CAPITOL DOME STUDY FOR THE STATE OF IOWA

OPN Architects, Inc. + Simpson Gumpertz & Heger Inc. + Vertical Access LLC + Shuck-Britson, Inc.

State of Iowa – Capitol Dome Report

Project Number: RFP1816335222

On-Site Review Dates: November 23 to November 25, 2015

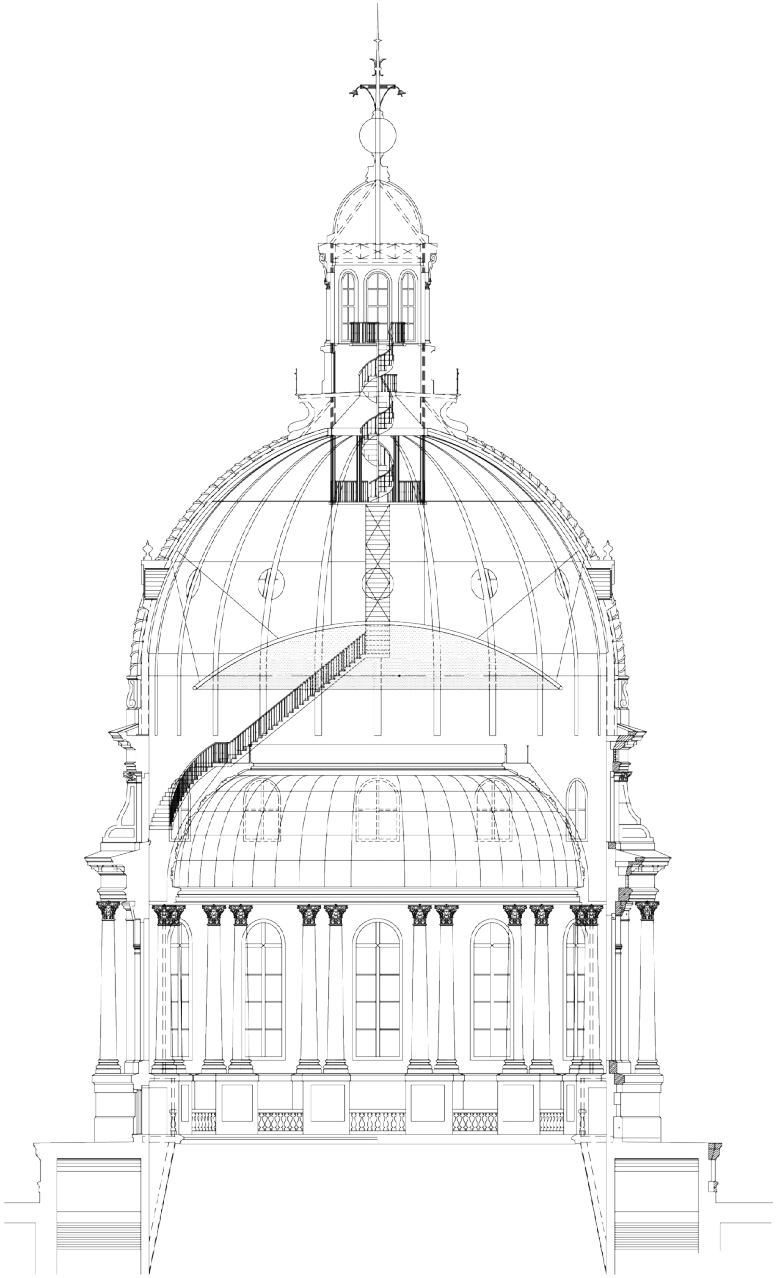
Report Date: January 12, 2016

Meeting on November 24, 2015 in the lantern to review live video feed down the dome.

Tim Ryburn	Iowa Department of Administrative Services
Jennie Elliott	Iowa Department of Administrative Services
Scott Gustafson	Iowa Department of Administrative Services
Bill Reynolds	Samuels Group
Mark Willemssen	Iowa Legislative Branch
Nicholas Floyd	Simpson Gumpertz & Heger
Casey Williams	Simpson Gumpertz & Heger
Evan Kopelson	Vertical Access
Kelly Streeter	Vertical Access
James Peters	OPN Architects
Abby Gilman	OPN Architects
Scott Allen	OPN Architects

Meeting on December 17, 2015 to review draft of the study.

Charlee Cross	Iowa Department of Administrative Services
Tim Ryburn	Iowa Department of Administrative Services
Jennie Elliott	Iowa Department of Administrative Services
Scott Gustafson	Iowa Department of Administrative Services
Jerry Dehnke	Samuels Group
Bill Reynolds	Samuels Group
Mark Willemssen	Iowa Legislative Branch
Steve King	Iowa Department of Cultural Affairs, Deputy State Historic Preservation Officer
Rick Seely	OPN Architects
James Peters	OPN Architects
Scott Allen	OPN Architects



Our team of OPN Architects, Inc. (OPN), Simpson Gumpertz & Heger, Inc. (SGH), Vertical Access LLC (VA) and Shuck-Britson, Inc. (SBI) was selected by Iowa Department of Administrative Services for this study to provide documentation and recommendations of the main interior dome issues recently observed inside of the Iowa State Capitol building. After the stairs to the lantern were cleaned, brick debris began falling at an accelerated rate. The top of the skydome was cleaned to the metal surface after the Phase 9 project (spring of 1998 to fall of 2000) and is now covered with brick and mortar debris. The scope of the study will review both the interior and exterior of the main dome from the stylobate level to the finial.

The team was on site together from November 23 to 25, 2015. Des Moines, Iowa, received about six inches of heavy snow starting the afternoon of November 20, 2015 and into the next day. By November 23, 2015 most of the snow had melted while ice was still found on the stylobate level roof and building projections. This water source provided a good opportunity to observe the water leaks and ice sheets falling off the main dome.

Summary of Restoration Completed During Phase 9, 1998-2000

- Iowa State Capitol Restoration Phase 9 scope was the last large portion of the exterior building restoration completed.
  - This phase included selective stone replacement of the light colored sandstone from Missouri with Indiana limestone. Most of the original sandstone had major surface erosion and was covered with a cement product that was also failing and falling on the building below. The selected area was resurfaced due to delaminated or exfoliation weathering of the original Missouri brown color sandstone by removal of an inch or more of the surface and then reset with the new limestone.
  - The original window frames were repaired by replacing the window sashes with new Honduras mahogany wood material. The painted elements were restored using sanded paint to create a faux stone.
  - The original exterior metal that had been painted was repaired and painted.
  - Light fixtures were replaced on the observation level and inside of the lantern.
  - The gold leaf on the dome was replaced with new 23-carat gold after the copper sheet metal details were repaired and after the new zinc-rich primer installation.
  - The copper flashing on the cornice entablature was replaced, original dome metal was repaired in selected locations and remained from the original 1880s.
  - New copper flatlock on the stylobate level was installed with expansion joints.
  - Fire sprinklers were installed in the interior of the dome to the level of the whispering gallery. New aluminum leaf was installed in the interior metal dome. Scagliola columns' paint was removed and the columns were restored. Reproduction of the GAR flag was installed under the repainted the skydome.

General Description of Dome Configuration

- The height to top of the finial down to the stylobate level is 158 feet, 6 inches while the exterior drum diameter is 78 feet, 6 inches.
- This study used the same architectural terms and nomenclatures for the building elements as the record drawings.
- The lantern is the 15 feet diameter cylinder that is 60 feet on the top of the main dome. Access from the lower lantern floor to the mid and upper lantern floor is provided by a spiral staircase.
- The radius of the interior of the main dome is 36 feet while the dome structure is supported by 24 radial ribs that span vertically along the dome from the 3-wyth masonry wall located 8 feet, 4 inches below the dome spring line, to the circular compression ring approximately 48 feet above. Flat masonry arches span between radial ribs. Masonry on the lower portions of the dome (longer span) consists of 3-wythes of masonry and transition to a single wythe of masonry at the top. Hangers extend down from the compression ring to support the lower lantern landing. Access to this landing is

provided by a stair that follows along the perimeter of the dome and crosses above the interior suspended dome to the lower landing.

- The drum height also called Level H and Level J in this study is 57 feet above the stylobate level roof with an interior diameter of 64 feet. The drum is brick masonry with skin of sandstone with limestone elements and opening in the drum are the large windows that can be seen from the whispering gallery level.

Summary Dome Study

- The Iowa State Capitol Restoration Phase 9 record drawings by RDG Planning & Design dated November 30, 2001 were available for this study. No specifications of the Iowa State Capitol Restoration Phase 9 were requested or provided.
- The team performed the exterior survey of the main dome and masonry drum using industrial rope access techniques on site for three days.
- The team provided a live video feed during a meeting in the lantern on November 24, 2015 by two rope access drops to allow the Iowa Legislative Branch, Iowa Department of Administrative Services and The Samuels Group individuals to observe our findings in real time. This allowed close video observation and redirection towards any architectural detail on the dome or drum. The video is attached to this study for future reference.
- The team performed hands-on inspection of portions of the interior masonry, where accessible from stairways.
- Our approach for the visual inspection of the dome lantern was to use video camera and telescoping pole. The video is attached to this study for future reference.
- The team performed moisture testing of brick masonry to detect elevated moisture levels that may be indicative of water leakage or condensation. We installed four data loggers to document ambient temperature, surface temperature of selected framing members, and relative humidity. The data loggers collected information for twenty-three days during the allowable time-frame to include this information with this study. The data loggers will remain on the building and continue to collect information until Spring of 2016.

Priority Repairs

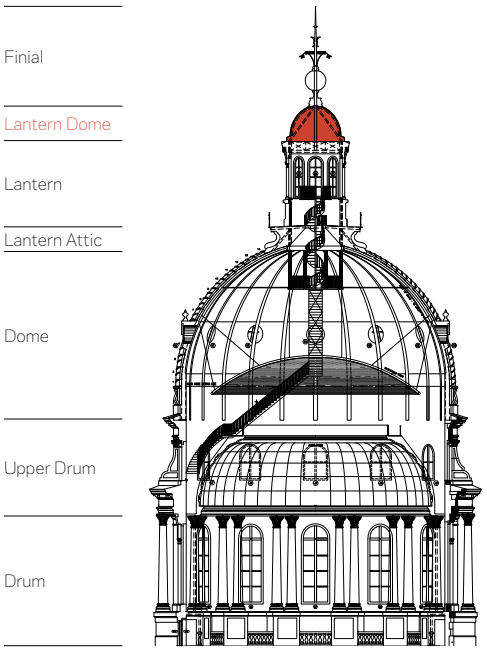
- Address bulk leakage at observation deck at the lantern level, the primary area that is causing damage to the masonry dome below. The source of the leakage is the observation deck planks and guardrail connections.
  - Solution: Provide plywood or heavy gauge sheet metal deck covered with continuous roof membrane under the observation metal deck planks. Repair the damaged masonry at the top of the dome with a new working platform.
- Address the condensation issues at lantern level and top of the dome.
  - Solution: Engage an MEP consultant to assess the current HVAC system and control systems. We understand that many of the existing HVAC systems are not currently in operation and should be placed back into operation to limit relative humidity within the building, particularly during cold winter months. Review with an MEP consultant the options to increase the ventilation of the lantern while limiting the amount of high humidity passing through the interior of the dome. Excess moisture in the air in contact with the uninsulated dome and sheet metal is an important issue to address for the life of the building.
- Perform waterproofing repairs to copper sheet metal to address direct leakage paths in the lantern cladding, dome and stylobate level.
  - Solution: Repair openings at the base of the brackets, repair holes and penetrations in the cladding, repair copper entablature roofing above the upper cornice and open joints in the flat lock copper on the stylobate level.
- Perform waterproofing repairs to address leakage through circle wood windows on the dome level.
  - Solution: Remove, salvage, reinstall and repaint window as needed to extend the life of the building.
- Perform repairs to the interior masonry that is falling to the surface of the skydome, stairs and the walking surfaces below. This brick spans between

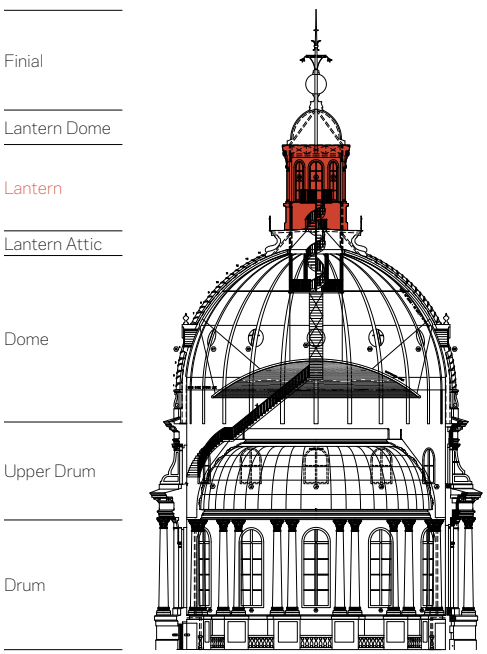
existing metal beams and is the structural component for the roof of the dome. While not at risk of immediate structural failure, portions of the top of the dome are only one brick in thickness.

- Solution: Install working platform inside the main dome to allow access for repair and replacement of brick masonry as needed as well as future monitoring of interior masonry dome.

Maintenance Repairs

- When the priority repairs are addressed above, the following maintenance repairs should also be completed during the same time frame while the scaffolding access is in place.
  - Point deteriorated mortar joints at large stone brackets above lower cornice.
  - Remove and replace sealant joint at lower cornice reglet-set counter flashing.
  - Repair wood windows, wood trim, and glazing on the drum.
  - Resurface delaminated or exfoliating sandstone in situ, primarily at lower entablature around each set of paired columns and soffits behind these paired columns.
  - Repair the damaged brick masonry at the top of the dome and clean the mortar and brick dust from surfaces below.





OBSERVATIONS

1.1 Interior Observations

The main dome configuration and nomenclature used in the following subsections is shown on diagrams to the left. A ladder was used to access the lantern attic (at the top of Level K), but otherwise we did not use any special access to make our interior observations.

1.1.1 Lantern Dome

The lantern dome is accessible via a built-in ladder and a small hatch in the lantern ceiling (Photo 2). We note the following observations relevant to our work:

- The underside of the dome's sheet metal roof is visible (Photos 3 and 4); there is no deck (other than wood blocking to support a projecting cornice) or secondary waterproofing system behind/under the metal roofing. The sheet metal is secured to the metal structure with riveted sheet metal clips.
- Prior to full team arrival at the site on November 17, 2015 while during a light rain, OPN accessed the dome attic and observed leakage at two locations under the projecting cornice (Photo 5)
- We observed condensation on the back side of the dome's sheet metal roofing and cladding (Photo 4). We are certain this moisture in Photo 4 is due to condensation and not leakage as the moisture was observed on a cold morning, several days after the most recent snow/rain. The moisture was also more prevalent on the north and west elevations, which had not yet seen any direct sun at the time of our observations. During the November 23 through 25, 2015 site visit, the condensation was observed collecting on a horizontal soffit formed with sheet metal cladding and metal support framing near the roof eave (Photo 6). Wood blocking and metal framing components that abut the cladding are typically water stained.
- The 1997 Phase 9 restoration drawings show removal of eight can lights originally installed in the overhanging soffit. These eliminated light fixture penetrations were closed with painted copper sheet metal.
- The ceiling access hatch has a louvered trap door that allows airflow between the dome and lantern below (Photo 2). The dome roof has no louvers or other openings that allow ventilation to the exterior.

We saw water stains and some limited surface corrosion of metal framing elements, but no other obvious signs of damage or water-related deterioration. We saw no daylight through the roof or sheet metal closures.

1.1.2 Lantern (Level L)

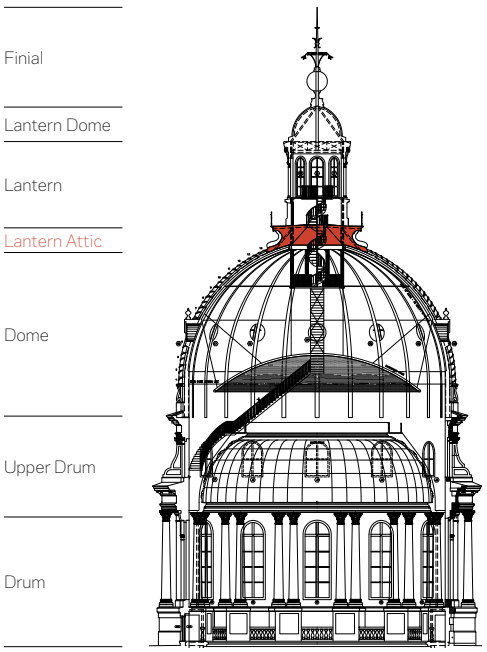
The lantern consists of two levels – a lower enclosed level with a door to the observation deck and an upper level with eight large arched divided-lite wood windows (Photos 7 and 8). The lantern interior is finished with painted wood cladding and window trim. We note the following observations relevant to our work:

- We observed condensation on interior face of the lantern window glazing (Photos 8 and 9). Wood finishes around the windows are water stained, particularly at horizontal mid-rails (Photo 10) and the base of the windows (Photo 11).
- Lantern glazing is single pane glass. The 1997 Phase 9 restoration drawings provided for new windows. The use of

insulating glass units (IGUs) were considered during the restoration project, but the section would have been too large to replicate the existing window frame profiles at this location.

- The lantern has two ceiling fans, which ran continuously during our time onsite (Photo 2). The 1997 Phase 9 restoration drawings show adding these fans using the existing electrical within this space. We saw no louvers or other roof openings that would allow for venting this space to the exterior. We felt a strong and sustained airflow to the exterior when we opened the observation deck door to the exterior.

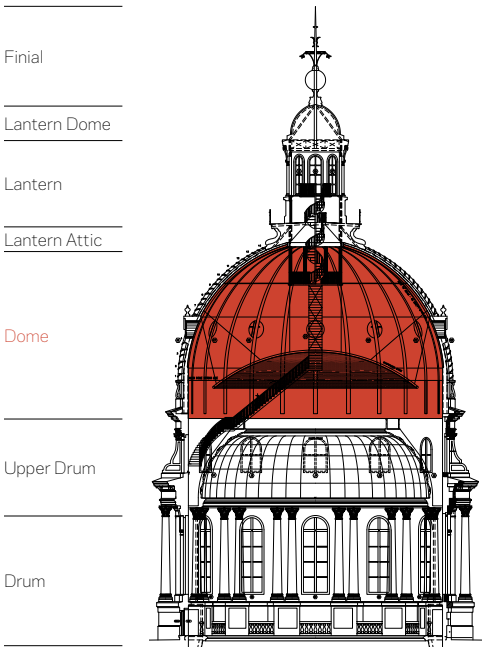
1.1.3 Lantern Attic (Lantern Level K)

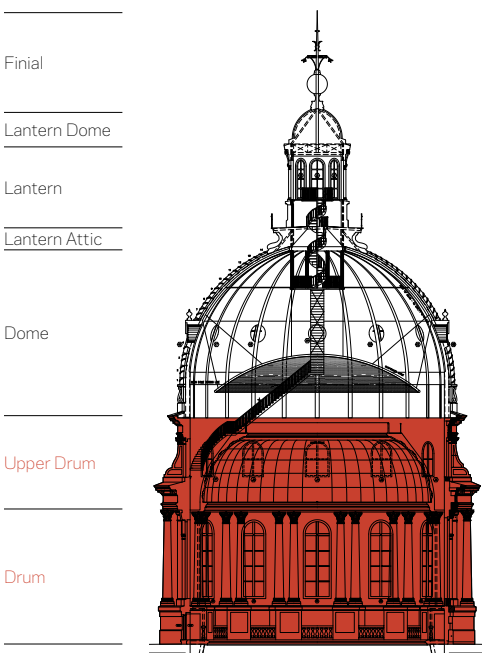


The lantern attic is an enclosed ring between the lantern observation deck and the main dome structure. This attic space is separated from the main dome interior by metal panels and is accessible only through a small opening in the panels (requires a ladder, which we borrowed from DAS) (Photo 12). We note the following observations relevant to our work:

- Similar to the lantern dome roof, the back side of the metal cladding enclosing this space is visible and there is no backup substrate or waterproofing behind the metal cladding (Photo 13). In this attic space, the sheet metal is typically mechanically anchored to the metal straps connected to the metal structure.
- The metal framing members supporting the lantern observation deck have varying stages of corrosion (Photo 14). Framing members directly below the observation deck are particularly corroded, with some members having nearly an inch of rust scale built up under the observation deck planks (Photo 14). We observed condensation on the underside of the dome's sheet metal roofing (Photo 15). Similar to the attic dome condensation, we are certain this moisture is condensation related, as we observed moisture several days after the most recent rain/snow event; we also noted frost/ice when observed early on a cold morning.
- We observed daylight shining through perforations or openings in the roof within the attic at several locations, most regularly near the exterior edge of the observation deck. Similar to the lantern dome roof, the sheet metal cladding has an overhanging profile that forms a horizontal "pan" below the observation deck. This "pan" is filled with wet debris (Photo 16).
- The top surface of the main dome's brick vault is visible from the attic space. Its brick surface is typically covered with debris, but we also observed crumbling and deteriorated brick surface. We also noted one location with an approximately 4-inch diameter hole through the brick (Photos 17 and 18). We did not determine if this hole was man-made (e.g., for a conduit or similar that has since been removed) or the result of brick deterioration or damage. At this hole, we measured and confirmed that the brick vault is only one wythe (approximately 4 inches) thick.

