniel Woodbury in charge of design and construction.**
1856	Plans being prepared for Dry Tortugas Light Station
1857	Dry Tortugas Light Station under construction
1858	**Dry Tortugas Light Station completed.**
July 1, 1858	Lantern lit at Dry Tortugas Lighthouse.
1858	Light List refers to Dry Tortugas Lighthouse as "brick-color".
1858	Benjamin Kerr appointed lighthouse keeper (transferred from Garden Key).
1860	Domestic disturbance involving Benjamin Kerr and family.
1860	Repairs made to roof of dwelling and new windows installed in tower.
1861	James Lightbourn appointed lighthouse keeper.
1861- 1865	**Civil War**

1862 Robert H. Thompson appointed lighthouse keeper.

1866 Extensive repairs and renovations made to Dry Tortugas.

1867 "New wick rings provided, new supply tubes pan burners, burners packed, curtain hooks put up into lantern."

1867 Yellow fever outbreak on Garden Key. Loggerhead Key used for quarantine

1868 "The old and rusty lightning conductor has been replaced by a new one of copper with horn insulators; supply pipes of burners repaired; eight panes of glass set in the lantern. This tower also shows the effects of the heavy rains in this climate. Much of the mortar on the south and southwest sides is washed out, in some places to the depth of nearly half an inch. These walls should be repointed with cement. The plastering of the oil room and kitchen has fallen down and needs repairs. A suitable enclosure fence is recommended."

1871 Repairs made to Boathouse.

1872 William B. Taylor appointed lighthouse keeper.

1872 Thomas Moore appointed lighthouse keeper.

1873 Yellow fever outbreak on Garden Key. Loggerhead Key used for quarantine.

1873 – October 6th Dry Tortugas Light Station severely damaged by hurricane.

1874 Temporary repairs made to hurricane-damaged tower.

1875 Upper 8'-9' of tower rebuilt. Anchors of lantern (rods) extended downward through structure. Tower received black and white paint scheme (daymark)

1875 Congress appropriates $75,000 for new tower to replaced hurricane-damaged lighthouse.

1878 Station repainted and miscellaneous repairs completed.

1880 "A new boat-house, 16 by 30 feet in plan was built. Twenty pairs of window blinds were hung, and three window frames in the tower were refastened. The station is in good order."

1881 Harry W. Magill appointed lighthouse keeper.

1881 Robert H. Thompson appointed lighthouse keeper.

1884 "New mineral lamps were put in and work well. A few minor repairs were made."

1885 "A new iron cone and damper piper were fitted for the illumination apparatus, and two sheets of plate glass for the lantern were cut and sent to the station."

1887 "A survey of the site was made, also tracings of the reservation and buildings. Three lights of plate-glass for use in the lantern were furnished."

1888 Light List refers to Oil House and Keeper's Dwelling as yellow brick.

1888 Charles A. Roberts appointed lighthouse keeper.

1888 George R. Bilberry appointed lighthouse keeper.

1889 "This station was thoroughly repaired. Two new washhouses were built. All new work was painted or whitewashed. "

	1893	"On April 30, 1893, the characteristic of this light was changed from fixed white to fixed white with a fixed red sector. A few minor repairs were made. This station will require extensive repairs during the ensuing year."
	1896	"Some 728 feet of wire fence were put up and painted. Various minor repairs were made."
1898		**Spanish American War**
	1899	"The iron work of the tower was thoroughly scraped, scaled, and given two coats of paint from the top of the dome to the bottom of the tower. New storm doors were made and put in; five windows were fitted with new frames and storm windows. The watch room [sic.] was ceiled and painted. An addition 10 feet long was made to the boathouse. New floors were laid throughout the house. The roof was thoroughly repaired, one entire side being supplied new. Walks were constructed leading from the kitchen to the washhouse and main building. Various repairs were made."
	1901	November 1, 1902, temporary change in character of light.
1904-1905		**"The Carnegie Biological Laboratory was granted a site for laboratory buildings on the light-house reservation, and the limits of this grant were surveyed and marked."**
	1906	"Two storerooms and new porches were built. About 164 feet of walk, 5 feet wide, was built, as was some 200 feet of picket fence 5 feet high. Various repairs were made."
	1907	Edgar J. Russell appointed lighthouse keeper.
1910		**Light House Board reorganized as the U.S. Bureau of Lighthouses (better known as the Lighthouse Service) under the Department of Commerce.**
	1910	Source of illumination or lamping changed to incandescent oil vapor (I.O.V.).
	1910-1911	Original first-order lens removed and a new second-order bivalve lens (by Henry Lepaute) and lens pedestal installed in Lighthouse. Lens pedestal includes mercury float apparatus to rotate lens.
	1911	Repairs to Lighthouse and roof of Keeper's Dwelling.
1914-1918		**World War I**
	1916	Old wharf destroyed in hurricane of July 5, 1916.[U]
	1917	"The act of September 8, 1916, appropriated $125,000 for repairing and rebuilding aids to navigation. Gulf of Mexico, from which an allotment of $2,800 was made for this station. During the year a wrought-iron pile wharf with cast-iron caps and wooden girders, stringers, and decking was erected in place of the old wharf, which was destroyed. All work was completed in May, 1917. Amount expended to June 30, 1917, $2,631.19."
	1917	Preliminary plans for new Keeper's Dwelling prepared.
	1919	Boathouse destroyed by hurricane.
	1919	Keeper – Charles H. Johnson

1920	$6,500 authorized for a two-family dwelling. Repairs made to roof of Keeper's Dwelling.
1921	Garden Key lighthouse decommissioned Dry Tortugas light becomes primary aid to navigation
1922	June – Materials and construction crew arrive to complete new dwelling.
1922	Request made for telephone system between Watch Room and keeper's residences.
1922	Copper parallel screens installed on lens.
1922	Dr. Alfred G. Mayor, Director of the Carnegie Marine Biology Research Laboratory dies on Loggerhead Key.
1923	New Keeper's Dwelling 90% completed. Interior trim work remains to be completed.
1926-1927	Original Oil House repurposed to house radio beacon equipment including construction of a concrete passageway connecting oil house to lighthouse.
1931	September 1, 1931 Dry Tortugas Lighthouse becomes most powerful light in America with 3,000,000 candlepower from newly installed electric light.
1933	Walls of watch room in poor condition due to corrosion and jacking of Lantern anchor rods embedded in masonry.
1935	Fort Jefferson designated a National Monument.
1939	**U.S. Bureau of Lighthouses is amalgamated into the operations of the U.S. Coast Guard**
1939	**Carnegie Institute ceases operations at Marine Research Laboratory**
1940-1945	**World War II**
1940-1945	Lighthouse used for lookouts during WWII.
1945	Fire destroys original Keeper's Dwelling.
1964	Fire destroys majority of abandoned structures of the Carnegie Institution's former Marine Research Laboratory.
1967	Extensive modifications made to Lighthouse and Oil House by USCG. Work included sandblasting and repainting of the Lighthouse, window replacement in the Lighthouse and Oil House, and extensive work in the Watch Room.
1977	Proposal by National Park Service to install solar power electrical generation system for Fort Jefferson and Dry Tortugas light station operations.
1982	Extensive repairs and improvements made to Lighthouse and Light Station structures by USCG crew of *White Sumac*
1984	Development of draft National Register of Historic Places nomination form for Dry Tortugas Light Station.
1985	Extensive improvements to Light Station's electrical system
1986	Second-order Fresnel lens decommissioned, removed and displayed at National Aids to Navigation School in Yorktown, Virginia
1986	Directional Code Beacon (DCB-24) installed in lighthouse.

1992	Dry Tortugas National Park established and Loggerhead Key and light station property transferred from USCG to the National Park Service
1996	VRB-25 Marine Rotating Beacon installed
1998	Emergency repair of underground fuel lines
2002	Photovoltaic solar array installed for generation of electrical power. Diesel fuel generator system abandoned.
2003	Two 3,000 gal. above-ground diesel fuel storage tanks and associated components removed from site. Diesel fuel system no longer necessary. Electrical power generation provided by photovoltaic array.
2003	Installation of water and wastewater disposal system
2003	Kitchen building septic system replaced.
2008	Testing of lead contaminated soils at base of light tower by USCG
2009	Lantern repair project completed
2009	Development of HSR

Physical Description

Dry Tortugas Lighthouse

Politics, need, cost, location, and geography of the site, as well as technology available at the time of construction influenced lighthouse designs.[60]

The Dry Tortugas Lighthouse is a terrestrial, or on-shore, brick conical tower constructed in 1858 to aid mariners in navigating the hazardous islands and shoals of the Dry Tortugas. The Lighthouse was designed to be the central element of a manned light station that originally consisted of several structures, including the tower, a keeper's dwelling, kitchen building, and brick cisterns for fresh water.

In response to numerous requests by mariners for additional navigational aids in the Dry Tortugas, $35,000 was appropriated by Congress in August 1856 for construction of the light station. The plans for the Lighthouse and Keeper's Dwelling were prepared by the engineers of the Lighthouse Board's 7th District. Captain H.G. Wright who was at the time overseeing construction of Fort Jefferson on nearby Garden Key, was solicited by the Board for design input as early as 1855. Wright prepared preliminary sketches for a lighthouse and developed a cost estimate for a project he assumed at the time would be constructed on Garden Key. Prior to commencing construction of the Lighthouse, Wright was replaced by Captain Daniel Phineas Woodbury of New Hamphire. Woodbury, who was an expert in masonry arch construction made a number of design changes to Wright's initial proposal. Woodbury, along with his master mason, George Phillips, would oversee construction of the fort and the light station during the 1850s.

The proximity of the large scale military construction and engineering project on Garden Key, undoubtedly provided logistical advantages to the Light Station project. Construction of the Lighthouse would not only benefit from the oversight provided by Woodbury and Phillips, but was also able to take advantage of an already assembled labor force. When the lighthouse project was started, the walls of the fort had barely risen above the waterline. It is likely that construction of the Light Station was supplemented with workers from the fort project. The labor force at the fort was made up of skilled workers primarily from the north as well as slaves borrowed or leased from their owners in Key West.

The height of the tower at over 150', its slim form, and lack of "ornamental flourishes," categorize the Dry Tortugas Lighthouse as an "Early Classic" brick tower. A majority of the early classic towers were constructed between



Figure 31. 2008 view of Dry Tortugas Lighthouse upon approach to main dock from the east.

[60] National Park Service, Maritime Heritage Program, Historic Lighthouse Preservation Handbook, 2009 http://www.nps.gov/history/MARITIME/handbook.htm

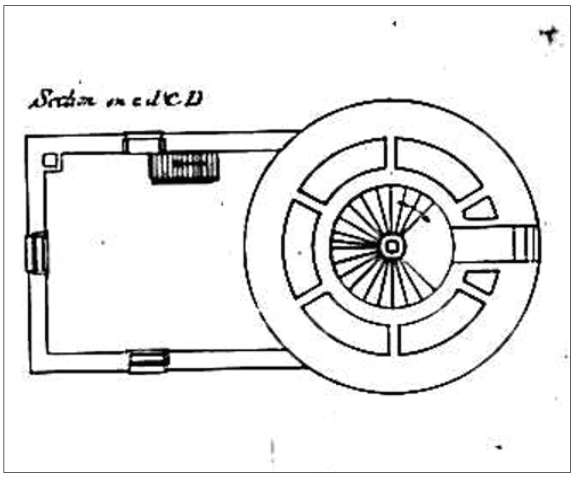


Figure 32. Section through Lighthouse and Oil House from 1857 architectural plans



Figure 33. View of Lighthouse Lantern and corbelled masonry supporting the Watch Room gallery.

1857 and 1860. The designs executed during this period are indicative of a transition that was occurring within the Lighthouse Establishment that saw the civilian leadership replaced with military engineering personnel in the early 1850s.

The Lighthouse is generally constructed according to the standard specifications issued by the Lighthouse Board in 1861 for brick tower lighthouses.[61] Its design is strikingly similar to that of the Pensacola Lighthouse, another early classic tower, built the same year. The primary difference between the towers is that the Pensacola Lighthouse is taller and was built with its oil house attached directly to the base of the tower, where the oil house at Dry Tortugas was built as a separate free-standing structure. A reinforced concrete passageway connecting the Oil House to the tower was constructed in 1927.

The diameter of the tower is approximately 28' at its base tapering to approximately 15' at the belt course below the watch room gallery. Although the actual material, depth and configuration of the foundation could not be confirmed the architectural plans show a battered "cement" foundation.

In his 1855 correspondence, Wright proposed the walls of the tower to be constructed of solid concrete with a brick veneer. The original architectural plans from 1857 and standard specifications issued a few years later, call for the exterior walls to consist of two "shells" of brickwork with an interior air-space or void. The plans show the outer shell at approximately 3'-9" thick at the base of the tower reducing to 1'-10 ½" in thickness at the top. Radiating brick walls divide the interior void into six equal segments. The void becomes thinner as the exterior walls taper.

The bricks used in the construction of the Lighthouse have similar characteristics to those used in the construction of Fort Jefferson's scarp wall and were likely obtained from the same brick yards in Pensacola or Mobile. The bricks range in color from light orange to salmon and brown and contain dark inclusions. The bricks measure approximately 8 ½" x 2 ¼" x 4" and are laid in a Flemish bond, the same coursing used at the fort. Originally unpainted, the tower's daymark or paint scheme (lower half painted white and the upper half painted black) was first applied ca. 1870.

The Lighthouse contains an entrance at grade. There are five windows in the brick portion of the tower corresponding to each of the interior landings. Two windows, vertically aligned over the tower entrance are oriented to the west. The remaining three windows are vertically aligned on the east elevation facing Fort Jefferson. The interior stair tower has a diameter of 10'-6" and a hollow central brick newel or column at its center. The blue slate stair slabs are set into the interior wall and central column. There are 30

[61] *Specifications for a First Order Light-House, (Brick Tower,)* , Washington: Government Printing Office, 1861.

treads between each of the five intermediate landings.

Above the belt course, the exterior wall of the tower corbels out for sixteen courses to support and form the floor of the Watch Room gallery. One of the signatures of the Early Classic Style, particularly in the south, is the use of corbelled masonry to support the gallery in favor of iron brackets. Cape Lookout Lighthouse in North Carolina, and the Pensacola Lighthouse share this construction characteristic. Among these, the Dry Tortugas Lighthouse was completed first, suggesting it may have served as the prototype for this design innovation.

The Watch Room level of the tower contains the lens pedestal and the mercury float apparatus associated with the second-order bivalve lens installed in 1910-1911. The interior and exterior walls of the watch room are stucco-covered masonry. The Watch Room elevations contain a window oriented to the east and an arched doorway oriented to the west. The doorway provides access to the gallery.

The Lantern is generally constructed according to the standard specifications for first order lanterns issued by the Office of the Lighthouse Board in 1862. The Lantern is a sixteen-segment structure with a skeleton of iron posts and ribs with bronze mullions and astragals. The exterior walls are entirely glazed with each bay containing three rectangular glass panels. Originally outfitted with a first-order Fresnel lens purchased from Sautter & Company of Paris, the existing light is a VRB-25 rotating marine beacon installed in 1996. The roof of the Lantern is copper and its form is referred to as a "French dome with ventilation ball." The vent ball and lightning rod, along with the Watch Room-level door were removed during a recent program of repairs conducted in early 2009. The removed ventilation ball, lightning rod and door are currently being stored at Everglades National Park' collection facility.

Character-Defining Features

Character-defining features of the Lighthouse are those visual and tangible elements of the structure that are significant and give the resource its distinct character. These features include elements of its original design and construction as well as modifications made during the historic period. The character-defining features of the Lighthouse should be retained and preserved as part of ongoing maintenance and repair activities. The identified character-defining features of the Lighthouse include:

- Isolated and sparsely vegetated subtropical setting – The character of the surrounding landscape is one of Light Station's most unique and important features contributing greatly to the resources sense of place. The relatively recent program to remove invasive species introduced by the Carnegie Institute in the early twentieth century has returned the landscape to a condition that is generally consistent with its nineteenth century appearance.
- 360 degree view shed of the surrounding gulf waters, shoals and keys including Garden Key and Fort Jefferson.
- "Early Classic" brick tower form with corbelled masonry support for Watch Room gallery.
- Flemish bond brick exterior walls.
- 1870s applied daymark – Lower portion of tower painted white and upper portion painted black.
- Windows are considered character-defining features of the Lighthouse. However, the existing modern units installed in the 1980s diminish rather than enhance the historic character of the structure.
- Painted brick stair tower with hollow brick newel, blue slate slab stair treads and granite landings.
- Carved initials (J.N. 58) in niche wall at third level
- Watch Room with stuccoed walls, diamond-pattern iron floor plate, bronze ventilation dampers, and arched iron door to gallery.
- Typical first-order Lantern with rectangular glazed panels and French dome copper roof with ventilation ball (now removed)
- Five-panel wood door and door frame at tower entrance.

- Lens pedestal with mercury float assembly associated with installation of the second-order bivalve lens in 1910-1911.
- Second-order bivalve lens removed from the Lighthouse in 1986 and placed on display at the National Aids to Navigation School in Yorktown, Virginia.

Structural Systems

Foundation: There are several references to proposed designs for the Lighthouse foundation in the historic documentation, but its actual material, depth, and configuration could not be confirmed.

Captain H. G. Wright's 1855 correspondence proposes a battered concrete foundation set upon a grillage of 8" x 6" yellow pine timbers. As mentioned previously, the correspondence and accompanying sketch refer to a project Wright assumed at the time was going to be constructed on Garden Key. It is unclear whether the system described by Wright was ultimately constructed at the Loggerhead Key site.

The architectural plans for the Lighthouse prepared by the 7th District engineers dated April 1st, 1857 show the outline of a battered foundation below the tower. The shape appears to be labeled "cement foundations." Although no detail is given, what is shown on the drawings appears generally consistent with both Wright's proposed system as well as the foundation description provided in the 1861 standard specifications for first-order brick towers:

> If the ground on which the tower is to be built is good and solid, the foundation pit must be excavated to the depth of ten (10) feet and suitably leveled for the bed of concrete which must be from two to three feet in thickness. But if in the judgment of the Superintendent, the ground be not sufficiently firm to build directly upon, then it must be closely piled, and covered with a



Figure 34. Undated aerial image of Loggerhead Key and the Dry Tortugas Lighthouse.

> grillage of heavy timbers, say 12" x 12". The upper side of the grillage to come within eight feet of the surface of the ground. All excavated material to be graded around the premises as may be directed. The foundation to be of good rubble masonry in random courses with level beds. The extreme diameter of the lowest course to be forty (40) feet. The largest stones obtainable must be used for this course.

In 1900 Keeper George Bilberry prepared a sketch of the base of the tower as part of an exercise in establishing the height of the focal plane. The sketch shows the base of the tower stepping out for four courses above grade. Once again, no information is provided about the below-grade construction of the foundation. The stepping out of the base of the tower as shown in the sketch is no longer visible having been modified or obscured by construction of a concrete walkway around the base of the tower.

Finally, construction data provided by the Coast Guard on their Web site lists "stone" as the foundation material for the Dry Tortugas Lighthouse. The source of this information is not provided.

Existing Condition: No evidence of foundation settlement or other foundation-related problems were noted during inspection of the tower. The build-up of paint on the brick exterior makes it difficult to detect the presence of repaired cracks that may have occurred as a result of previous settlement.

Floor: The floor at the base of the Lighthouse appears to be a granite slab divided into several segments.

Existing Condition: No signs of settlement cracking or deterioration of the granite slab were noted.

Exterior Walls: The exterior walls of the Lighthouse form the masonry structure of the tapered cylindrical tower. Constructed of bricks laid in a Flemish bond, the masonry portion of the Lighthouse, from the tower base to the Watch Room gallery floor is approximately 135' in height.

The use of Flemish bond for the Lighthouse walls is first proposed by Captain Wright in his 1855 sketch of the Lighthouse planned for Garden Key. This bonding pattern is consistent with that used in the construction of Fort Jefferson's scarp wall.

Wright's correspondence also proposes the mortar mix to be used in the walls should be one part powdered cement to two parts sand. Wright further suggests that lime be omitted from the mortar as it was found not to "fully resist" the extreme conditions of the area. Analysis of mortar samples extracted from the exterior wall of the Lighthouse revealed the composition of the mortar to be one parts natural cement to one-and-one-half parts local carbonate sand, not a precise match, but consistent with Wright's proposal (See Appendix B).



Figure 35. Dorothy Krotzer of Building Conservation Associates Inc. (BCA) works to remove a sample of the original mortar from the base of the Lighthouse.

At its base, the Lighthouse is approximately 28' in diameter tapering to approximately 15' in diameter at the belt-course below the Watch Room. The architectural plans show voids in the exterior walls that get smaller as the walls taper towards the top of the tower. The 1861 standard specifications for brick towers call for these internal voids to be ventilated by the addition of 4" x 4" weep holes at the base of the tower and five inch diameter copper ventilators installed below the Watch Room gallery. No evidence of this ventilation system was observed.

Below the Watch Room, the masonry wall corbels out for 16 courses, the extension of each corbel increases from bottom to top. The corbelled masonry supports the Watch Room gallery. The interior stair tower maintains a diameter of approximately 10'-6" throughout the height of the tower. A 2'-2"diameter hollow brick column is at the center of the stair shaft.

Originally, the mechanism to deliver oil to the lamps was driven by weights which would rise and fall within the column. The interior ends of the stair slabs are set into the column.



Figure 36. 2008 view of Lighthouse looking north. The painted finish of the tower is showing signs of weathering and deterioration. There is no discernable pattern to the paint loss.

Window openings are present at each of the intermediate landings. The windows are stacked vertically within the exterior wall. The windows on the first, third and fifth levels face east, towards Fort Jefferson and the entry door at the base of the tower and windows on the second and fourth levels face west.

Existing Condition: With the exception of window placement, the characteristics of the tower are similar on each elevation. The observed conditions will be discussed according to the zones of the daymark, first the lower half of the tower or white zone followed by the upper half or black zone. Inspection of the conditions was made from grade using 10x25 binoculars.

There is universal deterioration and weathering of the painted finish of the tower. In general the paint continues to adhere well to the brick surface. However, it has deteriorated more rapidly from the mortar joints. There are broad areas where this condition is more severe. In general terms, the white paint of the lower half of the tower appears to be adhering to the brick better than the black paint of the upper zone.

East Elevation: The lower half of the east elevation is in generally good condition. The brick, mortar and painted finish show only limited deterioration and weathering. A localized area of deteriorated mortar was noted around the lintel and above the first level window.

The upper half of the east elevation is showing signs of moderate mortar deterioration as well as an area of significant spalling just below the belt course. Two significant vertical cracks and several other small areas of mortar deterioration were noted as having been repaired. The first crack extends vertically from the top of the fifth-level window for approximately 10'. The second crack is located toward the bottom of the upper zone and extends into the lower zone. These cracks as well as several spot repairs were easily identifiable due to the liberal application of a relatively light-colored mortar.

West Elevation: The lower half of the west elevation is in generally good

condition. An area of minor deterioration, requiring repointing was observed near the transition to the black zone.

The upper half of the west elevation has experienced more severe mortar degradation. A large percentage of this elevation is in need of repointing. Mortar joints appear weathered and recessed throughout much of the elevation. Joints that remain intact appear to have been repaired as part of several previous repointing campaigns. The belt course below the corbelling at the top of the zone is severely deteriorated. A small plate with a bolt and threaded rod is located below the fourth-level window. The threaded rod extends to the interior where it is bolted to a much larger iron plate. Its function is unknown

North Elevation: The lower half of the north elevation is in generally good condition. In addition to the areas of paint loss there appears to be a perceptible strip extending from the upper zone to the lower zone. This may be attributed to the sand blasting that was completed in 1967 by the USCG. During this project an adjustment had to be made to the aggregate from silica sand to beach sand when it was discovered after the first pass that the cleaning process was damaging the host masonry. There are no windows in this elevation.

The upper zone is experiencing significant deterioration of the mortar joints. The most severe weathering appears to be concentrated at the head joints. Near the top of the zone, just below the corbelling, spalling of the host masonry was noted. Also in this area there appears to be a subtle bulge in the masonry extending downward from the belt course. Portions of the belt course are severely deteriorated.

South Elevation: The lower zone of this elevation is typical of the others in that it is in generally good condition but there are areas of minor mortar deterioration. There are no windows in this elevation.

The central portion of the upper zone is experiencing moderate to severe mortar deterioration requiring repointing. There is evidence of a vertical crack in the lower half of the zone. The crack appears to have been



Figure 37. Vertical crack extending from head of fifth-level window.



Figure 38. Close-up view of paint deterioration on exterior wall.



Figure 39. Middle zone of north elevation. There is a perceptible seam or strip on this elevation that may be the attributed to the 1967 sand blasting project.

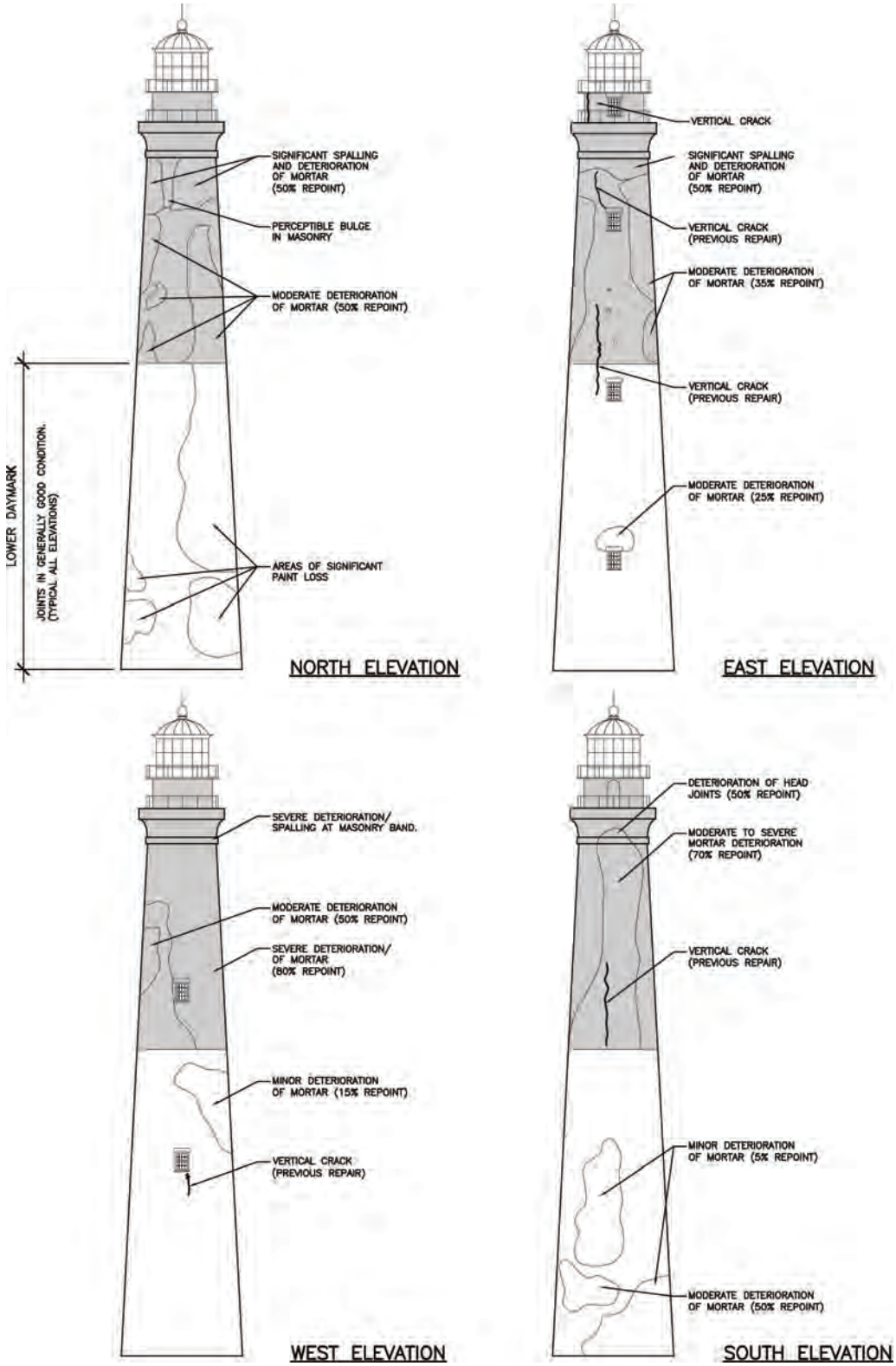


Figure 40. Exterior masonry conditions observed during site inspection conducted in 2009.



Figure 41. Typical aluminum double-hung window unit.



Figure 42. A concrete sill has been formed on top of the original granite sill at each window location to accommodate the installation of the modern aluminum sash.

repointed in the past with non-matching mortar. The area of mortar deterioration extends into the corbelling at the top of the zone. Degradation of the head joints is most prevalent in this area.

Analysis of the paint finish at the base of the tower revealed multiple layers of white or cream-colored paint. Observed under a microscope, the surface of the masonry, below the painted finish, appears weathered. This weathering would have occurred between 1858 and the 1870s when the Lighthouse was unpainted. The earliest layers of finish appear to be a white lime wash followed by subsequent layers of paint. The Lighthouse, Kitchen and cisterns share a similar finish history (See Appendix B).

Exterior Features

Windows: There are five windows in the brick masonry portion of the tower and one window at the Watch Room level. The first, second, and third-level windows are in the lower or white zone of the daymark and the fourth and fifth-level windows are in the upper or black zone. Each of the windows is recessed within the masonry wall of the tower approximately 6" from its face. No elements of the original windows survive. With one exception, the existing windows are modern bronze aluminum double-hung units installed in 1982. The window at the fifth level has been infilled with a simple plexi-glass panel set in a rough wood frame.

The window rough openings are defined by an approximately 10" granite lintel and 4" granite sill with side walls of masonry. There is a row of brick headers above each lintel. The masonry of the rough opening steps in approximately 1 ½" at the plane of the window providing a lip against which the unit is set. Clips have been installed on the window rails rendering them inoperable. A 2" high concrete sill reduces the height of the historic window opening. The sill was installed in 1967 to accommodate an earlier set of replacement windows.

There have been several generations of windows installed in the Lighthouse. The historic documentation reveals that the original windows required replacement as early as 1860, two years after completion of the Lighthouse. Undated drawings of the tower show eight-over-eight, double hung windows in each opening. This was the predominant window type used in nineteenth century lighthouse construction. The 1861 standard specifications describe the windows as being constructed of iron and gun metal with inner and outer sashes.

Images of the Lighthouse show both four-over-four double-hung windows and awning windows installed in the tower. The awning windows were installed in 1967. Exterior wood shutters were present on the windows up until the 1967 window replacement. Each of the tower windows had a pair of paneled shutters set within the rough opening that were held open with a member that spanned between the shutters (See images on p. 107). No evidence of the shutters remains.



Figure 43. Five-panel wood entry door to tower.



Figure 44. This escutcheon plate and the mortise lockset are the only remaining hardware components.

Tower Door: Originally exposed to the exterior, today the entry door to the tower is located within the 1927 concrete passageway. The door is set in a niche recessed approximately 3' within the exterior wall of the tower. The entry sequence is rather plain when compared with

Existing Condition: The existing aluminum window units are not in keeping with the historic character of the Lighthouse. In several locations, the existing windows have become loose in their rough openings, and at the second level, the window and frame have become completely unseated and the window is missing the upper glazed pane. Caulks or sealants have been applied to the interior perimeter of the windows. In some locations excessive amounts of the sealant have been applied in a haphazard manner. The caulks and sealants have become brittle and deteriorated and are not adhering to the material on which they have been applied and are no longer effective. other lighthouses constructed during the second half of the nineteenth century that have much more embellished entry ways including elaborate pedimented stone surrounds that are often adorned with a plaque commemorating the date the lighthouse was constructed.

The date of installation of the existing door is not known and it is possible that it was relocated from another structure. It is a large, single-leaf wood unit with five horizontal molded panels. The door measures 3'-9 ½" x 7'-8" x 2" and is hung with two large strap hinges. The strap hinges fasten to the door in an illogical manner (not centered on horizontal rails) and the proportions of the stiles and rails suggest the hinges do not relate to the existing door. A flat wood panel insert has been installed in the top and bottom panels to accommodate fastening of the hinges. The ghosting of four smaller hinges on the frame suggests that at least one other door was hung in the existing frame. A catch on the interior of the frame also does not relate to the existing door (See drawings on p. 72).

The knobs and exterior key escutcheon have been removed. A mortise lockset is set within the door. The lockset was not removed to try and determine a date of manufacture. A rope threaded through the door provides a pull and the unit is secured by a modern hasp and padlock.

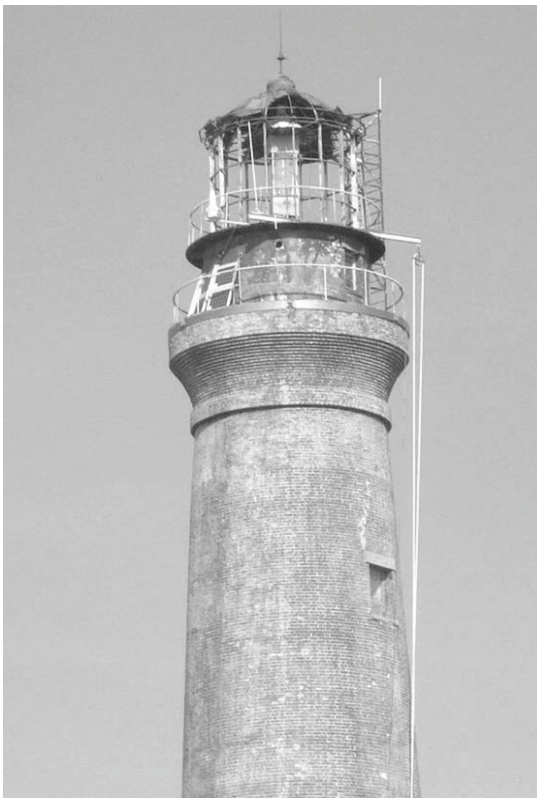


Figure 45. 2008 image showing condition of Lantern prior to recent repairs.



Figure 46. 2009 image of Lantern following repairs (Photo Courtesy of Enola Contracting Services Inc.).

An analysis of the paint layers on the door and frame revealed that the frame contained more layers of paint when compared with the door. This suggests the frame predates the door (See Appendix B).

Existing Condition: The existing tower door is in fair to poor condition. The door appears to be structurally intact, but many of its original hardware components are missing or have been modified.

Watch Room: The exterior brick masonry walls of the tower terminate at the floor of the Watch Room gallery. The Watch Room walls are formed by the continuation of the walls of interior stair tower. The walls of the Watch Room are stuccoed on the interior and exterior. According to the historic documentation, the existing stucco was applied during a project completed in 1983. The floor of the Watch Room gallery was also repaired at this time. There is a window on the east elevation with a granite lintel and sill. The window frame and sash have been removed and a plywood panel has been installed in the opening. Opposite the window on the west elevation is an arched doorway that provides access to the Watch Room gallery. The iron door was recently removed during the Lantern repair project and is being stored at the Everglades National Park collection facility. A storm-proof plywood insert has been installed in the door opening.

There are four solar panels mounted to the exterior wall of the Watch Room along the south elevation. The solar panels provide electrical power to the VRB-25 beacon. In addition to these, there are a number of other pieces of equipment along with their support members fastened to the Watch Room and Lantern galleries.

There is a steel access ladder extending from the Watch Room gallery to the Lantern roof. The ladder was installed in 1978. Originally fastened to the Lantern with cables, the cables were replaced by steel straps after 1983.

The existing Watch Room and Lantern gallery railings were installed in 1985. An 8” stainless steel tension ring located just below the floor of the Watch Room gallery was installed in 1967 by

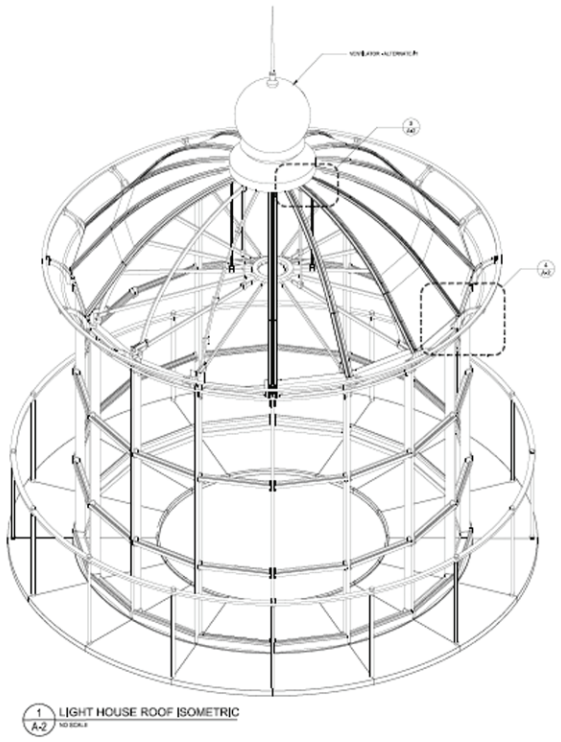


Figure 47. Isometric of lantern structure developed by Mesick, Cohen, Wilson, Baker Architects as part of the construction document package for the 2009 Lantern repair project.



Figure 48. A member of the construction crew works on the Lantern structure in 2009.

the USCG. This feature was installed to secure the masonry of the Watch Room gallery floor which was extensively repaired at the time.

Existing Condition: Access to the Watch Room gallery could not be gained at the time of inspection therefore exterior conditions were reviewed from grade using binoculars. The black painted finish of the Watch Room exterior has deteriorated exposing the light-colored stucco beneath. The stucco finish is in deteriorated condition with moderate to severe cracking on all elevations. There is a significant vertical crack on the east elevation that extends through the brick masonry wall to the interior. There is evidence that some attempt has been made in the past to patch the cracked stucco.

The existing modern access ladder is severely corroded.

Lantern: The Lantern is a round, 16-segment structure with a skeleton of bronze and steel components and glazed walls. Until recently the Lantern was in an extremely deteriorated condition. A comprehensive repair project occurred in early 2009 and included the scaling and painting of corroded iron elements, new lantern glazing, fabrication and installation of a new copper roof and a new lightning protection system.

Each bay of the exterior wall consists of three rectangular glazed panels separated by horizontal bronze mullions and vertical iron ribs. Each of the newly installed panels differ in height, the bottom panels measure 2'-6 $^{13}/_{16}$" X 2' 4 ½", the middle panels measure 3'-3 $^{1}/_{8}$" X 2'-4 ½" and the top panel measures 3'-2 ¾" X 2'-4 ½". The panels are $^{7}/_{16}$" thick tempered hurricane glass. Two bronze hand holds are present on the vertical astragals between each of the glazed panels. The new Lantern roof is composed of copper panels fastened with stainless steel clips to iron bar rafters.

When the recent Lantern repair project was first envisioned, temporary means were going to be used to protect the deteriorated Lantern elements from further damage or loss. A review of the project budget revealed that a limited or partial restoration of the copper roof was possible with the available funds. It is for this reason that the newly installed roof does not fully replicate the historic condition. The agreed upon scope of work did not include restoration

of the roof gutter system or repair or replication of the historic vent ball and lightning rod. As an interim design solution the copper roof panels have been extended behind the gutter support rail allowing rainwater to be shed from the structure and the vent ball was removed for reinstallation at a later date.

The floor of the gallery is made up of flat plate iron segments that extend into the interior of the Lantern. The existing galvanized steel bar railing was installed in 1985 and generally matches the original in design with widely spaced support stanchions. The original rail appears from historic photographs to have been a tube railing that was threaded through eyelets on the support stanchions. The existing railing does not meet current safety codes. Undated twentieth-century historic images of the Lighthouse show a ladder present at the Lantern and Watch Room gallery levels. A ladder on the galleries was a standard piece of equipment necessary for the keeper to clean the lantern glass and maintain the lantern roof. The ladder hooked over the rail that formed the edge of the integral gutter system. Below this another rail was provided for the Keeper to tie-off to as a means of fall protection. There is no ladder present on the Lantern or Watch Room galleries today.



Figure 49. Image showing pitting corrosion on Lantern gallery floor plates.



Figure 50. Undated image of the Lantern showing the second order bivalve lens in place. Note also the original ladder and pipe railings on the Lantern and Watch Room-level galleries.

Existing Condition: The recently completed Lantern repair project has corrected a number of deficiencies and provided a secure and weather-tight enclosure to protect the lens and Lantern interior from the elements. Generally, the bronze components of the Lantern are in good condition and show few signs of deterioration or corrosion. Some of the iron head and rib components have experienced deep corrosion and have become deformed. During the recent repair project these elements were preserved in place, scaled and painted to slow the corrosive process and increase longevity. All of the newly installed glazing and the copper roof are in good condition.

The iron floor plates of the gallery are showing signs of pitting corrosion. Pitting corrosion is a localized break down of metal that is common in marine environments where waterborne salts attack the metal surface. This type of corrosion can be problematic in that it can form deep holes and ultimately undermine the integrity of the material.

The Lantern gallery railing is also showing signs of corrosion, specifically at its connection points.

Interior Features

Stairs: A spiral stair of approximately 4” thick solid blue slate treads ascends the tower from grade to the Watch Room level. There are 30 individual treads between each of the five intermediate landings. The wedge-shaped treads are identical in dimension measuring approximately 6 ½” where they meet the central brick column and 17” at the exterior wall. The treads are approximately 49 ½” in width and have an 8” open riser. A row of headers is set above and below each tread where they are



Figure 51. 2009 view of Lighthouse upon completion of Lantern repair project (Photo courtesy of Enola Contracting Services Inc.).

embedded within the tower wall. The surface of each tread has been textured with delicate striations made with a chisel in order to improve slip resistance. The textured surface is only visible in limited areas as the surface of the treads has been painted with a black slip-resistant coating.

The original architectural drawings for the Lighthouse show the central stair constructed of thick slabs set into the interior wall and central column. Constructing the stair of masonry deviated from the 1861 standard specifications which called for cast iron stairs for first-order towers. The similar Pensacola Lighthouse built the same year has an iron stair. The use of stone slabs at Dry Tortugas was likely influenced by the availability of the blue slate, as this is the same material used for flooring in casemates at Fort Jefferson, and was therefore readily available.

It is much less likely that the deteriorative effects of the environment on iron was a consideration given that 20 years later the Lighthouse Board proposed a new structure entirely made of iron to replace the tower after it was damaged in the hurricane of 1873.

The existing 1¼" diameter, schedule 40, aluminum hand rail was installed in 1967 by the U.S. Coast Guard. The aluminum hand rail brackets are fastened with $^{3}/_{8}$" lag bolts embedded 2" into the brick masonry wall. At the time of installation, existing original eye-bolts were removed and the anchor holes drilled out to accommodate the new anchors. The original railing was likely tubular steel threaded through the removed eye-bolt anchors, similar to the Watch Room and Lantern gallery railings visible in early photographs. What appears to be an eye-bolt from the earlier railing system remains present between the fifth and sixth level.

Existing Condition: The stone stair slabs appear to be in good condition. No signs of cracking of the slabs or failure at the connection to the masonry walls were noted. The underside of some of the slabs appears eroded or pitted, but it was unclear if this was the original condition of the slabs or the result of some kind of deteriorative process. Two treads, the fifteenth tread of the fourth flight and second tread of the fifth flight, have experienced cracking and therefore have been stabilized by sandwiching the slab between plywood boards.



Figure 52. View of first four treads at base of tower.

The existing hand rail is broken and loose in several areas.

Interior Walls: The interior walls of the tower are identical from the ground level to the Watch Room. They are constructed of brick masonry laid in a Flemish bond. The walls have been painted white throughout the tower. At each landing there is a niche within the exterior wall that leads to a window. The brick walls of the niches are laid in a Common bond. The niches get smaller as the thickness of the exterior walls taper towards the top of the tower. Granite lintels form the ceiling of each niche.

At the center of the tower is a hollow masonry column sometimes referred to as the "newel." The column is made up of header courses and has an approximately 8" void in the middle. The inner ends of the stair treads are set into the masonry column. The column is painted white like the walls. The interior of the column has a smooth finish. There are two openings in the column, one at the base of the tower and one just below the Watch Room floor. The opening below the Watch Room floor was made to accommodate the lead weight for the clock works apparatus as shown in drawings from 1911. Drawings from a year earlier show the ropes holding the weights descending through a hole in the center of the floor plate. This change was made in an effort to increase the rotation speed of the lens and thus achieve more flashes per time interval.

The painted finish of the area above the fifth level appears much thicker than that on the



Figure 53. Hollow masonry "newel" at center of stair tower.



Figure 54. Close-up view of deteriorated mortar joints of stair tower walls. Almost universally the surface of the mortar has become friable, falling from the wall as powder.

lower levels. The finish applied to the central brick column is so thick it obscures the bonding pattern. The heavy application of paint in this area may be the result of attempts to repair and seal these upper level walls as they became saturated and then deteriorated from moisture entering the wall system from above.



Figure 55. Typical view of interior wall surface showing deterioration of mortar. Note the paint is adhering well to the brick but has failed at the mortar joints.

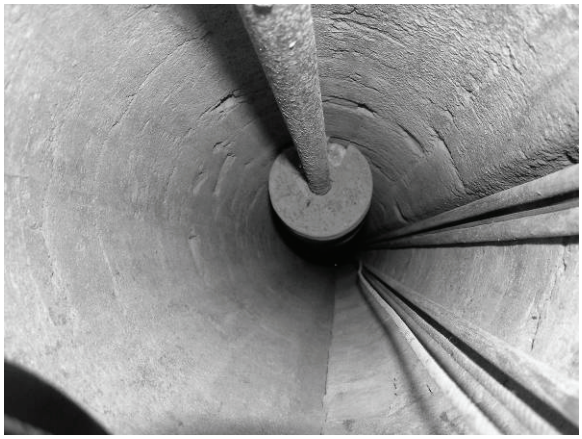


Figure 56. The hollow shaft within the central masonry newel accommodated weights that drove various components of the lamp and lens apparatus.

Existing Condition: The primary condition problem noted on the interior walls of the tower is the deterioration of the cement mortar and the associated painted finish. These condition problems were observed universally at all levels



Figure 57. Vertical crack extending down from Watch Room level floor plate.

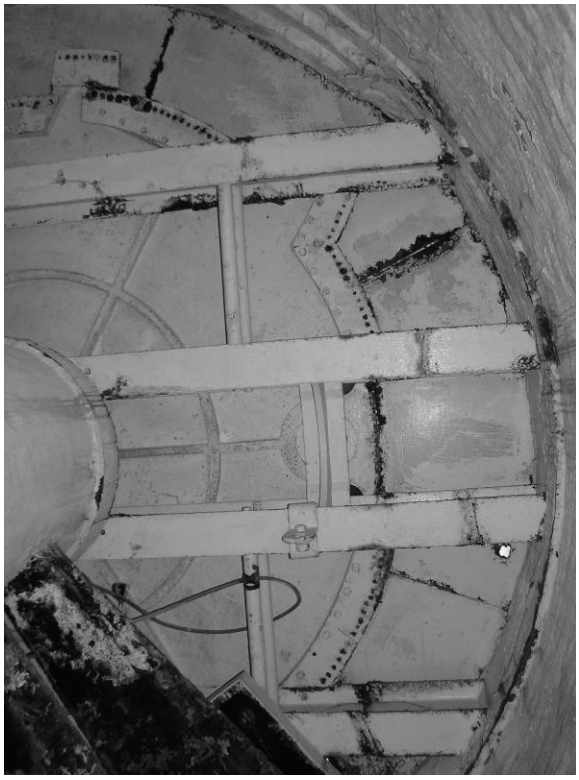


Figure 58. View looking up at the I-beams supporting the Watch Room level floor plate.

of the tower, but the severity of the condition varied significantly from location to location. No discernable patterns of deterioration could be identified that would lead one to a specific cause for this condition. In general, the outer $^{1}/_{8}$" to in some cases 1" of the mortar has become friable. In some areas, the friable mortar remains

trapped behind the painted finish. However in most cases the painted finish has also failed and the deteriorated mortar has fallen from the wall as fine sand. The head joints of the wall seem to be affected more severely than the bed joints. This condition was observed on the walls and the central column. The processes that are causing this condition are not entirely clear, but the migration of moisture through the wall assembly is thought to be at the root of the problem.

The mortar joints and painted finish of the window niche walls were found to be more severely eroded than the tower walls. This was especially true at the lower level window niches. This condition has been most likely caused by the effects of wind and rain on these walls due to the windows being left open for prolonged periods of time.

Several vertical cracks were noted above the fifth level landing. The cracks extend down from the iron ring embedded in the masonry wall as part of the structure of the Watch Room level floor plate. These cracks may be associated with corrosion and expansion of anchor rods placed within the walls to secure the Watch Room floor plate to the masonry tower.

Watch Room: Today, the Watch Room contains the lens pedestal installed in 1910-1911. The center portion of the Watch Room floor is a cast iron plate supported by four I-beams set upon an iron shelf embedded in the exterior masonry walls. Two of the I-beams span over the central brick column. The flooring around the perimeter of the room is diamond-plate panels hung by brackets from the exterior masonry wall and then secured to th e central plate Architectural drawings from the 1911 modifications of the lens show the floor was designed to be 2 ½" x4" tongue-and-groove wood flooring. It is unknown if the wood flooring was installed and then later removed.

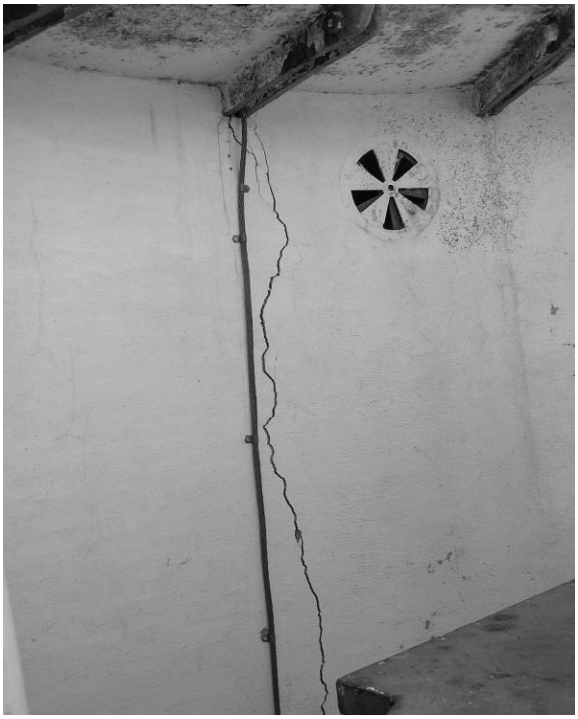


Figure 59. Vertical crack in watch room wall extending down from Lantern level floor plate.



Figure 60. The original arched iron door has been recently removed and replaced with a plywood insert.

The walls of the Watch Room are painted stucco over brick masonry. Beneath the painted finish, the stucco is grey in color and very hard suggesting it is a Portland cement based mixture. There are three bronze vent holes that penetrate the walls of the Watch Room. Air flow through the vents is controlled by a rotating damper. The vents were necessary in order to maintain air flow through the lantern so that fumes and smoke created by the oil-fired illuminant would be expressed through the ventilation ball in the roof of the lantern. The draft that was created also helped to keep the lantern glass free of condensation. A number of the vents are being used as conduit to route cables from the interior to the exterior of the Lighthouse and therefore by default are left fully open all of the time.

The pedestal that originally supported the rotating second-order lens is positioned in the center of the room. All of the components of the pedestal, as depicted on the original drawings, remain present with the exception of the clockworks. The largest component of the pedestal is the mercury float drum. In December 1986 a minor mercury spill occurred in the Watch Room. The contaminated area was subsequently cleaned and the spilled mercury removed and disposed of according to applicable requirements. This spill likely influenced the decision to upgrade the optic to an automated beacon.

A window opening present on the east wall of the Watch Room contains a plywood insert. No components of the original window remain present.

An arched doorway located on the west wall provides access to the Watch Room gallery. The door was removed during the recent Lantern repair project and a plywood insert installed.

A set of iron stairs are located along the west wall. The open stair treads are set into the exterior masonry wall and hung from the Lantern level floor to provide access between the two spaces.

There are several equipment panels mounted to the wall that are associated with the solar power generation for the VRB lamp. The panels are the panels, there are several weather-proof equipment cases stored under the mercury float drum. mounted to a channel frame that is

through-bolted through the exterior wall. In addition to

Existing Condition: The general character of the Watch Room appears today much as it would have in 1911 when the second order rotating lens was installed. There is extensive cracking of the stucco wall surface. Cracks range in size from hairline cracks to a vertical crack on the east wall that is ¼" in width. This crack and a number of others originate where the ribs of the Lantern level floor plates enter the wall. These cracks may be the result of the corrosion and expansion of the iron anchors that were extended within the masonry wall as part of the repairs following the 1873 hurricane. The large ¼" crack extends through the masonry wall and is expressed on the exterior of the Watch Room. The bronze components of the ventilation dampers are in good condition, but the center cap is missing on at least two of the vents. The missing caps inhibit the correct operation of the vents as do the numerous cables that have been routed through the vents.

The iron components of the lens pedestal as well as the diamond-plate floor panels, brackets, and iron stair to the Lantern room are experiencing moderate surface corrosion.

Lantern Room: The Lantern Room underwent an extensive program of repairs in early 2009. The floor of the Lantern Room, around the perimeter of the space, consists of individual iron plates that extend under the glazed wall to form the floor of the gallery. The lens pedestal assembly extends up from the Watch Room below filling the void in the center of the room. There is a bronze ladder incorporated into the pedestal assembly that originally provided access into the center of the bi-valve lens.

The segmented walls of the Lantern Room are entirely glazed. Vertical iron ribs and horizontal bronze mullions separate the glazed panels. The bronze sill of the glazed wall panels is shaped like a trough to collect water and condensation. The water is shed to the exterior through small weep holes.

A second inverted beacon is hung from the iron ribs of the roof structure by threaded rods. This beacon provides back up to the main optic and is only lit when there is a problem with the primary light.



Figure 61. Portion of lens pedestal and support structure.



Figure 62. Iron stair between Watch Room and Lantern.

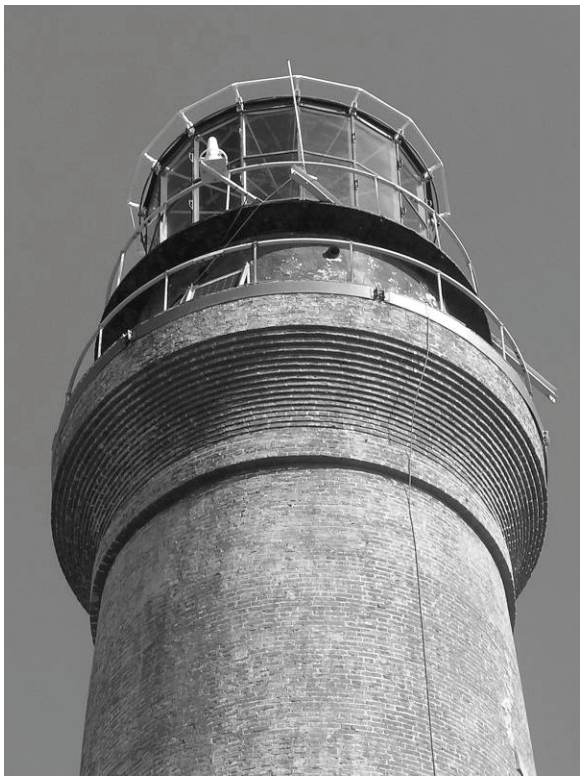


Figure 63. 2009 view of Lighthouse Lantern.

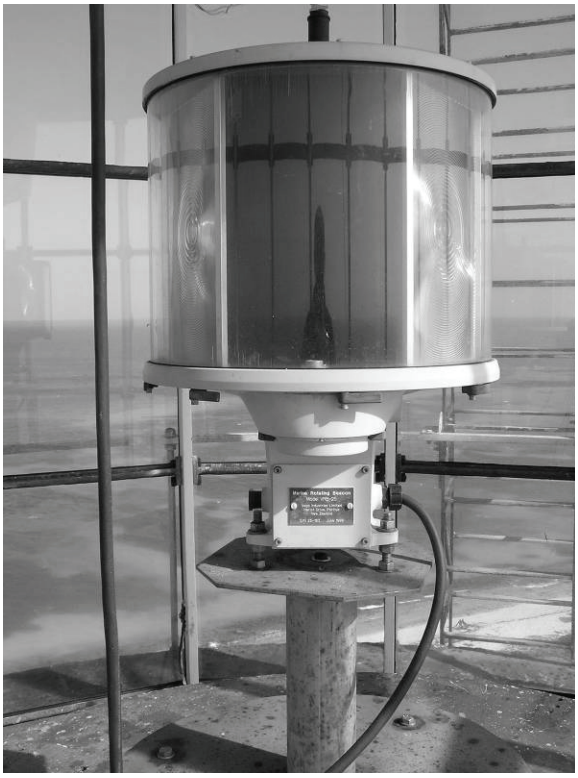


Figure 64. VRB-25 marine rotating beacon currently installed in tower.

The original liner or lantern hood remains present and is mounted within the roof structure of the Lantern. This hood funneled smoke from the oil burning lamp toward the ventilator ball. The second-order lens manufactured by Henry Lepaute and installed in 1911 was removed in 1986 and is now on display at the National Aids to Navigation School in Yorktown, Virginia. The platform on which the lens was mounted remains in place as part of the pedestal assembly. The new VRB-25 marine rotating beacon is platform. The optic was manufactured in New Zealand and installed in the Lighthouse in 1996.

Existing Condition: The Lantern elements are in generally good condition due to the recent program of repairs. The character of the Lantern Room interior has been diminished by the removal of the earlier prismatic lenses and installation of the much smaller modern electronic beacons. The glazed wall and roof elements are all in good condition.

The underside of the iron floor plates are experiencing moderate to severe corrosion. The corrosion appears to extend into the masonry wall where it may be exerting pressure on the masonry and causing cracking of the walls below.

The Lantern hood has been dented and deformed but remains in stable condition. This feature was removed and reinstalled as part of the recent repair program. The surface of the hood is rusted and the painted finish is substantially deteriorated.

The gallery level railing is experiencing moderate corrosion, particularly at its connection to the gallery floor.

Utilities

Electrical System: The lights that illuminate the interior stair of the Lighthouse are powered by the photovoltaic (pv) system installed by the National Park Service in 2002. This system also provides power to the Oil House and all of the other Light Station structures. The Lighthouse beacons are powered by solar array panels mounted to the south wall of the Watch Room gallery. The inverter and distribution panels for this system are mounted to the wall of the Watch Room. Also in the Watch Room are several

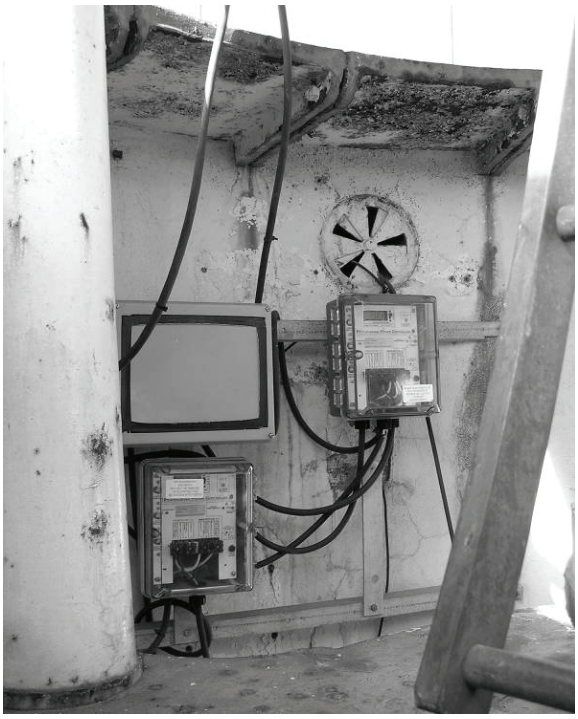


Figure 65. Equipment mounted to the Watch Room wall associated with the solar collection system that provides power to the primary and secondary beacons.

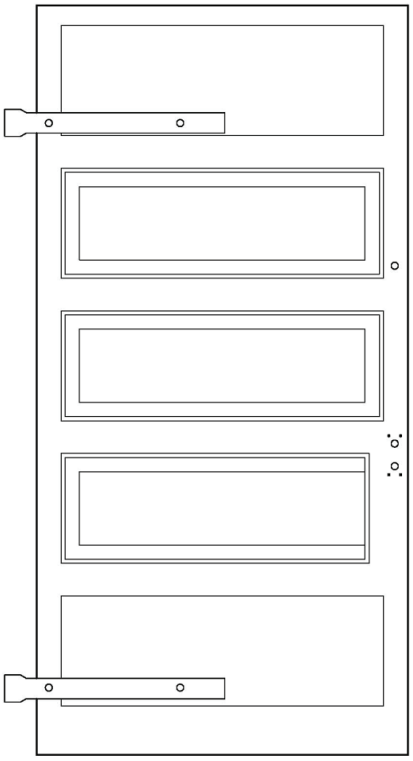


Figure 66. Exterior elevation of Lighthouse entry door.

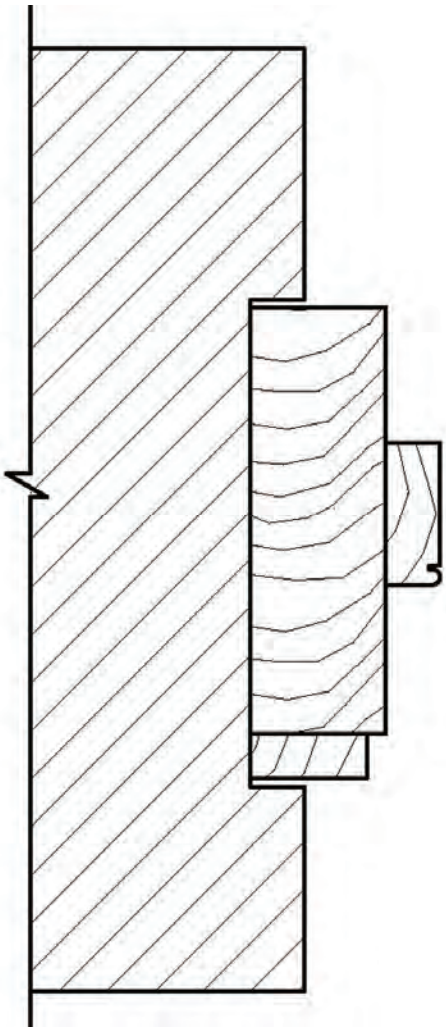


Figure 67. Section though entry door jamb.

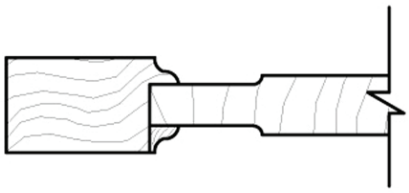


Figure 68. Section though entry door.

weather-proof cases that contain banks of 12V Delco – 2000 Series batteries used to back up the system. This system is maintained by the USCG.

The Lighthouse is not serviced by any other utilities.

Summary of Conditions

The following is a summary of the condition issues observed during inspection of the Lighthouse.

Description of observed condition

Tower Exterior

- Painted finish of the daymark has weathered/deteriorated reducing its intensity and protective qualities.
- General weathering/deterioration of the tower's mortar joints.
- Localized areas of severe weathering/deterioration of the tower brick and mortar joints.
- Vertical cracking of masonry walls below Watch Room and at fifth level window
- Existing bronze aluminum window units are in poor condition and are not in keeping with the historic character of the Lighthouse. Installation of a raised concrete sill at window openings.
- Tower entry door is missing hardware components.
- Deterioration of exterior paint at Watch Room level walls.
- Deterioration/cracking of stucco finish at Watch Room level walls.
- Through-wall crack on south elevation of Watch Room. May be associated with corrosion of embedded iron anchors.
- Corrosion and code compliance of Watch Room gallery railing.
- Installation of solar panels on Watch Room gallery.
- Moderate to severe corrosion of gallery access ladder.
- Moderate to severe pitting corrosion of Lantern gallery floor plates.
- Several iron headers of Lantern structure have become severely deformed and weakened due to corrosion.
- Full replication of dome roof features was not completed as part of recent repair program. Roof edge and integral gutter system were not replicated. Existing ventilation ball and lighting rod assembly was found to be in poor condition and removed.
- Arched iron door to Watch Room gallery was dislocated from hinges and found to be in poor condition and removed during recent repair project.
- Corrosion and code compliance of Lantern gallery railing.

Tower Interior

- General deterioration of painted finish of stair tower walls and central newel.
- General deterioration of mortar joints of the stair tower walls and central newel.
- Localized moderate to severe deterioration of the mortar joints of the



Figure 69. View of oil house looking northwest. Reinforced concrete passageway and concrete block addition are also visible in this image.

stair tower walls and central newel.

- Broken/temporarily stabilized stair treads (2).
- Stair rail is broken in several areas.
- Moderate corrosion of iron sill plate and ends of I-beams supporting Watch Room level floor plate.
- Missing caps on bronze vent hole dampers as well as the fishing of cables through the vent holes to the galleries preventing their correct operation.
- Hatch through Watch Room floor plate is no longer extant.
- Modern conversion and distribution panels for the solar collection system installed on the Watch Room walls.
- Second-order bivalve lens was removed in 1986 and replaced with the VRB-25 rotating beacon changing the character of the Lantern Room.
- Corrosion of iron floor plates and their potential impacts on masonry.
- General surface corrosion of lens pedestal components.

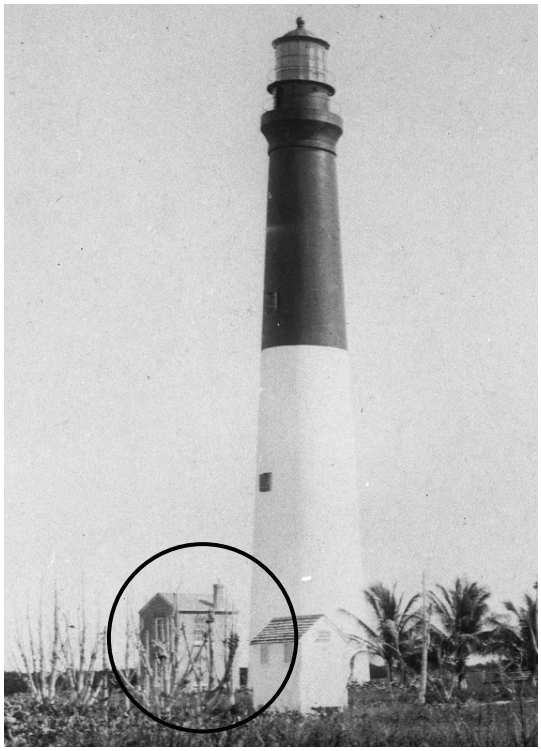


Figure 70. Portion of undated historic image showing unpainted oil house. Note also the presence of a chimney on the south elevation.

