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RADIAL BRICK CHIMNEY ASSESSMENT

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Bailey Edward Project No. 13X152

Naval Station Great Lakes – Radial Chimney Report

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I. Introduction

The Naval Station Great Lakes (NSGL) is renovating the base centralized steam plan, to a more localized system. Within the decentralization of the steam plant project was contemplation of the extent to which the existing facilities could be reused, renovated, or demolished. Since it was no longer required for its original function, it was contemplated to demolish the chimney.

The chimney, along with the adjacent Power House, was constructed circa 1906 and designed by noted architect Jarvis Hunt. Similar to other structures on the facility designed by Hunt, it was constructed of brick masonry and dark brown terra cotta, rising to a height of 181 feet. The stack rests on a square brick base. Due to equipment upgrades in the power plant, the stack has been out of service for a number of years. Its contemplated demolition caused concerns for the State Historic Preservation Office (SHPO) which is the Illinois State Historic Preservation (IHPA). NSGL hired the team of Environmental Design Incorporated (EDI), Bailey Edward (BE), and Arsee Engineering (AE) to provide environmental and feasibility assessments of the facilities in question.

The team prepared this report, including a structural review and feasibility study for the repair and continued presence of the chimney attached to Building 11 (B-11). The research included the review of the existing drawings, review of historical documents of repair campaigns, visual reviews from the ground with binoculars, close review by the Staff of BE and AE via crane on all sides of the chimney, and review of the interior by lowering down into the chimney 20 feet, all in order to assess the current condition of the stack. This written report outlines the existing conditions, a structural assessment, and discussion of the repercussions of demolishing the building and leaving the chimney standing, proposed repairs, an opinion of probable cost of the proposed repairs, and a photographic appendix.

II. Executive Summary

This report assesses the condition of the 1906 chimney attached to building B11 at the Naval Station Great Lakes as stable, but in need of repairs for its on-going longevity. The chimney consists of a radial red brick shaft, sitting on a square red brick base, with terra cotta bands at the intersection between the square base and the round shaft, and at the articulate top of the stack. In 1962, iron bands were installed at approximately every 10'. In the 1970's, a sprayed concrete finish was applied to the interior 25 feet, and reapplied in 1982, in an attempt to provide a smooth, acid-resistant flue surface. Generally, the chimney appears in good condition, with some masonry issues typical of a chimney of this age. These issues include mortar in need of repointing, some brick cracking / spalling, some terra cotta cracking and/or unit failure, sealant failure, oxidation of steel surfaces, and anchorage deterioration (cast iron bands, ladder anchors, lightning protection anchors). The specifics of the deterioration are outlined in detail later in the report.

Specific to this chimney is the deterioration of a sprayed concrete retrofit topping. Because it is non-permeable, its application prevented the drying of the masonry from the interior. As winter temperatures froze trapped water, the saturated brick and mortar was subjected to expansion pressures in the pores of the brick and mortar, which caused the deterioration. Over time, the same freeze/thaw cycling caused the cracking of the concrete topping. These cracks in turn let more moisture in, causing oxidation (rusting) of the reinforcing steel in the concrete, which in turn caused further deterioration of the concrete. This cycle has resulted in the top 20 feet of the chimney having extremely deteriorated or absent mortar, and spalling of the interior brick.

In addition to on-site observations, engineering calculations were performed to determine if the existing chimney could meet current requirement for seismic loads and wind load of ASCE 07-10 as modified by the Department of Defense's Unified Facilities Criteria UFC 3-301-01. A rudimentary set of calculations were performed focusing on the transition from the square base to the round shaft as the most likely point of failure. This is due to the concurrent location of the transition, as well as the chimney's breach and included terracotta detail. When subjected to the wind load of 120 mph at an Occupancy Category of III, the weight of the brick offsets the tensile forces induced by wind. Further calculations were performed for seismic loads, again focusing on the same vulnerable location. With a seismic load of Ss of 0.15 and an S1 of 0.06 and site class D, the MCEr figures indicates 1% chance of failure in 50 years. The analysis further finds a net tensile stress within the stack in a combined seismic/dead load analysis. It is possible to structurally reinforce the chimney against both wind and earthquake using techniques that would not be visible from the exterior, but they would not be reversible, which would be against the Secretary of the Interior Standards for Rehabilitation. Further calculations would be required to design a seismic / wind retrofit.

If a pure repair approach were taken, the concrete coating would be removed, and the top 20 feet of the interior of the chimney repaired (repointing, partial rebuilding). In lieu of replacing the concrete topping, it is proposed to install a new "roof" on the chimney, one which will keep out wind driven rain, but permits the release of stack-effect air. The rest of the exterior repairs consist of repointing, some terra cotta repairs and replacements, and some sealant and paint work. The cost would be $575,000 (rounded). In addition, a seismic upgrade would cost $100,000. Once the chimney is repaired, ongoing maintenance would be required for the sealants and some paint. This would require a budget of $75,000 (rounded) every 7-10 years (this figure does not include escalation). If the chimney were to be demolished, the cost would be $350,000.

Please see the report body for details and in-depth recommendations.

III. Background

Building 11 (B-11) is an historic building at Naval Station Great Lakes constructed circa 1906, designed by architect Jarvis Hunt, when he was designing 39 of the original Naval Stations Great Lakes base buildings. Constructed for the central power plant at NSGL, it is two years from its 2016 decommissioning for power plant use. Behind B-11 and adjacent to the Lake Michigan bluff there is a 181'-tall radial brick chimney that becomes redundant in conjunction with the steam decentralization project currently underway at NSGL. The State Historic Preservation Office (SHPO) is the Illinois Historic Preservation Agency, and they have requested that it not be demolished since it is a character defining portion of the historic structure, and it is a landmark on Lake Michigan for navigation. NSGL has concerns that "the chimney bricks are in poor condition and the base appears to be decomposing". The questions posed for answer by this report are 1) Is the chimney structurally safe in its present condition? and 2) If the chimney is not stable, what will it take to bring the chimney into a "safe" (stabilized) condition, and what will the cost for those repair be?

The chimney has not been used for its constructed purpose for several years and will not be put back into service. The purpose of its retention is to comply with the SHPO request to keep same after completion of decentralization project. The recommendations made in this report consider both the Navy's primary focus of meeting mission-critical needs of war fighters, and the SHPO's desire to retain the structure in perpetuity. Since these two purposes are different from each other, there is a desire on the part of the NSGL to minimize the cost and effort of maintaining the structure over the years to come.

All work in this report, including testing, analysis of the field data, retrofit recommendations, and preparation of opinions of probable cost, adhere to the following guidelines:

1. The Secretary of the Interior's Standards for Rehabilitation and Guidelines for Rehabilitating Historic Buildings;
2. National Historic Preservation Act (NHPA) Section 106 [36 CFR Part 800];
3. NAVFAC MO-913, *Historic Structures Preservation Manual*; and
4. The National Park Service (NPS) Technical Preservation Brief 43, *The Preparation and Use of Historic Structure Reports*

IV. Methodology:

The methodology decided upon for this project was to review drawings, survey on site from the ground with binoculars, from the basket of a crane in arm's length of the exterior, and from arm's length inside the chimney. Testing of the relative mortar condition was made using physical testing. Conditions were recorded with digital cameras. Structural calculations were performed based on historic drawings.

The existing documentation reviewed included the following:

1) Sheet 12 of possibly the original building drawing set.
2) Chimney Lightning Protection Repairs drawings dated August 1937
3) Chimney Repairs drawings dated May 1962 (steel bands placed)
4) Chimney Repairs drawings dated 1983 (?)
5) International Chimney Corporation report, dated April 4, 1977
6) Peabody Continental Heine report dated September 16, 1982

These are appended to this report.

The craning occurred on Thursday, June 26th and Friday June 27th, 2014. Personnel on site included the following:

Harvey Pokorny,	Project Manager	Naval Station Great Lakes
Robert Kidd	Safety Officer	Naval Station Great Lakes
Gary Flentge	Safety Officer	Environmental Design Incorporated
John Geiger	Project Manager	Environmental Design Incorporated
Susan Turner	Project Architect	Bailey Edward
Scott Drake	Historic Preservation Specialist	Arsee Engineering
Ted Larkin	Safety Officer	Stevenson Crane
Tim Hayden	Crane Operator	Stevenson Crane
Brendan Mier	Oiler	Stevenson Crane

The crane was assembled on day 1, with load tests occurring on Day 2. Survey of the lower 20' of the chimney was conducted on day 1, an area where the crane basket was obstructed from descent to grade by ducts and other building features. Safety preparedness was held on day 2 to cover confined space training and communications (primary, secondary and tertiary) prior to the first lift.

The initial lift was for air quality for enclosed spaces, containing Susan Turner and John Geiger. The purpose of this lift was to determine air quality within the stack, relative to Nitrogen, Carbon Monoxide, Oxygen, and particulate matter, to determine if the space was safe for the masonry review. Two meters were affixed to basket which continuously recorded readings for the duration of the lift until work inside the chimney was complete. A 20' tube was suspended below the basket, to sample air quality at one foot intervals down to 20' below the opening, thereby testing the air in the top 40' of the chimney. Once it was determined that the breathing conditions inside the chimney were safe, the basket was returned to grade.

The second lift to assess the chimney was done by Susan Turner and Scott Drake. The review began on the interior, beginning at the north and working clockwise, dropping 5 feet at a time. Once the 20' limit was reached, the basket was withdrawn from the interior. Exterior review began on the north façade, dropping down vertically, moving 1/8 way around the chimney, and surveying up the next section, until the entire perimeter was completed. Observations were recorded on pre-printed scale drawings, which were used to develop the drawings appended to this report. Timed drillings of mortar joints were performed at multiple elevations to provide a general comparison of mortar hardness relative to other locations on the stack. No other destructive testing was performed.