There is no hatch door or closure to cover the opening between this attic and the main dome (Photo 12). When accessing the attic, we typically noticed strong airflow into the attic from the main dome area. We saw no provisions for ventilating this space to the exterior, but we saw daylight through the roof assembly, indicating numerous small air leakage paths.





1.1.4 Dome Interior

The main dome is constructed with 24 12-inch-deep wide flange metal ribs extending vertically from the base of the dome (bottom of Level K) up to a compression ring at the base of the lantern (Photos 19 and 20). The ribs are recessed into the brick masonry of the dome. At the circular windows, a ½-inch thick circumferential strap is riveted to the exterior side of the wide flange ribs (Photo 20). No additional circumferential bracing is visible from the interior. The skydome, stairs, and lantern access platform are all supported via tie rods attached to the dome's metal frame (Photos 19 through 21).

The exterior dome consists of a brick masonry shell that spans between the metal ribs in a running bond pattern. The masonry is one wythe thick at the top (as measured at hole noted in previous section) and visibly steps out to a thickness of two and then three wythes at the lower portions of the dome (Photos 20 and 22). Wood blocking is installed around the wide flange web at the single-wythe areas (Photo 23), presumably to support the masonry termination and shoring during the original construction where it abuts the wide flange web.

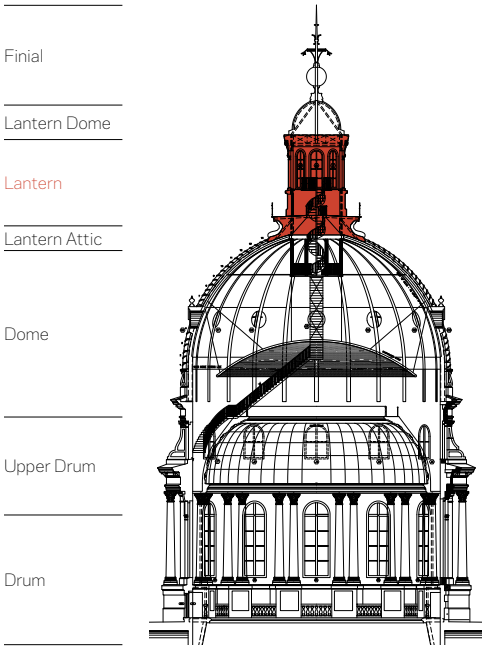
We note the following observations relevant to our work:

- The interior brick surface is deteriorated and crumbling at isolated locations (Photos 19 through 27). This deterioration typically consists of spalled brick shells that have exposed the red brick body below and has caused brick debris to fall to the top of the suspended sky dome and walkways below (Photo 28). Deteriorated areas with exposed red brick body are easily identifiable when compared to the dome's typical dark brick surface that is due to an early nineteenth century fire (January 4, 1904) in the building. Deterioration is most prevalent in the uppermost 6 to 8 feet brick below the lantern attic (Photos 19, 24 and 25) and adjacent to isolated circular windows (Photos 26 and 27).
- We also observed isolated brick deterioration on the brick walls below the dome (Photo 29), though only within the northwest quadrant.
- We observed water staining on the wood sill at all accessible circular windows on Level K (Photos 30 and 31).
- The spiral stairway leading up to the dome (Level H) has several rectangular round top wood windows. Wood components are aged and water stained (Photo 32).

1.1.4 Drum (Level H)

The interior of the drum at this level, also called the whispering gallery level, is currently the upper most level that visitors to the Iowa State Capitol building are allowed to tour with a Capitol Tour Guide. We note the following observations relevant to our work:

- We observed water staining on the wood sills at all windows on Level H and water staining on the plaster surfaces below the windows.
- Plaster delamination was visible in one location at the capital of the scagliola column in the northwest. At this point in time the plaster and paint repair is not the full cost but process to gain access is the issue. During the Phase 9 project, a 115-foot scaffolding platform extended to the basement level. At this point, we do not recommend addressing this issue because it will be challenging to access the area, which is well above that height.



1.2 Exterior Observations

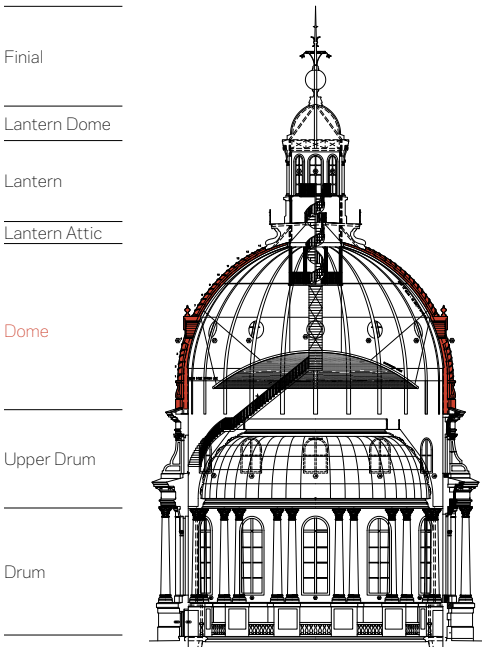
With assistance from Vertical Access LLC (VA), Simpson Gumpertz & Heger (SGH) performed a hands-on survey of the dome roof using industrial rope access (Photo 33). We also inspected the upper portions of the lantern using video documentation with a pole-mounted high definition camera.

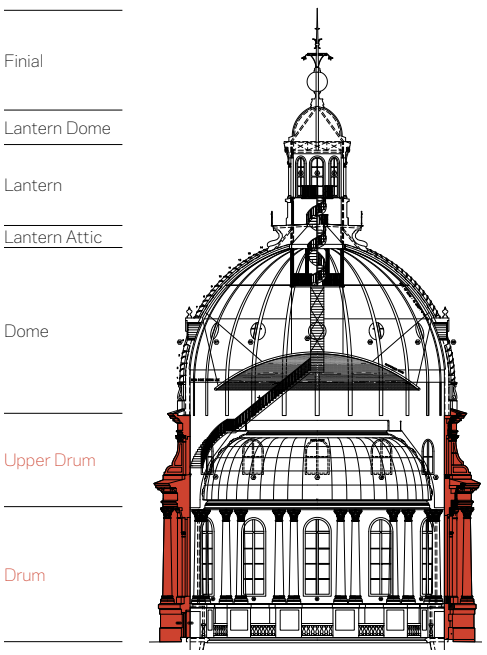
1.2.1 Upper Lantern

We saw no obvious damage or deterioration of the lantern's painted metal cladding, gilded dome roof, and finial (Photo 34). We also did not observe any obvious defects or leakage paths in the video documentation and were therefore unable to identify the source of the leakage we saw at the dome cornice.

1.2.2 Observation Deck and Lantern Attic

- The observation deck consists of twenty-four diamond plate metal planks (Photo 35) supported on the metal framing observed in the lantern attic below (Photo 14). Joints between metal plates are covered with metal covers that are mechanically fastened into the framing below.
- Multiple covers are loose, and two could be lifted off the deck. At these locations, we noted that the underlying framing is severely corroded and anchors are no longer engaged (Photo 36). At these joints, we observed the top of the metal framing in the attic below. We saw no roof deck or waterproofing membrane below the planks.
- In addition to the loose covers and open panel joints, we observed holes in several of the observation deck planks (Photo 37).
- At the lantern, the planks and covers have a slight upturn and are covered by the lantern cladding. At the observation deck edge, the planks and covers lap over the metal cladding below. This overlap is very small (visual estimate 1/4 inch), and we saw gaps at plank joint locations (Photo 38).
- We observed rust stains at multiple locations on the exterior of the lantern skirt (Photo 39 and 40) directly below the seams in the cladding soffit (horizontal interior shelf that collects water and debris shown in Photo 16).
- The paint on the metal cladding is peeling at some locations, including at panel seams (Photo 39). In addition to stains on the white painted skirt, rust-colored runoff appears to have stained the gilding below (Photo 41).
- Twelve decorative sheet metal brackets are aligned with major ribs of the dome below (Photo 42). We saw gaps in the sheet metal at the base of each bracket (Photo 43 and 44). We felt warm interior air flow out of these gaps and observed condensation and rust staining on the bracket and sheet metal below (Photos 43 and 44).
- We noted several isolated holes (Photo 45) and fastener heads where the coating had separated (Photos 46 and 47) in the painted metal cladding.
- The coating obscures most seams and anchor penetrations in the lantern skirt, but other than the conditions noted above, we saw no obvious damage or deterioration on the lantern skirt's sheet metal cladding.



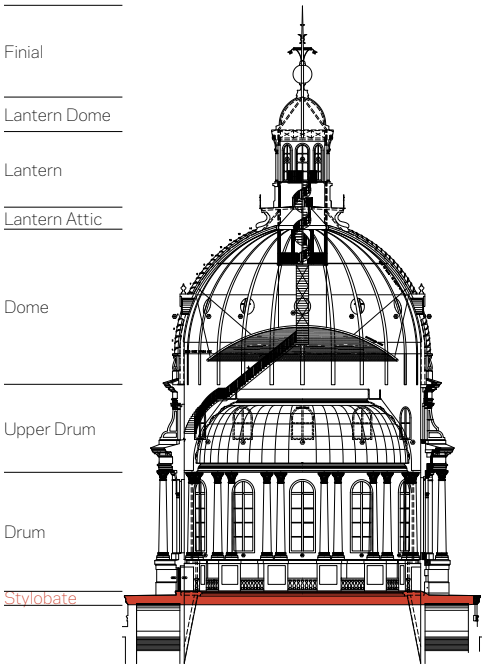


1.2.3 Dome (Level K)

- The dome roofing consists of continuous sheets of copper running circumferentially between twelve raised ribs. Individual copper sheets are separated by stepped horizontal lock joints (Photo 48). Vertical ribs are covered with a continuous cap flashing and a decorative coil (Photo 49). All metal roofing, flashing, and decorative metal is gilded.
- Roofing sheets, lock joints, and rib flashing are typically intact. We observed isolated splits where the sheet turns up at ribs (Photo 50), oil-canned or buckled sheets (Photo 51), and isolated sheet metal repair patches (Photo 52).
- Transitions between the sheet metal roofing and the lantern skirt sheet metal, window eyebrow dormers, and flashing at the base of the dome are covered with metal fillet (Photos 53 through 55). The fillet material is relatively soft and appears to be lead rather than solder (which is lead based, but typically includes tin, resulting in a stiffer more brittle alloy). We saw no obvious defects on this fillet; however, at several isolated locations, the fillet material is split or has separated from the sheet metal (Photos 53, 56, and 57). We also noted one location with a hole in the fillet and water staining below this hole (Photos 58 and 59). At the base of the dome, this fillet transitions to soldered cladding joints; in some cases, the solder appears intact and recently applied (Photo 55), though in most cases these joints are cracked or open (Photo 60).
- Each of the twelve dome bays has an eyebrow dormer with a circular window (Photos 54 and 61). The eyebrow dormer is clad with gilded metal. Other than through-bolts noted at the window interior (Photo 27), we could not observe any portion of the eyebrow dormer's structure or condition. We observed water stains coming from underneath isolated dormers (Photo 62).
- Dormer circular windows consist of a painted wood frame and single-pane glass secured with a mechanically fastened wood stop (Photo 63). We saw no sealant or putty glazing perimeter seal between the glass and the stop. The window frame is secured into the dormer opening by a mechanically fastened metal stop; there is no visible seal between the window and stop, or between the stop and gilded dormer cladding. We observed water stains on the horizontal portion of metal at the bottom of each window. We noted condensation on the inside of the window glazing during cold morning conditions (Photo 64).

1.2.4 Drum (Levels H and J)

- At the base of the gilded dome, the masonry drum that supports the dome is ringed by a copper-clad entablature and projecting masonry cornice with a lead-coated copper cornice flashing (Photo 65). The copper cladding on the entablature is typically intact. Non-skyward-facing joints are typically not soldered watertight (Photo 66). Skyward-facing joints are typically soldered, though many of these joint are cracked (Photo 67). We did not see any expansion joints in the soldered portions of the entablature.
- Based on the 1997 Phase 9 restoration drawings, the cornice masonry and flashing was removed and replaced in the late 1990s. This cornice flashing is typically intact and has locked joints at corners presumably to accommodate expansion; however, we periodically observed cracked solder joints, typically directly adjacent to these locked corner transitions (Photo 68).
- At the bottom of Level J, the drum has another masonry cornice that is also covered with lead-coated copper cornice



flashing (Photo 69). The 1997 Phase 9 restoration drawings also show replacement of this cornice flashing and portions of the masonry below. Similar to the upper masonry cornice above, this cornice flashing is typically intact and has locked joints at corners presumably to accommodate expansion, though we observed isolated cracked solder joints. This cornice flashing is counter flashed by a reglet-set metal flashing. The sealant in the reglet joint is debonded and failing over much of the length of the joint (Photo 70).

- Replacement cornice, entablature, and column capital stones are lighter colored than adjacent existing stones. OPN indicated replacement stones are limestone, while the original stone is sandstone. We use these terms in our descriptions. None of these areas appear to be a current source of leakage or immediate "hit by" hazard. The exterior masonry is typically in good condition except for the following areas of concern:
  - Mortar joints in the stone brackets at the base of Level J are typically cracked and failed (Photo 69 and 71).
  - Portions of the original sandstone frieze are weathered and delaminating (Photo 72), primarily within the entablature at the top of Level H. OPN indicated that many of the frieze stones at the top of Level J may have been removed, resurfaced (i.e., had an outer, damaged layer removed to expose intact stone), and reinstalled. This was completed to gain access to the light colored sandstone below and replace with limestone.
  - The stone soffit above stone columns at Level H is typically water stained and exfoliating (Photo 73).
  - We observed isolated cracks, epoxied stone repairs (e.g., stone dutchman), and surface deterioration at sandstone areas (Photos 74 and 75).
- Windows at Levels J and H are wood framed with single-pane glazing. Horizontal frame components are weathered and typically have peeling paint (Photos 76 and 77). Portions of the frame are coated with a sanded paint coating; this coating is generally intact, but beginning to crack and fail at isolated locations (Photo 77). We observed condensation on the interior of these windows during cold early morning conditions (Photo 77).

1.2.5 Stylobate Level

This is the level that the main drum to structure below creates the transition from the octagon shape in plan to the round drum at the base of the dome. The flatlock copper roof protects the building below and is a concern as bulk leakage was observed in the attic level directly under this roof level. Below the attic level you will find the gallery level of the House Chamber on the north and Senate Chamber on the south. At the time of the survey both attic space on the west had water leakage on the floor of the attic and water stains on the ductwork and metal framing.

We did observe the following moisture related issues connected to the stylobate level:

- Interior brick masonry spalling, salt buildup and deterioration at the attic ceiling.
- Active water on the surface of the attic floor. This review was after a 6 inch heavy snow that was melting on the copper surface (Photo 86).
- The expansion joint was new detail from the late 1990s project and this should the taken to the edge of the stylobate level, as cracks in the copper section are transferred from the expansion joint to the solder joint of this material (Photo 87).

The copper flashing on this cornices is generally intact, though we did observe cracked sealant joints, and suspect the solder joints on the outside of the corner are cracked while allowing some water infiltration into the masonry below.

1.3 Miscellaneous Observations

Our scope did not include the four smaller corner domes (Photo 78), but we noted from the exterior that the roof construction of these domes appears similar to the main dome. SGH and OPN also accessed the southeast and southwest dome attics to observe their interior construction. The small domes, appear constructed similarly to the main dome with wide-flange metal ribs, brick masonry vaults, circular eyebrow dormer windows, and lanterns. We did not have hands-on access to the dome masonry, but from the attic floor, we noted that small domes appear to have similar, but less severe, brick deterioration below the lantern and around windows as the main dome (Photo 79).

The small dome lanterns are also similar to those on the main dome, except that they have no observation decks and have louvers instead of fixed glazing. During our limited interior access in the southeast and southwest small dome, we noted that the louvers are covered but could have some partially available free area.

STRUCTURAL OBSERVATIONS

2.1 Shuck-Britson, Inc (SBI) completed the inspection and structural evaluation of the main dome at the State Capitol in Des Moines, Iowa. The purpose of our inspection/evaluation was to determine the following:

- Identify the dome framing system.
- Evaluate the framing condition and determine adequacy to support superimposed loads.
- Identify required dome repairs and propose a construction means and method sequence that could complete the repairs.

On November 24, 2015 SBI met with representatives from OPN Architects and the State of Iowa to review the condition of the structural framing system and discuss potential repair methods and the challenges to reach the interior dome masonry for possible repairs.

The main dome consists of the following components:

- **Lantern Dome**
  The lantern dome is supported by 8 cast-iron radial ribs (Photo 3). The radial ribs extend from the braced compression ring at the base of the dome to a cast-iron compression ring at the top. Purlins span between radial ribs which support the copper sheeting that forms the lantern dome.
- **Lantern**
  Eight cast-iron columns extend above the dome compression ring to form the structure of the lantern (Photo 13). Cantilevered radial floor beams form the structure of the mid lantern landing. A portion of this landing extends beyond the lantern walls to form the exterior lantern walkway. The lantern columns continue up to support the upper lantern observation level. Curved and radial floor beams frame the upper lantern floor. The lantern columns extend up to a braced compression ring at the bottom of the lantern dome. Access from the lower lantern floor to the mid and upper lantern floor is provided by a spiral staircase (Photo 19). Walls above the mid lantern floor are constructed with wood.
- **Dome**
  The dome is supported by 24 cast-iron radial ribs that span vertically along the dome from the 3-wyth masonry wall located 8 feet, 4 inches below the dome spring line, to the circular cast-iron compression ring approximately 48 feet above (Photo 19, 21). Flat masonry arches span between cast-iron ribs. Masonry on the lower portions of the dome (longer span) consists of 3-wythes of masonry and transition to a single wythe of masonry at the top (Photo 20). Hangers extend down from the cast-iron compression ring to support the lower lantern landing. Lateral ties extend from each hangar to the radial ribs, to stabilize the landing (Photo 21). Access to this landing is provided by a cast-iron stair that follows along the perimeter of the dome and crosses above the interior suspended dome to the lower landing. All cast-iron connections are either riveted or bolted. Flat masonry arches are supported on the flange of the radial ribs by continuous wood sleepers (Photo 23).

2.2 **Based on our site visit and evaluation of the existing conditions we make the following conclusions and recommendations**:

2.2.1 Lantern Dome

- The cast-iron ribs and purlins appear to be in good condition. Minor surface rust was noted.
- The source of moisture should be repaired to prevent further damage to the lantern dome framing.

2.2.2 Lantern

- Exposed portions of lantern columns appear to be in good condition. All exposed rivets and bolts are solid and intact.
- Mid lantern floor framing shows signs of significant deterioration from moisture in the secondary members. Main circular and radial members appear to be in good condition.

Repairs to the members require replacement. Temporary removal of floor plates will be required to access the deteriorated members.

- Upper lantern floor framing shows signs of deterioration from moisture in the secondary members. Main floor framing members appear to be in good condition. Deteriorated members under the observation level will need to be replaced. Temporary removal of floor plates will be required to access the deteriorated members.
- Exterior wood lantern walls show signs of moisture penetration and deterioration. All deteriorated members should be replaced.

2.2.3 Dome

- The exposed portion of the cast-iron ribs appear to be in good condition. Portions of the ribs covered by masonry or wood sleepers could not be observed. However, we did not observe any type of deformation in the cast-iron ribs.
- The masonry flat arch dome exhibited areas with significant deterioration that requires repairs to the masonry. Most of the masonry in the upper 10 feet of the dome had significant section loss from moisture penetration. Several other areas along the remaining portions of the dome showed signs of deterioration from moisture penetration. Repairs to the masonry require removal down to solid masonry, and replace with either mortar or new brick.
- The exposed portions of the cast-iron compression ring appear to be in good condition. All bolts and rivets connected to the hangers or ribs appear to be solid and intact.
- Lower lantern landing framing appears to be in good condition. Rivets and bolts appear to be solid and intact. Floor plates appear to be solid. Lateral bracing rods appear to be tight and are preventing lateral movement.

2.2.4 Working Platform Access To Masonry Repairs

- Access to repairs of the dome masonry arch creates significant challenges. We propose building a permanent mezzanine platform above the circular portal windows that would cover the entire area encircled by the dome (refer to the “working platform” section). The platform would be hung from the dome compression ring in the center and connected to the cast-iron ribs along the perimeter. To minimize weight we would propose fiberglass beams and grating. All materials would come through the round circle windows. In addition to providing access for repairs, the platform, if left in place, also provides access for future inspections.

FIELD TESTING

3.1 Water Testing

Using a water bottle, we poured water onto a failed observation deck cover and onto holes in the observation deck planking. In both cases, water leaked immediately into the attic space below (Photo 80), ran over corroded framing members, and collected on the horizontal soffit where we observed wet debris. We did not have access to an adequate water source to perform formal tests (e.g., water tests in accordance with ASTM E2128 and ASTM E1105) of potential water leakage paths at metal cladding, windows, or observed flashing defects.