Dry Tortugas Light Station Oil House

The Dry Tortugas Light Station Oil House was constructed in 1858 as an original component of the Light Station. Originally a free-standing building, the small (14' x 16'), two-story, load-bearing brick masonry structure was connected to the Lighthouse in 1927 and further altered by the construction of two additions. Although the original building remains discernable, the additions have altered the structure's massing and character.

The 1857 architectural plans for the Lighthouse show an Oil House attached directly to the base of the tower, consistent with the standard specifications developed by the Lighthouse Board from just after the construction period. This suggests that the decision to construct the Oil House as a free-standing building was an afterthought, possibly made following initial design or during construction. It is unknown why the decision was made to depart from the standard design for the Dry Tortugas installation.

A concrete passageway connecting the Oil House to the base of the tower was constructed in 1927 when the function of the building was changed from storing oil to housing radio beacon equipment. At the time of its conversion a new one-story Oil House was constructed just to the north of the existing structure.

Between 1935 and 1941 a one room reinforced concrete addition was constructed on the west elevation of the former Oil House. A second wood-frame gable roofed addition was constructed after 1943 extending from the south elevation. This addition was removed in 1969 and then later in 1982 was replaced with a slightly larger reinforced concrete structure.

Construction of the additions and changes in building's function over time resulted in the modification of all but two of the Oil House's original openings. The original openings are identifiable by their granite lintels and sills. None of the original windows or frames has survived.

The cornice of the front facing gable roof is distinctive in that the roof slope terminates at the top of the exterior masonry walls with no overhang. Although this design is not consistent with the original Lighthouse plans which shows the proposed Oil House with overhanging eaves supported by brackets, this same minimalist cornice detail is seen on structures at other nineteenth century light stations. Historic images of the Dry Tortuga Light Station dating from the turn of the century show this simple cornice arrangement employed on all of the station's buildings. Elimination of the traditional overhanging eaves can almost certainly be attributed to the desire to reduce building features that would be susceptible to damage in the high winds and hurricanes common to the region. Originally slate, the roof is currently covered with modern asphalt shingles.

Originally unpainted, the exterior of the Oil House received a white lime-wash finish in the 1880s or 1890s. Analysis of paint samples taken from the building exterior reveals multiple layers of white or cream-colored paint have been applied to the building over the years (See Appendix B).

The interior of the Oil House has also been extensively modified. The original Lighthouse plans show the first floor of the proposed Oil

House divided into three sections, a central corridor with small narrow rooms on each side. This common plan configuration included an oil storage room on one side and a work room on the other. Currently the first floor of the Oil House is a single undivided space. Due to the installation of later wall, floor and ceiling finishes it could not be determined if this space was originally divided as indicated on the original plans. It is possible that due to the remoteness of the Station, and the need to stockpile materials, that the entire first floor may have been dedicated to the storage of oil and that the second floor was reserved for workroom functions. Correspondence from the 1920s states that there were eight, 30-inch steel oil tanks housed on the first floor of the building.

The original drawings and historic images show a chimney or flue penetrating the roof in the southeast corner of the building. The first and second floor bead-board ceiling finishes have been disrupted where the flue would have penetrated the ceiling, suggesting the small fireplace shown on the original building section was removed after the 1920s modifications. In addition to servicing the fireplace, it is likely the flue was also used to ventilate fumes that would accumulate in the oil storage room.

The interior finishes of the second floor are primarily the product of the1920s renovation that occurred as part of the buildings conversion to a radio beacon house. Originally plaster, the walls and ceilings of the first and second floors were furred out and covered with bead board at this time. Modern wood paneling has been applied directly onto bead board walls on the first floor. There is an open stair along the north wall as indicated on the original architectural plans. This feature may date to the original construction.

Character-Defining Features

Character-defining features of the Oil House are those visual and tangible elements of the structure that are significant and give the resource its distinct character. These features include elements of its original design and construction as well as modifications made during the historic period. The character-defining features of the Oil House should be retained and preserved as part of ongoing maintenance and repair activities. The identified character-defining features of the Oil House include:

- Isolated and sparsely vegetated subtropical setting – The character of the surrounding landscape is one of light station's most unique and important features contributing greatly to the resources sense of place. The relatively recent program to remove invasive species introduced by the Carnegie Institute in the early twentieth century has returned the landscape to a condition that is generally consistent with its nineteenth century appearance.
- Two-story building form with projecting one story concrete and concrete block additions.
- Front facing gable roof with simple cornice.
- Painted brick exterior walls.
- Bead-board wall and ceiling finishes installed beneath modern wood paneling.
- Interior open wood stair to second floor.
- Windows are considered character-defining features of the Oil House. However, the existing modern units diminish rather than enhance the historic character of the structure.
- Although the existing door of the Oil House has been modified and its date of installation is unknown, it should be considered a character defining feature.

Structural Systems

Foundation: The level of grade around the perimeter of the Oil House did not permit inspection of the building foundation. The exterior load-bearing masonry walls extend below grade without interruption. Information on the original architectural drawings stops at grade providing no detail about the designed depth or configuration of the foundation of the Oil House. The 1861 standard specifications issued by the Lighthouse Board calls for an 18" thick rubble masonry foundation extending three feet below and three feet above grade.



Figure 71. Image of roof framing members taken in attic of Oil House. Note evidence of moisture, minor termite damage and the different patina of the members.

Undated early drawings of the Keeper's Residence and detached kitchen building show load-bearing brick masonry walls extending approximately 1'-6" below grade to a concrete foundation 2'-3" in width and 1'-6" in depth. Given these structures were built contemporaneously with the Oil House it is plausible that the foundation design for the Oil House would be substantially consistent with these other buildings.

Existing Condition: No cracking of the exterior walls that would suggest active settlement or movement of the foundation was noted. The build-up of finishes on the brick exterior made it difficult to detect the presence of repaired cracks that may have occurred as a result of previous settlement.

Floor Structure: The first floor of the Oil House is concrete slab installed after 1926. The existing slab is raised approximately 6" above the elevation of the original threshold suggesting it was poured on top of an earlier floor slab.

The same undated drawings of the keeper's residence and kitchen building mentioned above show the floor framing of these structures raised above grade on wood joists with a 2'-6" crawl space below.

The 1861 standard specifications calls for oil house floors to be paved with hard bricks laid on edge. Given the first floor structure would have been required to carry the substantial weight of the stored oil, it is likely that the first floor structure would have been installed as a slab or brick pavers directly over compacted sand or soil.

The 1926 construction drawing prepared when the Oil House was converted to a radio beacon house shows the first floor structure as a concrete slab in line with the original stone threshold. The existing raised slab may have been installed due to the poor condition of this earlier slab or to protect the radio beacon equipment from potential flooding (See drawing on p.91).

The second floor framing was not accessible at the time of inspection, but the 1926 documents mentioned above shows the framing as 2" x10" joists spanning the building from north to south. The joists are shown to be fire-cut at one end. Fire-cutting refers to the technique of cutting the ends of the joists at an angle so that in the event of a fire, the joists would burn through and fall out of the masonry wall without collapsing the wall itself. Application of this construction technique is consistent with the original purpose of the structure as a storage space for highly flammable materials.

Existing Condition: The first floor slab is in good condition. No major cracking or signs of settlement or deterioration were noted. Although, installation of floor and ceiling finishes prevented the visual inspection of second floor wood framing members, no signs of settlement were noted.

Roof Structure: Access to the attic of the Oil House is provided through a hatch in the second floor ceiling. The gable roof of the building is framed with 3" X 5" circular-sawn rafters spaced at 16" on center with no ridge board. One of the rafters appears to have been recently replaced. The ceiling joists are 2" x 6" circular-sawn boards spanning the width of the structure. The joists are fastened to the rafters approximately $^{1}/_{3}$ up their slope increasing the height of the second floor ceiling. The finish or patina of the rafters and the ceiling joists differs significantly.



Figure 72. Image showing interruption of second floor ceiling finishes in the southeast corner of the room where the chimney for the fireplace would have penetrated the roof.

The rafters are dark brown unfinished wood while the joists have a deteriorated white-wash or white paint finish.

Historic images of the Oil house indicate a chimney penetrating the roof at the southeast corner of the building. No indication of the chimney was visible within the attic space. The Oil House underwent extensive roof work during the 1982 improvements.

Existing Condition: The attic space was dry at the time of inspection. No evidence of active leaks was observed, but some moisture staining was noted on the ceiling joists. In addition minor termite damage was observed on several rafters. No active termites were observed.

Exterior Features

Roofing: The gable roof of the Oil House is clad with modern, gray, thee-tab asphalt composition shingles. Reference to the Oil House's original roofing material is not recorded in the historic documentation. However, it is likely the building was originally clad with slate, as this is the material called for in the 1861 standard specifications. In addition, an archaeological survey conducted in 1998 of the area around the Lighthouse and Oil House yielded significant amounts of slate roofing tile.

An undated twentieth century image of the Oil House shows the building with a standing seam metal roof.

The roof sheathing, visible from the attic space, is relatively new plywood. The roofing finish is attached to the sheathing with wire cut nails. The 1861 standard specifications call for a sheathing of 1" boards and for the slates to be fastened with zinc nails.

The building currently does not have gutters or downspouts. Historic images show no evidence of these features having been installed on the building in the past.

Existing Condition: The existing composition shingle roofing is in generally good condition, but several shingles are missing.

Roof Cornice: The top of the exterior wall is corbelled out for two courses creating a simple masonry cornice along the sides of the building. The roof rafters have been cut so that the roof finish intersects with the top of the masonry wall eliminating a roof overhang. The corbel has been painted dark green along the north elevation but remains white, like the body of the structure, along the south elevation. On the east and west gable ends a simple 1" x 6" rake board makes up the cornice. Copper roof flashing covers approximately one-half of the fascia board at the gable ends and covers the top masonry course along the sides of the building. Elimination of roof overhangs and millwork cornice components is likely a response to the climatic conditions of the region.

Existing Condition: The wood elements of the cornice are in fair to good condition. The painted finish shows minor signs of deterioration, but remains intact.

Exterior Walls: The exterior walls of the Oil House are load-bearing brick masonry. Visible from within the attic, the bricks range in color from a light orange or salmon to a deep red or purple and contain dark inclusions similar to the bricks used in the construction of Fort

Jefferson's scarp wall. The coursing of the masonry in the attic is consistent with the Common bond pattern (header row every 6th course), but the extreme build-up of finishes on the exterior of the building makes it difficult to verify if this coursing is carried to the exterior. Lime-washing of the Oil House's exterior occurred sometime after the 1880s or 1890s. An early undated image of the Light Station shows the Oil House unpainted.

Paint analysis showed the exterior of the Oil House, lower half of the Lighthouse and brick cistern had a similar finish history. The earliest



Figure 73. East elevation of Oil House with reinforced concrete passageway.

finish layers indicate that a lime wash was first applied to the structure followed by successive layers of white or cream-colored paint.

Sampling and analysis of the Oil House mortar revealed that it consists of one part natural cement to one–and-one-half parts local carbonate sand. Analysis further determined this mix is common to all of the original Light Station structures (See Appendix B).

Existing Condition: The build-up of finishes makes it difficult to assess the underlying condition of the exterior bricks and mortar. No obvious signs of masonry deterioration were noted. No flaking or bubbling of the painted finish was observed and there were no signs of spalling or deterioration of the underlying host masonry. The mortar joints did not exhibit any perceivable tooling, appearing to be brought flush with the brick.

In numerous locations, iron anchors and eyebolts have been embedded within the exterior masonry wall. In a few areas these items are corroding and staining the exterior paint. Continued corrosion and expansion of these elements may result in localized damage to the masonry.

East Elevation: The east, or primary elevation of the Oil House, faces the Lighthouse. The main entrance to the Oil House is located on this elevation. The ca. 1890s image of the Light Station does not show a second floor window present on this elevation. It is likely the second floor window was added after 1933 when a request was made to install two new windows in the building to provide increased ventilation to help dissipate the summer heat from the structure.

Originally exposed, most of the first floor of this elevation is now enclosed within the concrete passageway constructed between the Oil House and Lighthouse in 1927. Evidence of a small window south of the first floor entryway outside of the connector was noted during inspection. Now infilled with masonry, the distinct outline of a small window and its associated lintel and sill could be discerned within the masonry wall. An undated image of the Oil House shows a window present in this location.

West Elevation: The lower portion of this elevation is covered by the radio beacon equipment room addition added to the rear of the Oil House between 1935 and 1943. As part of the expansion, the first floor window in the west elevation was replaced by a 3' x 7' door installed to provide access to the addition. According to the construction drawings, the removed window was to be salvaged and installed in the west elevation of the addition. This window has since been removed and there is currently no window in the opening.



Figure 74. North elevation of Oil House.



Figure 75. West elevation of oil house with 1935-1943 addition in foreground.

The second floor of the west elevation contains a window. With the exception of the entrance on the east elevation, this is the only original opening that has not been altered.

North Elevation: This elevation contains no openings. No physical evidence of previous openings is present and historic photographs do not indicate openings on this elevation during the historic period. There are two small holes penetrating the wall just below the cornice. Their purpose is unknown. There are several anchors or iron elements embedded within the masonry. The interior stair from the first to second floor is located on this wall which may be the reason for the absence of fenestration.

South Elevation: The south wall of the Oil House is exposed within the concrete addition. There are several electrical panels installed on the east half of the wall and evidence of a previous door opening is present on the west half of this elevation. Originally a window, the opening was extended to the floor at some point in the past to accommodate a door. The opening has been infilled with brick. Historic images as well as the 1926 architectural plans of the Oil House show window openings on the first and second floor.

The original opening on the second floor was altered when the gable-roofed, wood-frame addition was constructed. A single "propeller-type" shutter dog or tie-back remains embedded in the wall at bottom corner of the second floor opening, just above the roof line of the concrete block addition. Images from the 1960s show shutters present on the window openings and correspondence from 1933 talks about replacing the "old wooden shutters" on the Oil House with storm shutters.

Doors: The entry door to the Oil House is located on the east elevation. The existing **1 ¾**" thick wood door has been modified. The door appears to have originally been a screen door with a central rail separating large, open, upper and lower panels. A plywood panel has been applied to the exterior side of the door giving it the appearance of a flush door. The door does not have any hardware with the exception of a modern hasp and padlock that secures the door, and a rope for a pull. The door is attached to the frame with two bronze butt hinges.



Figure 76. Propeller type shutter dog in wall below second story window on south elevation.



Figure 77. North elevation of Oil House.

Existing Condition: The door and frame are in fair condition. Like the tower door, the handle set and locking hardware are no longer present. two-pane, awning windows with bronze aluminum frames. The window on the west elevation is a five-pane, awning window with an unfinished aluminum frame. Hurricane shutters were installed over all of the windows at the time of inspection.

Historic images of the Oil House from the late-nineteenth century show six-over-six or eight-over-eight double hung windows with a light-colored painted finish on the sash and frames. By 1926 it appears these windows had been changed to four-over-four, double-hung units.

Existing Condition: The existing modern aluminum windows are in fair to poor condition. In all instances the hardware is broken rendering the windows inoperable. A pane is broken out of the window on the east elevation. The metal components of the windows are significantly corroded.

Interior Features

Room OH101

Floor: The existing floor of the Oil House is a concrete slab installed sometime after 1926. The floor is currently painted gray. There are several layers of paint on the floor including an intermediate layer of bright red paint. There are discernable ghost patterns in the floor that may correspond to the placement of radio beacon equipment. The ghosting does not appear to correspond to previous partition locations. A raised pedestal is located beneath the stair. covers the walls. The wood paneling has been applied directly over 4" wide bead-board walls. The bead-board wall is furred out from the masonry wall on 3 ½" framing. A hole through the wall allowed this assembly to be recorded. From this hole, it was observed that there is an approximately $^{5}/_{8}$" layer of plaster applied to the interior face of the masonry. The historic documentation confirms that the original wall finish in the oil house was plaster. It appears from the 1926 architectural drawings for the addition that the installation of the furred out bead-board walls occurred as part of the conversion of the Oil House to Radio Beacon House. It should be noted that the wood

paneling and bead-board walls terminate at the infilled opening on the south wall suggesting this opening was present when the modern paneling was installed.

Ceiling: The ceiling is covered with 3 ½" bead-board running east-west. The bead-board has been patched in the southeast corner of the room where the fire place flue would have penetrated the ceiling. There is also an oval stove-pipe cover centrally located in the room.

Stair: A flight of stairs along the north wall ascends in a straight run up to the second floor. The stairs have 7 ½" open risers attached to a 2" stringer that extends down to the floor. The backside of the stair is clad with 3 ½" bead-board. The treads measure 10" and have a rounded nose. A simple 1 ½" diameter pipe railing is attached to the wall.

Existing Condition: The stair is not exhibiting any signs of deterioration and its materials are in generally good condtion.

Walls: Quarter-inch, modern-era wood paneling

Moldings: A simple 3" baseboard with a natural finish is present in Room OH101. There is no shoe-molding present. The 1927 door opening in the west elevation has a simple 6" wide casing at the head and jambs. The jamb casings terminate into the head which extends past the jamb casings approximately ½".

Although the casing and jamb assembly at the main entry door is different, it was likely installed as part of the same 1927 renovation of the building. The casing is 3 ½" wide and is chamfered to meet a 1" half-round molding that forms the transition between the jamb and casing.

Existing Conditions: The condition of the finishes in Room OH101 is good. Items noted include paint build-up, loose boards and moldings and isolated holes or damage.

Room OH201

Floor: The flooring of the second floor is 12" x 12" vinyl tile. The 1926 architectural drawings indicate 1"x 6" wood flooring applied directly to the wood floor joists.

Walls: The walls are clad with 4" bead-board, furred out from the masonry wall as indicated



Figure 78. Image showing bead board wall finishes below wood paneling.



Figure 79. An open stair leading to the second floor is located along the north wall of Room OH101.



Figure 80. Interior image of second floor of Oil House.

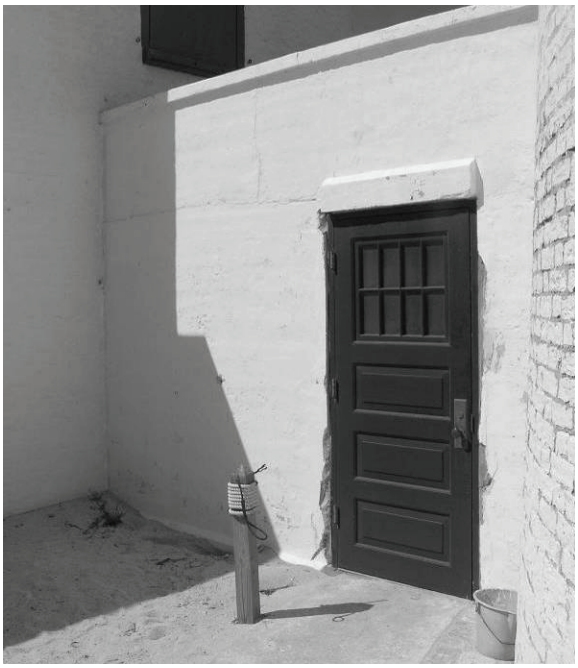


Figure 81. South elevation of Oil House.

on the 1926 drawings. The original plaster finish is visible through a small hole in the bead-board. A patch in the bead-board is present below the south window confirming the window was modified following the 1927 renovations. The stair is enclosed by a thin frame wall clad with flush vertical boards.

Ceiling: The ceiling is clad with 4" bead-board running east-west and may have been installed during the 1982 repairs. The ceiling angles down to meet the walls and is trimmed with a simple cavetto profile wood molding. A patch is present in the ceiling in the southeast corner of the room where the masonry from the fireplace was removed.

Moldings: All of the windows are cased with flat 1" x 6" boards with mitered corners. A simple 3 ½" baseboard is installed around the perimeter of the room.

Existing Condition: The condition of the finishes in Room OH201 is good. Items noted include paint build-up, loose boards and moldings and isolated holes or damage.

Concrete Passageway (1927)

The Concrete Passageway connecting the original Oil House to the Lighthouse was constructed in 1927. The passageway was constructed as part of the Oil House's conversion to a Radio Beacon House. The stated purpose of the passageway was to protect the radio beacon equipment from getting wet when opening the door during inclement weather and also to provide safe passage for the keeper when passing between the radio beacon room to the Lighthouse during the same.

The Passageway is a one-story reinforced concrete structure that spans between the original Oil House and the Lighthouse. The structure has a flat roof with flanking parapet walls and provides a 5'-0" corridor between the two structures. The walls are 8" thick and the foundation is shown on the original architectural drawings to extend 3'-0" below grade. The interior and exterior of the passageway is painted concrete. Aligned doorways at the east end of the structure, adjacent to the tower, provide access through passageway. The concrete at the head of the doors projects to provide a drip edge over the door opening. The roof is sloped ½" per foot to the north and is drained by two, 2" galvanized pipes that penetrate the parapet.

Correspondence from the period of construction indicates the use of reinforcing in the construction of the Passageway was a contentious issue. Although the original architectural drawings call for its use, the Superintendent of Lighthouses cites at the time that present practice and experience within the region dictate that reinforcing should be

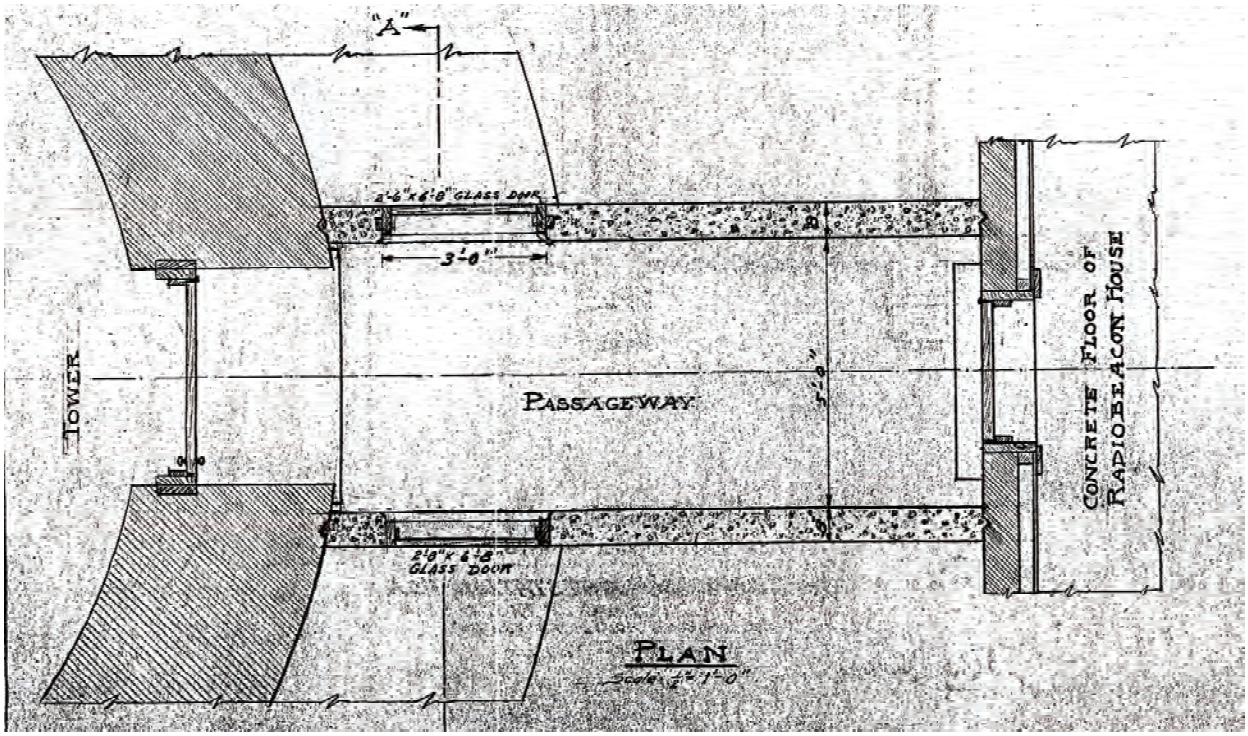


Figure 82. Original 1926 drawing of the reinforced concrete passageway connecting the Radio Beacon House (former Oil House) to the Lighthouse.

eliminated from the design. He goes on to more strongly state his position:

> "Notwithstanding the distance it is to be located from the surface the reinforcing will eventually result in extensive repairs from time to time and the ultimate destruction of the walls and roof. In the opinion of this office it is unnecessary and detrimental rather than beneficial. As a matter of information it might be stated that this office does not know of a single piece of reinforced concrete in this district, similarly situated, that has been in service 10 years but what is now seriously affected and in some instances replacements are only a question of a short time." [3]

The reinforcing was ultimately installed in the walls. The original architectural drawings call for the reinforcing to be "thoroughly covered with a thin coating of Portland cement," presumably in an effort to prevent moisture from attacking the metal.

The wood doors shown on the original architectural plans measure 2'-6" X 6'-8" and have three horizontal molded panels below an eight-light glazed upper panel. The original doors were replaced in 2005. The new units are wider than the original doors at 3'-0" but replicate the original doors in all other detail.

Existing Conditions: Isolated areas of concrete spalling on the interior walls and ceiling of the passageway were noted during the review of conditions. In addition, identical patterns of horizontal and vertical cracking are present on the exterior of the north and south elevations and around the through-wall galvanized roof drain pipes. Both the spalling and the cracking can be attributed to corrosion and expansion or "jacking" of the internal reinforcing and drain pipes. Given that segments of the reinforcing have now been exposed and the cracking that has formed is providing a pathway for water to infiltrate the walls, it is expected that this condition will continue to worsen in the short term.

Other items of note include the jagged edges and unfinished appearance of the modified door openings and the deterioration of the interior and exterior painted finish.

[3] Superintendent of Lighthouses to Commissioner of Lighthouses, 04 May1927, Record Group 26, NA, Washington, DC.

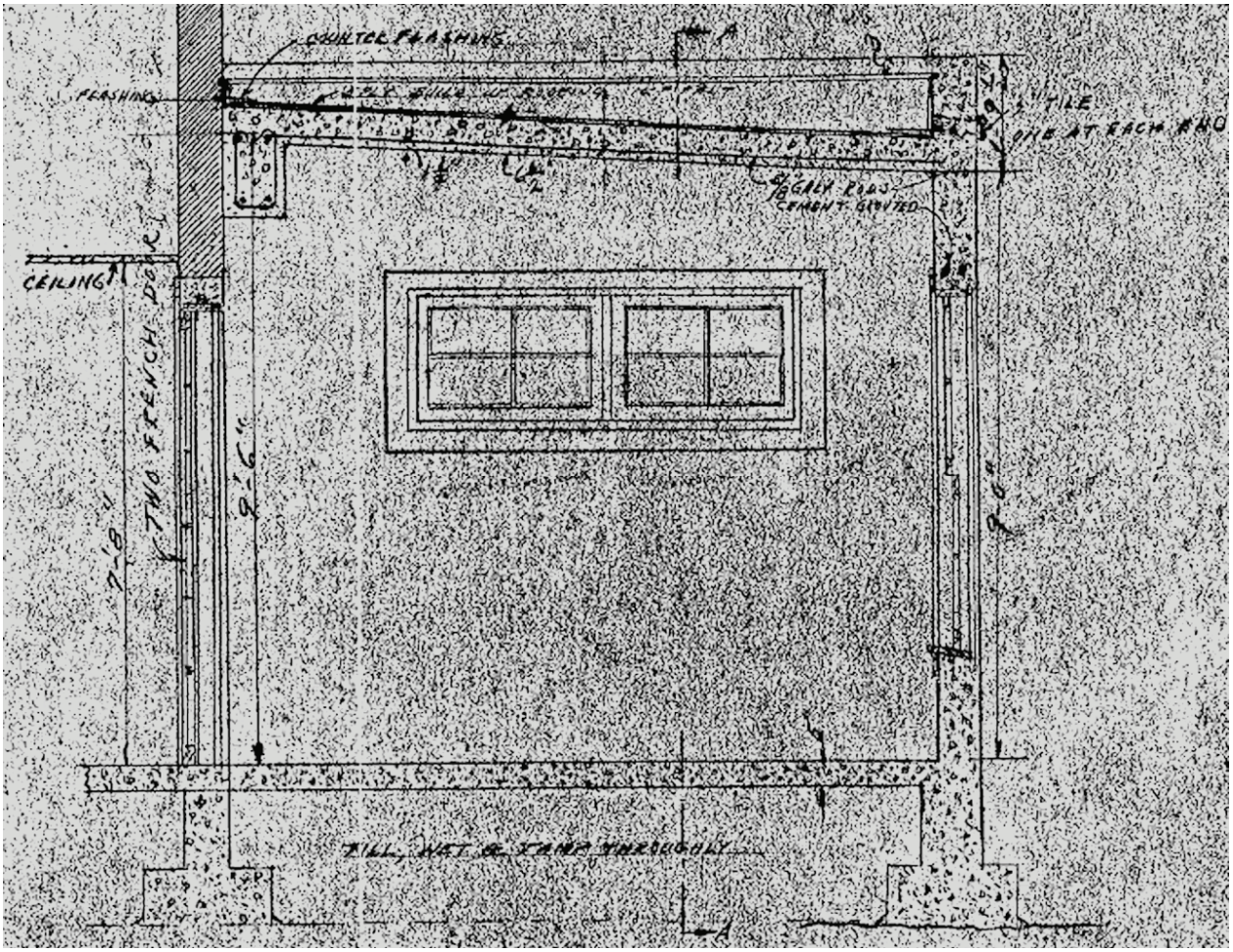


Figure 84. Section through West Addition to Oil House (Battery Room).

West Addition (ca. 1935-1941)

The one-story addition to the west wall of the Oil House was constructed between 1935 and 1941. Initially in 1926 when the Oil House was converted to house radio beacon equipment there was much discussion about the ability of the structure to accommodate the new function. Several options were considered for relocating the oil tanks from the first floor of the Oil House including storing them outside, lengthening the existing building or building a new oil house. At the time, the Lighthouse Board decided to build a new structure for storage of the oil and renovate the first and second floors of the existing Oil House to accommodate the radio beacon equipment. It appears from the drawings that the generators were installed on the first floor with the radio receiving equipment on the second floor.

The west extension to the original oil house is present in the background of a 1941 image of the pump house. It is possible the extension was constructed to house batteries as it is labeled "Battery Rm. Extension" on a site plan of the station prepared in 1943.

Although the original architectural drawings for the addition are available, they are undated. The drawings show the concrete addition constructed upon a 1'-0" wide foundation wall set upon a 2'-0" wide footing. The depth of the foundation is not provided on the drawings. The walls, floor, and roof slab of the addition are constructed of reinforced concrete. A 14" deep reinforced concrete beam supports the roof slab. The beam is set against the exterior wall of the Oil House. The roof slab is sloped to the west and was covered with a built up roofing system. Two, 2" drain tiles in the west wall allow rainwater to drain through the exterior wall.



Figure 85. Concrete block addition constructed in 1982 by the crew of the USCG vessel *White Sumac*. When originally constructed the addition did not have any openings.

The original window in the west wall of the Oil House was converted to a 3'-0" x 7'-0" door to provide access to the new room. This window was salvaged and moved to the west wall of the addition. Paired, four-light, wood awning windows were installed in the north and south elevations.

Existing Conditions: The addition to the Oil House is in relatively good condition with no significant signs of component failure or deterioration. A horizontal crack was noted on the interior extending from the middle of the window on the west elevation to the bottom corner of the window on the north elevation. The interior painted finish is experiencing localized flaking. The west window has been removed.

South Addition (1982)

The south addition to the former Oil House was constructed in 1982. An undated image of this structure shows the south and west elevations void of openings with the exception of a small opening on the south elevation for a through-wall air conditioning unit. Since the time the image was taken, a number of windows and doors have been added to the structure. The building is currently being used as a garage for a small utility vehicle and also houses reverse osmosis water purification equipment.

Existing Conditions: The south addition to the Oil House has been modified from its original construction by the addition of several openings. As the function of the building has evolved over the past 27 years it has been necessary to add new openings for both ventilation and access. The building components are performing well with no significant signs of deterioration.

Utilities

Electrical System: Electrical power is provided to the Oil House and other Light Station structures by the photovoltaic (pv) system installed by the



Figure 86. View of photovoltaic array located west of the Lighthouse and Oil House.

National Park Service in 2002. Prior to installation of the pv system, electricity was produced by two diesel-powered generators. Fuel for these generators was provided by the USCG. However, due to the cost and hazards associated with delivering fuel to the island, the Coast Guard installed solar panels on the tower to power the Lighthouse optic. Shortly thereafter, the National Park Service installed an expanded pv system to service all of the structures of the Light Station.

Today power for the Light Station utility systems and structures, including the Oil House, is generated by the large photovoltaic array located west of the tower. A bank of batteries, located in the rear addition of the Oil House stores power from the system for use at night and for times when the array cannot provide enough current for demand during the day. The system's controllers and conversion panels are located on the south wall of the Oil House and the distribution load centers are located in the south addition. From here electricity is delivered to the Light Station structures through underground conduits.

Existing Conditions: The photovoltaic array has an anticipated useful life of 20 years, which leaves a minimum of 13 years before it will need to be replaced. However, the lifespan of the individual components of the system, and the batteries range from one to three years. Regular maintenance of the system is required primarily due to the effects of the environment on individual system components.

The existing system has sufficient capacity to service the demand required by a general level of use. However, at certain times when the housing units are filled and demand for cooling is highthe system is required to operate near its capacity. It has been suggested that better educating those that use the housing facilities about the limits of the system and energy saving measures would help to mediate these periods of peak demand and reduce strain on the system.

Summary of Conditions

The following is a summary of the condition issues observed during inspection of the Oil House.

Description of observed condition

Oil House

- Exterior painted finish shows only very minor signs of deterioration and is in good condition.
- Exterior masonry appears to be in good condition with only minor signs of deterioration noted.
- Existing bronze aluminum window units are in poor condition with broken hardware and missing panes noted. The windows are not in keeping with the historic character of the Oil House.
- Oil House entry door is missing hardware components.
- The roof of the Oil House is performing well, but several missing shingles were noted.
- Modern faux wood paneling has been installed over the 1920s era bead board walls.
- Panels associated with photovoltaic system installed on south interior wall.

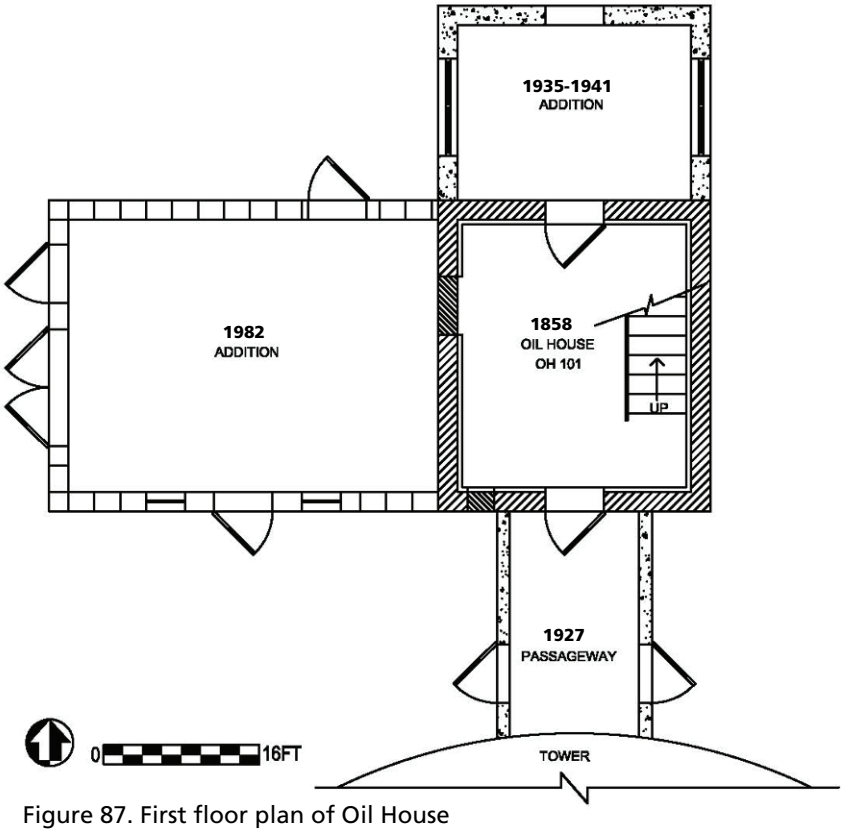


Figure 87. First floor plan of Oil House

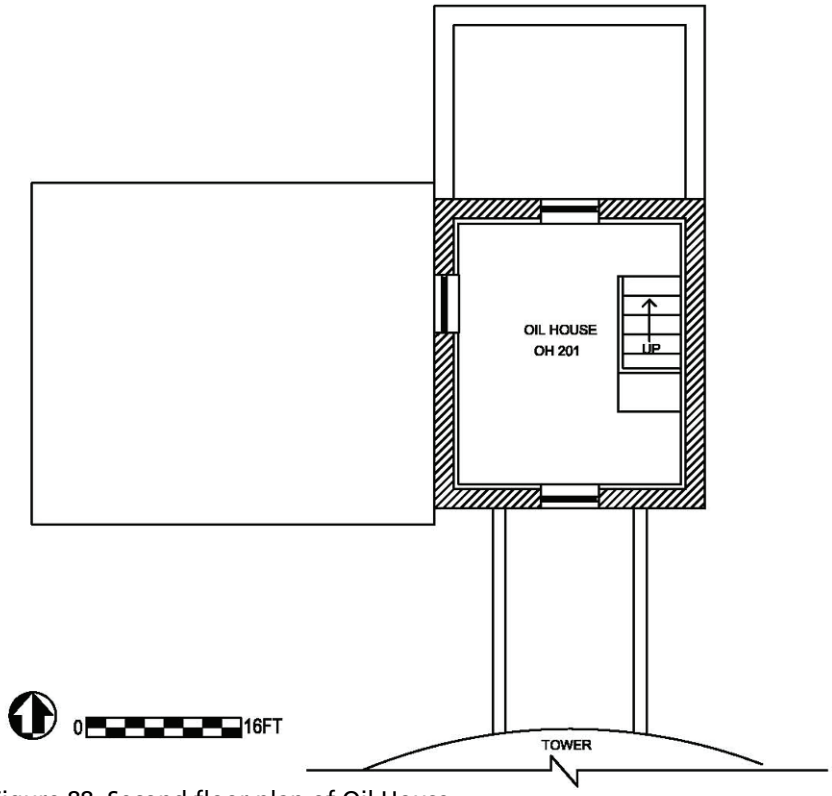


Figure 88. Second floor plan of Oil House

Concrete Passageway

- Corrosion and expansion of internal reinforcing has caused spalling in several areas.
- The interior and exterior painted finish of the passageway is deteriorated and requires repainting.

West Addition

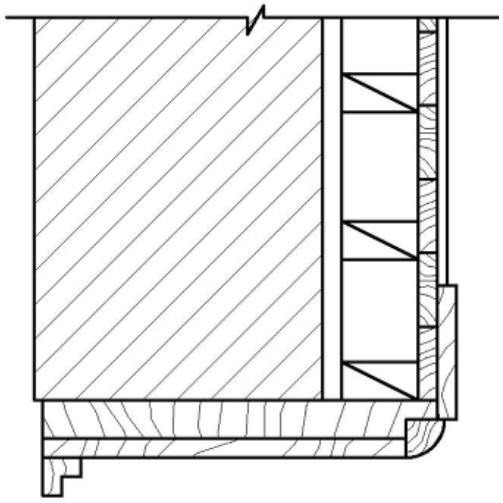


Figure 89. Oil House entry door jamb.

- Significant horizontal crack in west wall.
- No window or window frame in west elevation.

South Addition

- No significant signs of deterioration.

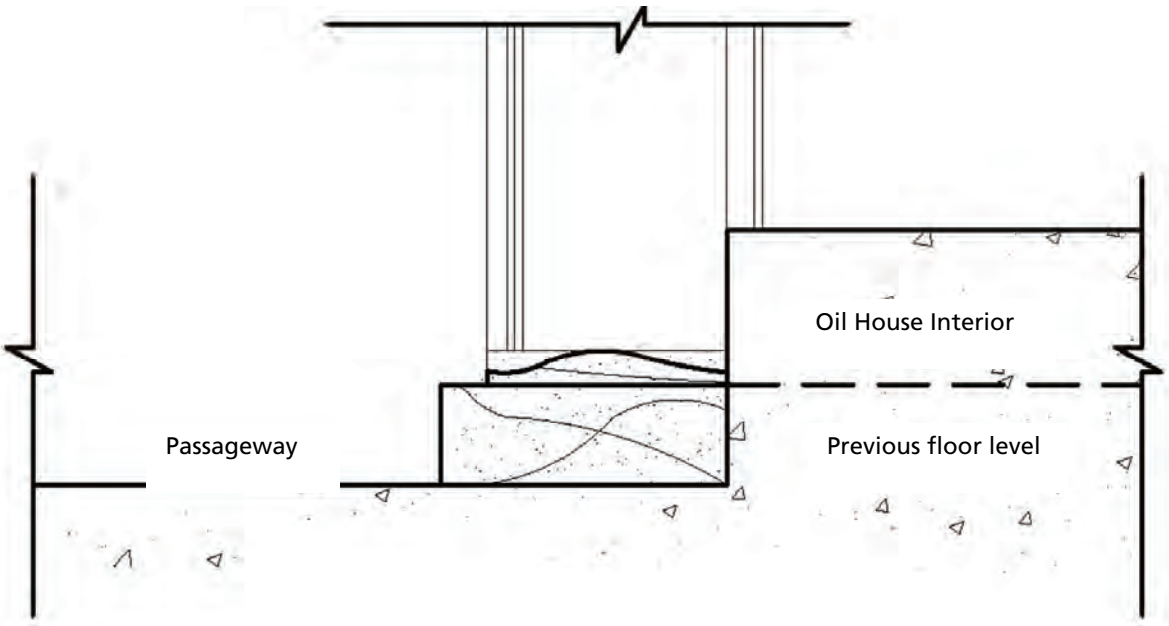


Figure 90. Oil House entry door threshold.

Requirements for Treatment and Use

The treatment and use of the Dry Tortugas Lighthouse and Oil House must be considered within a framework of applicable laws, policies and agreements. These various mandates govern a wide range of management issues beyond the preservation, protection and interpretation of the Park's cultural resources. They extend to issues of visitor and staff use, safety, and universal accessibility among others. Also, because the Lighthouse remains an active aid to navigation, treatment and management of the Lighthouse will in part be bound by current and future cooperative agreements between the National Park Service and the U.S. Coast Guard.

The National Historic Preservation Act

Section 106 of the National Historic Preservation Act mandates that Federal agencies, including the National Park Service take into account the effects of their actions on properties listed or eligible for listing on the National Register of Historic Places. The goal of this directive is to encourage agencies to avoid or minimize adverse impacts to cultural resources and to make sure preservation is fully considered as part of the planning process. The Section 106 process also requires consultation with parties outside the National Park Service that may have an interest in the property.

In 1995, in an effort to expedite the review process, a programmatic agreement was made between the Advisory Council and the NPS that allows for exclusion of some activities from the full Section 106 review process. These excluded activities are limited to routine repairs and maintenance that do not alter the appearance of the historic structure or involve widespread or total replacement of historic features or materials. The programmatic agreement was revised in 2008.

Accessibility

The National Park Service is committed to providing persons with disabilities the highest feasible level of physical access to historic properties.

The Architectural Barriers Act of 1968, the Rehabilitation Act of 1973 and the Americans with Disabilities Act of 1990 set forth the federal mandate for making buildings and facilities more accessible. The guidelines that accompany these Acts as well as the Uniform Federal Accessibility Standards (UFAS; 41 CFR 19.6; 49 FR 31528) provide design direction for accessibility modifications to historic structures in the national park system. With regard to outdoor developed areas, such as trails, beaches and picnic and camping areas, the National Park Service has adopted the U.S. Access Board's Outdoor Environments Guidelines.

Given that full compliance with these mandates in many cases would require alteration of significant features of a historic property, provisions have been made within the acts for achieving alternative means of compliance. This approach has been used at a number of lighthouse sites where providing access to the Lantern would not be practicable. In some cases an accessible route is provided to the base of the tower and the experience of ascending the stair and viewing the lens and surrounding landscape is delivered through alternative means such as wayside exhibits, videos or slide shows.

In addition to building-related accessibility issues, the primary challenge at the Dry Tortugas Light Station is accessing Loggerhead Key itself. Although at least one of the commercial vessels used to transport visitors to the Park is accessible and equipped to accommodate a wheelchair, currently the only debarkation point within the park is on

Garden Key. There are currently no public docking facilities provided at Loggerhead Key. Thus there is currently no accessible route that could bring a mobility-impaired visitor to Loggerhead Key or the Light Station. If accessible access to the island could be established, improvements to the wharf and walkways would have to be completed to access the Light Station. Due to the topography of the Key, providing an accessible route from the dock to the Light Station may require significant alteration of the historic landscape.

Recognizing its obligation to make the Park accessible to the widest audience possible, the Park has outlined its management direction in the General Management Plan Amendment.

> Make visitor and management facilities as accessible as practicable, depending on the nature of the area and of the facility, to persons with visual, hearing, mobility and mental impairments. Strive to provide the highest level of accessibility possible to facilities, programs, and services consistent with the nature of the area, the conservation of resources and the mandate to provide a quality experience for everyone.
>
> Meet accessibility standards on visitor transportation vessels and aircraft with the limits of marine and aircraft design and safety requirements. Work with organizations that encourage and enable use of the park areas by special populations, which will increase awareness o f the needs of these populations and help to ensure that potential visitors with particular needs are aware of the opportunities offered at the Dry Tortugas.

International Building Code

As a matter of policy, the National Park Service has adopted the International Building Code which establishes minimum regulations for the design and installation of building systems with an emphasis on preserving public health and safety. Its requirements are applicable to both new construction and the repair and alteration of existing buildings. Full compliance with IBC requirements is not mandatory for historic buildings where there is no threat to life safety.

> 3407.1 Historic Buildings: The provisions of this code related to the construction, repair, alteration, addition, restoration and movement of structures, and change of occupancy shall not be mandatory for historic buildings where such buildings are judged by the building official to not constitute *a distinct life safety hazard* [emphasis added].

Alternatives to full code compliance can be sought where compliance would needlessly compromise the integrity of the historic building.

DO #58 and NFPA Code 914

Among many other issues, the National Park Service Management Policies address the protection of historic resources against fire. Section 5.3.1.2 of the policy document states that:

> In the preservation of historic structures and museum and library collections, every attempt will be made to comply with national building and fire codes. When these cannot be met without significantly impairing a structure's integrity and character, management and use of the structure will be modified to minimize potential hazards rather than modifying the structure itself.

Introduction of a fire suppression system within the Lighthouse would result in a significant negative impact on the historic character of the structure since these systems would have to be exposed. Based on the anticipated level of use and the non-flammable nature of the building materials that make up the Lighthouse, protection against fire should be addressed by minimizing hazards and implementing appropriate management policies.

The Secretary of the Interior's Standards

Treatment of historic resources associated with the Light Station is to be guided by *The Secretary of the Interior's Standards for the Treatment of Historic Properties*. These standards provide a framework for planning and implementing responsible preservation practices and ensuring there is a philosophical

consistency to the work. A series of guidelines have been developed to accompany the standards and assist with their interpretation.

Additionally, the *Preservation Briefs* published by the National Park Service provide technical guidance for the appropriate treatment of a variety of materials, features and conditions found in historic buildings.

Cooperative Agreements with USCG

When Dry Tortugas National Park was established in 1992 the U.S. Coast Guard determined the facilities on Loggerhead Key to be "excess to its needs" and transferred the property (the entire key) to the National Park Service. The transfer of property excluded the Dry Tortugas Lighthouse with the stipulation that the USCG would continue to "maintain and utilize" the structure for its own purposes, primarily as an active aid to navigation. In 2007 the USCG and National Park Service entered into a cooperative agreement regarding the use of facilities and utilities on Loggerhead Key. This agreement requires the NPS to reserve a room within the Keeper's Residence for the exclusive use of USCG personnel and provide water and power to the building. Among other minor items the USCG agreed to provide propane and gasoline storage tanks to the island and to refrain from making modifications to the Keeper's Residence with the exception of rehabilitating the rainwater collection system.

In 2008 a Memorandum of Agreement was prepared between the USCG and the National Park Service that establishes the parameters for the formal transfer of ownership of the Lighthouse. Transfer of the Lighthouse is contingent upon several requirements, one being completion of this Historic Structure Report. Upon transfer of the Lighthouse, the USCG will retain ownership of the lens, radio beacon and associated equipment and require continued access to the Lighthouse to maintain this equipment.

Ultimate Treatment and Use

Use

The Dry Tortugas Lighthouse has served continuously as an aid to navigation since its light was first lit in 1858. Current cooperative agreements with the USCG call for this use to continue for the foreseeable future. These agreements primarily affect the lighthouse optic and are not anticipated to limit potential use of the Lighthouse or the Oil House.

The Park's 2002 General Management Plan Amendment (GMPA) calls for the resources of the Light Station to be preserved and protected according to the Park's authorizing legislation and also that they be managed to support operational needs and public visitation. An important outcome of the GMPA has been the establishment of management zones that prescribe the types and levels of visitor use and the amount of manipulation of the natural or cultural setting that is appropriate for different areas of the Park.

Two management zones have been applied to Loggerhead Key. The Historic Preservation/Adaptive Use (HP/AU) Zone encompasses the resources of the Light Station in the center of the Key and the remainder of the island falls within a Research Natural Area (RNA) Zone. The HP/AU zone applies to those areas within the Park that contain historic and cultural resources and where the visitor experience will be primarily focused on educational and interpretive opportunities.

The parameters established by the GMPA for Loggerhead Key's HP/AU zone, limit the number of visitors that can be on the island per day to 24 (12 originating from the commercial carriers and 12 from private vessels). This number has been established as an initial baseline that may be adjusted in the future pending the results of a monitoring program and the completion of the re-vegetation project.

Permissible uses within Loggerhead Key's HP/AU zone include unrestricted picnicking, hiking, and exploring. The GMPA currently restricts visitor access to the buildings until such time as the structures can be "made safe" and the appropriate programs are in place to support this level of use.

Since the transfer of Loggerhead Key and the Light Station to the National Park Service in 1992, public visitation to the Key has been limited. Existing concession agreements do not include provisions for transporting visitors to Loggerhead Key. Therefore the site is only accessible to those reaching the island by private boat or through special arrangements with the National Park Service.

Looking forward, the Park administration is exploring ways that it can increase public access to the Key through renewed concession agreements. In addition, consideration is being given to using the Light Station as a "base of operations" for an expanded program of research.

Under these scenarios, the use of the Lighthouse is not anticipated to change. It will serve a dual purpose as an active aid to navigation that will also be interpreted as the central component of the Light Station and as a significant example of Pre-Civil War maritime architecture. It should be noted that the ultimate treatment and use of the Lighthouse must not interfere with its primary function as a navigational aid.

Challenges of Increased Public Access

Visiting Loggerhead Key and exploring the resources of the Dry Tortugas Light Station provides an impressive, and for some, likely a once-in-a-lifetime experience. With this said,

increasing public access to the site carries with it several limitations and challenges.

Assuming that transportation to the Key is resolved, visitors to Loggerhead will likely disembark onto the main dock on the east shore of the island and then walk a short distance on concrete walkways to the Light Station. The incline from the dock to the Light Station is gradual but in certain areas exceeds permissible slope limits for wheelchair use. In addition, wind-blown sand often covers the surface of the concrete walks.

Providing full access to the interior of the Lighthouse and Oil House to the mobility impaired may not a practicable expectation. The limited space within the Lighthouse, Oil House and connecting passageway, as well as the height of the existing thresholds, make this unfeasible without extensive modifications to the historic fabric. Therefore as discussed in the Requirements for Treatment, an "alternative minimum" approach to accessibility should be explored to extend the interpretive experience to those who cannot witness it firsthand.

The extent to which it is practical to permit able-bodied visitor's to explore the interior of the Lighthouse and ascend the tower must also be considered. The Watch Room and Lantern levels at the top of the tower have a limited physical capacity. It is estimated that no more than four or five people could be comfortably or safely accommodated within these spaces. In addition, these spaces are accessed by a non-compliant stair and a small access hatch in the Watch Room floor. Another factor to be considered when evaluating the practicality of visitors accessing the top of the tower includes the physical exertion required to ascend the tower, the warm climate of the site, the temperatures within the tower, and the limited access to medical assistance in case of an emergency.

Additionally, the wedge shaped stairs and the decreasing capacity of the landings will limit the number of visitors that can be in the stair tower at the same time. It would be undesirable to have larger groups passing on the stairs or congregating on the landings. This may require that access to the interior of the tower be limited to a few small groups that can use the landings to let other groups pass. Managing visitor use in this way may require supervision by several volunteers or staff.

The low light level in the stair tower is also a safety consideration that will need to be addressed if visitors are allowed to access the Lighthouse interior.

The windows are another component that has to be considered when assessing visitor use and safety. Since the windows are accessible from the landings and should remain operable, screens should be installed to prevent visitors from dropping objects from the windows. The existing windows are loose in their frame and do not have integral screens. These factors, along with the importance of ventilating the tower interior must be taken into account when designing replacement window units.

Finally, the Watch Room level gallery would not be considered safe for visitor use unless modifications are made to the railing to address safety concerns. The addition of a higher railing with closely spaced balusters on the galleries would have a visual impact on the character of the Watch Room/Lantern. An option that may be less visually intrusive would be to span a mesh grid between the widely-spaced balusters.

Recommendation: Taking into consideration both life safety and visitor experience, it is recommended that groups of no more than 4-5 persons be allowed in the Watch Room/Lantern level at one time. Additional small groups could be held on intermediate landings while others descend the tower stairs.

The Oil House and its additions have become the control center for the island's critical utility systems. Utility-related components and equipment are housed in the additions where they can be secured and protected from storms. There are several electrical panels associated with the photovoltaic system mounted to the south wall of the Oil House. If consideration is given to allowing visitor access to the Oil House for interpretive purposes, it would be necessary to relocate these panels.

Building Fabric

The appearance of the Dry Tortugas Lighthouse has changed little since the early

1870s when the black and white painted daymark was first applied. A great majority of the existing building fabric dates to the Lighthouse's original construction. Architecturally the Lighthouse is a relatively simple structure with a few basic components; the brick masonry tower penetrated by several window openings and a door at grade, the stone stair treads, the Lantern structure made up of iron and glass and finally, within the Lantern, the iron lens pedestal and platform assembly. Changes to these building elements have been limited. In some cases minor repair or replacement has been made as these components have worn out with age or have been damaged by storms. In other cases, advancements in technology have resulted in the removal and replacement of original equipment.

The structure's largest mass of material, the load-bearing, brick masonry walls, remain intact having only been intermittently repointed and repaired. The daymark, first applied ca. 1870 has been repainted a number of times throughout the history of the structure. Today its intensity has been diminished due to removal of the paint in 1967 and subsequent weathering.

The existing windows in the tower were installed in 1982 by the USCG. The windows are bronze aluminum, one-over-one, double-hung units that differ greatly from the multi-pane, wood, double-hung windows that were present in the tower from the late nineteenth century through the mid twentieth century. In addition, the wood shutters that were installed over the windows following the 1873 hurricane were removed in 1967 and not reinstalled as part of the most recent window replacement projects. The 1967 and 1982 installation of aluminum windows in the Lighthouse were reactions to an immediate need and were not completed in a manner consistent with the Secretary of the Interior Standards. Although installed during the USCG era, the existing windows are not architecturally significance and they detract from the Lighthouse's historic character.

The recently repaired Lantern exists today in a state of partial completion. The 2009 project repaired the deteriorated iron skeleton of the Lantern and replaced the copper panels of the dome roof but did not have sufficient funds to reconstruct the integral gutters and replicate and reinstall the vent ball and lighting rod. Once the full scope of the repair project has been completed, the Lantern will appear much like it did when it was originally constructed.

The interior features of the masonry tower date from its original construction. The masonry walls, newel, and blue slate stair treads are original fabric and remain intact. At the Watch Room and Lantern Levels the lens pedestal, including the mercury float assembly date from 1910-1911 when the original first-order lens was replaced with the second-order bivalve lens. These components represent an important milestone in the evolution of the lighthouse and are historically and architecturally significant.

In contrast with the Lighthouse, the Oil House has experienced extensive modifications that have impacted the building's original form, its fenestration and interior and exterior finishes. With the exception of the masonry bearing walls, little of the Oil House's original building fabric has survived. The modifications made to the Oil House are indicative of its evolving use and in some cases have acquired historical importance. For example the concrete passageway and the interior wall finishes that survive below the existing wood paneling date from the 1920s when the Oil House was converted to a Radio Beacon House. More recent changes to the Oil House such as the installation of aluminum windows and the construction of the concrete block addition on the south elevation have diminished the historic character of the structure.

Recommended Ultimate Treatment and Use

It is recommended that the ultimate treatment and use of the Light Station resources remain consistent with the guidelines established in the GMPA for the HP/AU Management Zone. As the name implies, this zone calls for the preservation, protection and interpretation of cultural resources yet recognizes the need to adaptively use these resources to accommodate critical functions, such as housing, sheltering essential equipment and

maintaining the Lighthouse optic as an active navigational aid.

The Recommended Ultimate Treatment therefore proposes actions that will repair deteriorated building fabric while rehabilitating the exterior and interior of the Lighthouse. It is further recommended that key features of the Lighthouse that are in need of replacement, such as the windows, be returned to their pre-1967 appearance.

Although not a pivotal date in the history of the Lighthouse, the 1967 restoration date was chosen because it was during this year that significant modifications were made to the Lighthouse and Oil House that removed important character-defining features and either did not replace them or installed new components that were not in keeping with the historic character of the structures. This philosophy of repair was continued during the last decades of the twentieth century. It is therefore recommended that this date be used as a framework for making design and treatment decisions. This approach has the following advantages:

Lighthouse

- Addresses deferred maintenance and needed repairs to prevent further deterioration or loss of historic fabric.
- Preserves in place for interpretation, building fabric from a broad spectrum of the Lighthouse's history.
- Removes modifications made during the recent past that are in poor condition and are not in keeping with the historic character of the Lighthouse (such as the aluminum windows and associated sill modifications).
- Restores character defining features such as the multi-pane, wood windows and shutter assemblies that were present prior to 1967 and throughout much of the structure's history. Replacement units should address considerations of durability, visitor safety and tower ventilation.
- Retains the option to reinstall the second-order bivalve lens if feasible.
- Potentially removes the deteriorated steel access ladder mounted to the Lantern exterior.
- Allows for the continued reconstruction of the Lantern roof and reinstallation of the vent ball and lightning rod.

Oil House

- Addresses deferred maintenance and needed repairs to prevent further deterioration or loss of historic fabric
- Preserves in place for interpretation, building fabric from a broad spectrum of the Oil House's history.
- Removes modifications made during the recent past that are in poor condition and are not in keeping with the historic character of the Oil House (such as the windows)
- Restores important character defining features such as the multi-pane, wood windows and shutter assemblies that were present prior to 1967.
- Returns the interior of the Oil House to its 1920s appearance by removing wall and floor finishes installed during the recent past that are not in keeping with the historic character of the building.
-

This approach has the following disadvantages:

Lighthouse

- Removes tangible evidence of modifications made during final the USCG and NPS eras.

- Potentially removes VRB-25 optic installed by USCG in 1996.

Oil House

- Potentially removes tangible evidence of modification made during the USCG and NPS eras.
- Potentially removes the south addition to the Oil House constructed in 1982.

Alternatives for Treatment and Use

Use

The Dry Tortugas Lighthouse was designed for a single purpose: to elevate and house a beacon that would warn mariners of hazardous sailing conditions. It continues to be used for this same purpose today.

The architecture of the Lighthouse is efficient, responding solely to this narrow function. The structure contains only three spaces, the stair tower, the Watch Room and the Lantern. Potential to adapt the structure for alternative uses, other than interpretation, is therefore limited.

The Oil House and its additions currently house utility-related equipment and panels. The interior spaces of the original two-story Oil House are used only minimally for this purpose. Therefore opportunity exists for restoring the interior only for interpretative programming. Given that the surviving historic fabric generally dates from the 1920s, when the building was converted to a Radio Beacon House, this would be the most logical period on which to focus.

Alternatively, increased use and visitation to the site will likely require the upgrade or expansion of existing utility systems, and possibly the addition of more equipment. With this said it may be prudent to reserve these currently underutilized spaces to accommodate future needs.

Treatment

The proposed ultimate treatment recommends restoring certain features (primarily the windows) of the Lighthouse to their pre-1967 appearance. This would be done in order to remove fabric from the recent past that diminishes rather than enhances the historic character of the resource. This approach also supports the potential reinstallation of the second-order bivalve lens removed in 1986.

An alternative treatment approach would be to preserve all existing fabric, including that from the recent past, regardless of its aesthetic character.

Recommendations for Treatment and Use

Dry Tortugas Lighthouse

Masonry

An assessment of the Lighthouse conducted in 1984 by National Park Service personnel identified the deterioration of the Lighthouse's mortar joints as a condition requiring treatment. The conditions observed today match precisely those described in the assessment. Both the exterior and interior mortar joints of the Lighthouse are eroding or becoming friable and falling from the wall as fine sand or powder. This condition varies in severity from approximately $^1/_8$" to 1" loss of mortar depth, and seems to affect the head joints more than the bed joints. On a positive note, the mortar that remains is stable, very hard, and well bonded. Although this condition is not currently jeopardizing the stability of the structure, there are areas of severe mortar loss, particularly at the interior newel where, if left to progress, may in the short term result in bricks becoming loose or possibly falling from the wall.

Although the processes causing this condition are not entirely known, the movement of moisture through the wall or possibly surface condensation are probable contributing factors. Based on the previous deteriorated condition of the Lantern and past problems with the Watch Room gallery floor, it is likely that moisture is presently, or has in the past, been able to enter the wall system at the top of the tower.

Ideally a comprehensive program of repointing and repair should be conducted wherein the exterior and interior masonry walls of the tower are repaired in a single effort. This approach would be the most cost effective because of the significant costs associated with contractor mobilization and the erection of scaffolding. If funding limitations and sequencing require a phased approach, repair should be focused on those areas of the tower interior that are exhibiting the most severe deterioration. Phasing the exterior work is less practical because scaffolding would need to be erected to access the most deteriorated areas unless the exterior repairs are performed from a hanging scaffolding or basket as has been done in the past (which has its own limitations).

Loss of mortar to a depth of more than $^5/_8$" is a general rule of thumb that can be used to determine which areas require treatment in the short term. This is not to say that individual spot repairs should be made at each and every location where the mortar has receded beyond this point, but rather that this measurement be used to identify broad areas that can be repointed in their entirety.

Based on inspections made during the development of the HSR we estimate that approximately 35% of both the interior and exterior of the Lighthouse should be repointed as a priority.

Recommendations for design development and masonry repair.

- Verify construction of the masonry walls through boroscopic examination.
- If necessary, make repairs to Watch Room gallery floor to prevent infiltration of moisture into tower masonry wall system.
- Investigate the possibility of ventilating the interior voids of the masonry wall if found to be present during the boroscopic investigation.

- Identify areas of critical mortar loss both on the exterior and interior of the tower. The most severe loss of mortar on the exterior walls appeared to be confined to the top third of the tower. It may be necessary to dry brush the interior walls to remove mortar fall out so that the amount of mortar loss can be accurately measured.
- Formulate repointing mortar to match the composition of the existing mortar. The results of the mortar analysis identified that the historic mortar is a mixture of one part natural cement to 1.5 parts local carbonate sand.
- Repair corroded iron elements embedded within the masonry prior to conducting repointing. (See Watch Room recommendations below).
- Conduct paint removal (see discussion below)
- Repoint all exterior mortar joints within defined areas of the Lighthouse (to be more specifically identified during final design as described above), comprising approximately 35% of the overall area.
- Repoint all interior mortar joints within defined areas of the Lighthouse (to be more specifically identified during final design as described above), comprising, approximately, 35% of the overall area.
- Coordinate the extent of repointing with lead-containing paint removal and reapplication of finishes, described below.

The **hairline vertical cracking** below the Watch Room floor plate is a condition that should be monitored. This phenomenon has been identified at numerous lighthouses and has been attributed to a variety of causes from lighting strikes, to wind loading, to stresses caused by the corrosion of embedded steel components, and thermal expansion and contraction. In some cases vertical cracking of the tower masonry was identified early in the history of the structure. It is unknown if the observed vertical cracking in this structure is active or dormant. The extreme build-up of finishes at the fifth and sixth levels suggest an effort to mask a recurring condition.

Recommendation: Begin a program of crack monitoring and conduct further investigation once the painted finish has been removed. The use of deep penetration mortar may be a repair option that can be determined once the scope and severity of the condition is confirmed.

Reapplying the Daymark and Interior Finish

According to historic documentation, the existing painted finish of the tower was applied in 1967 following a program of sandblasting that removed all previous layers of finish. A 1984 analysis of the paint confirmed that only two layers remained on the tower and that the paint was a "lead-zinc based acrylic-polyvinyl acetate mixture."

Since this time weathering and deterioration have reduced the intensity of the daymark and started to expose the underlying brick. The reapplication of the daymark and interior finish are important not only because they are significant character-defining features of the structure but also because the applied finish will protect the masonry once repaired.

Removing the existing paint prior to applying a new finish is an important consideration. Although it may or may not be necessary to remove the paint in order to achieve good adhesion, improving permeability and ridding the structure and the site of lead-based paint should remain a priority. Permeability of the existing finish is not a concern on the exterior where only a few weathered layers are present. It may be a concern however on the interior of the Lighthouse, at the upper levels, where there is significant paint build-up.

In recent years the USCG has conducted surveys to determine the extent of lead contamination in the soils around the base of the Lighthouse. The lead contaminated soils have not been removed as of the date of this report. To avoid recontamination of abated soils during repair efforts, we recommend removing the lead-containing paint before repairing and refinishing the Lighthouse exterior. The limited availability of potable

water and the logistics of collecting and transporting the hazardous paint remnants from the island should be given careful consideration when developing a program for removal. If the decision is made not to remove the existing paint, an adhesion test should be performed before applying a new finish.

As part of the current study, paint samples were taken from that portion of the exterior wall of the Lighthouse that is protected within the Concrete Passageway. Analysis revealed a range of paint layers applied over the original finish of the structure since it was first painted in the 1870s. The earliest layers of finish appear to be a lime wash followed by layers of paint. Because the Watch Room gallery was not accessible at the time of inspection, the upper portion of the tower was not sampled. It is likely that the original black finish would have been achieved using paint or a carbon black loaded lime wash. The key factors in selecting a finish for the Lighthouse exterior will be compatibility with the historic masonry, breathability, durability and maintenance requirements.

Recommendation: Remove existing interior and exterior finishes, and, after repair and repointing of the masonry, renew the daymark and interior finishes. It is recommended that a lime wash be applied to the tower interior and exterior using traditional renders (both black and white) such as the mineral coatings and renders by Keim. These would provide a breathable coating that would be compatible with the historic masonry and have an expected longevity measured in decades, as opposed to a fraction of that for ordinary paints.