V. Forces at work:

There are many typical deterioration forces at work. They are listed below as a brief explanation of how these forces impact the existing construction, causing the deterioration symptoms observed. Typically, the top of a chimney sustains the most damage over time, being most exposed to wind, rain, and freezing temperatures. Given the height of the chimney, and the low height of the surrounding buildings, the top of the chimney is subject to the greatest wind forces. Chimneys are generally stiff.

Phase change of moisture:

Steam is air saturated with moisture. When it is airborne, and comes in contact with a cooler surface (such as the side of the chimney in winter) it will condense, depositing liquid moisture on the surface. When liquid moisture is exposed to freezing temperatures, it expands in volume as it freezes. In terms of exposure of the chimney to moisture, there are two sources in operation. Steam is condensing on the brick adjacent to the relief exhaust on the lower building, and it effects the chimney stack on the SE face from about the roof line up 40'. Rain will saturate the brick during rain events. In either case, since both the brick and the mortar are porous, they absorb moisture. It would normally dry out in due course.

Certain procedures which occur after the brick is in service can reduce its ability to dry. Repointing campaigns which change the original lime (permeable) mortars used on the 1900s with Portland (impermeable) mortars reduces the brick's ability to dry. In the case of this chimney, since high strength dense mortar was used, the porosity of the mortar has not changed. Coatings, such as those for water repellence or a cementitious coating such as is present on the interior of this chimney in question, are intended to stop the moisture entering the brick. However, over time, these coatings can fail by cracking, which permits liquid moisture into the substrate. At the same time, the majority of the coating intact prevents the brick from drying at the applied face. Trapped moisture in the brick that is not dried out prior to the onset of winter's freezing temperatures will freeze in the pores of the brick, and it expands while doing so. The ice expansion exceeds the volume of the brick pores, which causes spalling and disintegration of the brick. It can also similarly cause reduction in the strength of the mortar.

Thermal movement:

As materials are heated, generally they expand. As materials are exposed to cold, generally they contract. At the top of the chimney, while the chimney was in operation, the interior was exposed to the high temperatures of waste heat from the boilers, while the exterior of the chimney was exposed to freezing temperatures of winter. This causes internal stresses at the top of the stack.

Stack Effect:

The stack effect, also known as the "chimney effect", is the movement of air into and out of buildings (chimneys) and is driven by buoyancy. Buoyancy occurs due to a difference in indoor-to-outdoor air density resulting from temperature and moisture differences. The result is either a positive or negative buoyancy force. Contributing to this phenomena is the fact that warm/hot air rises. The greater the thermal difference, and the higher the structure, the greater the buoyancy force, or stack effect. In the case of the chimney, the stack effect, which is drawing warm air from the power plant, helps to keep the masonry dry.

Oxidation:

When water falls on a surface, it comingles with the substrate. Chemicals included in the substrate make-up can react to the water and air (oxygen) over time, resulting in oxidation. With the steel, the resulting oxides appear as a reddish scaling surface (corrosion, or more simply, rust). Over time, this oxidation process will result in section loss, or reduction in the thickness of the sound steel, but the oxide layer will take up more volume than the original metal. This expansion can generate enormous forces, which caused fracturing of the adjacent softer materials, such as brick.

These phenomena will be referred to in later sections when discussing the deterioration observed.

VI. Structural Assessment

Structural analysis can be found in Appendix C.

Is the chimney structurally safe in its present condition?
The chimney is safe in its present condition, as in, it is not in any danger of falling over absent of wind and seismic forces. There are deterioration forces at work which have caused some small areas of brick to spall, and these are in danger of falling. Personnel working below the chimney should wear hard hats until such time as the chimney is repaired.

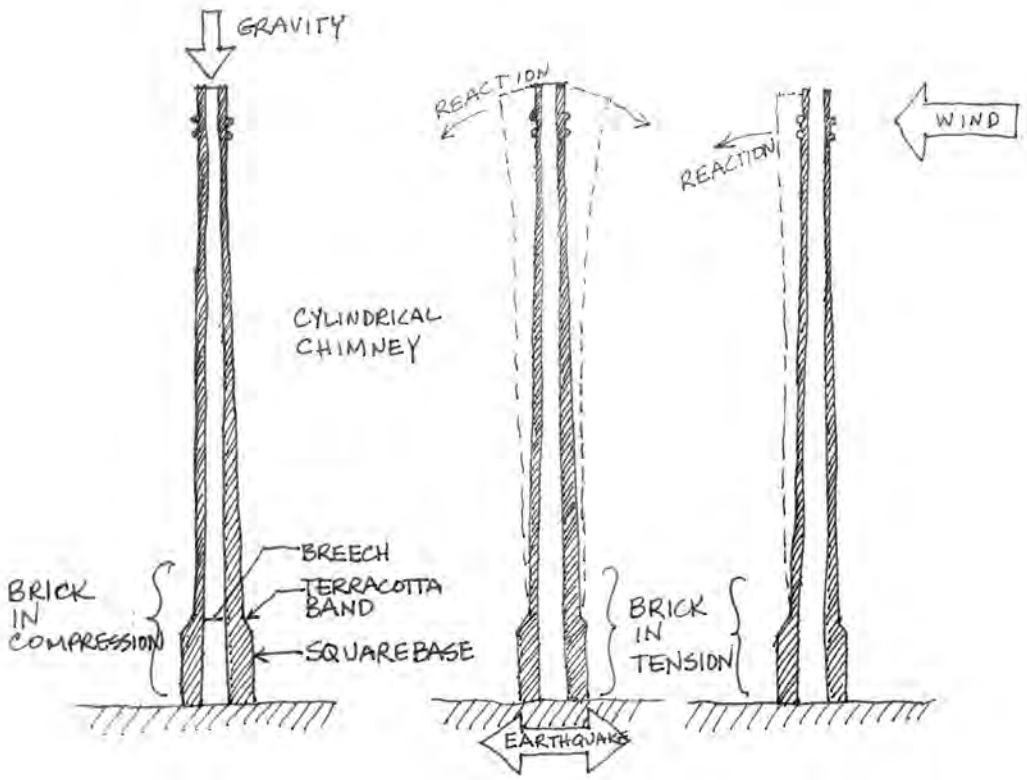
If the chimney is not stable, what will it take to bring the chimney into a "safe" (stabilized) condition, and what will the cost for those repairs be?
The repairs to the chimney are more in the line of maintenance work than needing any large intervention. Assuming that the chimney will receive no repair funding for the next 30 years, the scope of work found in Section VII is recommended.

Structural Analysis:

In performing the structural analysis, the most likely point of failure was selected as the focus. This was identified as the point of transition between the cylindrical stack and the square base. Not only does the structure change configuration at this point, it is weakened by the presence of a terracotta band, which is less strong than brick, and further weakened by the co-location of the breech.

A structural analysis was performed at this point to determine if the chimney is currently structurally adequate to resist wind forces in accordance with current code requirements per ASCE 7-05 as modified by UFC 3-301-01 to a 120 mph wind speed, based on Occupancy Category III. A lengthier explanation can be found in appendix B. The chimney was determined to be structurally adequate for combined wind and dead loads at the transition from the round stack to the square base.

A seismic analysis was performed to determine if the chimney is currently structurally adequate withstand current code design seismic forces per ASCE 7-10 as modified by UFC 3-301-01, assuming Ss = 0.15 and S1 =0.06 with a site class D. The MCEr figures indicate a risk of collapse due to seismic forces is 1% in 50 years. The analysis indicates a combined seismic and dead load results ina tensile stress over a portion of the stack perimeter. Current masonry code does not permit tension in unreinforced masonry. This rudimentary analysis indicates a combined seismic load and dead load results in a tensile stress over a portion of the stack perimeter.



Retrofit Option:
To resist the combined seismic and dead loads on this historic chimney, it would need to be inconspicuous from the exterior to meet SHPO requirements. Given that the chimney is no longer required to be in service, it makes interior retrofit an option. This would reinforce the area of transition from the cylindrical stack onto the square base where its structural efficacy is further reduced by the terracotta and the breech. This would require more calculation and design, but the basic concept has been costed in the appended estimate.

VII. Existing Conditions / Site Observations / Structural Assessment / Proposed Repairs

The cost of the repairs is estimated at approximately $570,000, based on the full recommended scope of work contained in this section. This is the amount for the chimney only, and does not include work to the main power house building. The format of this section identifies the type of the materials encountered, their location, the general condition observed, possible causes of any observed deterioration, and proposed repair methodology. This information can then be considered within the context of the opinion of probable cost that is appended to this report.

This chimney consists of a Base, Middle and Top. The red brick Base is square in plan, approximately 20 feet high. The Base transitions into the circular form of the Middle, by stepping back the brick Base at the corners which forms "shoulders". These shoulders have had a concrete topping applied to them. The Middle consists of circular radial red brick shaft, which was retrofitted with an iron band every 10' (approximately). The Middle tapers smoothly without corbelling up to the Top. The Top consists of a lower terra cotta band, above which red brick corbels out to the top terra cotta band, which provides a wash course below the top 10 feet of brick, capped by a cast iron coping.

Generally, the chimney appears stable, with some limited masonry issues typical of a chimney of this age. These issues include mortar in need of repointing, some brick cracking / spalling, some terra cotta cracking and/or unit failure, sealant failure, oxidation of steel surfaces, and anchorage deterioration (cast iron bands, ladder anchors, and lightning protection anchors). Specific to this chimney is the deterioration of a sprayed concrete topping (gunite) that was applied to the interior of the top 20 feet of the chimney. This coating and its failure has in turn caused other issues. These materials, their condition and repair are described below.