3.2 Temperature and Relative Humidity Readings

OPN installed temperature and relative humidity (RH) data loggers in the lantern (Photo 81), base of dome, drum (Level H), and exterior. On November 25, 2015, SGH also used these data loggers to take spot readings at representative interior spaces on the lower occupied floors. At the time of this report, we only have data from November 17 through December 10, 2015 (not through the colder winter months). We note the following from this initial data provided:

- The temperatures of the drum ranged from the high 50s to mid-60s (°F). RH ranged from approximately 45% to 65%.
- The temperatures of the dome ranged from the mid-40s to high 60s (°F). RH ranged from approximately 45% to 65%.
- Temperatures in the lantern are typically in the 50s (°F) with an RH between 50% and 70%. This space is influenced by the sunlight entering the mostly window glass wall construction.
- OPN and SGH took spot readings in the southwest and southeast small dome attics. In both attics, the temperature was approximately 64 °F and the RH was 46% to 48%.
- OPN and SGH took spot readings in a Ground Level office spaces, the Senate Chamber, House Chamber, Law Library and within the Second Level open rotunda space toward the Grand Stair. In all locations, temperature was 74 to 76 (°F) and the RH was between 33% and 38%.
- OPN and SGH recommend leaving the data loggers in these spaces over the cold winter months in order to obtain additional data that may be useful during the eventual design of any ventilation or HVAC modifications.

3.3 Brick Moisture Readings

OPN and SGH used a Tramex MRH III moisture meter with 1 1/2 inch masonry pin probes to take representative moisture readings in the surface of the brick and at a depth of approximately 1 3/8 inch. (Photo 82). Individual moisture readings are not relevant and intended only as a comparison between intact brick and spalled/deteriorated locations. The moisture readings in damaged areas were nearly twice as high as the readings in the intact brick. We also note that the brick is relatively soft (both at intact and damaged locations) as we were able to fully insert the prongs of the testing probe into the brick using only the integral hammer/plunger on the probe handle.

3.4 Infrared Scanning

VA and SGH conducted limited infrared (IR) scans of the dome interior using an FLIR IR camera. Wet materials typically have different thermal conductivity than their dry counterparts, so thermal anomalies identified in an IR scan may indicate saturated components. Our IR scans are shown in Appendix section of the study and titled "Infrared (IR) Scans" and we note the following:

- The most notable temperature variations correspond to the extents of the interior attic (which covers a portion of the dome, so not exposed to exterior temperatures) and steps in the brick masonry thickness.
- At the south and east elevations (where sun was shining at the time of the scan), the scan identified horizontal thermal anomalies at regular intervals down each bay. It is likely that these bands correspond with embedded metal within or outboard of the brick, though we cannot confirm.

- The weather during our site visit was relatively warm, so there was not a significant temperature differential between interior and exterior conditions during our scanning. Therefore, the temperature variations observed in our IR scan are limited, and we could not discern patterns or thermal anomalies that may correspond with leakage or saturated brick.

DISCUSSION & CONCLUSIONS

4.1 Leakage

Other than the drum cornices rebuilt in the late 1990s, all of the existing sheet metal roofing and cladding systems on the dome lack a backup substrate or secondary waterproofing system. These existing systems thus rely solely on the sheet metal to prevent water entry to the interior or saturation of masonry components below. The sheet metal roofing and cladding is generally intact, but aged, and we observed isolated penetrations, open seams, and other potential water entry paths at all roofing and cladding locations.

The most reliable and comprehensive method to address all leakage would be to remove the original 1880's sheet metal roofing, reinstall the sheet metal roofing and cladding on the lantern, dome, and drum with a continuous underlayment (e.g., self-adhering membrane). Replacement sheet metal could be designed to allow drainage of this secondary membrane and to better accommodate expansion at cornices and other soldered elements. This approach would also expose the exterior side of the brick shell and metal ribs, allowing for thorough assessment of these structural components. Given the enormity of this undertaking, a targeted repair of current known leakage areas is a reasonable initial approach; however, we note that piecemeal repairs will not address all potential leakage sources and repairs to existing sheet metal components lack the redundancy that would be provided by an underlayment. In the targeted repair approach, the State must plan for continued periodic inspections and budget for semi regular maintenance and repairs resulting from these inspections.

4.2 Condensation

The relative humidity observed within the dome and lantern attic space are very high (45% and greater), resulting in relatively high dew point temperatures (40°F and above). The dome attic is uninsulated, so exterior wall and roof components (particularly conductive materials like glass and metal cladding) regularly drop below these dew point temperatures during colder months and produce condensation.

Relative humidity (RH) is the ratio of the amount of water vapor in the air at a specific temperature to the maximum amount that the air could hold at that temperature. Cold air can hold less water vapor than warm air, so when cold air is heated the maximum amount of water vapor the air can hold goes up, while the actual amount of water vapor in the air remains constant, resulting in a lower relative humidity. In cold climates, interior heated spaces typically have an RH of 10-20% during cold winter months unless actively humidified. The dome attic is completely open to the rotunda and occupied space below, so active humidification within these occupied spaces below appears to be the cause of the elevated relative humidity observed within the dome and lantern spaces.

DAS reported that the building is actively humidified in offices and chamber spaces, though we do not have detailed information on the MEP or control systems. OPN had a follow-up conversation with the mechanical engineer that was with Brooks Borg Skiles Engineering LLP at the time of interior Iowa State Capitol projects. After a brief walk through the building, it was determined that HVAC units are not in operation for the office spaces or the rotunda space. These HVAC units need to be placed back in operation for the ventilation air requirements and to reduce the RH in the building. The rotunda HVAC unit above the Law Library provides the exhaust in the building and is at least one of the reasons the building has an odor in the restroom spaces.

The relatively high temperatures (for an unheated space) and high RH in these attics is also due to the stack effect. The stack effect is the result of warm air rising due to its buoyancy relative to colder exterior air. The large oculus atop the rotunda provides a direct path for warm, humid interior air to rise up and into the dome and lantern. This direct link between the humidified space and attic makes it impractical to prevent airflow or eliminate the supply of humid air into this space. Without any current ventilation path, this warm, humid air stagnates in these attic spaces. If ventilation were provided at the top of the space, the stack effect would provide natural passive ventilation; however, it would also draw more warm humid air from the space below.

Passive ventilation is relatively easy to accomplish in this space, but may not significantly reduce condensation potential due to the large continuous source of moisture provided by the humidified building spaces below. The high RH, combined with incidental leakage, also adds stress on the aged masonry and roofing materials and may eventually result in more

substantial deterioration that requires a significant repair program. Modifying the HVAC system controls to limit the wintertime RH is a necessary project goal, and an MEP consultant should be engaged to review and provide recommendations relating to the existing HVAC and control systems. An MEP consultant may also consider HVAC additions to condition the attic space (and thus reduce RH) or heat the space (to essentially "pressurize" attic with warm dry air and reduce the amount of warm humid air drawn in from below); these options must be coordinated with any ventilation approach (which may negatively impact these approaches). After units have been placed back into operation, an evaluation is needed to assign costs to the required repair or replacement.

If the State is unwilling to sufficiently reduce the RH for comfort or other reasons, alternative options could include isolating areas with the worst condensation potential (e.g., close off the lantern from the main dome; provide interior storm windows to separate windows from interior conditions; etc.). This approach may limit condensation in isolated areas, but would not address RH-related moisture concerns within the main dome attic.

4.3 General Discussion by Area

4.3.1 Lantern

The lantern appears to suffer from isolated leakage at the dome roof. We also observed condensation, which we suspect is a significant moisture source during cold winter months due to the warm interior temperatures and elevated relative humidity within this space. Ventilating this small space would help lower both temperatures and air moisture content, thus limiting potential for condensation. The relative humidity source should be addressed with a MEP consultant to review the operation of the HVAC units.

4.3.2 Dome

The dome interior masonry shows signs of moisture-related deterioration, primarily below the lantern, but also around windows and isolated other locations. The deterioration below the lantern appears primarily attributable to bulk water leakage through the observation deck. We suspect regular condensation within the lantern attic space is also a significant moisture contributor in cold winter months.

Brick deterioration below windows openings is likely due to both leakage through the window and condensation on the window surface. We did not have a water source to confirm leakage paths (if any), but we suspect windows leak based on the interior and exterior water stains and the lack of visible glazing seals or seals between the window frame and exterior stop. The exterior metal cladding appears to run underneath the window frame, but due to the interior wood trim we could not see if the cladding has an upturn to act as a sill pan flashing. Removal and reinstallation of these windows would allow for a reconfigured perimeter flashing with an upturned interior flange and slope to the exterior to better manage both window leakage and condensation.

Other brick deterioration is likely due to isolated leakage and/or lantern leakage that can travel down the dome slope underneath the copper. The warm, high relative humidity interior conditions combined with continuous metal cladding (which is a strong vapor barrier) can limit the potential for leakage to dry to the interior or exterior, which may exacerbate deterioration. The high relative humidity may also result in condensation on the underside of the metal roofing, as the brick shell is relatively vapor permeable.

Brick deterioration is typically isolated to the brick's interior surface and areas with the worst deterioration are located under the lantern attic. If the masonry continues to deteriorate, any full-depth brick failures could result in a loss of arching action within a masonry bay and cause a localized collapse falling on the skydome and in the rotunda space. Deteriorated masonry areas should be regularly inspected (annually at a minimum) until moisture sources are addressed.

The team considered some desire to repair or coat the failed interior brick areas. Unless the underlying mechanism for the failure is addressed, any coating or repair will be for aesthetics only and may do more harm (i.e. by trapping moisture) if not well considered. There is also significant associated cost to access and perform these repairs. We could instead provide some debris netting or a platform to collect this debris and prevent any "hit-by" hazard until the sources of moisture are addressed, followed by some time to monitor repair effectiveness and allow the masonry to dry before applying any coating. The cost model for this study has selective replacement and repair of the interior damaged brick with access provided by a working platform installed above the skydome.

Bulk leakage through the observation deck has also resulted in significant corrosion of metal framing members supporting the deck and isolated straps supporting the metal cladding below. Metal framing remains sufficiently intact, and the observation deck does not appear to be a structural hazard; however, corrosion and resultant rust scale and section loss have resulted in failures of the deck cover attachments, which allows further leakage. Ongoing corrosion and section loss will also eventually compromise this framing's support of the observation deck plates. Corroded framing within the lantern attic should be periodically inspected (typically every 2 years, minimum) until leakage is addressed. The concern of the deck cover is the possible lost over the edge of the platform causing damage to the building below if not secured in place. Similar to the discussion in the leakage section above, the most reliable repair will involve removing and reinstalling the deck to allow for replacement of deteriorated framing components and addition of a substrate and membrane roofing system for redundancy. Our recommended system is proposed in the following section.

4.3.3 Drum

The drum interior and exterior masonry is generally in good condition, and older bulk leakage and masonry failures appear to have been largely addressed by the late 1990s restoration work, however, we did observe the following moisture-related issues:

- Interior brick masonry spalling and deterioration below the upper cornice.
- Exterior masonry delamination, particularly on the sandstone frieze and soffit stones below the lower cornice.

Both areas are located below copper-covered cornices. The copper flashing on these cornices is generally intact, though we did observe cracked solder joints and suspect cladding (upper cornice) or reglet-set counter flashing and open masonry joints (lower cornice) above this flashing. We did not have a water source to confirm potential leakage paths, but suspect this defects allow some water infiltration into the masonry cornice below. Water testing or further documentation of the late 1990s as-built conditions would be required to confirm.

4.3.4 Stylobate

The stylobate flatlock copper is generally in good condition closer to the drum of the dome, and more bulk leakage and failures of the solder joints appear towards the edge of this level (Photo 83). The cause of the damage is the snow and ice falling from the main dome and breaking the solder joints (Photo 84, 85). The open joints allow the active water leaking into the building at the attic level and then to the both Chambers galleries below on the west. A number of the open joints were already indicted on the roof in pencil but have not been addressed. This will cause damage to the brick arch system and wood underlayment below the copper flatlock if allowed to continue.

RECOMMENDATIONS

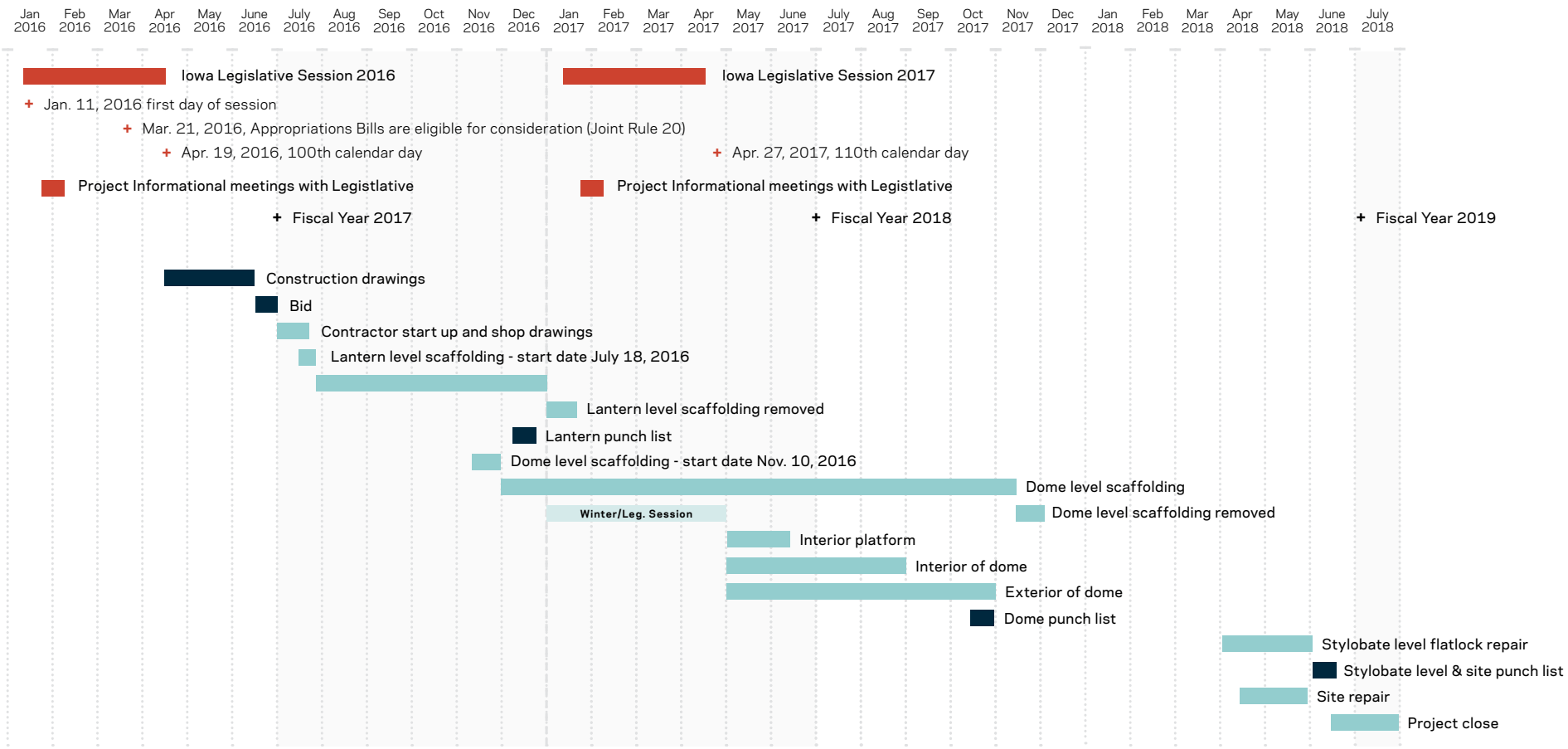
We separate our repair recommendations into "priority repairs," which are required to address ongoing moisture accumulation and should be performed in the next 1 to 2 years, and "maintenance" which is intended to limit future risk of moisture accumulation and should be performed in the next 5 years (though the State may wish to complete now assuming access is provided for priority repairs).

5.1 Priority Repairs

- Address bulk leakage at observation deck. We present the following conceptual scope of work to address this leakage.
  - Remove observation deck planks and guard rail.
  - Remove and replace corroded metal framing at each plank joint (twenty-four members) with shallower members to allow for new decking. Provide corrosion resistant framing.
  - Provide plywood or heavy gauge sheet metal deck covered with continuous roof membrane. Lap underlayment over existing skirt cladding to allow drainage of the roof membrane.
  - Provide revised attachment concept that elevates the deck planks above the membrane and provides improved membrane flashing height at penetrations. Minimize penetrations required to support the deck planks, and detail penetrations into the membrane to ensure they are watertight.
  - Provide new or reuse the existing observation deck planks and secured to the framing below. Provide ship-lapped joints and seal anchor penetrations to limit the amount of water that can reach the membrane.
  - Provide new or reuse the existing guardrail. Detail guardrail attachment through vertical flashing surfaces only. Waterproof guardrail penetrations.
  - Remove and reconfigure metal cladding at lantern rising wall as required to complete work on deck.
  - Remove the damaged metal structure and provide new structure to support the lantern skirt while replacing the corroded metal framing on the observation planks.
- Engage an MEP consultant to assess the current HVAC system and control. Control system should be modified to limit RH within the building, particularly during cold winter months.
- Perform waterproofing repairs to address direct leakage paths in the lantern cladding as follows:
  - Repair openings at base of the brackets.
  - Repair holes and penetrations in the cladding.
- Perform waterproofing repairs to address leakage through the circular windows as follows:
  - Remove, salvage, and reinstall window as needed to provide new metal flashing within the circular opening. Provide upturned flange at interior and slope flashing to exterior to allow drainage.
  - Provide wet seal at glazing perimeter.
  - Provide perimeter seal between the window frame and glazing stop, and between glazing stop and gilded metal cladding. Provide weeps at sill to allow drainage of sill/condensate flashing.
- Repair open seams and gaps in the copper entablature above the upper cornice.
- Repair failed copper joints at upper and lower cornice flashing. Reconfigure cornice flashing as required to allow thermal expansion without damaging seams.

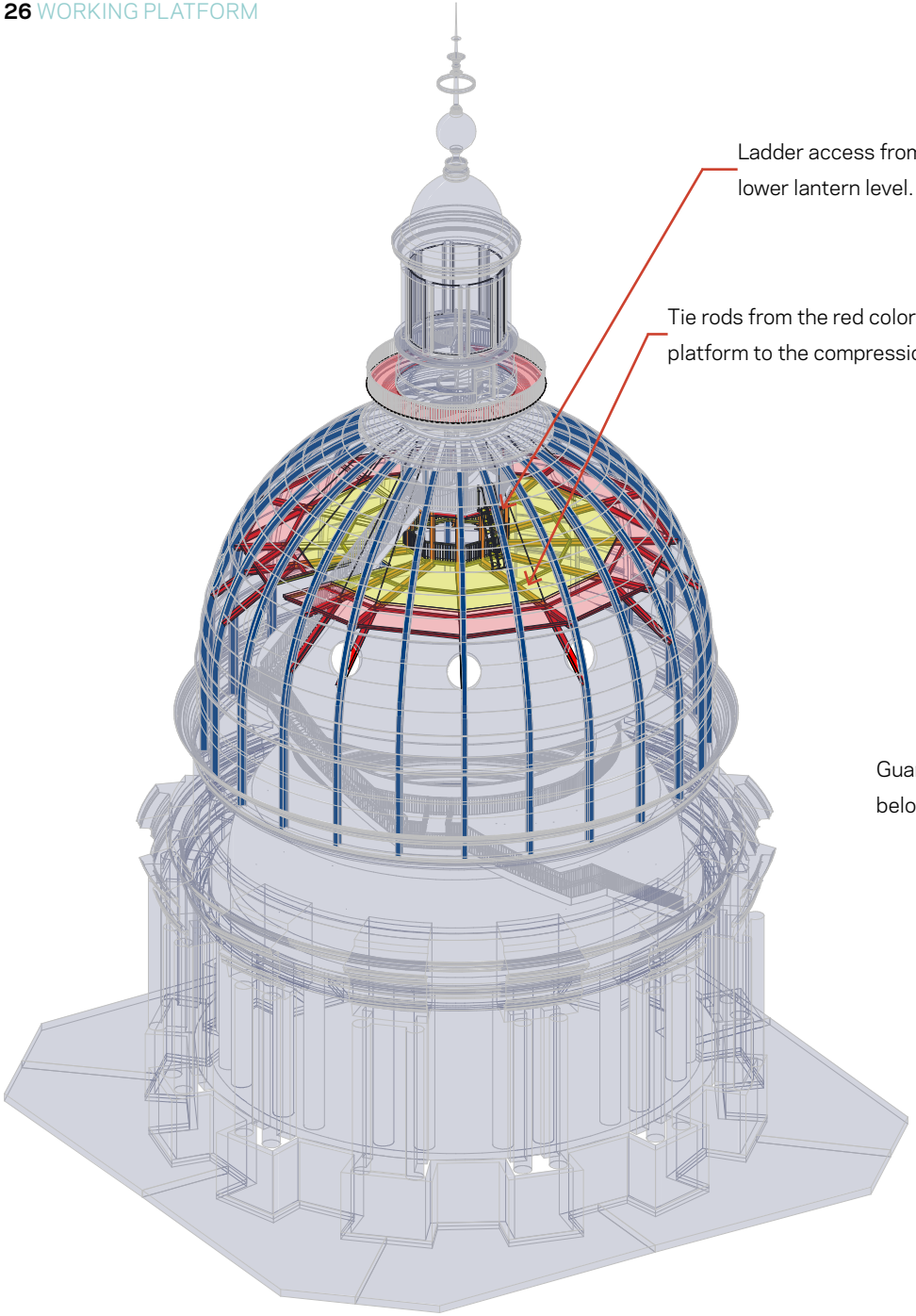
5.2 Maintenance

- Point deteriorated mortar joints at large stone brackets above lower cornice.
- Remove and replace sealant joint at lower cornice reglet-set counter-flashing.
- Repair failed copper joints at upper and lower cornice flashing.
- Repair wood windows, wood trim, and glazing on the drum. Consider performing waterproofing improvements (e.g., provide metal sill flashing and membrane perimeter flashing) to limit maintenance intervals and leakage risk.
- Resurface delaminated or exfoliating sandstone, primarily at lower entablature around each set of paired columns and soffits behind these paired columns.
- Seal or solder water tight open seams and gaps in the copper entablature above the upper cornice.
- Scrape and repaint upper and lower wood windows on the drum, including both frame components and decorative sand texture-coated trim.
- Solder water tight open seams and gaps in the copper flatlock at the stylobate level. During the restoration phases on the building similar items were reviewed in the spring and fall, as the falling of the snow and ice damage from the main dome extends on to the adjacent standing seam copper roofs.