Figure 90. Undated view of the Lighthouse showing four-over-four double-hung windows and wood shutters.



Figure 91. Pre-1967 image showing four-over-four, double hung windows with shutters.

Windows

The USCG installed the existing tower windows in the early 1980s to replace aluminum awning windows installed approximately 15 years earlier. (Prior to 1967, the windows were four-over-four, double hung sash with wood shutters. Moving back through time from this point, historic images and drawings suggest that several generations of multi-light sash were installed in the tower.)

The replacement windows installed in the 1980s were described at the time as "heavy duty" units designed to better withstand the high winds and severe climatic conditions of the region. No attempt was made to replicate the four-light, double-hung windows that were present in the tower throughout much of twentieth century, nor did the replacement units incorporate the wood shutters that had been present on the windows from the 1870s through to 1967.



Figure 92. Close-up of window and shutters present in Lighthouse prior to 1967.

The existing bronze anodized aluminum windows in the tower are experiencing significant condition problems. All of the units have become loose or unseated from their frames and several are missing panes. One unit has been removed and replaced with a plexi-glass insert.

Recommendation: Given the harshness of the local environment, selecting a durable weather-resistant and maintainable replacement window is of primary importance. A wood replacement window would most closely match the historic condition. However, the desired level of durability is simply not available from standard wood window manufacturers and therefore only a custom fabricated, custom finished window unit constructed of a weather- and termite-resistant durable species, such as teak, would be appropriate. A similarly durable species should be used for replacement shutters.

Alternatively it is recommended that the existing windows be replaced with new fluoropolymer coated aluminum units having profiles and sightlines in keeping with the pre-1967 four-over-four double-hung wood units. The aluminum units should also be selected with quality and durability as the primary criterion. The windows and shutters in the tower should be painted white and the window and shutter at the Watch Room level should be painted black (see Figure 90).

Tower Door

The existing tower door is not original and was likely installed in an effort to "make do" with that which was available. The paint analysis reveals that the door frame has several more layers of paint than the door, and therefore likely predates installation of the door. However, the 30 to 35 layers of paint on both the door and door frame suggest that they have both been in place for some time or that they could have been moved from another location. Assuming repainting occurred at 2-3 year intervals the door and frame were installed circa 1910 – 1940.

Only the mortise lock and the interior escutcheon plate remain on the tower door and no documentation could be located showing the door with a full complement of hardware. Paint ghosting suggests that there was once an exterior escutcheon and it is likely that the door included a handle set. It is recommended that these items be replicated and installed to improve security and operability.

The existing mortise lock may provide additional information about the age of the door. Often these components contain manufacturer information and serial or model numbers that can be used to date the hardware.

Stairs

We recommend that the two failed stair treads that are being temporarily stabilized be

replaced with matching treads. This will require the removal of a small amount of masonry at the exterior wall and newel. A source for acquiring blue slate slabs that match the dimensions of the original treads should be identified. We did not observe any other weakened or broken treads.

We recommend that the stair rail installed in 1967 be repaired where the anchors have failed. This may require fabrication of new anchors and sections of rail.

Watch Room

There are several condition issues impacting the Watch Room that require attention. The most critical is the significant ($^1/_4$" wide) **vertical crack** that extends through the Watch Room wall along its east elevation. Similar conditions were identified during the 1984 assessment and linked to the probable corrosion of tie rods that were extended down through the masonry wall as part of the repairs made following the 1873 hurricane and again in the 1930s. The corrosion and resulting expansion of these embedded elements imposes stresses on the masonry that cause cracking of the wall. It is anticipated that if this issue is not addressed the condition will worsen and accelerate. The 1984 study recommended that the tie rods be exposed, inspected and treated with an anti-corrosive coating, but it is unknown if these repairs were implemented.

Recommendation: Given that the significant crack on the east elevation extends through the wall to the exterior, it is serving as a pathway for water to infiltrate the structure. If left unchecked, this moisture will continue to corrode the iron elements in the Watch Room and, if filtering down into the masonry of the tower, will continue to deteriorate the bricks and mortar. We recommend that at a minimum the crack on the east wall be further explored to determine its origin and, if found to be associated with corrosion of the embedded anchor rods, that the rods be exposed through the removal of masonry and treated.

The **existing stucco finish** applied to the Watch Room walls was not analyzed as part of the current investigation. However, it appears to be a Portland cement based mixture. The stucco is extremely hard and grey in color. The finish exhibits wide-spread hairline cracking. Although hairline cracking of the stucco was observed universally throughout the Watch Room, no other obvious signs that individual anchor rods are imposing stresses on the masonry were noted.

Removal of the existing stucco would allow close inspection of the underlying masonry; but removing the Portland cement-based finish may result in considerable damage to the historic brick. We recommend that the existing stucco be left intact and repaired as required unless extensive removal of the existing stucco is necessary to facilitate masonry repair.

If the stucco is removed, reapplication of the stucco finish should take place using a formulation that is based on historic precedent and more compatible with the historic masonry. The stucco finish coat should have integral color so as to eliminate frequent repainting.

Another issue impacting the Watch Room is the **corrosion of the sill plate and I-beams** supporting the floor plate. Significant corrosion of the I-beams at their ends was noted during inspection. It appears that adequate cross section remains, but this condition should be treated as a priority. Further corrosion and expansion of these embedded iron elements will quickly result in damage to the historic masonry and greatly increase the cost of future repair.

Recommendation: As is the case with the corroded anchors in the Watch Room walls, treatment should include removal of the masonry around these elements to expose those surfaces embedded in the walls, blast cleaning of the iron to remove the built-up corrosion, and then application of an appropriate anti-corrosion coating. A zinc-rich primer and two coats of catalyzed epoxy should be applied to other interior areas where metals are experiencing corrosion. In locations where the corroding metal is exposed to sunlight, such as the Lantern gallery floor plates, a urethane or fluoro-urethane should be applied as the final coat.

The **arched iron door** that provides access to the Watch Room gallery was removed and

replaced with a plywood insert during the recent Lantern repair project. The door had experienced severe corrosion at its base and had broken free from its hinges. According to the contractor that removed the door, repair is not feasible. The door, which is being stored at the Everglades National Park collections facility, was inspected as part of the current investigation. The bottom third of the door is severely deteriorated and the hinges broken. Repair would require splicing new material on the bottom portion of the door and casting new iron to repair the fractured hinges. A repair approach may not be practicable.

Recommendation: The Watch Room door is a significant character-defining feature. It is recommended that a replica of the historic door be fabricated and installed.

The **exterior walls of the Watch Room** are painted stucco. The painted finish of the walls is fading and peeling exposing the light-colored stucco beneath. The stucco is also experiencing cracking throughout much of its surface. Removal of at least some of the stucco may be necessary to investigate and repair the large crack and embedded elements. If it is found that the exterior stucco is also Portland cement based, the same treatment approach recommended for the interior should be applied to the exterior. As a means to reduce maintenance, we recommend a stucco system with integral black coloring. In conjunction with these repairs, it is further recommended that the circular vents in the Watch Room walls be made operable to promote adequate ventilation of the Watch Room and Lantern.

Finally, both the **Watch Room and Lantern gallery railings** are experiencing corrosion, primarily at their connection points. Neither of the non-historic railings, which were installed in 1985, is compliant with applicable codes. If it is the intention of the National Park Service to allow visitor access to the Watch Room gallery (The Lantern-level gallery is only accessible by exterior-mounted ladder) modification of the railing may be required given the existing condition constitutes a "distinct life safety hazard". Design of a new railing or guard that complies with the IBC for strength and attachment, height (42") and opening limitations would impact the visual character of the Lantern. Therefore design options should be explored that address life-safety concerns while at the same time maintain the historic character of the Lantern.

Options for addressing opening limitations may be to preserve the main supports and use a small diameter intermediate baluster or mesh screen to span between balusters. Given the exposed location, a glazed panel option would not be practical. If the Watch Room or Lantern galleries are not to be opened to the public, we recommend that connection deterioration be repaired and corrosion be arrested with zinc-rich/epoxy/urethane coatings mentioned previously. At all times, proper safety precautions should be taken when accessing the galleries for maintenance, repair or other purposes.

Lantern

The recent repair and reconstruction of the Lantern roof did not fully replicate the historic condition. Due to limited funding, a reduced scope of work was implemented that eliminated reconstruction of the roof edge and integral gutter system and replication of the vent ball and lighting rod. The historic vent ball and lightning rod removed from the roof during the repair project are severely deteriorated and cannot be reinstalled. These important historic features should be replicated and installed to complete the accurate reconstruction of the Lantern roof. We recommend that the Lantern roof repair project be completed, including roof edge, gutter, vent ball, and lightning rod.

Also associated with this project was the de-scaling and repainting of **iron components of the Lantern structure**. Many of the iron headers were deformed and weakened by severe corrosion. Although these members were de-scaled and painted as part of the recent repairs, it may be necessary to replace corroded headers with newly cast members. The contractor that completed the roof repair has recommended that all of the headers be replaced although only 6-8 have been severely deformed by corrosion. It should be noted that replacement of these components will be a labor intensive operation as the headers are incorporated into an interconnected "knuckle" where the vertical bar columns,

headers, roof rafters and gutter supports all come together. Repair of these headers should not be conducted in isolation but should be completed as part of a comprehensive project that includes completion of the copper roof. Replacement of the headers will require removal of a number of copper roof panels. Special attention needs to be paid to the isolation of dissimilar metals when conducting repairs to the Lantern's structural components.

Recommendation: It is recommended that the corroded and deformed headers be removed, and new headers be recast and installed.

The gallery and roof **access ladder** installed in 1978 is experiencing significant corrosion, especially at its connections. Given that a 1967 date is proposed for making treatment decisions, it is recommended that the access ladder be removed. During the recent restoration of the Lantern roof, a hatch was installed thus reducing the need for the ladder to provide roof access. A small ladder, more in keeping with the historic condition could be fabricated to provide a means of access between the Watch Room and Lantern galleries.

The **Lantern gallery floor plates** are experiencing moderate to severe pitting corrosion both in their field and at the joint between plates. These conditions do not appear to compromise structural integrity, but if left untreated will eventually lead to more significant deterioration and potentially costly repairs. In addition continued corrosion of the underside of the floor plates will stress and damage the masonry walls of the Watch Room. Treatment of the pitting corrosion generally includes blast cleaning the surface, and the applying a protective coating system (organic zinc primer, two coats of epoxy paint, and urethane topcoat). The underside of the floor plates requires this treatment promptly because it is here that the most significant corrosion is taking place and causing stress to the historic masonry at the top of the Watch Room walls. This same treatment should be applied to the lens pedestal components and Lantern stairs to remove and arrest surface corrosion.

The proposed ultimate treatment allows for the future **reinstallation of the second-order lens** that was installed in the Lighthouse in 1911 and removed in 1986. The return of this important character defining feature would greatly enhance the interpretive experience and historic character of the Lantern. We recommend that the feasibility of obtaining and reinstalling the second-order bi-valve lens be further investigated.

Dry Tortugas Oil House

Exterior Masonry Walls

The masonry exterior of the Oil House shows no signs of significant deterioration. There remains numerous small iron anchors embedded in the masonry in various locations that if left to corrode may cause localized harm to the masonry. We recommend that the anchors be removed and the voids left in the masonry be pointed and painted. Documentation of the anchors and their location should be conducted before their removal.

The painted finish of the exterior walls has been well maintained and also shows no signs of significant deterioration. Removal of the existing exterior paint may not be necessary (since it is currently serviceable), but the finish likely contains lead and therefore consideration should be given to its removal. Removal of the paint would allow close inspection of the underlying masonry.

Roof

The roof of the Oil House is performing well and therefore its replacement is not necessary at this time. Composition shingles or possibly asbestos shingles, similar in appearance to those currently installed on the building can be seen in the pre-1969 image below (Figure 92). Therefore when replacement is necessary it is recommended that the composition shingles be reapplied.

Windows and Doors

Like the Lighthouse, the Oil House received new windows in 1967 and 1982. A single awning window remains from the 1967 installation and the remainder of the windows are bronze aluminum awning units similar to those installed in the Lighthouse. The hardware on all of the existing windows is deteriorated or damaged and in most cases the windows are no longer operable. We recommend that the windows be replaced in the short term.

Available documentation from the 1920s conversion of the Oil House shows four-over-four, double-hung windows installed at the time (see Figure 26). Consistent with the proposed ultimate treatment, we recommend that existing aluminum units be removed and four-over-four, fluoropolymer coated

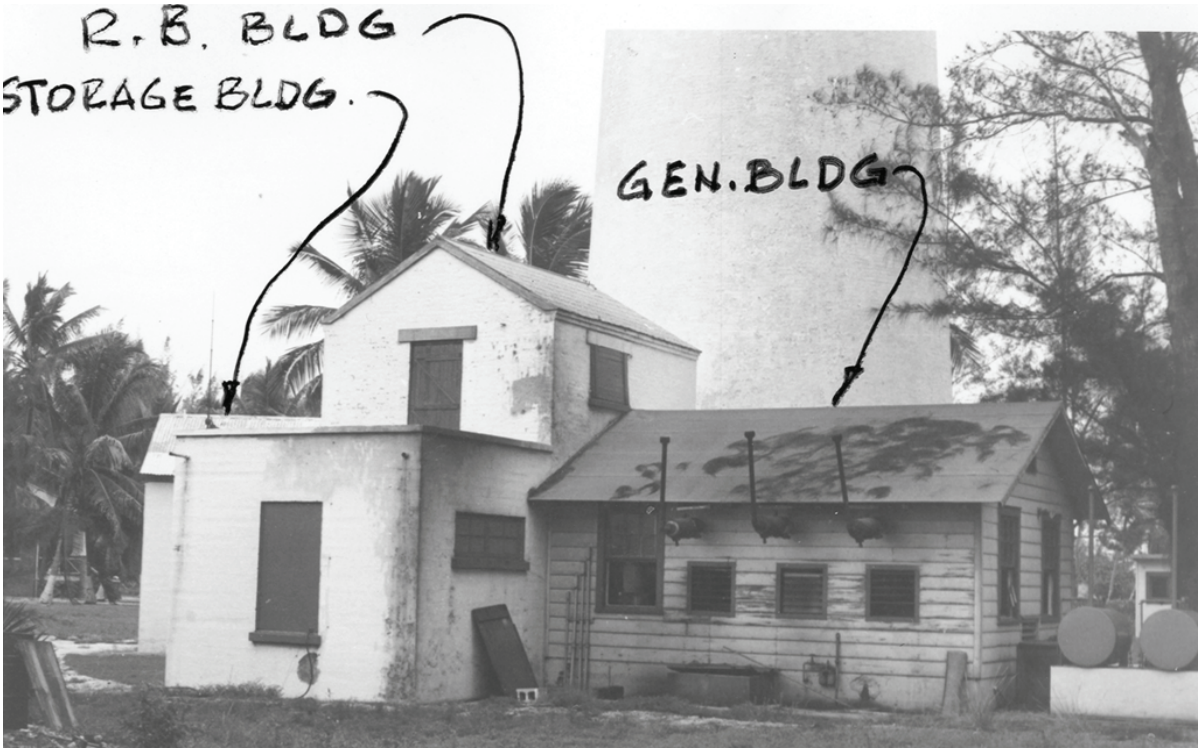


Figure 93. Pre-1969 image of Oil House showing wood-frame addition and shutters on the Oil House windows.

aluminum double-hung units be installed similar to the treatment prescribed for the Lighthouse. We also recommend that the vertical board shutters with "Z-bracing" that were present on the Oil House be replicated and installed as part of the window replacement (see Figure 93).

No documentation exists that verifies when the existing door of the Oil House was installed. We recommend that the existing door be preserved and repaired as necessary.

Oil House Interior

Currently, the interior of the original Oil House structure is underutilized; therefore treatments may be contingent upon its ultimate use. If it is anticipated that the interior of the Oil House will be accessed as part of an interpretive program, we recommend that the existing faux wood paneling be removed to reveal the 1920s bead board wall finishes and the electrical panels be relocated to the south addition. This modification, as well as the installation of the four-over-four, double-hung windows would return the original portion of the Oil House to its pre-1967 appearance.

It is also recommended that if the building is interpreted that the existing vinyl tile flooring on the second floor be removed and 1" x 6" wood flooring be installed per the 1926 architectural plans.

Concrete Passageway (1927)

The reinforced concrete passageway exhibits initial signs of deterioration. In a few areas the embedded reinforcing has begun to corrode, resulting in spalled concrete. This initial deterioration now provides a pathway for moisture to infiltrate the concrete and further corrode the embedded reinforcing. This condition will continue to worsen and accelerate if it is not addressed. The longevity of reinforced concrete structures in a marine environment was a concern when the passageway was first built in 1927 and continues to be a consideration today. Unless diligently maintained, it is likely that the structure will continue to succumb to the effects of the corroding and expanding reinforcing, resulting in deterioration similar to that occurring on the Dry Tortugas Boat House.

The preservation of reinforced concrete structures in marine environments is a challenge that requires diligent attention and intensive maintenance. For these reasons it may not be practicable to preserve the existing structure in its current state for the long term.

We recommend the following steps to repair the existing spalled concrete;

- Confirm the integrity/water tightness of the Passageway roof by flooding it with water and looking for leaks through the concrete slab. If integrity of roof is compromised, replace roof.
- chip away all loose concrete at spalled areas,
- remove concrete to exposing all surfaces of the rebar,
- square the edges of the concrete repair area,
- clean rebar to a bright finish with wire brush,
- paint rebar with corrosion-inhibitor / bonding agent,
- patch hole with special latex modified compound appropriate for use in marine environments.

The interior and exterior painted finish of the passageway is deteriorated. We recommend that it be repainted following repair of the spalled concrete. This will provide another level of protection against moisture and salt infiltration.

West Addition to Oil House (1935-1941)

We recommend that the horizontal crack in the north and west walls be pointed and a crack monitor installed to determine if the structure is continuing to move. The crack does not appear to correspond with the location of internal reinforcing shown on the drawings and therefore may be the result of

foundation settlement. If it is found that the structure is continuing to settle, measures should be taken to stabilize the foundation.

There is currently no window in the rough opening on the west elevation. It is recommended that a new window be fabricated and installed in this opening as indicated in the original architectural plans (four-over-four, double hung unit) and as proposed for the two-story portion of the Oil House.

South Addition to Oil House (1982)

The south addition to the Oil House currently houses equipment associated with the various critical utility systems.

Given that a 1967 date is being used as a framework for making treatment decisions, technically the 1982 concrete-block addition should be removed and the gable-roof frame addition, present until 1969, be reconstructed. However unless the interpretive program calls for the precise restoration of the historic scene, this approach would not be recommended.

It is recommended that the 1982 addition remain in place as long as it is needed to house utility equipment.

Sources of Information

Bearss, Edwin C. *Historic Structure Report, Historical Data Section, Fort Jefferson: 1846-1898 Fort Jefferson National Monument.* 1983.

_____. *Shipwreck Study-The Dry Tortugas.* Washington, DC: Eastern Service Center-Office of History and Architecture, Department of the Interior, National Park Service, 1971.

Calder, Dale R. and Lester D. Stephens. *Seafaring Scientist: Alfred Goldsborough Mayor, Pioneer in Marine Biology,* Columbia, South Carolina: University of South Carolina Press, 2006.

Cipra, David L. *Lighthouses, Lightships, and the Gulf of Mexico.* Alexandria, Virginia: Cypress Communications, 1997.

Dean, Love. *Lighthouses of the Florida Keys.* Sarasota, Florida: Pineapple Press, 1998.

Ebert, James D. "Carnegie Institution of Washington and Marine Biology: Naples, Woods Hole, and Tortugas." Washington, DC: Carnegie Institute of Washington, 1985.

Florida Center for Instructional Technology, College of Education. "Florida's Role in the Civil War: 'Supplier of the Confederacy'." University of South Florida. http://fcit.usf.edu/Florida/cvl_war1.htm.

Holland, Jr., Francis R. *America's Lighthouses: Their Illustrated History Since 1776.* Brattleboro, Vermont: Stephen Greene Press, 1972.

Hurley, Neil E. *Lighthouses of the Dry Tortugas, An Illustrated History.* Aiea, Hawaii: Historic Lighthouse Publishers, 1998.

Johnson, Stuart and Richard Ramsden. *Rehabilitation Report and National Register Nomination for the United States Coast Guard Light Station Dry Tortugas Light Station, Loggerhead Key, Florida.* National Park Service, 1984.

Manucy, Albert. *A Constructional History of Fort Jefferson 1846-1874.* Atlanta, Georgia: National Park Service Southeast Region, 1961.

Organization and Duties of the Light-House Board and Regulations, Instructions, Circulars, and General Orders of the Light-House Establishment of the United States, Washington, DC: Government Printing Office, 1871.

Tag, Thomas. "The Early Development of the Fresnel Lens." U.S. Lighthouse Socieity, *The Keeper's Log,* Summer, 2005. www.uslhs.org.

_____. "The Sautter Lens Works Producers of the Fresnel Lens—Parts 1 and 2" U.S. Lighthouse Society, *The Keeper's Log,* Summer, 2005. www.uslhs.org.

U.S. Congress. *Light-house and Appropriation Bill. Lighthouse Board.* 32nd Congress, 1st sess., *Statues at Large of the United States of America, 1789-1873.* vol. 10, August, 1852.

_____. *Light-house and Appropriation Bill.* 34th Congress, 1st sess., *Statues at Large of the United States of America, 1789-1873.* vol. 11, August, 1856.

U.S. Lighthouse Board. *Registers of Lighthouse Keepers, 1845-1912.* National Archives and Records Administration Southeast Region, Morrow, Georgia.

_____.List of General Correspondence, 1791-1900. National Archives and Records Administration, Washington, DC. Record Group 26. NC-31. Series 38.

United States Coast Guard. Records Concerning Illuminating Apparatus, 1839-1960. National Archives and Records Administration, Washington, DC. Record Group 26. NC-31. Entry 59.

_____. Logbook of Lightstations. National Archives and Records Administration, Washington, DC. Record Group 26. NC-31. Entries 5, A1 330E, A1 330M, A1 330T, A1 330S, A1 330Z, A1 330AF,159D-159I.

_____. Studies and Surveys. National Archives and Records Administration, Washington, DC. Record Group 26. NC-31. Entry A1 345.

_____. Boards of Survey (Real Property) Case Files. National Archives and Records Administration, Washington, DC. Record Group 26. NC-31. Entries A1 99 and 99a.

_____. Light Station Files. National Archives and Records Administration, Washington, DC. Record Group 26. NC-31. Entry 381.

United States Department of Commerce. Recommendations as Aids to Navigation.National Archives and Records Administration, Washington, DC, Record Group 26 (These forms are filed within NC-31. Entry 51. Boxes 408 and NC-31. Entries A1 99 and 99a and occasionally among other records. They are standard appropriation request forms.)

United States Lighthouse Board. Dry Tortugas Clipping File. National Archives and Records Administration, Washington, DC. Record Group 26. NC-63. Entry 13.

United States Bureau of Lighthouses. National Archives and Records Administration, Washington, DC. Record Group 26. NC-31. Entry 51. Boxes 408 and 862.

APPENDIX A

Draft National Register Nomination

Museum Curator

H3223 (SER-OCR)

Memorandum

To: Acting Chief Historian, WASO

From: Deputy Associate Regional Director, Cultural Resources, Southeast Region

Subject: Submittal of National Register Nomination for Dry Tortugas Light Station, Dry Tortugas National Park

This nomination was initially prepared in 1984 by the Southeast Regional Office for the United States Coast Guard (USCG). The draft nomination was sent to the Seventh District Office of the Coast Guard that year. The USCG took no further action regarding the nomination. In 1989 the Superintendent of Everglades National Park requested that we seek a review of the nomination because the Coast Guard had expressed an interest in the National Park Service (NPS) assuming management of the Dry Tortugas Light Station on Loggerhead Key. In November 1989 a copy of the draft nomination was sent to the Chief Historian with a request for review by his office and the National Register. It was returned in early 1990 with specific comments and suggestions. For a variety of reasons nothing was done with the nomination until early 1993.

At that point we contacted the USCG and were able to retrieve the original photographs taken in 1984 and sent to their Miami office. Historian Len Brown went over the comments from the National Register staff, made the suggested changes, and updated it in accordance with National Register Bulletin 16A. We also field checked the photographs and determined that they still represented existing conditions. Marilyn Harper of the Register staff suggested this. Because the process of transfer of the property from USCG to the NPS had not been completed the nomination was not pursued for another year and a half. In November of 1994, the Superintendent of Everglades and Dry Tortugas National Parks indicated that we could submit the nomination.

Since it was reviewed five years ago, we ask that it be given a second review and, unless there are major problems, that it be entered on the National Register of Historic Places.

bcc:
Supt. EVER

LBrown: LB: 2/14/95

NPS Form 10-900
(Rev. 10-90)

OMB No. 1024-0018

United States Department of the Interior
National Park Service

NATIONAL REGISTER OF HISTORIC PLACES
REGISTRATION FORM

This form is for use in nominating or requesting determinations for individual properties and districts. See instructions in How to Complete the National Register of Historic Places Registration Form (National Register Bulletin 16A). Complete each item by marking "x" in the appropriate box or by entering the information requested. If any item does not apply to the property being documented, enter "N/A" for "not applicable." For functions, architectural classification, materials, and areas of significance, enter only categories and subcategories from the instructions. Place additional entries and narrative items on continuation sheets (NPS Form 10-900a). Use a typewriter, word processor, or computer, to complete all items.

1. Name of Property

historic name: Dry Tortugas Light Station

other names/site number: NA EVER

2. Location

street & number: NA _..cation ___
city or town: Loggerhead Key Dry Tortugas_____ _____ vicinity ___
state: Florida _____ code 12_ county: monroe_____ code 087____
zip code 33130___

3. State/Federal Agency Certification

As the designated authority under the National Historic Preservation Act of 1986, as amended, I hereby certify that this ____ nomination ____ request for determination of eligibility meets the documentation standards for registering properties in the National Register of Historic Places and meets the procedural and professional requirements set forth in 36 CFR Part 60. In my opinion, the property ____ meets ____ does not meet the National Register Criteria. I recommend that this property be considered significant ___ nationally ___ statewide ___ locally. (___ See continuation sheet for additional comments.)

_____ _____
Signature of certifying official Date

_____
State or Federal agency and bureau

In my opinion, the property ____ meets ____ does not meet the National Register criteria. (___ See continuation sheet for additional comments.)

_____ _____
Signature of commenting or other official Date

_____
State or Federal agency and bureau

4. National Park Service Certification

I, hereby certify that this property is:

____ entered in the National Register _____ _____
___ See continuation sheet.
____ determined eligible for the _____ _____
National Register
___ See continuation sheet.
____ determined not eligible for the _____ _____
National Register
____ removed from the National Register _____ _____

____ other (explain): _____

_____ _____ _____
Signature of Keeper Date of Action

5. Classification

Ownership of Property (Check as many boxes as apply)

___ private
___ public-local
___ public-State
X__ public-Federal

Category of Property (Check only one box)

___ building(s)
X__ district
___ site
___ structure
___ object

Number of Resources within Property

Contributing	Noncontributing	
_5____	0___	buildings
_1___	_____	sites
_4___	_2___	structures
_____	_____	objects
10___	2___	Total

Number of contributing resources previously listed in the National Register _____

Name of related multiple property listing (Enter "N/A" if property is not part o a multiple property listing.) _____

6. Function or Use

Historic Functions (Enter categories from instructions)

Cat:	Sub:
TRANSPORTATION	Water-related
DOMESTIC	Institutional

Current Functions (Enter categories from instructions)

Cat:	Sub:
TRANSPORTATRION	Water-related
DOMESTIC	Institutional

7. Description

Architectural Classification (Enter categories from instructions)

LATE 19TH/EARLY 20TH CENTURY AMERICAN MOVEMENT--Bungalow

OTHER--Lighthouse

Materials (Enter categories from instructions)

foundation Not Known

roofs Copper/Asphalt; Sheetmetal; Asphalt Shingle; Metal Shingle

walls Brick

other

Narrative Description (Describe the historic and current condition of the property on one or more continuation sheets.)

8. Statement of Significance

Applicable National Register Criteria (Mark "x" in one or more boxes for the criteria qualifying the property for National Register listing)

_X__ A Property is associated with events that have made a significant contribution to the broad patterns of our history.

____ B Property is associated with the lives of persons significant in our past.

_X__ C Property embodies the distinctive characteristics of a type, period, or method of construction or represents the work of a master, or possesses high artistic values, or represents a significant and distinguishable entity whose components lack individual distinction.

____ D Property has yielded, or is likely to yield information important in prehistory or history.

Criteria Considerations (Mark "X" in all the boxes that apply.)

____ A owned by a religious institution or used for religious purposes.
____ B removed from its original location.
____ C a birthplace or a grave.
____ D a cemetery.
____ E a reconstructed building, object,or structure.
____ F a commemorative property.
____ G less than 50 years of age or achieved significance within the past 50 years.

Areas of Significance (Enter categories from instructions)
_TRANSPORTATION_____
_ENGINEERING_____
_____
_____
_____
_____
_____
_____

Period of Significance ____1855 to Present_____
____1856 to 1858_____
____1920s_____

Significant Dates _1856-58_____
_1920s_____
_____

Significant Person (Complete if Criterion B is marked above)
_____NA_____

Cultural Affiliation _____NA_____
_____
_____

Architect/Builder _Captain Daniel P. Woodbury, U.S. Corps of Engineers_____

Narrative Statement of Significance (Explain the significance of the property on one or more continuation sheets.)

9. Major Bibliographical References

(Cite the books, articles, and other sources used in preparing this form on one or more continuation sheets.)

Previous documentation on file (NPS)
_NA preliminary determination of individual listing (36 CFR 67) has been requested.
NA_ previously listed in the National Register
NA_ previously determined eligible by the National Register
NA_ designated a National Historic Landmark
NA_ recorded by Historic American Buildings Survey # _____
NA_ recorded by Historic American Engineering Record # _____

Primary Location of Additional Data
___ State Historic Preservation Office
___ Other State agency
_X_ Federal agency
___ Local government
___ University
___ Other
Name of repository: __U.S. Coast Guard__Miami, FL._____

10. Geographical Data

Acreage of Property __1.85_____

UTM References (Place additional UTM references on a continuation sheet)

	Zone	Easting	Northing		Zone	Easting	Northing
1	17	305600	2725500	3	__	_____	_____
2	__	_____	_____	4	__	_____	_____

___ See continuation sheet.

Verbal Boundary Description (Describe the boundaries of the property on continuation sheet.)

Boundary Justification (Explain why the boundaries were selected on a continuatio sheet.)

11. Form Prepared By

name/title__Stuart Johnson, Historian (1984) _Updated Len Brown ,Hist. (1993)_

organization__SE Region,__National Park Service_____ date__January__1995_____

street & number__75__Spring__St.__SW_____ telephone_404-331-5989____

city or town____Atlanta_____ state_GA_ zip code __30303_____

Additional Documentation

Submit the following items with the completed form:

Continuation Sheets

Maps

A USGS map (7.5 or 15 minute series) indicating the property's location.
A sketch map for historic districts and properties having large acreage or numerous resources.

Photographs

Representative black and white photographs of the property.

Additional items (Check with the SHPO or FPO for any additional items)

Property Owner

(Complete this item at the request of the SHPO or FPO.)
name _____

street & number_____ telephone_____

city or town_____ state_____ zip code _____

Paperwork Reduction Act Statement: This information is being collected fo applications to the National Register of Historic Places to nominate propertie for listing or determine eligibility for listing, to list properties, and to amen existing listings. Response to this request is required to obtain a benefit i accordance with the National Historic Preservation Act, as amended (16 U.S.C. 47 et seq.).

Estimated Burden Statement: Public reporting burden for this form is estimate to average 18.1 hours per response including the time for reviewing instructions gathering and maintaining data, and completing and reviewing the form. Direc comments regarding this burden estimate or any aspect of this form to the Chief Administrative Services Division, National Park Service, P.O. Box 37127 Washington, DC 20013-7127; and the Office of Management and Budget, Paperwor Reductions Project (1024-0018), Washington, DC 20503.

The

Dry Tortugas are located approximately 65 miles west of Key West, Florida, and 90 miles north of Cuba. These islands are the last in the 150 mile string of reefs and islands that make up the Florida Keys. There is no fresh water on the islands.

Loggerhead Key, one of the ten islands in the Dry Tortugas group, is approximately 4,200 feet long and 700 feet wide at its widest point (photo no. 1, maps 1--USGS Quad. and 2). Early reports indicate that vegetation on this island, as in the rest of the Dry Tortugas, was sparse consisting of scrub brush, cacti, and grass. At present, however, the island has a relatively thick vegetative cover. This is likely attributable to the fact that scientists from the Carnegie Institute introduced a variety of non-indigenous plants in the first decade of this century including coconut palms, azaleas, date palms, rubber trees, bananas, and ornamental cacti.

Historically there have been only two complexes of structures on Loggerhead Key. The main complex, the Dry Tortugas Light Station, is the subject of this nomination and is described in detail later in this section. However, from 1904 to 1939, the Carnegie Institute of Washington, D.C. maintained several buildings and structures at the northern tip of the island which were used during the summers as a marine biology laboratory (drawing 5). This site is heavily overgrown and, except for one ruined frame building, no structures survive. There are still several very deteriorated concrete specimen tanks and a plaque erected in honor of the first director of the laboratory, Alfred G. Mayer. The property lacks physical integrity and it does not appear that it would meet National Register criteria. Therefore it is not included in this nomination. However it should be assessed under Criteria D as an archeological property.

The Dry Tortugas Light Station is situated near the center of the island. Within the boundaries of that portion of the Station being nominated to the National Register are 12 structures (drawing 3). Of these two post-date World War II, and are considered to be intrusions. The rest of the structures date from 1856-58, the period of original construction, and the 1920s, a period in which the Lighthouse Service modernized the station to a considerable extent. A description of each structure (including intrusions) within district boundaries follows. One building outside the district is also described. This is the generator building that was constructed in the early 1960s.

A. **Lighthouse** Drawings: 2 to 5

Built in 1856-58, the Dry Tortugas Lighthouse is a conical shaped brick tower that is 150 feet in height and topped by a lantern containing a first order lens. Walls at the base of the lighthouse are approximately 8 feet 9 inches thick, and the diameter of the tower at that point is approximately 28 feet. From the base a winding staircase of cut granite blocks leads to a watch room

beneath the lantern. The diameter of the tower at this point (to the exterior surface of the watch room walls) is approximately 13.5 feet. Beginning approximately 12 feet beneath the watch room, the exterior of the tower is corbelled out to form the floor of an exterior gallery around the watch room. Resting atop the watch room is an iron lantern with a polygonal arrangement of windows. The roof and finial are of copper and have been coated with roofing asphalt. There is a narrow gallery around the lantern. The bottom half of the tower is painted white, while the upper half is painted black. This color scheme is not original, but apparently dates to about 1984.

U.S. Corps of Engineers Captain H.G. Wright, the officer in charge of construction of Fort Jefferson on Garden Key, developed schematic plans for the lighthouse in 1855. More detailed drawings of the lighthouse as well as other structures in the complex were produced in 1857, apparently by Wright's successor at Fort Jefferson, Captain Daniel P. Woodbury. These drawings show that the lighthouse has changed little since originally constructed.

Aside from routine maintenance, the only substantive repair of the facility came as a result of an 1873 hurricane which necessitated in 1875 the virtual reconstruction of a nine foot section of the tower directly beneath the lantern. This was accomplished by cutting out the existing masonry in narrow vertical sections and rebuilding each section before moving on to the next. Other repairs included the extension of the lantern anchors downward into the masonry being reconstructed to better secure the lantern to the tower. These repairs cost $75,000.

Construction of the Dry Tortugas Lighthouse was completed in 1858 with the installation of a first order Fresnel lens supplied by L. Sautter and Company of Paris, France. This lens was illuminated by oil lamps and its range was 20 miles. Initially the character of the light was fixed white, but in 1893 the character was changed to fixed white with a fixed red section. In 1909 the Lighthouse Service purchased a new first order bivalve lens from Henry Lepaute of Paris, France. The next year the character of the light was changed from fixed to flashing, and in 1922 parallel screens for the bivalve lens were installed. Sometime after World War II, the Coast Guard converted the illuminating apparatus for the lens to electricity. The light had a nominal range of 28 miles. The Coast Guard removed the classical lens in February 1987 and replaced it with a new automated system consisting of a rotating 24" high intensity lens with two emergency lights. The original lens is at the National Aids to Navigation School USCG Reserve Training Center, Yorktown, Virginia.

B. **Bosun's Workshop** (Former Oil Storage Building) Drawings 3 and 8

This 16' by 14' one story structure of formed concrete was built in 1926 to replace the original oil storage building that had been converted to house radio equipment. The roof is gabled and covered with corrugated metal. The single rear window has been filled in, the only apparent change to the building. Despite its

utilitarian nature, this structure is clearly linked to the modernization effort at the light station during the 1920s. In addition, its simple rectangular form and flat door and window sills and lintels give this structure an appearance that is very similar to the original oil house and kitchen.

C. **Radio Room** (Original Oil Storage Building) Drawings: 3, 5, and 8.

Built in 1856-58, this two story, brick structure measures 16' by 14' and originally served as a storage building for the oil used to illuminate the lamps in the lighthouse. The roof is gabled and covered with sheet metal. The c. 1900 photograph of the light station shows the building unpainted and with an internal chimney (since removed) against the south wall. Originally freestanding, this building was connected to the lighthouse in 1926 by a 12' by 6'4" passageway of formed concrete during the same time that it was converted to house radiobeacon equipment. It is interesting to note that original 1857 construction drawings for the lighthouse and other buildings in the complex called for the oil storage building to be connected to the lighthouse tower. After World War II, additional poured concrete additions were built against the south and west walls of the structure. Other changes to the exterior of this structure include the relatively recent installation of metal jalousie windows. On the interior, wooden stairs (presumably original) along the north wall lead to the second floor. On the walls and ceiling, 1" by 4" beaded panelling remains although it has been partially obscured on the walls by the subsequent installation of modern artificial panelling. Despite changes to this building it is still clearly identifiable as one of the original structures in the light station complex.

D. **Crew's Quarters** (Former Keeper's Residence) Drawings: 3 and 8.

Built in 1922 as the residence for the principal lighthouse keeper and his family, this building is a one story brick bungalow with a hipped roof covered with asphalt shingles. A front porch partially wraps around the northeast side of the house. Its roof is supported by tapered wooden columns resting on brick piers trimmed in coral stone. The piers themselves, the porch foundations, and the brick balustrade for the porch steps are all built of the same yellowish brick as the rest of the house except that a diamond pattern of contrasting red brick was "woven" into the masonry at the time of construction. A small rear porch serves as an outdoor service area for the kitchen. It has a shingled side wall, and its foundation is patterned in a fashion similar to that of the front porch. The buildings's exterior is apparently unaltered with the exception of the metal jalousie windows which have been substituted for the original double hung wooden windows. In addition, air conditioning units have been placed in several windows. The interior plan has been altered and wallsurfaces (originally plaster) have been covered with modern sheet panelling. The building is an excellent example of the bungalow style, one of the most common suburban housing types of the period. The choice of this style by the Light House Service was part of the overall modernization of the station which took place during the 1920s.

E & K. **Concrete Cisterns** Drawings: 4, 5, and 8.

These cisterns were built in 1922 to replace the original brick cisterns at the light station. Each measures 16′ by 10′ by 8′6" with approximately 4′ extending above the ground level. Cistern K collected rainwater from the original keeper's quarters, and Cistern E collected water from the new keeper's quarters built in 1922. These cisterns played an important role in the 1920s modernization of the light station. Unlike the older brick cisterns, water from the new cisterns was pumped to the plumbing systems which were installed in the light station buildings at this time.

F. **Fiberglass Water Tanks** INTRUSION

These tanks were installed between 1951 and 1977 and have replaced the concrete cisterns in function. They are noncontributing elements.

G. **Paintlocker** INTRUSION

This concrete block structure was built about 1951 and is used to store paint and flammable liquids. A noncontributing structure.

H. **Guest House** (Original Kitchen Building) Drawings 4, 5, 7, and 8.

Built in 1856-58, this two story brick structure measures approximately 20′ by 17′. It has a gabled roof covered with metal shingles. On the front of the building, the roof extends out from the building some 9′ and is supported on brick columns to form a porch. This was added when the building was renovated in 1922, and it is not known if the present porch replaced an earlier one. The building was unpainted originally, but is now painted white. Jalousie windows have replaced the original wooden, double-hung sash and the rear door has been filled in by concrete block. The interior has been changed considerably and the only remaining original feature appears to be the stairs leading to the second floor. The 1922 renovation plans for the building show that there was a bake oven built into the base of the chimney. This was modified for use as a closet, and the chimney stack above the roof was removed. The upstairs may have served as quarters for one of the assistant keepers. The building is now used to house visitors and work parties. Despite changes, this building retains the original form and character evident in the c. 1900 historic photographs.

I. **Foundation of Original Keepers Quarters** Maps/Drawings: 3 to 5 and 8.

Built in 1856-1858, this structure originally housed the principal lighthouse keeper, his two assistants, and their families. The 1857 construction drawing for the light station called for a frame dwelling, but brick was the actual construction material. As revealed by the c. 1900 historic photograph and a 192 renovation plan this structure was a two story, brick dwelling with Greek Revival features. Each floor had two rooms off a central stair hall, and there were two

nterior chimneys, one for each side of the house. Galleries ran across the front nd back of the structure with the rear gallery being partially enclosed. This uilding burned in 1945, and the site was razed several years later leaving only he outline of the foundation. Although the building itself is gone, its site is till significant in terms of understanding the original layout of the light tation.

& L **Brick Cisterns** Drawings: 5 and 8.

hese structures were built in 1856-58 to collect rainwater for general use by the ight station keepers and their families. Each cistern is 14' in diameter and xtend 4' above the ground. As seen in the c. 1900 photograph, cistern J ollected rainwater via the guttering system of the lighthouse keepers house. istern L collected water in a similar manner from the kitchen building. Although he cisterns have apparently been unused since the 1920s, when new concrete isterns were built, they are nevertheless important original features of the ight station. They show how a constant water supply was maintained in an area ithout natural water, and they are also important in defining how the original ight station was laid out and how it functioned.

Generator Building

he metal building lies just outside the district boundaries. It was excluded rom the district due to its recent construction date--post 1960.

Summary Paragraph

The Dry Tortugas Light Station on Loggerhead Key has been in continuous operation since 1858 serving as an aid to navigation for vessels cruising the Florida Straits between the Gulf of Mexico and the Atlantic Ocean. Officers of the U.S. Corps of Engineers who were in charge of the construction of Fort Jefferson on nearby Garden Key also planned and supervised the erection of the 150 foot brick lighthouse and several support structures in 1856-58 for the U.S. Lighthouse Board. Thus the Dry Tortugas Light Station is significant primarily for its role in facilitating America's ocean-borne commerce and as a notable example of the kind of civilian public works projects undertaken by Army engineers prior to the Civil War. While the lighthouse is clearly the most important structure within the boundaries of the nominated area, there were several ancillary structures built at the same time as the lighthouse, and also from the 1920s, a period in which the station was extensively modernized.

Loggerhead Key, the westernmost island in the Dry Tortugas group, is located approximately 65 miles west of Key West, Florida, and 90 miles north of Cuba. The Dry Tortugas are the last in the 150 mile string of coral reefs and islands that make up the Florida Keys. The Spanish explorer, Ponce de Leon, discovered the islands in 1513 during his first Florida expedition and called them "Las Tortugas" for the large number of green sea turtles he found there. Over time, the islands became known as the Dry Tortugas due to the absence of fresh water.

By mid-sixteenth century, homeward bound Spanish ships carrying silver mined in Peru and New Spain sailed a standard course across the Gulf of Mexico and through the Florida Straits and the Bahama Channel in order to take advantage of the Gulf Stream which would carry them into the Atlantic and north along the east coast of Florida. Later on, ships sailing to and from the colonial ports that were established on the Gulf Coast added to this traffic. Speed was the advantage of this route, but there were hazards as well. Once ships passed the Dry Tortugas at the entrance to the Florida Straits, they were vulnerable to pirate attack and could be driven onto hidden reefs and shoals by tropical storms and hurricanes.

The first advance in navigation in the Dry Tortugas came while the British controlled Florida. George Gauld surveyed the islands in the early 1770s for the Board of Admiralty and published a chart of the Tortugas in 1773 that mariners relied on for the next 75 years. Gauld also named the islands, including Loggerhead (originally Loggerhead Turtle) Key.

Additional improvements to navigation in the Dry Tortugas did not come until Spain ceded Florida to the United States in 1821. By this time trade between Atlantic and Gulf Coast ports was burgeoning, and the number os ships passing through the Florida Straits was increasing. Loss of ships and their cargoes due

o storms in the Florida Keys, by then considered to be within the territorial aters of the United States continued to be a problem. This was compounded by reckers who carried on a lucrative and sometime illegal, business of salvaging recked American ships which they sold along with their cargoes in the British ahamas. Attacks by Caribbean based pirates still occurred with regularity. o protect American shipping interests in the Keys, the United States purchased he island of Key West in January 1822 as a base of operations. In March of hat year, Lt. Commander Matthew C. Perry took formal possession of the island nd reconnoitered the surrounding area. in his report to the Secretary of the avy, Perry emphasized the need to halt piracy and to curb the excesses of the reckers. He also recommended that four lighthouses be built in the Keys ncluding one in the Dry Tortugas.

ater in 1822, Captain David Porter sailed to Key West with a small squadron of hips to combat piracy in the Caribbean, and by 1828 a U.S. District Court had een established in Key West to license wreckers and to require them to sell alvaged cargoes and vessels in U.S. ports.

n regard to the need to build lighthouses in the Keys, Congress acted promptly y allocating funds for this endeavor in 1822, but the overall objective of uilding enough lighthouses to make the keys genuinely safe for shipping proved o be a difficult and lengthy task that was not completed until after the Civil ar. Nevertheless, by the end of 1826, three lighthouses were in service ncluding one in the Dry Tortugas, a 65 foot high brick tower with fixed light n Bush Key, three miles east of Loggerhead Key. It was soon apparent that it as not adequate to warn mariners of the shoals and reefs in the area. Ship recks continued, and ship captains complained that in stormy weather it was mpossible to safely gauge their distance from the light. In 1836, Captain John hompson, the keeper of the light, recommended that two other lighthouses be uilt in the Tortugas. Article published in the American Coast Pilot, a popular ournal about maritime issues, also singled out the Bush Key light for riticism.

o steps were taken to correct the situation until 1845 when Simon Pleasonton, ifth Auditor of the Treasury, ordered Adam Gordon, the Lighthouse uperintendent at Key west to determine if complaints about the Dry Tortugas ight were valid. Gordon took advantage of the fact that the U.S. Corps of ngineers was studying the Dry Tortugas to determine what kinds of ortifications to build there, and he secured the recommendations of Engineer aptains William H. Chase and George Dutton who both agreed that to be ufficiently visible the Dry Tortugas light should be relocated to Loggerhead ey and that the new lighthouse should be 120 feet high. The Lighthouse Board, owever, took no action aside from having the existing light adjusted.

s part of a 1851 study of United States lighthouses, the Lighthouse Board sent circular letter to captains of packets and mail boats for recommendations.

he responses regarding the Dry Tortugas light were not positive. Some captains eplied that they routinely avoided the Tortugas altogether, preferring to use he better marked Cuban coast as their point of reference. Others said that nly a new first order light would make the Tortugas safe.

inally, the Lighthouse Board took action in August 1855 when the Secretary of he Board, Naval Lieutenant T.A. Jenkins, wrote to U.S. Corps of Engineers aptain H.G. Wright, the officer in charge of the on-going construction of Fort efferson on Garden, formerly Bush, Key. Jenkins requested that he provide onstruction cost estimates and preliminary plans for a new Dry Tortugas ighthouse. Wright responded in September by submitting to the Lighthouse Board ost estimates, a description of materials, and a sketch of a 150 foot brick ighthouse tower designed to accommodate a first order Fresnel lens. The next ear Congress allocated $35,000 for the project and construction was begun. By his time Wright had been reassigned to another duty station, and Captain Daniel . Woodbury had been placed in charge of the continuing work at Fort Jefferson s well as the new lighthouse on Loggerhead Key. The brick lighthouse as well s several support structures including a two-story residence for the lighthouse eeper, a kitchen building, an oil storage building, and two cisterns--all built f brick--were completed in 1858. The lighthouse was officially placed in ervice on July 1 of that year. The 1826 lighthouse on Garden Key was reduced o the status of a fourth order harbor light. An 1873 hurricane damaged the lder structure severely and in 1876 the Lighthouse Board erected a new wrought ron tower on one of the bastions of Fort Jefferson. This lighthouse, still tanding today, was also designed and built under the supervision of Army ngineers.

he fact that the U.S. Corps of Engineers played a major role in the onstruction of the Dry Tortugas Light Station on Loggerhead Key was not an solated occurrence. The U.S. Corps of Engineers, first organized in 1802, had ajor responsibilities in regard to improving navigation on rivers and streams nd developing America's harbors including the construction of a significant umber of lighthouses. Other lighthouses in the Florida Keys that were either esigned and/or built by the engineers include the Carysfort Reef Lighthouse 1848-1852), the Sand Key Lighthouse (1851-53), and the Sombrero Key Lighthouse 1854-58).

ne Dry Tortugas remained in Union hands during the Civil War, and the operation f the new lighthouse on Loggerhead Key was not hindered in any way. In 1867 nd 1873, Loggerhead Key served as a quarantine station for military personnel uring yellow fever epidemics at Fort Jefferson. Again the operation of the ight station was apparently not affected.

n the post-Civil War period, one of the most notable features of the operation f the Dry Tortugas Light Station was the continual round of maintenance ctivities and repairs needed to keep the lighthouse and other structures in a

sable condition despite frequent storm damage and the day-to-day problems ssociated with the harsh marine environment. Congressional appropriations for epairs were frequent. The most serious threat to the lighthouse resulted from he 1873 hurricane. In 1875 the virtual reconstruction of a nine foot section f the tower immediately beneath the lantern was completed at a cost of $75,000. ven after the repairs were finished, the Lighthouse Board considered the ossibility of building a new tower, but the ability of the lighthouse to eather several subsequent storms convinced the board that a new tower was not eeded.

.C. Bell, surveyor of lighthouses for the seventh and eighth districts, mapped oggerhead Key and the light station in 1887. His work showed that the station ad changed very little since its construction thirty years earlier. This emained true until the 1920s. The major changes on Loggerhead Key from 1880 o 1910 were administrative in nature and had little impact on the station tself. In 1888, the War Department approved a request by the Treasury epartment to reserve Loggerhead, Garden, and Bird Keys as possible sites for uarantine stations, presumably in case of future Yellow Fever outbreaks. It oes not appear that the islands were actually used for this purpose in ubsequent years. In 1900 the military reservation of Dry Tortugas, including oggerhead Key, was transferred to the Navy Department from the Army who had ontrolled the area since 1842. This came about, because Fort Jefferson was no onger an active army post, but was used instead by the Navy as a coaling tation for ships of war. Four years later the Carnegie Institution of ashington was permitted to build a marine biology research station on the orthern tip of the island. Until the outbreak of World War II, this facility erved as a summer laboratory for scientists who studied marine flora and fauna n the Keys. In 1908 Loggerhead Key was recognized as a bird sanctuary by xecutive Order of President William H. Taft.

epairs to the Dry Tortugas Light Station were constant and frame structures uch as the wash house, privies, boathouse and docks had to be replaced on everal occasions. During 1920s, however, the Lighthouse Service undertook the irst major building program on the island since the station's original onstruction. The original keepers quarters and the kitchen building were efurbished and a brick bungalow was erected as the residence of the lighthouse eeper. The oil storage building was equipped with an electrical generator and adio equipment, used primarily to monitor and respond to calls from ships in istress. Electricity does not appear to have been supplied to other buildings n the island at this time. Other new construction during the 1920s included formed concrete addition to the former oil storage building to connect it to he lighthouse tower, a new storage building, and a boathouse. The original rick cisterns were apparently capped at this time and new cisterns of formed oncrete were constructed..

In administrative change of some importance was the inclusion in 1935 of Loggerhead Key within the boundaries of Fort Jefferson National Monument. In 1939 the Lighthouse Service merged with the U.S. Coast Guard, and the following year the Coast Guard and the National Park Service entered into a formal agreement in which the Coast Guard retained all management responsibilities for Loggerhead Key and the Dry Tortugas Light Station.

Additional changes to the Dry Tortugas Light Station did not come until the completion of World War II. In 1945, the original keepers quarters burned and its ruins were razed several years later. Other changes in the post-war period included the construction of a metal generator building, the erection as a 365 foot high antenna, the addition of modern communication equipment to the lighthouse tower, and the construction of two formed concrete additions to the original oil storage building. Despite these and more recent changes, the light station still retains the basic qualities it possessed in the 1920s when the Lighthouse Service upgraded the original 1856-58 station to meet more modern needs.

MAJOR BIBLIOGRAPHICAL REFERENCES

earss, Edwin C. Historic Structure Report, Historical Data Section, Fort Jefferson, 1846-1898. Washington, DC: U.S. Department of Interior, National Park Service, 1982.

earss, Edwin C. Shipwreck Study--The Dry Tortugas. Washington, DC: U.S. Department of Interior, National Park Service, 1971.

arnegie Institution of Washington. Yearbooks. Washington, D.C.: Carnegie Institution of Washington, 1904-1939.

ean, Love. Reef Lights, Seaswept Lighthouses of the Florida Keys. Key West, Florida: The Historic Key West Preservation Board, 1982.

eneral Services Administration. National Archives and Records Service. Record Group 26, U.S. Coast Guard Records, Site File Florida No. 16.

anucy, Albert C. "A Handbook for Fort Jefferson History," St. Augustine, Florida: Fort Marion National Monument, 1942.

auer, Carl Otwin. Sixteenth Century North America. Berkeley: University of California Press, 1971.

ection 10

erbal Boundary Description:

roceed from center of lighthouse base 65 feet due east to a point on the istoric District boundary. From that point proceed 114 feet due north; 122 eet due east; 141.5 feet due north; 239 feet due west; 343 feet due south; 20 feet due east; 220 feet due north; 45 feet due east; and 87.5 feet north o point of beginning.

oundary Justification:

he boundary selected encompassess the historic buildings that comprise the istrict as shown on Map 3 and described above.

orm 10-900-a
8-86)

OMB No. 1024-0018

nited States Department of the Interior
ational Park Service

ATIONAL REGISTER OF HISTORIC PLACES
ONTINUATION SHEET

ection ____ Page __

Dry Tortugas Light Station___
name of property
__Monroe, Florida_____
county and State

==========

IST OF PHOTOGRAPHS

ith a few exceptions these photographs were taken by Stuart Johnson, National ark Service, in January 1984. The original negatives are filed with the United tates Coast Guard, Seventh District Office in Miami, Florida. Though taken ten ears ago these photos were field tested in 1993 and were determined to ccurately portray existing conditions.

hotograph #

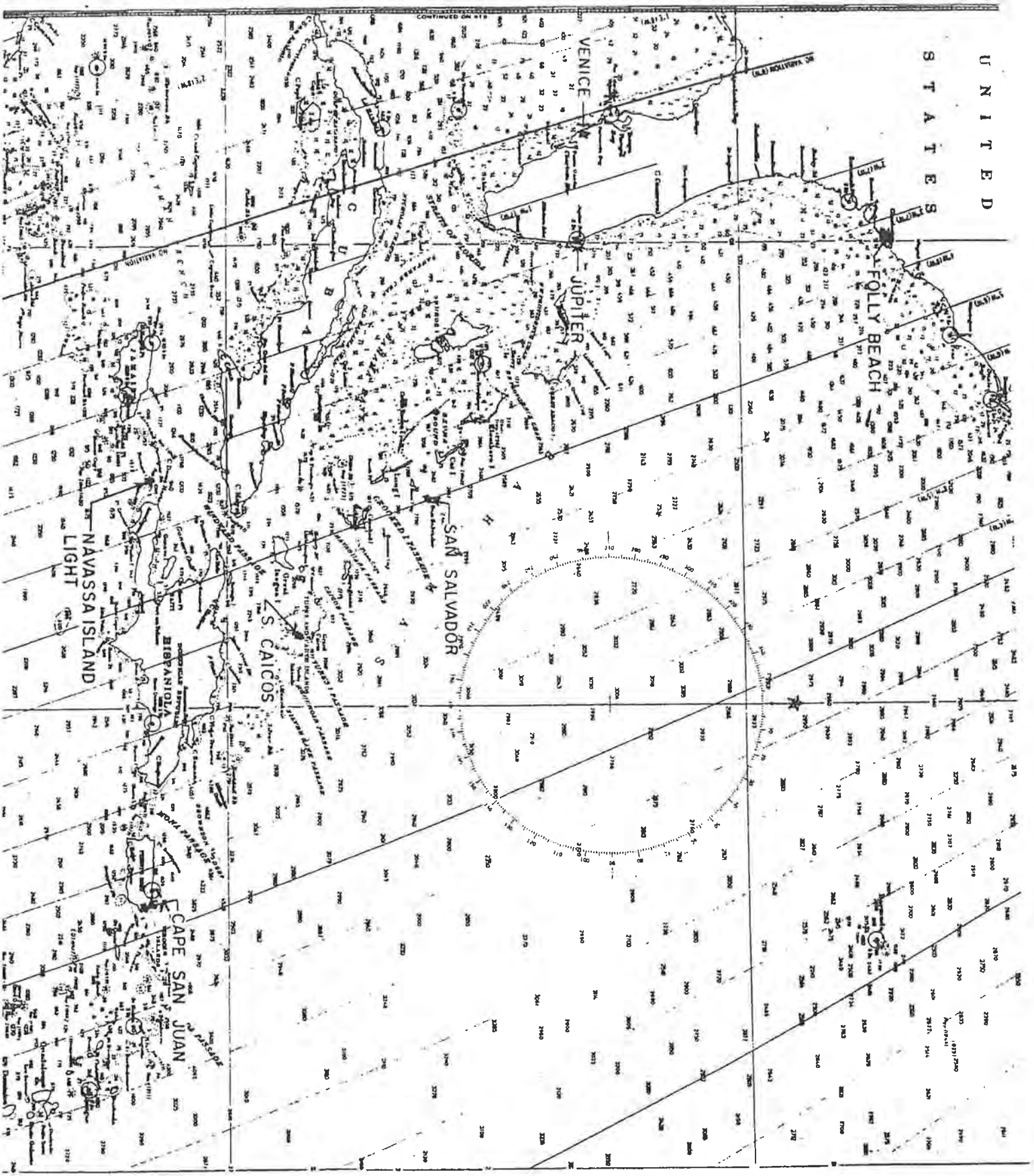
1. Loggerhead Key--aerial view looking northwest. Lighthouse is in right center of the picture. Photographer: Richard Ramsden, NPS. Negative filed with U.S. Coast Guard, Seventh District Office.
2. Not included.
3. Dry Tortugas Lighthouse and Radio Room, looking NW. Dry Tortugas Light Station. Buildings A and C.
4. Watchroom and lantern of lighthouse, looking NW. Building A.
5. Interior of lighthouse showing spiral granite steps.

6. Entry at base viewed from connector with radio room.
7. Dry Tortugas lighthouse, iron door from watchroom to gallery at top of lighthouse. Building A.
8. Bosun's Work Shop (formerly the Oil House), looking west. Dry Tortugas Light Station. Building B.
9. Bosun's Work Shop (formerly the Oil House). looking southwest
10. Radio Room at Dry Tortugas Light Station, looking NE.

11. Radio Room, looking NW. Building C.
12. Crew's Quarters (formerly Keeper's Residence), Dry Tortugas Light Station, looking west. Building D.
13. Crew's Quarters (formerly Keeper's Residence), looking east.
14. " " " " " , looking north.
15. Brick cistern at former kitchen building, Dry Tortugas Light Station, looking SE. Structure L.

16. Brick cistern and concrete cistern that served original Keeper's Residence. Looking south. Structures J and K.
17. Guest House, primary facade, facing west. Dry Tortugas Light Station. Building H
18. Guest House, original kitchen, Building H. Facing west.
19. Guest House, note remnants of chimney, facing north.
20. Interior stairs of guest house (Building H).

21. Dry Tortugas Light Station Complex showing original features. Looking South. Guest House and cistern that served original kitchen are in right foreground.
22. Metal Generator Building, looking north. Dry Tortugas L.S. Located outside of historic district. Noncontributing structure.
Photograph by Richard Ramsden, NPS. Filed USCG, Miami, FL.



Dry Tortugas Light Station Area Map
Loggerhead Key, Florida
Map #2

1 Keepers Residence
2 Asst Keepers Residence
3 2d & 3d Keepers Residence
4 Radio
5 Oil House
6 Boat House
OFFICE OF SUPERINTENDENT OF LIGHT-HOUSES
SEVENTH DISTRICT, KEY WEST, FLA.
BAY TORTUGAS LIGHT STATION
PLAN
Scale 1"=80'
Approved June
Superintendent
Washington, D.C.
No 701

APPENDIX B

Materials Analysis

Dry Tortugas Light Station

Materials Analysis

Dry Tortugas, Florida



August 2009

BCA

BUILDING CONSERVATION ASSOCIATES INC

Dry Tortugas Light Station

Materials Analysis

Dry Tortugas, Florida

Prepared For

Lord Aeck & Sargent Architecture
Ann Arbor, Michigan

Prepared By

Building Conservation Associates, Inc.
329 Race Street
Philadelphia, Pennsylvania 19106

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4.2 Mortar 31

APPENDICES

Appendix A: Sample Stratigraphies and Photomicrographs

Appendix B: Mortar and Plaster Analysis Report (Testwell, Inc. 2009)

Appendix C: *Rehabilitation Report and National Register Nomination for the United Stated Coast Guard Light Station, Dry Tortugas Lighthouse, Loggerhead Key, Florida,* 1984

1.0 INTRODUCTION

At the request of Rob Yallop of Lord Aeck & Sargent Architecture (LAS), Building Conservation Associates, Inc. (BCA) prepared an analysis of select building materials removed from buildings associated with the Dry Tortugas Light Station, including the Dry Tortugas lighthouse. The light station is located in the Dry Tortugas National Park in Florida. The materials investigated as part of this study include mortar and paint finishes. The buildings investigated as part of this study include: the lighthouse, original oil house, kitchen building, keeper's residence and the south brick cistern. The primary goal of the materials analysis is to document the buildings' original mortars and paint finishes for inclusion in a Historic Structure Report (HSR). A secondary goal is to provide recommendations for future restoration work based on the findings of the analysis. (*Figures 1-5*)

The report summarizes the findings of both the mortar analysis and the finishes study. Following the introductory information regarding the site and study methodology, the report discusses the findings of the research and then makes recommendations for appropriate restoration mortar mixes and paint colors. All mounted cross-sections have been labeled and permanently housed and will be archived at BCA's Philadelphia office unless otherwise requested by the client.

All work required for the execution of this study was performed by Dorothy S. Krotzer, BCA Regional Director, with assistance from Testwell, Inc. for completion of the laboratory portion of the mortar analysis. Mortar and paint samples were taken from the site in March 2009 and laboratory analysis was performed in April and May 2009.



Figure 1. Lighthouse, March 2009. Photograph by author.



Figure 2. Oil house, March 2009. Photograph by author.



Figure 3. Original kitchen building. March 2009. Photograph by author.



Figure 4. Keeper's residence. March 2009. Photograph by author.



Figure 5. South brick cistern. March 2009. Photograph by author.

2.0 METHODOLOGY

Prior to the site visit and removal of samples, information related to the history of the Dry Tortugas Light Station provided by LAS was reviewed. Portions of the draft HSR, including historic images and information on the construction chronology and materials, were studied in order to gain a general understanding of the history of the site and any information related to the buildings' paint finishes and masonry construction. The archival information included a 1984 *Rehabilitation Report and National Register Nomination* that contained paint and mortar analysis of the lighthouse. (*Appendix C*)

Once the relevant historical documentation was reviewed, a site visit was made and the buildings were physically examined for areas from which representative samples of mortar and paint finishes could be removed. Once these intact areas were identified, samples were removed. Mortar and plaster samples were removed using a small masonry chisel or five-in-one tool and a hammer. Paint samples were removed using a scalpel. A total of eleven mortar and plaster samples and sixteen finish samples were removed from the buildings and taken back to the laboratory for analysis.

2.1 Finishes Analysis

All finish samples were initially examined in reflected light using a Nikon high-resolution stereomicroscope SMZ-1500 with variable magnification (16x-160x) to identify which samples would be embedded and sectioned for analysis. The selected samples were then mounted in a commercial polyester/methacrylate resin polymerized with a methyl ethyl ketone peroxide catalyst (Bioplast®). Embedded samples were sectioned on a Leco® VC-50 micro-saw for microscopic examination. The sectioned samples were dry-polished using a series of fine Micromesh® polishing cloths ranging from 6,000 to 12,000 grit. Sectioned samples were observed under a Nikon 50i compound microscope in both visible light filtered through a daylight correction filter and ultraviolet light. The ultraviolet light was generated by a mercury illumination system filtered through a violet filter cube (EF4 V-2A Ex400/40 Dm430 Bar 450). Photomicrographs of representative samples were taken using a five megapixel Nikon DigiSight color digital camera system and are included in this report to illustrate specific observations.

All paint samples were viewed in cross-section and their paint layering sequences, or stratigraphies, recorded. These stratigraphies are included in Appendix A. Once the stratigraphies of every sample were deciphered, significant paint layers were identified and raw samples were manipulated in order to expose these layers for color matching purposes. Once the target layers were exposed, they were subjected to a bleaching process in order to reverse any yellowing that may have occurred over time. It is well documented that linseed oil-based paints (especially pale-colored paints) darken and yellow over time if not exposed to sunlight. This even affects oil-based finishes that have been covered with

subsequent paint layers. In order to diminish this yellowing of paint layers, they were exposed to an ultraviolet light source for approximately two weeks.

Following the bleaching process, the exposed layers were subjected to a portable spectrophotometer, a GretagMacbeth X-Rite *EyeOne*®, in order to generate a CIE L*a*b* value for each sample. Then, each sample was visually matched to two different color systems, the standardized Munsell color system and the commercial Benjamin Moore paint palette. The spectrophotometer was then used to generate CIE L*a*b* values for each of the color matches.

A color in the CIE L*a*b* system is defined according to three axes. The L*-axis (from 0 to 100) is the light-dark axis. The a*-axis (from –100 to +100) is the green-red color axis. The b*-axis (from –100 to +100) is the yellow-blue axis. Delta E is a measurement of the color difference between the original paint surface color and the closest color matches that BCA has identified. A perfect match would have a Delta E value of 0.00. Delta E equals the square root of $[(L^*_1 – L^*_2)^2 + (a^*_1 – a^*_2)^2 + (b^*_1 – b^*_2)^2]$. Where L^*_1, a^*_1, b^*_1 are the original paint surface values and L^*_2, a^*_2, b^*_2 are the commercial paint values. Consequently, the lower the value of Delta E, the closer the match. Although several commercial colors were tested for each element, only the closest match has been presented. All color matches are included in Section 4.1 of this report.