1) Terra Cotta
   a. Locations:
      i. Top continuous horizontal band (wash course) at the Top
      ii. Second continuous horizontal band (water course) below the Top
      iii. Continuous horizontal band (wash course) between the Base and the Middle.
      iv. Continuous horizontal band (water course) on the Base just below the shoulders.
      v. Continuous horizontal band (water course) at the base of the base.
   b. Condition:
      i. The upper band of terra cotta in the Top of the stack exhibits a significant amount of damage. Many of the units in the upper wash course have cracked parallel to the face of the chimney as shown in Photos 8 through 11.
      ii. Several of the units in the base course of the upper band of terra cotta have cracked as shown in Photo 13.
      iii. Previous repair programs have patched spalled terra cotta units with mortar; many of these patches have since failed.
      iv. The joints within the terra cotta have typically failed at all levels as shown in Photo 12.
      v. The second band of terra cotta serves to divide the head of the stack from the middle section. The terra cotta at this level was found to be in much better condition that those above, as shown in Photos 14.
      vi. Several terra cotta pieces near grade level were also found to be cracked as shown in Photo 15.
   c. Possible cause
      i. It appears as though the terracotta was subjected to wind driven rain, and was not able to dry out prior to freezing temperatures.

ii. Joints have failed due to lack of maintenance of the mortar and / or the sealant joints.

d. Proposed Repair Methodology:
   i. Replace severely cracked wash course of top terra cotta band with new terra cotta.
   ii. Epoxy inject select cracked terra cotta.
      1. At base course of the top terra cotta band.
      2. At the second terra cotta band.
   iii. Remove and replace existing sealant joints in and adjacent to terra cotta. It may be desirable to install lead joint covers or some other sort of durable protection for these joints, particularly at the more exposed locations on the upper portion of the stack.

2) Brick Masonry
   a. Locations:
      i. Base, Middle, and Top.
   b. Condition:
      i. The brick has the appearance of being black in a lot of areas.
      ii. Cracks within the brick masonry of the upper portion of the stack were common. Photo 21 shows one such crack passing through the corbelled brick in the top portion of the stack.
      iii. As shown in Photo 22 and 23, several small areas of displaced brick masonry were also observed beneath the corbelled details. Such areas should also be removed, salvaged and reconstructed.
      iv. Many of the previous attempts to repair cracks within the upper segment of the stack have since re-cracked and are again in need of repair as shown in Photo 24.
      v. The interior of the stack has been covered and recovered with a gunite lining reinforced with wire mesh as shown in Photos 35 through 38. Cracks and spalls were common within the lining to the extent that the coating that was intended to protect the masonry from the elements now traps moisture within the brick. The trapped moisture has in turn oxidized the reinforcing mesh, rendering section loss, and the resultant volumetric expansion causing further deterioration of the coating. The coating itself is falling off when touched. The mortar behind the gunite lining was found to be damp and in poor condition. As shown in Photos 39 and 40, it was similar in consistency to wet sand. The outer layer of material was easily scraped away with the pointed end of a masonry hammer.
      vi. Several areas of displaced masonry, shown in Photo 41, were observed at the transition from the lined to unlined portion of the stack at an elevation of approximately 145 feet.
   c. Possible causes
      i. By removing certain failed bricks encountered, it appears that the black coloration is a crust of soiling, which likely accumulated during the chimney's operation. The black appearance has a more dense appearance farther up the chimney, and is less dense towards the base.
      ii. Cracking can be caused by movement due to wind, or thermal stresses between interior and exterior.
      iii. Displaced bricks generally occur at locations of saturated brick, where moisture freezing "ice jacks" the bricks out of position.
   d. Proposed Repair Methodology:
      i. No repair/cleaning of the black soiling is proposed. Given that the chimney is no longer operational, it is not going to get worse and is doing no harm.
      ii. Remove, salvage and reconstruct displaced brick masonry in following areas:
         1. All brick above the top terra cotta course.
         2. Area just below second terra cotta belt as noted on survey drawings (N&W)
         3. Interior of chimney just below the extent of the existing gunite wash (NE).
         4. Adjacent to concrete wash on shoulders of Base.

iii. Crack repair in brick masonry including brick replacement.
   1. In locations as noted on survey drawings attached.
iv. 100% Repointing at Locations:
   1. Entire exterior of top of chimney not already reconstructed (above the lower terra cotta at elev. +/- 150' and up)
   2. At eroded area mid to lower level at steam damage (SE) as noted on drawings.
v. The gunite lining should be removed and interior mortar joints be repointed. It is also proposed to install a vented chimney cap to prevent the ingress of precipitation, while permitting the stack effect heat to escape. The design of the cap needs to meet with SHPO (IHPA) approval, and address the disposal of any condensation that may occur.
vi. Remove and replace individual cracked or spalled brick.
   1. Locations as noted on drawings
   2. Provide an allowance for an amount more.

3) Mortar

A series of timed drillings were performed using a masonry hammer drill and a stopwatch to develop an understanding of relative mortar hardness across multiple locations on the stack. A test hole of two inches in depth was drilled at several elevations along the south elevation of the stack. Since test sites near the middle of the stack took longer to drill than test sites near the head of the stack, it is reasonable to expect that the mortar in the middle of the stack is harder than that in the top. See Photos 16 through 18 and Figure 1.

a. Locations:
   i. Mortar is the binder between terra cotta units
   ii. Mortar is the binder between bricks
b. Condition:
   i. The mortar joints near the head of the chimney were typically found to be cracked and eroded as shown in Photo 19.
   ii. Previous repair programs in this area have simply smeared a thin layer of repair mortar over a deteriorated joint as shown in Photo 20. Such repairs are an aesthetic fix at best and do little to extend the service life of the masonry.
   iii. Deteriorated mortar joints were found within the upper and middle portions of the stack to an elevation of approximately 140 feet as shown in Photos 27 and 28.
   iv. Other deteriorated mortar joints were observed on the lower portion of the middle section of the stack as shown in Photos 29 and 30. These locations were observed to correspond with an area receiving deposits from steam exhaust from shorter vents on the nearby power plant.
   v. The remainder of the mortar joints in this segment of the tower were generally found to be in good condition as shown in Photo 31.
c. Possible Cause:
   i. Weathering of the mortar joint is caused by exposure to moisture, followed by freeze/thaw cycles.
   ii. Weathering is exacerbated by exposure of the chimney to steam in some locations.
   iii. Weathering is exacerbated by limiting of the masonry's ability to dry, due to the application of a concrete (gunite) coating on the interior of the top 20 feet of the chimney.
d. Proposed repair methodology:
   i. Replace failed joints as shown in Photo 6.
   ii. Remove "cap-pointing" by cutting out back to sound, stable mortar (minimum 3/4") and repointed with an appropriate repair mortar. Since the study mandate is for repairs to last 30 years, 100% repointing is recommended.
   iii. Remove abandoned metal embedments and patch.

4) Cast Iron

a. Locations:
   i. The masonry stack at Building 11 is topped by a segmented cast iron cap that helps protect the masonry from the elements, as shown in Photo 5.
b. Condition:
   i. Many of the joints within this cap have failed
   ii. Spalls have occurred within the cast iron cap such as the one shown in Photo 7.
c. Possible Cause:
   i. Joint failure is possibly due to differential thermal movement. This cause cannot be eliminated.
d. Proposed repair methodology:
   i. Replace failed joints as shown in Photo 6.
   ii. Spalls within the cast iron cap sections such as the one shown in Photo 7 should be replaced.

5) Steel

a. Locations:
   i. A series of steel bands were installed in approximately 1962 in an effort to restrain the outward force of the masonry. This is sound and traditional practice for this type of structure. A fillet bead of sealant was installed to help prevent water infiltration behind the bands.
   ii. A metal access ladder is affixed to the north elevation of the smoke stack as shown in Photo 45.
b. Condition:
   i. As shown in Photos 43 and 44, these sealant joints have typically failed.
   ii. Corrosion to the ladder has resulted in cracked and spalled masonry at its anchor points as shown in Photo 46. Split welds within the ladder itself were also observed as shown in Photo 47.
c. Possible Cause:
   i. Sealant joint failure is due to age and lack of maintenance.
   ii. Age of the ladder and exposure to the elements has caused the oxidation. Thermal movement likely caused the failure of the welded joints.
d. Proposed repair methodology:
   i. Remove and replace all sealant joints on the steel bands.
   ii. Repaint bands.
   iii. The desire of NSGL is to replace the ladder with a contemporary caged access ladder in compliance with OSHA. The replacement ladder should be designed to be historically appropriate.

6) Other Materials and Systems

a. Locations:
   i. Four masonry "shoulders" are found at the transition from the round profile of the stack to the square base. As shown in Photo 32, these shoulders have typically been covered with a concrete wash cap
   ii. A lightning arrest cable system has been installed to protect the stack from lightning strikes. It consists of a ring of "Spikes" at the top, which are grounded by leads running down the north and south faces of the chimney.
   iii. There is an existing steel ladder on the north side of the chimney.
b. Condition:
   i. A significant amount of brick damage occurs below these "shoulders" as evidenced by spalling and soft brick and mortar in these areas, as shown in Photos 33 and 34.
   ii. Many of the components of the lightning system were found to be loose and displaced as shown in Photos 48 and 49
   iii. The desire of the NSGL is to replace it with a caged ladder conforming to OSHA standards.
c. Possible cause:
   i. Runoff from the concrete wash detail concentrates streaming water on the adjacent brick masonry, which has resulted in a significant amount of brick damage in this area.
   ii. The loose anchorage of the lightning protection could be from wind forces, or from the energy of an actual lightning strike.
   iii. The exposure of the ladder to thermal expansion and contraction over time could result in broken welds. Loose anchorage and corrosion of the steel would be caused by exposure to the elements over time.
d. Proposed Repair Methodology:
   i. Replace concrete "shoulders" with similarly configured elements constructed of fiber-reinforced-concrete elements designed to provide a drip edge. This drip edge would provide a means for the descending water to be kicked off the face of the Base, and slow down the wash over of the brick once repaired.
   ii. Reattach loose components (lightning spikes and ground cables) of the lightning arrest system.
   iii. Replace the existing ladder with a new caged ladder in the same location.