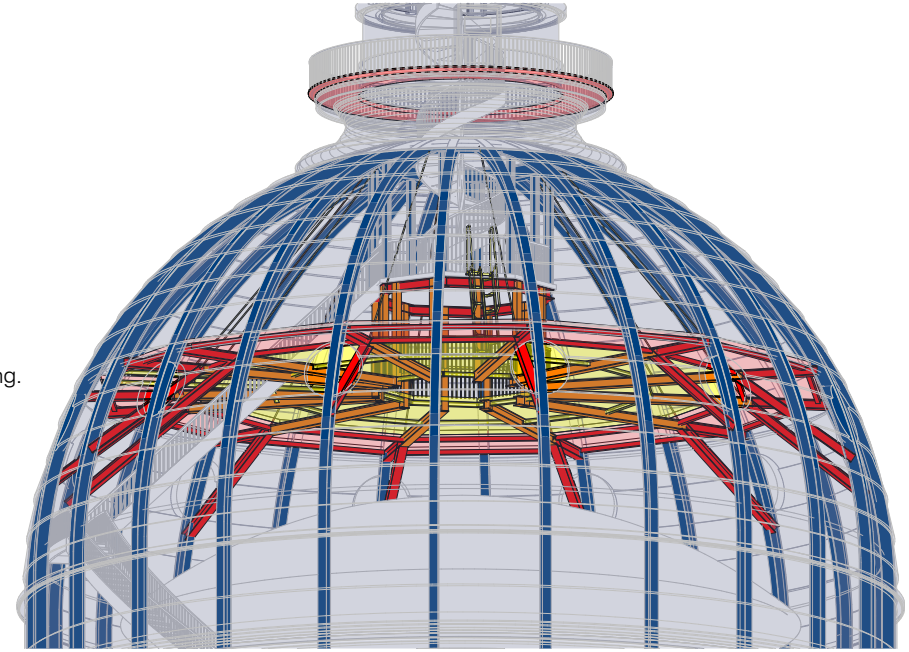

Jan 2016
Feb 2016
Mar 2016
Apr 2016
May 2016
June 2016
July 2016
Aug 2016
Sep 2016
Oct 2016
Nov 2016
Dec 2016
Jan 2017
Feb 2017
Mar 2017
Apr 2017
May 2017
June 2017
July 2017
Aug 2017
Sep 2017
Oct 2017
Nov 2017
Dec 2017
Jan 2018
Feb 2018
Mar 2018
Apr 2018
May 2018
June 2018
July 2018
Iowa Legislative Session 2016
Iowa Legislative Session 2017
Jan. 11, 2016 first day of session
Mar. 21, 2016, Appropriations Bills are eligible for consideration (Joint Rule 20)
Apr. 19, 2016, 100th calendar day
Apr. 27, 2017, 110th calendar day
Project Informational meetings with Legistlative
Project Informational meetings with Legistlative
Fiscal Year 2017
Fiscal Year 2018
Fiscal Year 2019
Construction drawings
Bid
Contractor start up and shop drawings
Lantern level scaffolding - start date July 18, 2016
Lantern level scaffolding removed
Lantern punch list
Dome level scaffolding - start date Nov. 10, 2016
Dome level scaffolding
Winter/Leg. Session
Dome level scaffolding removed
Interior platform
Interior of dome
Exterior of dome
Dome punch list
Stylobate level flatlock repair
Stylobate level & site punch list
Site repair
Project close

*See the appendix for line item breakdown of the project cost.

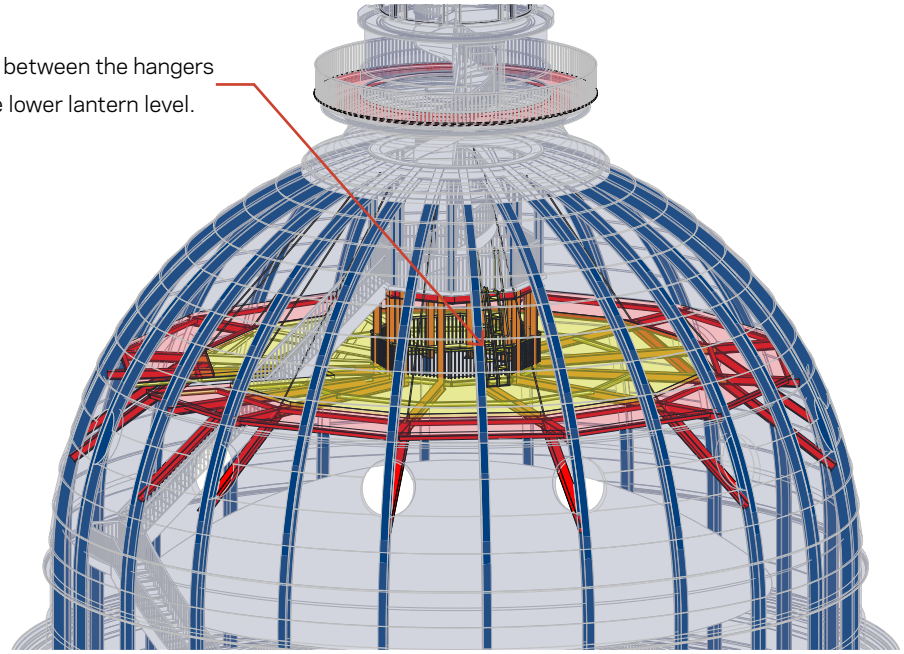
	Lantern Level	$560,520	
	Dome Level	$987,451	
	Drum Level	$2,030,874	
	Stylobate and Attic level	$1,166,204	
Subtotal		$4,745,049	
Overhead & Profit	15%	$711,757.35	
General Conditions	8.5%	$463,829	
Building Cost Index projected to 4th Quarter of 2017 (9 quarters) and with Des Moines Construction Factor (12% + 6% = 18%)	18%	$1,065,714	
Subtotal		$6,986,349	
Contingency	15%	$1,047,952	
Total		$8,034,301	Statement of Probable Construction Cost
		$888,259	Design Fee
		$7,632	Design Reimbursables
		$100,000	DAS - Owner's Representative fee
		$80,343	DAS - Builders Risk
		$8,775	DAS - EADOC project management software fee
		$871,589	Construction Manager fee
		$9,990,899	Project Cost



Axonometric transparent view of the main dome showing the new working platform in color.



Axonometric view of the underside of the working platform.



Axonometric view of the topside of the working platform.

Aerial view of Iowa State Capitol's west elevation.

Photo 2 Lantern ceiling. Note grated hatch into lantern dome attic and ceiling fan.

Photo 3 Metal framing and underside of lantern dome sheet metal cladding.

Photo 4 Condensation on backside of sheet metal cladding at the base of lantern dome.

Photo 5 Leakage observed below lantern dome cornice during a rainstorm.

Photo 6 Condensation accumulation in the lantern dome soffit.

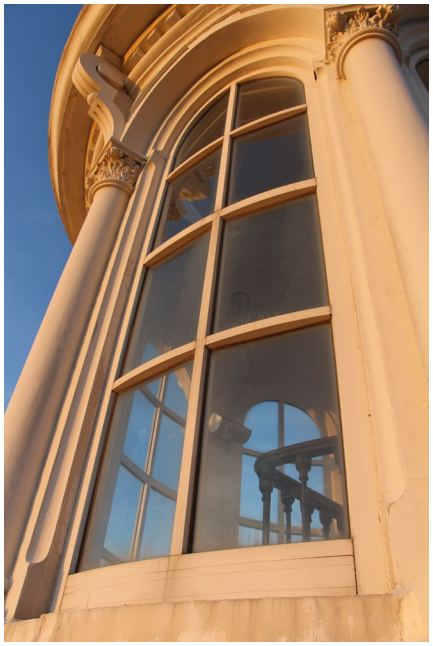


Photo 7 Typical lantern window.

Photo 8 Lantern interior with typical condensation observed on glazing in morning.

Photo 9 Lantern window condensation.

Photo 10 Deteriorated wood at lantern window midrail.

Photo 11 Typical failing paint, deteriorated wood & corroding fasteners at lantern window sill.

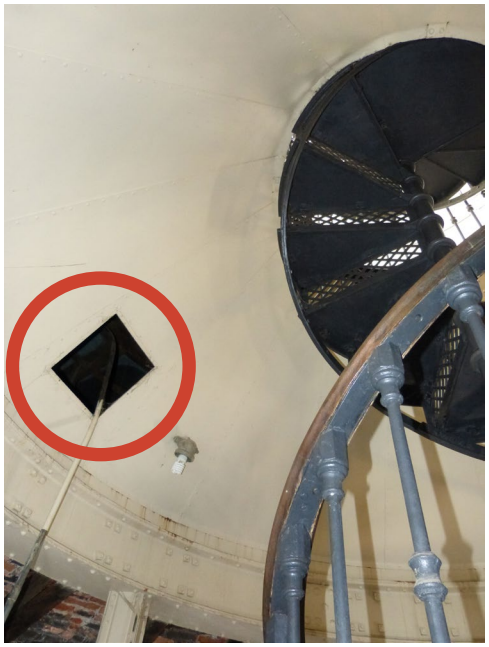


Photo 12 Spiral stair leading up to lantern and access hatch leading into lantern attic.

Photo 13 Metal framing & backside of sheet metal cladding (arrow) within the lantern attic.

Photo 14 Framing below observation deck planks (yellow arrows) is corroded; note built-up rust scale at WT member directly below planks (red arrow).

Photo 15 Condensation observed on the underside of the lantern sheet metal cladding.

Photo 16 Wet and debris-filled soffit within the lantern attic.

Photo 17 Top side of the dome's brick shell visible within the lantern attic; note hole in masonry.

Photo 18 Spalling brick at top of dome and underside of hole noted in previous photo.

Photo 19 Stair, platform, and lantern access. Note extent of brick deterioration (red brick areas) is concentrated at top of dome.

Photo 20 Typical brick shell and ribs; note steps in brick thickness (yellow), horizontal bracing visible at windows (red), and suspended sky dome with water stains and brick debris (blue).

Photo 21 Platform and stair access viewed from base of lantern.

Photo 22 Brick shell's step from two to three wythes.

Photo 23 Brick shell and ribs; note wood blocking through-bolted to rib webs at upper single-wythe shell area.

Photo 24 Typical brick deterioration at top of dome.

Photo 25 Brick deterioration and efflorescence at top of dome, southeast quadrant.

Photo 26 Brick deterioration adjacent to west window.

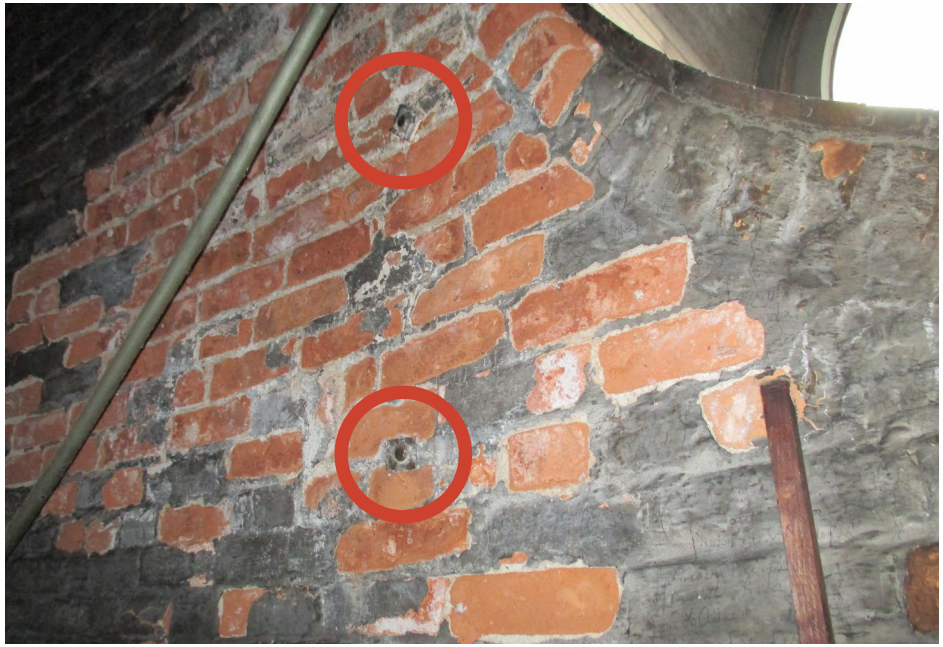


Photo 27 Closer view of brick deterioration shown in previous photo; note anchor heads from original construction.

Photo 28 Brick debris on top of sky dome.

Photo 29 Isolated brick deterioration and debris at base of dome.

Photo 30 Typical dome window interior.

Photo 31 Water staining on wood finishes at interior of window.

Photo 32 Wood-framed window within spiral staircase access up to dome attic.

Photo 33 Industrial rope access used for exterior inspection.

Photo 34 Lantern exterior.

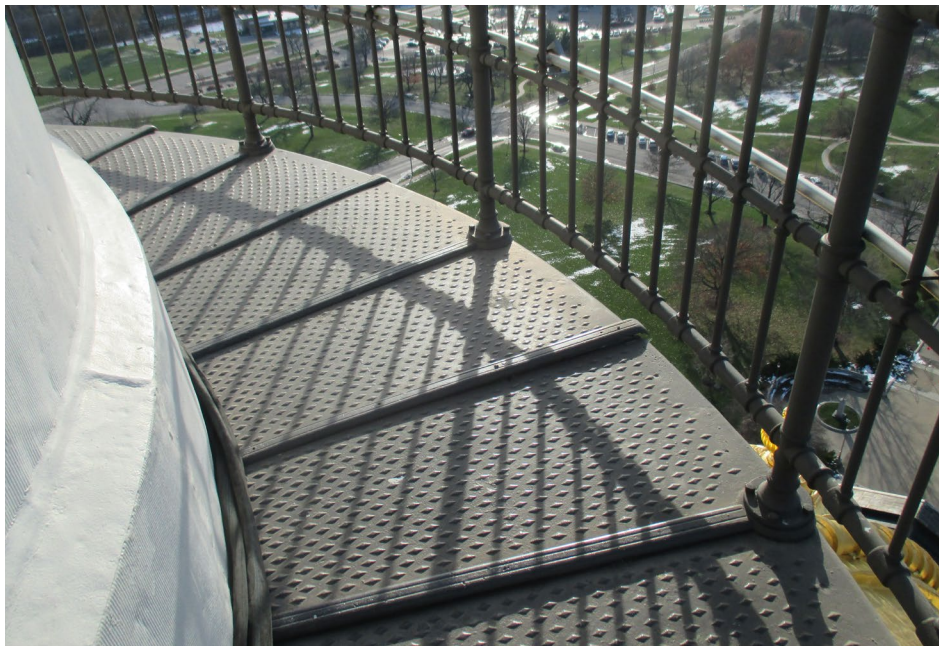


Photo 35 Observation deck planks, covers, and guardrail.

Photo 36 Unsecured cover; corroded framing is visible below.

Photo 37 Holes in observation deck plank.

Photo 38 Edge of observation deck plank has limited overlap onto cladding below; note gap at end of cover.

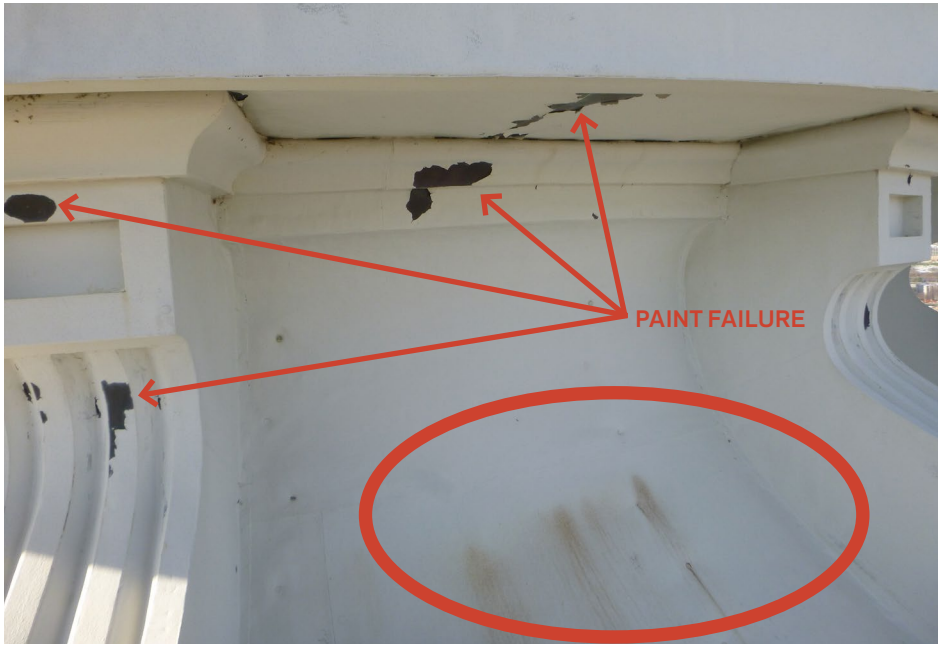


Photo 39 Failing paint at soffit seam and rust stains on lantern skirt cladding below.

Photo 40 Rust stain on skirt cladding below a seam in soffit.

Photo 41 Stains on gilding below rust stain noted in previous photo.

Photo 42 Lantern skirt and typical decorative sheet metal bracket.

Photo 43 Typical gap at base of bracket; note water on cladding below (several days after any rain/snow).

Photo 44 Typical gap at base of bracket and water on cladding below (several days after any rain/snow).

Photo 45 Hole in cladding directly below observation deck.

Photo 46 Fastener heads visible through coating.

Photo 47 Closer view of one fastener head shown in previous photo.

Photo 48 Typical gilded dome roofing.

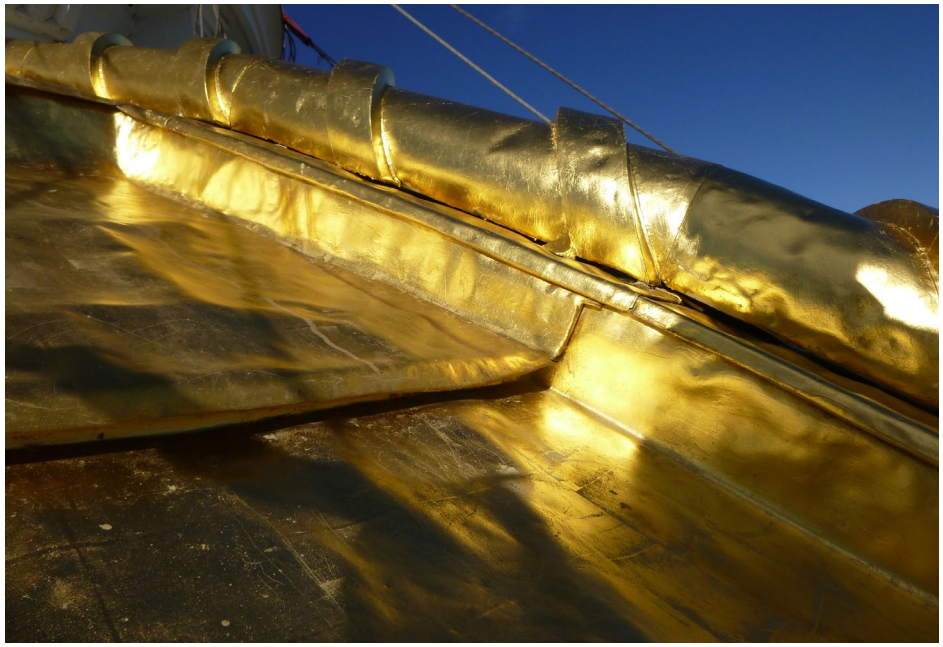


Photo 49 Decorative coil at ribs; note coil sits above a continuous rib flashing.