Finish samples were removed from the following locations:

LOKE.F.1	Oil house	Exterior, east wall (now enclosed), finishes on brick.
LOKE.F.2	Passageway between oil house & lighthouse	Interior, south wall, finishes on concrete. For comparison with LOKE.F.1.
LOKE.F.3	Oil house	Exterior, east wall (exposed), finishes on brick.
LOKE.F.4	Oil house	Exterior, east wall (now enclosed), door frame, finishes on wood.
LOKE.F.5	South brick cistern	Exterior, west wall, finishes on brick.
LOKE.F.6	Lighthouse	Exterior, west elevation (now enclosed), finishes on brick.
LOKE.F.7	Lighthouse	Exterior, west wall (now enclosed), door frame, finishes on wood.
LOKE.F.8	Lighthouse	Exterior, west wall (now enclosed), door to lighthouse, finishes on wood.
LOKE.F.9	Lighthouse	Interior, ground floor level, finishes on brick.
LOKE.F.10	Kitchen building	Exterior, east elevation, finishes on brick.
LOKE.F.11	Oil house	Exterior, south elevation (now enclosed), finishes on brick.

LOKE.F.12	Keeper's residence	Interior, hallway outside bathroom, original west wall (covered by drop ceiling), finishes on plaster.
LOKE.F.13	Keeper's residence	Interior, hallway outside bathroom, original west wall (covered by drop ceiling), original wood cornice, finishes on wood.
LOKE.F.14	Keeper's residence	Interior, bathroom, original west wall, finishes on plaster.
LOKE.F.15	Keeper's residence	Exterior, east elevation, front door frame, finishes on wood.
LOKE.F.16	Keeper's residence	Exterior, east elevation, front porch beam above columns, back face, finishes on wood.

2.2 Mortar and Plaster Analysis

Cursory visual examination of the mortar samples was performed by D. Krotzer and subsequent laboratory analysis was executed by John Walsh of Testwell Laboratories, Inc. in Ossining, New York. John Walsh specializes in the analysis and identification of historic mortar materials. Testwell's laboratory work included: petrographic examination; chemical analysis (gravimetric analysis and atomic absorption spectroscopy); statistical point counting (used instead of acid digestion to gain information on the quantity of aggregate since it is an acid-soluble carbonate sand); and water-soluble chloride analysis. The goal of Testwell's analysis was to identify the binder and aggregate components of each mortar, as well as the original component ratio and any deterioration due to salt crystallization or hydration.

Although Testwell's findings are discussed in Section 3.2 of this report, the full mortar analysis report has also been included in Appendix B.

Samples of brick mortar and plaster were removed from the following locations:

LOKE.M.1	Oil house	Exterior, east elevation, mortar. Taken from protected wall now enclosed. Sample from interior of wall (from an area where a hole was cut through wall for a pipe).
LOKE.M.2	South brick cistern	Exterior, east elevation, mortar.
LOKE.M.3	South brick cistern	Interior, parging. Taken from upper portion of interior wall.
LOKE.M.4	Lighthouse	Exterior, west elevation, mortar. Taken approx. 8-feet from ground.
LOKE.M.5	Lighthouse	Exterior, west elevation, mortar. Taken from former exterior wall now enclosed, adjacent to entrance to lighthouse.
LOKE.M.6	Lighthouse	Interior, mortar. Taken from wall at ground floor level.
LOKE.M.7	Lighthouse	Interior, mortar. Taken from wall below watch level (supposedly rebuilt in 19th century).
LOKE.M.8	Oil house	Interior, south wall, plaster. Taken from behind modern wood paneling and earlier beadboard wall; three-layer plaster system applied over brick.
LOKE.M.9	Kitchen building	Exterior, north elevation, mortar. Sample from interior of wall.
LOKE.M.10	Keeper's residence	Exterior, west wall, mortar.
LOKE.M.11	Keeper's residence	Interior, bathroom, west wall, plaster. Two-coat plaster system.

3.0 SUMMARY OF FINDINGS

3.1 Finishes Analysis

The paint finishes of five historic buildings at the Dry Tortugas Light Station were examined as part of this study. The majority of paint samples were removed from exterior brick and wood trim elements. However, samples of interior paint were also removed from the keeper's residence and the lighthouse.

MASONRY

The exterior brick masonry surfaces of the oil house, south brick cistern and lower half of the lighthouse all seem to share a similar finish history. Each of these buildings has been painted a version of cream or white throughout its history, although the total number of layers varies. In addition, the earliest finish appears to be a white lime wash, followed by paint finishes (presumably oil-based) that are also white/cream in color. The brick masonry of the kitchen building was examined and found to only have four layers of modern white paint. The upper portion of the lighthouse (currently painted black) was not accessible at the time of the field investigation.

Although the brick masonry of the oil house, kitchen building, lighthouse and south brick cistern is currently painted, historic documentation indicates that originally the brick on these buildings was left unpainted. An undated historic photograph shows both the kitchen building and the oil house as exposed brick structures. (*Figure 6*) Although the date of this photograph is unknown, it must pre-date 1892 because a photograph taken circa 1892 clearly shows the oil house painted. (*Figure 7)* In the same circa 1892 photograph, the brickwork of the kitchen building, barely visible through the palm trees, remains unpainted. In addition, there are several written descriptions of the lighthouse dating from 1858 that refer to it as being a "natural color brick" or as a "brick-color tower."[1]

Physical evidence confirms the historical documentation. The surface of the brick in samples removed from these buildings appears somewhat weathered and uneven, suggesting it was worn by exposure to the elements before being painted. The only structure that may have always been painted was the south brick cistern. As evidenced in Figure 9 the sample removed from the brickwork of the cistern shows a relatively clean brick surface, suggesting it has always been protected from the weather. (*Figures 8-9*)

[1] "Loggerhead Key Lighthouse, Dry Tortugas, Florida." Printed October 21, 1993. PP. 1-2



Figure 6. Historic image showing the oil house and kitchen building as unpainted brick masonry buildings. The Lighthouse has been painted black and white but the oil house is not yet painted, dating this photograph to some time between 1870 and 1892.



Figure 7. Historic image showing the lighthouse, oil house and old keeper's residence circa 1892. Note that the oil house has been painted white in this photograph. Photograph courtesy of LAS.

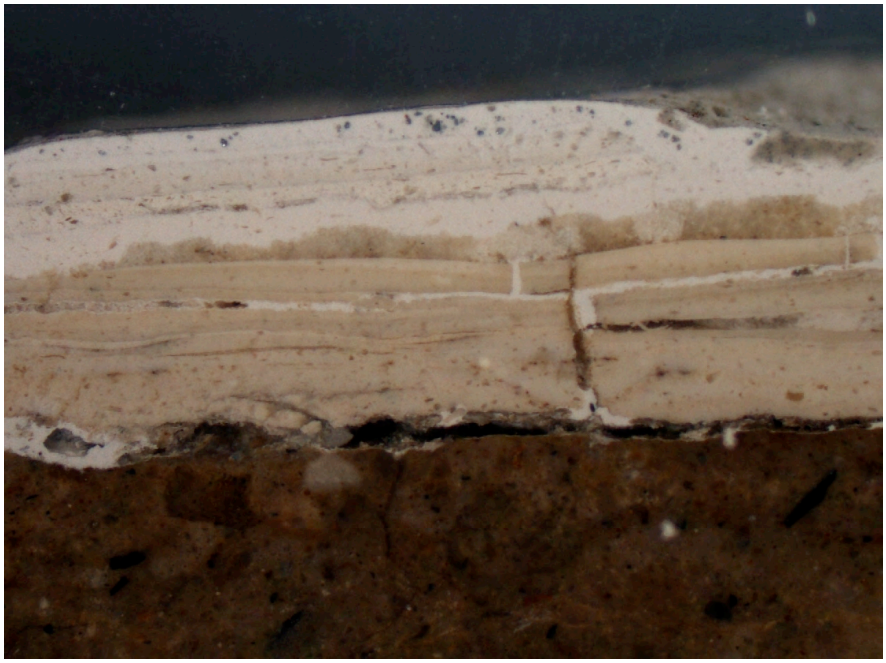


Figure 8. Oil house. Photomicrograph of painted exterior brick showing numerous layers of cream and white-colored paint. (40x magnification, visible light).



Figure 9. South brick cistern. Photomicrograph of earliest finish applied to brick wall of cistern. Note first layer is more translucent than the others and appears to be a limewash. Also, the surface of the brick is relatively unsoiled. (100x magnification, visible light).

Although archival documentation indicates that the lighthouse was not originally painted, records document that it has been painted black and white at least since 1875, when an inspection log states that "The black portion of the tower has been painted, and the remainder whitewashed."[2] Interestingly, this reference illustrates the use of two different types of paint finishes on the brick structures of the Dry Tortugas Light Station, a practice that may have been applied to not only the lighthouse but to the other buildings as well. For the lighthouse, it would have been necessary for the black finish to be a paint (presumably oil) instead of a lime wash, as achieving a truly black-colored lime wash would have been difficult if not impossible.

A *Rehabilitation Report and National Register Nomination* on the Dry Tortugas lighthouse from 1984 included materials analysis of the paint by Law Engineering Testing Company. One paint sample from the lighthouse was provided for analysis. Although the location of the sample was not indicated, it is assumed that the sample was removed from the exterior of the lighthouse. According to the 1984 report, the paint sample consisted of two paint layers, both found to be an acrylic-polyvinyl acetate mixture with lead and zinc-based pigments. A recent in situ examination of the lighthouse exterior for this report confirms the presence of only a few layers of modern white paint on the exposed portion of the lighthouse exterior. This number of paint layers is far fewer than the approximately 30 paint layers documented for the paint sample removed from a protected area of the lighthouse exterior (from a wall inside the connector building) as part of the current study. This discrepancy in number of paint layers can most likely be attributed to the fact that the exterior of the lighthouse was sandblasted in 1967. The blasting would have removed any early coatings, explaining why the sample examined in 1984 had only two paint layers and why the recent in situ investigation revealed only a few paint layers on the exposed portion of the lighthouse exterior. The paint sample removed from the protected area inside the connector is more representative of the complete finish history of the lighthouse exterior and provides insight into the building's earliest finishes.

WOODWORK & METALWORK

The exterior woodwork of the four buildings (oil house, lighthouse, kitchen building and keeper's residence) was also examined. The exterior door and doorframe of the lighthouse, currently enclosed by the link to the original oil house, contain between 30-35 layers of paint. The doorframe contains more paint layers than the door, suggesting it may pre-date the door. The earliest paint layers on the frame are cream-colored paint. After these, the frame was painted various shades of grays approximately 30 times. The door contains slightly fewer layers (approximately 30), all of which are various shades of gray. The doorframe of the original oil house was also painted numerous times (approximately 40 paint layers). The earliest finish is a medium gray. Subsequent layers are predominantly gray with a few creams later in the sequence. The wood trim of the kitchen building

[2] LAS, Draft Historic Structure Report (HSR), "Background" section.

contains only a few layers of modern paint, indicating the woodwork is relatively modern or that it has been stripped. (*Figures 10-11)*

The historic photographs provide some insight into the color palette of the exterior woodwork of these buildings. In both photographs, the window sash and frames of all of the buildings appear to be a pale color (likely white or cream) and the shutters are a dark color. However, at the time of this study, there was no access to historic windows in these buildings, as many have been replaced with modern units and the shutters have been removed. This prevented a positive identification of the actual color of the pale paint visible in the photographs.

In the historic images shown in *Figures 6* and 7, the doors of the buildings are typically open in the photographs, preventing the color of the doors from being seen; they could have been painted the light color of the windows or the dark color of the shutters. As discussed above, the physical evidence indicates that the door frame (and possibly the door) of the lighthouse was originally painted white, followed by numerous layers of gray paint. It is not know when the transition from white to gray occurred for the lighthouse. By contrast, the door frame of the original oil house was always painted gray. Again, there is no photographic evidence to corroborate either of these observations.

There is, however, written historic documentation regarding paint for the metalwork and woodwork of the lighthouse. In an 1862 document entitled "Instructions and Directions for Light-House and Light-Vessel Keepers of the United States", paint colors and paint types are carefully specified for the interior and exterior metal and wood work of the lighthouse. All paint is linseed-oil based and generally glossy in sheen. The interior of the lighthouse lantern is to be painted white, while the exterior is to be painted black or red. Black seems to be the most prevalent color called for, although there are also references to "lead", "gray", "yellow", "straw", "brick", "oak wood" and "Portland stone." In addition, all ironwork is supposed to be primed with red lead.[3] Although the metal components of the lighthouse were not examined as part of this study, the colors found on the existing woodwork (white and gray) are in keeping with the colors specified in 1862.

The exterior woodwork of the keeper's residence was originally painted white, a conclusion based on both physical and archival documentation. Samples removed from the front porch trim show 11 layers of white and cream paint. In addition, historic photographs of the house show white-colored trim and the preliminary specifications for the building that date to 1917 state that all woodwork was to be painted white. (*Figure 12*) The original hurricane blinds, which appear a dark color in the historic photographs, do not remain on the building and could therefore not be sampled to confirm

[3] Instructions and Directions for Light-House and Light-Vessel Keepers of the United States, 4th edition, 1862. Pages 106-110.

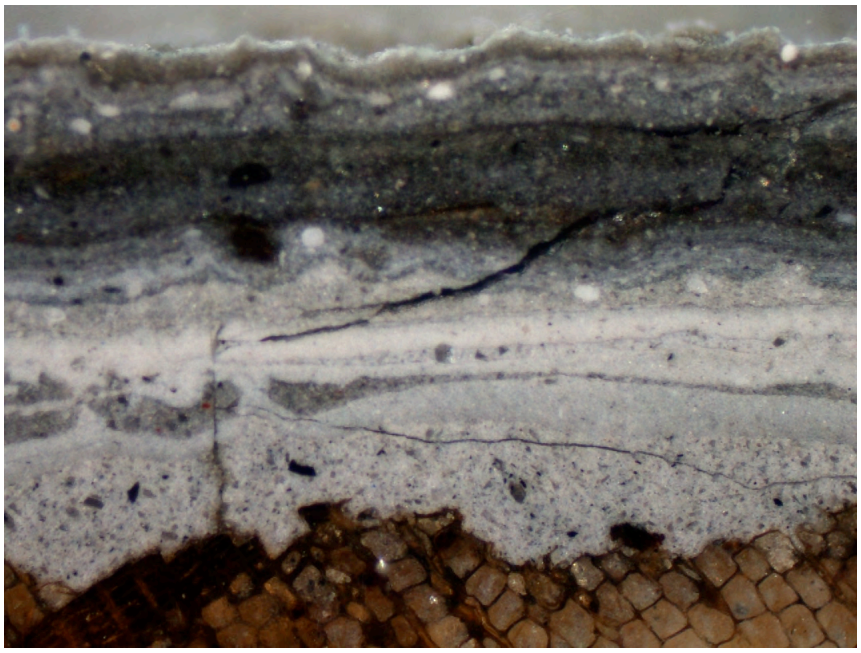


Figure 10. Oil house. Photomicrograph of a paint sample removed from the exterior door of the oil house showing numerous layers of gray paint applied to the frame over time. (100x magnification, visible light).



Figure 11. Lighthouse. Photomicrograph of a paint sample removed from the exterior door frame of the lighthouse showing a similar range of gray paint colors as the sample above, although the earliest paint color was cream. (40x magnification, visible light).

their original color. However, the preliminary specifications state that they are to be painted green. (*Figure 13*)

Select interior finishes of the keeper's residence were also examined. Samples were removed from the plaster walls of the hallway and bathroom and the wood cornice of the hallway. The walls of both the hall and bathroom were painted a pale gray-green originally and the cornice was painted white, after having been sealed with a clear coat. The preliminary specifications call for the wood to be sealed with shellac and for a three-coat paint system (1 primer and 2 finish coats), all white in color. While the sealer layer and three-coat system seems to have been employed, the color varied from that included in the specification. (*Figure 14)*



Figure 12. Historic image showing the exterior of the keeper's residence. Note light-colored trim on most exterior woodwork with the exception of the hurricane blinds.

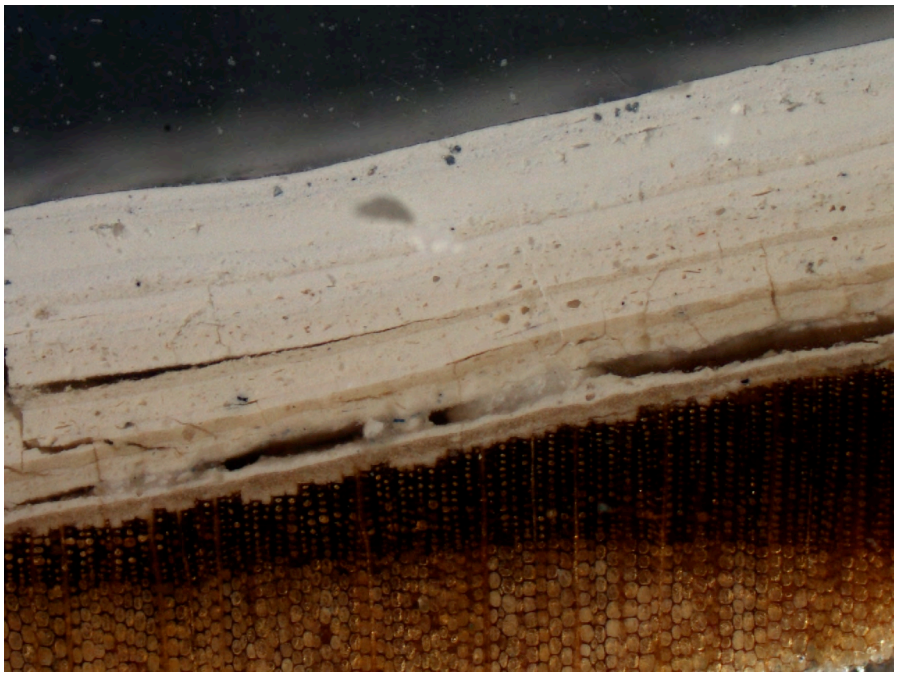


Figure 13. Keeper's residence. Photomicrograph of a paint sample removed from the exterior porch trim contains only cream and white-colored paint. (100x magnification, visible light).

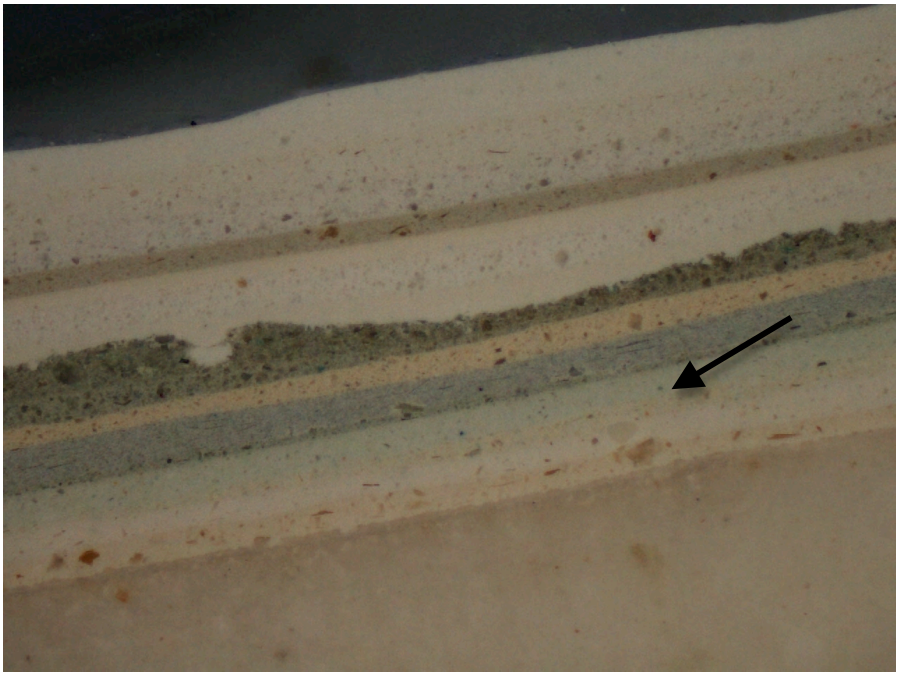


Figure 14. Keeper's residence. Photomicrograph of a sample of paint removed from the plaster wall's of the bathroom. Note original three-layer paint system of two primers topped by a pale gray-green. (100x magnification, visible light).

3.2 Mortar & Plaster Analysis

MORTAR

Laboratory analysis indicates that the majority of mortars used historically at the Dry Tortugas Light Station are composed of natural cement and local carbonate sand. Lime, which would have been added to the mortars as a gauging material to improve workability, was not documented in any of the historic mortars analyzed as part of this study. The natural cement and sand mortars were found at the lighthouse, the oil house, the original kitchen building and the south brick cistern. In addition, samples of mortar removed from four different locations within the lighthouse, including the portion of brick masonry directly below the watch room floor plate, were as natural cement and carbonate sand mortars that ware virtually indistinguishable from one another. The similarity of these mortars makes it difficult to draw any conclusions about the date of installation or type of mortars used for the numerous repair campaigns made to the lighthouse, which were documented in extensive written material. However, the physical evidence suggests that, although there were numerous repairs campaigns, the same mortar mix and ingredients were used consistently for the majority of the re-pointing campaigns in the 19th century. (*Figure 15*)

The natural cements in these mortars were identified as American natural cements, typical of those manufactured in Rosendale, New York or Louisville, Kentucky. The sand in all mortar samples was identified as a natural carbonate sand containing coral and shell fragments, presumably the same sand found along the shore of Loggerhead Key. The sand is fairly narrowly-graded, with the bulk of the material falling between a No. 16 and a No. 30 sieve. Given the remote location of the key, use of materials at hand such as beach sand for the construction of these buildings would have been practical as well as commonplace.

Establishing original component proportions for these mortars was challenging due to the acid-soluble carbonate sand. Instead of dissolving the binder through chemical means and extracting the insoluble sand, a different approach involving microscopical point-counting of sand and binder components and bulk chemical analysis of representative mortar samples had to be preformed. Using this non-traditional two-tiered approach revealed that the original binder to aggregate ratio of the Dry Tortugas Light Station mortar samples is approximately 1 part natural cement to 1.5 parts sand, by volume. This is a fairly typical mix for historic natural cement mortars. A more in-depth discussion of the methodology used to determine this ratio is discussed in Appendix B.

A natural cement is defined as an eminently hydraulic lime that is typically derived from the burning of highly impure limestone. It is these impurities that give the lime the characteristic of hydraulicity, or the ability to set by reaction with water (no air is needed, unlike with pure high calcium limes). Natural cements differ from Portland cements, which were produced later, in that the latter are artificially produced. Portland cements of the 19th century were made by grinding together chalk and

clay and then heating the mixture at high temperatures to produce a simulated natural cement. Both natural and Portland cements can have quite high strength and durability. Natural cement based mortars were quite common in the mid to late 19th century and would have been readily available when these buildings were constructed. [4]

The use of natural cement and carbonate sand mortars is, of course, not surprising given what we know about the construction of nearby Fort Jefferson, which dates to roughly the same period and is associated with the same builders. In fact, Captain H.G. Wright, who oversaw the construction of Fort Jefferson, wrote a proposal to the Light House Board for the construction of the Dry Tortugas lighthouse in which he calls specifically for the use of cement mortars with no lime. Writing in 1855, he states: "I am disposed to believe that the mortar for both brickwork and concrete should be made of cement and sand without any admixture of lime, and in the proportion of two parts of the latter to one of the former in powder."[5] Note that the ratio Wright calls for is quite close to that documented in the current lab analysis.

Although Wright does not specifically call for "natural cement", there was no other commercially available cement in the United States until Portland cement was introduced in the 1870s. So, the mortar Wright was specifying was indeed meant to be a natural cement based mortar. There were many subsequent repair campaigns that involved re-pointing weathered brick joints as well as significant reconstruction of a portion of the masonry below the lighthouse lantern in 1875. Natural cement mortars were specified for some of the re-pointing repairs, namely those made to the lighthouse in 1868.

The *Rehabilitation Report* from 1984 also included chemical analysis of a mortar sample taken from the Dry Tortugas lighthouse. The results of this report conflict with the findings presented here. The report identified the mortar sample as a lime-based mortar with a small percentage of Portland cement and possibly gypsum as the binder mix, and fine silica sand and shell fragments as the aggregate. Because the aggregate contains calcium carbonate-based shell fragments, the acid in the chemical analysis will dissolve the aggregate as well as the binder, and will therefore not provide an accurate reflection of the mortar proportions. In addition, it also may cause the binder to be misidentified as lime. The author of the 1984 report does note that because of the shell content of the mortar, precise identification of the binder to aggregate ratio is impossible, but they still provide an approximate ratio of 1part cement, 3 parts lime and 12 parts sand.

[4] Eckel, Edwin C. *Cements, Limes and Plasters. Reprinted Third Edition.* Dorset: Donhead Publishing, 2005. Page 242.



Figure 15. Lighthouse. Area of historic mortar removed for analysis. Note characteristic carbonate sand inclusions.



Figure 16. Oil house. Area of early plaster, discovered behind later wall finishes, removed for analysis.

[5] LAS, Draft Historic Structure Report (HSR), "Background" section. [Reference: Dry Tortugas Light Station clipping file, Appendix no. 17, H.G. Wright, Capitan of Engineers, Fort Jefferson, FL, letter to Lieutenant T.A. Jenkins, U.S.N., secretary, Light-house Board, Washington, D.C., September 23, 1855, Record Group 26, NA.]

The only mortar analyzed as part of this study that did not contain natural cement was the mortar removed from the exterior brickwork of the keeper's residence, which dates from 1922-23. This mortar is composed exclusively of Portland cement and the same local carbonate sand; no lime was detected in this mortar either. The estimated cement to sand ratio, by volume, is 1 part cement to 2.4 parts sand.

Archival research supports the use of Portland cement and local sand in the construction of the keeper's residence. The 1920 specifications for the construction call for mortar to be composed of "1 part [Portland] cement and 2-1/2 parts sand. Hydrated lime not to exceed 10% by volume of the cement shall be used for tempering."[6] Although the mortar specifications were written for concrete block and not brick, the information can certainly be applied to the brick. In fact, the ingredients and proportions documented in the current lab analysis are almost identical to those included in the 1920 specifications.

The mortars were also examined for the presence of any deterioration due to salt crystallization or salt hydration. This examination was performed petrographically, looking for signs of microcracking, and chemically, looking for elevated levels of water-soluble alkali salts (sodium, potassium and chloride). In general, most mortar samples exhibit "good microstructural integrity", with no evidence of deterioration from salts. Although some minor sulfate deposits and chlorides were detected, they are not related to any significant cracking distress. In addition, the presence of alkali salts is most likely due to the original mortar mix and the use of unwashed sands, an not from subsequent deposits of salt from the environment.

PLASTER

Interior plaster of two of the historic buildings was also examined. In the oil house, a sample of a three-coat plaster system, discovered behind a layer of modern wood paneling and a bead board wall, was removed for analysis. The plaster is composed of: a lime and carbonate sand scratch coat gauged with natural cement, a natural cement and carbonate sand brown coat, and a lime-based finish coat that is gauged with gypsum (no sand). Although it is unclear when this plaster dates from, it is possible that it is original to the building and dates to the 1850s. The sand used in the scratch and brown coats is the same as that used in the brick mortar of the same building, a local carbonate sand. (*Figure 16)*

The other interior plaster examined for this study was removed from the keeper's residence, and presumably dates to the original 1922-23 period of construction. The plaster is a two-coat system, with gypsum and sand-based scratch coat and a gypsum-based finish coat gauged with lime. The brown coat is consistent with a Keene's cement mixture. Keene's cement is a slow-setting, hard-

[6] 1920 specification, page 3.

finish plaster produced by burning very pure gypsum at high temperatures and treating the material with alum or other chemicals during the manufacturing process.[7] The current lab findings indicate that a different plaster was used than what was originally specified. The preliminary specifications for the keeper's residence, which date to 1920, call for the use of cement and lime plaster and not gypsum. However, the finish plaster was to be "cement plaster equal to the US Gypsums Co's Adamant"', a fire-resistant type of early drywall.

For a more in depth discussion of the specific findings of the mortar and plaster analysis performed as part of this study, including detailed characterization of the aggregate and binder as well as annotated photomicrographs, refer to *Appendix B.*

[7] Edwin C. Eckel. *Cements, Limes and Plasters: Their Materials, Manufacture and Properties*. Michigan: Donhead Publishing Co. 2005 (originally published 1905), 78.

4.0 CONCLUSIONS AND RECOMMENDATIONS

4.1 Finishes

MASONRY

The recommendation for an appropriate paint finish for the masonry of the historic buildings at the Dry Tortugas Light Station is fairly straightforward. The white finish on the brick masonry portions of the lighthouse, oil house, south brick cistern and kitchen building should be maintained (note that the masonry portions of the keeper's residence were never painted). Even though archival and physical evidence indicates that these buildings were not originally painted (possibly with the exception of the cistern), a white finish was applied early enough in their history that it can be considered historically significant. For instance, the oil house was painted white by circa 1892 and the lighthouse was painted with its current black and white scheme by 1875. In the case of the lighthouse, not only is the black and white paint scheme historic, but it also defines the lighthouse's appearance and its identity. In addition to being historically appropriate, the use of a finish on the brick masonry of these buildings also affords a level of protection for the brick substrate by protecting it from wind and moisture that would no doubt take a toll on the surface of the brick over time, possibly eroding away the fire skin and making the brick even more susceptible to weathering.

Although the brick of these buildings should be maintained white, the type of finish used to achieve this white color should be carefully considered. Archival evidence indicates that both limewash and oil paints were used historically on the buildings at the Dry Tortugas Light Station, although where each of these finishes was used is not always made clear. Physical evidence, however, suggests that white limewash was used on the brick portions of these buildings, with the exception of the black paint on the top half of the lighthouse, and oil paint was used on the wood elements. The use of limewash on masonry structures was commonplace throughout history and into the early 20th century. It was an inexpensive and readily available finish. From a preservation perspective, limewash is a perfect finish for masonry substrates because it forms a good bond, it is moisture-permeable and it resists biological growth. It could also be renewed both easily and cheaply.

The majority of the white finishes currently on the brick buildings at the Dry Tortugas Light Station appear to be modern acrylic- or oil-based paints. While the color of the finish is appropriate, the finish type is not. These modern finishes, which in some cases appear to be trapping moisture in the wall, should be removed and white limewash applied instead. Of course, care should be taken to carefully remove the modern paint layers in a way that does not damage the brick substrate (this would exclude the use of many abrasive blasting techniques). In addition, the existing paint should be tested to determine any lead content prior to removal. The materials analysis included in the 1984 rehabilitation report cites that the paint on the exterior of the lighthouse is an acrylic-polyvinyl acetate mixture with lead and zinc-based pigments. It is likely this paint still remains on the lighthouse

and that other buildings of the light station were painted with the same lead-based paint. Further testing would be required to identify lead content in any of the paint coatings on the buildings.

Once the modern coatings are successfully removed from the brick masonry, the limewash will bond well to the brick, the mortar and any traces of earlier limewash. The limewash will allow any moisture present in the brick walls to escape without compromising the limewash finish (as opposed to the less permeable modern paints which can fail when moisture gets trapped behind them). Performing a mock-up of such a finish is strongly advised in order to assess the longevity of this type of finish in the environmental conditions associated with the island.

The only masonry surface that should not get painted with a lime wash is the top half of the day mark, which is painted black. Achieving a truly black limewash is difficult if not impossible, so some other type of finish will have to be used in this location. Although oil paints were most likely used historically, a better paint may be currently available. Modern paints such as those based on potassium silicate or even some highly permeable acrylic paints designed for historic masonry should be considered for the lighthouse.

WOODWORK & METALWORK

Recommendations for appropriate restoration finishes for the woodwork and metalwork of the oil house, lighthouse and keeper's residence are included in the chart below; no paint colors are provided for the kitchen building because no historic paint was found on the wood trim of this building. Wherever surviving physical evidence remains, a color match to the historic paint color is provided. Color matches are made to both the Munsell and Benjamin Moore color systems. However, in cases where there is no longer any physical paint evidence or access to a particular element was not permitted during the study, recommendations for appropriate restoration colors are provided but are based solely on archival information (written or photographic). In the latter case, a general recommendation is provided but a specific color match is not. The basis for each color match is provided in the "Source" column of the chart below.

The recommended restoration paint colors are provided below. Specific color matches have been made to both the standardized Munsell color system and the commercial Benjamin Moore paint palette. CIE L*a*b values for the actual color as well as the color matches are also provided so that the difference between the actual color and the matches can be determined. Please note that, although there was subtle variation in the color of the limewashes on the different buildings, a single color match to the limewash is provided.

It should also be mentioned that the recommended colors for the lighthouse and oil house door trim (which are based on physical evidence) may represent original paint colors that were on the buildings when the brick masonry was exposed and not once the brick was painted white. Unfortunately, it is

not possible to determine the paint color on the wood door trim when the brick was first painted white.

Any attempt to reproduce the following pages, including printing from the electronic version of the report, will distort the color of the provided chips. Only the actual color chip or notation should be used for paint replication purposes.

Building	Component	Date	Description	Source	Color Match	CIE L*a*b* Values	Color Chip
Lighthouse	Brick masonry	1858-1870	Exposed brick	Written archival references, physical evidence	Not Provided - not a paint color		
	Brick masonry	1870	Bottom half white limewash and top half black paint	Written archival references, historic photographs, physical evidence	*Munsell Match: N 9.5* *B. Moore Match: OC-45* *Access to white limewash only*	*Sample:* L*89.7 a*0.1 b*4.4 *Munsell Match:* L*96.7 a*-0.7 b*1.1 Delta E = 7.8 *B. Moore Match:* L*93.0 a*-0.5 b*5.4 Delta E = 3.5	B. Moore OC-45
	Window sash and frames	circa 1892	Pale-colored paint, possibly cream or white	Historic photograph	Not Provided - no physical evidence		
	Door	possibly 1858	Gray paint	Physical evidence	*Munsell Match: N 5.75* *B. Moore Match: HC-161*	*Sample:* L*56.3 a*-2.3 b*0.7 *Munsell Match:* L*59.0 a*-1.0 b*0.4 Delta E = 3 *B. Moore Match:* L*54.4 a*-5.0 b*-1.8 Delta E = 4.1	B. Moore HC-161

Building	Component	Date	Description	Source	Color Match	CIE L*a*b* Values	Color Chip
	Door frame	possibly 1858	Cream paint	Physical evidence	*Munsell Match: 2.5Y 9/2* *B. Moore Match: 1149*	*Sample:* L*83.6 a*2.3 b*13.8 *Munsell Match:* L*92.0 a*2.2 b*16.1 Delta E = 8.7 *B. Moore Match:* L*89.5 a*3.9 b*11.1 Delta E = 6.7	B. Moore 1149
	Lantern exterior	1862	Black paint	Written archival reference	Not Provided - not a paint color		
	Lantern interior	1862	White Paint	Written archival references,	Not Provided - not a paint color		
Oil house	Brick masonry	1858	Exposed brick	Historic photographs, physical evidence	Not Provided - not a paint color		

Building	Component	Date	Description	Source	Color Match	CIE L*a*b* Values	Color Chip
	Brick masonry	circa 1892	White limewash	Historic photographs, physical evidence	*Munsell Match: N 9.5* *B. Moore Match: OC-45*	*Sample:* L*89.7 a*0.1 b*4.4 *Munsell Match:* L*96.7 a*-0.7 b*1.1 Delta E = 7.8 *B. Moore Match:* L*93.0 a*-0.5 b*5.4 Delta E = 3.5	B. Moore OC-45
	Window sash and frames	circa 1892	Pale-colored paint, possibly cream or white	Historic photograph	Not Provided - no physical evidence		
	Door frame	1858	Gray paint	Physical evidence	*Munsell Match: 10Y 6/1* *B. Moore Match: 1483*	*Sample:* L*50.5 a*-1.4 b*1.1 *Munsell Match:* L*35.2 a*-0.4 b*0.2 Delta E = 15.3 *B. Moore Match:* L*33.4 a*-0.6 b*-1.5 Delta E = 17.3	B. Moore 1483
Kitchen building	Brick masonry	1858	Exposed brick	Historic photographs, physical evidence	Not Provided - not a paint color		

Building	Component	Date	Description	Source	Color Match	CIE L*a*b* Values	Color Chip
	Brick masonry	unknown	White limewash	Physical evidence	*Munsell Match: N 9.5* *B. Moore Match: OC-45*	*Sample:* L*89.7 a*0.1 b*4.4 *Munsell Match:* L*96.7 a*-0.7 b*1.1 Delta E = 7.8 *B. Moore Match:* L*93.0 a*-0.5 b*5.4 Delta E = 3.5	 B. Moore OC-45
South brick cistern	Brick masonry	1858	White limewash	Physical evidence	*Munsell Match: N 9.5* *B. Moore Match: OC-45*	*Sample:* L*89.7 a*0.1 b*4.4 *Munsell Match:* L*96.7 a*-0.7 b*1.1 Delta E = 7.8 *B. Moore Match:* L*93.0 a*-0.5 b*5.4 Delta E = 3.5	 B. Moore OC-45
Keeper's dwelling exterior	Door surround and porch trim	1917	White paint	Written archival references, historic photographs, physical evidence	*Munsell Match: 5Y 9/1* *B. Moore Match: 974*	*Sample:* L*88.3 a*-0.4 b*11.2 *Munsell Match:* L*92.1 a*0.2 b*10.3 Delta E = 3.9 *B. Moore Match:* L*89.0 a*0.1 b*8.4 Delta E = 2.9	 B. Moore 974
Keeper's dwelling interior	Plaster walls of hallway and bathroom	1917	Pale gray-green paint	Written archival references, physical evidence	*Munsell Match: 10Y 7/1* *B. Moore Match: 1486*	*Sample:* L*78.5 a*-2.0 b*4.9 *Munsell Match:* L*71.9 a*-1.6 b*8.7 Delta E = 7.6 *B. Moore Match:* L*76.9 a*-0.5 b*7.3 Delta E = 3.3	 B. Moore 1486

Building	Component	Date	Description	Source	Color Match	CIE L*a*b* Values	Color Chip
	Wood cornice of hallway	1917	White paint	Written archival references, physical evidence	*Munsell Match: 5Y 9/1* *B. Moore Match: 974*	*Sample:* L*87.2 a*0.0 b*12.7 *Munsell Match:* L*92.1 a*0.2 b*10.3 Delta E = 5.5 *B. Moore Match:* L*89.0 a*0.1 b*8.4 Delta E = 4.7	 B. Moore 974

4.2 Mortar

Analysis of the brick mortars of the buildings at the Dry Tortugas Light Station indicates that the original mortars were composed of natural cement. Such mortars were typical for the period, especially for maritime construction. The mortar has generally held up well through the years, even in the harsh environment of wind and salt-laden sea air; although exceptions can be seen at the lighthouse, where the mortar is friable in many areas and paint loss occurs regularly at the mortar joints. However, as previously discussed, this deterioration is most likely a factor of moisture permeating through the wall and inappropriate paint films and not failure of the original material. A more comprehensive evaluation of this aspect of the masonry construction falls outside of the scope of this research.

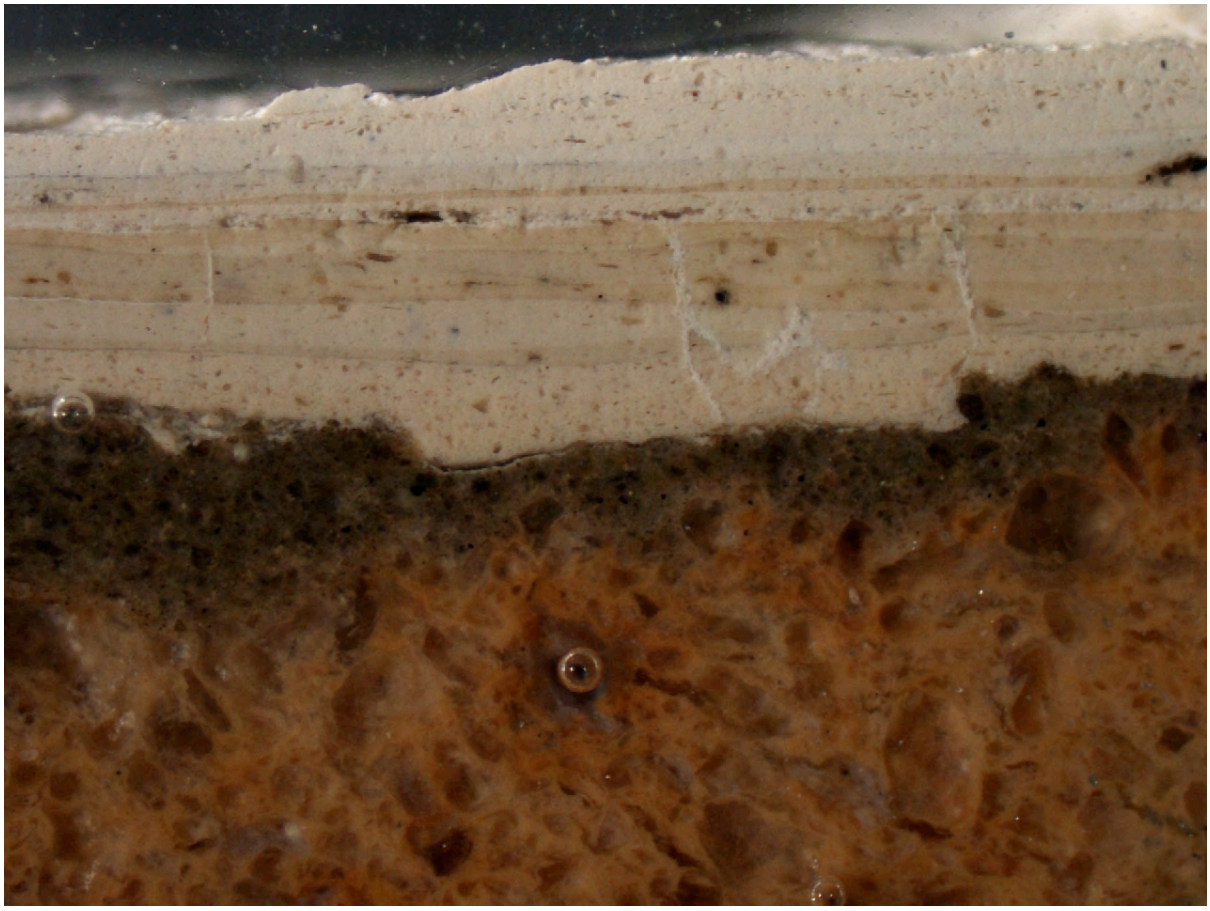
For future re-pointing campaigns, it is important that the correct mortar be used. It may also be prudent to replace existing repair campaigns with a more appropriate mortar. Mortars based on large amounts of Portland cement are typically too strong and dense to be used in combination with the type of low-fired brick found on most of these buildings. Although, the keeper's residence, which was built later, is an exception, as it is constructed of high-fired modern brick and Portland cement mortar. In general, the use of a high calcium or hydraulic lime mortar would also be inappropriate for these buildings. Therefore, the recommended restoration mortar for the historic buildings at the Dry Tortugas Light Station is as follows:

<u>Lighthouse, Oil House, Kitchen Building & South Brick Cistern</u>
Binder: natural cement
Sand: natural carbonate sand (to match existing)
Component Ratio (binder: sand): 1:1.5

<u>Keeper's Residence</u>
Binder: Portland cement
Sand: natural carbonate sand (to match existing)
Component Ratio (binder: sand): 1:3 (note this mix is slightly less binder-rich than the original)

APPENDIX A.

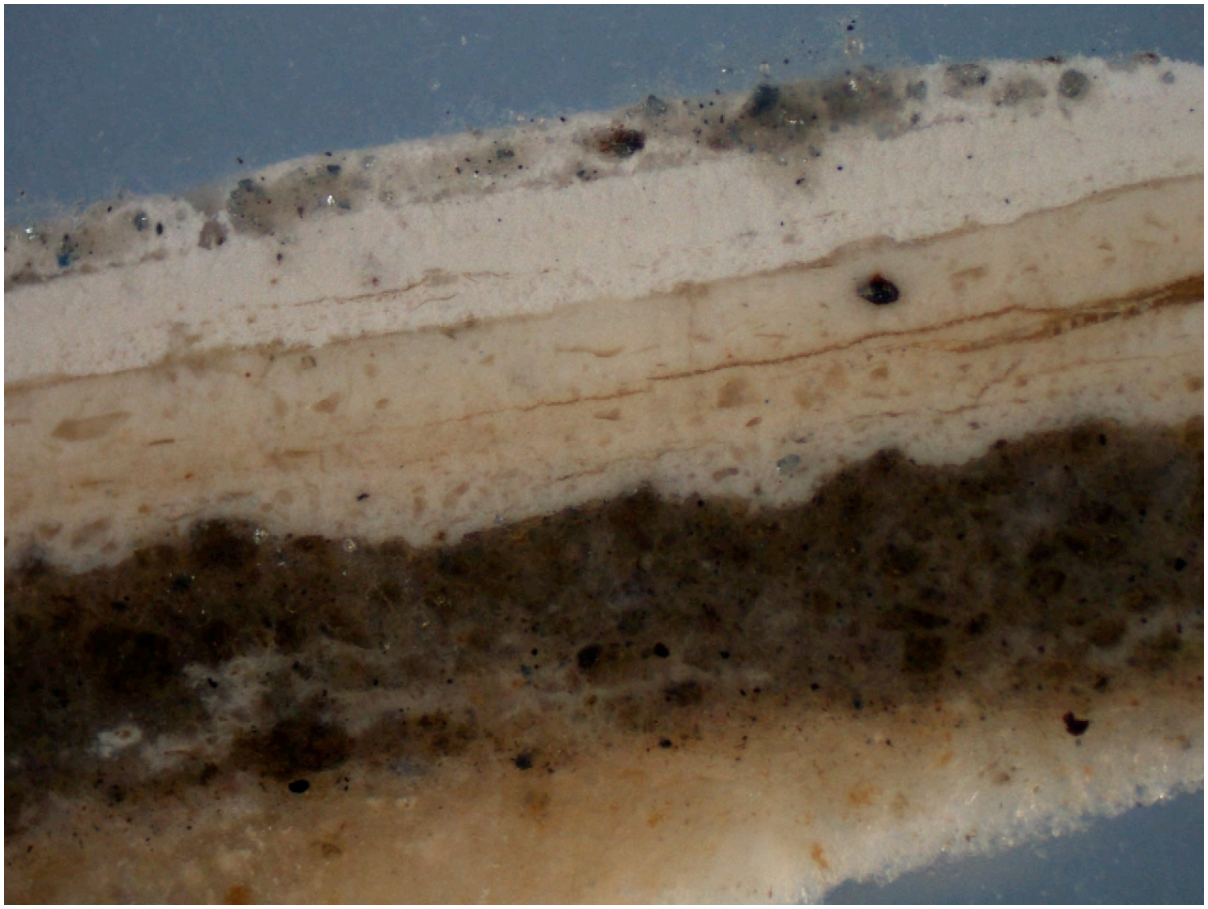
PHOTOMICROGRAPHS AND STRATIGRAPHIES



SAMPLE NO:	LOKE.F.1 (40x, Visible Light)
LOCATION:	Oil House, exterior, east elevation now enclosed, finishes on brick.

LAYER*	***COLOR***	***NOTES***
Substrate	Brick	Surface looks weathered and soiled, suggests exposure prior to painting
1	Cream	All finishes look like paint, missing early limewash layer visible in LOKE.F.9
2	Off-white	
3	Off-white	
4	Cream	
5	Cream	
6	Cream	
7	Off-white	
8	Cream	
9	Off-white	
10	Off-white	
11	Off-white	Current finish

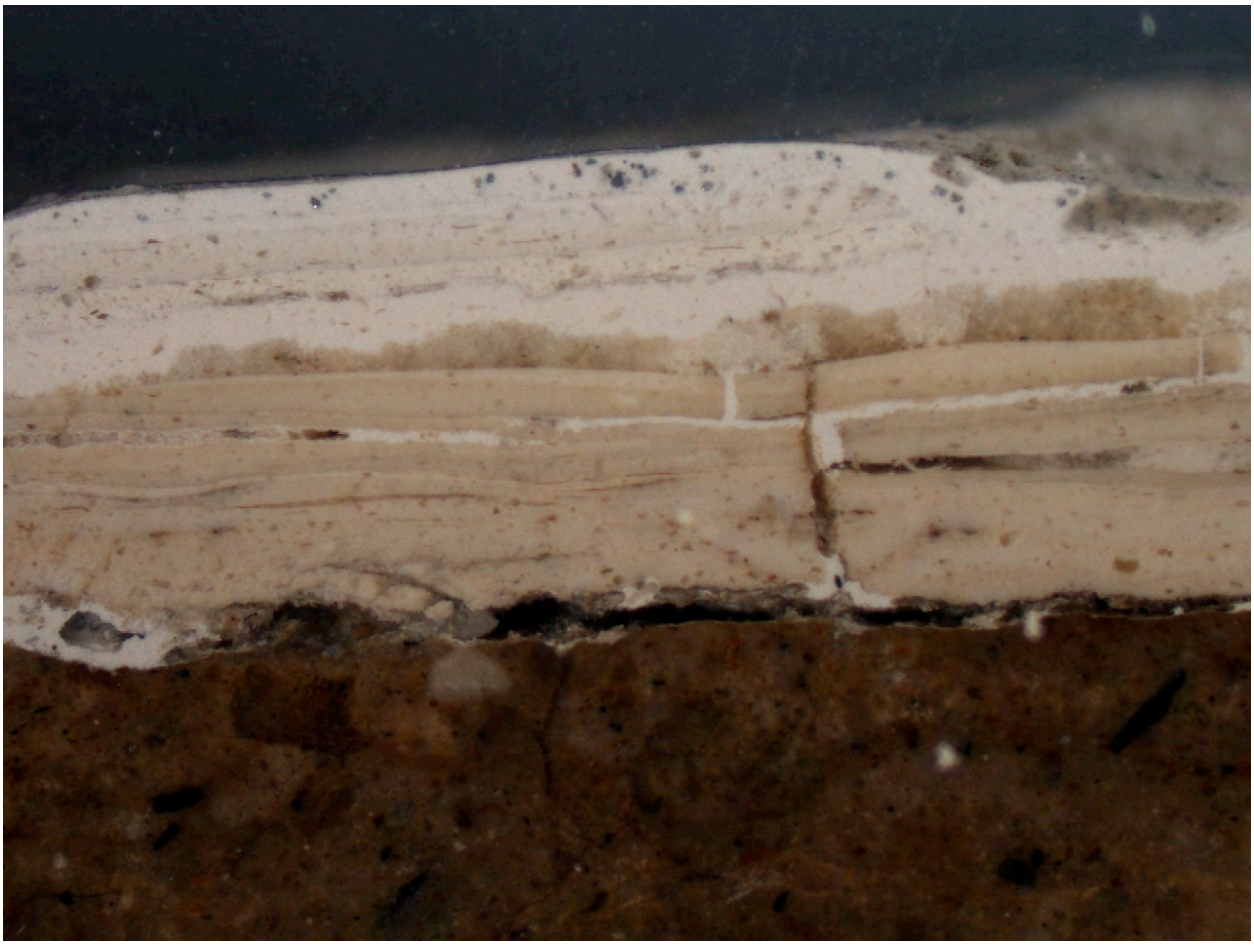
* **bold** indicates a finish layer and not a primer



SAMPLE NO:	LOKE.F.2 (100x, Visible Light)
LOCATION:	Passageway between Oil House & Lighthouse, south wall, finishes on concrete.

LAYER*	***COLOR***	***NOTES***
Substrate	Concrete	
1	Off-white	
2	Cream	
3	Cream	
4	Off-white	
5	Off-white	Modern paint
6	Off-white	Current finish

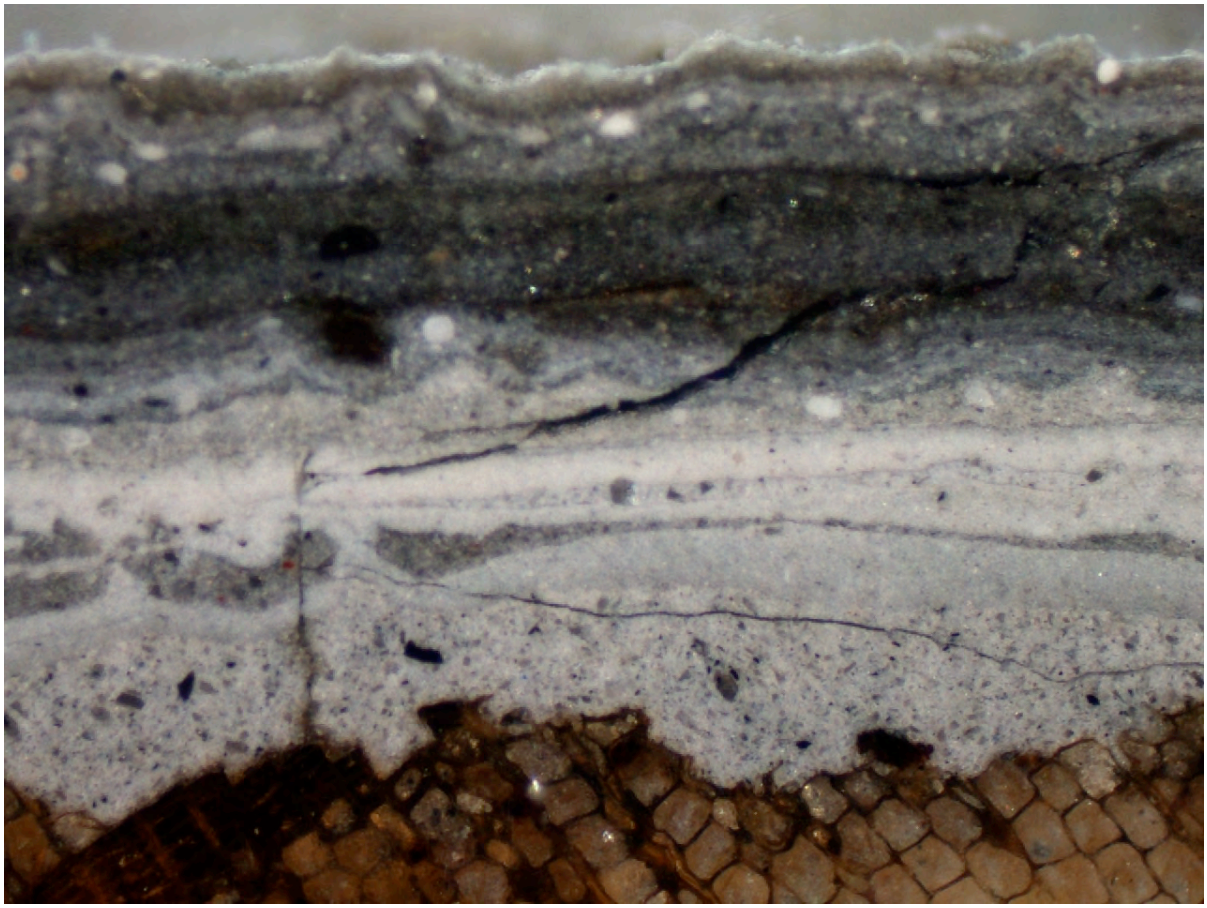
* **bold** indicates a finish layer and not a primer



SAMPLE NO:	LOKE.F.3 (40x, Visible Light)
LOCATION:	Oil House, exterior, east elevationl, finishes on brick.

LAYER*	***COLOR***	***NOTES***
Substrate	Brick	Fracture at surface suggests weathering prior to painting
1	Cream	
2	Cream	
3	Cream	
4	Cream	
5	Cream	
6	Cream	
7	Cream	
8	Cream	
9	Cream	
10	Cream/tan	Translucent
11	White	
12	Off-white	
13	Off-white	
14	Off-white	
15	White	Current finish

* **bold** indicates a finish layer and not a primer

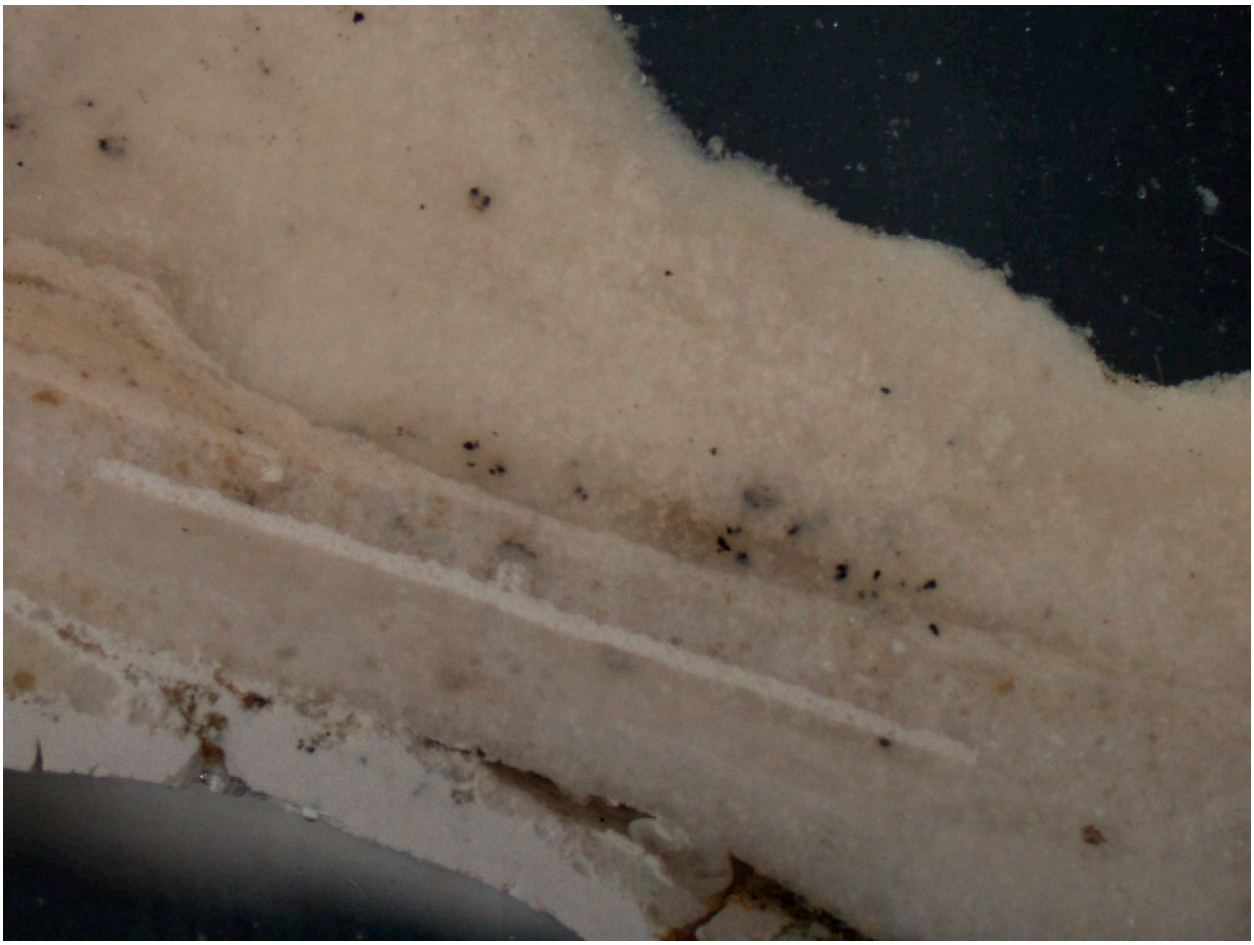


SAMPLE NO:	LOKE.F.4 (100x, Visible Light, only earliest layers visible in photo)
LOCATION:	Oil House, exterior, east elevation, door frame, finishes on wood.

LAYER*	***COLOR***	***NOTES***
Substrate	Wood	
1	Pale gray	
2	Pale gray	
3	Pale gray	
4	Gray-green	Translucent
5	Pale gray	
6	Pale gray	
7	Pale gray	
8	Pale gray	
9	Medium gray	
10	Pale gray	
11	Medium gray	
12	Medium gray	
13	Medium gray	
14	Pale gray	
15	Medium gray	
16	Off-white	

17	Gray-green	
18	Gray-green	
19	Light gray-green	
20	Pale gray	
21	Off-white/ pale gray	
22	Pale gray	
23	Pale gray	
24	Dark gray	
25	Cream	
26	Off-white	Remaining paints look more modern
27	Dark gray	
28	Gray	
29	Blue-gray	
30	White	
31	Dark gray	
32	Cream	
33	Cream	
34	Cream	
35	Cream	
36	Cream	
37	Cream	
38	Cream	
39	Gray	
40	Olive green	
41	Dark gray	
42	White	
43	Dark gray	
44	Dark gray	
45	Dark gray	
46	Light Gray	
47	Gray	Current finish

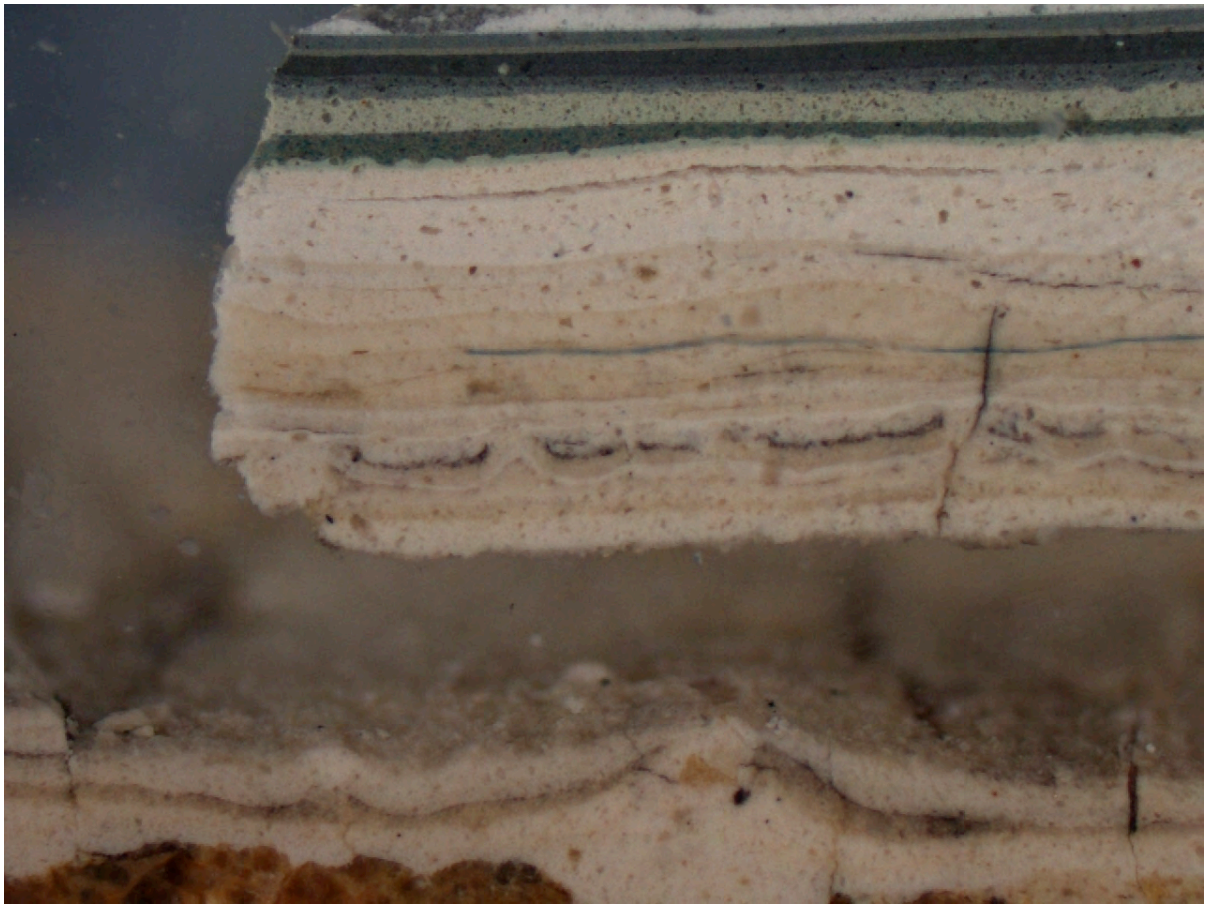
* **bold** indicates a finish layer and not a primer



SAMPLE NO:	LOKE.F.5 (100x, Visible Light)
LOCATION:	Cistern, west elevation, finishes on brick.

LAYER*	***COLOR***	***NOTES***
Substrate	Brick (missing in photo)	No sign of weathering of brick surface, suggests brick was always finished
1	Off-white	Translucent, white wash
2	Off-white	Translucent, white wash
3	Off-white	
4	Off-white	Modern paint
5	White	
6	White	Current finish

* **bold** indicates a finish layer and not a primer



SAMPLE NO:	LOKE.F.6 (40x, Visible Light)
LOCATION:	Lighthouse, exterior, north wall now enclosed adjacent to door, finishes on brick.