VIII. Ongoing Maintenance

After the completion of the indicated repairs, the chimney should be in good condition to continue in service for another 30 years. While all repairs are designed to be the most durable possible, sealants will require on-going maintenance every 7-10 years. On that cycle, the sealants will need to be removed and replaced. Concurrently, some minor touch-ups of paint may be necessary. While performing this repair work, while access is available, it would be prudent to review the masonry to monitor new or recurring problems, so that they may be addressed in a timely manner. The cost for repairs and access for periodic maintenance can be found in Appendix C.

IX. Discussion of Repair versus Demolition

Budgetary estimates have been prepared for the proposed scope of repair work (appended). Bailey Edward came up with this independent opinion of probable cost in the amount of $575,000, rounded up. This assumes a one-time mobilization for rigging, with two specialized scaffolding rigs providing mobile working platforms, which would be moved down as work completed.

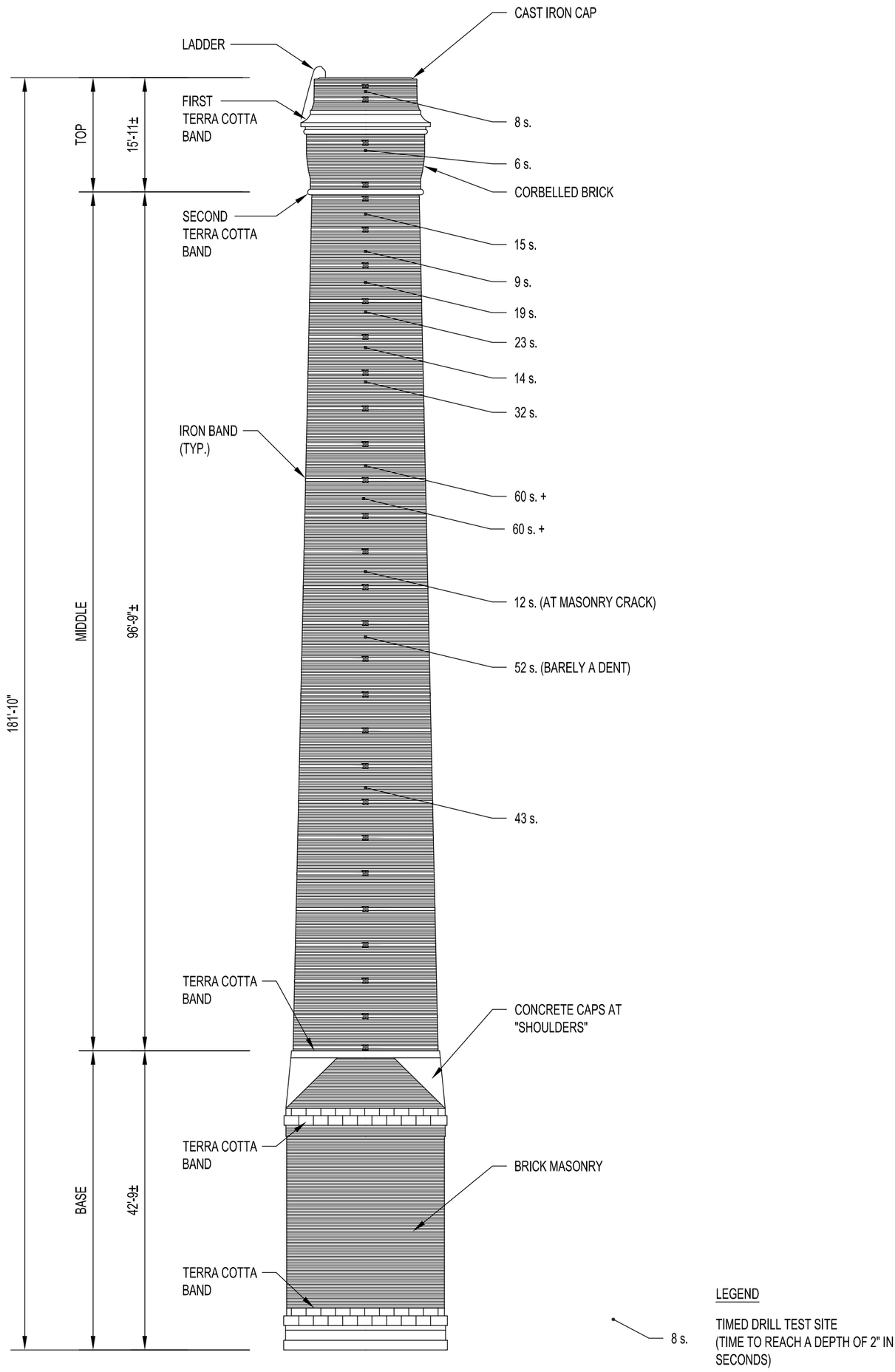
Separately, contractors specializing in the repair and demolition of chimneys were consulted. Anticipated construction costs by the contractors ranged from $400,000 to $750,000, in 2014 dollars, not including contingencies for design or unforeseens, and not including soft costs such as overhead and profit or consultant fees or NSGL's project management costs.

For the current stack to meet current code, a seismic upgrade would also be required. This could be completed at the same time as the repairs, saving the cost of the crane. The cost for an interior reinforced concrete seismic retrofit would be in the order of magnitude of $100,000.

After the completion of the above described repairs, periodic maintenance would be anticipated about every 10 years. It would involve rigging a mobile scaffold, which can be repositioned every 6 feet or so, to work down the chimney. If only the sealants at the bands were removed and reinstalled, then the scaffold would move every 10 feet to each band. To remove and reinstall sealants at each band would take one man one day, with 26 bands. Each band would require 3 hours to relocate it down. Based on this scenario, it would take about one month, at a cost of $75,000, which includes labor for the removal and reinstallation of sealant applicator, and amount for touch-up painting, and scaffolding costs. See appended spreadsheet in Appendix D.

In comparison to the total repair and retrofit cost of $675,000, if NSGL determined that they required the demolition of the chimney, the cost to demolish the chimney would be in the order of magnitude cost of $350,000, including disposal of material into the landfill. This cost does not anticipate hazardous materials being encountered. If hazardous materials were found, there would be additional abatement costs in either scenario. The logistics of demolition would be to erect scaffolding around the top, and construct an engineered opening at the base of the chimney. Demolition would commence at the top, and the debris would be directed into the interior of the chimney, working off the scaffolding. The debris would be removed through the opening at the base. The scaffolding would be lowered once that level is demolished, the scaffolding lowered, and the process repeated. There would be no ongoing maintenance costs.

Appendix A: Survey / Repair Drawings



TYPICAL ELEVATION

1/16"=1'-0"

0 2 4 10 15

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BE Project Name: BUILDING. 11 STACK ASSESSMENT

SHEET NAME: TYPICAL ELEVATION AND MATERIALS

Drawn By:	Date:	BE Project No.	DWG No.
JND	07/23/2014		001

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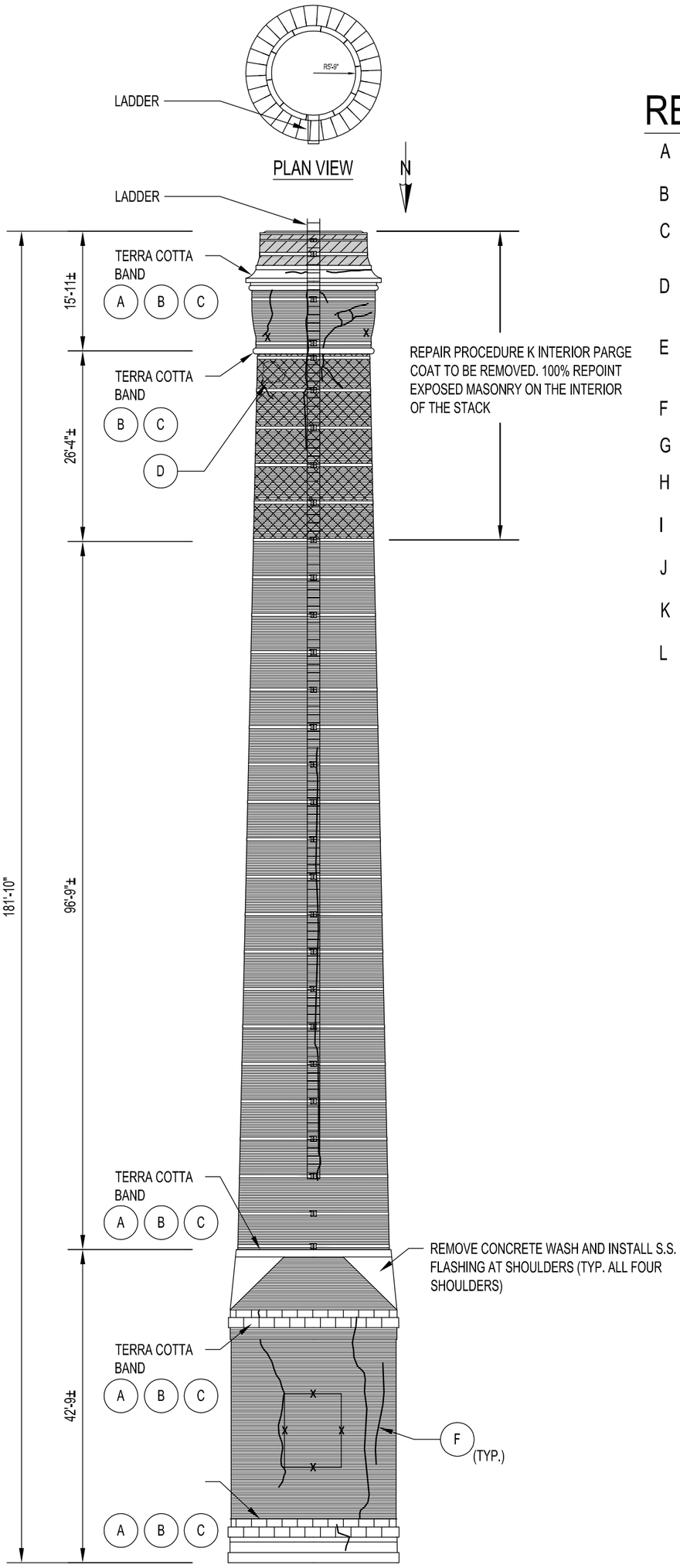

NORTH ELEVATION

1/16"=1'-0"

0 2 4 10 15

REPAIR PROCEDURE LEGEND

A - REPLACE SEVERELY CRACKED TERRA COTTA WITH NEW TERRA COTTA.