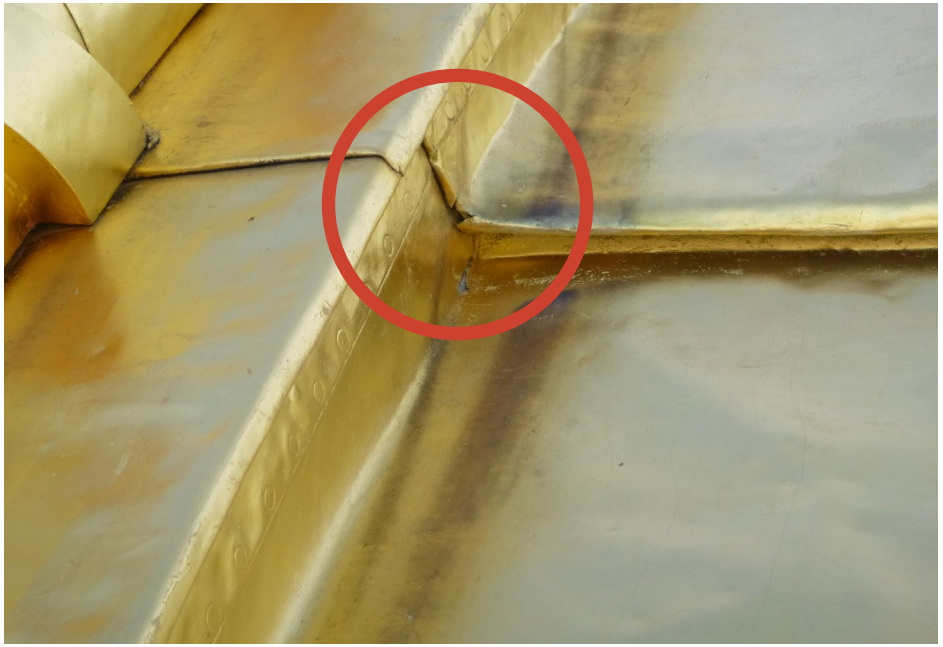


Photo 50 Split sheet metal and pinhole at typical stepped roofing sheet's transition to rib.

Photo 51 Buckling and waviness typically observed in dome roofing sheets.

Photo 52 Repair patch (yellow) and lead cant (red).

Photo 53 Lead fillet at transition between dome roofing and lantern skirt cladding; note separation between fillet and roofing/cladding.

Photo 54 Typical dome eyebrow dormer viewed from the side; note continuous lead fillet along eyebrow transition to roof.

Photo 55 Small cornice at top of copper entablature at base of dome; note cracked solder joints.

Photo 56 Splits and separation of typical lead fillet at eyebrow dormer.

Photo 57 Separation of lead fillet at eyebrow dormer head.

Photo 58 Water stains at hole in lead fillet at eyebrow dormer finial.

Photo 59 Closer view of hole shown in previous photo.

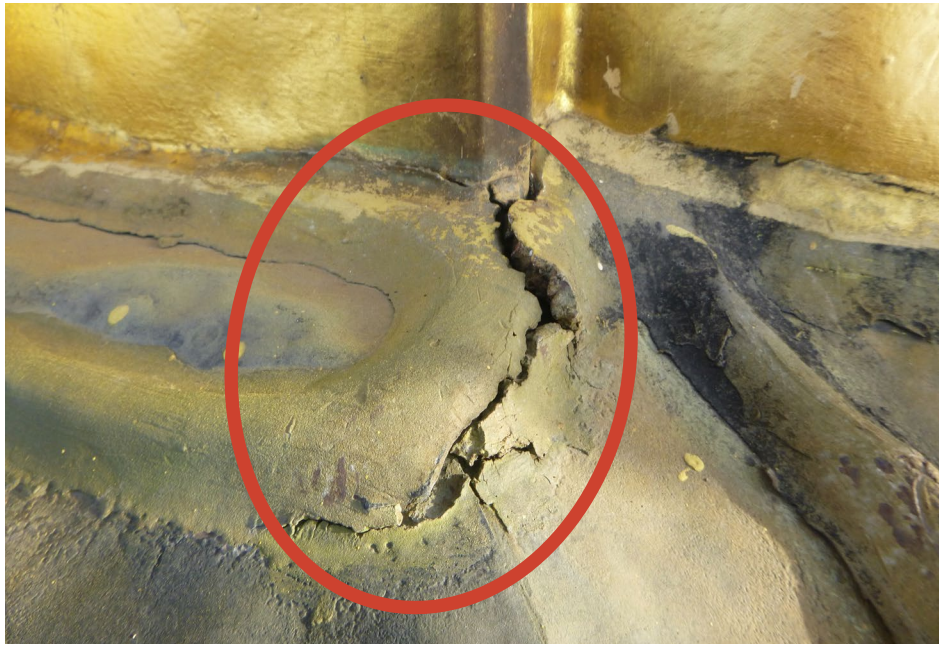


Photo 60 Cracked solder joint (or lead) at small cornice at base of dome.

Photo 61 Typical dome eyebrow dormer viewed from below.

Photo 62 Water stains originating from base of eyebrow dormer.

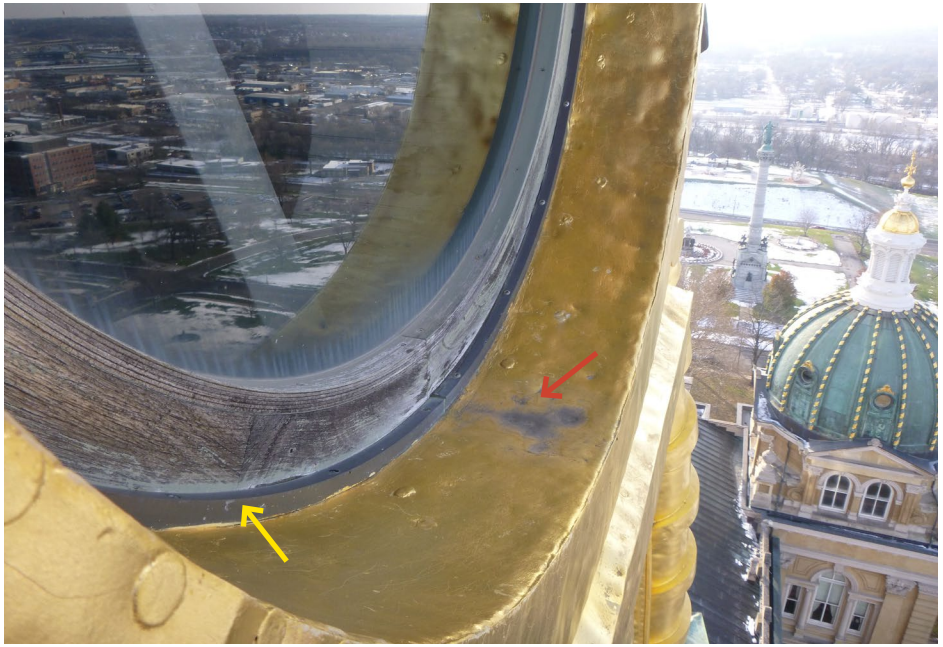


Photo 63 Wood-framed circular window with unsealed metal stop (yellow); note water stain on metal cladding in front of window sill (red).

Photo 64 Condensation on circular window interior.

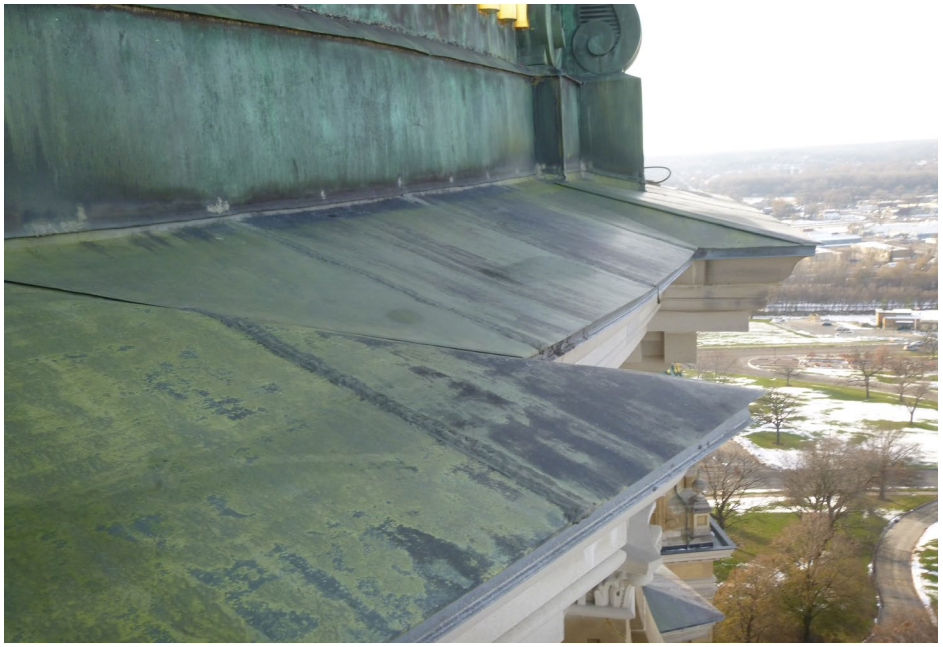


Photo 65 Copper-covered upper cornice at base of dome.

Photo 66 Typical open seams in non-skyward-facing joints of copper entablature at base of dome.

Photo 67 Typical failed solder in skyward-facing joints of copper entablature at base of dome.

Photo 68 Cracked solder joint in upper cornice flashing.

Photo 69 Stone bracket at lower cornice; note failed mortar joints at base of bracket.

Photo 70 Failed sealant and gaps in reglet-set counter flashing at lower cornice.

Photo 71 Failed mortar joints in brackets above lower cornice.

Photo 72 Delamination at sandstone frieze within lower cornice entablature.

Photo 73 Exfoliation at stone soffit below lower cornice and behind pair columns.

Photo 74 Typical isolated masonry crack.

Photo 75 Typical isolated delamination.

Photo 76 Typical drum window; note failing paint on horizontal wood framing members.

Photo 77 Typical dome window; note failing textured coating on wood mullion and sill.

Photo 78 Typical small dome.

Photo 79 Interior of southwest minor dome.

Photo 80 Prompt leakage produced at observation deck water test.

Photo 81 Data logger in lantern (data noted is from November 24, 2015 at 8 a.m.).

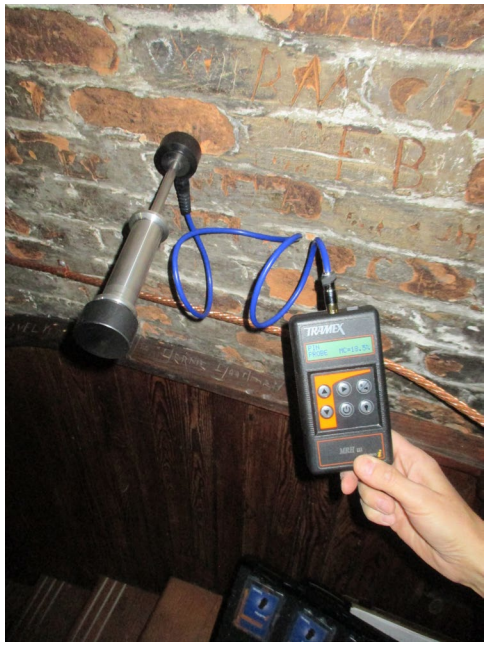


Photo 82 Brick moisture testing using a Tramex MRH III with 1 1/2-inch masonry pin probes.

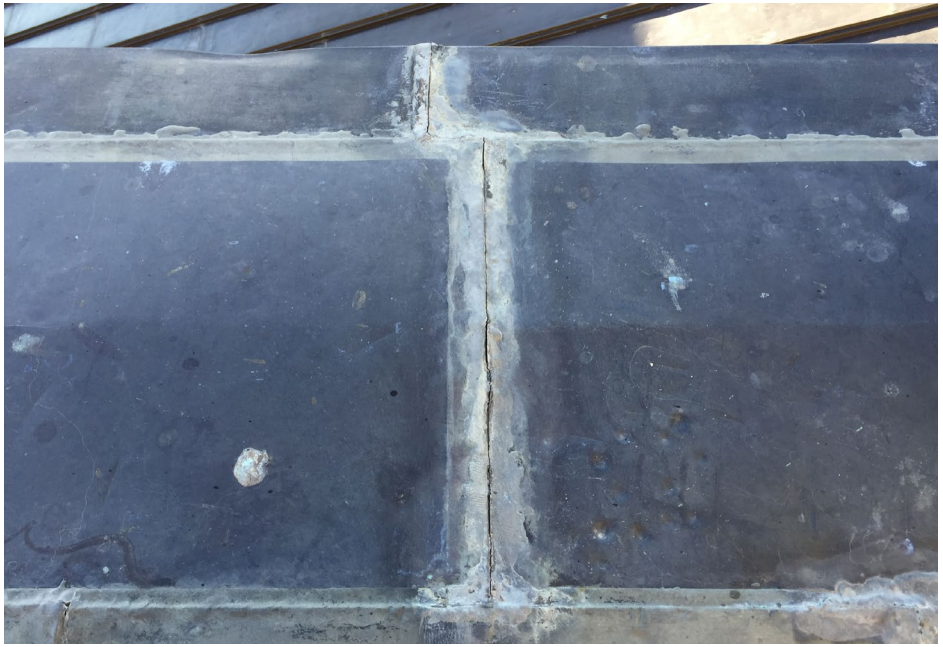


Photo 83 Stylobate level - Solder joint failure.

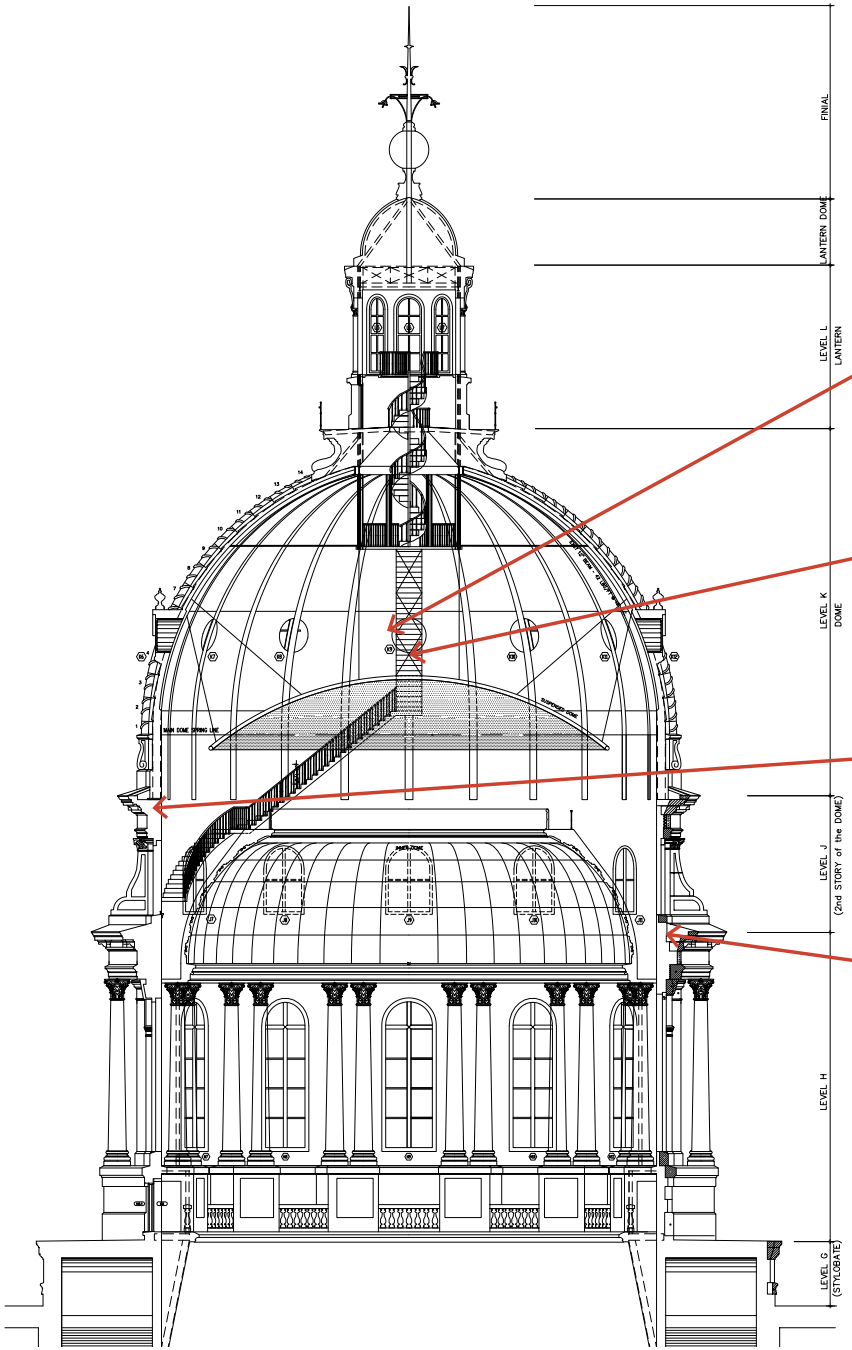
Photo 84 Ice about to fall from the base of Level J intermediate cornice copper.

Photo 85 Stylobate level - Dented copper flatlock.

Photo 86 Stylobate level - Active water leak to the attic floor.

Photo 87 Stylobate level - Masonry joint fallen from above on copper flatlock.

APPENDIX

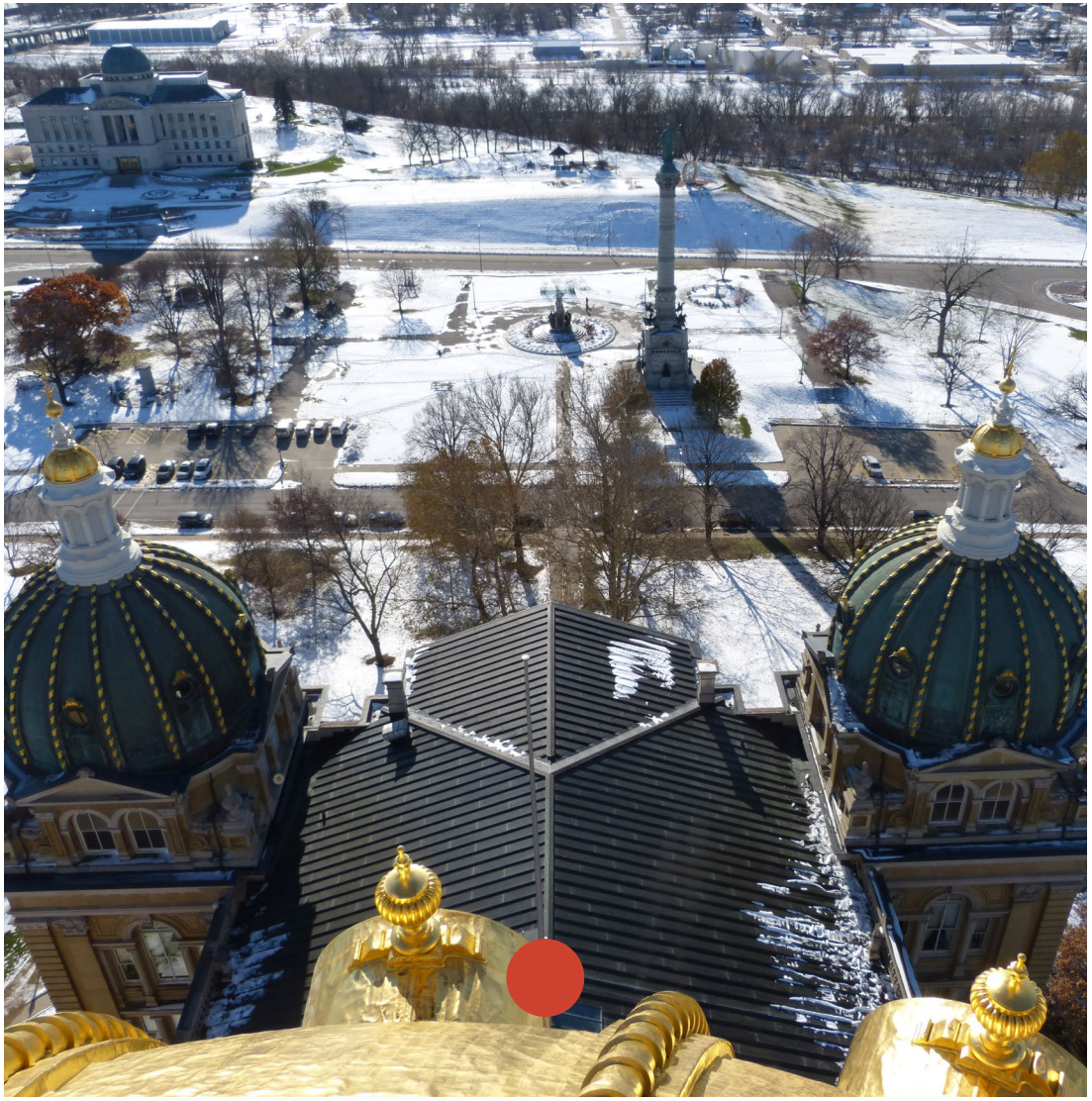


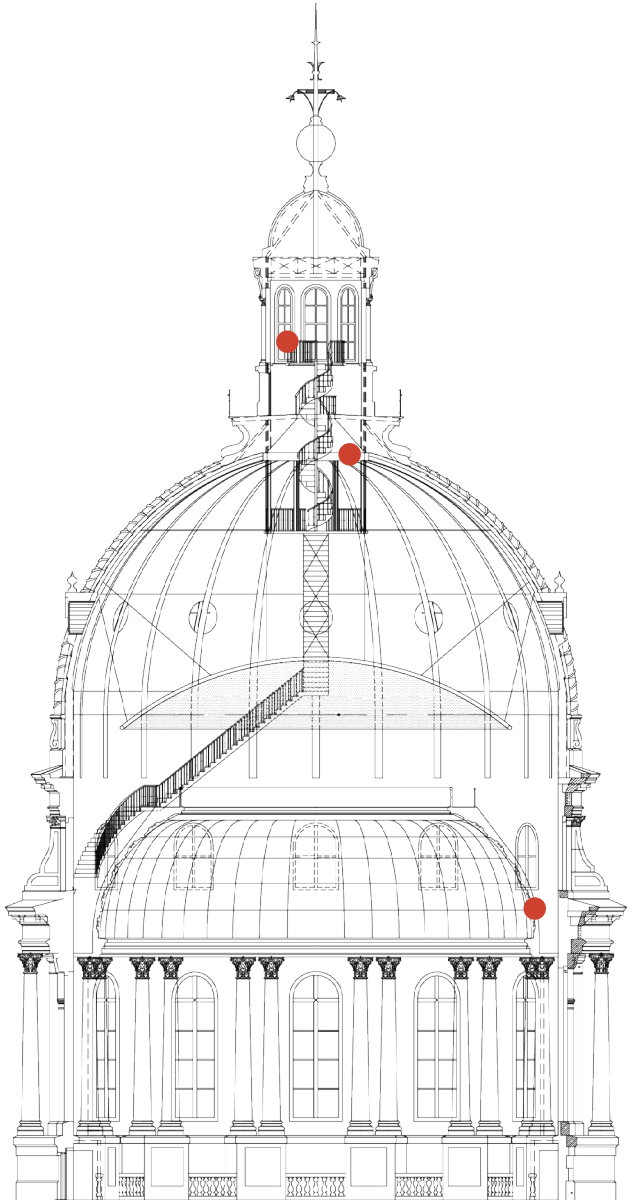
Damaged brick Location
30% 1 3/8-inch deep into the masonry
24.5% surface