LAYER*	***COLOR***	***NOTES***
Substrate	Brick	Surface looks soiled
1	Tan	Thin, translucent, lime wash
2	Cream	
3	Tan	Translucent
4	Cream	
5	Tan	
6	Cream	
7	Buff	
8	Cream	
9	White	
10	Cream	
11	Cream	
12	Cream	
13	Cream	
14	Cream	
15	Cream	
16	Cream	

17	Cream	
18	Cream	
19	Cream	
20	[fracture]	
21	White	
22	Light Green	
23	Blue	
24	Light Green	
25	Blue	
26	Dark Blue	
27	Dark Blue	
28	Gray	
29	Gray-blue	
30	White	Current finish

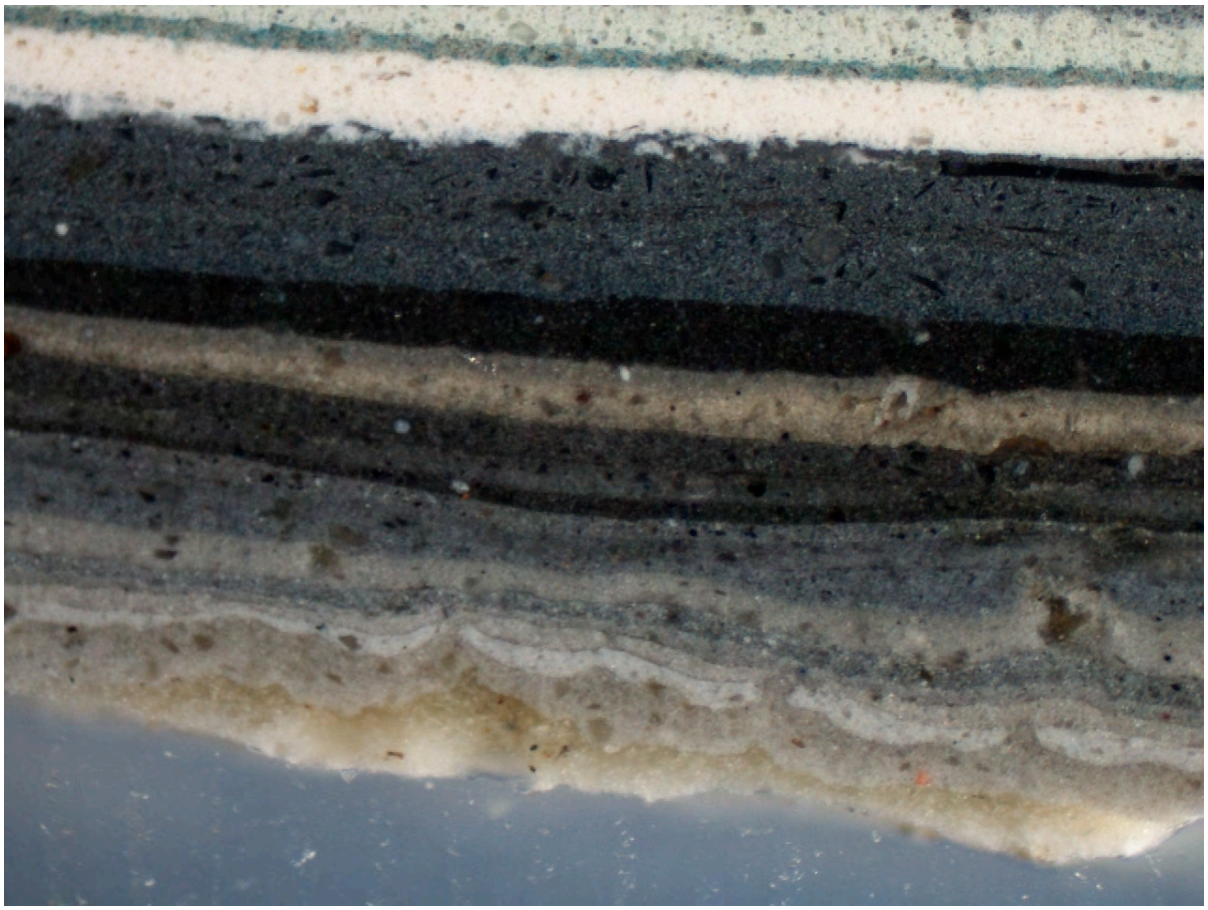


SAMPLE NO:	LOKE.F.7 (40x, Visible Light)
LOCATION:	Lighthouse, exterior, west wall now enclosed, door frame, finishes on wood.

LAYER*	***COLOR***	***NOTES***
Substrate	Wood	
1	Cream	
2	Off-white	
3	Off-white	
4	Cream	
5	Off-white	
6	Cream	Translucent
7	Off-white	
8	Cream	
9	Off-white	
10	Dark green-gray	Translucent
11	Blue-gray	
12	Dark blue-gray	
13	Gray	
14	Blue-gray	
15	Light blue-gray	
16	Light blue-gray	
17	White	
18	Light blue-gray	

19	Light blue-gray	
20	Blue-gray	
21	Blue-gray	
22	Dark blue-gray	
23	Light blue-gray	
24	Gray	
25	Light gray	
26	Gray	
27	Blue-gray	
28	Blue-gray	
29	Blue-gray	
30	Blue-gray	
31	Blue-gray	
32	Blue-gray	
33	Blue-gray	
34	Gray	Thin
35	Dark blue-gray	
36	Blue-gray	
37	White	
38	White	
39	Blue-gray	
40	Light blue-gray	
41	Gray	Current finish

* **bold** indicates a finish layer and not a primer

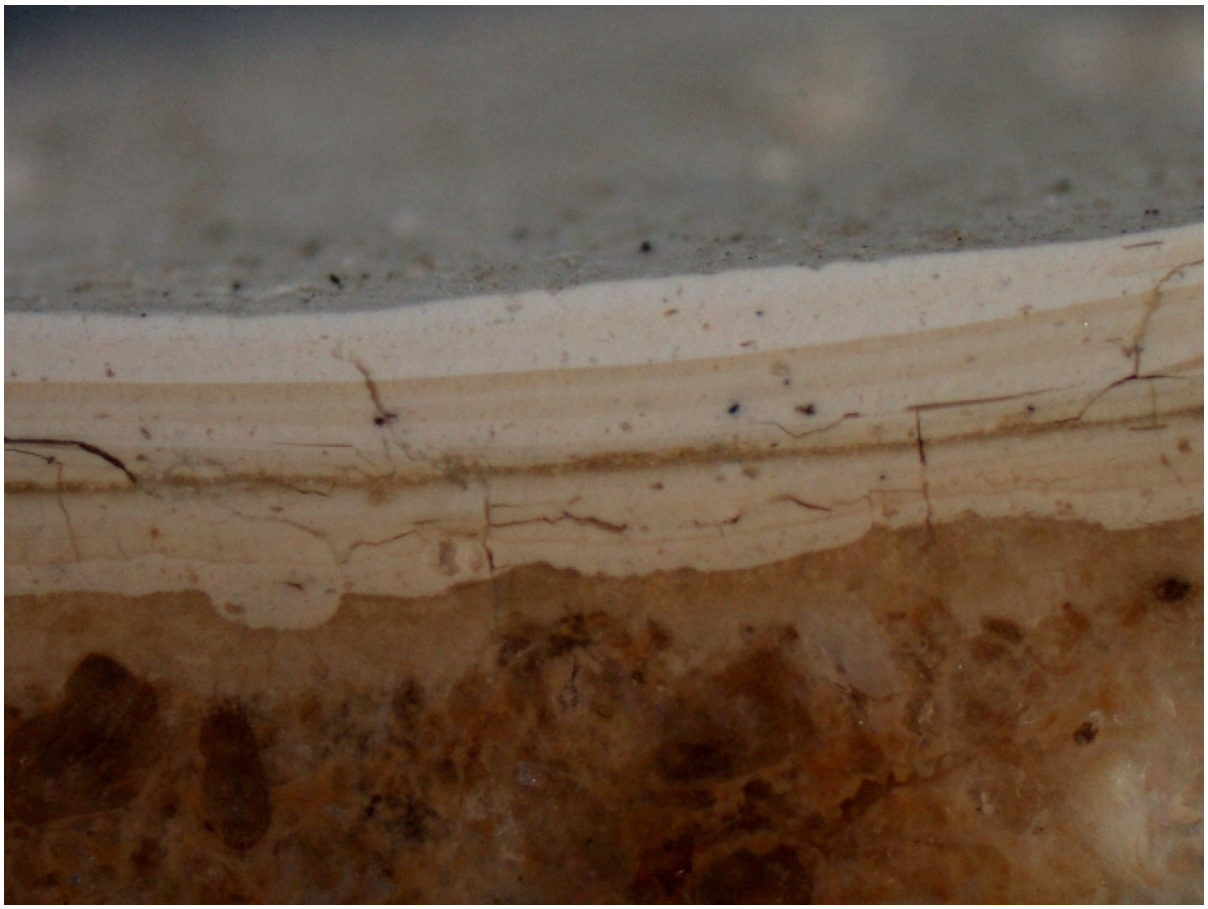


SAMPLE NO:	LOKE.F.8 (100x, Visible Light, only earliest layers visible in photo)
LOCATION:	Lighthouse, exterior, west wall now enclosed, door, finishes on wood.

LAYER*	***COLOR***	***NOTES***
Substrate	Wood (not visible in photo)	
1	Cream	
2	Light gray	
3	Light gray	
4	Gray	
5	Gray	
6	Blue-gray	
7	Gray	
8	Blue-gray	
9	Blue-gray	
10	Blue-gray	
11	Blue-gray	
12	Light blue-gray	
13	Light blue-gray	
14	Dark blue-gray	
15	Blue-gray	
16	Blue-gray	
17	White	
18	Blue-green	

19	Light blue-green	
20	Blue-green	
21	Blue-gray	
22	Blue-gray	
23	Blue-gray	
24	Light blue-gray	
25	Light blue-gray	
26	Light green	
27	Dark blue	
28	Blue-gray	
29	Light blue-gray	
30	Gray	Current finish

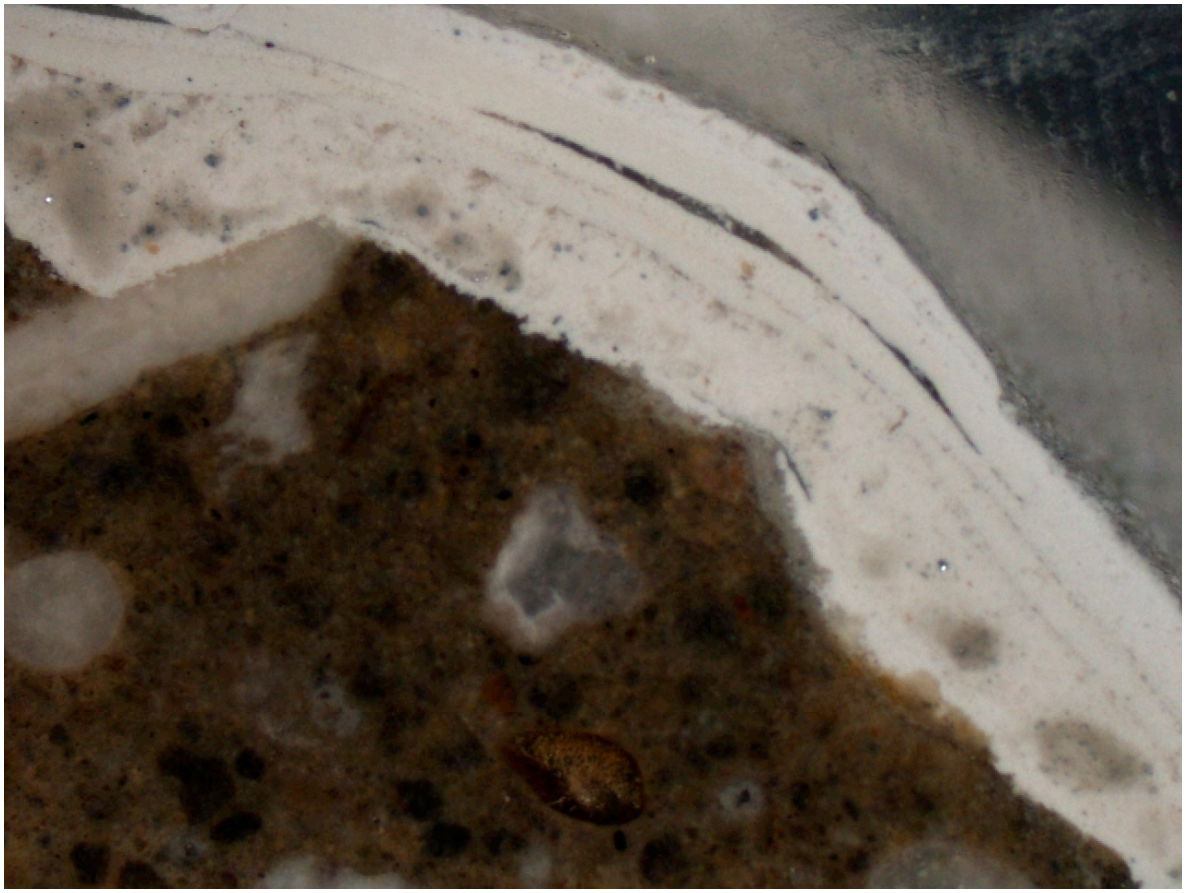
* **bold** indicates a finish layer and not a primer



SAMPLE NO:	LOKE.F.9 (40x, Visible Light)
LOCATION:	Oil House, exterior, east wall, finishes on brick.

LAYER*	***COLOR***	***NOTES***
Substrate	Brick	Surface looks weathered
1	Cream	Translucent, limewash
2	Cream	Remaining layers look like paint
3	Cream	
4	Cream	Translucent material at surface
5	Cream	
6	Off-white	
7	Cream	
8	Cream	
9	Cream	
10	White	Translucent
11	Cream	
12	White	Current Finish

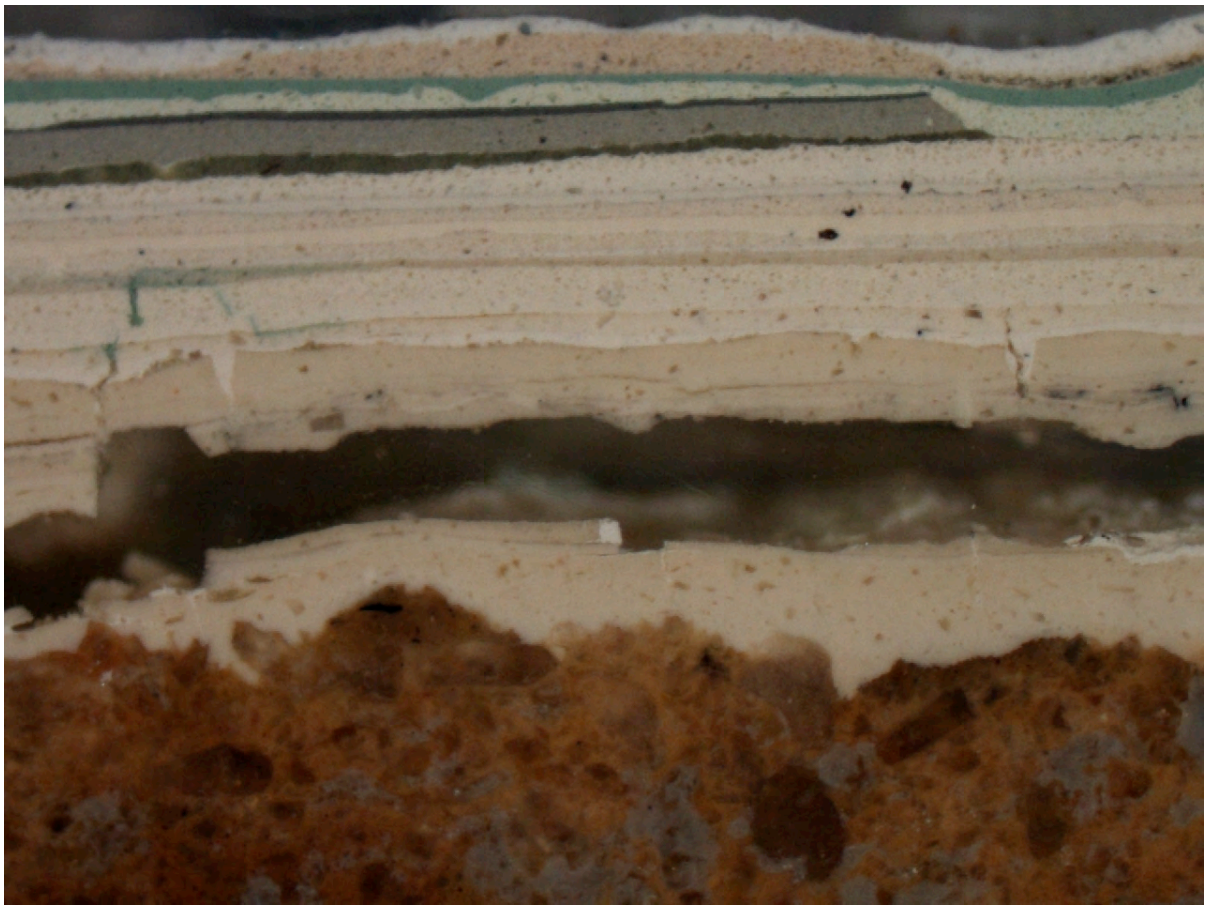
* **bold** indicates a finish layer and not a primer



SAMPLE NO:	LOKE.F.10 (40x, Visible Light)
LOCATION:	Kitchen Building, exterior, east elevation, finishes on brick.

LAYER*	***COLOR***	***NOTES***
Substrate	Brick/Mortar	
1	White	All layers are modern paint
2	White	
3	White	
4	White	
5	White	Current Finish

* **bold** indicates a finish layer and not a primer

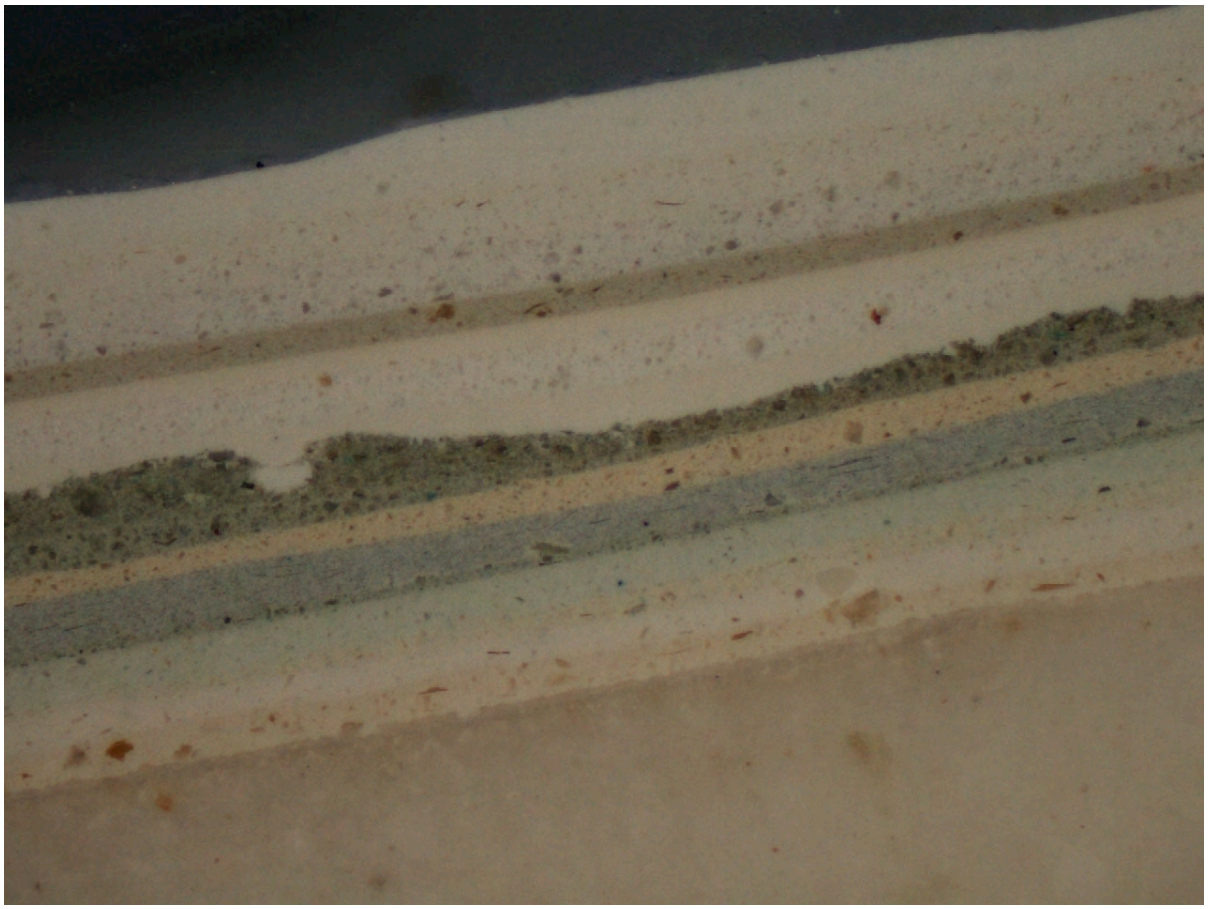


SAMPLE NO:	LOKE.F.11 (40x, Visible Light)
LOCATION:	Oil House, exterior, south elevation now enclosed, finishes on brick.

LAYER*	***COLOR***	***NOTES***
Substrate	Brick	Surface is weathered, suggests exposure
1	Cream/tan	Translucent, lime wash (partial layer)
2	Cream	
3	Cream	
4	Cream	
5	Light cream	
6	Cream	
7	Cream	
8	Cream	
9	Cream	
10	Cream	
11	Cream	
12	Cream	
13	White	
14	Off-white	
15	White	
16	Gray	
17	Light gray	
18	Light gray/off-white	

19	Off-white	
20	Cream	
21	Off-white	
22	Light gray/off-white	
23	Off-white	
24	Green	
25	Gray	
26	Dark blue-gray	
27	Light green	
28	Green	
29	Peach	
30	White	Current finish

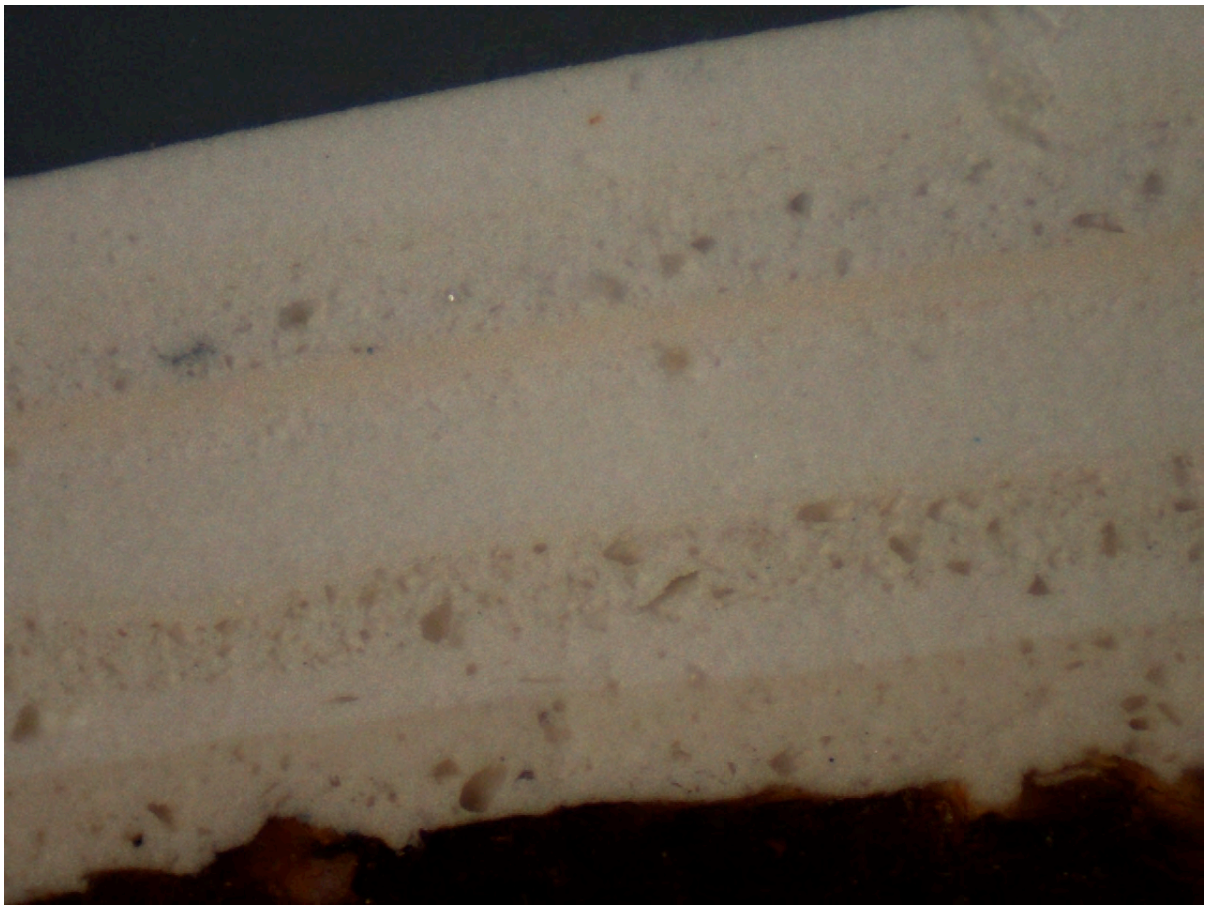
* **bold** indicates a finish layer and not a primer



SAMPLE NO:	LOKE.F.12 (100x, Visible Light)
LOCATION:	Keeper's Dwelling, interior, hallway outside bathroom, west wall, finishes on plaster.

LAYER*	***COLOR***	***NOTES***
Substrate	Plaster	
1	Cream	
2	White	
3	Cream	
4	Light green	
5	Light green	
6	White	
7	Medium blue	
8	Warm yellow	
9	Medium green	
10	Cream	
11	White	
12	Cream	
13	Light gray/beige	
14	White	
15	Cream	
16	White	Current finish

* **bold** indicates a finish layer and not a primer



SAMPLE NO:	LOKE.F.13 (200x, Visible Light)
LOCATION:	Keeper's Dwelling, interior, hallway outside bathroom, cornice, finishes on wood.

LAYER*	***COLOR***	***NOTES***
Substrate	Wood	Sealed with clear coat
1	Cream	
2	White	
3	Cream	
4	White	
5	Cream	
6	White	
7	Cream	Current finish

* **bold** indicates a finish layer and not a primer



SAMPLE NO:	LOKE.F.14 (100x, Visible Light)
LOCATION:	Keeper's Dwelling, interior, bathroom, west wall, finishes on plaster.

LAYER*	***COLOR***	***NOTES***
Substrate	Plaster	
1	Cream	
2	White	
3	Light Green	
4	Light Gray	
5	Gray	
6	Blue	
7	Warm cream	
8	White	
9	Light blue	
10	White	
11	Light blue	Current finish (behind drywall)

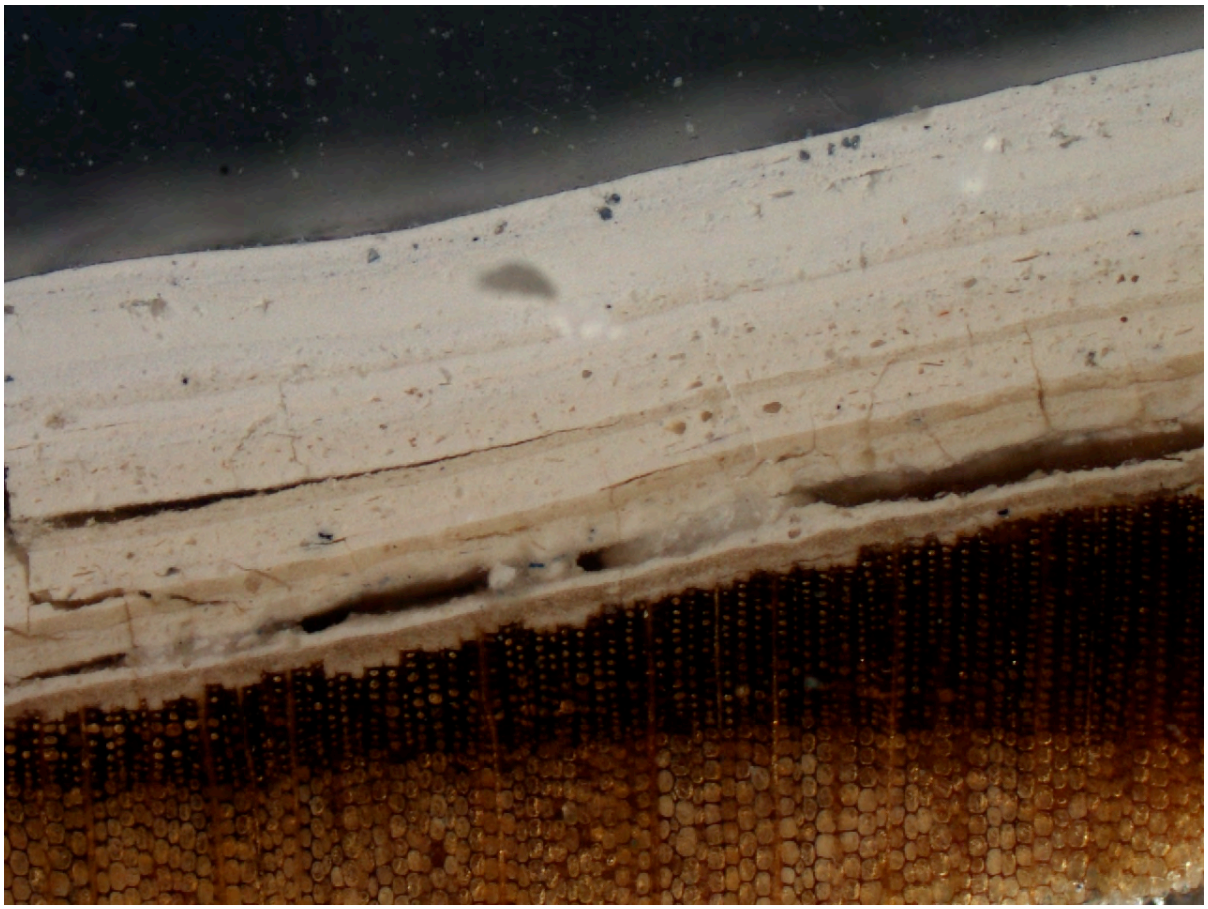
* **bold** indicates a finish layer and not a primer



SAMPLE NO:	LOKE.F.15 (100x, Visible Light)
LOCATION:	Keeper's Dwelling, exterior, east elevation, front door surround, finishes on wood.

LAYER*	***COLOR***	***NOTES***
Substrate	Wood	Surface distressed, looks stripped, missing earliest finish?
1	Dark green	Soaked into pores of wood at surface
2	Cream	
3	White	Thin
4	Gray-green	
5	White	
6	Dark red	Thin
7	Dark gray	
8	Dark red	Disrupted, weathered
9	White	
10	White	Current finish

* **bold** indicates a finish layer and not a primer



SAMPLE NO:	LOKE.F.16 (40x, Visible Light)
LOCATION:	Keeper's Dwelling, exterior, east elevation, porch soffit (rear face), finishes on wood.

LAYER*	***COLOR***	***NOTES***
Substrate	Wood	
1	White	
2	Cream	Translucent
3	White	
4	Cream	
5	Off-white	
6	Cream	
7	Cream	
8	White	
9	Cream	
10	White	
11	White	Current finish

* **bold** indicates a finish layer and not a primer

APPENDIX B.

MORTAR AND PLASTER ANALYSIS REPORT
(TESTWELL, INC. 2009)

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1. Introduction

On March 27, 2009, Testwell received eleven mortar and plaster samples from Ms. Dorothy Krotzer of Building Conservation Associates, Inc. reported to have been sampled from various structures at the Loggerhead Key Light Station in the Dry Tortugas National Park, FL (Figs. 1 through 4). Samples are identified by the client as follows:

Sample No.	Building	Description
LOKE.M.1	Oil House	Exterior, east elevation mortar. Taken from protected wall now enclosed. Sample from interior of wall (from an area where a hole was cut through wall for a pipe).
LOKE.M.2	Brick Cistern	Exterior, east elevation mortar.
LOKE.M.3	Brick Cistern	Interior, parging. Taken from upper portion of interior wall.
LOKE.M.4	Lighthouse	Exterior, west elevation, mortar. Taken approximately 8-feet from ground.
LOKE.M.5	Lighthouse	Exterior, west elevation, mortar. Taken from former exterior wall now enclosed, adjacent to entrance to lighthouse.
LOKE.M.6	Lighthouse	Interior, mortar. Taken from wall at ground floor level.
LOKE.M.7	Lighthouse	Interior, mortar. Taken from wall below watch level (supposedly rebuilt in 19th century).
LOKE.M.8	Oil House	Interior, south wall, plaster. Taken from behind modern wood paneling and earlier beadboard wall; three-layer plaster system applied over brick.
LOKE.M.9	Kitchen Building	Exterior, north elevation, mortar. Sample from interior of wall.
LOKE.M.10	Keeper's Dwelling	Exterior, west wall, mortar.
LOKE.M.11	Keeper's Dwelling	Interior, bathroom, west wall, plaster. Two-coat plaster system.

At the client's request, all samples are examined petrographically in order to identify material constituents and assess the degree of microcracking and associated mineral deposition. Aside from some of the plaster coats, all samples are also analyzed chemically in order to provide information regarding original binder chemistries and estimate original component proportions. Water-soluble chloride analysis is also requested for the four lighthouse mortar samples in order to provide information regarding possible salt crystallization or hydration distress. Finally, statistical point-count analysis is performed on three strategically chosen samples in order to provide a cross-check of the material proportion estimates generated from the chemical analyses.

2. Methods of Examination

The petrographic examination is conducted in accordance with the standard practices contained within *ASTM C 1324: Standard Test Method for Examination and Analysis of Hardened Masonry Mortar*. Data collection is performed by a degreed geologist who by nature of his/her education is qualified to operate the analytical equipment employed. Analysis and interpretation is performed or directed by a supervising petrographer who satisfies the qualifications as specified in Section 3 of *ASTM C 856*.

Chemical analysis was conducted via a modification of the procedures outlined in *ASTM C 1324: Standard Test Method for Examination and Analysis of Hardened Masonry Mortar*. Water, carbon dioxide and aggregate weight percentages are determined gravimetrically. Oxide weight percentages are determined by atomic absorption spectroscopy.

Statistical point counting was conducted in general accordance with the procedures outlined in *ASTM C 457: Standard Test Method for Microscopical Determination of Parameters of the Air-Void System in Hardened Concrete.* Sample sizes do not satisfy the minimum requirements outlined in the method and results are used as an approximate cross-check for other more quantitative methods.

Water-soluble chloride analysis was performed in accordance with *ASTM C 1218: Standard Test Method for Water-Soluble Chloride in Mortar and Concrete.*

3. Petrographic Findings

SAMPLE ID	**LOKE.M.1 (Oil House)**
GENERAL APPEARANCE	
Sample Type/Dimensions	Multiple, irregular, mortar fragments weighing 17.91g.
Surfaces	One piece has two parallel sides that may be a joint surface. Approximately 0.5" thick.
Hardness / Friability	Moderately hard and non-friable.
Appearance	Luster on freshly exposed surfaces is dull. Fresh paste color is light gray (Munsell color designation approximately 2.5Y 7/2).
Cracks, Deposits, Etc.,	Cracking cannot be assessed due to the fragmental nature of the sample. No mineral deposits are observed. There is a low abundance of coal fragments detected.
AGGREGATE	
Lithology and Mode	Carbonate natural sand consisting of shell fragments and porous coral fragments. Low abundance of opaques are also detected.
Appearance	Viewed on weathered surfaces the sand is white in some cases and with a pale yellow hue (Munsell color code approximately N9 to 5Y 8/1). The luster is slightly reflective to dull.
Size and Gradation	The sand is medium-grained and somewhat narrowly graded. The nominal top size is estimated at the No. 16 sieve with most material estimated to pass. Peak abundance is estimated between the No. 16 and No. 30 sieve and few fines are present below No. 50.
Shape	Subrounded in shape on average. Aspect ratios are subequant to subelongate.
Distribution	Homogeneous and somewhat randomly oriented though there is a somewhat preferential alignment of more elongate grains parallel or subparallel to the bed.
Other	No cracking, coatings, or chemical reactions are detected.
BINDER MATRIX	
Hardened Binder	Dense and homogeneous cementitious matrix with moderate to moderately high capillary porosity on average. No significant calcium hydroxide as a cementitious hydrate is detected and the paste is almost completely carbonated.
Residual Hydraulic Grains	Natural cement relicts are found in moderate to moderately high abundance. These are fine to medium grained and generally carbonated in cross polarized light. Microtextures are varied but include typical calcined dolomite rhombs with rims of iron-bearing ferrite and distributed grains of partially combined quartz silt. Rimmed quartz silt is also commonly found as isolated grains within the paste matrix. No significant clinkered material is detected but there are traces of inert aluminate clusters.
Residual Lime Grains	None detected.
Residual Pozzolans	None detected.
Pigments	None detected.
AIR-VOID SYSTEM	
Estimated Air Content	Estimated at 4% - 6%
Consolidation / Distribution	The mortar is well consolidated and the air distribution is homogeneous.
Size / Shape	Voids are generally less than 1 mm in dimension. Voids are rounded and subspherical to irregular in shape on average.
Secondary Deposits	No secondary deposits are positively identified.
AGGREGATE INTERFACES	
Details	Sand grains are well coated with binder. No variation in binder characteristics are found adjacent to aggregate. No cracking or secondary mineral deposits are found at aggregate interfaces. In honed section, interfaces are moderately soft when scratched with a steel pick but do not exhibit any significant friability.
SECONDARY REACTIONS	
Carbonation	In thin section, all portions of the sample exhibit virtually full carbonation.
Other	No other evidence for chemical reaction is found within the bulk of the material.
CRACKING	
Details	Trace microcracking is found along one edge of the sample in thin section. Otherwise, no significant macroscopic or microscopic cracking is detected.

SAMPLE ID	**LOKE.M.2 (Brick Cistern)**
GENERAL APPEARANCE	
Sample Type/Dimensions	Multiple, irregular, mortar fragments weighing 26.79 g.
Surfaces	One piece has two parallel sides that may be a joint surface. Approximately 0.5" thick.
Hardness / Friability	Moderately hard and non-friable.
Appearance	Luster on freshly exposed surfaces is dull with some waxy areas where there are cement streaks. Fresh paste color is light gray (Munsell color designation approximately 2.5Y 7/2).
Cracks, Deposits, Etc.,	Cracking cannot be assessed due to the fragmental nature of the sample. There is an adherent veneer of a white coating on many pieces. Sand grains are exposed below this wash indicating prior weathering. Low abundance of coal fragments are detected.
AGGREGATE	
Lithology and Mode	Carbonate natural sand consisting of shell fragments and porous coral fragments. Low abundance of opaques are also detected.
Appearance	Viewed on weathered surfaces the sand is white in some cases and with a pale yellow hue (Munsell color code approximately N9 to 5Y 8/1). The luster is slightly reflective to dull.
Size and Gradation	The sand is medium-grained and somewhat narrowly graded. The nominal top size is estimated at the No. 16 sieve. Peak abundance is estimated between the No. 16 and No. 30 sieve and few fines are present below No. 50.
Shape	Subrounded in shape on average. Aspect ratios are subequant to subelongate.
Distribution	Homogeneous and somewhat randomly oriented. Preferential alignment of more elongate grains are not obvious.
Other	No cracking, coatings, or chemical reactions are detected.
BINDER MATRIX	
Hardened Binder	Dense and homogeneous cementitious matrix with moderate to moderately high capillary porosity on average. No significant calcium hydroxide as a cementitious hydrate is detected and the paste is almost completely carbonated.
Residual Hydraulic Grains	Natural cement relicts are found in moderate abundance. These are fine to medium grained and generally carbonated in cross polarized light. Microtextures are varied but include typical calcined dolomite rhombs with rims of iron-bearing ferrite and distributed grains of partially combined quartz silt. Rimmed quartz silt is also commonly found as isolated grains within the paste matrix. No significant clinkered material is detected but there are traces of inert aluminate clusters.
Residual Lime Grains	None detected.
Residual Pozzolans	None detected.
Pigments	None detected.
AIR-VOID SYSTEM	
Estimated Air Content	Estimated at 3% - 5%
Consolidation / Distribution	The mortar is well consolidated and the air distribution is homogeneous.
Size / Shape	Voids are generally less than 1 mm in dimension. Voids are rounded and subspherical to irregular in shape on average.
Secondary Deposits	No secondary deposits are positively identified.
AGGREGATE INTERFACES	
Details	Sand grains are well coated with binder. No variation in binder characteristics are found adjacent to aggregate. Minor abundance of microcracking found around aggregate paste interfaces. No secondary mineral deposits are found at aggregate interfaces. In honed section, interfaces are moderately soft when scratched with a steel pick but do not exhibit any significant friability.
SECONDARY REACTIONS	
Carbonation	In thin section, all portions of the sample exhibit virtually full carbonation.
Other	No other evidence for chemical reaction is found within the bulk of the material.
CRACKING	
Details	Minor abundance of polygonal microcracking found passing through the paste and around aggregate paste interfaces. Some green-colored organic material is observed within cracks. No other significant macroscopic or microscopic cracking is detected.

SAMPLE ID	**LOKE.M.3 (Brick Cistern)**
GENERAL APPEARANCE	
Sample Type/Dimensions	Multiple, irregular, parging mortar fragments weighing 97.83 g.
Surfaces	Approximately 0.25” - 0.5” in thickness.
Hardness / Friability	Moderately hard and non-friable.
Appearance	Luster on freshly exposed surfaces is dull. Fresh paste color is light brownish gray (Munsell color designation approximately 10YR 6/2).
Cracks, Deposits, Etc.,	No significant cracking is detected in hand sample. Paste is in positive relief over the aggregate at the microscopic scale along the exposed surface. There is a low abundance of coal fragments detected. No mineral deposits are observed.
AGGREGATE	
Lithology and Mode	Carbonate natural sand consisting of shell fragments and porous coral fragments. Low abundance of opaques are also detected.
Appearance	Viewed on weathered surfaces the sand is white in some cases and with a pale yellow hue (Munsell color code approximately N9 to N8). The luster is slightly reflective to dull.
Size and Gradation	The sand is medium-grained and somewhat narrowly graded. The nominal top size is estimated at the No. 16 sieve. Peak abundance is estimated between the No. 16 and No. 30 sieve and few fines are present below No. 50.
Shape	Subrounded in shape on average. Aspect ratios are subequant to subelongate.
Distribution	Homogeneous and somewhat randomly oriented though there is a somewhat preferential alignment of more elongate grains parallel or subparallel to the bed.
Other	No cracking, coatings, or chemical reactions are detected.
BINDER MATRIX	
Hardened Binder	Dense and homogeneous cementitious matrix with moderate to moderately high capillary porosity on average. The paste has a very slightly clumpy texture. No significant calcium hydroxide as a cementitious hydrate is detected and the paste is almost completely carbonated.
Residual Hydraulic Grains	Natural cement relicts are found in moderate abundance. These are fine to medium grained and generally carbonated in cross polarized light. Microtextures are varied but include typical calcined dolomite rhombs with rims of iron-bearing ferrite and distributed grains of partially combined quartz silt. Rimmed quartz silt is also commonly found as isolated grains within the paste matrix. No significant clinkered material is detected but there are traces of inert aluminate clusters.
Residual Lime Grains	None detected.
Residual Pozzolans	None detected.
Pigments	None detected.
AIR-VOID SYSTEM	
Estimated Air Content	Estimated at 5% - 7%
Consolidation / Distribution	The mortar is well consolidated and the air distribution is homogeneous.
Size / Shape	Voids are generally less than 1 mm in dimension. Voids are subrounded and subspherical to irregular in shape on average.
Secondary Deposits	Most voids are free of secondary deposits with only traces of sparry carbonate detected.
AGGREGATE INTERFACES	
Details	Sand grains are relatively well coated with binder. No variation in binder characteristics are found adjacent to aggregate. Moderate abundance of small discontinuous polygonal cracking found along aggregate paste interfaces. Secondary mineral deposits are found at aggregate interfaces in trace abundance as sparry carbonate. In honed section, interfaces are moderately soft when scratched with a steel pick but do not exhibit any significant friability.
SECONDARY REACTIONS	
Carbonation	In thin section, all portions of the sample exhibit virtually full carbonation.
Other	No other evidence for chemical reaction is found within the bulk of the material.
CRACKING	
Details	Microscopic discontinuous hairline polygonal cracking detected in moderate abundance throughout the thin section. No other significant macroscopic or microscopic cracking is detected.

SAMPLE ID	**LOKE.M.4 (Lighthouse)**
GENERAL APPEARANCE	
Sample Type/Dimensions	Multiple, irregular, mortar fragments weighing 24.14 g.
Surfaces	One piece has two parallel sides that may be a joint surface. Approximately 0.5" thick.
Hardness / Friability	Moderately hard and non-friable.
Appearance	Luster on freshly exposed surfaces is dull. Fresh paste color is light gray (Munsell color designation approximately 2.5Y 7/2).
Cracks, Deposits, Etc.,	Cracking cannot be assessed due to the fragmental nature of the sample. There is an adherent veneer of a white powdery coating on many pieces. There is a low abundance of coal fragments detected.
AGGREGATE	
Lithology and Mode	Carbonate natural sand consisting of shell fragments and porous coral fragments. Low abundance of opaques are also detected. One chalcedony grain detected may belong to the cement.
Appearance	Viewed on weathered surfaces the sand is white in some cases and with a pale yellow hue (Munsell color code approximately N9 to 5Y 8/1). The luster is slightly reflective to dull.
Size and Gradation	The sand is medium-grained and somewhat narrowly graded. The nominal top size is estimated at the No. 16 sieve with most material estimated to pass. Peak abundance is estimated between the No. 16 and No. 30 sieve and few fines are present below No. 50.
Shape	Subrounded in shape on average. Aspect ratios are subequant to subelongate.
Distribution	Homogeneous and somewhat randomly oriented though there is a somewhat preferential alignment of more elongate grains parallel or subparallel to the bed.
Other	No cracking, coatings, or chemical reactions are detected.
BINDER MATRIX	
Hardened Binder	Dense and homogeneous cementitious matrix with moderate capillary porosity on average. No significant calcium hydroxide as a cementitious hydrate is detected and the paste is mostly carbonated though some areas remain isotropic.
Residual Hydraulic Grains	Natural cement relicts are found in varied abundance with some mortar pieces exhibiting a high abundance. These are variously sized grains and are generally carbonated in cross polarized light. Microtextures are varied but include typical calcined dolomite rhombs with rims of iron-bearing ferrite and distributed grains of partially combined quartz silt. Rimmed quartz silt is also commonly found as isolated grains within the paste matrix. No significant clinkered material is detected but there are traces of inert aluminate clusters.
Residual Lime Grains	None detected.
Residual Pozzolans	None detected.
Pigments	None detected.
AIR-VOID SYSTEM	
Estimated Air Content	Estimated at 4% - 6%
Consolidation / Distribution	The mortar is well consolidated and the air distribution is homogeneous.
Size / Shape	Voids are generally less than 1 mm in dimension. Voids are irregular in shape on average.
Secondary Deposits	No secondary deposits are positively identified.
AGGREGATE INTERFACES	
Details	Sand grains are well coated with binder. No variation in binder characteristics are found adjacent to aggregate. No cracking or secondary mineral deposits are found at aggregate interfaces. In honed section, interfaces are moderately soft when scratched with a steel pick but do not exhibit any significant friability.
SECONDARY REACTIONS	
Carbonation	In thin section, most portions of the sample exhibit virtually full carbonation.
Other	No other evidence for chemical reaction is found within the bulk of the material.
CRACKING	
Details	No significant macroscopic or microscopic cracking is detected.
MISCELLANEOUS	
Details	Opaque finishes are detected above a discontinuous microscopic veneer of depleted material in some areas of the perimeter.

SAMPLE ID	**LOKE.M.5 (Lighthouse)**
GENERAL APPEARANCE	
Sample Type/Dimensions	Multiple, irregular, mortar fragments weighing 28.28 g.
Surfaces	All pieces exhibit irregular surfaces.
Hardness / Friability	Moderately hard and non-friable.
Appearance	Luster on freshly exposed surfaces is dull. Fresh paste color is light gray (Munsell color designation approximately 2.5Y 7/2).
Cracks, Deposits, Etc.,	Cracking cannot be assessed due to the fragmental nature of the sample. There is an adherent veneer of a white powdery coating on many pieces and a minor amount of adherent brick residue. There is a low abundance of coal fragments detected.
AGGREGATE	
Lithology and Mode	Carbonate natural sand consisting of shell fragments and porous coral fragments. Low abundance of opaques are also detected.
Appearance	Viewed on weathered surfaces the sand is white in some cases and with a pale yellow hue (Munsell color code approximately N9 to 5Y 8/1). The luster is slightly reflective to dull.
Size and Gradation	The sand is medium-grained and somewhat narrowly graded. The nominal top size is estimated at the No. 16 sieve with most material estimated to pass. Peak abundance is estimated between the No. 16 and No. 50 sieve and moderately low amount of fines are present below No. 50.
Shape	Subrounded in shape on average. Aspect ratios are subequant to subelongate.
Distribution	Homogeneous and somewhat randomly oriented though there is a somewhat preferential alignment of more elongate grains parallel or subparallel to the bed.
Other	No cracking, coatings, or chemical reactions are detected.
BINDER MATRIX	
Hardened Binder	Dense and homogeneous cementitious matrix with moderate to moderately high capillary porosity on average. No significant calcium hydroxide as a cementitious hydrate is detected and the paste is almost completely carbonated.
Residual Hydraulic Grains	Natural cement relicts are found in moderately low abundance. These are fine to medium grained and generally carbonated in cross polarized light. Microtextures are varied but include typical calcined dolomite rhombs with rims of iron-bearing ferrite and distributed grains of partially combined quartz silt. Rimmed quartz silt is also commonly found as isolated grains within the paste matrix. No significant clinkered material is detected but there are traces of inert aluminate clusters.
Residual Lime Grains	None detected.
Residual Pozzolans	None detected.
Pigments	None detected.
AIR-VOID SYSTEM	
Estimated Air Content	Estimated at 4% - 6%
Consolidation / Distribution	The mortar is well consolidated and the air distribution is homogeneous.
Size / Shape	Voids are generally less than 1 mm in dimension. Voids are irregular in shape on average.
Secondary Deposits	Most voids are free of secondary deposits.
AGGREGATE INTERFACES	
Details	Sand grains are well coated with binder. Zones of possible bleed water channels are found around some aggregate paste interfaces. Trace, small discontinuous cracks are found subparallel to the surface and passing around aggregates interfaces. No secondary mineral deposits are found at aggregate interfaces. In honed section, interfaces are moderately soft when scratched with a steel pick but do not exhibit any significant friability.
SECONDARY REACTIONS	
Carbonation	In thin section, all portions of the sample exhibit virtually full carbonation.
Other	Traces of very fine grained deposits are found only within one microcrack surface and these have characteristics consistent with either sulfates or chlorites.
CRACKING	
Details	Small discontinuous cracks are found subparallel to the surface and passing around aggregates interfaces. Otherwise no significant macroscopic or microscopic cracking is detected.
MISCELLANEOUS	
Details	A layer of lime wash is detected that is well bonded to the mortar. Lime wash appears to have two distinct layers. There is an opaque finish found above the lime wash.

SAMPLE ID	**LOKE.M.6 (Lighthouse)**
GENERAL APPEARANCE	
Sample Type/Dimensions	Multiple, irregular, mortar fragments weighing 59.75 g.
Surfaces	One piece has two parallel sides that may be a joint surface. Approximately 0.5" thick.
Hardness / Friability	Moderately hard and non-friable.
Appearance	Luster on freshly exposed surfaces is dull. Fresh paste color is light gray (Munsell color designation approximately 10YR 7/2).
Cracks, Deposits, Etc.,	Cracking cannot be assessed due to the fragmental nature of the sample. There is an adherent veneer of a white powdery coating on many pieces and a minor amount of adherent brick residue. There is a low abundance of coal fragments detected.
AGGREGATE	
Lithology and Mode	Carbonate natural sand consisting of shell fragments and porous coral fragments. Low abundance of opaques are also detected.
Appearance	Viewed on weathered surfaces the sand is white in some cases and with a pale yellow hue (Munsell color code approximately N9 to 5Y 8/1). The luster is slightly reflective to dull.
Size and Gradation	The sand is medium-grained and somewhat narrowly graded. The nominal top size is estimated at the No. 8 sieve with all material estimated to pass. Peak abundance is estimated between the No. 16 and No. 30 sieve and few fines are present below No. 50.
Shape	Subrounded in shape on average. Aspect ratios are subequant to subelongate.
Distribution	Homogeneous and somewhat randomly oriented though there is a somewhat preferential alignment of more elongate grains parallel or subparallel to the bed.
Other	No cracking, coatings, or chemical reactions are detected.
BINDER MATRIX	
Hardened Binder	Dense and homogeneous cementitious matrix with moderate capillary porosity on average. No significant calcium hydroxide as a cementitious hydrate is detected and the paste is almost completely carbonated.
Residual Hydraulic Grains	Natural cement relicts are found in moderate to moderately high abundance. These are variously sized grains and are generally carbonated in cross polarized light. Microtextures are varied but include typical calcined dolomite rhombs with rims of iron-bearing ferrite and distributed grains of partially combined quartz silt. Rimmed quartz silt is also found as isolated grains within the paste matrix. No significant clinkered material is detected but there are traces of inert aluminate clusters.
Residual Lime Grains	None detected.
Residual Pozzolans	None detected.
Pigments	None detected.
AIR-VOID SYSTEM	
Estimated Air Content	Estimated at 6% - 8%
Consolidation / Distribution	The mortar is well consolidated and the air distribution is homogeneous.
Size / Shape	Voids are generally less than or equal to 1 mm in dimension. Voids are rounded and subspherical to irregular in shape on average.
Secondary Deposits	Most voids are free of secondary deposits.
AGGREGATE INTERFACES	
Details	Sand grains are well coated with binder. No variation in binder characteristics are found adjacent to aggregate. No cracking or secondary mineral deposits are found at aggregate interfaces. In honed section, interfaces are moderately soft when scratched with a steel pick but do not exhibit any significant friability.
SECONDARY REACTIONS	
Carbonation	In thin section, all portions of the sample exhibit virtually full carbonation.
Other	A microscopically thin lining of isotropic, low relief secondary deposits tends to line the exterior surfaces of many of the mortar pieces. Some are also found within voids just adjacent to the surface but never in the interior.
CRACKING	
Details	No significant macroscopic or microscopic cracking is detected.

SAMPLE ID	**LOKE.M.7 (Lighthouse)**
GENERAL APPEARANCE	
Sample Type/Dimensions	Multiple, irregular, mortar fragments weighing 42.36 g.
Surfaces	All pieces exhibit irregular surfaces.
Hardness / Friability	Moderately hard and non-friable.
Appearance	Luster on freshly exposed surfaces is dull. Fresh paste color is light gray (Munsell color designation approximately 10YR 7/2).
Cracks, Deposits, Etc.,	Cracking cannot be assessed due to the fragmental nature of the sample. No mineral deposits are observed. There is a low abundance of coal fragments detected.
AGGREGATE	
Lithology and Mode	Carbonate natural sand consisting of shell fragments and porous coral fragments. Low abundance of opaques are also detected.
Appearance	Viewed on weathered surfaces the sand is white in some cases and with a pale yellow hue (Munsell color code approximately N9 to 5Y 8/1). The luster is slightly reflective to dull.
Size and Gradation	The sand is medium-grained and somewhat narrowly graded. The nominal top size is estimated at the No. 16 sieve. Peak abundance is estimated between the No. 16 and No. 30 sieve and few fines are present below No. 50.
Shape	Subrounded in shape on average. Aspect ratios are subequant to subelongate.
Distribution	Homogeneous and somewhat randomly oriented. Preferential alignment of more elongate grains is not obvious.
Other	No cracking, coatings, or chemical reactions are detected.
BINDER MATRIX	
Hardened Binder	Dense and homogeneous cementitious matrix with moderate capillary porosity on average. No significant calcium hydroxide as a cementitious hydrate is detected and the paste is almost completely carbonated.
Residual Hydraulic Grains	Natural cement relicts are found in moderate to moderately high abundance. These are variously sized grains and are generally carbonated in cross polarized light. Microtextures are varied but include typical calcined dolomite rhombs with rims of iron-bearing ferrite and distributed grains of partially combined quartz silt. Rimmed quartz silt is also commonly found as isolated grains within the paste matrix. No significant clinkered material is detected but there are traces of inert aluminate clusters.
Residual Lime Grains	None detected.
Residual Pozzolans	None detected.
Pigments	None detected.
AIR-VOID SYSTEM	
Estimated Air Content	Estimated at 3% - 5%
Consolidation / Distribution	The mortar is well consolidated and the air distribution is homogeneous.
Size / Shape	Voids are generally less than 1 mm in dimension. Voids are rounded and subspherical to irregular in shape on average.
Secondary Deposits	No secondary deposits are positively identified.
AGGREGATE INTERFACES	
Details	Sand grains are well coated with binder. No variation in binder characteristics are found adjacent to aggregate. No cracking or secondary mineral deposits are found at aggregate interfaces. In honed section, interfaces are moderately soft when scratched with a steel pick but do not exhibit any significant friability.
SECONDARY REACTIONS	
Carbonation	In thin section, all portions of the sample exhibit virtually full carbonation.
Other	No other evidence for chemical reaction is found within the bulk of the material.
CRACKING	
Details	No significant macroscopic or microscopic cracking is detected.

SAMPLE ID	**LOKE.M.8 (Oil House)**
GENERAL APPEARANCE	
Sample Type/Dimensions	The sample represents a complete cross section of a three coat plaster system. One large piece and several smaller pieces were received from the interior, south wall weighing 40.17 g. The nominal thickness of the whole sample is 0.75". Three distinct material types are detected. Thicknesses of the three general layers is as follows: Scratch coat: approximately 1/8" Brown coat: approximately 3/8" Finish coat: approximately 1/8"
Surfaces	Contact surfaces are more or less planar. The scratch and finish coats are partially adhered to the brown coat. The finish coat disbonds easily along a relatively clean surface.
Hardness / Friability	Scratch coat: Moderately soft and moderately non-friable. Brown coat: Hard and non-friable. Finish coat: Moderately soft and moderately friable.
Appearance	Scratch coat: Dull luster and nearly white on fresh exposure (Munsell color code approximately 5Y 8/1). Brown coat: Opaque waxy luster and light gray on fresh exposure (Munsell color code approximately 10YR 7/2). Finish coat: Moderately dull luster and bright white on fresh exposure (Munsell color code approximately N9).
Cracks, Deposits, Etc.,	No significant cracking is visible in the larger sample though incipient disbonds may be present at layer contacts. No mineral deposits are observed. There is a low abundance of coal fragments detected within the brown coat.

SAMPLE ID	**LOKE.M.8 (Oil House plaster scratch coat)**
AGGREGATE	
Lithology and Mode	Carbonate natural sand consisting of shell fragments and porous coral fragments.
Appearance	Viewed on weathered surfaces the sand is white in some cases and with a pale yellow hue (Munsell color code approximately N9). The luster is dull.
Size and Gradation	The sand is medium-grained and narrowly graded. The nominal top size is estimated at the No. 8 sieve with all material estimated to pass. A strong peak abundance is estimated between the No. 16 and No. 30 sieves and only a moderately low abundance of material is estimated to pass the No. 30 sieve.
Shape	Subrounded in shape on average. Aspect ratios are subequant to subelongate.
Distribution	Homogeneous and somewhat randomly oriented. Preferential alignment of more elongate grains is not obvious.
Other	No cracking, coatings, or chemical reactions are detected.
BINDER MATRIX	
Hardened Binder	Homogeneous mildly hydraulic matrix with high capillary porosity on average and a moderate abundance of discontinuous polygonal microscopic cracks.
Residual Hydraulic Grains	Natural cement relicts are found in very low abundance. These are fine to medium grained and generally carbonated in cross polarized light. Microtextures are varied but include typical calcined dolomite rhombs with rims of iron-bearing ferrite and trace grains of partially combined quartz silt isolated within the paste matrix.
Residual Lime Grains	Low abundance of fine residual lime grains. Grains are fully carbonated with no internal relict rock textures or hydraulic inclusions. However, textures are difficult to assess due to a limited sample size.
Residual Pozzolans	None detected.
Pigments	None detected.
AIR-VOID SYSTEM	
Estimated Air Content	Estimated at 2% - 3%
Consolidation / Distribution	The plaster is well consolidated and the air distribution is homogeneous.
Size / Shape	Voids are generally less than 1 mm in dimension. Voids are rounded and subspherical in shape on average.
Secondary Deposits	No secondary deposits are positively identified.
AGGREGATE INTERFACES	
Details	Sand grains are well coated with binder. No variation in binder characteristics are found adjacent to aggregate. Discontinuous polygonal cracking is detected along some of the interfaces. Otherwise, no significant cracking or secondary mineral deposits are found at aggregate interfaces. In honed section, interfaces are soft when scratched with a steel pick.
SECONDARY REACTIONS	
Carbonation	In thin section, all portions of the sample exhibit virtually full carbonation.
Other	No other evidence for chemical reaction is found within the bulk of the material.
CRACKING	
Details	Discontinuous polygonal cracking. Otherwise, no significant macroscopic or microscopic cracking is detected.

SAMPLE ID LOKE.M.8 (Oil House plaster brown coat)

AGGREGATE	
Lithology and Mode	Carbonate natural sand consisting of shell fragments and porous coral fragments. Low abundance of opaques are also detected.
Appearance	Viewed on weathered surfaces the sand is white in some cases and with a pale yellow hue (Munsell color code approximately N9 to 5Y 8/1). The luster is slightly reflective to dull.
Size and Gradation	The sand is medium-grained and narrowly graded. The nominal top size is estimated at the No. 8 sieve with all material estimated to pass. A strong peak abundance is estimated between the No. 16 and No. 30 sieves and only a moderately low abundance of material is estimated to pass the No. 30 sieve.
Shape	Subrounded in shape on average. Aspect ratios are subequant to subelongate.
Distribution	Homogeneous and somewhat randomly oriented though there is a somewhat preferential alignment of more elongate grains parallel or subparallel to the bed.
Other	No cracking, coatings, or chemical reactions are detected.
BINDER MATRIX	
Hardened Binder	Dense and homogeneous cementitious matrix with moderate capillary porosity on average. No significant calcium hydroxide as a cementitious hydrate is detected and the paste is almost completely carbonated.
Residual Hydraulic Grains	Natural cement relicts are found in moderate to moderately high abundance. These are fine to medium grained though fines are much more abundant and are generally carbonated in cross polarized light. Microtextures are varied but include typical calcined dolomite rhombs with rims of iron-bearing ferrite and distributed grains of partially combined quartz silt. Rimmed quartz silt is also commonly found in high abundance as isolated grains within the paste matrix. No significant clinkered material is detected but there are traces of inert aluminate clusters.
Residual Lime Grains	None detected.
Residual Pozzolans	None detected.
Pigments	None detected.
AIR-VOID SYSTEM	
Estimated Air Content	Estimated at 4% - 6%
Consolidation / Distribution	The mortar is well consolidated and the air distribution is homogeneous.
Size / Shape	Voids are generally less than 1 mm in dimension. Voids are rounded and subspherical to irregular in shape on average.
Secondary Deposits	No secondary deposits are positively identified.
AGGREGATE INTERFACES	
Details	Sand grains are well coated with binder. No variation in binder characteristics are found adjacent to aggregate. No cracking or secondary mineral deposits are found at aggregate interfaces. In honed section, interfaces are moderately soft when scratched with a steel pick but do not exhibit any significant friability.
SECONDARY REACTIONS	
Carbonation	In thin section, all portions of the sample exhibit virtually full carbonation.
Other	No other evidence for chemical reaction is found within the bulk of the material.
CRACKING	
Details	No significant macroscopic or microscopic cracking is detected.

SAMPLE ID LOKE.M.8 (Oil House plaster finish coat)

AGGREGATE	
Details	No aggregate is present in the finish coat.
BINDER MATRIX	
Hardened Binder	Homogeneous mixed binder matrix with high capillary porosity and no significant microcracking. The matrix consists of a mixture of very fine grained, hydrated gypsum crystallites and fine mostly carbonated lime.
Residual Hydraulic Grains	None detected.
Residual Lime Grains	Residual lime grains are found in high abundance as fine- to medium grained particles. Most are fully carbonated though fully uncarbonated grains are also observed. Relict rock textures are rare and are difficult to interpret. However, these have the character of partially calcined silicate minerals. No evidence for significant hydraulic inclusions is observed.
Residual Gypsiferous Grains	Medium-grained gypsum relicts are relatively rare. Some of rehydrated to gypsum while some still represent unhydrated hemihydrate. Dead-burned anhydrite crystals are extremely rare.
Residual Pozzolans	None detected.
Pigments	None detected.
AIR-VOID SYSTEM	
Estimated Air Content	Estimated at 2% - 3%
Consolidation / Distribution	The plaster is well consolidated and the air distribution is homogeneous.
Size / Shape	Voids are generally less than 1 mm in dimension. Voids are irregular in shape on average.
Secondary Deposits	No significant secondary deposits are observed.
SECONDARY REACTIONS	
Carbonation	In thin section, all portions of the sample exhibit virtually full carbonation.
Other	No other evidence for chemical reaction is found within the bulk of the material.
CRACKING	
Details	No significant macroscopic or microscopic cracking is detected.

SAMPLE ID	**LOKE.M.9 (Kitchen Building)**
GENERAL APPEARANCE	
Sample Type/Dimensions	Multiple, irregular, mortar fragments weighing 28.75 g.
Surfaces	One piece has two parallel sides that may be a joint surface. Approximately 0.5" thick.
Hardness / Friability	Moderately hard and non-friable.
Appearance	Luster on freshly exposed surfaces is dull. Fresh paste color is light gray (Munsell color designation approximately 2.5Y 7/2).
Cracks, Deposits, Etc.,	Cracking cannot be assessed due to the fragmental nature of the sample. There is an adherent veneer of a white coating on many pieces. There is a low abundance of coal fragments detected.
AGGREGATE	
Lithology and Mode	Carbonate natural sand consisting of shell fragments and porous coral fragments. Low abundance of opaques are also detected.
Appearance	Viewed on weathered surfaces the sand is white in some cases and with a pale yellow hue (Munsell color code approximately N9 to 5Y 8/1). The luster is slightly reflective to dull.
Size and Gradation	The sand is medium-grained and somewhat narrowly graded. The nominal top size is estimated at the No. 16 sieve with most material estimated to pass. Peak abundance is estimated between the No. 16 and No. 30 sieve and few fines are present below No. 50.
Shape	Subrounded in shape on average. Aspect ratios are subequant to subelongate.
Distribution	Homogeneous and somewhat randomly oriented though there is a somewhat preferential alignment of more elongate grains parallel or subparallel to the bed.
Other	No cracking, coatings, or chemical reactions are detected.
BINDER MATRIX	
Hardened Binder	Dense and homogeneous cementitious matrix with a moderately high to high capillary porosity. No significant calcium hydroxide as a cementitious hydrate is detected and the paste is almost completely carbonated.
Residual Hydraulic Grains	Natural cement relicts are found in moderate abundance. These are medium grained and generally carbonated in cross polarized light. Microtextures are varied but include typical calcined dolomite rhombs with rims of iron-bearing ferrite and distributed grains of partially combined quartz silt. Rimmed quartz silt is also commonly found as isolated grains within the paste matrix. No significant clinkered material is detected but there are traces of inert aluminate clusters.
Residual Lime Grains	None detected.
Residual Pozzolans	None detected.
Pigments	None detected.
AIR-VOID SYSTEM	
Estimated Air Content	Estimated at 4% - 6%
Consolidation / Distribution	The mortar is well consolidated and the air distribution is homogeneous.
Size / Shape	Voids are generally less than 1 mm in dimension. Voids are rounded and subspherical to irregular in shape on average.
Secondary Deposits	No secondary deposits are positively identified.
AGGREGATE INTERFACES	
Details	Sand grains are well coated with binder. No variation in binder characteristics are found adjacent to aggregate. No cracking or secondary mineral deposits are found at aggregate interfaces. In honed section, interfaces are moderately soft when scratched with a steel pick but do not exhibit any significant friability.
SECONDARY REACTIONS	
Carbonation	In thin section, all portions of the sample exhibit virtually full carbonation.
Other	No other evidence for chemical reaction is found within the bulk of the material.
CRACKING	
Details	No significant macroscopic or microscopic cracking is detected.