B - EPOXY INJECT CRACKED TERRA COTTA.

C - REMOVE AND REPLACE EXISTING SEALANT JOINTS IN AND ADJACENT TO TERRA COTTA WITH MORTAR AND LEAD JOINT STRIPS.

D - REMOVE, SALVAGE AND RECONSTRUCT DISPLACED BRICK MASONRY. (AS SHOWN BY)

E - REMOVE AND RECONSTRUCT DETERIORATED BRICK MASONRY. (AS SHOWN BY)

F - CRACK REPAIR IN BRICK MASONRY INCLUDING BRICK REPLACEMENT.

G - REPOINTING (AS SHOWN BY)

H - REMOVE AND REPLACE INDIVIDUAL CRACKED OR SPALLED BRICK.

I - REMOVE AND REPLACE SEALANT WASH AT IRON BANDS AT ALL LEVELS.

J - REMOVE ABANDONED METAL EMBEDMENTS AND PATCH.

K - REMOVE AND DISPOSE OF PARGE COATING ON THE INTERIOR OF THE STACK.

L - REATTACH LOOSE COMPONENTS OF THE LIGHTNING ARREST SYSTEM.

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BE Project Name:
BUILDING 11 STACK ASSESSMENT

SHEET NAME
NORTH ELEVATION - PROPOSED REPAIRS

Drawn By:	Date:	BE Project No.	DWG No.
JND	07/23/2014		002

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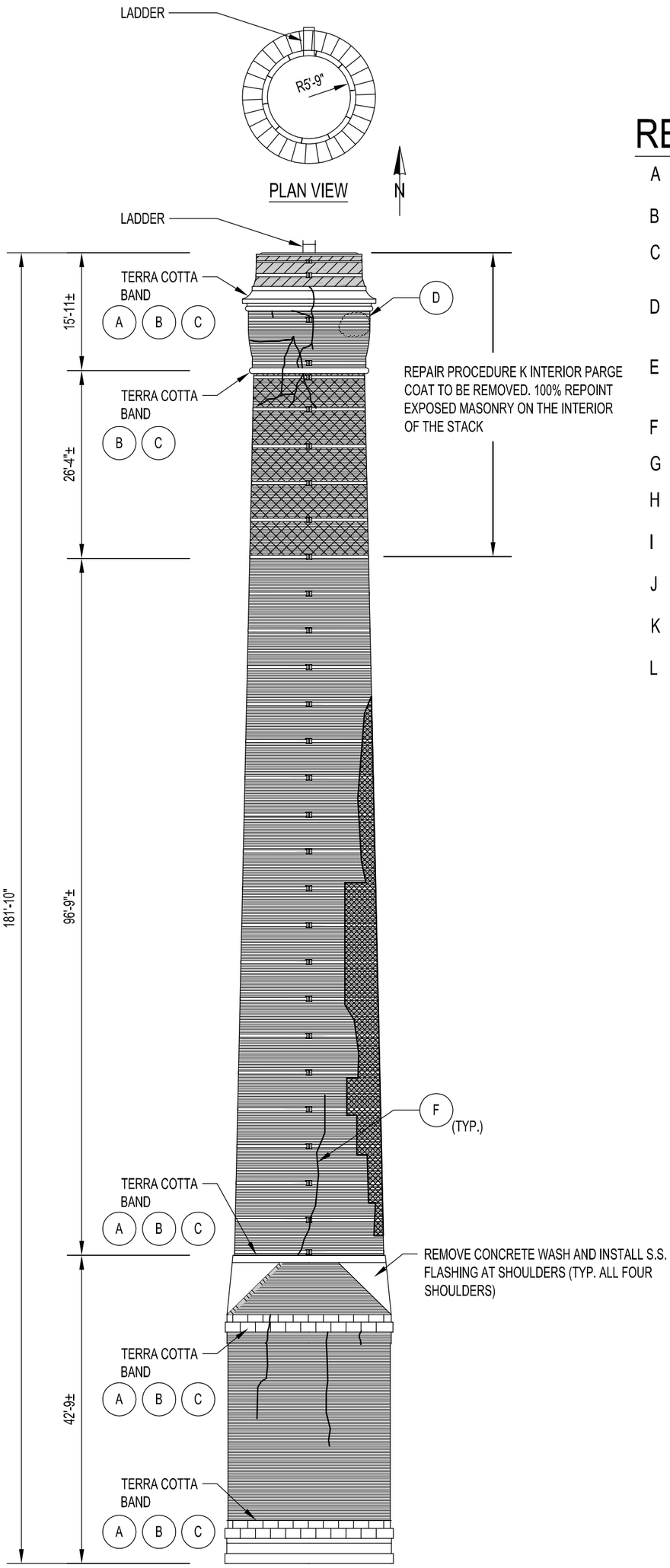

REPAIR PROCEDURE LEGEND

A - REPLACE SEVERELY CRACKED TERRA COTTA WITH NEW TERRA COTTA.

B - EPOXY INJECT CRACKED TERRA COTTA.

C - REMOVE AND REPLACE EXISTING SEALANT JOINTS IN AND ADJACENT TO TERRA COTTA WITH MORTAR AND LEAD JOINT STRIPS.

D - REMOVE, SALVAGE AND RECONSTRUCT DISPLACED BRICK MASONRY. (AS SHOWN BY)

E - REMOVE AND RECONSTRUCT DETERIORATED BRICK MASONRY. (AS SHOWN BY)

F - CRACK REPAIR IN BRICK MASONRY INCLUDING BRICK REPLACEMENT.

G - REPOINTING (AS SHOWN BY)

H - REMOVE AND REPLACE INDIVIDUAL CRACKED OR SPALLED BRICK.

I - REMOVE AND REPLACE SEALANT WASH AT IRON BANDS AT ALL LEVELS.

J - REMOVE ABANDONED METAL EMBEDMENTS AND PATCH.

K - REMOVE AND DISPOSE OF PARGE COATING ON THE INTERIOR OF THE STACK.

L - REATTACH LOOSE COMPONENTS OF THE LIGHTNING ARREST SYSTEM.

SOUTH ELEVATION

1/16"=1'-0"

0 2 4 10 15

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BE Project Name: BUILDING 11 STACK ASSESSMENT

SHEET NAME: SOUTH ELEVATION - PROPOSED REPAIRS

Drawn By:	Date:	BE Project No.	DWG No.
JND	07/24/2014		003

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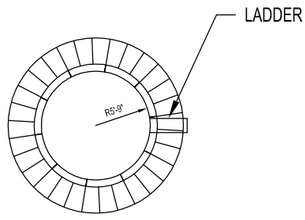
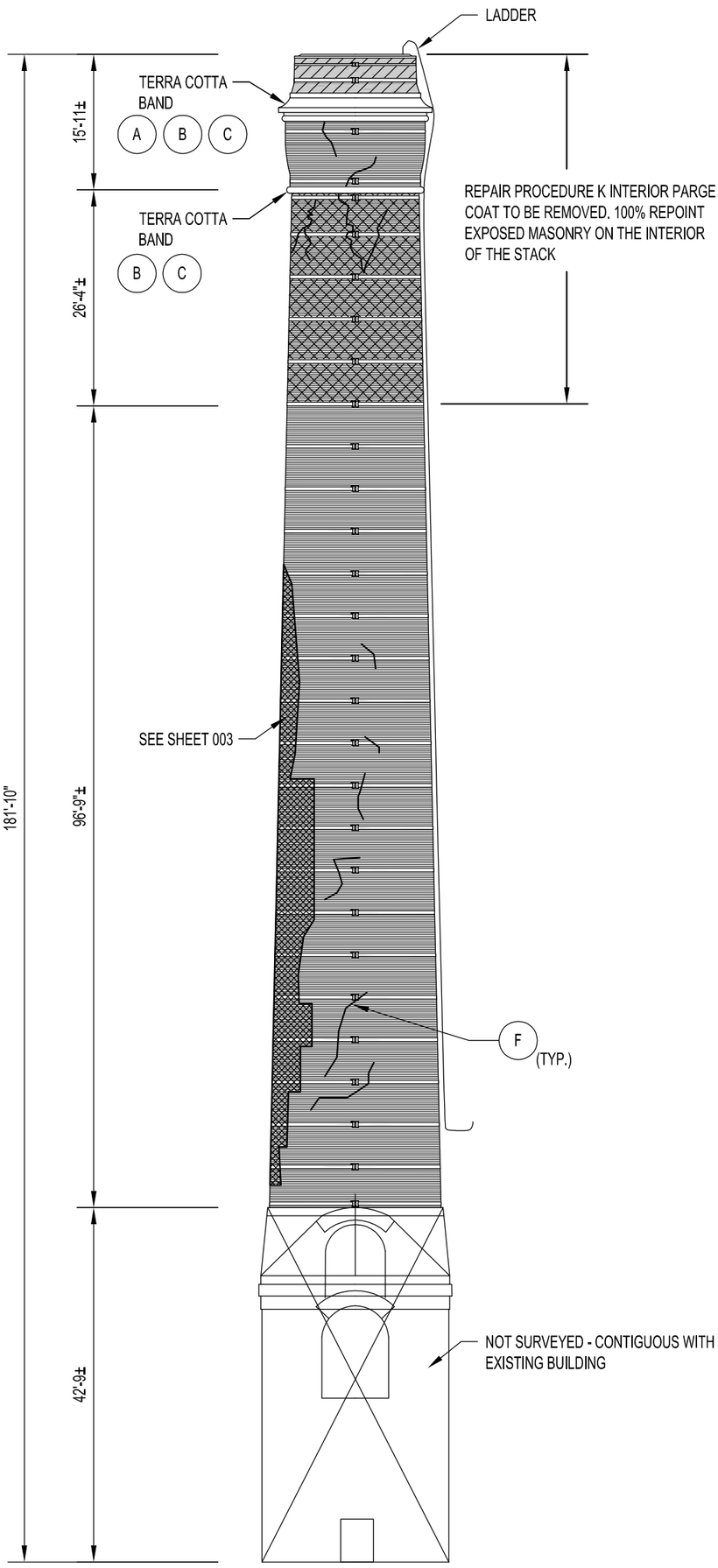


PLAN VIEW N



EAST ELEVATION

1/16"=1'-0"

0 2 4 10 15

REPAIR PROCEDURE LEGEND

A - REPLACE SEVERELY CRACKED TERRA COTTA WITH NEW TERRA COTTA.