Typical brick location
18.6% 1 3/8-inch deep into the masonry
12.7% surface

GAR flag elevation
17.2% 1 3/8-inch deep into the masonry
12.7% surface

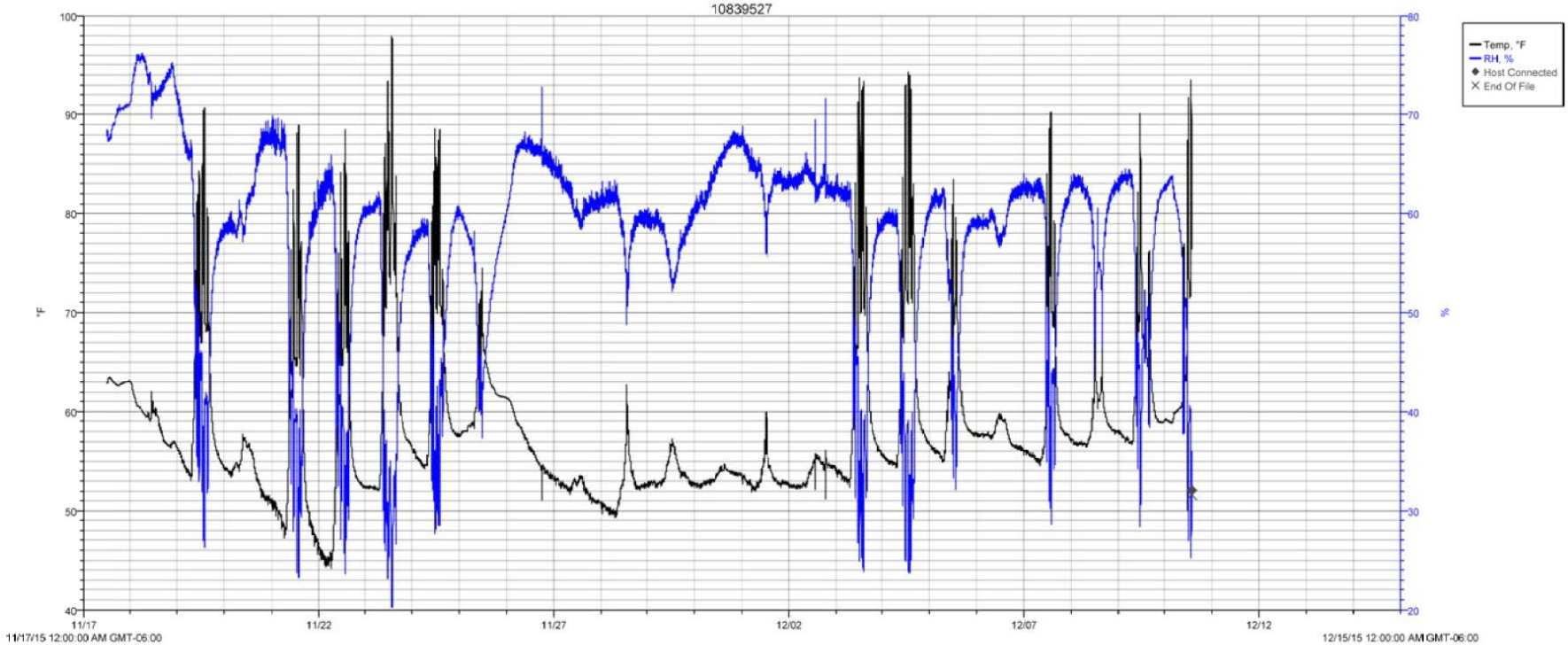
North window about 10 feet above the floor
38.7% 1 3/8-inch deep into the masonry
29.0% surface

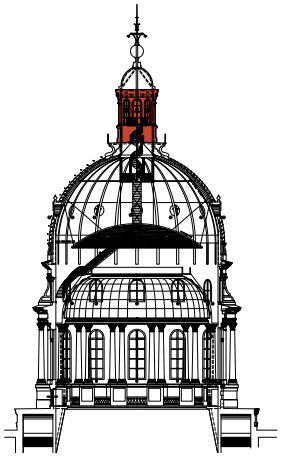




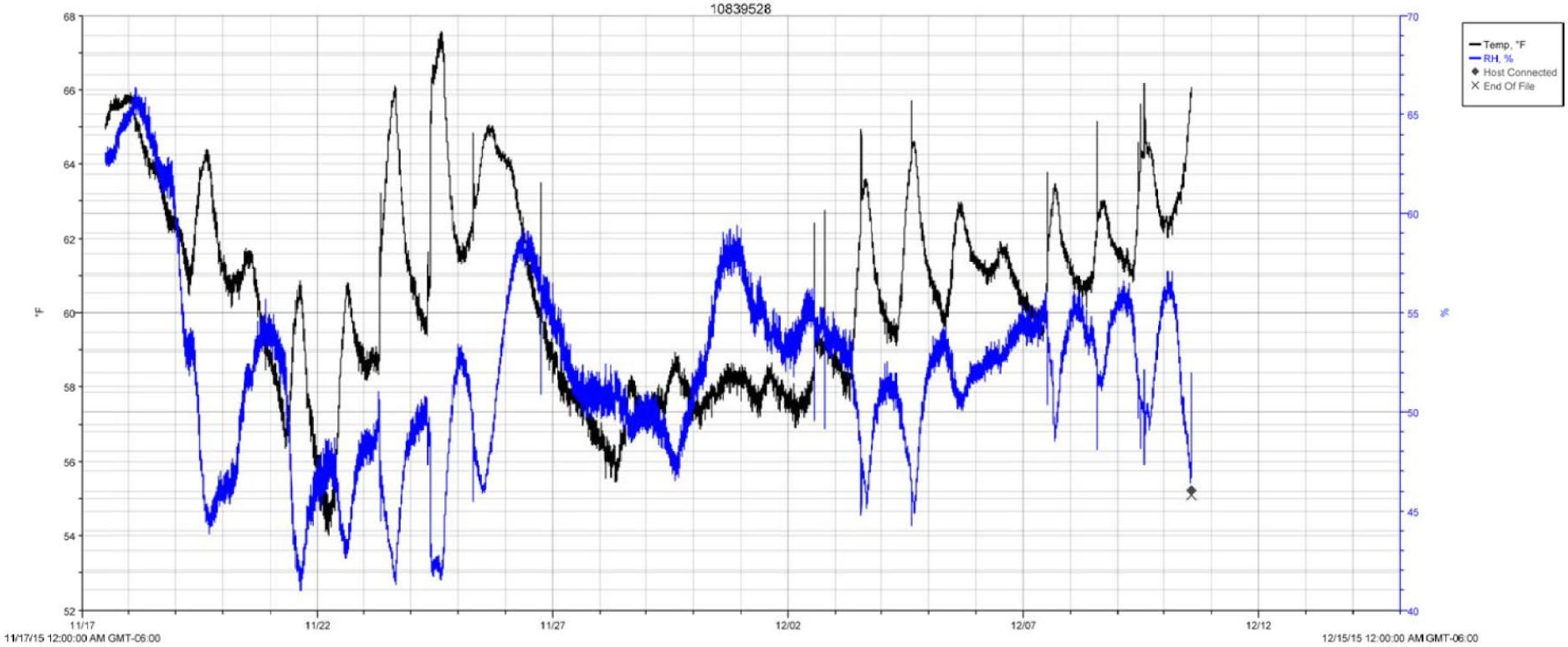
Location of data loggers

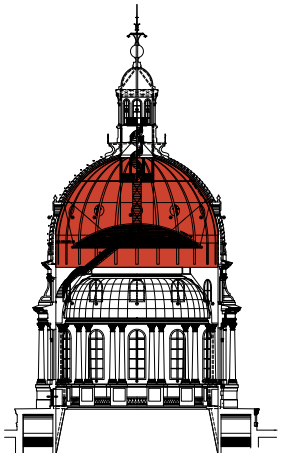
LANTERN LEVEL NOVEMBER 27 TO DECEMBER 10, 2015



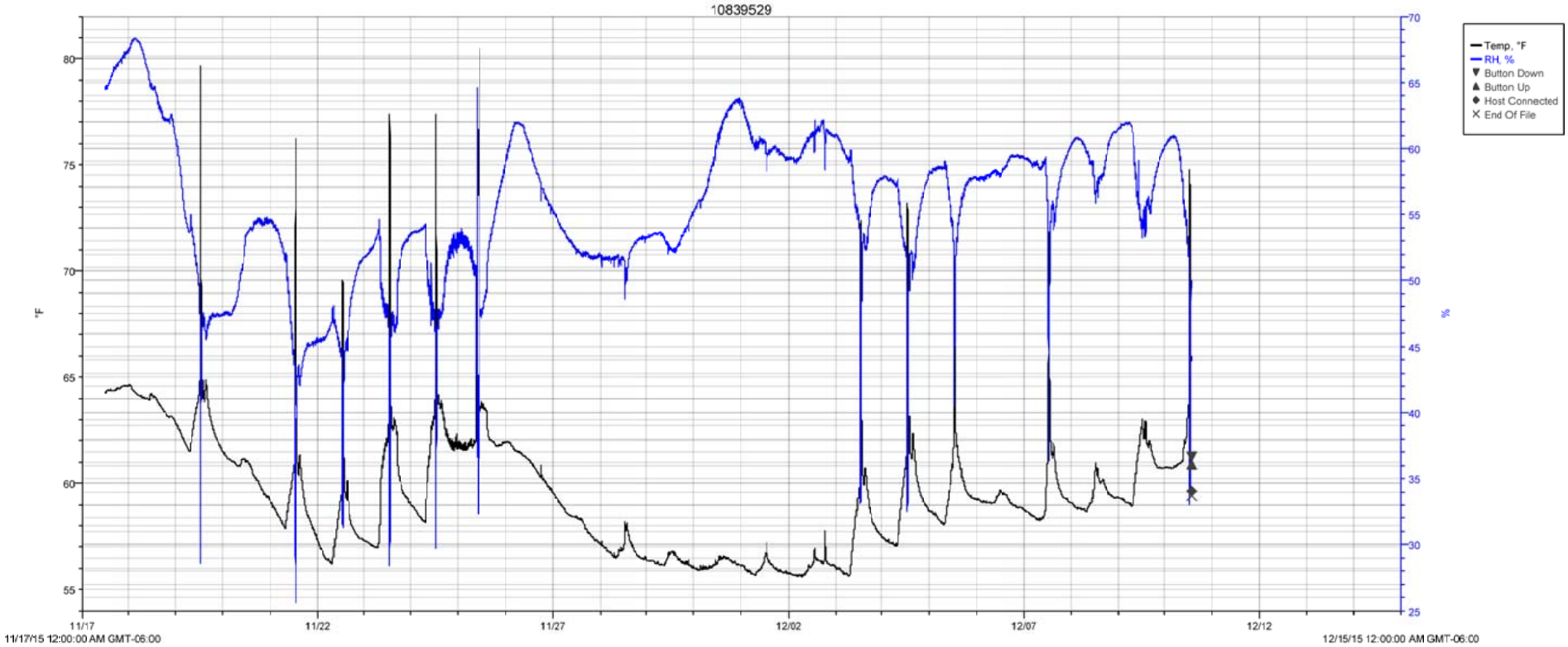


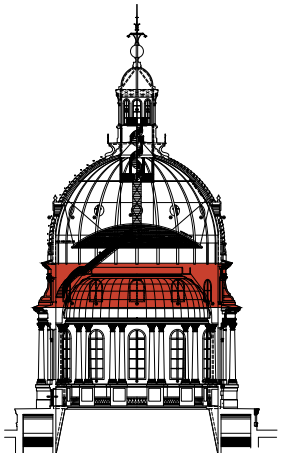
DOME LEVEL NOVEMBER 27 TO DECEMBER 10. 2015



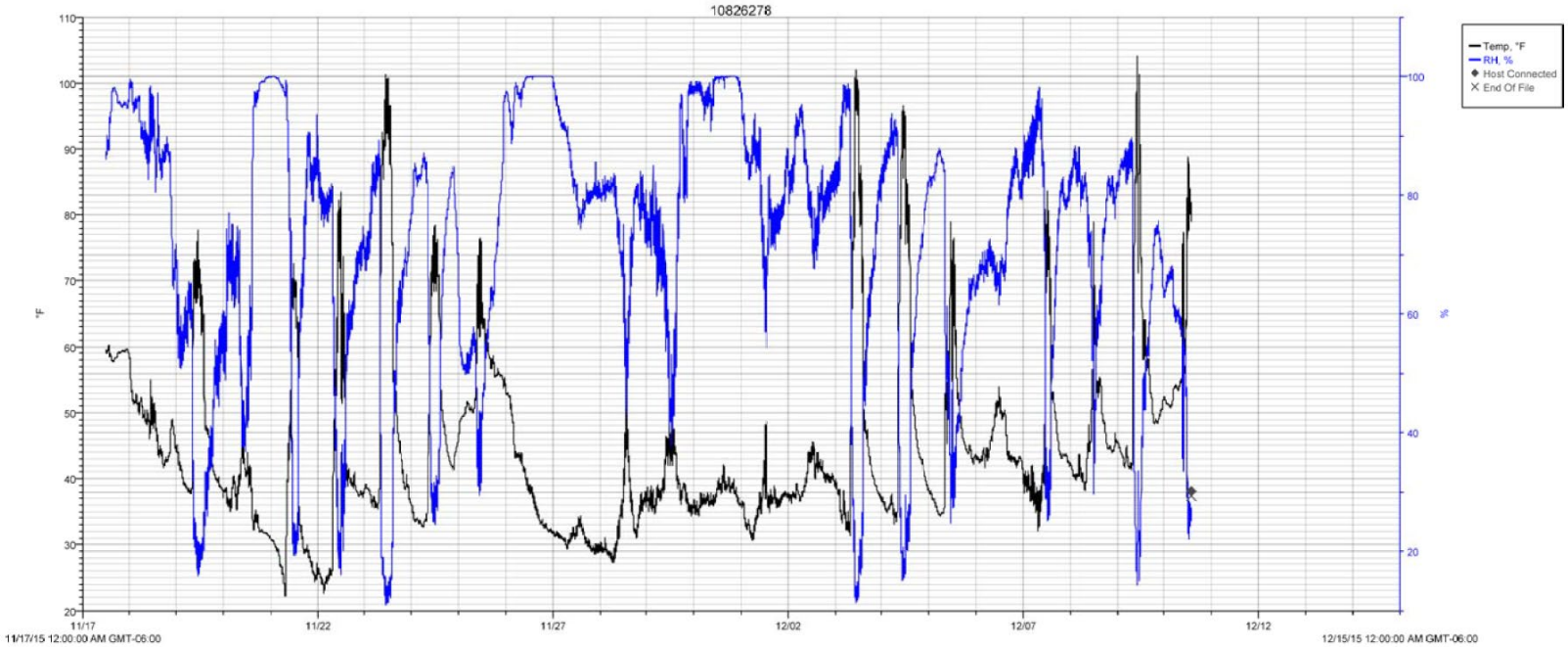


DRUM LEVEL NOVEMBER 27 TO DECEMBER 10, 2015





EXTERIOR NOVEMBER 27 TO DECEMBER 10. 2015



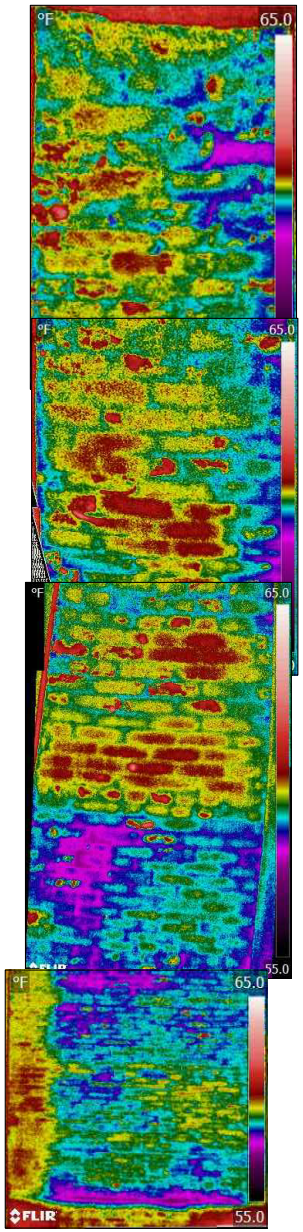
**Note the sunlight on the existing standing seam copper caused the high temperatures and low relative humidity to be recorded in the graph above.*

TEMPERATURE & RELATIVE HUMIDITY DATA FOR DES MOINES, IOWA

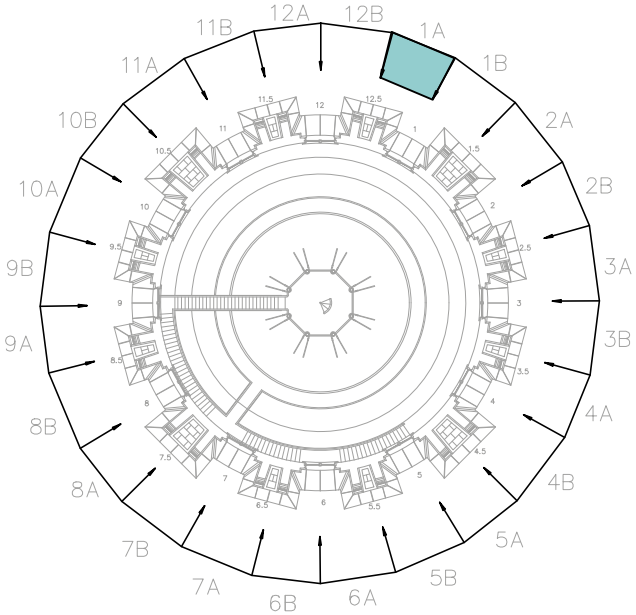
Date	High Temp (°F)	Low Temp (°F)	High Humidity (%)	Low Humidity (%)
11-17-2015	61	54	90	84
11-18-2015	60	41	93	61
11-19-2015	47	31	63	21
11-20-2015	40	27	89	34
11-21-2015	31	15	92	50
11-22-2015	38	16	80	54
11-23-2015	46	29	78	45
11-24-2015	54	30	82	50
11-25-2015	58	47	77	51
11-26-2015	53	32	93	82
11-27-2015	32	27	85	72
11-28-2015	33	26	81	66
11-29-2015	37	32	82	52

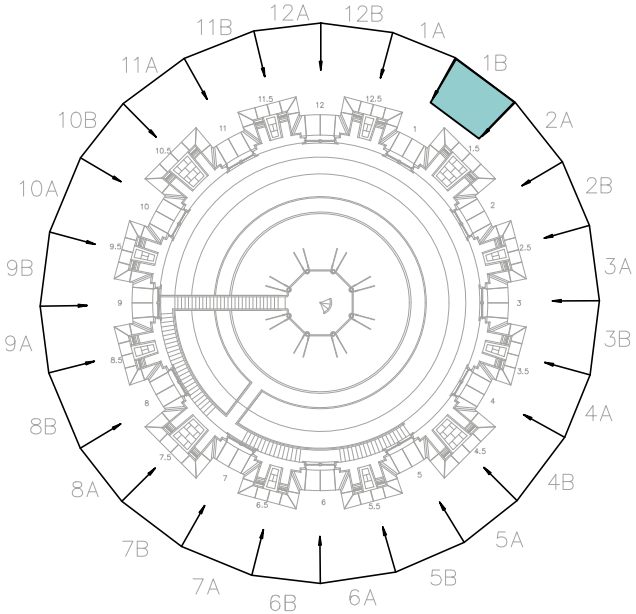
Date	High Temp (°F)	Low Temp (°F)	High Humidity (%)	Low Humidity (%)
11-30-2015	38	32	92	82
12-1-2015	36	30	82	69
12-2-2015	37	32	89	75
12-3-2015	47	24	92	45
12-4-2015	52	27	92	50
12-5-2015	52	35	82	41
12-6-2015	44	34	92	62
12-7-2015	51	31	96	50
12-8-2015	51	34	89	56
12-9-2015	56	35	85	55
12-10-2015	58	40	66	39
12-11-2015	53	37	71	50
12-12-2015	52	38	93	76