SAMPLE ID	**LOKE.M.10 (Keeper's Dwelling)**
GENERAL APPEARANCE	
Sample Type/Dimensions	Multiple, irregular, mortar fragments weighing 32.83 g.
Surfaces	One piece has two parallel sides that may be a joint surface. Approximately 0.5" thick. There are weathered areas with a type of biological growth present in low abundance.
Hardness / Friability	Moderately hard and non-friable.
Appearance	Luster on freshly exposed surfaces is mostly dull, however the mortar does exhibit streaking and high variation. Fresh paste color is very pale brown (Munsell color designation approximately 10YR 8/2).
Cracks, Deposits, Etc.,	Cracking cannot be assessed due to the fragmental nature of the sample. No mineral deposits are observed.
AGGREGATE	
Lithology and Mode	Carbonate natural sand consisting of shell fragments and porous coral fragments.
Appearance	Viewed on weathered surfaces the sand is white in some cases and with a pale yellow hue (Munsell color code approximately N9 to 5Y 8/1). The luster is slightly reflective to dull.
Size and Gradation	The sand is medium-grained and somewhat narrowly graded. The nominal top size is estimated at the No. 16 sieve with most material estimated to pass. Peak abundance is estimated between the No. 16 and No. 50 sieve and few fines are present below No. 50.
Shape	Subrounded in shape on average. Aspect ratios are subequant to subelongate.
Distribution	Homogeneous and somewhat randomly oriented. Preferential alignment of more elongate grains is not obvious.
Other	No cracking, coatings, or chemical reactions are detected.
BINDER MATRIX	
Hardened Binder	Dense and homogeneous cementitious matrix with moderate to moderately high capillary porosity on average. No significant calcium hydroxide as a cementitious hydrate is detected and the paste is almost completely carbonated.
Residual Hydraulic Grains	Residual portland cement is detected in moderate abundance as medium grained belite agglomerates with interstitial ferrite. Virtually all grains are well hydrated and consist only of a ferrite "skeleton". Alite forms are also detected within agglomerates in moderately low abundance.
Residual Lime Grains	None detected.
Residual Pozzolans	None detected.
Pigments	None detected.
AIR-VOID SYSTEM	
Estimated Air Content	Estimated at 3% - 5%
Consolidation / Distribution	The mortar is well consolidated and the air distribution is homogeneous.
Size / Shape	Voids are generally less than 1 mm in dimension. Voids are rounded and subspherical to irregular in shape on average.
Secondary Deposits	Some voids are lined with secondary deposits with optical characteristics consistent with gypsum. Otherwise most voids are free of secondary deposits.
AGGREGATE INTERFACES	
Details	Sand grains are well coated with binder. No variation in binder characteristics are found adjacent to aggregate. No cracking or secondary mineral deposits are found at aggregate interfaces. In honed section, interfaces are moderately hard when scratched with a steel pick and do not exhibit any significant friability.
SECONDARY REACTIONS	
Carbonation	In thin section, all portions of the sample exhibit virtually full carbonation.
Other	No other evidence for chemical reaction is found within the bulk of the material.
CRACKING	
Details	No significant macroscopic or microscopic cracking is detected.

SAMPLE ID LOKE.M.11 (Keeper's Dwelling)

GENERAL APPEARANCE

Sample Type/Dimensions	The sample represents a complete cross section of a two coat plaster system. Several pieces were received from the interior bathroom, west wall weighing 30.60 g. The nominal thickness of the whole sample is approximately 0.5 including brown coat and finish coat. The brown coat is well bonded to the finish coat. A layer of paint is also detected on the finish coat. Approximate thicknesses of the two coats is as follows: Brown Coat: 3/8" Finish Coat: 1/8"
Surfaces	The contact surface is mostly planar and the two coats well bonded.
Hardness / Friability	Brown coat: Moderately hard and moderately non-friable. Finish coat: Moderately hard and non-friable.
Appearance	Brown coat: Luster on freshly exposed surfaces is dull. Fresh paste color is nearly white with a yellowish cast (Munsell color designation approximately 5Y 8.5/1). Finish coat: Luster on freshly exposed surfaces is dull. Fresh paste color is white (Munsell color designation approximately N9).
Cracks, Deposits, Etc.,	No significant cracking, efflorescence, or secondary mineral deposits are detected in hand sample. However, cracking is difficult to assess due to the fragmental nature of the sample. A moderately low abundance of light-colored fiber reinforcement is identified in the brown coat.

SAMPLE ID LOKE.M.11 (Keeper's Dwelling plaster brown coat)

AGGREGATE

Lithology and Mode	Carbonate natural sand consisting of shell fragments and porous coral fragments.
Appearance	The sand is white in most cases and with a pale yellow hue (Munsell color code approximately N9 to 5Y 8/1). The luster is slightly reflective to dull.
Size and Gradation	The sand is medium-grained and somewhat narrowly graded. The nominal top size is estimated at the No. 16 sieve with most material estimated to pass. Peak abundance is estimated between the No. 16 and No. 50 sieve and few fines are present below No. 50.
Shape	Subrounded in shape on average. Aspect ratios are subequant to subelongate.
Distribution	Homogeneous and somewhat randomly oriented though there is a somewhat preferential alignment of more elongate grains parallel or subparallel to the bed.
Other	No cracking, coatings, or chemical reactions are detected.

BINDER MATRIX

Hardened Binder	Homogeneous gypsiferous matrix with high capillary porosity on average. While the matrix consists of an interlocking network of fine-grained gypsum crystals, the texture is somewhat coarse.
Residual Hydraulic Grains	None detected.
Residual Lime Grains	None detected.
Residual Gypsiferous Grains	A high abundance of medium-grained gypsum residuals are detected and almost all are fully hydrated to coarser grained gypsum. Finer unhydrated hemihydrate crystals are less common. There is moderately low abundance of very fine-grained, dead burned anhydrite.
Residual Pozzolans	None detected.
Pigments	None detected.

AIR-VOID SYSTEM

Estimated Air Content	Estimated at 8% - 10%
Consolidation / Distribution	The plaster is well consolidated and the air distribution is homogeneous.
Size / Shape	Voids are generally less than or equal to 1 mm in dimension. Voids are subspherical in shape on average.
Secondary Deposits	No significant secondary deposits are detected.

AGGREGATE INTERFACES

Details	Sand grains are well coated with binder. No variation in binder characteristics are found adjacent to aggregate. No cracking or secondary mineral deposits are found at aggregate interfaces. In honed section, interfaces are moderately soft when scratched with a steel pick but do not exhibit any significant friability.

SECONDARY REACTIONS

Carbonation	No carbonation is detected.
Other	No other evidence for chemical reaction is found within the bulk of the material.

CRACKING

Details	No significant macroscopic or microscopic cracking is detected.

SAMPLE ID	**LOKE.M.11 (Keeper's Dwelling plaster finish coat)**
AGGREGATE	
Details	No aggregate is present in the finish coat.
BINDER MATRIX	
Hardened Binder	Homogeneous mostly gypsiferous matrix with high capillary porosity on average. The matrix consists of a network of ultrafine gypsum crystallites with a minor carbonated component.
Residual Hydraulic Grains	None detected.
Residual Lime Grains	Residual lime grains are found in very low abundance as fine-grained mostly carbonated particles. No internal rock textures or hydraulic inclusions are detected within lime grains.
Residual Gypsiferous Grains	A low abundance of fine-grained gypsum residuals are detected and almost all are fully hydrated to coarser grained gypsum. Finer unhydrated hemihydrate crystals and dead burned anhydrite are both relatively uncommon.
Residual Pozzolans	None detected.
Pigments	None detected.
AIR-VOID SYSTEM	
Estimated Air Content	Estimated at 2% - 4%
Consolidation / Distribution	The plaster is well consolidated and the air distribution is homogeneous.
Size / Shape	Voids are generally less than 1 mm in dimension. Voids are subspherical in shape on average.
Secondary Deposits	No significant secondary deposits are detected.
SECONDARY REACTIONS	
Carbonation	In thin section, the lime portions of the sample exhibit virtually full carbonation.
Other	No other evidence for chemical reaction is found within the bulk of the material.
CRACKING	
Details	No significant macroscopic or microscopic cracking is detected.

4. Point-Count Analyses

Point-count analysis was performed using methods adapted from ASTM C 457. Honed cross sections of the materials were prepared for the analysis. Sample LOKE.M.3 was chosen as a robust cross-check sample as sufficient material was available for both chemical analysis and point-count analysis. LOKE.M.4 and LOKE.M.7 were chosen for point-count analysis as these represent natural cement mortar samples with extremes in binder to sand ratio estimated via chemical analysis. It should be noted that that surface area of these latter two prepared samples and the number of points counted is smaller than required to produce the accuracy reported by the test method.

Table 4.1 - Point-Count Data

Sample ID Location	**LOKE.M.3** Cistern Exterior	**LOKE.M.4** Lighthouse Exterior	**LOKE.M.7** Lighthouse Interior
Approximate surface area ($in.^2$)	1.9	0.9	0.4
Sand points	252	72	116
Paste points	342	108	194
Air-void points	34	12	13
Total points	**628**	**192**	**323**

Table 4.2 - Solid Volume Percentages

Sample ID Location	**LOKE.M.3** Cistern Exterior	**LOKE.M.4** Lighthouse Exterior	**LOKE.M.7** Lighthouse Interior
Sand	40.1	37.5	35.9
Paste	54.5	56.3	60.0
Air-voids	5.4	6.2	4.0
Totals	**100.0**	**100.0**	**99.9**

Table 4.3 - Calculated Bulk Ratios

Sample ID Location	**LOKE.M.3** Cistern Exterior	**LOKE.M.4** Lighthouse Exterior	**LOKE.M.7** Lighthouse Interior
Sand volume percentage	56	53	50
Cement volume percentage	44	47	50
Cement : Sand Ratio (by volume)	**1 : 1.3**	**1 : 1.1**	**1 : 1.0**

Notes:
1) Solid volume of sand is adjusted by considering the void ratio of the sand in damp, loose condition. Paste volume is adjusted downward to account for the volume increase resulting from hydration of the cement. Counted sand volumes are divided by 0.62 to account for void space and paste volumes divided by 1.05 to account for volume increase upon hydration.
2) Adjusted bulk volumes are normalized to 100% as presented in this table.
3) Cement to sand ratios represent the ratios of these normalized values.

5. Chemical Analyses

The chemical preparations used on all samples with the exception of the finish coat plaster represent significant deviations from the standard procedures given in ASTM C 1324. The carbonate sand is exceptionally soluble in any acid capable of dissolving the binder and there is no effective way to separate the binder and sand effectively. Therefore, it was decided to fuse the sample into a glass, dissolve that in concentrated acid and measure the bulk chemistry of the entire sample. A separate acid digestion was performed in order to produce an insoluble residue. Instead of representing the sand, this residue is used to examine the uncalcined inclusions within the natural cement binder. Water-soluble chloride was also measured for the Lighthouse samples and this was done in general accordance with ASTM C 1218.

The analysis for the finish plaster also represents a deviation from ASTM C 1324 in that a hot acid digestion was used to bring all sulfate species into solution as well as all lime. These methods are more consistent with those of ASTM C 114 for the measurement of sulfates in cement.

Table 5.1a: Chemical Analysis Results

SAMPLE ID	**LOKE.M.4**	**LOKE.M.5**	**LOKE.M.6**	**LOKE.M.7**
Location	Lighthouse Exterior	Lighthouse Exterior	Lighthouse Interior	Lighthouse Interior
Component (wgt. %)				
SiO_2	7.06	8.63	8.34	10.26
CaO	40.17	37.42	38.30	37.20
MgO	6.97	7.65	7.18	5.63
Al_2O_3	1.26	1.41	1.22	1.53
Fe_2O_3	0.95	0.98	1.01	1.08
Na_2O	0.98	1.30	0.69	2.28
K_2O	0.08	0.38	0.65	1.01
Cl	1.12	0.43	1.35	1.09
Insoluble residue	1.35	3.09	2.53	5.26
LOI %, to 110°C (Free water)	4.03	4.75	4.30	4.82
LOI %, 110°C-550°C (Combined water)	8.48	9.75	8.32	10.04
LOI %, 550°C-950°C (Carbon dioxide)	28.41	25.93	28.90	24.44
Measured Totals	**98.40**	**98.20**	**98.92**	**98.27**

Notes:
1) The insoluble residue is not included in the totals calculation as it represents an intentional duplicate measurement.
2) Chloride is also not included in the totals calculation nor is an adjustment made for the reduced oxygen that must accompany the alternate anion.

Table 5.1b: Chemical Analysis Results

SAMPLE ID	**LOKE.M.2**	**LOKE.M.3**	**LOKE.M.9**	**LOKE.M.10**
Location	Cistern Exterior	Cistern Exterior	Kitchen Bldg. Exterior	Keeper's Dwelling
Component (wgt. %)				
SiO_2	8.18	8.87	7.98	5.44
CaO	42.03	40.07	40.24	45.67
MgO	5.52	5.85	6.93	1.62
Al_2O_3	1.71	1.58	1.40	1.27
Fe_2O_3	1.07	1.07	1.31	0.68
Na_2O	0.34	0.31	0.35	0.36
K_2O	0.01	0.07	0.17	0.34
Insoluble residue	2.33	3.09	2.90	0.72
LOI %, to 110°C (Free water)	2.77	2.49	3.33	2.37
LOI %, 110°C-550°C (Combined water)	5.27	4.19	7.67	6.19
LOI %, 550°C-950°C (Carbon dioxide)	31.88	32.80	29.95	32.34
Measured Totals	**98.80**	**97.31**	**99.33**	**96.27**

Notes:
1) The insoluble residue is not included in the totals calculation as it represents an intentional duplicate measurement.

Table 5.1c: Chemical Analysis Results

SAMPLE ID	**LOKE.M.1**	**LOKE.M.8**	**LOKE.M.8**
Location	Oil House Exterior	Oil House Plaster Brown Coat	Oil House Plaster Finish Coat
Component (wgt. %)			
SiO_2	8.05	6.22	0.67
CaO	40.05	41.20	45.20
MgO	5.43	6.94	3.55
Al_2O_3	1.83	1.33	0.15
Fe_2O_3	1.09	1.13	0.14
Na_2O	1.18	0.61	0.79
K_2O	0.38	0.22	0.23
SO_3	n.d.	n.d.	13.57
Insoluble residue	2.70	4.03	0.00
LOI %, to 110°C (Free water)	3.59	2.29	1.54
LOI %, 110°C-550°C (Combined water)	7.60	9.01	7.70
LOI %, 550°C-950°C (Carbon dioxide)	28.68	29.66	27.23
Measured Totals	**97.88**	**98.62**	**100.78**

Notes:
1) The insoluble residue is not included in the totals calculation for the natural cement samples as it represents an intentional duplicate measurement.

Table 5.2a: Calculated Components

SAMPLE ID	**LOKE.M.4**	**LOKE.M.5**	**LOKE.M.6**	**LOKE.M.7**
Location	Lighthouse Exterior	Lighthouse Exterior	Lighthouse Interior	Lighthouse Interior
Component				
Portland cement (wgt. %)	Not detected	Not detected	Not detected	Not detected
Natural cement (wgt. %)	32	41	39	47
Lime expressed as dry hydrate (wgt. %)	Not detected	Not detected	Not detected	Not detected
Hydraulic lime (wgt. %)	Not detected	Not detected	Not detected	Not detected
Pozzolans (wgt. %)	Not detected	Not detected	Not detected	Not detected
Mineral pigment (wgt. %)	Not detected	Not detected	Not detected	Not detected
Sand (wgt. %)	68	59	61	53
Binder : sand ratio (by volume)	1 : 2.0	1 : 1.4	1 : 1.5	1 : 1.1

Table 5.2b: Calculated Components

SAMPLE ID	**LOKE.M.2**	**LOKE.M.3**	**LOKE.M.9**	**LOKE.M.10**
Location	Cistern Exterior	Cistern Exterior	Kitchen Bldg. Exterior	Keeper's Dwelling
Component				
Portland cement (wgt. %)	Not detected	Not detected	Not detected	33
Natural cement (wgt. %)	35	39	36	Not detected
Lime expressed as dry hydrate (wgt. %)	Not detected	Not detected	Not detected	Not detected
Hydraulic lime (wgt. %)	Not detected	Not detected	Not detected	Not detected
Pozzolans (wgt. %)	Not detected	Not detected	Not detected	Not detected
Mineral pigment (wgt. %)	Not detected	Not detected	Not detected	Not detected
Sand (wgt. %)	65	61	64	67
Binder : sand ratio (by volume)	1 : 1.7	1 : 1.5	1 : 1.7	1 : 2.4

Table 5.2c: Calculated Components

SAMPLE ID	**LOKE.M.1**	**LOKE.M.8**	**LOKE.M.8**
Location	Oil House Exterior	Oil House Plaster Brown Coat	Oil House Plaster Finish Coat
Component			
Portland cement (wgt. %)	Not detected	Not detected	Not detected
Natural cement (wgt. %)	36	28	Not detected
Lime expressed as dry hydrate (wgt. %)	Not detected	Not detected	68
Hydraulic lime (wgt. %)	Not detected	Not detected	Not detected
Gypsum as hemihydrate (wgt. %)	Not detected	Not detected	32
Pozzolans (wgt. %)	Not detected	Not detected	Not detected
Mineral pigment (wgt. %)	Not detected	Not detected	Not detected
Sand (wgt. %)	64	72	Not detected
Binder : sand ratio (by volume)	1 : 1.7	1 : 2.4	n/a
Gypsum : lime ratio (by volume with lime as a hydrate)	n/a	n/a	1 : 0.2
Gypsum : lime ratio (by volume with lime as a putty)	n/a	n/a	1 : 0.3

Notes:

1) For the natural cement mortars, parging, and plaster coats, the cement weight is calculated assuming an original cement silica content of 27% and calcium oxide content of 35%. Cement content is calculated assuming all measured silica is attributed to this average natural cement composition. Excess calcium is then attributed to the carbonate sand and the equivalent weight of calcium carbonate is calculated by molecular weight conversion. Both calculated weights are then normalized to 100%. Volumetric ratios are calculated assuming bulk densities for natural cement and damp loose sand of 75 lb./cu. ft. and 80 lb./cu. ft. respectively.
2) For the portland cement mortar (LOKE.M.10), the cement weight is calculated assuming an original cement silica content of 21% and calcium oxide content of 63%. Cement content is calculated assuming all measured silica is attributed to this average cement composition. Excess calcium is then attributed to the carbonate sand and the equivalent weight of calcium carbonate is calculated by molecular weight conversion. Both calculated weights are then normalized to 100%. Volumetric ratios are calculated assuming bulk densities for portland cement and damp loose sand of 94 lb./cu. ft. and 80 lb./cu. ft. respectively.
3) For the Oil House plaster finish coat (LOKE.M.8), the gypsum weight as hemihydrate is calculated by assuming that all measured sulfate is attributed to this component. Sufficient calcium oxide is taken up to account for this calculated gypsum component. The remaining calcium oxide and all magnesium oxide is attributed to the lime component and the mass is calculated by molecular weight conversion for both calcian and magnesian lime species. All calculated weights are then normalized to 100%. Volumetric ratios are calculated assuming bulk densities for dry gypsum plaster and dry lime hydrate of 93.5 lb./cu. ft. and 40 lb./cu. ft. respectively. A separate calculation is presented considering lime as a putty rather than a dry hydrate. This assumes an approximate 40% loss in bulk volume to turn a volume of dry lime hydrate into a stiff putty by addition of water.

6. Discussion and Conclusions

6.1 Mortar Materials

All mortar samples are identified as pure cement mortars containing a natural carbonate sand (Figs. 5 through 15). Additionally, the brown coat of the Oil House plaster sample LOKE.M.8 is very similar and is grouped in this discussion for convenience. No lime-type binders, pozzolans, or mineral pigments are identified in any of these samples. Original water to cement ratios are difficult to assess due to the advanced age of the materials. However, variations in the quantity of cement relicts, differences in capillary porosity, and differences in lightness of the cement paste indicate relative differences in water to cement ratios between the samples. For the most part, the lighthouse samples exhibit slightly lower capillary porosities suggestive of a lower original water to cement ratio (Figs. 8 and 9). Sample LOKE.M.10 (Keeper's Dwelling) differs in that the binder is a portland rather than natural cement and this sample will be discussed separately. Therefore, this discussion includes samples LOKE.M.1 through LOKE.M.7 as well as LOKE.M.9 and the brown coat of LOKE.M.8.

The cement in these samples are all identified as American natural cements typical of those manufactured in the more productive cement regions such as Rosendale, NY or Louisville, KY. All unhydrated cement relicts exhibit microstructural properties consistent with the low-temperature calcination of an argillaceous and partly ferruginous dolomitic limestone. Such textures include fine-grained, calcined carbonate rhombs surrounded by a rim of iron-bearing phase as well as partly burned quartz silt and sand grains surrounded by a rim of hydraulic product (Figs. 12 through 15). While some variation is observed across all samples, the general cement characteristics are grossly similar. Furthermore, the chemical analysis of all samples indicates a magnesium component no less than half that of the silica component and usually much more than this. Such chemistries are characteristic of the American natural cements and this clearly distinguishes them from a European product. Minor fine-grained coal fragments are also detected in most samples and these are interpreted to be contaminants from the cement burning.

While difficult to ascertain different placement vintages based on cement characteristics, there are some subtle variations observed both petrographically and chemically that appear to group cements into similar batches or sources. Three of the four lighthouse samples (all but LOKE.M.5) exhibit a greater variation in the grind of the cement. All other samples exhibit a fine to medium grind but these three contain unhydrated cement relicts that are found as large as several hundred microns in dimension (Fig. 12). It is tempting to interpret this coarseness as representative of an earlier vintage but this would be purely speculative. The very slight difference in the sand gradation in LOKE.M.5 (discussed below) in addition to slightly different cement characteristics could suggest that this sample is not contemporaneous with the other lighthouse samples. It is also noted that some variation exists within the fragments of sample LOKE.M.4 (Fig. 9). Some portions of this sample exhibit cement characteristics more similar to those of the Oil House plaster brown coat (LOKE.M.8) rather than those of the other lighthouse samples . The distinctive texture here is a much greater abundance of very fine-grained, partially calcined quartz silt grains dispersed as isolated cement residuals throughout the paste (Fig. 13). The acid-insoluble residues measured chemically for both samples is also the highest in these two samples and this is consistent with the petrographic observation. The cement in these two samples is clearly of a different quality than the others and this has implications in the estimation of sand to binder ratios as discussed below. What is not clear based on examination of the fragments is the reason that LOKE.M.4 appears to contain two different types of cement within one sample.

The sand in all samples is virtually identical with only subtle differences in gradation (Figs. 5 through 11). The sand is identified as a natural carbonate sand containing coral and shell fragments similar to that making up the sediment of the Dry Tortugas. A local source is certainly expected given the isolated nature of the site. No obviously crushed particles or foreign siliceous sands are identified that might suggest some modification to the local source. While it would be impossible to separate the sand from the binder through acid digestion, it is fairly clear through low-powered examination of fresh surfaces that the sand is homogeneous in color ranging from nearly white to pale yellow with no significant variegation. The grains are rounded due to natural weathering processes but tend to be somewhat elongate due to the original shapes of the organisms. All samples exhibit a relatively narrow sand gradation. Generally, all grains are estimated to pass a No. 8 sieve, most passing No. 16, with a minor to a moderately low amount of grains estimated to pass the No. 50 sieve. With some minor exception, the samples exhibit a sharp peak abundance of material between the No. 16 and No. 30 sieves. Such narrow gradations within this size range make geological sense in beach zones subject to regular wave action. While the site sand was not examined for this report, it is fully expected from a geological perspective that the local material would match the observed gradations without further processing.

Several subtle differences are detected in the sand gradations but these are very minor when compared to the general pattern. Some samples contain a slightly higher abundance of material retained on the No. 16 sieve. These include samples

LOKE.M.2, M.3, M.6, M.7, M.8 and (brown coat). In two cases the nominal top size is estimated at the No. 8 rather than No. 16 sieve where it appears that more than 10% of the material is retained on No. 16. and these include samples LOKE.M.6 and M.8. Some minor differences are also found in the fine end of the gradation. In most cases, minor material is estimated to pass the No. 50. A slightly higher abundance of fines is found in sample LOKE.M.5. The brown coat of sample LOKE.M.8 contains only a moderately low abundance of material estimated to pass the No. 30 sieve and is therefore even more narrowly graded.

Generally speaking, all samples discussed in this section exhibit cement and sand components that are well mixed and distributed. Air contents tend to be low and the mortars are well consolidated. Hydration qualities of the cement are adequate with a homogeneous distribution of cementitious product. While some variation in original water to cement ratios are suggested by minor variations in capillary porosity (Figs. 8 through 11), all appear to have been mixed without an excess of water or significant retempering.

Establishing original component proportions is challenging for this particular combination of sand and cement. Typically, a chemical methodology would be utilized whereby insoluble sand would be separated chemically for gravimetric measurement and the elemental chemistry of the dissolved binder component would be reverse engineered based on a fairly robust assumption of original binder chemistry. In this case, the sand is completely soluble and original natural cement chemistries are more variable than those of American portland cements or limes. Two analytical options are available to overcome these complications. The first is a microscopical point-counting of sand and binder components on polished slabs of the mortar. This method is insensitive to variations in the original binder chemistry and only measures paste and sand volume. The second is a complete fusion, or bulk chemical analysis of the mortar. Analysis of this chemistry requires an assumption of the original binder chemistry in order to partition the binder portion. This is followed by a calculation of the sand based on the remaining calcium unaccounted for by the binder partitioning. The former method may be considered more robust but requires a relatively large sample in order to be statistically significant. As such large sized samples were not available, it was agreed in discussions with the client that the chemical analysis that requires a smaller sample would be performed on all samples. The point-count method is then performed on sample LOKE.M.3 as a large sample is available. Comparison of the independent results is then expected to inform how well the chemical analysis may estimate the proportions. Additional point-counts on less than adequate samples are then performed on mortar samples estimated to exhibit extremes of binder to sand ratios based on the chemistry. These are performed on sample LOKE.M.4 and LOKE.M.7. A summary of the estimates are given in the table below based on bulk volume.

Sample ID	Cement to sand ratio by chemical analysis	Cement to sand ratio by point-count analysis
LOKE.M.1	1 : 1.7	n.d.
LOKE.M.2	1 : 1.7	n.d.
LOKE.M.3	1 : 1.5	1 : 1.3
LOKE.M.4	1 : 2.0	1 : 1.1
LOKE.M.5	1 : 1.4	n.d.
LOKE.M.6	1 : 1.5	n.d.
LOKE.M.7	1 : 1.1	1 : 1.0
LOKE.M.8 (brown coat)	1 : 2.4	n.d.
LOKE.M.9	1 : 1.7	n.d.

Some interesting features are revealed particularly in light of the qualitative petrographic observations. First, the independent methods result in good agreement for the binder to sand ratio in sample LOKE.M.3. This suggests that the assumption of original natural cement chemistry is relatively effective at estimating ratios from the bulk chemical analysis. Similar agreement is found in sample LOKE.M.7 even though the point-count sample is smaller than might be desired for statistical significance. Interestingly, the chemical analysis of samples LOKE.M.4 and M.8 result in a higher sand content calculation than the other mortars yet such variation is not evident by qualitative petrographic observations where all sand contents appear more or less similar. These are the two samples where the characteristics of the relict cement grains are distinctly different than the others in the suite with a high abundance of partially burned quartz silt. Point-count analysis of LOKE.M.4 suggests half the sand content as that estimated from the chemical analysis. It is interpreted that the original cement chemistry is different in these samples and the proportions estimated via the chemical analysis may represent an overestimation of sand content for these two.

Based on these analyses, it is interpreted that most binder to sand ratios are approximately 1 : 1.5 by volume. Samples LOKE.M.4 and LOKE.M.7 may be closer to 1 : 1. Such low sandings with narrow and relatively coarse sand gradations are considered typical of historical natural cement mortars. If in-kind replication is a priority, mix designs with these proportions and gradations may be considered viable.

6.2 LOKE.M.10 Materials

The exterior mortar of the Keeper's dwelling (LOKE.M.10) appears identical to the other mortars based on visual characteristics and is also identified as a pure cement mortar (Figs. 6 and 10). However, the binder is identified as a pure portland cement with no lime additions identified. The distinctive low-magnesium, low insoluble residue values measured chemically are consistent with this qualitative identification. Cement relicts are identified petrographically as medium-sized agglomerates of well-hydrated calcium silicates with interstitial ferrite (Fig. 14). The iron-bearing ferrite identifies the binder as an ordinary gray portland cement. The medium grind and homogeneity of calcium silicate size is consistent with cements produced in the early twentieth century and is considered consistent with the early 1920's vintage reported by the client.

The sand in this sample is identical in composition and only slightly different in gradation as that observed in the natural cement mortars discussed above. As with these, the sand is a natural carbonate sand consistent with the local source (Figs. 6 and 10). The appearance of the sand is also homogenous and light-colored ranging from nearly white to pale yellow. The grains are rounded due to natural weathering processes but tend to be somewhat elongate due to the original shapes of the organisms. The gradation is still narrow with a nominal top size estimated at the No. 16 sieve but the peak abundance is estimated to be spread more evenly between the No. 16 and No. 50 sieves as compared to other samples in the suite. Still, there are relatively few fines in the sand estimated to pass the No. 50 sieve size. As with the other samples, this relatively narrow gradation is considered geologically consistent with the local sediment.

LOKE.M.10 exhibits cement and sand components that are well mixed and distributed. Air contents tend to be low and the mortar well consolidated. Hydration qualities of the cement are virtually complete with a homogeneous distribution of cementitious product. The original water to cement ratio is estimated to be moderate based on the observed capillary porosity and the mortar appears to have been mixed without an excess of water or significant retempering (Fig. 10).

Chemical analysis was performed in order to estimate the original binder to sand ratios. In this case, an estimate based on chemical analysis is considered more robust as portland cement has a less variable chemistry than natural cement. Assuming a typical portland cement chemistry and bulk densities of cement and damp, loose sand, the binder to sand ratio is estimated at 1 : 2.4. The sand content is higher than that observed in the other natural cement mortars but this is considered consistent with historic practice.

6.3 LOKE.M.8 Materials

LOKE.M.8 is reported to represent an Oil House plaster sample and consists of a three-coat plaster system (Figs 16 through 20). Substrate is not included with the sample. The sample includes a relatively soft and porous scratch coat identified as a sanded, lime-based plaster gauged with natural cement, a relatively hard and dense brown coat identified as a sanded, pure natural cement plaster, and a fine-textured, unsanded finish coat consisting of lime gauged with gypsum. Generally speaking, these materials are considered consistent with a mid-nineteenth century vintage and certainly are inconsistent with twentieth century practice. The use of gypsum-based plaster as a gauging material is less well understood. While the use of calcined gypsum as a binder has a long history, the author is unaware of any American references to its use in the States prior to approximately 1880.

The sand in the scratch and brown coats is more or less identical (Fig. 7). As discussed earlier for the brown coat, the aggregate is identified as a natural carbonate sand containing coral and shell fragments similar to that making up the sediment of the Dry Tortugas. Visual examination indicates a homogeneous color ranging from nearly white to pale yellow with no significant variegation. Grains are rounded due to natural weathering processes but tend to be somewhat elongate due to the original shapes of the organisms. The gradation is quite narrow with a nominal top size estimated at the No. 8 sieve with all material estimated to pass. A strong peak abundance is estimated between the No. 16 and No. 30 sieves with only a moderately low abundance of material estimated to pass the No. 30 sieve.

The binder matrix in the scratch coat is characterized by a highly porous, carbonated paste, with a moderate abundance of microscopic shrinkage cracks. The paste matrix is typical of a high lime binder (Fig. 16). Larger relict lime grains are observed in low abundance and these exhibit homogeneous internal textures. Given the limited sample available for the scratch coat, it is not possible to speculate on the source of the lime. Furthermore, a chemical analysis could not be performed and no information is available for the lime chemistry. Natural cement grains identical to those of the brown coat are found in very low abundance (Fig. 17). The cement is estimated to represent a minor gauging affording only minimal hydraulic property to the scratch coat. While no quantitative estimate is offered, it is unlikely that the cement represents more than one tenth part of the lime by volume. The sanding is interpreted to be relatively low based on petrographic observations and the binder to sand ratio is probably less than 1 : 2 by volume.

Due to the similarity of the brown coat to the natural cement mortars, more detail for this layer is provided above. The binder matrix is moderately dense and consists of a natural cement binder with no lime addition. The cement is identified as a magnesium natural cement consistent in texture with the more productive American manufactories. However, a higher abundance of calcined silt is observed than in any of the other mortar samples with the exception of portions of sample LOKE.M.4. Chemical analysis was performed on this sample and binder to sand ratio estimated at 1 : 2.4 by volume. However, based on arguments presented earlier, this is likely a significant overestimate due to a distinctly different chemistry for this cement. Petrographic similarity of this sample with those of the other mortar samples suggest that the actual ratio may be closer to 1 : 1.5.

The finish coat matrix is fine-textured and porous (Fig. 19). An abundance of fine residual lime grains indicates the layer is mostly lime based. Chemical analysis was performed on this layer. Even assuming that all magnesium is contained in the lime, a CaO/MgO weight ratio of 10 (an order of magnitude higher than an ideal dolomitic ratio of 1.4) suggests a high calcium rather than dolomitic lime. Traces of calcined silicate contaminants suggest a rock lime source but not enough material is observed petrographically to offer a definitive statement. Gypsum plaster is identified as a gauging material (Fig. 20). Very few unhydrated gypsum relicts are identified. The rare abundance of coarser hemihydrate or finer dead-burned anhydrite suggests that the plaster was not a cement plaster or Keene's cement but rather a fine finishing plaster such as Plaster-of-Paris.

Chemical analysis was performed on the finish coat in order to estimate the lime to plaster proportions. Assuming the lime was added as a dry hydrate, the lime to plaster ratio is estimated at 1 : 0.2. It is unlikely that the lime was a prepackaged hydrate. However, a given volume of dry hydrate has a more constant weight ratio of constituent elements than a given volume of putty and the estimate may be considered more robust. Assuming a similar mass of hydrate loses approximately 40% of its volume when mixed with water to the consistency of a stiff putty, the ratio is recalculated at 1 : 0.3 by volume.

6.4 LOKE.M.11 Materials

LOKE.M.11 is reported to represent an Keeper's Dwelling plaster sample and consists of a two-coat plaster system (Figs. 21 through 24). Substrate is not included with the sample. The sample includes a relatively hard but porous brown coat identified as a sanded, gypsum-based plaster and a relatively hard but porous, unsanded finish coat consisting of a fine-textured gypsum gauged with lime. The use of gypsum materials rather than lime for interior plastering is considered consistent with the 1920's vintage reported by the client.

The brown coat contains a relatively coarse-textured and porous binder matrix composed of a network of fine-grained gypsum hydrate (Fig. 21). Coarser hydrated residuals are relatively common and unhydrated hemihydrate and fine-grained, dead-burned anhydrite are also present though in lower abundance (Fig. 22). A chemical analysis was not requested for this sample and further information regarding the plaster provenance cannot be provided. However, the microtexture of the coat clearly discounts a refined finishing plaster and the presence of the dead-burned gypsum (anhydrite) suggests that the plaster may have been a Keene's cement. It should be noted that the term "cement" here does not refer to hydraulic calcium silicates and Keene's cement represents a relatively pure calcium sulfate product.

The sand in the brown coat is identical to that of the other samples in the suite and is most similar to the other Keeper's Dwelling sample (LOKE.M.10) in gradation (Figs. 7 and 21). The aggregate is identified as a natural carbonate sand containing coral and shell fragments similar to that making up the local sediment. Visual examination indicates a homogeneous color ranging from nearly white to pale yellow with no significant variegation. Grains are rounded due to natural weathering processes but tend to be somewhat elongate due to the original shapes of the organisms. The gradation is

somewhat narrow with a nominal top size estimated at the No. 16 sieve. The peak abundance is estimated between the No. 16 and No. 50 sieves with only a minor abundance of material estimated to pass the No. 50 sieve.

The finish coat matrix is fine-textured and moderately porous. The paste matrix is dominated by a network of very-fine grained hydrated gypsum crystallites (Fig. 23). Very few unhydrated gypsum relicts are identified. The rare abundance of coarser hemihydrate or finer dead-burned anhydrite suggests that the plaster was not a cement plaster or Keene's cement but rather a fine finishing plaster such as Plaster-of-Paris (Fig. 24). A very low abundance of carbonated lime grains are dispersed throughout the largely gypsum-based matrix. While a chemical analysis was not performed for this sample, the lime is interpreted to represent a minor gauging rather than a major component of the finish plaster.

6.5 Cracking Distress and Salt Crystallization

The client requested some discussion regarding the possible role of salts as a deleterious agent in the examined suite of samples. A combination of petrographic and chemical techniques are utilized in order to address this concern.

First, it is noted that while some samples are provided in fragmental condition, very little internal microcracking is detected in the majority of the samples (Fig. 25). Most exhibit good microstructural integrity. Some minor to moderate microcracking is detected in the cistern samples (LOKE.M.2 and M.3) and some minor microcracking is found in the Lighthouse sample LOKE.M.5. It should be stated that while minor salt deposits are detected within some of these cracks and other samples have chemistries suggestive of some soluble salt content, there is no evidence suggesting that any sample in the suite has undergone any deterioration related to either salt crystallization or salt hydration distress (Fig. 26). Minor sulfate deposits are observed petrographically in sample LOKE.M.5 as well as fine deposits likely to represent chloride salts based on their optical character. Similar salts consistent with chlorides are found as minor thin surface linings in sample LOKE.M.6. The greatest amount of secondary sulfate as gypsum is found within air-voids of sample LOKE.M.10. This is not surprising as this is the only sample containing a portland cement binder with hydrates more susceptible to secondary gypsum recrystallization. Even here however, the deposits are not related to any significant cracking distress.

The alkali elements sodium and potassium were measured quantitatively for all samples analyzed chemically. These are somewhat elevated for most samples. Additionally, water-soluble chloride was measured for the four Lighthouse samples and these may also be considered slightly elevated in content. However, it is likely that the local carbonate sand was unwashed prior to mixing and was rich in soluble alkali salts (particularly chlorides). It is also noted that no natural freshwater sources are present in the Dry Tortugas and all freshwater would have to have been collected by cistern systems. Given the scarcity of freshwater, it is also likely that the mortars were mixed with saltwater. A greater proportion of the alkali content is more likely to be related to the original mix constituents rather than later contamination. It is interesting to note that the cistern samples (LOKE.M.2 and M.3) exhibit the lowest alkali contents. Given the application, these mortars and pargings likely had a greater exposure to freshwater through drinking water storage and the reduced alkali content may be related to leaching and dilution of original chloride salts.

John J. Walsh
Senior Petrographer/ Geologist

Samples will be discarded 30 days after the final report date unless otherwise instructed. This report is the confidential property of the client and any unauthorized reproduction is strictly prohibited. The interpretations and conclusions presented in this report are based on the samples provided.

Appendix I: Photographs and Photomicrographs

Microscopic examination is performed on an Olympus BX-51 polarized/reflected light microscope and a Bausch and Lomb Stereozoom 7 stereoscopic reflected light microscope. Both microscopes are fitted with an Olympus DP-11 digital camera. The overlays presented in the photomicrographs (e.g., text, scale bars, and arrows) are prepared as layers in Adobe Photoshop and converted to the jpeg format. Digital processing is limited to those functions normally performed during standard print photography processing. Photographs intended to be visually compared are taken under the same exposure conditions whenever possible.

The following abbreviations may be found in the figure captions and overlays and these are defined as follows:

cm	centimeters	PPL	Plane polarized light
mm	millimeters	XPL	Crossed polarized light
μm	microns (1 micron = 1/1000 millimeter)		
mil	1/1000 inch		

Microscopical images are often non-intuitive to those not accustomed to the techniques employed. The following is offered as a brief explanation of the various views encountered in order that the reader may gain a better appreciation of what is being described.

Reflected light images: These are simply magnified images of the surface as would be observed by the human eye. A variety of surface preparations may be employed including polished and fractured surfaces. The reader should note the included scale bars as minor deficiencies may seem much more significant when magnified.

Plane polarized light images (PPL): This imaging technique is most often employed in order to discern textural relationships and microstructure. To employ this technique, samples are milled (anywhere from 20 to 30 microns depending on the purpose) so as to allow light to be transmitted through the material. In many cases, Testwell also employs a technique whereby the material is impregnated with a low viscosity, blue-dyed epoxy. Anything appearing blue therefore represents some type of void space (e.g.; air voids, capillary pores, open cracks, etc.) Hydrated cement paste typically appears a light shade of brown in this view (with a blue hue when impregnated with the epoxy). With some exceptions, most aggregate materials are very light colored if not altogether white. Some particles will appear to stand out in higher relief than others. This is a function of the refractive power of different materials with respect to the mounting epoxy.

Crossed polarized light images (XPL): This imaging technique is most often employed to distinguish components or highlight textural relationships between certain components not easily distinguished in plane polarized light. Using the same thin sections, this technique places the sample between two pieces of polarizing film in order to determine the crystal structure of the materials under consideration. Isotropic materials (e.g.; hydrated cement paste, pozzolans and other glasses, many oxides, etc.) will not transmit light under crossed polars and therefore appear black. Non-isotropic crystals (e.g.; residual cement, calcium hydroxide, calcium carbonate, and most aggregate minerals) will appear colored. The colors are a function of the thickness, crystal structure, and orientation of the mineral. Many minerals will exhibit a range of colors due to their orientation in the section. For example, quartz sand will appear black to white and every shade of gray in between. Color differences do not necessarily indicate material differences. When no other prompt is given in the figure caption, the reader should appeal to general shapes and morphological characteristics when considering the components being illustrated.

Chemical treatments: Many chemical techniques (etches and stains typically) are used to isolate and enhance a variety of materials and structures. These techniques will often produce strongly colored images that distinguish components or chemical conditions.



Figure 1: Photographs of the four Lighthouse mortar samples as received by Testwell for examination.



Figure 2: Photographs of mortar samples from the cistern, Kitchen Building and Keeper's Dwelling as received by Testwell for examination.

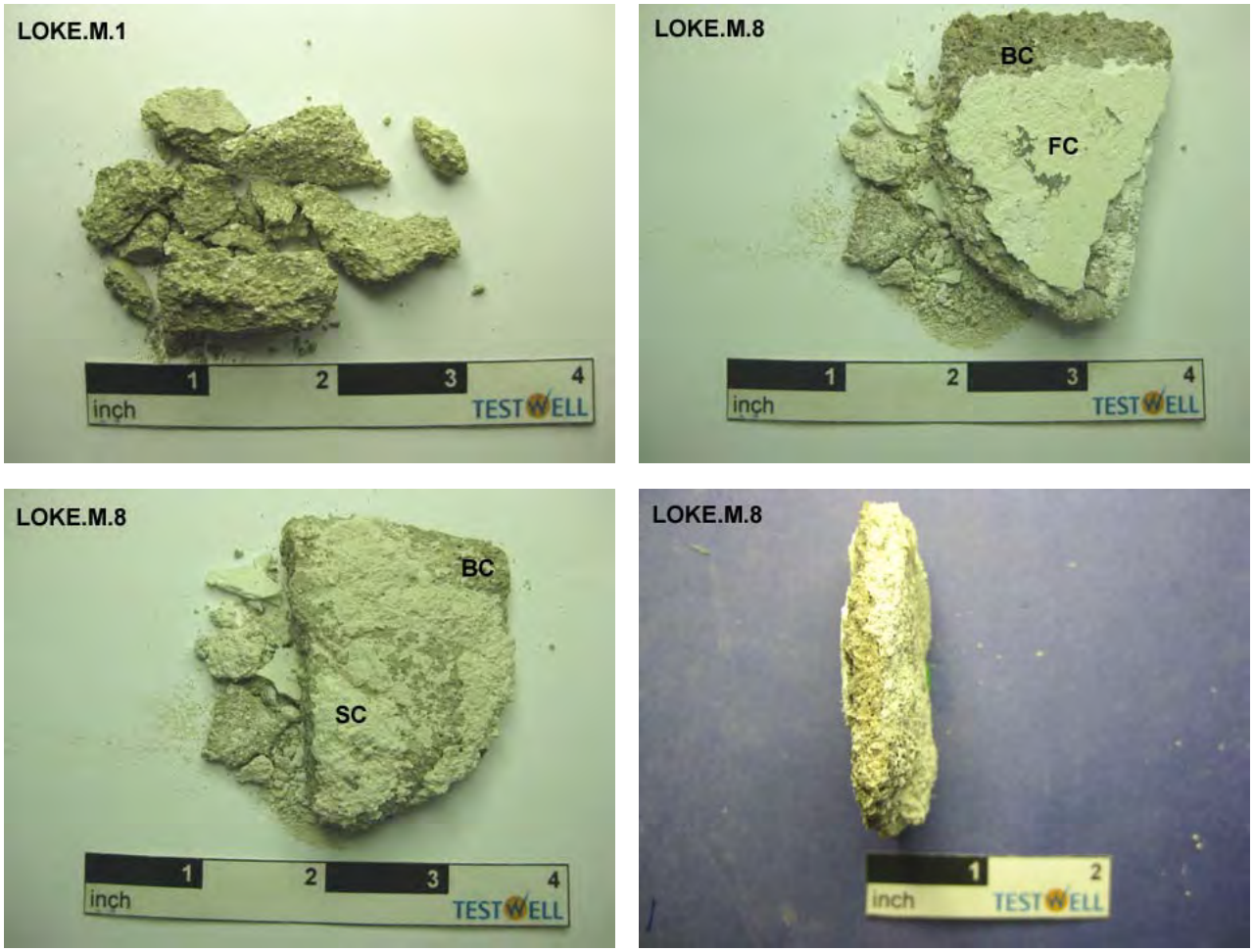


Figure 3: Photographs of the samples from the Oil House as received by Testwell for examination. Sample LOKE.M.8 is a plaster sample. A top view (top right) and rear view (bottom left) show the scratch coat (SC), brown coat (BC), and finish coat (FC) in this three-coat plaster. The last photograph presents a side view.

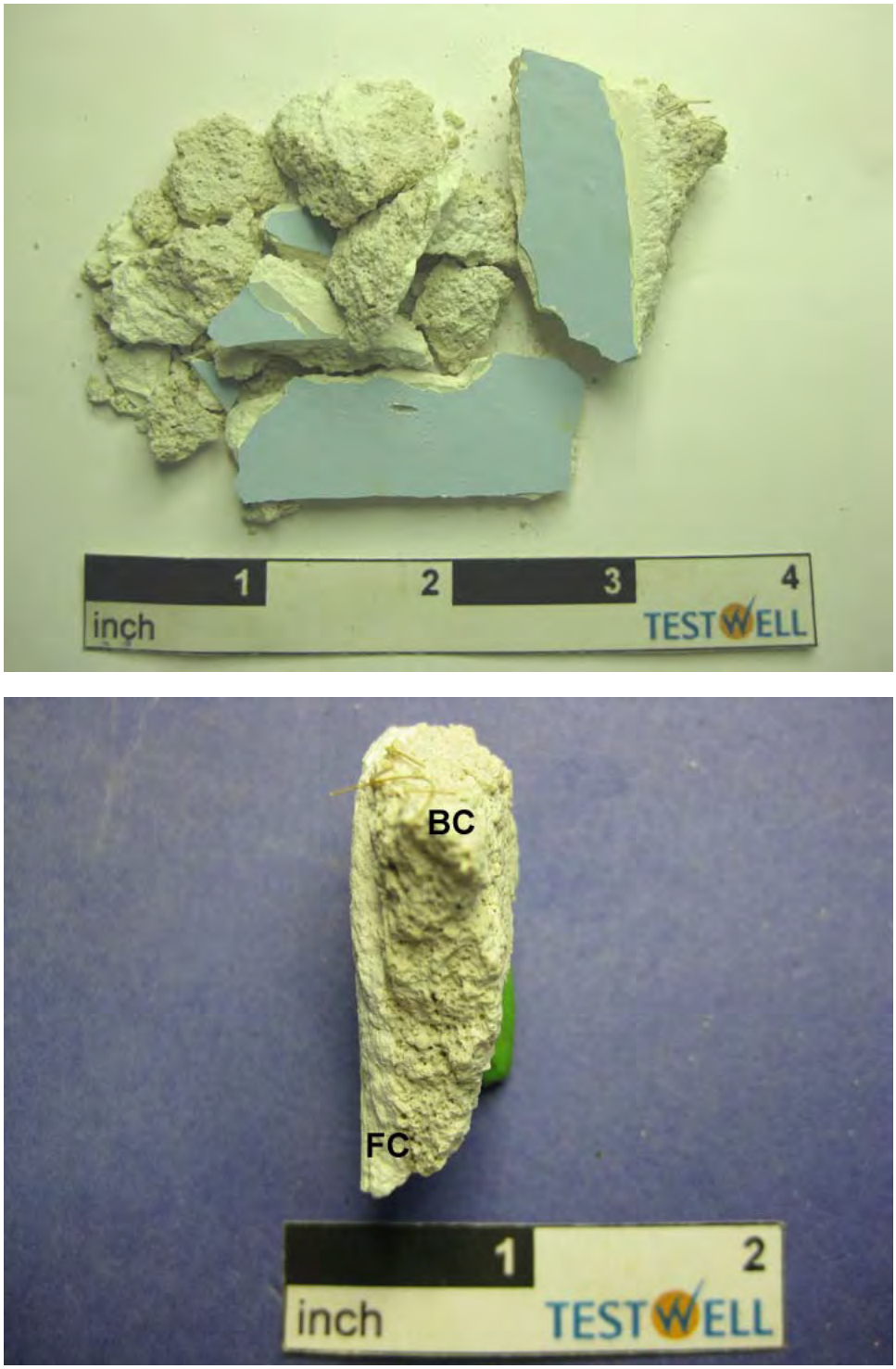


Figure 4: Photographs of the plaster sample from the Keeper's Dwelling as received by Testwell for examination. The bottom photograph presents a side view of the two-coat plaster with brown coat (BC) and finish coat (FC) visible.

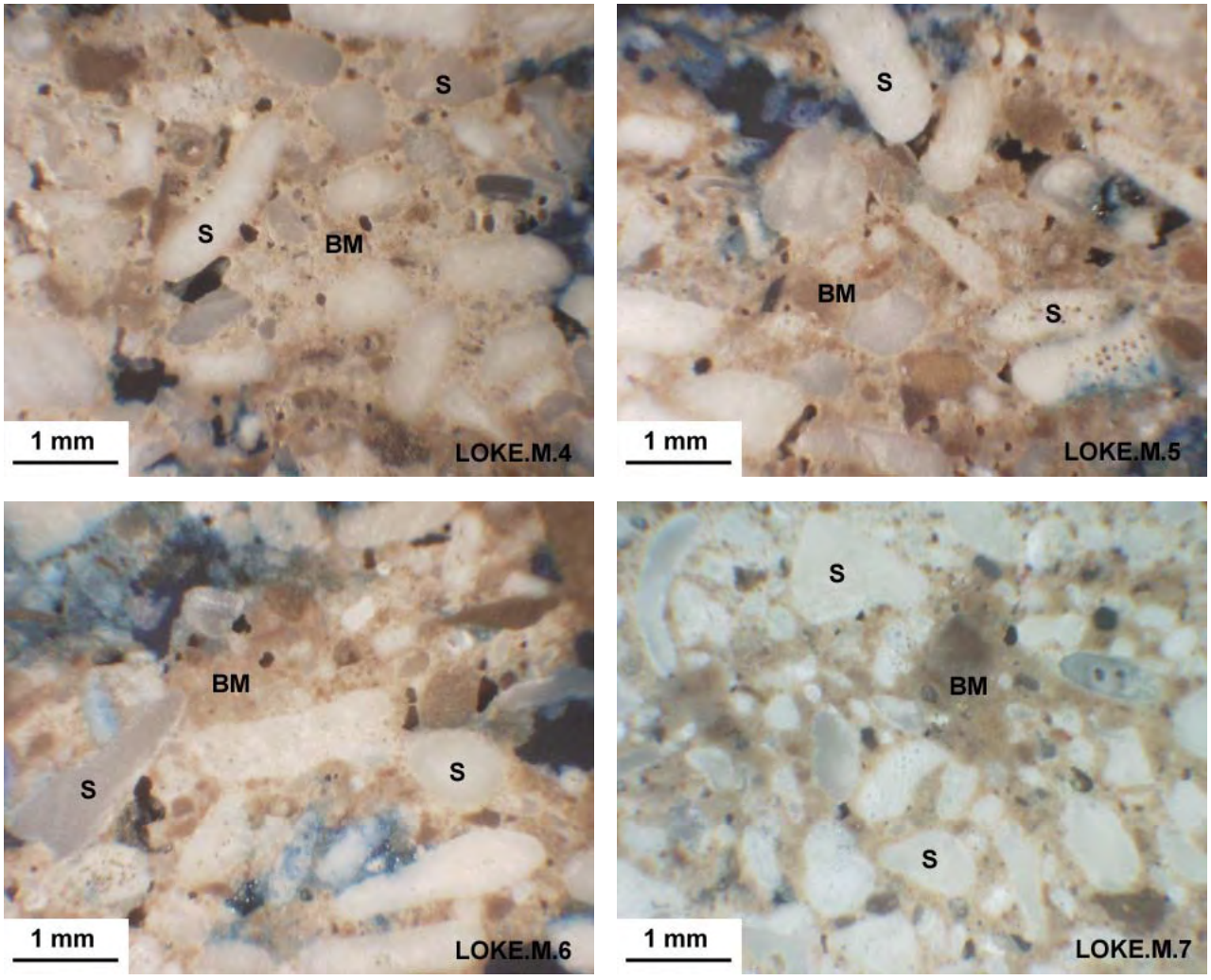


Figure 5: Reflected light photomicrographs of honed cross sections of the Lighthouse mortar samples. Binder matrix is well compacted and consolidated around sand grains (S). The sand is light-colored and homogeneous and the same type of sand component is found in all samples. Gradations tend to be relatively narrow with all material estimated to pass a No. 8 sieve and little material found below the No. 50 sieve. Blue coloration in some of the samples is due to the impregnation of a low-viscosity blue dyed epoxy. Several of the honed sections were prepared directly from residual thin section billets where total sample size is small.

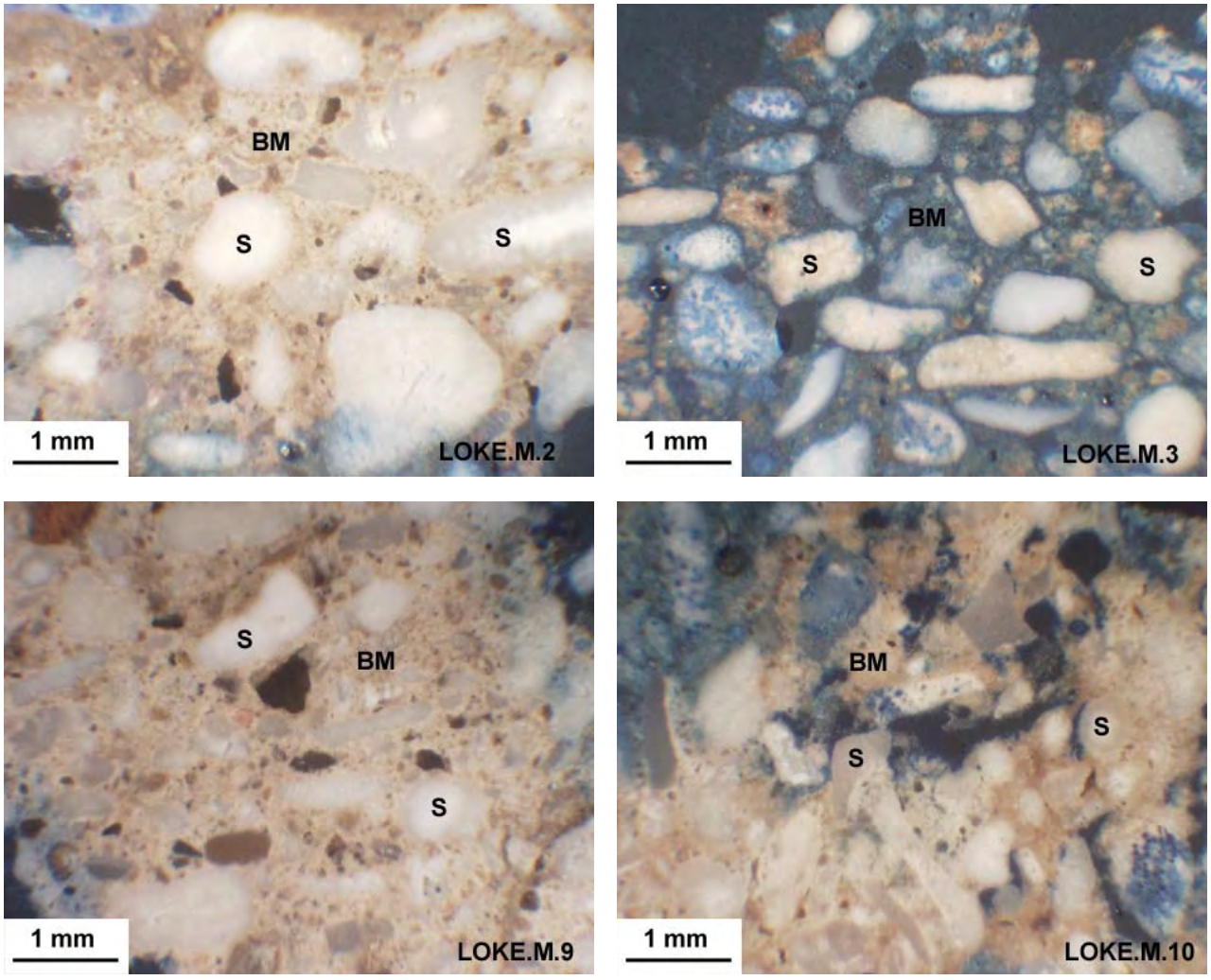


Figure 6: Reflected light photomicrographs of honed cross sections of mortar samples from the cistern, Kitchen Building and Keeper's Dwelling. Binder matrix is well compacted and consolidated around sand grains (S). The sand is light-colored and homogeneous and the same type of sand component is found in all samples. Gradations tend to be relatively narrow with all material estimated to pass a No. 8 sieve and little material found below the No. 50 sieve. Blue coloration in some of the samples is due to the impregnation of a low-viscosity blue dyed epoxy. Several of the honed sections were prepared directly from residual thin section billets where total sample size is small.

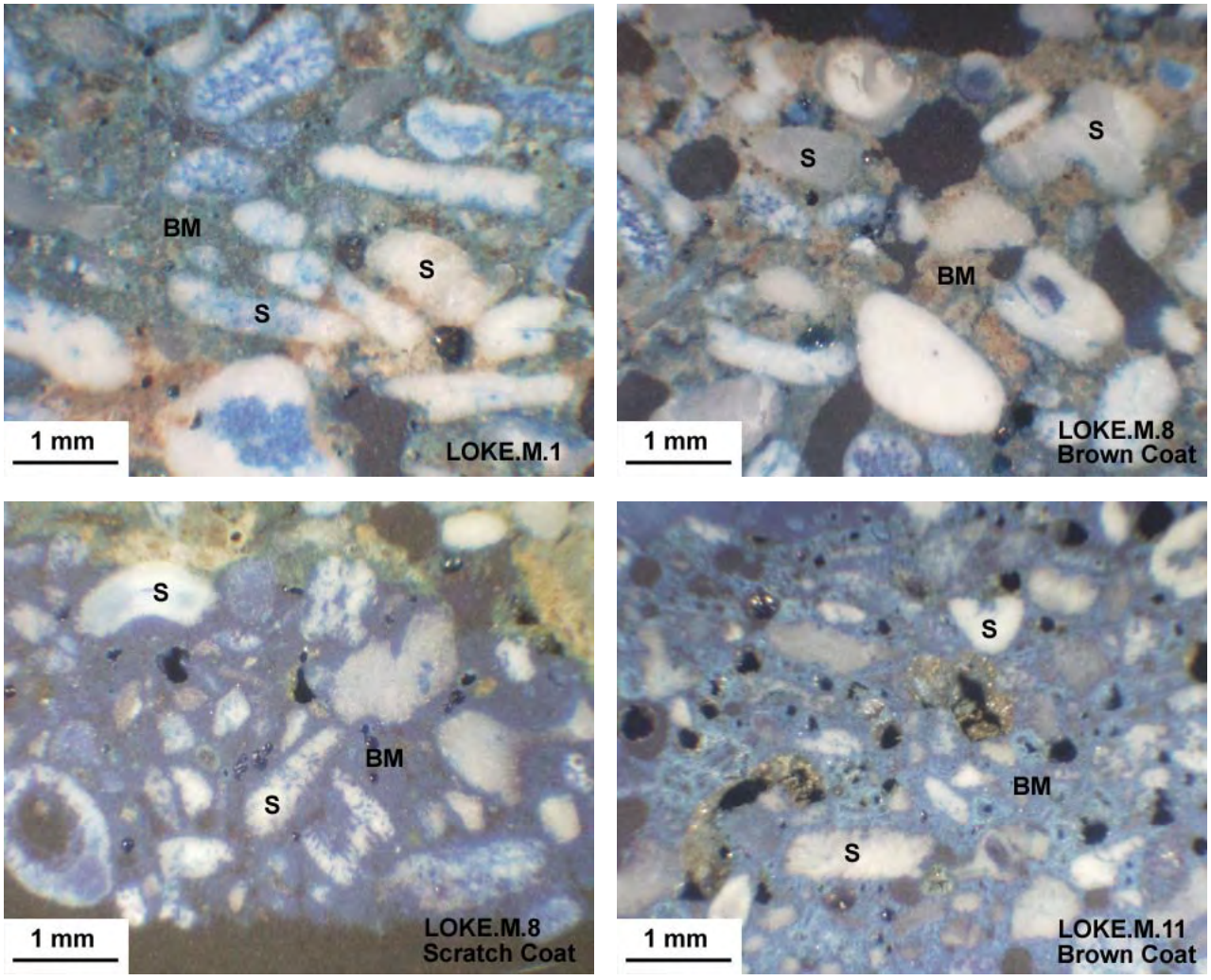


Figure 7: Reflected light photomicrographs of honed cross sections of samples from the Oil House and sanded plaster coats. Binder matrix is well compacted and consolidated around sand grains (S). The sand is light-colored and homogeneous and the same type of sand component is found in all samples. Gradations tend to be relatively narrow with all material estimated to pass a No. 8 sieve and little material found below the No. 50 sieve. Blue coloration in some of the samples is due to the impregnation of a low-viscosity blue dyed epoxy. Several of the honed sections were prepared directly from residual thin section billets where total sample size is small.

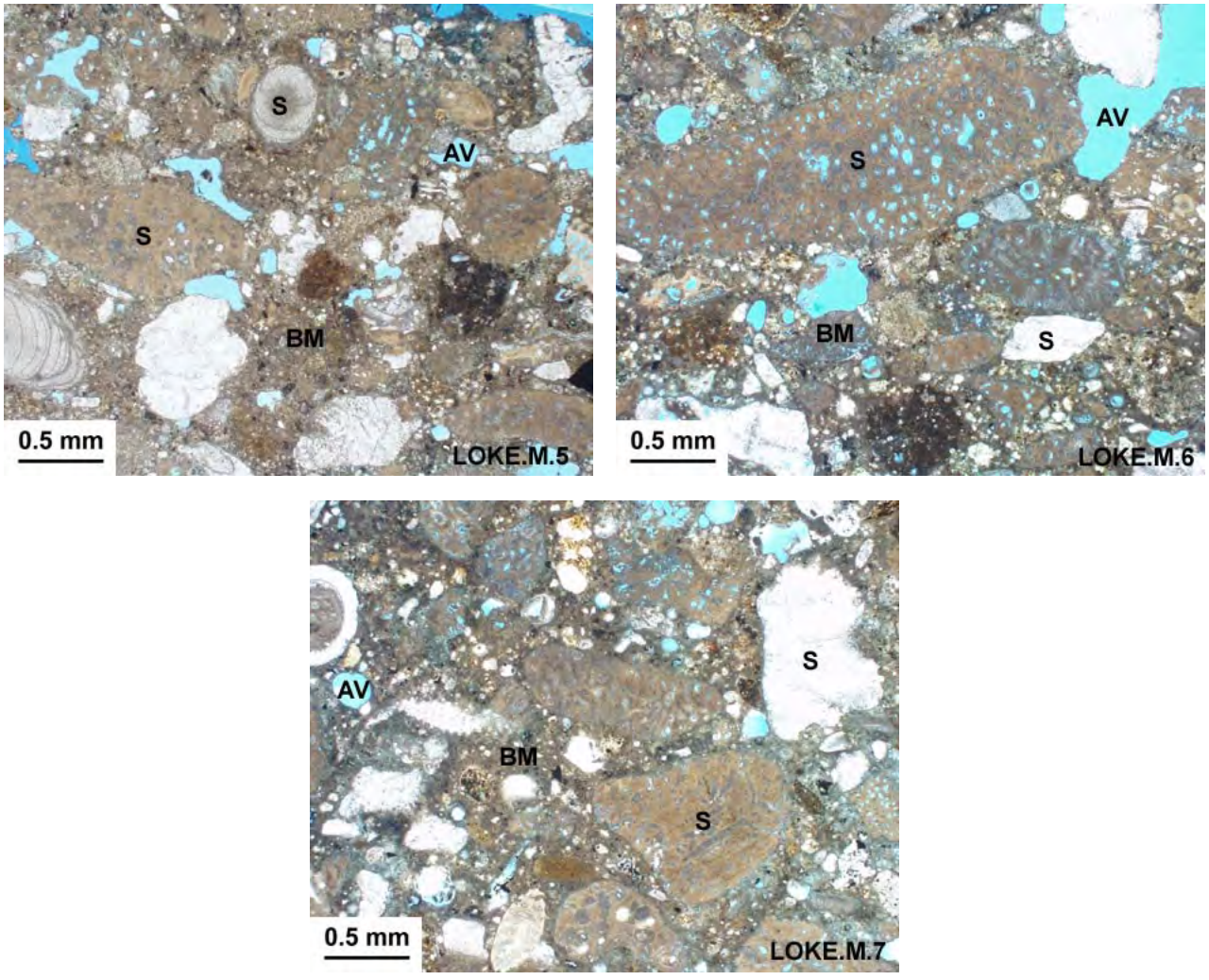


Figure 8: PPL photomicrographs illustrating the overall microstructure of the Lighthouse mortar samples. Sample LOKE.M.4 is not shown here and is presented in the next figure. The hydraulic binder matrix (BM) is well developed. Porosities tend to be moderate for the Lighthouse samples and this is demonstrated by the relatively low absorption of blue-dyed epoxy used in the sample preparation. The sand (S) is well coated with binder and is identified as a soft, natural carbonate sand composed of a variety of coral and shell fragments. Air-voids (AV) are not abundant.