B - EPOXY INJECT CRACKED TERRA COTTA.

C - REMOVE AND REPLACE EXISTING SEALANT JOINTS IN AND ADJACENT TO TERRA COTTA WITH MORTAR AND LEAD JOINT STRIPS.

D - REMOVE, SALVAGE AND RECONSTRUCT DISPLACED BRICK MASONRY. (AS SHOWN BY)

E - REMOVE AND RECONSTRUCT DETERIORATED BRICK MASONRY. (AS SHOWN BY)

F - CRACK REPAIR IN BRICK MASONRY INCLUDING BRICK REPLACEMENT.

G - REPOINTING. (AS SHOWN BY)

H - REMOVE AND REPLACE INDIVIDUAL CRACKED OR SPALLED BRICK.

I - REMOVE AND REPLACE SEALANT WASH AT IRON BANDS AT ALL LEVELS.

J - REMOVE ABANDONED METAL EMBEDMENTS AND PATCH.

K - REMOVE AND DISPOSE OF PARGE COATING ON THE INTERIOR OF THE STACK.

L - REATTACH LOOSE COMPONENTS OF THE LIGHTNING ARREST SYSTEM.

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BE Project Name: BUILDING 11 STACK ASSESSMENT

SHEET NAME: EAST ELEVATION - PROPOSED REPAIRS

Drawn By:	Date:	BE Project No.	DWG No.
JND	07/24/2014		004

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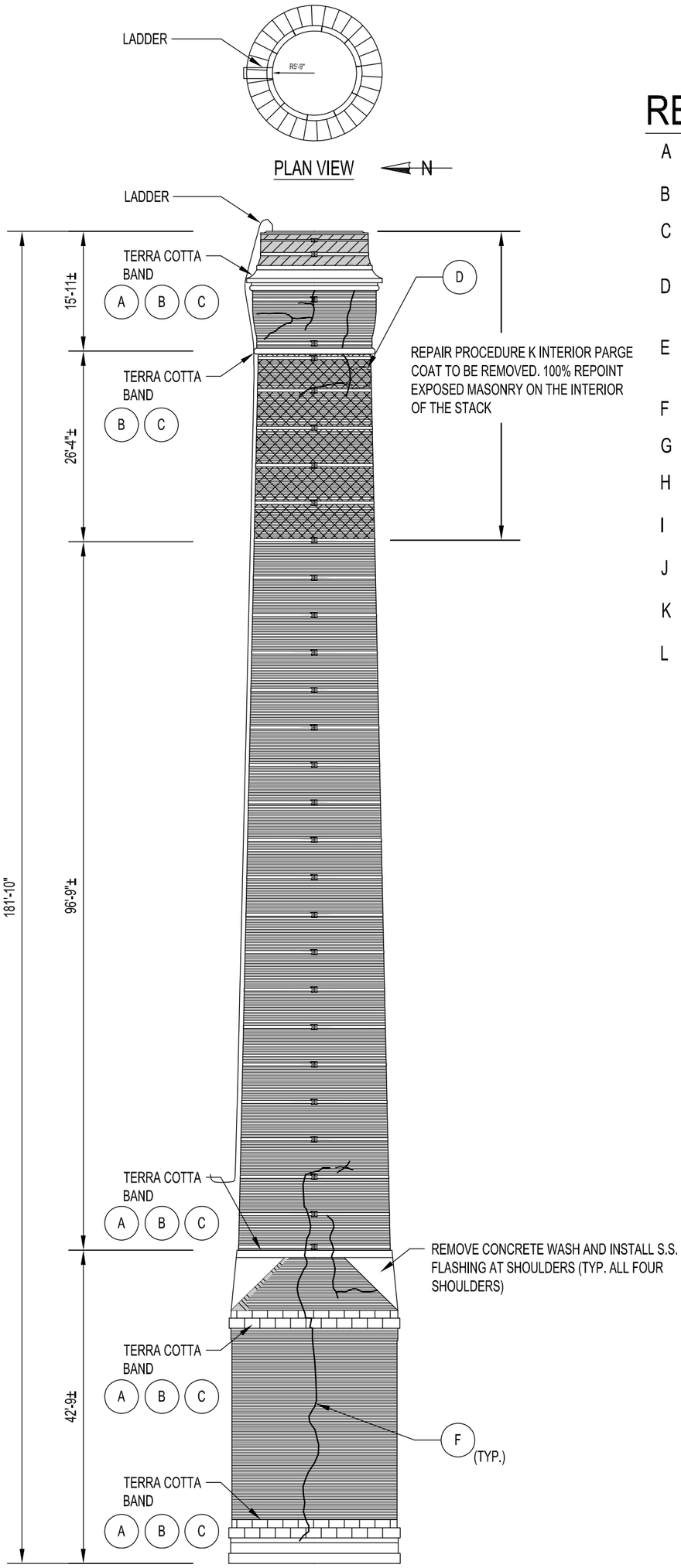

WEST ELEVATION

1/16"=1'-0"

0 2 4 10 15

REPAIR PROCEDURE LEGEND

A - REPLACE SEVERELY CRACKED TERRA COTTA WITH NEW TERRA COTTA.

B - EPOXY INJECT CRACKED TERRA COTTA.

C - REMOVE AND REPLACE EXISTING SEALANT JOINTS IN AND ADJACENT TO TERRA COTTA WITH MORTAR AND LEAD JOINT STRIPS.

D - REMOVE, SALVAGE AND RECONSTRUCT DISPLACED BRICK MASONRY. (AS SHOWN BY)

E - REMOVE AND RECONSTRUCT DETERIORATED BRICK MASONRY. (AS SHOWN BY)

F - CRACK REPAIR IN BRICK MASONRY INCLUDING BRICK REPLACEMENT.

G - REPOINTING (AS SHOWN BY)

H - REMOVE AND REPLACE INDIVIDUAL CRACKED OR SPALLED BRICK.

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J - REMOVE ABANDONED METAL EMBEDMENTS AND PATCH.

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BE Project Name:
BUILDING 11 STACK ASSESSMENT

SHEET NAME
WEST ELEVATION - PROPOSED REPAIRS

Drawn By:	Date:	BE Project No.	DWG No.
JND	07/23/2014		005

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Appendix B: Photographs

Photo 1

The masonry smoke stack at Building 11.

Photo 2

Bands of speckled brown terra cotta adorn the stack.

Photo 3

The stack rests on a square base.

Photo 4

A series of iron bands reinforce the masonry.

Photo 5 The stack is topped with a cast iron cap.

Photo 6 The joints in the cap have failed and should be replaced.

Photo 7 The cap has spalled in at least one location.

Photo 8 Many of the terra cotta units in the wash course of the uppermost band have cracked.

Photo 9 Spalled units have been patched with mortar.

Photo 10 The majority of the units in the wash course are damaged.

Photo 11

A closer look at a typical cracked terra cotta unit.

Photo 12

The joints within the terra cotta have typically failed.

Photo 13

Many of the units in the second course of the upper band have cracked.

Photo 14

The second band of terra cotta is in much better condition.

Photo 15 Many of the terra cotta units near grade level are also damaged.

Photo 16 A timed drill test in progress.

Photo 17 Tests in the upper portion of the stack indicated softer mortar.

Photo 18 Joints lower on the stack were much harder.

Photo 19 Cracking and deteriorated mortar joints in the uppermost section of the stack.

Photo 20 Previous repair programs have simply smeared a shallow layer of new mortar over the existing joint.

Photo 21 Cracks in the brick masonry were common in the upper sections of the stack.

Photo 22 Several areas of displaced masonry were also observed beneath the corbelled brick.

Photo 23

Bulging masonry was observed in this location on the southwest corner of the stack.

Photo 24

Many of the previous repairs have again failed.

Photo 25 Cracks were observed within the square base of the stack.

Photo 26 An earlier repair on the west side of the base has since re-cracked.

Photo 27 Mortar joints in the upper portion of the stack were in poor condition.

Photo 28 Deteriorated joints in the middle section of the stack.