SECTION 1A

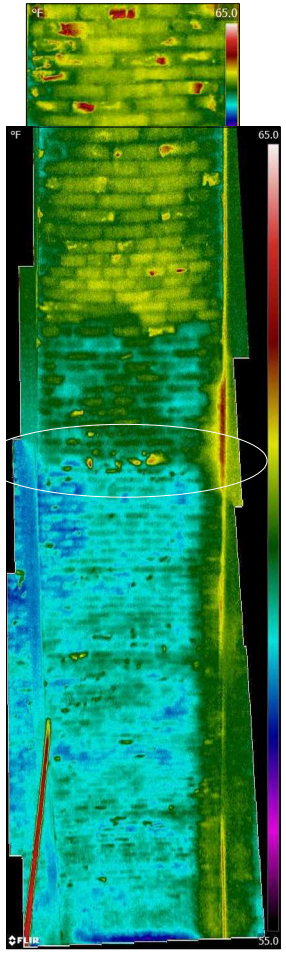


11.23.15 | 10:00 - 11:00 am



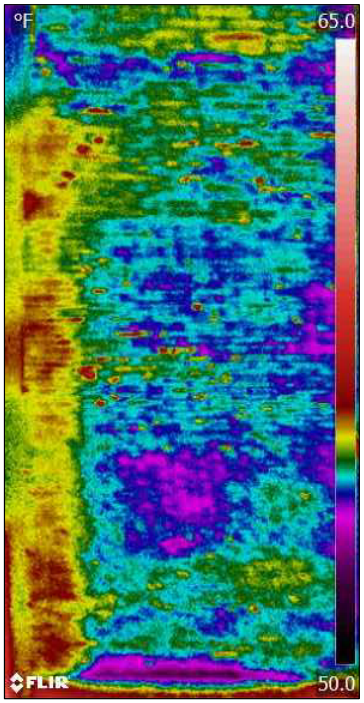


SECTION 1B

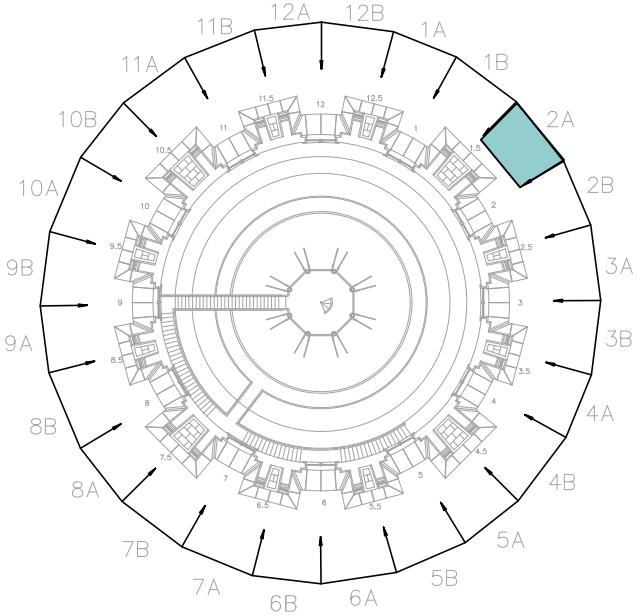


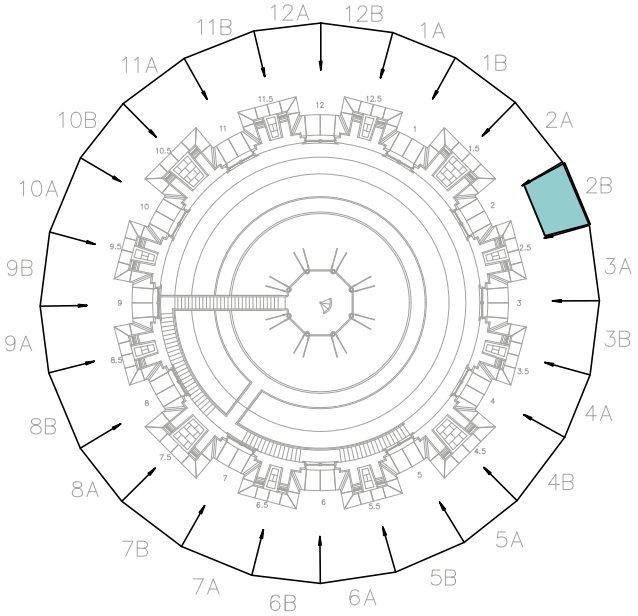
11.23.15 | 10:00 - 11:00 am

SECTION 2A

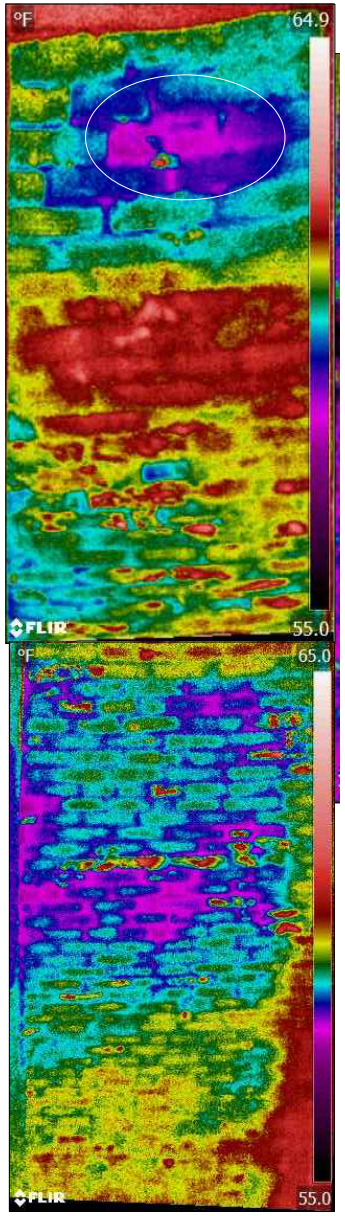


11.23.15 | 10:00 – 11:00 am



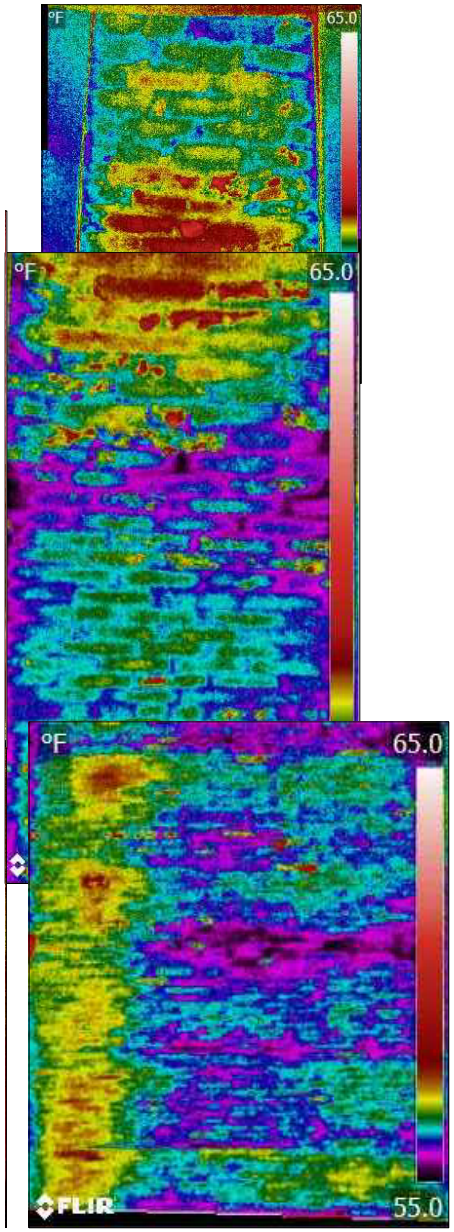


SECTION 2B

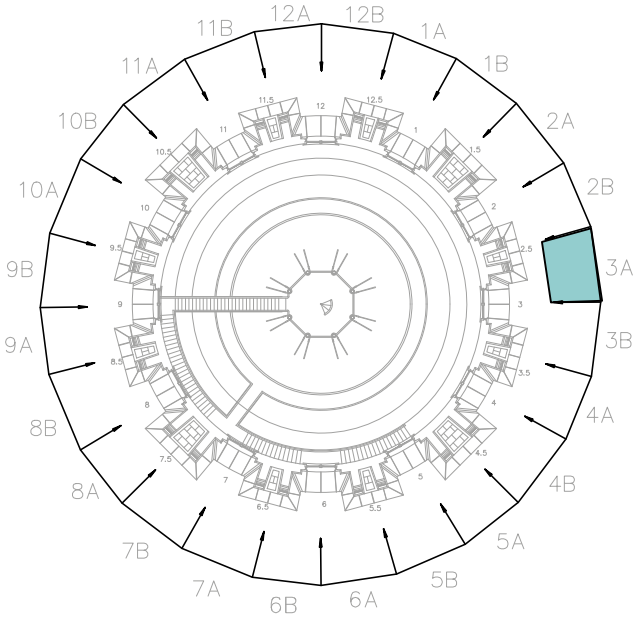


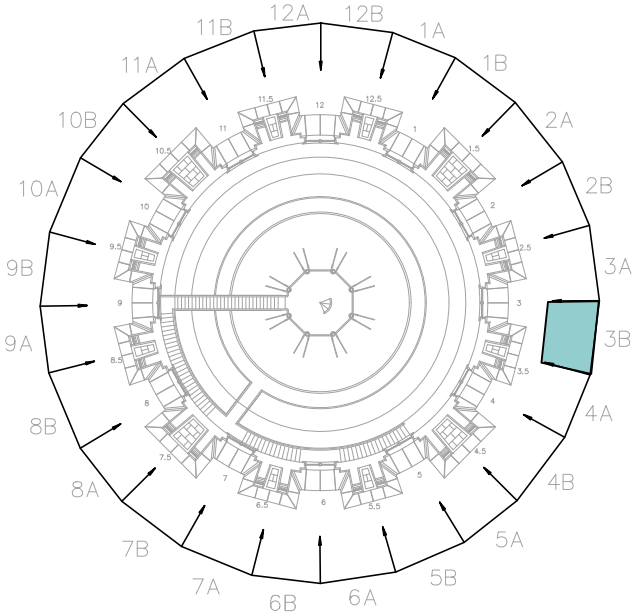
11.23.15 | 10:00 – 11:00 am

SECTION 3A

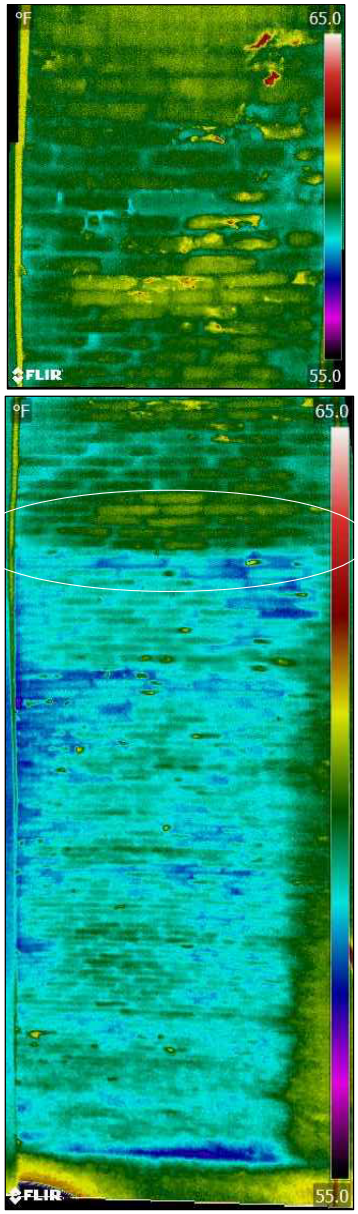


11.23.15 | 10:00 - 11:00 am



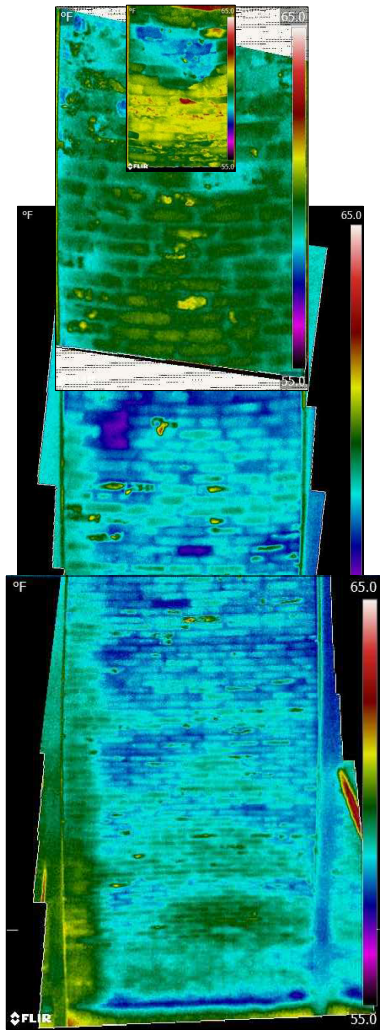


SECTION 3B

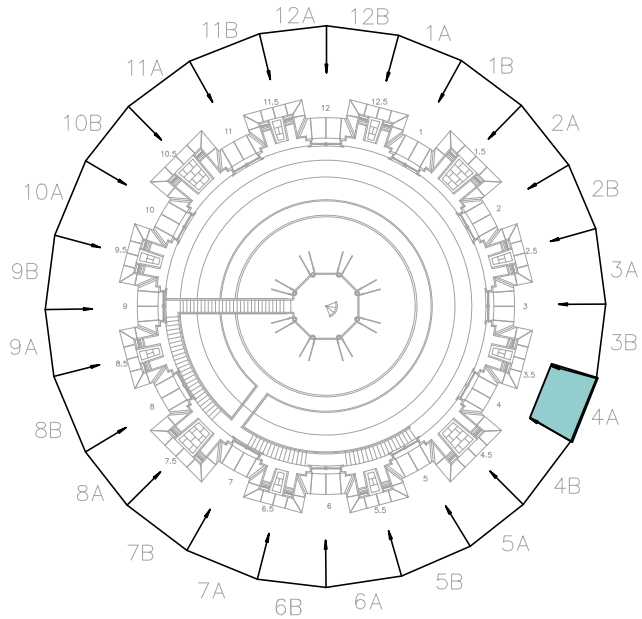


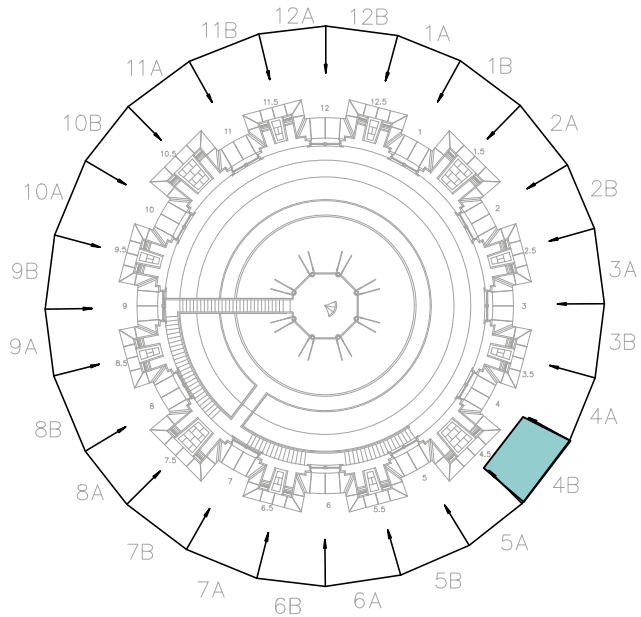
11.23.15 | 10:00 - 11:00 am

SECTION 4A

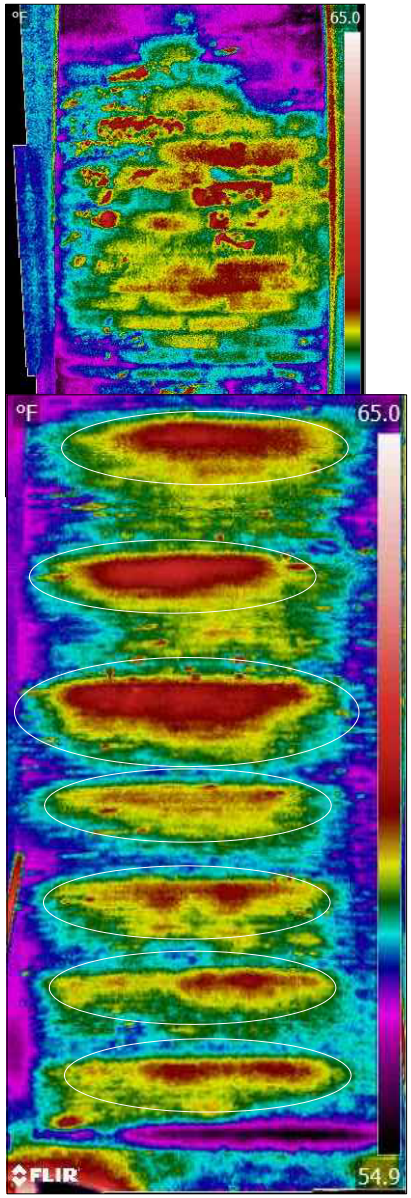


11.23.15 | 10:00 - 11:00 am



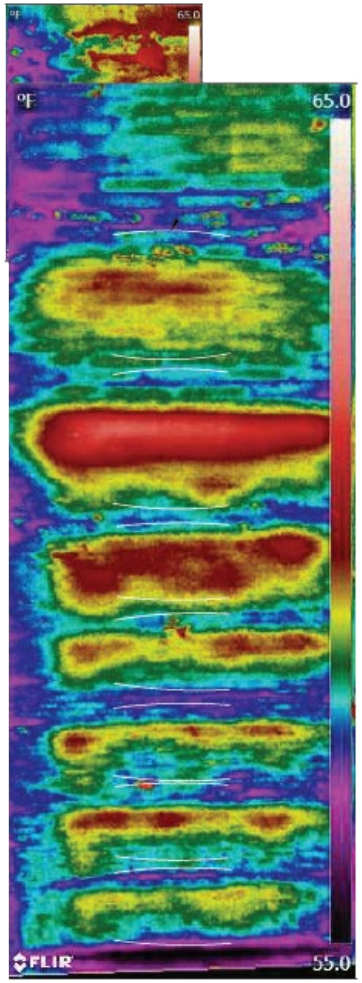


SECTION 4B

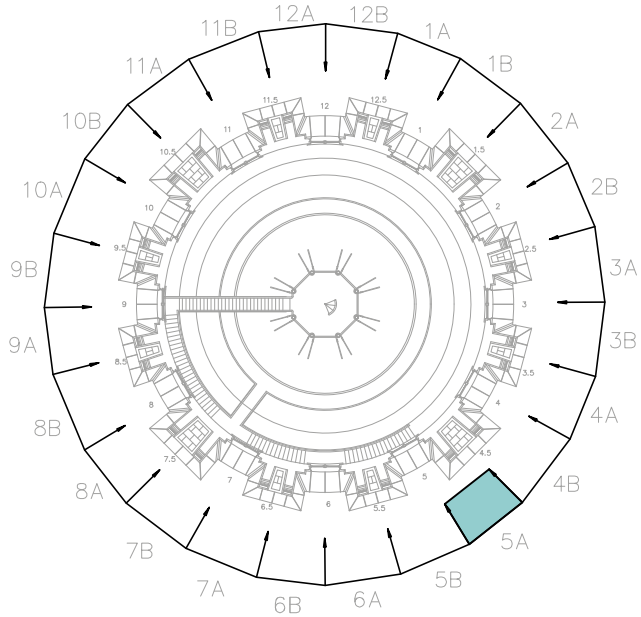


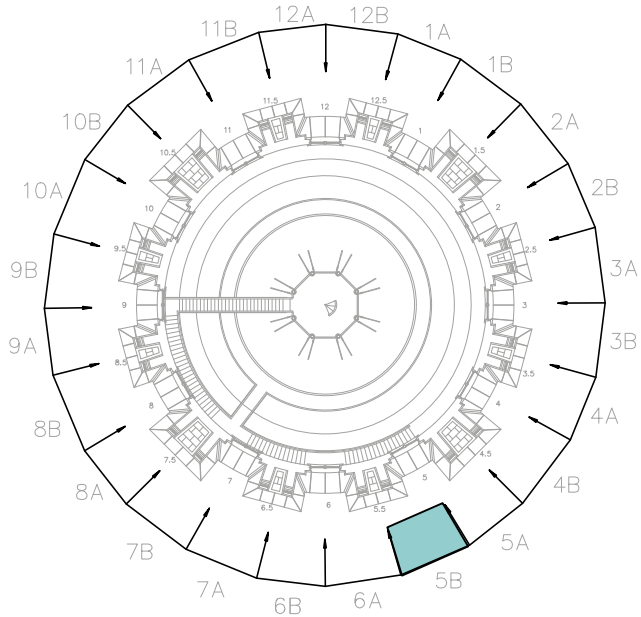