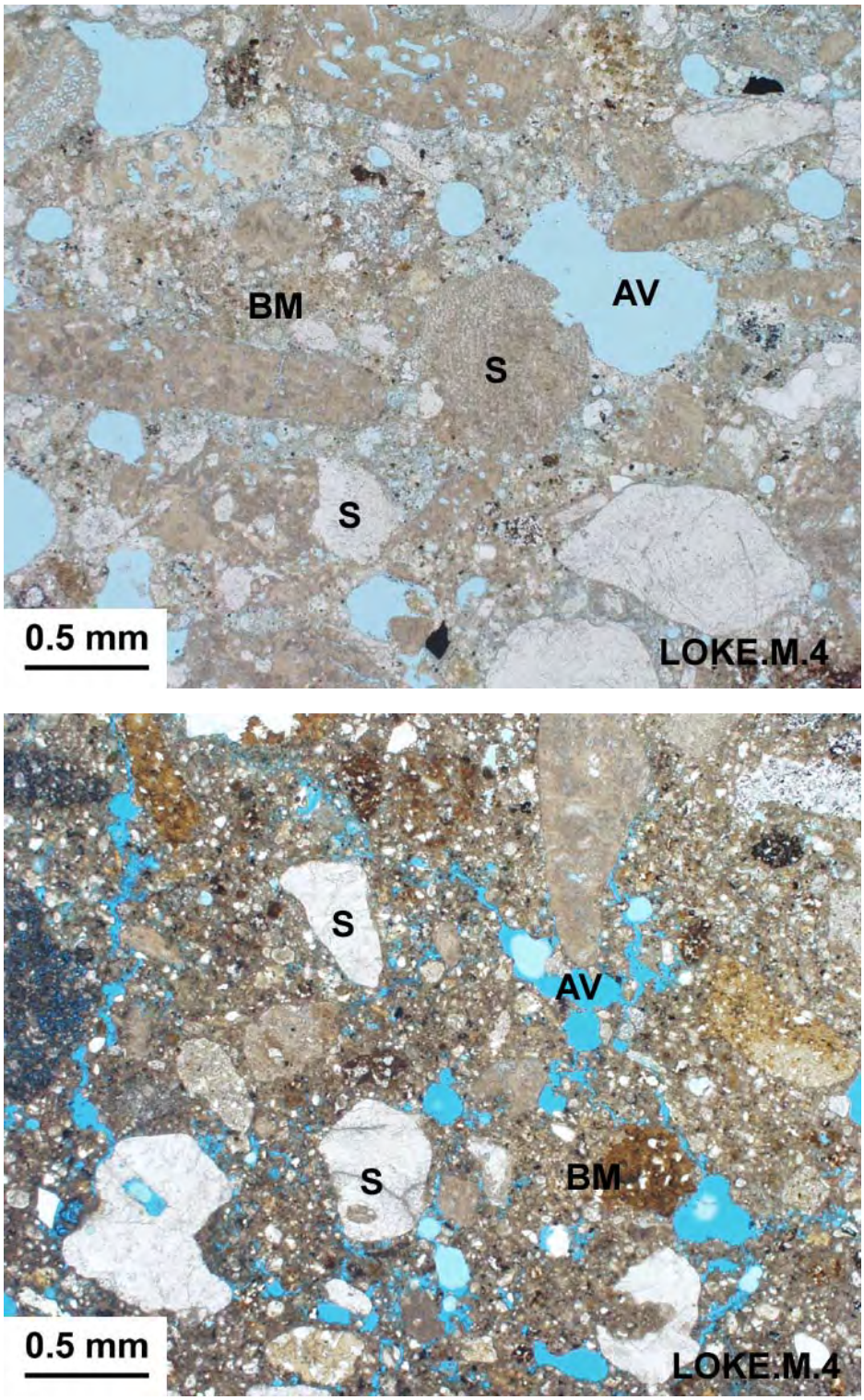


Figure 9: PPL photomicrographs illustrating the overall microstructure of Sample LOKE.M.4. Sample LOKE.M.4 is unusual in that two different microtextures are found within the same sample. The top image shows a binder matrix (BM) that has a higher porosity than the one in the image below. This is shown by the difference in absorption of blue-dyed epoxy used in the sample preparation. The binder matrix in the lower image also has a "grittier" character. This is interpreted to be due to a difference in the cement for this portion of the sample. The feature is shown in greater detail in Figure 13 below. The sand (S) has the same characteristics as that of the other Lighthouse samples. Air-voids (AV) are not abundant.

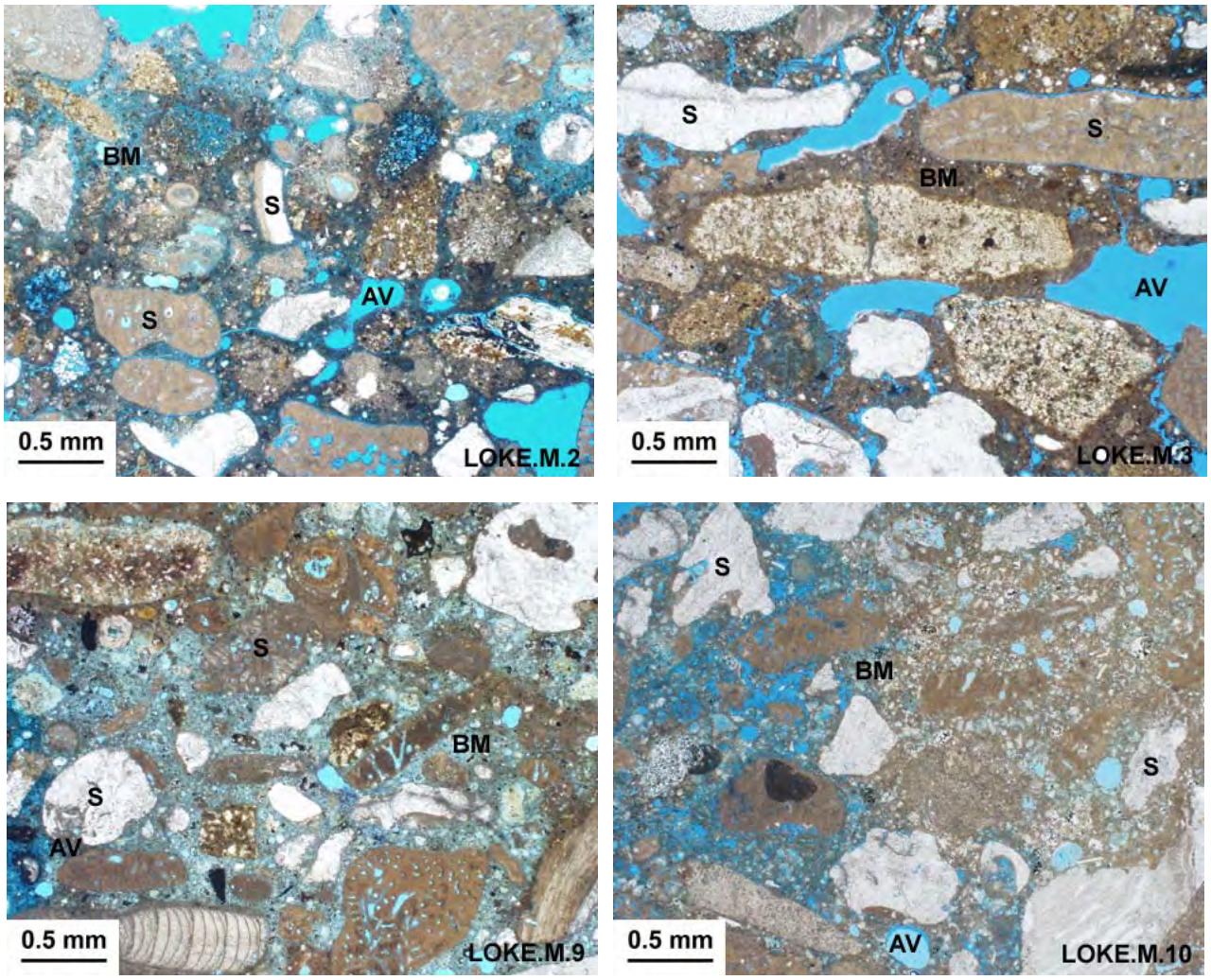


Figure 10: PPL photomicrographs illustrating the overall microstructure of mortar samples from the cistern, Kitchen Building and Keeper's Dwelling. The hydraulic binder matrix (BM) is well developed. Porosities tend to be moderate to moderately high for these samples and this is demonstrated by the moderate absorption of blue-dyed epoxy used in the sample preparation. Sample LOKE.M.9 has a high porosity in some areas of the sample. The sand (S) is well coated with binder and is identified as a soft, natural carbonate sand composed of a variety of coral and shell fragments. Air-voids (AV) are not abundant.

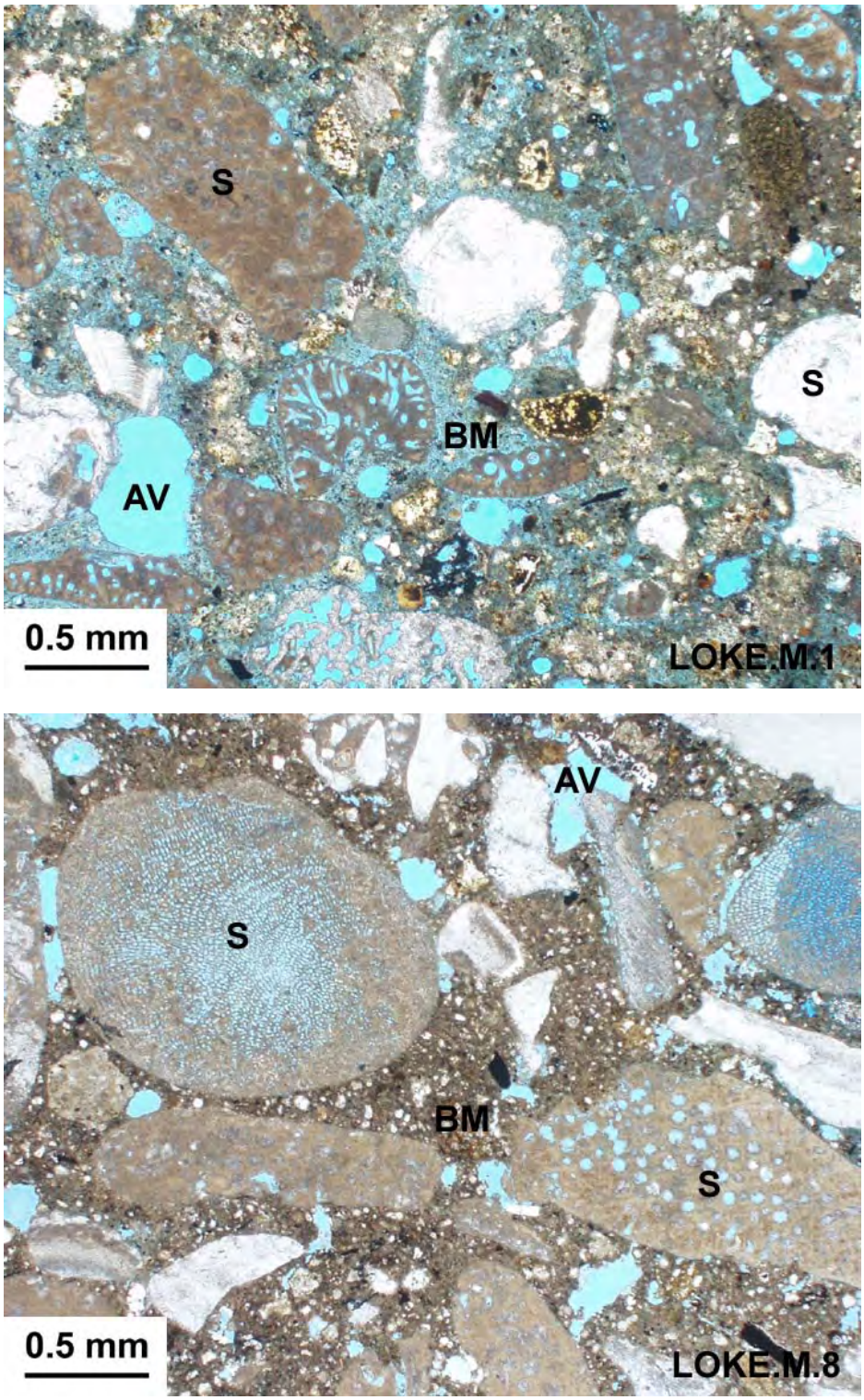


Figure 11: PPL photomicrographs illustrating the overall microstructure of the Oil House samples. The brown coat is shown for LOKE.M.8 as this material is more or less identical to that of the masonry mortar samples. The hydraulic binder matrix (BM) is well developed. Porosities tend to be moderately high for LOKE.M.1 and moderate for the brown coat of LOKE.M.8 samples and this is demonstrated by variations in the absorption of blue-dyed epoxy used in the sample preparation. The sand (S) is well coated with binder and is identified as a soft, natural carbonate sand composed of a variety of coral and shell fragments. The brown coat contains the coarsest sand of all examined samples and this is evident in this photomicrograph. Air-voids (AV) are not abundant in either sample.

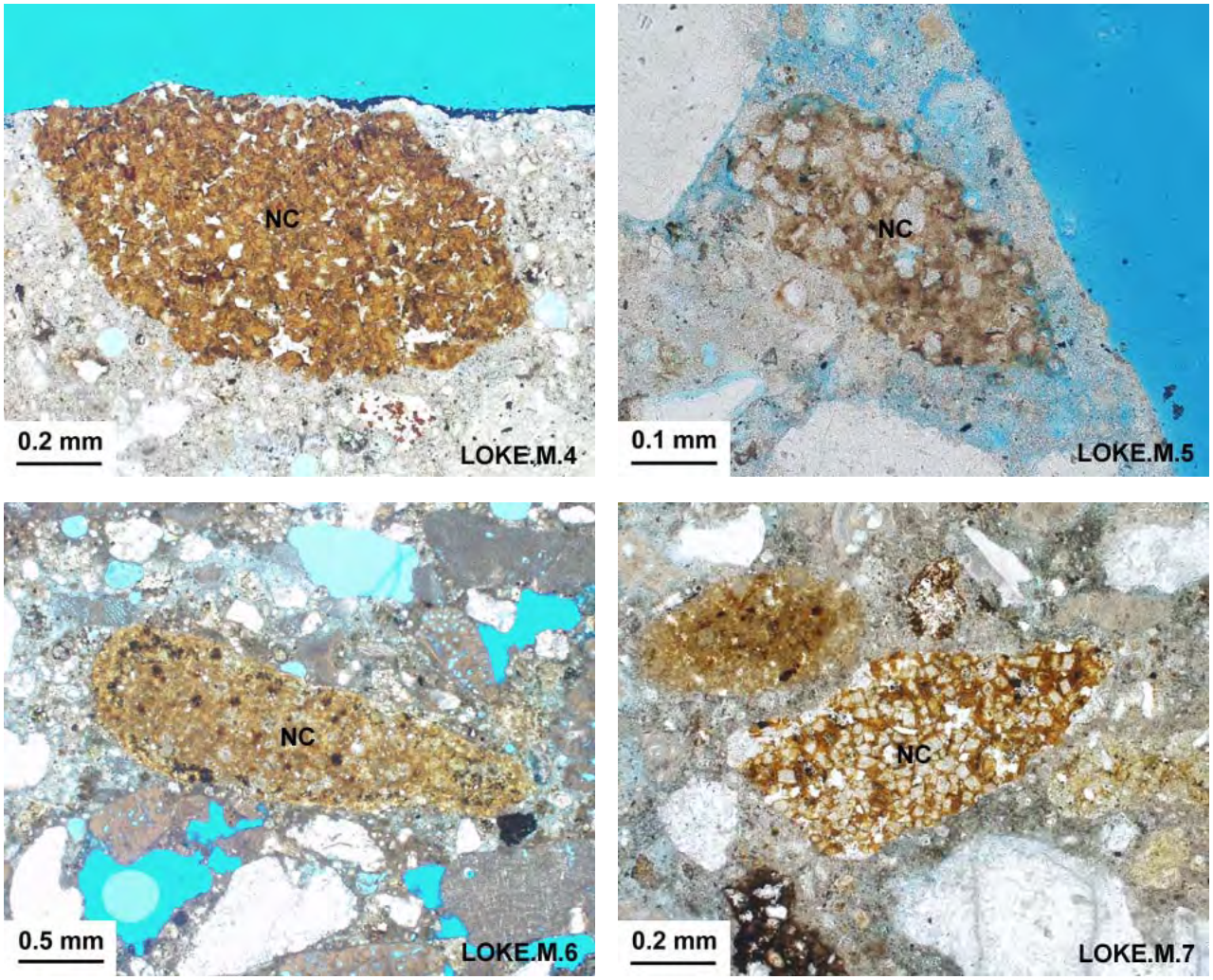


Figure 12: PPL photomicrographs illustrating binder residuals in the Lighthouse mortar samples. All are identified as natural cement relicts (NC). Typical textures within these grains include calcined dolomite rhombs surrounded by an iron-rich hydraulic product and partially burned quartz silt grains evenly dispersed throughout the particles. These textures are characteristic of magnesium-rich American cements of the nineteenth century. With the exception of sample LOKE.M.5, the Lighthouse samples tend to have more variably-sized cement relicts with coarse grains not uncommon. This is different than other samples in the suite and may suggest a different cement batch or source for these three mortars.

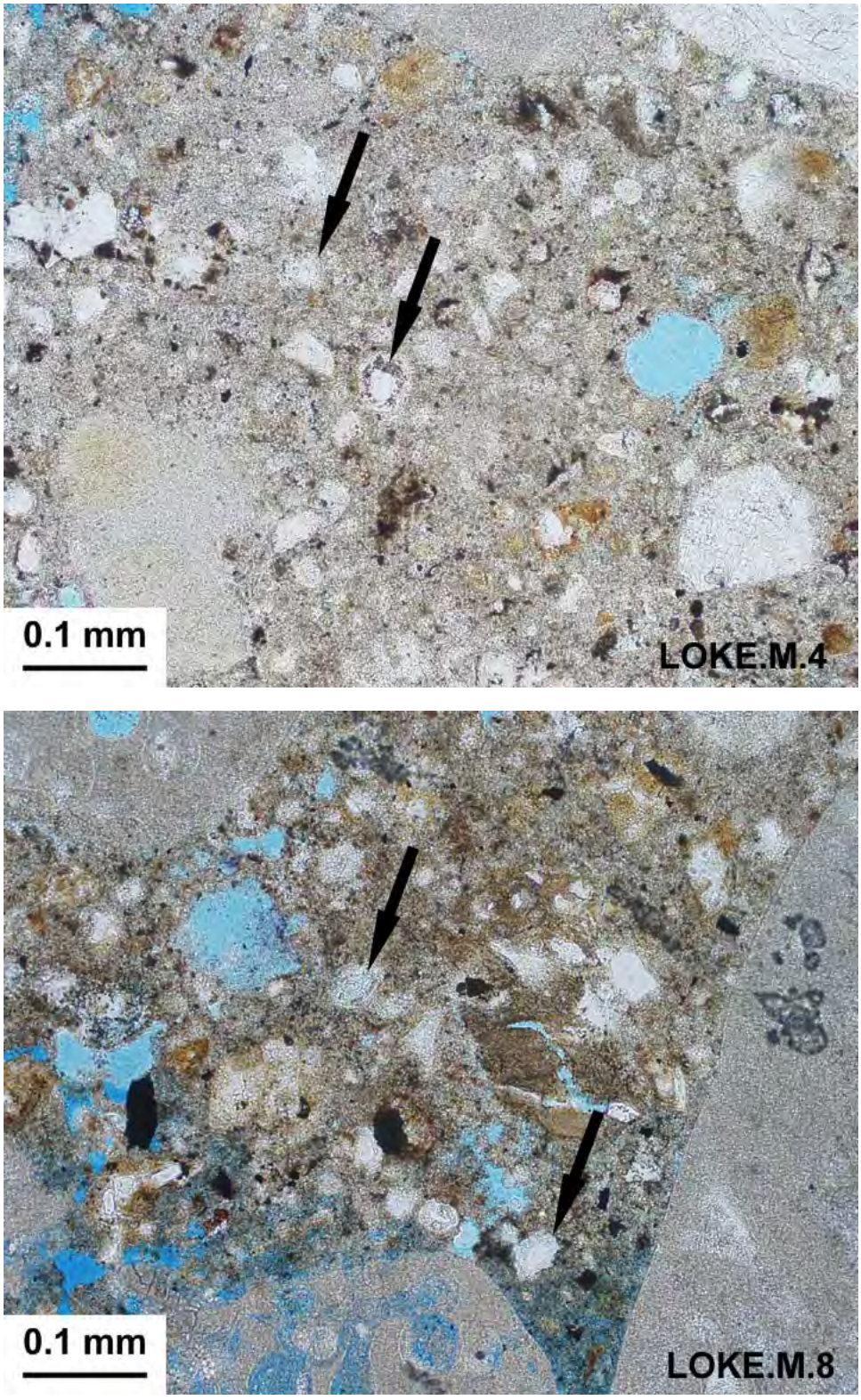


Figure 13: PPL photomicrographs illustrating distinctive cement microtextures in portions of LOKE.M.4 and all of the brown coat in LOKE.M.8. The arrows exhibit isolated fine silt grains dispersed throughout the paste matrix. These are not a component of the sand as closer inspection reveals fine calcination rims around these grains. Such calcined quartz silt is a common component of natural cements and in fact, these are found in all the natural cement mortars examined for this report. However, the abundance is distinctively high in these two samples suggesting a different cement batch or source.

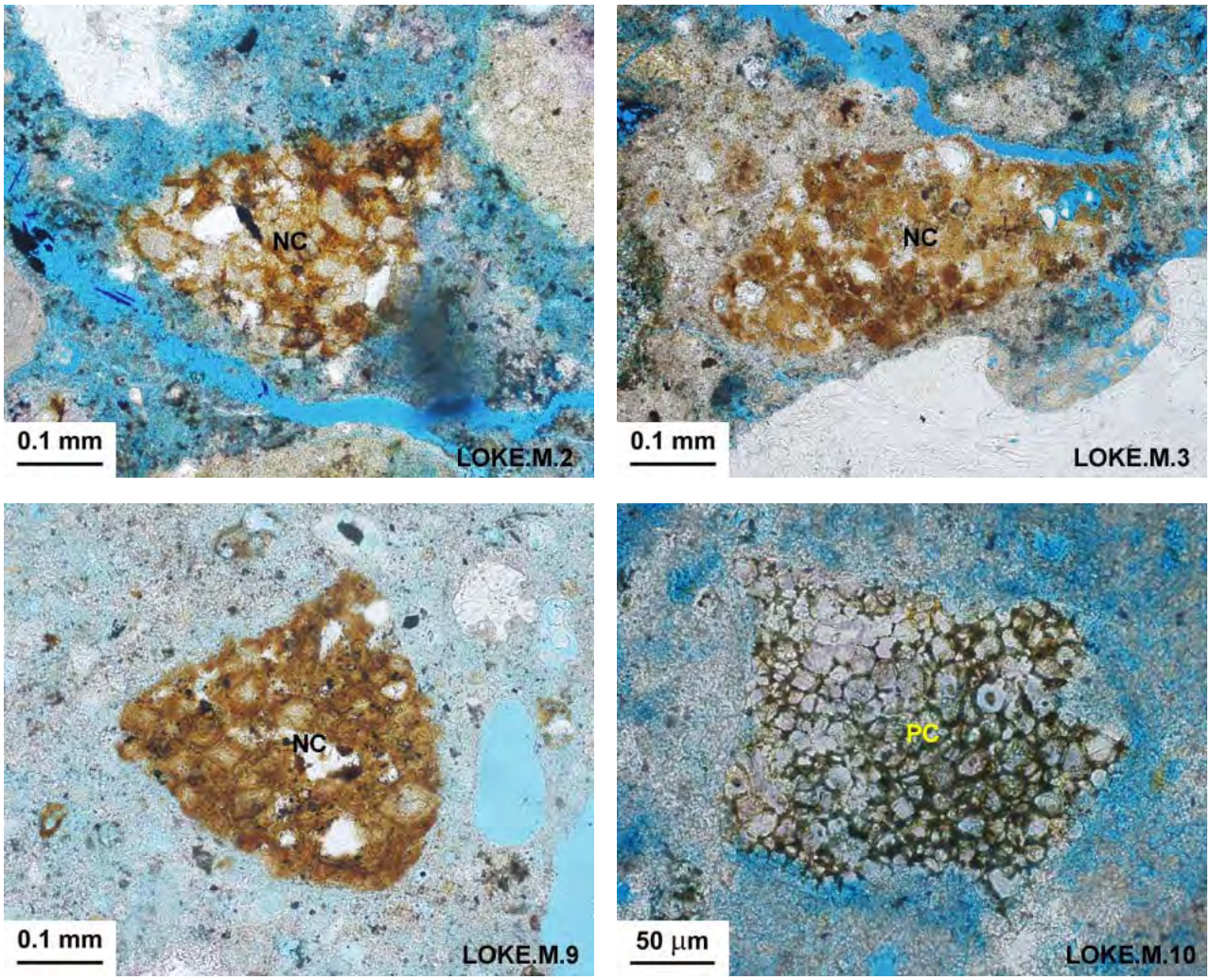


Figure 14: PPL photomicrographs illustrating binder residuals in mortar samples from the cistern, Kitchen Building and Keeper's Dwelling. All but those in LOKE.M.10 (Keeper's Dwelling) are identified as natural cement relicts (NC). Typical textures within these grains include calcined dolomite rhombs surrounded by an iron-rich hydraulic product and partially burned quartz silt grains evenly dispersed throughout the particles. These textures are characteristic of magnesium-rich American cements of the nineteenth century. Residual cement tends to fine- to medium-grained. The residual binder in LOKE.M.10 is identified as an ordinary gray portland cement (PC). The grain shown here contains rounded "ghosts" of fully hydrated calcium silicate with interstitial iron-bearing cement phases. The grind and consistency of the cement is characteristic of early twentieth century portlands.

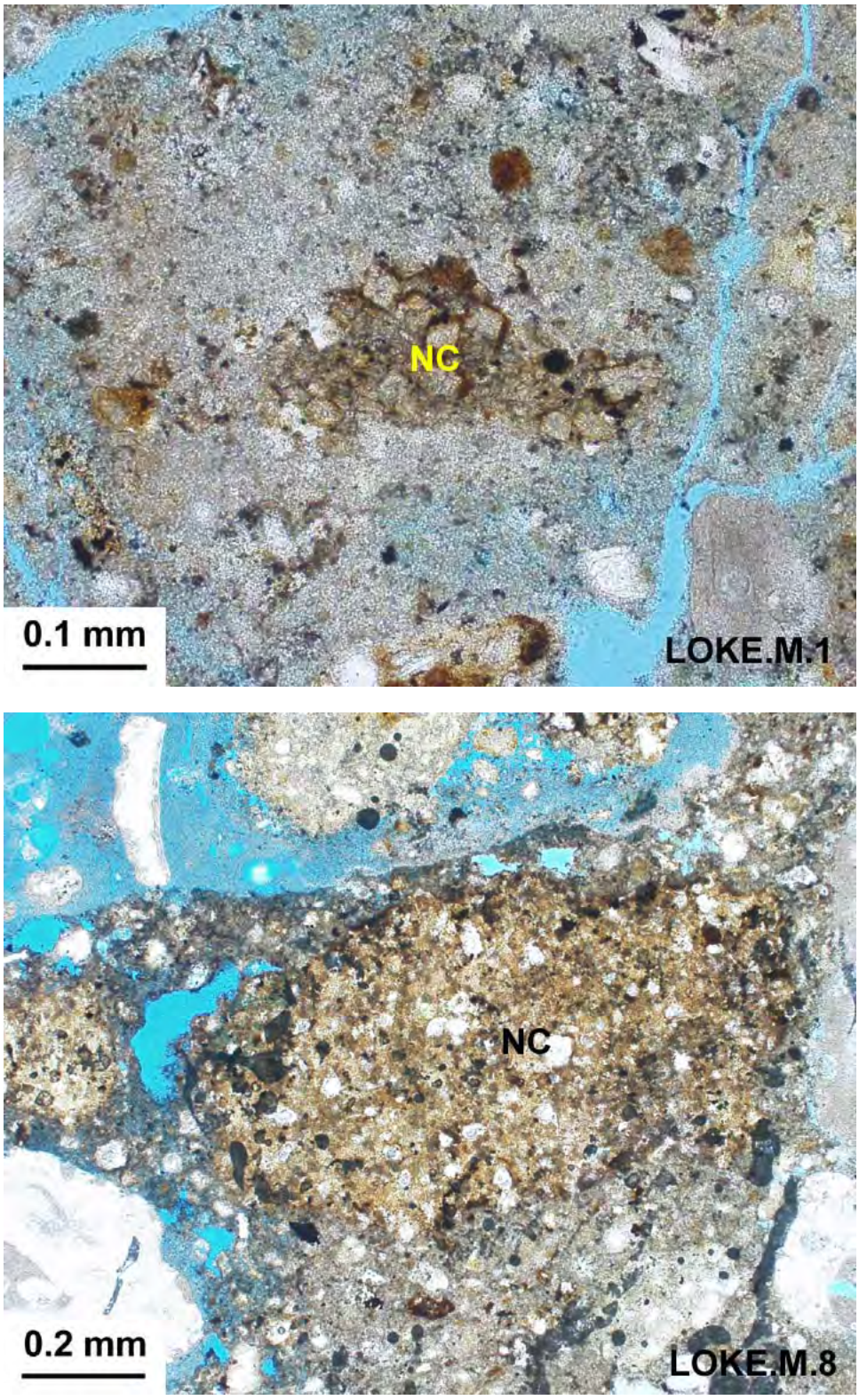


Figure 15: PPL photomicrographs illustrating binder residuals in some of the Oil House samples. The brown coat is shown for LOKE.M.8 as this material is more or less identical to that of the masonry mortar samples. All are identified as natural cement relicts (NC). Typical textures within these grains include calcined dolomite rhombs surrounded by an iron-rich hydraulic product and partially burned quartz silt grains evenly dispersed throughout the particles. These textures are characteristic of magnesium-rich American cements of the nineteenth century. Residual cement tends to fine- to medium-grained.

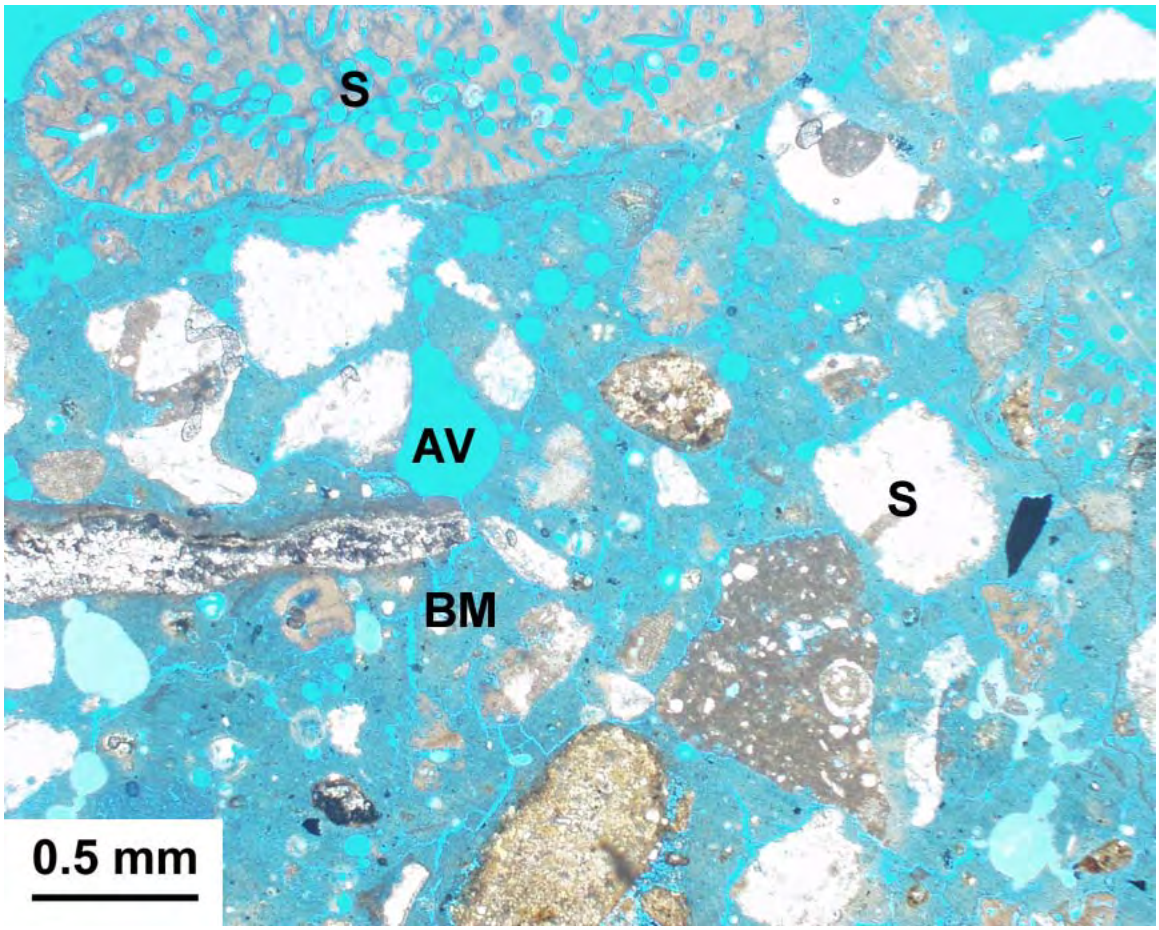


Figure 16: PPL photomicrograph illustrating the overall microstructure of the scratch coat in sample LOKE.M.8. The binder matrix (BM) has a high capillary porosity as indicated by the high absorption of blue-dyed epoxy used in the sample preparation. Fine shrinkage cracks are also detected within the matrix and these two features are characteristics of high-lime binder matrices. The sand (S) is the same soft, natural carbonate sand found in the mortar samples. Air-voids (AV) are moderately abundant.

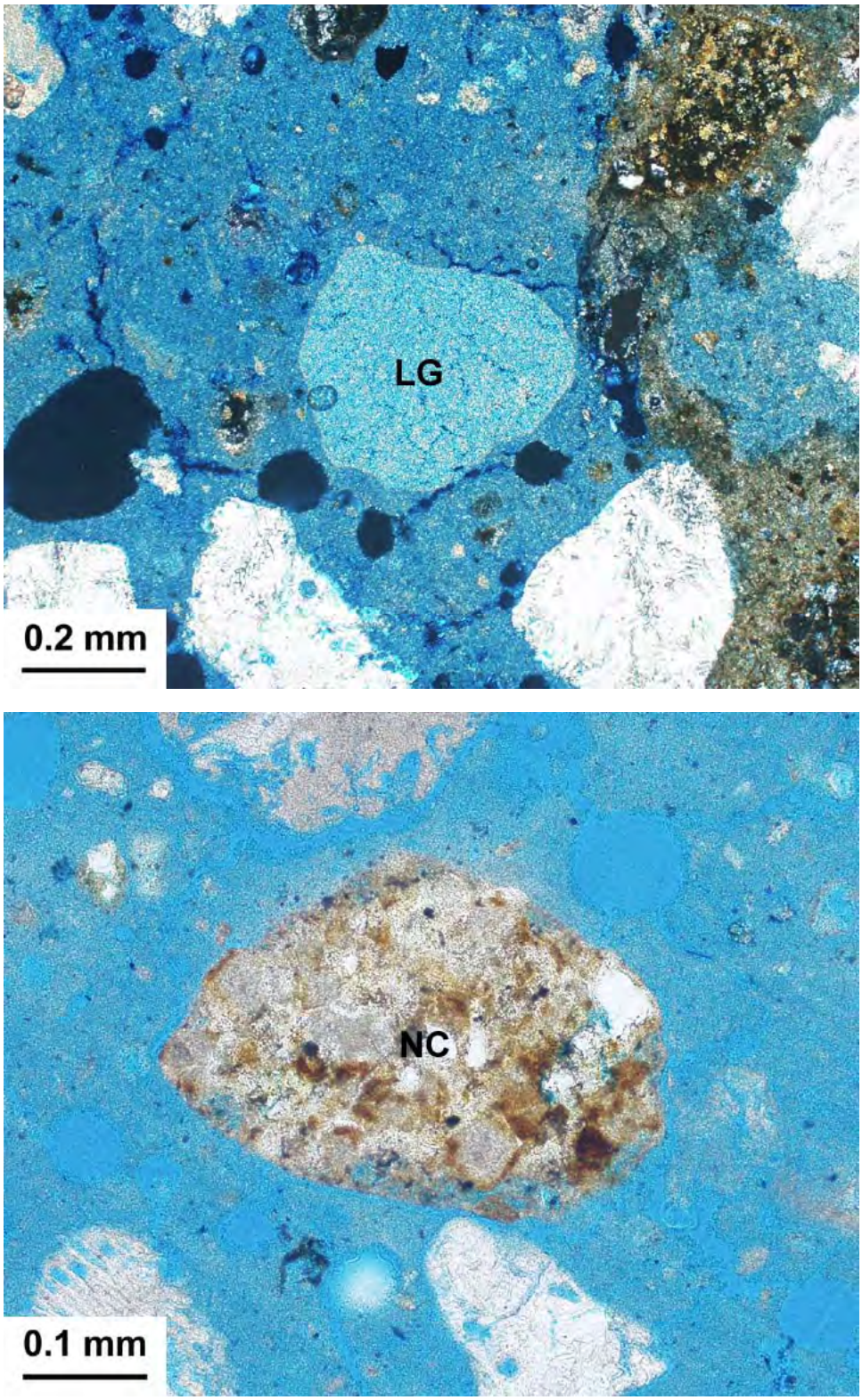


Figure 17: Photomicrographs illustrating binder residuals in the scratch coat in sample LOKE.M.8. (Top) XPL image. A lime grain (LG) is shown. The internal texture of the lime is homogeneous and little evidence is provided that might suggest the provenance of the lime. (Bottom) PPL image. A natural cement relict is shown (NC). These have the same characteristics as other cements in the sample suite. The cement is present in low abundance and is estimated to represent a minor gauging of an otherwise non-hydraulic lime plaster.

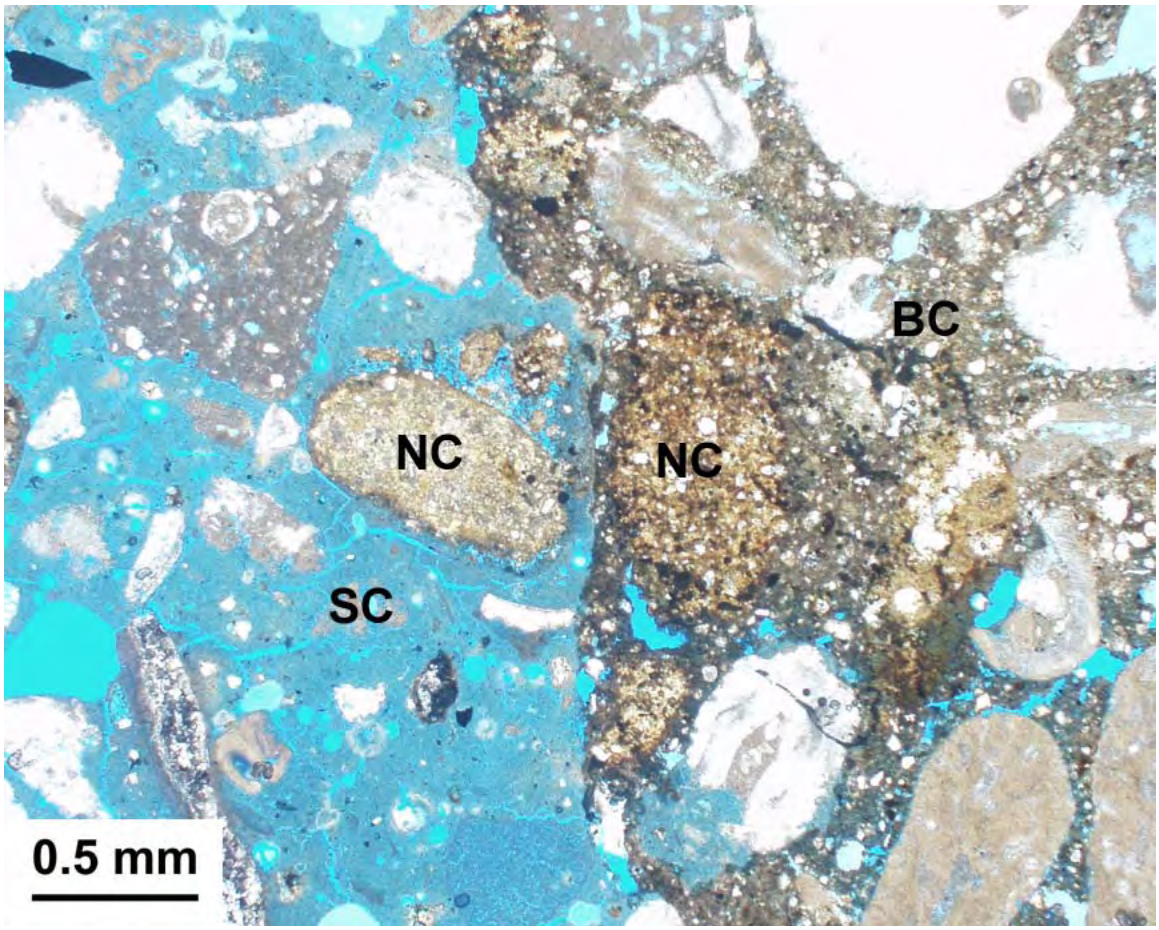


Figure 18: PPL photomicrograph illustrating the contact between the scratch coat (SC) and brown coat (BC) in LOKE.M.8. While natural cement (NC) is present in both, the difference in binder texture between a lime plaster gauged with cement (left) and a pure cement plaster (right) is quite apparent and difficult to mistake. Other details of the brown coat are presented above and are not repeated here.

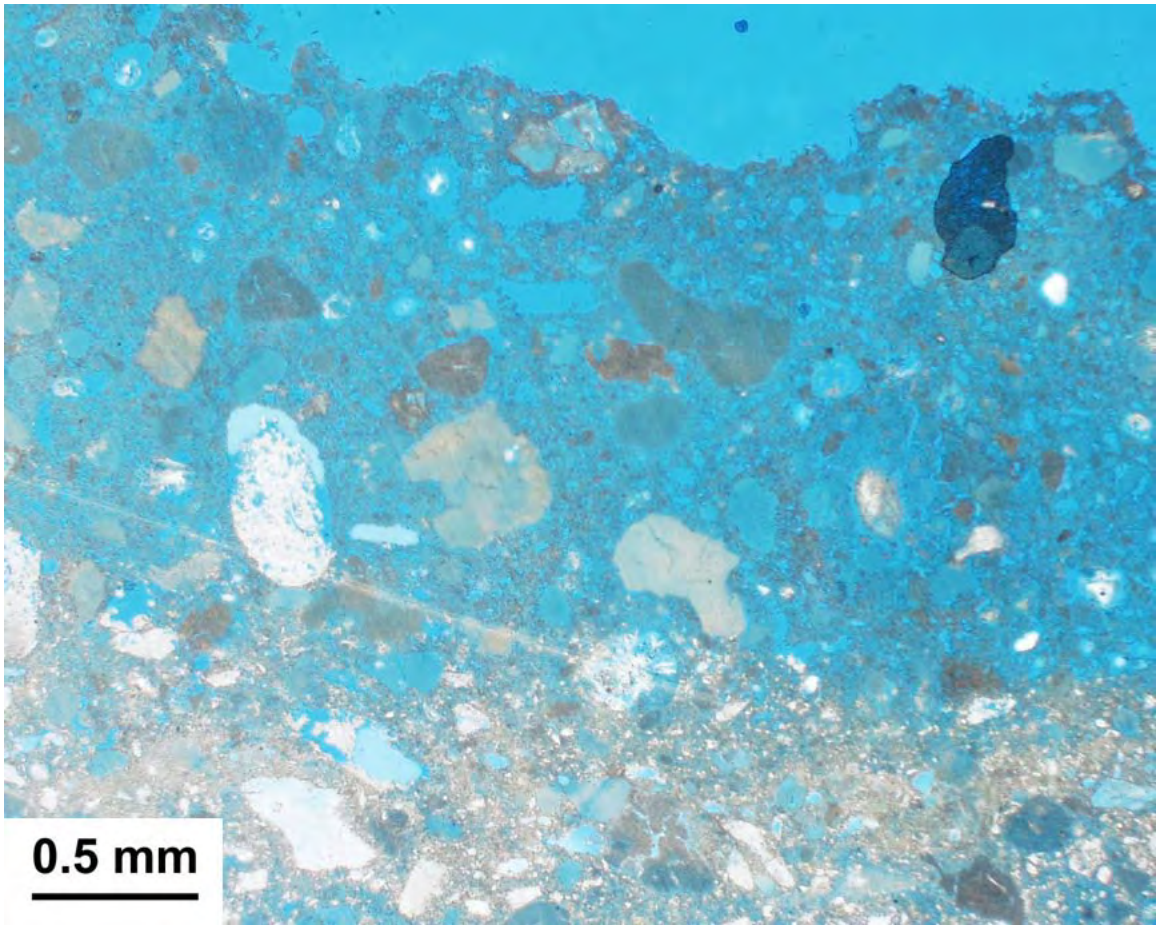


Figure 19: PPL photomicrograph illustrating the overall microstructure of the finish coat in sample LOKE.M.8. The binder matrix (BM) has a high capillary porosity as indicated by the high absorption of blue-dyed epoxy used in the sample preparation. The layer is unsanded and all grains observed here are part of the binder.

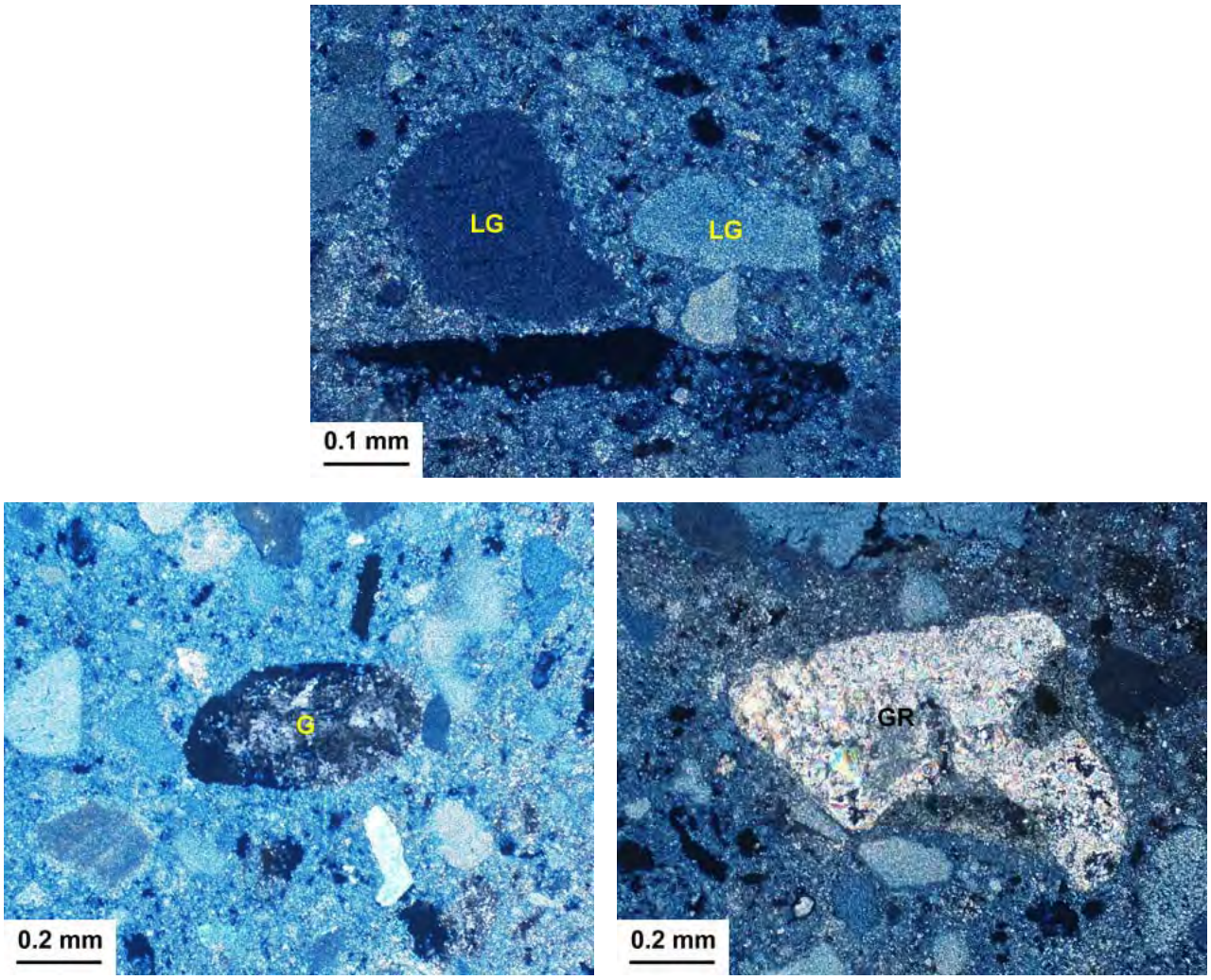


Figure 20: Photomicrographs illustrating binder residuals in the finish coat in sample LOKE.M.8. (Top) XPL image. Lime grains (LG) are found in high abundance. Chemical analysis indicates that the finish is principally a lime plaster with a moderate gypsum gauging. The darker appearance of the grain at left indicates that it has not carbonated. The brighter grain at right is carbonated as are most observed residuals. (Bottom left) A gypsum residual (G) represents a grain of originally unhydrated hemihydrate that has hydrated to coarser grained gypsum. (Bottom right) This gypsum residual (GR) contains residual unhydrated hemihydrate. Both types of residual are relatively rare in this fine-textured plaster coat.

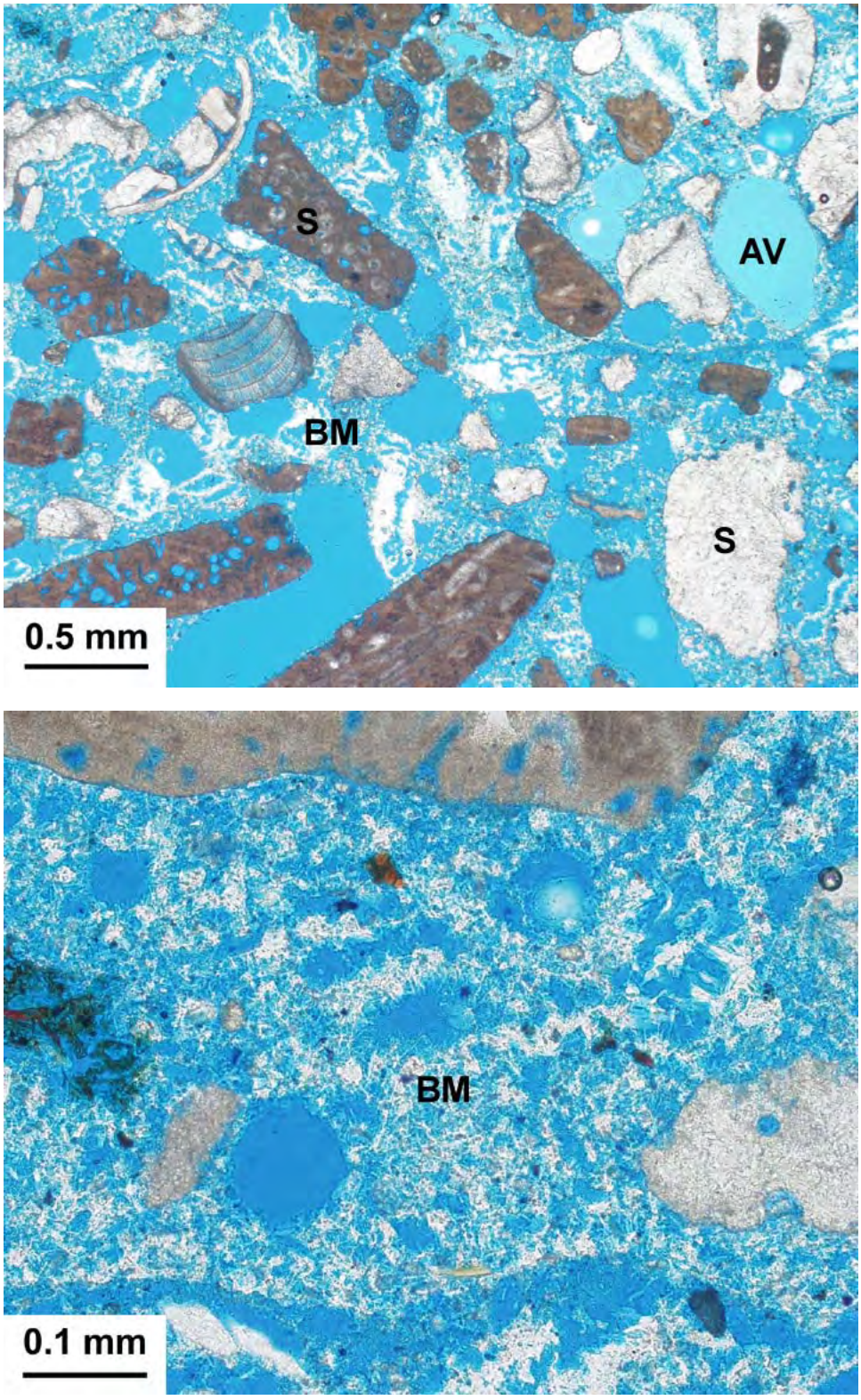


Figure 21: PPL photomicrographs illustrating the overall microstructure of the brown coat in sample LOKE.M.11. (Top) The binder matrix (BM) has a high capillary porosity as indicated by the high absorption of blue-dyed epoxy used in the sample preparation. The sand (S) is the same soft, natural carbonate sand found in the mortar samples. Air-voids (AV) are moderately abundant. (Bottom) The matrix is defined by a network of fine hydrated gypsum crystals. Still, the texture is somewhat coarse when compared to the finish coat (Fig. 23 below) and the plaster in this coat may have been a Keene's cement.

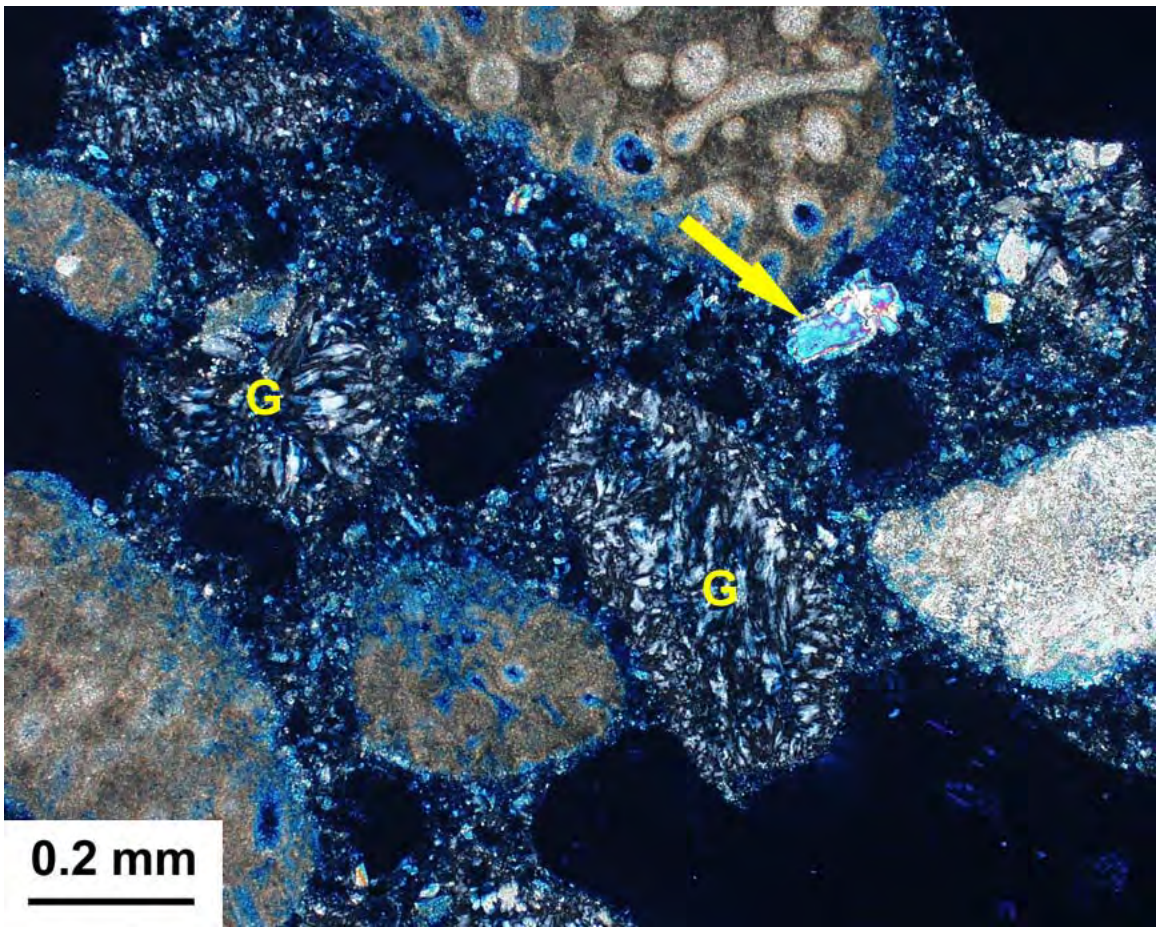


Figure 22: XPL photomicrographs illustrating binder residuals in the brown coat of sample LOKE.M.11. Gypsum residuals (G) represent grains of originally unhydrated hemihydrate that has hydrated to coarser grained gypsum. The arrow indicates a fine crystal of dead-burned anhydrite. This type of inclusion is typical of Keene's cement and would not be abundant in a Plaster-of-Paris.

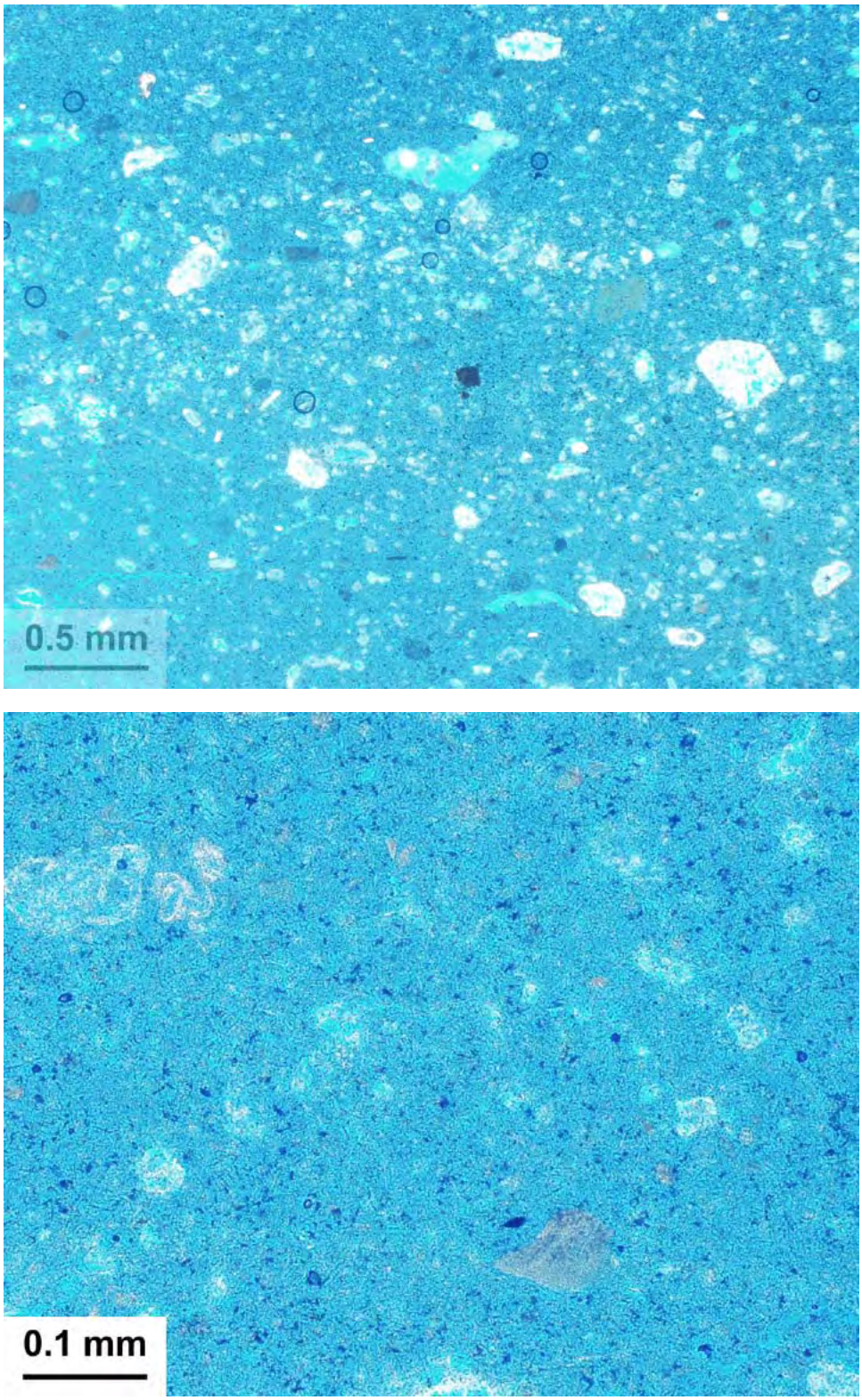


Figure 23: PPL photomicrographs illustrating the overall microstructure of the finish coat in sample LOKE.M.11. (Top) The binder matrix (BM) has a high capillary porosity as indicated by the high absorption of blue-dyed epoxy used in the sample preparation. The layer is unsanded and all grains observed here are part of the binder. (Bottom) The matrix is defined by a network of fine hydrated gypsum crystals. Even in this higher magnification image, the texture is difficult to see and the finish coat plaster is much finer textured.

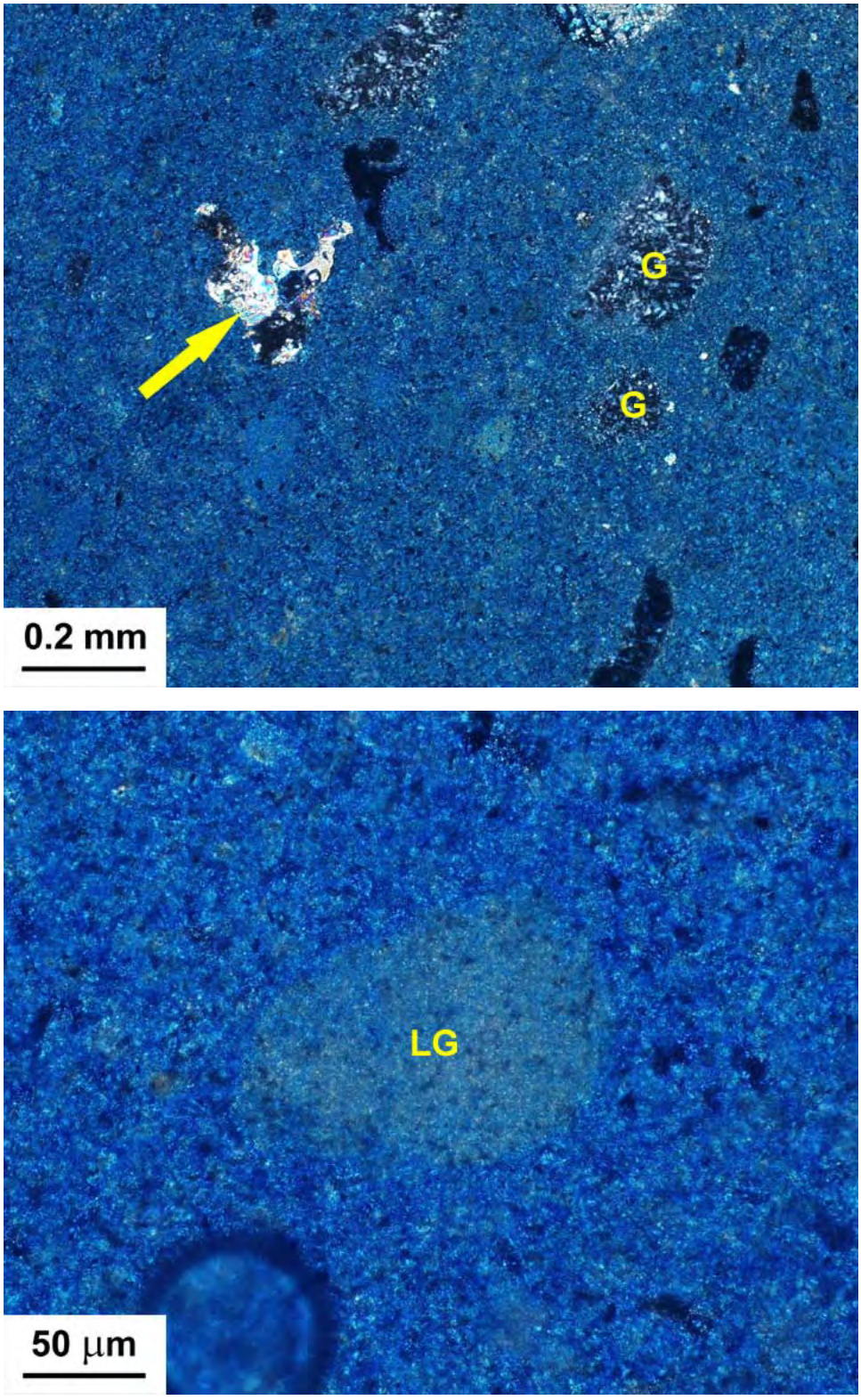


Figure 24: Photomicrographs illustrating binder residuals in the finish coat in sample LOKE.M.11. (Top) XPL image. Gypsum residuals (G) represent grains of originally unhydrated hemihydrate that have hydrated to coarser grained gypsum. The arrow indicates an unhydrated hemihydrate residual. Both types of residual are relatively rare in this fine-textured plaster coat. (Bottom) A carbonated lime grain is shown (LG). While chemical analysis was not performed on this sample, the lime is interpreted to represent a very minor gauging based on its observed abundance.