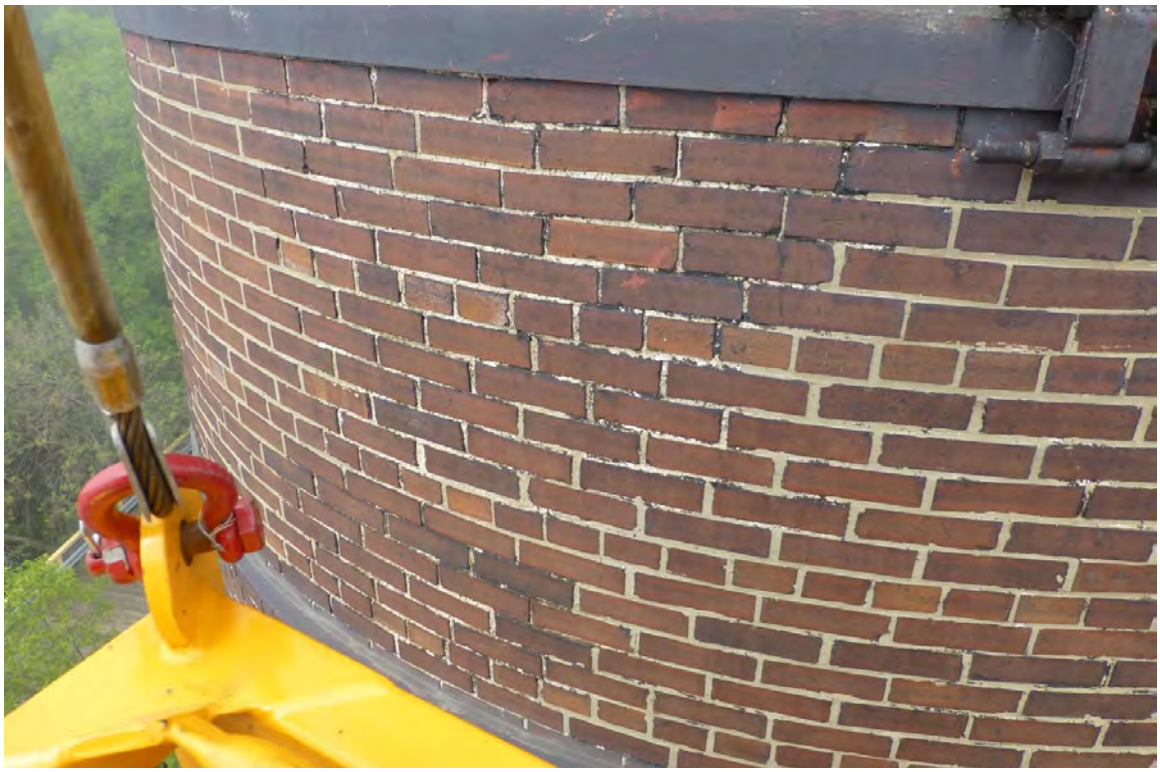

Photo 29 Eroded joints lower on the stack correspond to vents on the roof of the adjacent power house.

Photo 30 Another area of eroded mortar lower on the stack.

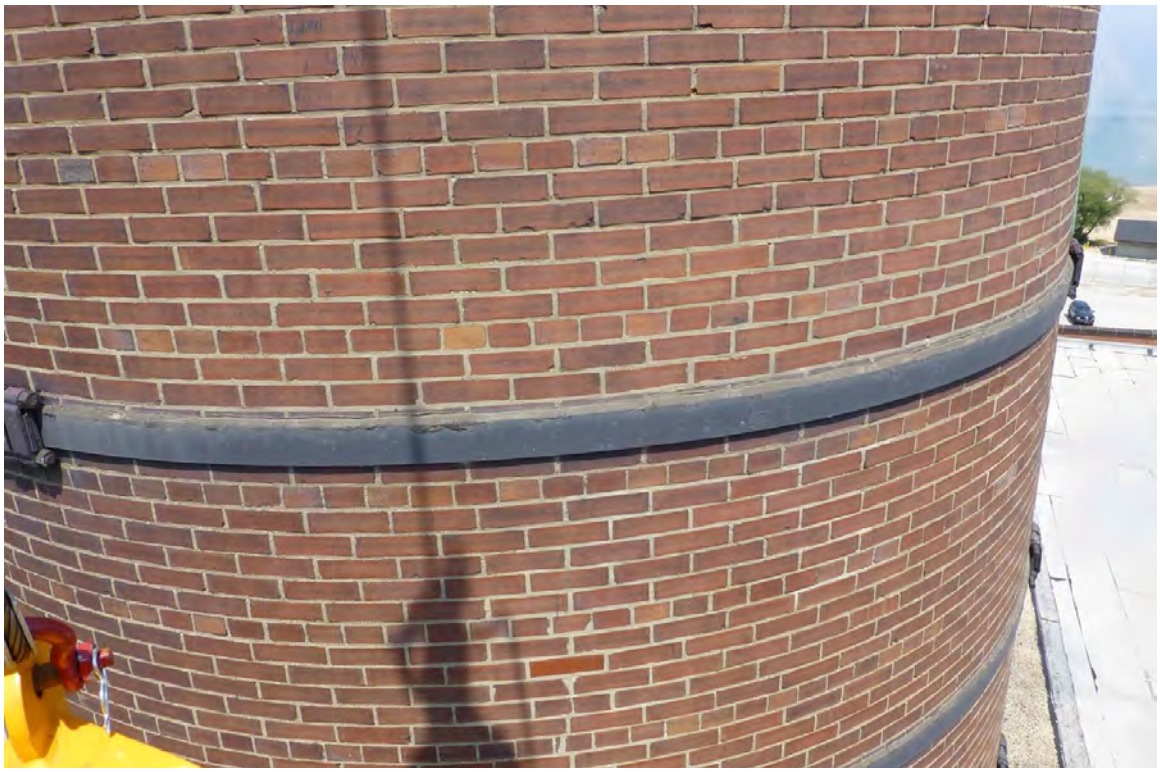

Photo 31 The majority of the joints on the lower portion of the stack are in good condition.

Photo 32 The shoulders at the base of the stack have been partially covered with concrete caps.

Photo 33 Runoff from the wash above is directed onto the angled brick masonry below.

Photo 34 Cracks within the concrete caps allow even more water to saturate the brick.

Photo 35

The interior of the stack has been partially covered with a layer of gunite.

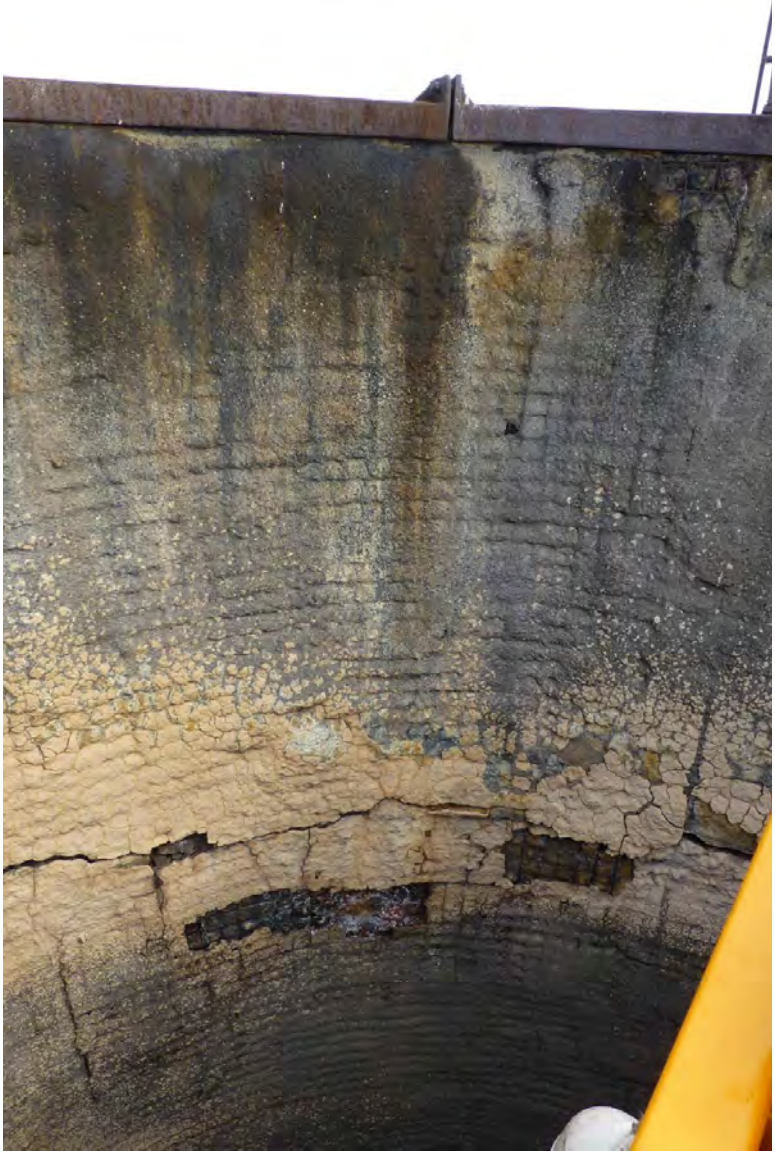

Photo 36

Cracking and spalls were commonplace within the gunite lining.

Photo 37 A crack extending the full circumference of the stack corresponds to the upper terra cotta band on the exterior.

Photo 38 A closer look at the wire mesh reinforcement within the gunite lining.

Photo 39 Saturated mortar was easily scraped away with a pointed hammer.

Photo 40 The mortar was easily penetrated by an ice pick.

Photo 41 Displaced masonry at the bottom of the gunite lining.

Photo 42 The brick masonry below the lining was generally in good condition.

Photo 43 A fillet bead of sealant has been installed at each of the reinforcing bands.

Photo 44 The sealant joints have typically failed and should be replaced.

Photo 45 A metal access ladder is affixed to the north elevation of the stack.

Photo 46 Damaged brick was observed at several of the anchor points.

Photo 47

Failures within the ladder itself were also found.

Photo 48

Components of the lightning arrest system are not properly secured to the stack.

Photo 49

Many of the anchors for the grounding cables have failed.

Appendix C: Structural Calculations

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Frederick A. Herget, PE
Kenneth L. Pensinger, PE
Allen R. Pulley
John A. Seest, PE
Scott A. Jones, PE
Victoria A. Emery, PE
Albert C. Kovacs, PE
Laura E. Metzger, PE
Matthew D. Kilgour, PE
Daniel M. Calabrese, PE

September 5, 2014

Susan Turner, AIA
Bailey Edward
35 East Wacker Drive, Suite 2800
Chicago, Illinois 60601-2308

Re: Structural Analysis of Chimney Stack
Great Lakes Naval Training Station

Dear Susan:

At your request, we have performed a rudimentary analysis of the stack to determine whether it meets current requirements of ASCE 07-10 as modified by UFC 3-301-01. An Occupancy Category of III was assumed. While the stack is not occupied, collapse of the stack onto adjacent structures could pose a substantial risk. The stack was only analyzed to the bottom of the circular portion of the stack. The rectangular breach area below the circular stack will likely require retrofit based upon the following analysis.

The stack was analyzed for a wind speed of 120mph as required for an Occupancy Category III. Analysis indicates that the stresses in the masonry for combined wind and dead load are within allowable limits.

The seismic analysis assumed an Ss of 0.15 and an S1 of 0.06, these are the approximate values indicated in the MCEr figures. A site class D was assumed. The MCEr figures indicate a risk of collapse of 1% in 50 years. The analysis indicates that a combined seismic load and dead load results in a tensile stress over a portion of the stack perimeter. The current masonry code does not allow tension in unreinforced masonry. Therefore, this rudimentary analysis indicates the stack should be reinforced for seismic loads.

If the determination is made to stabilize the chimney, more detailed calculations will need to be performed to refine this analysis and design any retrofits that are necessary.

Yours truly,

Frederick A. Herget
Professional Engineer

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Appendix D: Opinion of Probable Cost

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OPINION OF PROBABLE CONSTRUCTION COST

REPAIRS

September 12, 2015

Naval Station Great Lakes

100% Complete Study Document

Building B11 Radial Brick Chimney Assessment

Bailey Edward Project No: 13x152

This estimate represents Bailey Edward's opinion of probable construction cost for this project and is made on the basis of our experience and qualifications. We have exercised professional care in the preparation of this estimate. Since we have no control over market conditions or bidding strategies, no guarantee is given or implied with this estimate.

DESCRIPTION	QUANTITY	UNIT	COST	TOTAL	DIVISION TOTAL
Quantities					
Plan Radius interior	5.75	Ft	35.88		
Plan Radius exterior	8.2	Ft	51.168	9261.408	Area
Chimney height	181				
Number rings	26		35.88	932.88	LF Sealant
Number of round TC bands	3		51.168	153.504	
Number of Square TC bands	2		20	40	
DIVISION 1 - GENERAL REQUIREMENTS					
Site Superintendent	4	MO	$10,000.00	$40,000.00	
Trailer	4	MO	$1,000.00	$4,000.00	
Scaffolding - mobilization	1	LS	$15,000.00	$15,000.00	
Scaffolding - 2 teams, relocating scaffolding down	26	LS	$700.00	$18,200.00	
Scaffolding - Rental	4	MO	$2,000.00	$8,000.00	
Temporary Protection and Barricades	4	MO	$1,000.00	$4,000.00	
Dumpsters	4	MO	$100.00	$400.00	
Trash Haul Away	4	MO	$400.00	$1,600.00	
					$91,200.00
DIVISION 2 - EXISTING CONDITIONS					
Selective Demolition (top of chimney)	410	SF	$25.00	$10,250.00	
Selective demolition of interior gunite coating	897	SF	$4.00	$3,588.00	
Selective demolition of concrete sholders	4	EA	$250.00	$1,000.00	
					$14,838.00
DIVISION 3 - CONCRETE					
Removal of concrete grout (gunite)	897	SF	$15.00	$13,455.00	
					$13,455.00

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DESCRIPTION	QUANTITY	UNIT	COST	TOTAL	DIVISION TOTAL
DIVISION 4 - MASONRY					
Brick installation (top of chimney)	819	SF	$20.00	$16,373.76	
Brick Replacement (estimated)	80	EA	$200.00	$16,000.00	
Repointing	10158	SF	$6.50	$66,029.65	
Terracotta Replacement	205	SF	$150.00	$30,700.80	
Brick Rebuilding (select areas)	20	SF	$350.00	$7,000.00	
Terracotta Crack injection	90	LF	$35.00	$3,150.00	
Remove metal embedment and patch (estimated)	30	EA	$50.00	$1,500.00	
Reattach lightning protection anchors and patch (estimated)	30	EA	$50.00	$1,500.00	
Engineered Opening for Debris Removal	30	EA	$50.00	$1,500.00	
					$143,754.21
DIVISION 5 - METALS					
Cast Iron Cap repair	3	EA	$1,500.00	$4,500.00	
New metal roofing "shoulders"	4	EA	$1,400.00	$5,600.00	
New lead flashing at terracotta joints	60	LF	$150.00	$9,000.00	
New Ladder (Installed)	181	LF	$250.00	$45,250.00	
					$64,350.00
DIVISION 6 - WOOD, PLASTICS, COMPOSITES					
			$0.00	$0.00	
			$0.00	$0.00	
					$0.00
DIVISION 7 - THERMAL AND MOISTURE PROTECTION					
New Continuous Sealant at Steel Bands	1330	LF	$18.00	$23,946.62	
New cap on chimney including structure	210	SF	$40.00	$8,391.55	
					$32,338.18
DIVISION 8 - OPENINGS					
			$0.00	$0.00	
			$0.00	$0.00	
					$0.00

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DESCRIPTION	QUANTITY	UNIT	COST	TOTAL	DIVISION TOTAL
DIVISION 9 - FINISHES					
Paint Steel Bands	1330	LF	$18.00	$23,946.62	
			$0.00	$0.00	
					$23,946.62
DIVISION 26 - ELECTRICAL					
Lightning Protection Replacement	1	LS	$20,000.00	$20,000.00	
			$0.00	$0.00	
					$20,000.00

Subtotal	$403,882.01
Performance Bond (3%)	$12,116.46
Payment Bond (3%)	$12,116.46
Overhead and Profit (8%)	$32,310.56
Subtotal	$460,425.49
Design Contingency (25%)	$115,106.37
Total Including Construction Costs, OH&P and Contingency	$575,531.87

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OPINION OF PROBABLE CONSTRUCTION COST

SEISMIC UPGRADE

September 12, 2014

Naval Station Great Lakes

100% Complete Study Document

Building B11 Radial Brick Chimney Assessment
Bailey Edward Project No: 13x152

This estimate represents Bailey Edward's opinion of probable construction cost for this project and is made on the basis of our experience and qualifications. We have exercised professional care in the preparation of this estimate. Since we have no control over market conditions or bidding strategies, no guarantee is given or implied with this estimate.

DESCRIPTION	QUANTITY	UNIT	COST	TOTAL	DIVISION TOTAL
Quantities					
Plan Radius interior	5.75	Ft	103.2	area	
Plan Radius exterior	8.2	Ft	209.8	area	
Plan Radius Interior Concrete Void	3	Ft	28.1	area	
Chimney height	181	Ft			
Extent of seismic reinforcing	30	Ft			
DIVISION 1 - GENERAL REQUIREMENTS					
Site Superintendent	1	MO	$10,000.00	$10,000.00	
Trailer	1	MO	$1,000.00	$1,000.00	
Crane mobilization	1	LS	$15,000.00	$15,000.00	
Temporary Protection and Barricades	1	MO	$1,000.00	$1,000.00	
Dumpsters	1	MO	$100.00	$100.00	
Trash Haul Away	1	MO	$400.00	$400.00	
					$27,500.00
DIVISION 2 - EXISTING CONDITIONS					
Selective Demolition access opening (brick removal)	60	EA	$20.00	$1,200.00	
				$0.00	
					$1,200.00
DIVISION 3 - CONCRETE					
Pump charge for Concrete	85	CY	$15.00	$1,275.00	
Concrete Supply	85	CY	$105.00	$8,925.00	
Formwork and reinforcement, supply and instal	5	T	$2,400.00	$12,000.00	
					$22,200.00
DIVISION 4 - MASONRY					
Engineered Opening for Debris Removal	65	SF	$200.00	$13,000.00	
Engineered Opening for concrete pumping	25	SF	$200.00	$5,000.00	
Repointing	90	SF	$6.50	$585.00	
					$18,585.00
				Subtotal	$69,485.00
				Performance Bond (3%)	$2,084.55
				Payment Bond (3%)	$2,084.55
				Overhead and Profit (8%)	$5,558.80
				Total	$9,727.90
				Design Contingency (25%)	$17,371.25
				Total Including Construction Costs, OH&P and Contingency	$96,584.15

OPINION OF PROBABLE COST

MAINTENANCE

September 12, 2015

100% Complete Study Document

Naval Station Great Lakes

Building B11 Radial Brick Chimney Assessment

Bailey Edward Project No: 13x152

This estimate represents Bailey Edward's opinion of probable maintenance costs for this project and is made on the basis of our experience and qualifications. We have exercised professional care in the preparation of this estimate. Since we have no control over market conditions or bidding strategies, no guarantee is given or implied with this estimate.

DESCRIPTION	QUANTITY	UNIT	COST	TOTAL	VISION TOTAL
Quantities					
Plan Radius interior	5.75	Ft	35.88		
Plan Radius exterior	8.2	Ft	51.168	9261.408	Area
Chimney height	181				
Number rings	26		35.88	932.88	LF Sealant
Number of round TC bands	3		51.168	153.504	
Number of Square TC bands	2		20	40	
DIVISION 1 - GENERAL REQUIREMENTS					
Scaffolding Mobilization	1	LS	$15,000.00	$15,000.00	
Scaffolding Level Change	26	EA	$700.00	$18,200.00	
Scaffolding weekly rental	1	MO	$1,000.00	$1,000.00	
					$34,200.00
DIVISION 7 - THERMAL AND MOISTURE PROTECTION					
Cut Sealants, reinstall	8	HR/Ring	$85.00	$680.00	
Number rings	26	# Ring	$680.00	$17,680.00	
					$17,680.00
Total Maintenance Cost Per Occurance					$51,880.00