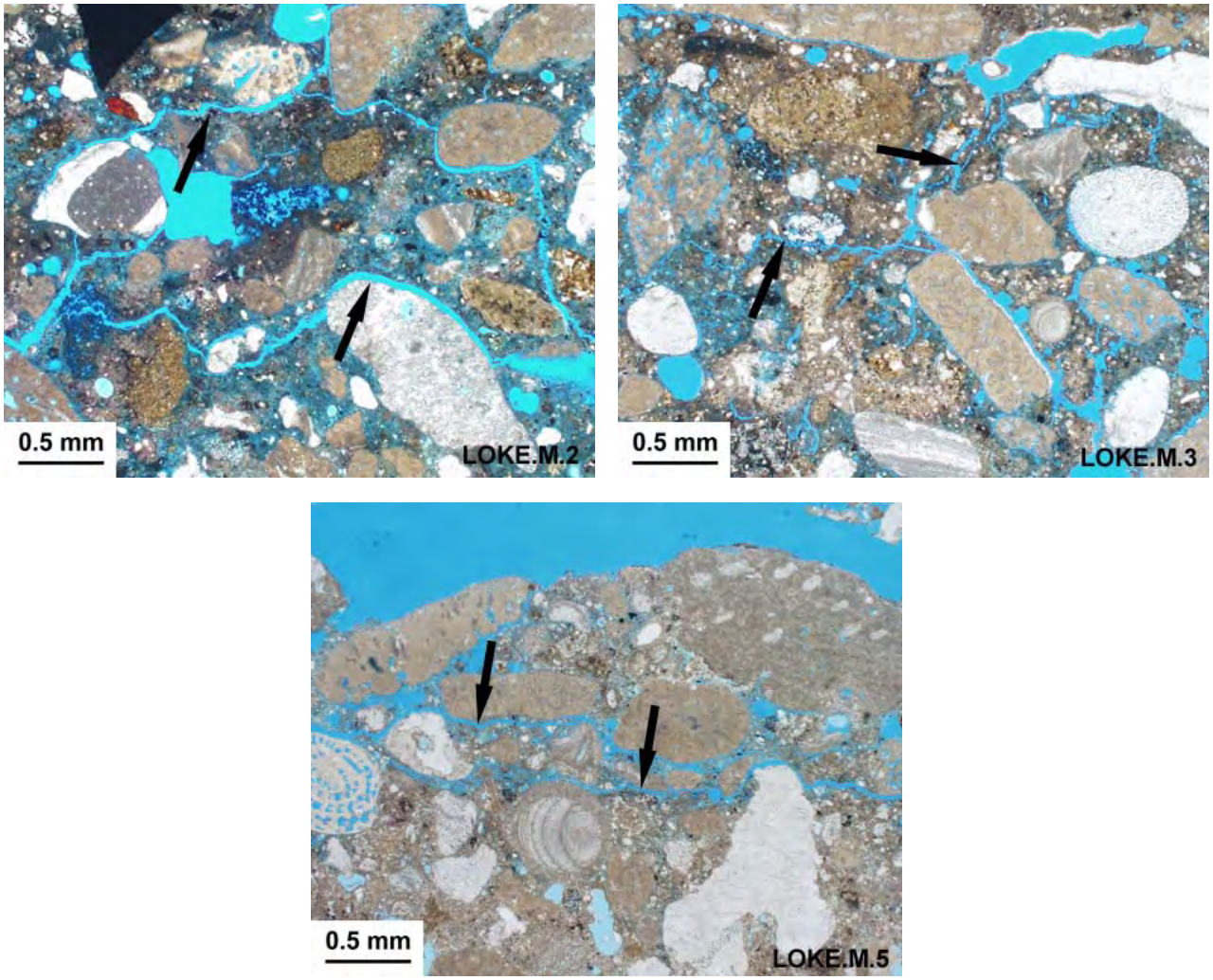


Figure 25: PPL photomicrographs illustrating microcracks in the cistern samples and one of the Lighthouse samples (arrows). These are minor and no sample in the examined suite exhibits any significant cracking distress.

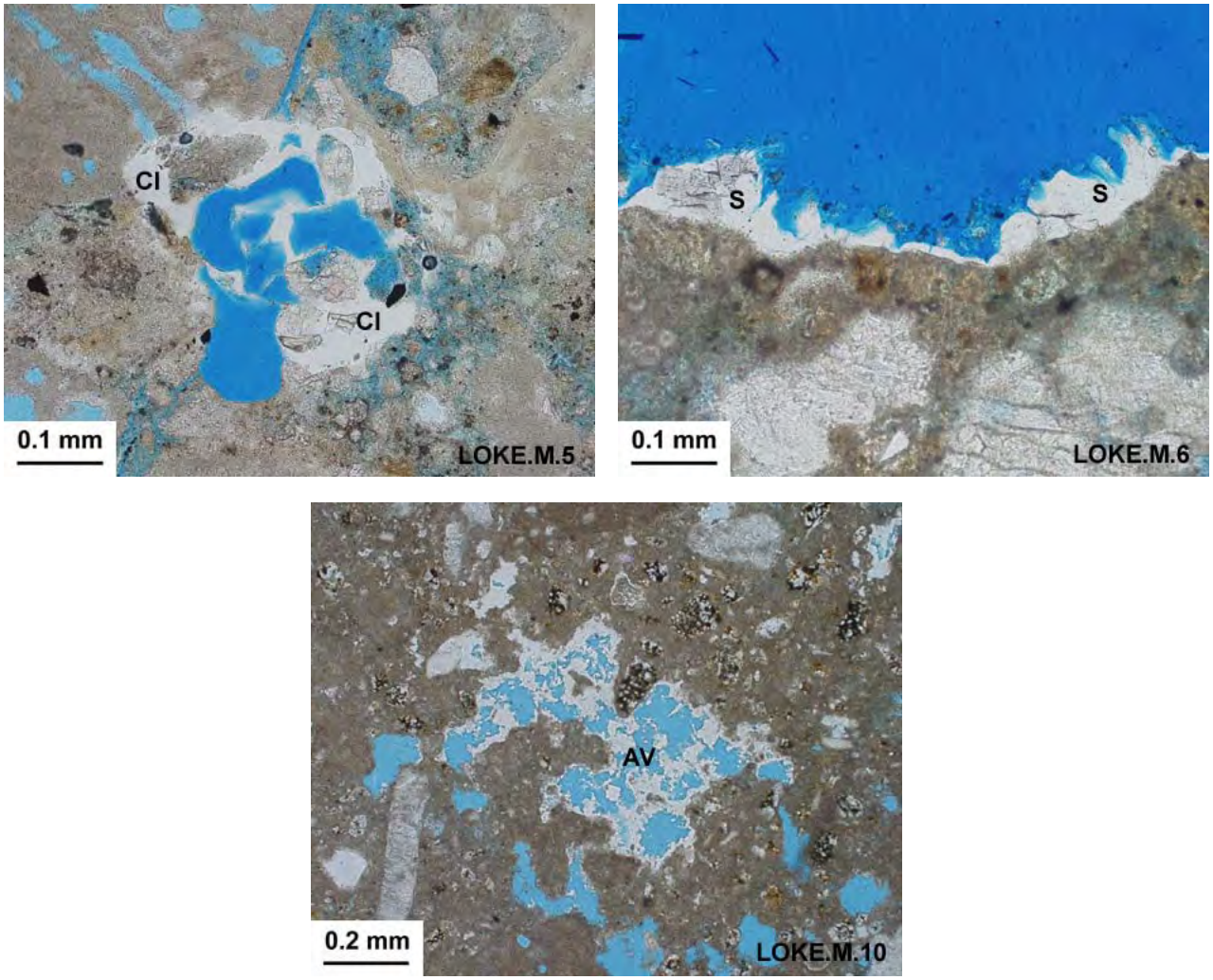


Figure 26: PPL photomicrographs illustrating the few secondary chemical deposits detected petrographically in the examined sample suite. No visible distress is associated with any of these deposits. (Top left) Isotropic mineral deposits consistent with chlorides (Cl) are found in low abundance in samples LOKE.M.5 and LOKE.M.6. (Top right) Fine secondary deposits consistent with sulfates (S) are quite rare. (Bottom) Some air-voids in the portland cement mortar of sample LOKE.M.10 contain linings of secondary gypsum but again, no associated distress is noted.

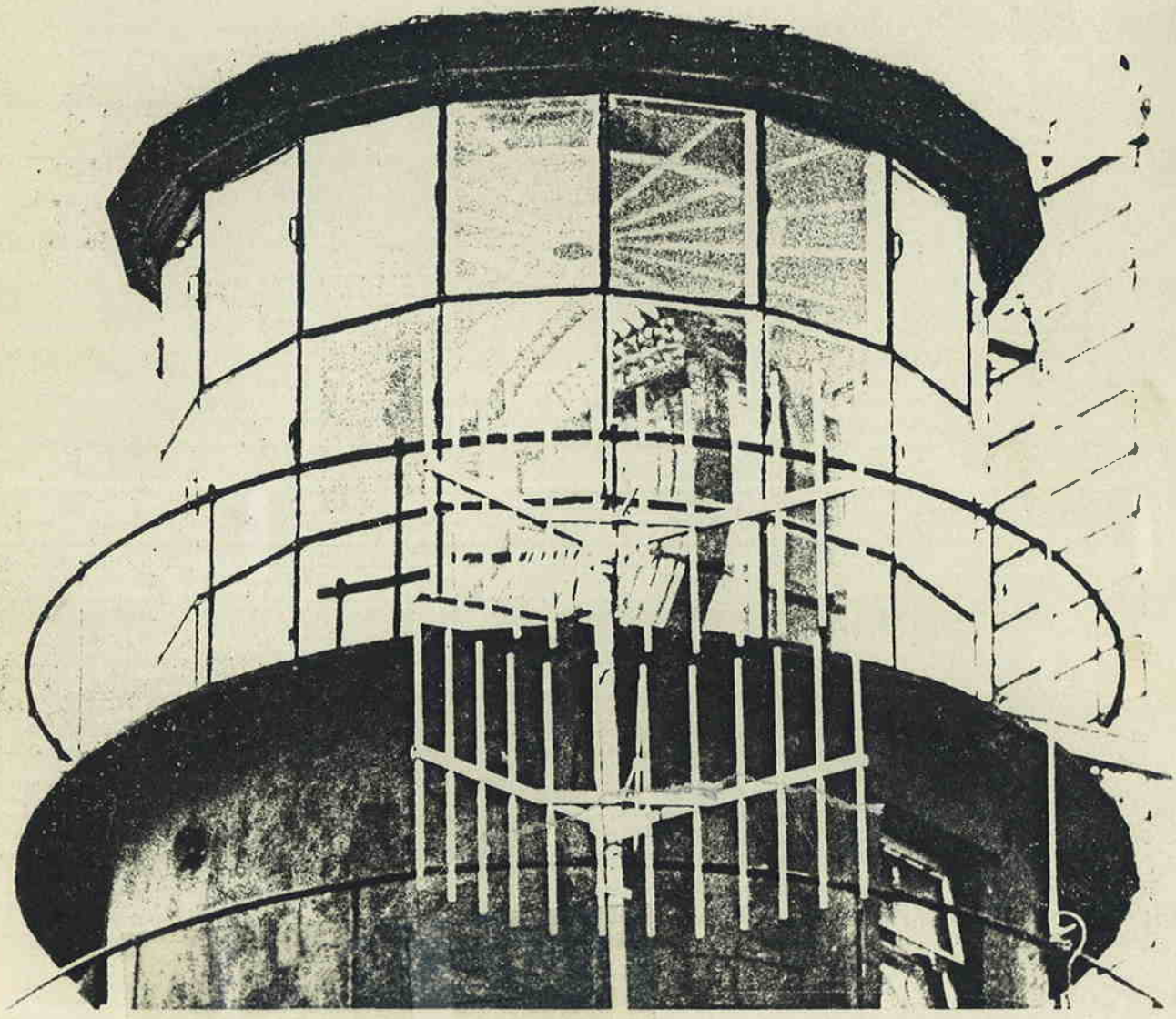
APPENDIX C.

REHABILITATION REPORT AND NATIONAL REGISTER NOMINATION FOR THE UNITED STATED COAST GUARD LIGHT STATION DRY TORTUGAS LIGHTHOUSE, LOGGERHEAD KEY, FLORIDA (1984)

REHABILITATION REPORT
and
NATIONAL REGISTER NOMINATION

for the

UNITED STATES COAST GUARD LIGHT STATION
DRY TORTUGAS LIGHTHOUSE
LOGGERHEAD KEY, FLORIDA



ACKNOWLEDGEMENTS

THE DOCUMENT DETAILED HEREIN WAS PREPARED BY THE STAFF OF THE DEPARTMENT OF INTERIOR, NATIONAL PARK SERVICE, NATIONAL REGISTER PROGRAMS DIVISION, PRESERVATION SERVICES BRANCH FOR THE DEPARTMENT OF TRANSPORTATION, UNITED STATES COAST GUARD, SEVENTH COAST GUARD DISTRICT. THE REHABILITATION REPORT WAS PREPARED BY RICHARD RAMSDEN, HISTORICAL ARCHITECT. THE NATIONAL REGISTER NOMINATION WAS PREPARED BY STUART JOHNSON, HISTORIAN. THE DOCUMENT WAS COMPLETED AND SUBMITTED TO THE DEPARTMENT OF TRANSPORTATION, ON OCTOBER 31, 1984.

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REHABILITATION REPORT/INTRODUCTION

THIS REHABILITATION REPORT IS MEANT TO BE USED AS A GUIDE IN THE PREPARATION OF CONTRACT DOCUMENTS. THE FOLLOWING RECOMMENDATIONS FOR REHABILITATION ARE NOT EXPECTED TO COVER THE TOTAL SCOPE OF THE LIGHTHOUSE AUTOMATION AND MODERNIZATION PROJECT, BUT WILL ADDRESS SPECIFIC ISSUES PERTAINING TO THE RECONDITIONING OF HISTORIC FABRIC.

REHABILITATION REPORT/LIGHTHOUSE

MASONRY TOWER - EXISTING CONDITIONS

THE EXISTING SURFACE CONDITIONS WHICH REQUIRE REHABILITATION OF THE INTERIOR AND EXTERIOR OF THE MASONRY TOWER ARE AS FOLLOWS:

1.) RANDOM BREAKDOWN OF MORTAR JOINTS IS OCCURRING AT THE WALL'S SURFACE ON BOTH THE INTERIOR AND EXTERIOR OF THE TOWER. APPROXIMATELY 20% OF THE TOWERS GROSS SURFACE AREA DEMONSTRATES THIS CONDITION. THE MORTAR JOINT DEPTH OF DETERIORATION VARIES FROM 1/8" DEEP TO 3/4" DEEP (SEE ILLUSTRATIONS I-3 & I-7). THE BREAKDOWN OF MORTAR STOPS AT 3/4" AND THE CONSISTENCY OF THE MORTAR FROM THAT DEPTH ON BECOMES STABLE. THEREFORE, UPON INSPECTION AND ANALYSIS OF THE MASONRY TOWER AND MORTAR SAMPLES, IT CAN BE CONCLUDED THAT THE BREAKDOWN IS CONFINED TO THE AREA AT THE FACE OF THE WALL ON BOTH INTERIOR AND EXTERIOR SURFACES.

2.) THE PAINT HAS LOST ITS ABILITY TO ADHERE AT THE AREAS WHERE THE MORTAR IS BREAKING DOWN ON BOTH THE INTERIOR AND EXTERIOR SURFACES.

RECOMMENDATIONS FOR RECONDITIONING

THE RECOMMENDATIONS FOR RECONDITIONING OF INTERIOR AND EXTERIOR WALL SURFACES ON THE MASONRY TOWER ARE AS FOLLOWS:

1.) THE MORTAR JOINTS DEMONSTRATING FAILURE SHOULD BE REPOINTED. THE REMOVAL OF DETERIORATED MORTAR SHOULD BE CARRIED OUT BY TRAINED CRAFTS-MEN FAMILIAR WITH REPOINTING TECHNIQUES FOR

HISTORIC BUILDINGS. DETERIORATED MORTAR SHOULD BE RESTORED BY MANUAL MEANS ONLY; I.E. HAND RAKING OR STIFF BRISTLE BRUSHES SHOULD BE USED. THE DEPTH OF MORTAR REMOVAL SHOULD BE APPROXIMATELY 1 INCH THUS ALLOWING SUFFICIENT DEPTH FOR BEDDING. JOINTS DEMONSTRATING 1/8" OR LESS BREAKDOWN WITH STABLE MORTAR BACK UP SHOULD NOT BE REPOINTED BUT BRUSHED CLEAN. MECHANICAL DEVICES I.E. POWER GRINDERS, SAWS, ETC., SHOULD NOT BE USED IN ATTAINING SUFFICIENT BEDDING DEPTH. (SEE ENCLOSED PRESERVATION BRIEF # 2 FOR FURTHER DISCUSSION ON PROPER TECHNIQUES AND PRECAUTIONS). THE NEW MORTAR APPLICATION SHOULD DUPLICATE THE EXISTING INTACT STABLE JOINT PROFILE. THE COMPOUND/MIX USED IN REPOINTING SHOULD BE THAT RECOMMENDED IN THE MORTAR ANALYSIS FURNISHED BY LAW ENGINEERING TESTING COMPANY. (LETC PP 11 THRU 16)

2.) UPON PROPER PREPARATION OF WALL SURFACES, BOTH EXTERIOR AND INTERIOR, A NEW APPLICATION OF PAINT SHOULD BE APPLIED. THE PAINT USED SHOULD CONFORM TO RECOMMENDATIONS AND SPECIFICATIONS BY LETC (ENCLOSED).

PAINT ANALYSIS OF THE EXISTING FACE OF THE MASONRY TOWER CONCLUDES THAT THERE ARE TWO EXISTING LAYERS OF PAINT. THIS CONDITION COUPLED WITH THE 20% EXISTING DETERIORATION CAUSED BY THE MORTAR BREAKDOWN POINT TO THE REMOVAL AND APPLICATION OF NEW PAINT AS THE RECOMMENDED ACTION. THE EXISTING LAYERS OF PAINT SHOULD BE REMOVED BEFORE A NEW APPLICATION OF AN ALKALI RESISTANT PAINT IS APPLIED. REMOVAL OF PAINT LAYERS SHOULD BE PERFORMED BY THE GENTLEST MEANS POSSIBLE. (SEE ENCLOSED PRESERVATION BRIEF #6 FOR FURTHER DISCUSSION ON PROPER TECHNIQUES

AND PRECAUTIONS). A LARGE NUMBER OF RESTORATION CLEANERS EXIST ON TODAY'S MARKET SUCH AS PRO SO CO "SURE-KLEAN RESTORATION CLEANER", AND DIEDRICH 606 MULTI LAYER PAINT REMOVER "DIEDRICH CHEMICAL". CHEMICAL CLEANING WITH CHEMICALS SUCH AS HYDROCHLORIC (MURIATIC) ACID AND MECHANICAL CLEANING WITH GRINDERS AND SANDING DISCS SHOULD BE AVOIDED AT ALL TIMES. THE RESTORATION CLEANER USED SHOULD BE PATCH TESTED PRIOR TO GENERAL APPLICATION. MOST RESTORATION CLEANERS REQUIRE PRESSURE WASH RINSES OF APPLIED SOLVENTS. BUT BY NO MEANS SHOULD THE WATER RINSE BE ALLOWED TO EXCEED 600 PSI/6 GALLONS PER MINUTE. FURTHER DISCUSSION CONCERNING THIS SUBJECT CAN BE FOUND IN PRESERVATION BRIEF #1 ENCLOSED.

THIS CONCLUDES THE RECOMMENDATIONS FOR RECONDITIONING OF THE MASONRY TOWER.

GALLERY/WATCH ROOM - EXISTING CONDITIONS (ILLUSTRATIONS 2,9,& 10)

THE EXISTING STRUCTURAL AND SURFACE CONDITIONS WHICH REQUIRE REHABILITATION OF THE INTERIOR AND EXTERIOR OF THE MASONRY GALLERY ARE AS FOLLOWS:

1.) THE INTERIOR AND EXTERIOR STUCCOED SURFACES OF THE WATCHROOM ARE IN STRUCTURAL DISREPAIR. VISUAL EXAMINATION DEMONSTRATES VERTICAL AND HORIZONTAL CRACKS AT THE SURFACE. STUCCO AT THE UPPER PART OF THE ARCHED DOOR IS CRACKING AND FALLING OFF. THE SURFACE CRACKS ARE NUMEROUS ON BOTH THE INTERIOR AND EXTERIOR WALL SURFACES. THESE CRACKS ARE FOLLOWING A MASONRY VERTICAL/ HORIZONTAL COURSE PATTERN.

2.) THE EXTERIOR RAIL AND PICKET ASSEMBLY ON THIS LEVEL SHOWS SEVERE CORROSIVE DETERIORATION, SPECIFICALLY, AT CONNECTIONS.

RECOMMENDATIONS FOR RECONDITIONING.

THE RECOMMENDATIONS FOR RECONDITIONING THE WATCH ROOM ARE AS FOLLOWS:

1.) BOTH INTERIOR AND EXTERIOR STUCCO SURFACES SHOULD BE REMOVED FOR STRUCTURAL MASONRY EXAMINATION AND PROBABLE REPAIR. A REFERENCE FROM THE UNITED STATES COAST GUARD CLIPPING FILE DATED 1875 DESCRIBES ALTERATIONS UNDERTAKEN THEN. BE WATCHFUL FOR THOSE MODIFICATIONS AS DESCRIBED HEREIN BELOW:

"IN ORDER TO CONTINUE THE LIGHT, REPAIRS TO THE OLD TOWER WERE ESSENTIAL, AS THE UPPER PORTION WAS CONSIDERED UNSAFE IN HIGH WINDS. THE OLD PART, FOR A DISTANCE OF 8 OR 9 FEET BELOW THE LANTERN, INCLUDING WATCH-ROOM WALLS, HAS BEEN ENTIRELY REBUILT, AND THE ANCHORS OF THE LANTERN EXTENDED DOWNWARD THROUGH THE ENTIRE DISTANCE, WITHOUT IN ANY WAY INTERFERING WITH THE REGULAR EXHIBITION OF THE LIGHT. WHEN IT IS REMEMBERED THAT THE TOWER IS ABOUT 150 FEET HIGH, THE DIFFICULTY IN MAKING THESE REPAIRS WILL BE BETTER APPRECIATED. THEY WERE ACCOMPLISHED BY CUTTING OUT THE OLD MASONRY IN NARROW VERTICAL SECTIONS, REPLACING EACH SECTION ENTIRE BEFORE REMOVING THE NEXT."

IF THE LANTERN ASSEMBLY TIE RODS ARE IN FACT EMBEDDED IN THE MASONRY OR STUCCO THEY SHOULD, UPON DISCOVERY, BE INSPECTED FOR STRUCTURAL SOUNDNESS. IF SURFACE CORROSION IS PRESENT, THE TIE RODS SHOULD BE PREPPED AND TREATED WITH AN ANTI-CORROSIVE COATING. THE MASONRY WALL UNITS AND MORTAR JOINTS SHOULD BE INSPECTED FOR STRUCTURAL SOUNDNESS AND CONSEQUENT REPAIRABILITY. STRUCTURAL REPAIRS TO THE WATCH ROOM

WALL AT THIS POINT MAY CONSIST OF MINOR REPOINTING RANGING TO REMOVAL AND REPLACEMENT OF ISOLATED WHOLE SECTIONS AS REQUIRED IN THE 1875 REHABILITATION.

AFTER STRUCTURAL REPAIRS ARE MADE TO THE TIE RODS, MASONRY UNITS AND MORTAR JOINTS; THE WATCH ROOM PERIMETER WALL SHOULD BE RESTUCCOED ON THE EXTERIOR WITH A WATER RESISTANT MIX. TWO VERTICAL CONTROL JOINTS AT MID POINTS SHOULD BE INCORPORATED TO ALLOW MOVEMENT OF SURFACE FABRIC.

2.) EXTERIOR RAIL AND PICKET ASSEMBLY SHOULD BE BLAST-CLEANED TO REMOVE EXISTING PAINT AND CORROSIVE SCALING AND PITTING. AFTER SURFACE IS CLEANED, CONNECTIONS SHOULD BE INSPECTED FOR STRUCTURAL SOUNDNESS. BOLT AND THREADED PICKETS WHICH NEED REPLACING SHOULD BE REPLACED WITH A COMPATIBLE SUBSTITUTE. UPON COMPLETION OF SURFACE PREPARATION AND REPLACEMENT OF DETERIORATED MEMBERS, ALL RAIL AND PICKET SURFACES SHOULD BE TREATED WITH A SELF-CURING COATING WHICH IS HARD, ABRASION RESISTANT AND PROVIDES CATHODIC PROTECTION SIMILAR TO GALVANIZING.

NOTE: A VISUAL INSPECTION OF THE CAT WALK AT THE WATCH ROOM LEVEL SHOWS NO STRUCTURAL OR SURFACE DETERIORATION. AS A MAINTENANCE PRECAUTION, THE STAINLESS STEEL TENSION COLLAR SHOULD BE INSPECTED FOR TORQUE RESISTENCE ONLY.

THIS CONCLUDES THE RECOMMENDATIONS FOR RECONDITIONING THE GALLERY/WATCH ROOM.

METAL LANTERN ROOM - EXISTING CONDITIONS (ILLUSTRATIONS 2,3,8 & 9)

THE EXISTING SURFACE CONDITIONS WHICH REQUIRE REHABILITATION ON THE EXTERIOR OF THE LANTERN ROOM ARE AS FOLLOWS:

1.) THE RAIL AND PICKET ASSEMBLY HAVE DETERIORATED TO THE SAME CONDITION AS THAT OF THE ASSEMBLY ON THE WATCH ROOM LEVEL. THE METAL CAT WALK SURFACE IS IN FAIR CONDITION BUT THE CONNECTIONS ARE SHOWING SEVERE SIGNS OF CORROSIVE DETERIORATION.

IN ADDITION IT HAS BECOME DESIRABLE TO EFFECT THE FOLLOWING ALTERATIONS:

A.) BULLET PROOF GLAZING IS REQUIRED IN ORDER TO CURB VANDALISM OF THE LIGHT.

B.) THE FRENCH LENS ASSEMBLY HAS TO BE REMOVED TO FACILIATE AUTOMATION.

NOTE: THE STRUCTURAL INTEGRITY OF THE METAL LANTERN ROOM IS EXCELLENT.

RECOMMENDATIONS FOR RECONDITIONING AND AUTOMATION

THE FOLLOWING ARE RECOMMENDATIONS ADDRESSING THE REHABILITATION ISSUES OF THE METAL LANTERN ROOM:

1.) THE RAIL AND PICKET ASSEMBLY SHOULD BE RE-HABILITATED IN A MANNER SIMILAR TO THAT RECOMMENDED FOR THE GALLERY/WATCH ROOM ASSEMBLY WHICH WAS DISCUSSED EARLIER. (REFER TO GALLERY/WATCHROOM, ITEM #2 PAGE 6).

THE CANTILEVERED METAL CAT WALK SHOULD BE BLASTED CLEAN WITH SAND. THE NUT AND BOLT CONNECTIONS ON THE UNDER SIDE SHOULD BE REPLACED IN-KIND WITH A COMPATIBLE METAL. THE EXISTING SURFACE SHOULD THEN BE TREATED WITH AN ANTI-CORROSIVE PAINT.

2.) THE EXISTING WIRE SAFETY GLASS AND CAULKING BED WILL NEED TO BE REMOVED. UPON REMOVAL OF THE GLAZING, THE STEEL FRAMES SHOULD THEN BE PREPPED FOR PAINTING BY LIGHT BLAST CLEANING WITH SAND (80-100PSI). NEXT, AN ANTI-CORROSIVE PRIMER SHOULD BE APPLIED TO ALL METAL SURFACES. INDIVIDUAL BULLET PROOF PANES SHOULD THEN BE INSTALLED IN THE EXISTING GRID CONFIGURATION. NEW METAL STOPS/GLAZING ANGLES WHICH ARE NOW SECURED TO THE STRUCTURAL GRID WILL NEED TO BE FABRICATED TO COMPENSATE FOR THE ADDED THICKNESS IN GLAZING. AT PRESENT, THE EXISTING FACE GLAZING ANGLES ARE SECURED TO THE GRID WITH SCREWS. THIS DETAIL IS CAUSING MOISTURE PROBLEMS. THE PROBLEM CAN BE ALLEVIATED BY USE OF A PROPER SEALANT MATERIAL AND GLAZING ANGLES WITH A STIFFER DESIGNED SECTION MODULAS. THE FACE SEALANT TYPE USED IN RETROFIT SHOULD BE POLYURETHANE OR VINYL ACRYLIC. FURTHER DISCUSSION CONCERNING THIS SUBJECT CAN BE FOUND IN PRESERVATION BRIEF #13, ENCLOSED.

3.) THE FRENCH LENS ASSEMBLY SHOULD BE REMOVED FROM THE LANTERN ROOM PRIOR TO REHABILITATION. ON SITE STORAGE OR STORAGE AT OTHER COAST GUARD FACILITIES IS ADEQUATE BUT NOT PREFERABLE. A COMPETENT MUSEUM THAT SPECIALIZES IN NAVAL AND/OR LIGHTHOUSE ARTIFACTS SHOULD BE CONTACTED AND ARRANGEMENTS MADE FOR DISPOSITION OF THE ASSEMBLY TO THAT FACILITY.

THIS CONCLUDES THE RECOMMENDATIONS FOR RECONDITIONING AND AUTOMATION OF THE METAL LANTERN ROOM.

COPPER DOME AND FINIAL - EXISTING CONDITIONS (ILLUSTRATIONS 2,5,&6)

THE EXISTING SURFACE CONDITIONS ARE AS FOLLOWS:

1.) THE COPPER DOME HAS HAD SEVERAL LAYERS OF TAR APPLIED TO ITS ENTIRE EXTERIOR SURFACE.

2.) THE FINIAL IS IN GOOD CONDITION WITH TAR ALSO APPLIED TO ITS SURFACE.

RECOMMENDATIONS FOR RECONDITIONING.

THE RECOMMENDATIONS FOR RECONDITIONING THE COPPER DOME AND FINIAL ARE AS FOLLOWS:

1.) AT PRESENT, IT IS INDECERNABLE WHETHER OR NOT THE COPPER SHEATHING CAN BE REPAIRED. USING STRIPPERS, THE TAR MUST BE REMOVED TO PROPERLY ASSESS THE AMOUNT OF DAMAGE TO THE HISTORIC FABRIC. THIS INVESTIGATION IS RECOMMENDED FIRST OVER TOTAL IMMEDIATE REPLACEMENT AS A MEASURE WHICH MIGHT SAVE THE EXISTING HISTORIC FABRIC, IN ADDITION TO MODERATING COSTS. IF IT IS FINALLY DETERMINED THAT REPAIR TO THE DOME IS NOT POSSIBLE, THEN REPLACEMENT IN-KIND IS RECOMMENDED.

IN EITHER CASE, THE EXISTING FINIAL SHOULD BE CLEANED AND RETAINED.

THIS CONCLUDES THE RECOMMENDATIONS FOR RECONDITIONING OF THE DOME AND FINIAL AND ALSO CONCLUDES THE INVESTIGATION OF THE DRY TORTUGAS LIGHTHOUSE, PROPER.

REHABILITATION REPORT/SUPPORT STRUCTURES

Bosun's Work Shop, Radio Room, Guest House, Crews Quarters and Masonry Cisterns - EXISTING CONDITIONS (ILLUSTRATION I-1)

THE EXTERIOR AND INTERIOR OF THE SUPPORT STRUCTURES LISTED ABOVE ARE IN STABLE CONDITION.

RECOMMENDATIONS

IF THE INTERIOR SURFACES ARE TO BE REHABILITATED, CONSIDERATION SHOULD BE GIVEN TO THE REMOVAL OF APPLIED NON-HISTORIC FABRIC I.E., SIMULATED WOOD PANELING AND THE RETENTION OF HISTORIC ROOM CONFIGURATIONS.

THIS CONCLUDES THE OBSERVATION CONCERNING THE SUPPORT STRUCTURES.

LAW ENGINEERING TESTING COMPANY
geotechnical, environmental & construction materials consultants
396 PLASTERS AVENUE, N.E.
P.O. BOX 13260 • ATLANTA, GEORGIA 30324
(404) 873-4761

August 2, 1984

National Park Service
Southeast Regional Office
75 Spring Street S.W.
Suite 1140
Atlanta, Georgia 30303

Attention: Mr. Richard Ramsden

Subject: Engineering Evaluation
of Paint and Mortar Samples
United States Coast Guard
Dry Tortugas Lighthouse
Key West, Florida
LETCO Job Number G-10170

Dear Mr. Ramsden:

As authorized by your purchase order PX 5000-4-0666, an engineering evaluation was performed on paint and mortar samples taken from the Dry Tortugas Lighthouse in Key West, Florida and delivered to Law Engineering Testing Company. The purpose of the work was to determine the possible causes of mortar breakdown and the composition of the paint of the lighthouse.

BACKGROUND

Background information was furnished by Mr. Richard Ramsden of National Park Service.

The Dry Tortugas Lighthouse has been a landmark in southern Florida for approximately 100 years. Recent collapses of the mortar and bricks brought the need to renovate the structure. Testing of the mortar and paint was requested to restore the lighthouse to its original condition with the same type materials.

INVESTIGATIVE PROCEDURES

The as-received samples of mortar and paint were submitted for chemical analysis to determine the composition of each. This data was then utilized to determine the cause of mortar breakdown, paint type and possible recommendations to prevent further deterioration.

MORTAR ANALYSIS

The chemical analysis of the mortar samples submitted was performed in accordance with the general procedures outlined in ASTM C 85, "Cement Content of Hardened Portland Cement Concrete". The results of the chemical analysis are presented in the attached Table I.

Pieces of the mortar were examined under the stereo microscope to evaluate the aggregates and to assist in the analysis of the mortar. The fine aggregate in the mortar is a combination of fine silica sand and broken shells. The paste appeared to be a dull tan color.

The shell aggregates are calcium carbonate and appear in the chemical analysis as soluble calcium oxide, the same as lime. Because of this it is not possible to determine the exact proportions of the mortar. There appears to be a small percentage of portland cement in the mortar and possibly some gypsum. The majority of the cementitious binder is lime. The aggregate is silica sand and shells (calcium carbonate).

The proportions of the mortar appear to be high in lime. A mortar mixture which would probably be similar to the material in place would be:

Cement	1 part
Lime	3 parts
Sand	12 parts

This mortar proportion may not be as weather resistant as a mortar which contained a higher proportion of cement. Mortars with high lime proportions harden by carbonation of the lime. These mortars can be attacked by the elements and with time become chalky and crumble. Old age has probably caused the breakdown of the existing mortar. If the mortar will be covered with paint, a mortar with a much higher cement content may be appropriate for use in repairing the lighthouse. The proportions and guidelines for selection of masonry mortars are outlined in ASTM C 270, "Specification for Mortar for Unit Masonry".

PAINT ANALYSIS

Microscopic examination of the paint flakes showed that they consisted of two layers. Infrared analysis of each layer proved to be of similar composition. A composite analysis of the non-volatile portion is also shown in Table II. The results summarized in Table II show that the paint was primarily a lead-zinc based acrylic-polyvinyl acetate mixture and would be considered alkali resistant. This type of paint would be considered appropriate for a marine environment such as a lighthouse.

CONCLUSIONS

Based on the engineering evaluation of the paint and mortar samples the following conclusions are relevant to the purpose of the work:

1) The paint flakes were determined to be composed of two paint coats of similar chemical composition. The paint was determined to be a lead and zinc based acrylic-polyvinyl acetate mixture which would be highly suitable for a marine environment and would be considered alkali resistant.

2) The mortar proportions can not be determined due to broken shells in the aggregate fraction. The shell fragments contain soluble calcium oxide which masks the lime content of the mortar. Based on the microscopic examination the mortar appears to contain a high proportion of lime. A mortar proportion which would probably be similar to the in place material would be:

Cement	1 part
Lime	3 parts
Sand	12 parts

Please let us know if we may assist you further in this matter. Thank you for calling on LETCO.

Very truly yours,

LAW ENGINEERING TESTING COMPANY

Richard H Norris

Richard H. Norris
Staff Materials Engineer

Robert S. Jenkins, P.E.
Senior Materials Engineer

RHN:RSJ/ljh

TABLE I

CHEMICAL ANALYSIS OF MORTAR
DRY TORTUGAS LIGHTHOUSE
KEY WEST, FLORIDA
LETCO JOB NUMBER G-10170

Loss on Ignition	39.4%
Total Acid Insoluble	10.0%
Soluble Silica (SiO_2)	1.47%
Calcium Oxide (CaO)	35.4%
Sulfates (SO_3)	1.16%

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TABLE II

CHEMICAL ANALYSIS OF PAINT FLAKES
DRY TORTUGAS LIGHTHOUSE
KEY WEST, FLORIDA
LETCO JOB NUMBER G-10170

Binder 30.6%

Infrared spectrographic analysis of the binder showed it to be an acrylic-polyvinyl acetate mixture

Pigment 69.4%

Semiquantitative spectrographic analysis of the pigment(%):

Silicon (Si)	0.1 - 1.0
Iron (Fe)	0.1 - 1.0
Aluminum (Al)	0.1 - 1.0
Calcium (Ca)	1.0 - 10.0
Magnesium (Mg)	1.0 - 10.0
Sodium (Na)	1.0 - 10.0
Potassium (K)	0.1 - 1.0
Phosphorus (P)	0.01 - 0.1
Barium (Ba)	0.1 - 1.0
Lead (Pb)	Major
Zinc (Zn)	Major

Quantitative Analysis: % of Pigment

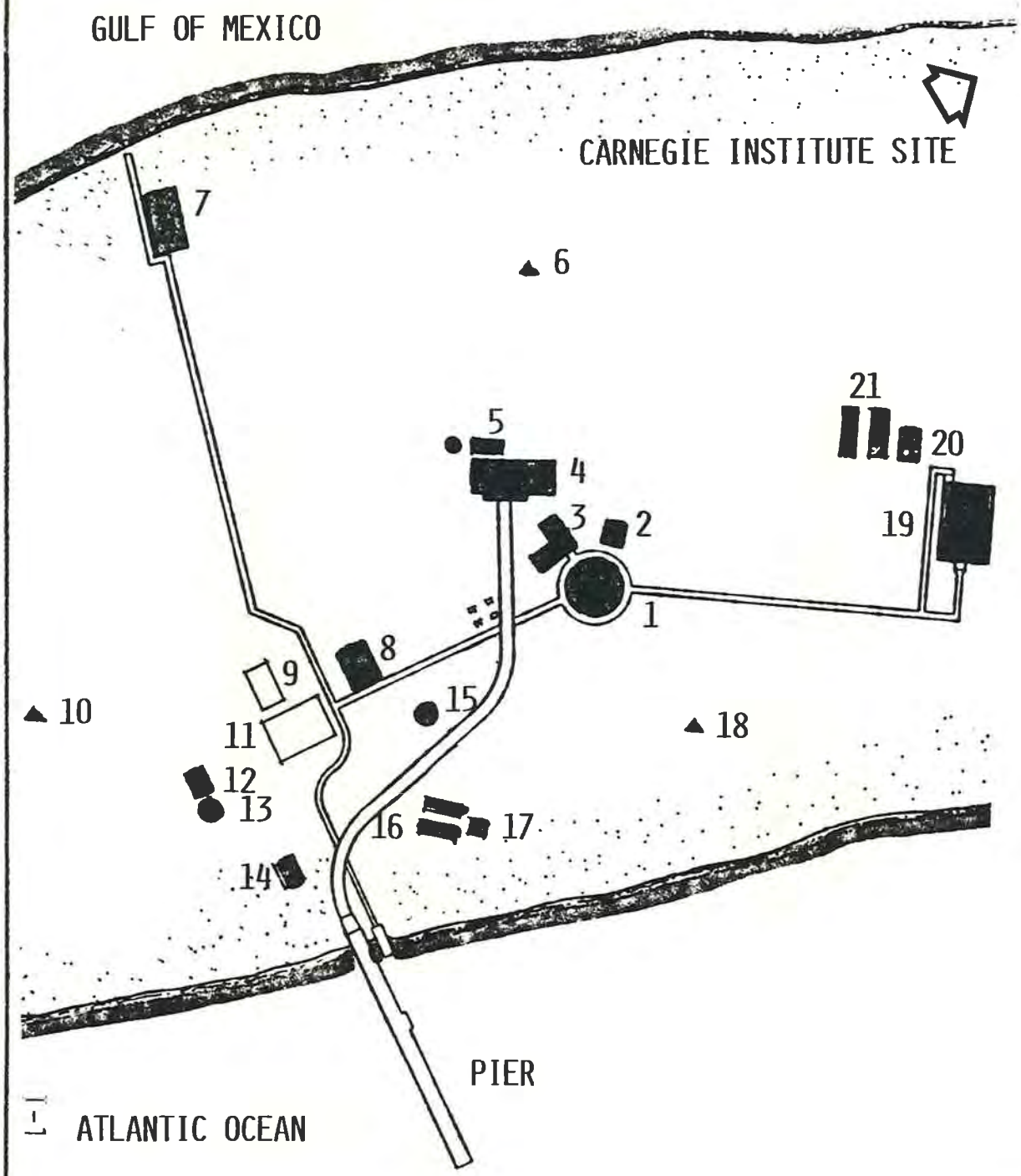
Calcium Carbonate ($CaCO_3$)	9.6
Magnesium Carbonate ($MgCO_3$)	4.5
Sodium Oxide (Na_2O)	3.5
Lead Oxide (PbO)	41.6
Zinc Oxide (ZnO)	28.7

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REHABILITATION REPORT/CONCLUSION

IF ALTERATIONS WHICH WILL IMPACT HISTORIC FABRIC, I.E., WINDOW REPLACEMENT, NEW PARTITION DESIGNS, ETC. ARE PLANNED FOR ANY OF THE BUILDINGS LISTED ON THE NATIONAL REGISTER NOMINATION, DOCUMENTATION SHOULD BE SUBMITTED TO THE NATIONAL PARK SERVICE DESCRIBING THOSE ALTERATIONS SO THAT THEY CAN BE REVIEWED FOR COMPLIANCE WITH THE SECRETARY OF THE INTERIOR'S STANDARDS FOR REHABILITATION.

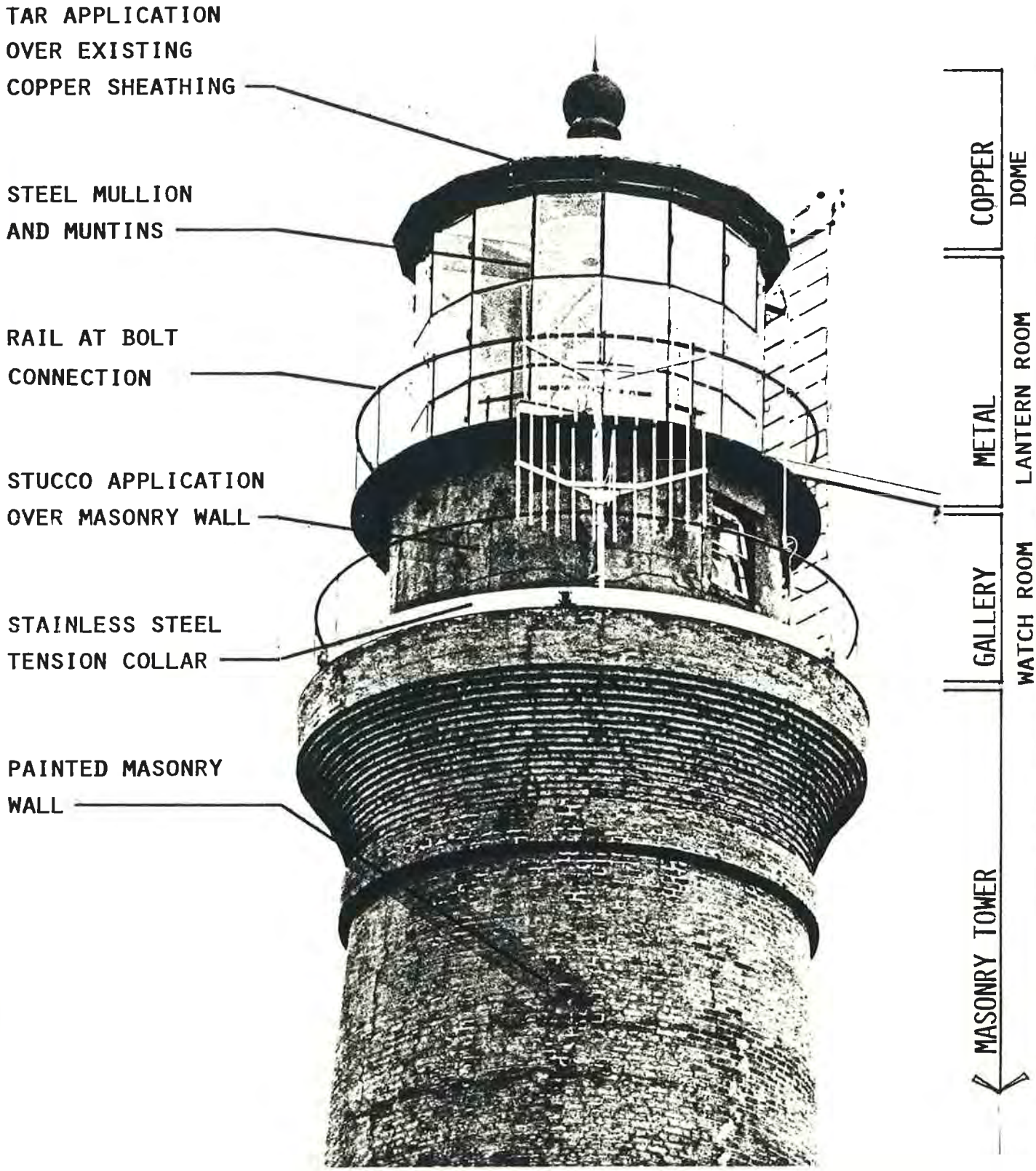
ALL AREAS OF REHABILITATION ON THIS PROJECT WHICH REQUIRE SKILLED LABOR, SHOULD BE CONTRACTED TO PROFESSIONALS AND CRAFTSMEN WHO ARE KNOWLEDGEABLE OF RESTORATION SKILLS AND TECHNIQUES.



NO.	STRUCTURE/USE	REMARKS/MATERIAL
1.	Dry Tortugas Lighthouse	Brick
2.	Bosun's Work Shop (Former Oil Storage Building)	Concrete
3.	Radio Room (Former Oil Storage Building)	Brick
4.	Generator Building	Metal
5.	Day Tanks (2-280 Gallon) Salt Water Well	N/A
6.	Instrument Tower	N/A
7.	Boat House	Concrete
8.	Guest House (Former Kitchen Building)	Brick
9.	Former Kitchen & Dining Building	Demolished
10.	Radio Beacon Antenna	N/A
11.	Former Assistant Keepers Apartments	Demolished
12.	Cistern (10,000 Gallon)	Concrete
13.	Cistern (6,400 Gallon)	Brick
14.	Paint Locker	Metal
15.	Cistern (8,600 Gallon)	Brick
16.	Storage Tanks (2-5000 Gallon)	N/A
17.	Pump House	N/A
18.	Antenna	N/A
19.	Crews Quarters (Former Keepers Quarters)	Brick
20.	Cistern (12,000 Gallon)	Concrete
21.	2-Water Tanks	Fiberglass

SITE PLAN

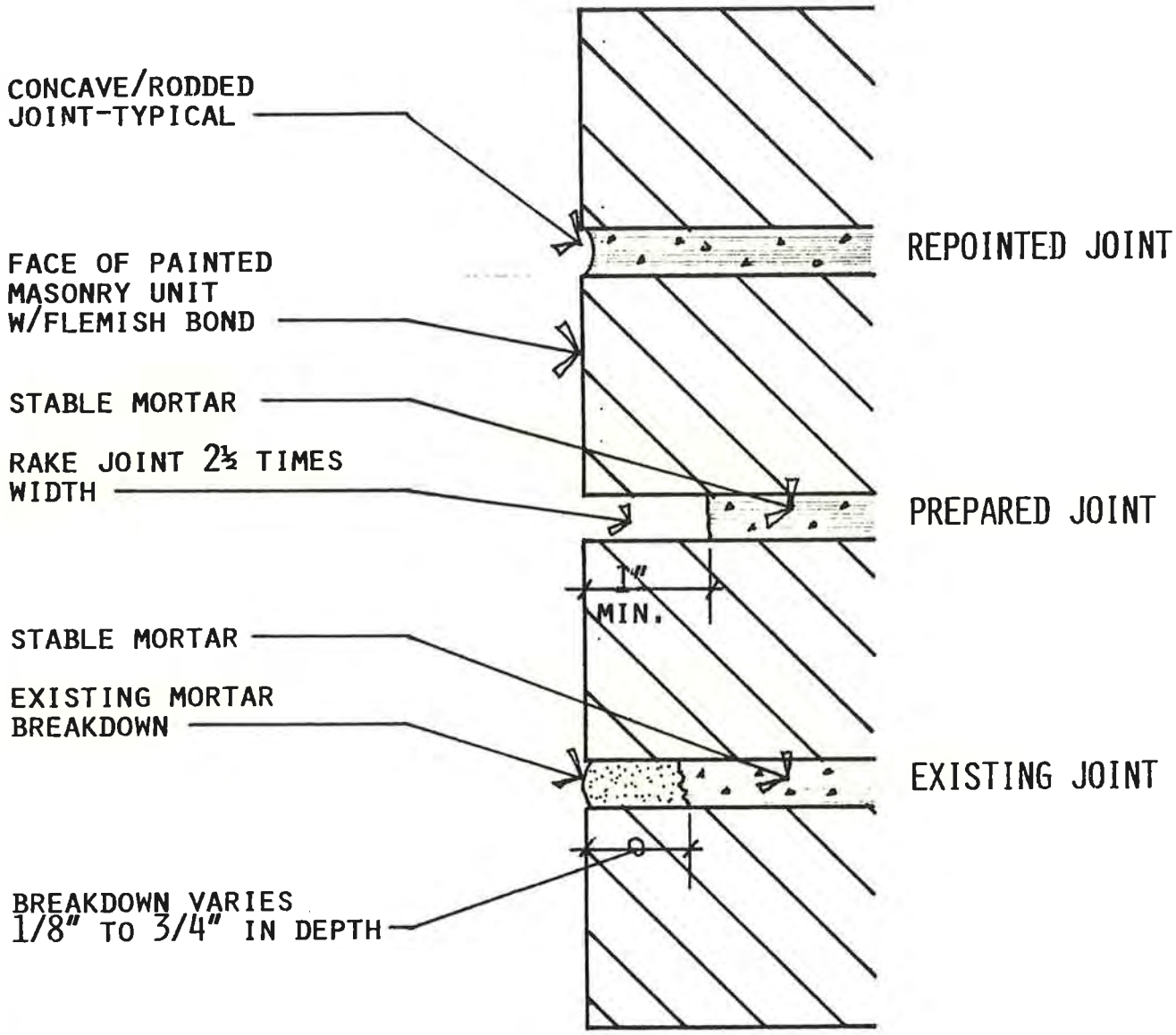
UNITED STATES COAST GUARD LIGHT STATION
DRY TORTUGAS LIGHTHOUSE
LOGGERHEAD KEY, FLORIDA



LIGHTHOUSE ELEVATION

UNITED STATES COAST GUARD LIGHT STATION
DRY TORTUGAS LIGHTHOUSE
LOGGERHEAD KEY, FLORIDA

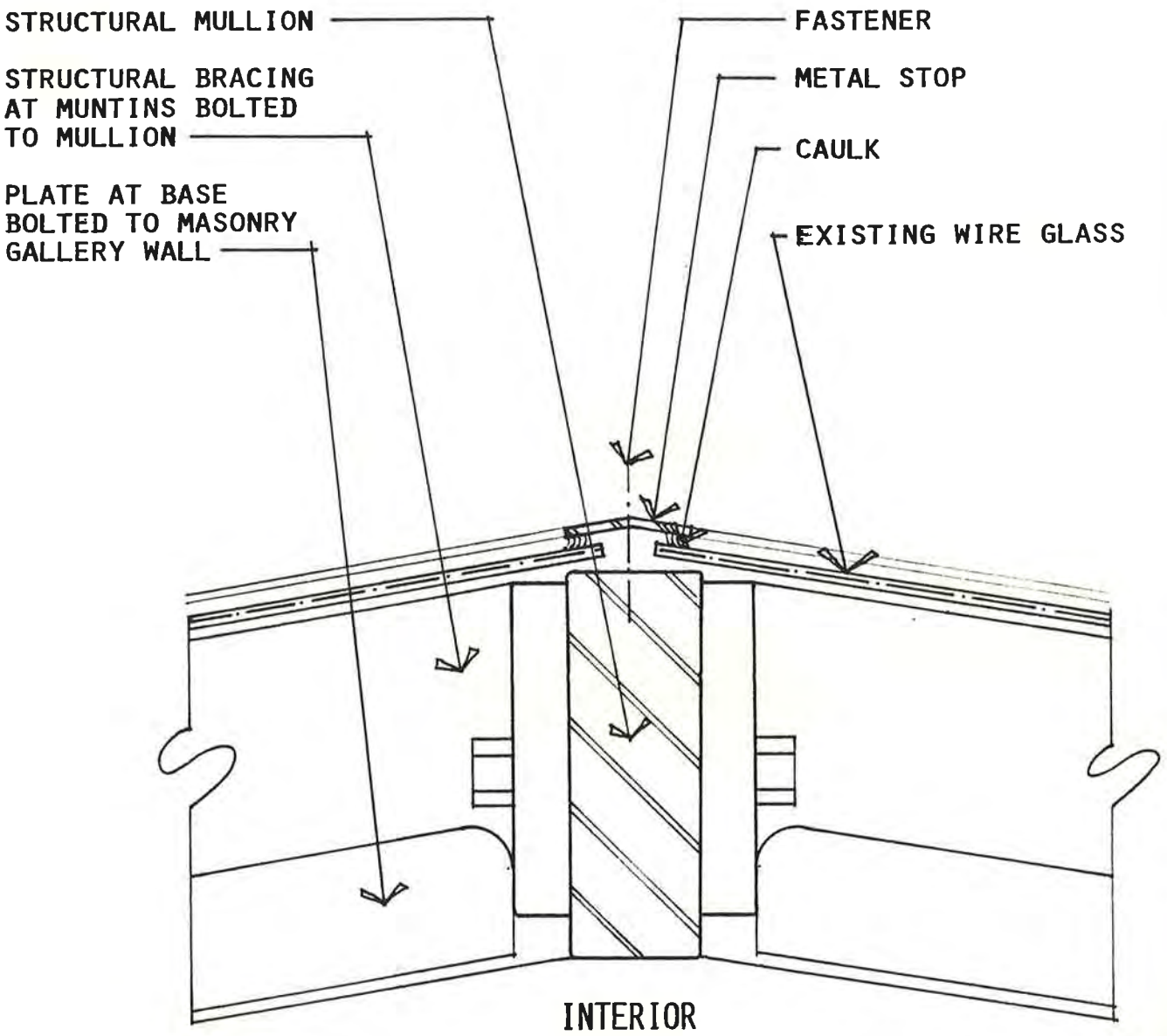
EXTERIOR/INTERIOR



SECTION at MASONRY WALL

UNITED STATES COAST GUARD LIGHT STATION
DRY TORTUGAS LIGHTHOUSE
LOGGERHEAD KEY, FLORIDA

EXTERIOR



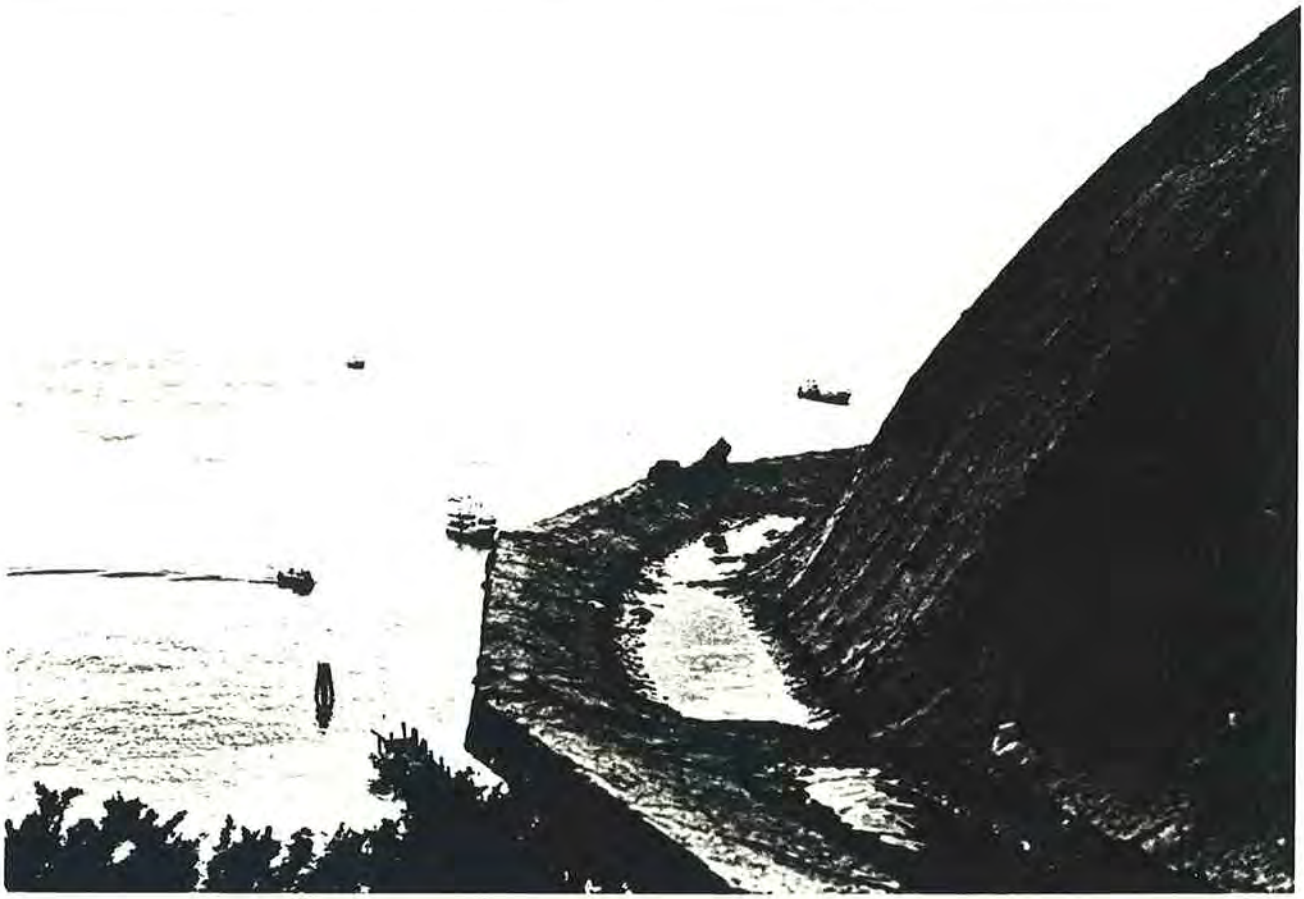
INTERIOR

SECTION at LANTERN ROOM MULLION

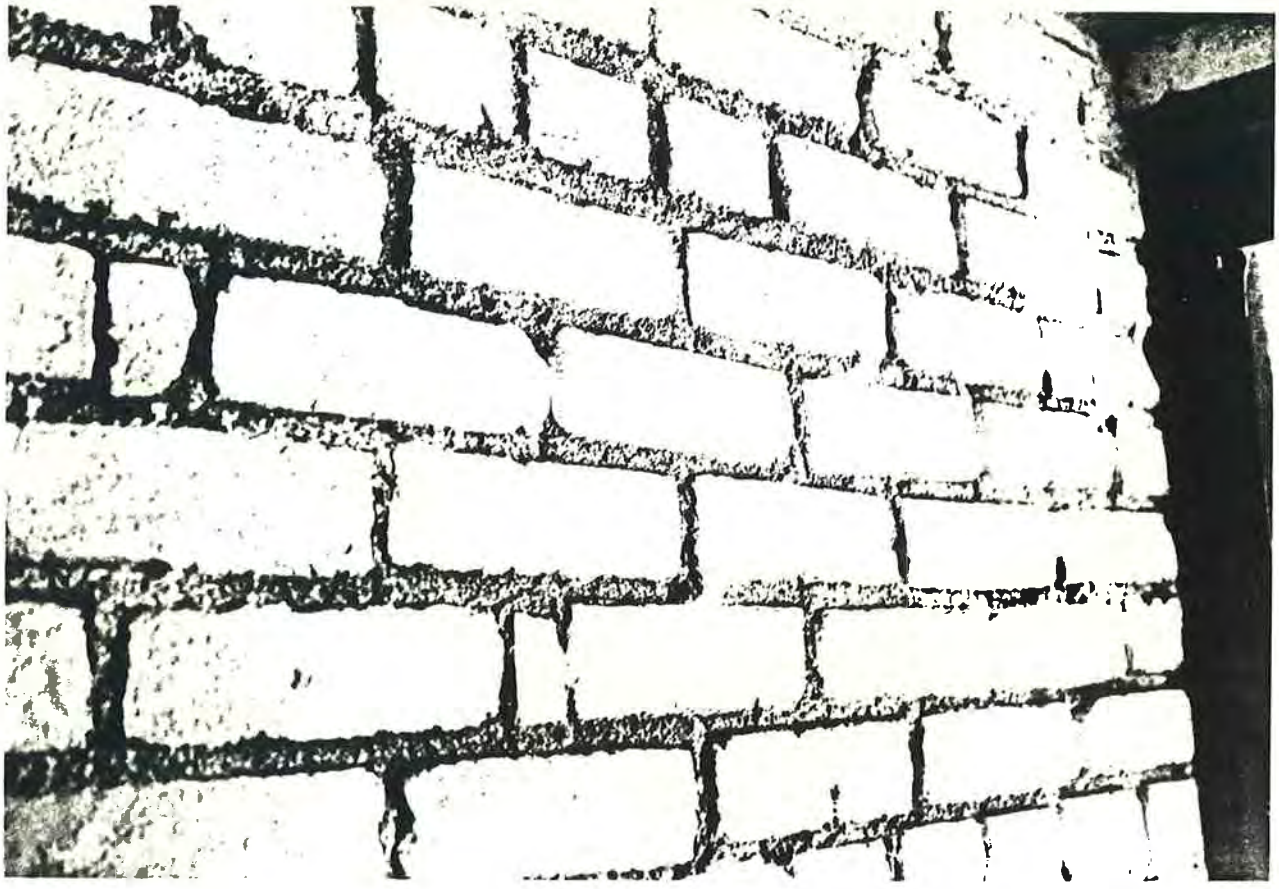
UNITED STATES COAST GUARD LIGHT STATION
DRY TORTUGAS LIGHTHOUSE
LOGGERHEAD KEY, FLORIDA



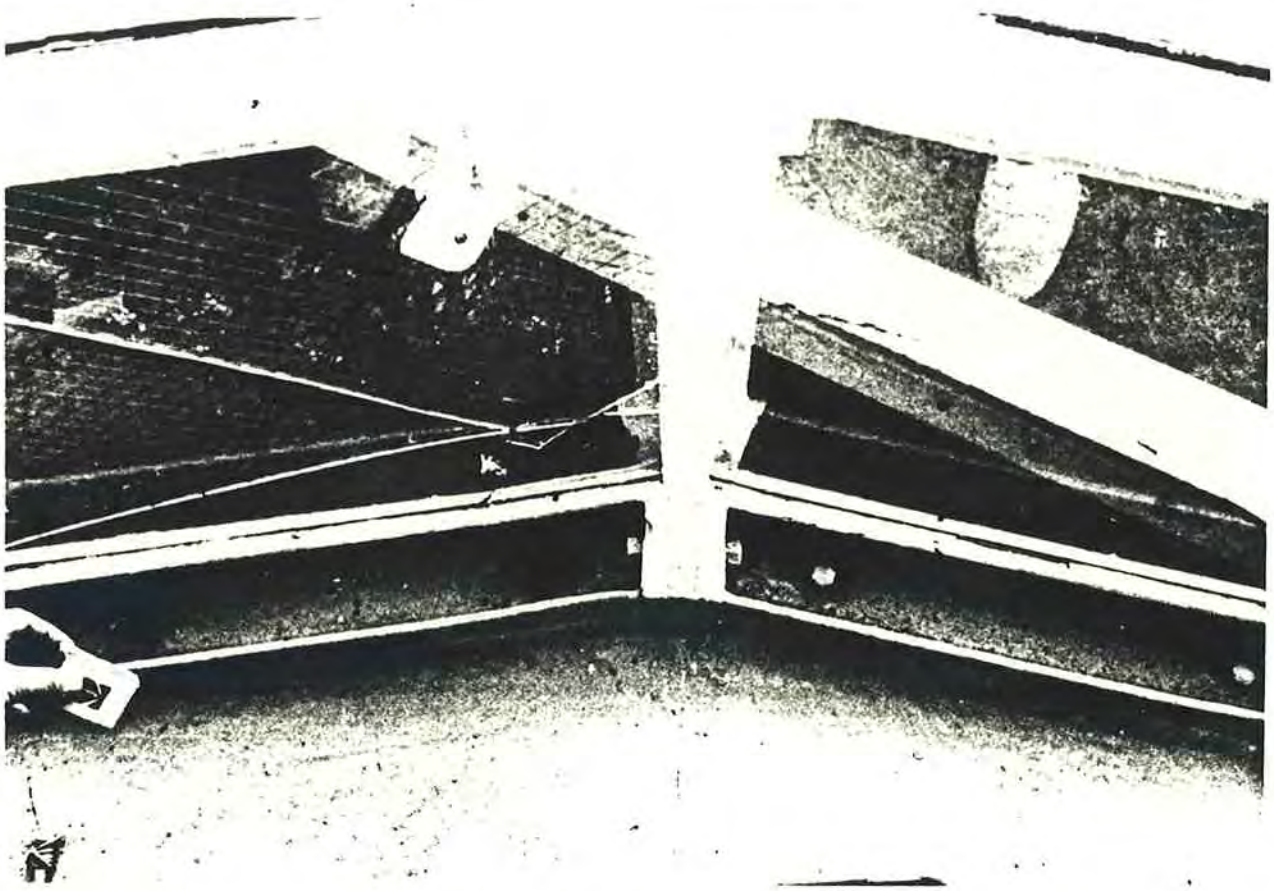
EXISTING CONDITION OF FINIAL AT DOME



EXISTING CONDITION OF GUTTER AT DOME
I-6



EXISTING CONDITION OF INTERIOR MASONRY WALL (TYPICAL)
I-7



EXISTING CONDITION OF INTERIOR MULLION AT METAL LANTERN ROOM
I-8



EXISTING CONDITION OF EXTERIOR RAIL AND PICKET
AT METAL LANTERN ROOM AND GALLERY I-9



EXISTING CONDITION OF EXTERIOR STUCCO WALL AT GALLERY ROOM
I-10





As the nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

364/105054 August 2010