11.23.15 | 10:00 - 11:00 am

SECTION 5A

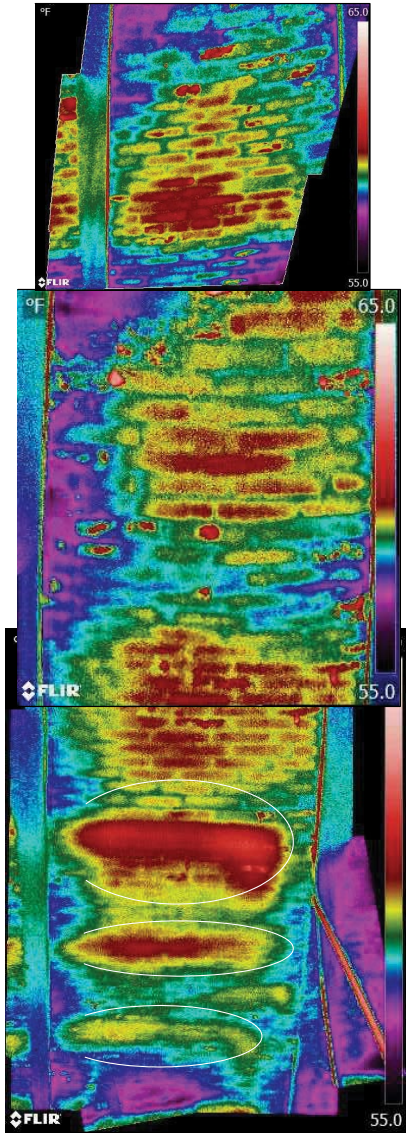


11.23.15 | 10:00 - 11:00 am



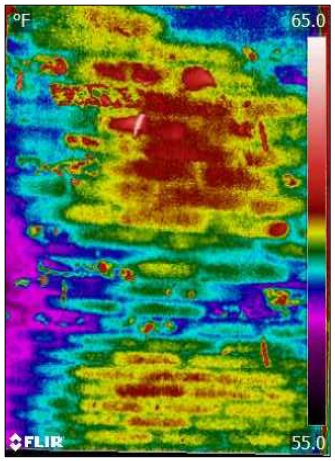


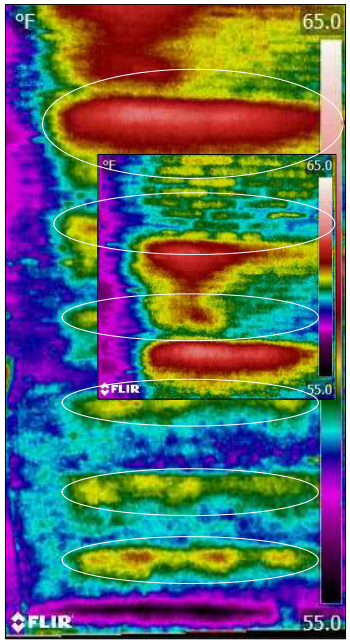
SECTION 5B



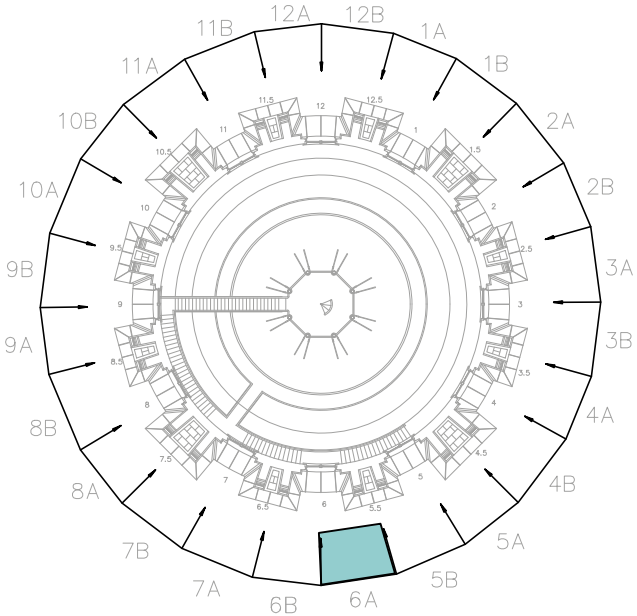
11.23.15 | 10:00 - 11:00 am

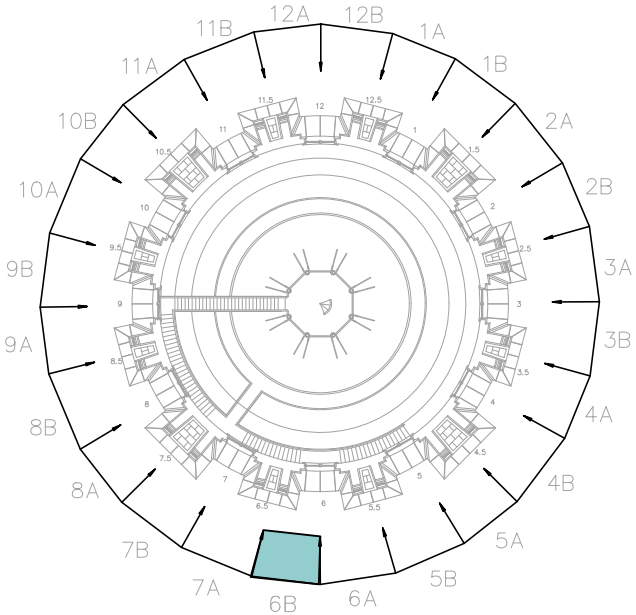
SECTION 6A



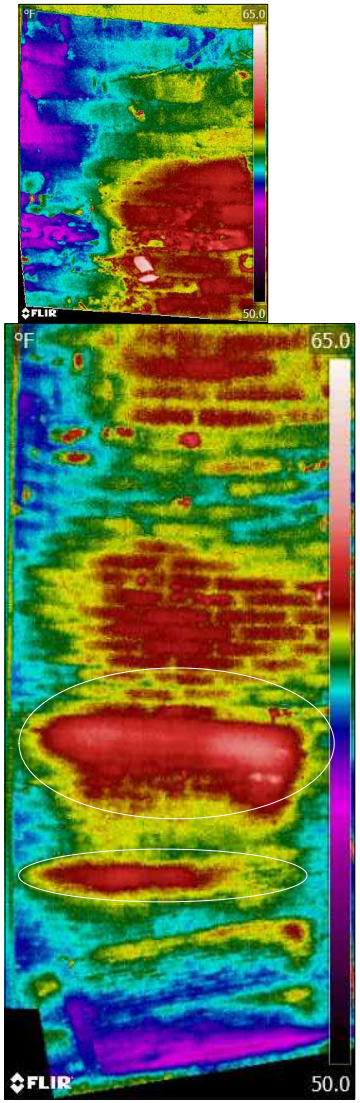


11.23.15 | 10:00 - 11:00 am



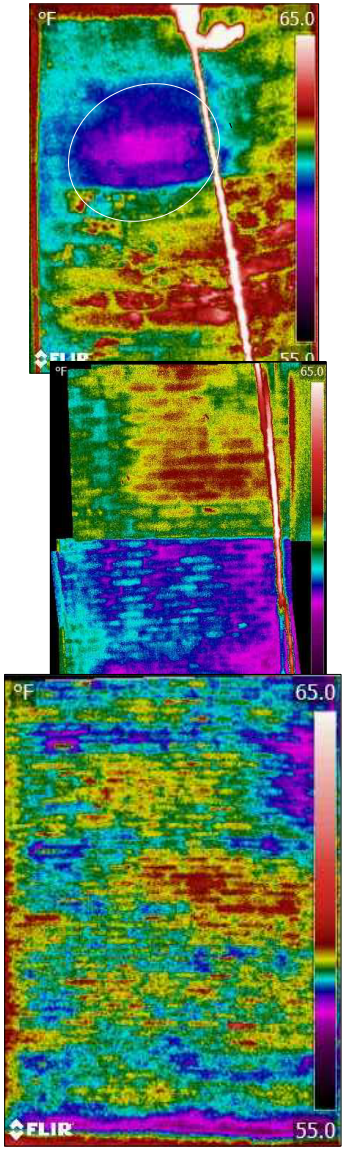


SECTION 6B

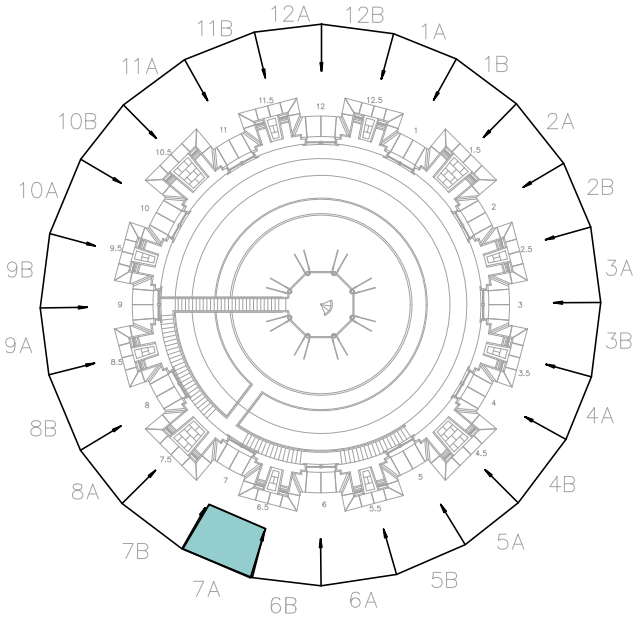


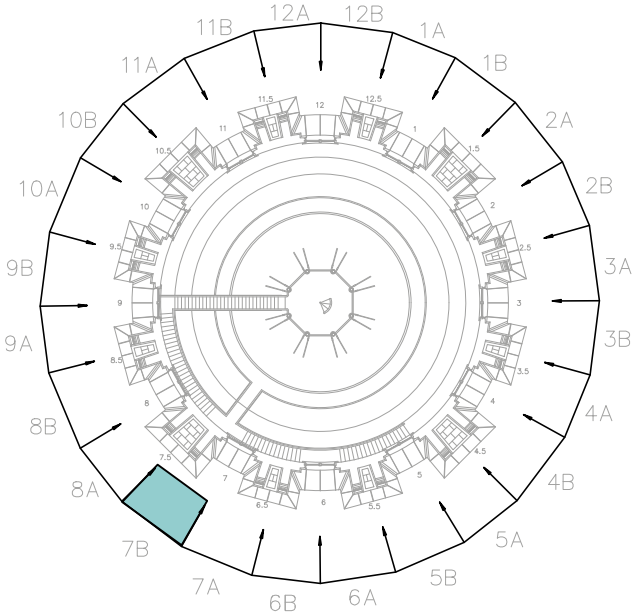
11.23.15 | 10:00 - 11:00 am

SECTION 7A

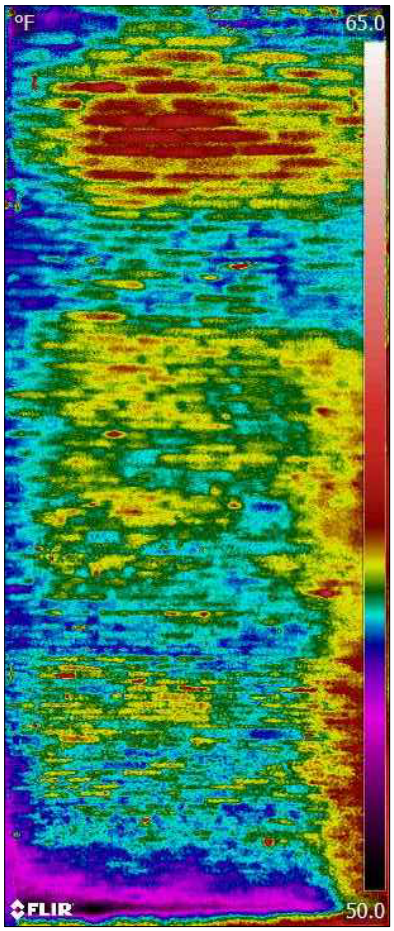


11.23.15 | 10:00 - 11:00 am



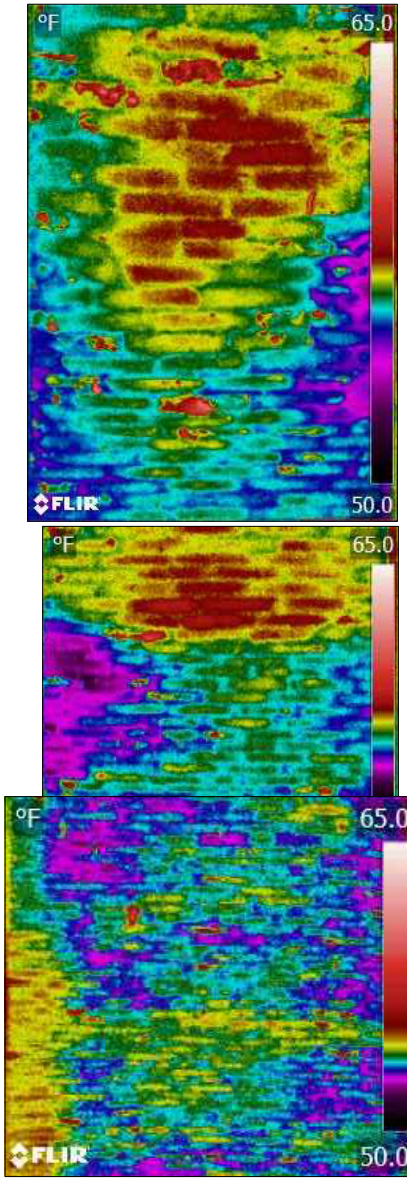


SECTION 7B

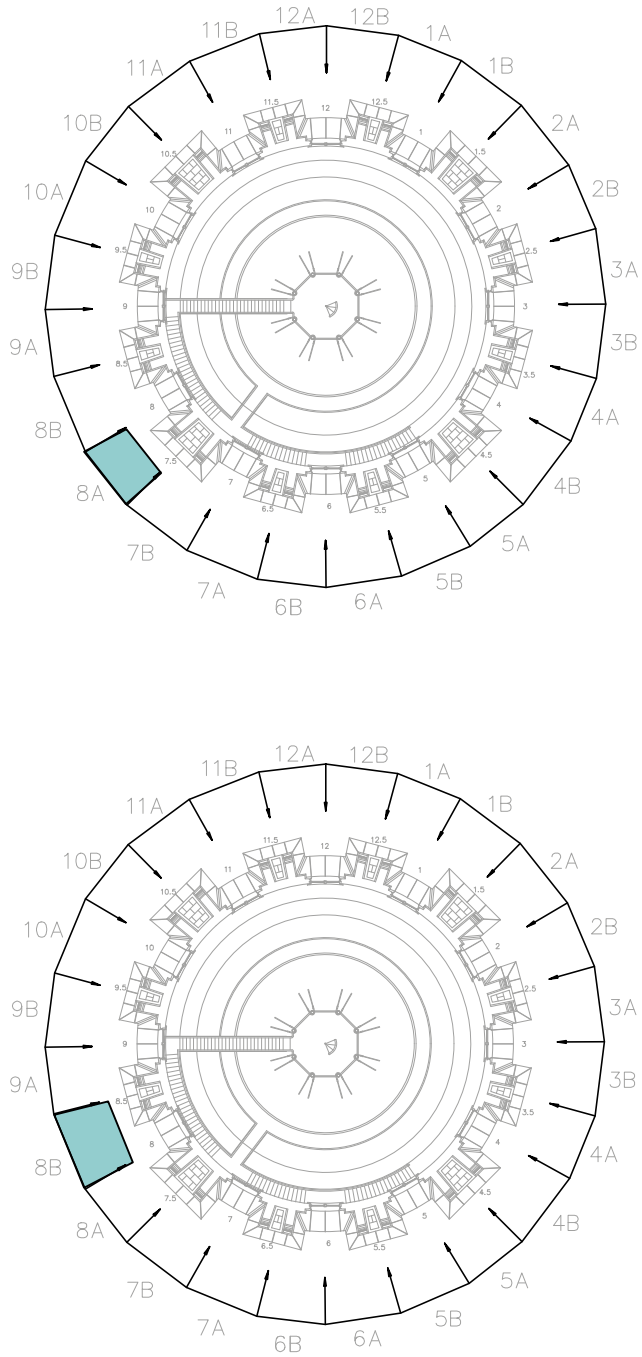


11.23.15 | 10:00 - 11:00 am

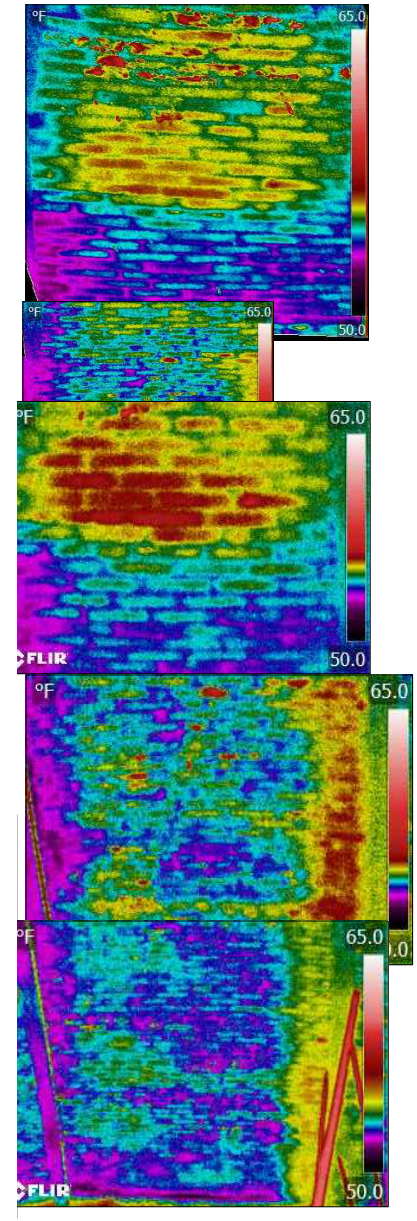
SECTION 8A



11.23.15 | 10:00 - 11:00 am

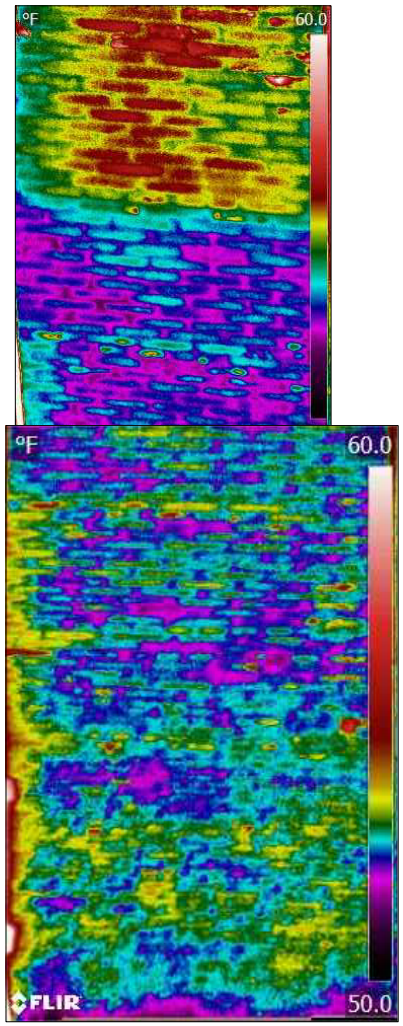


SECTION 8B

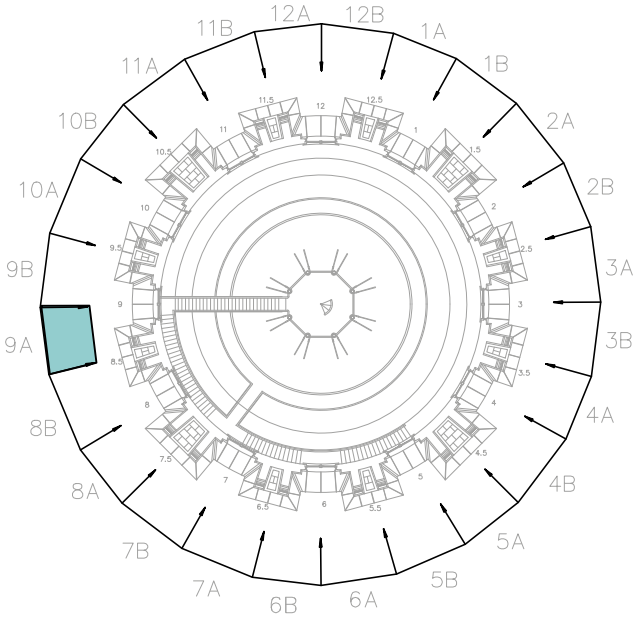


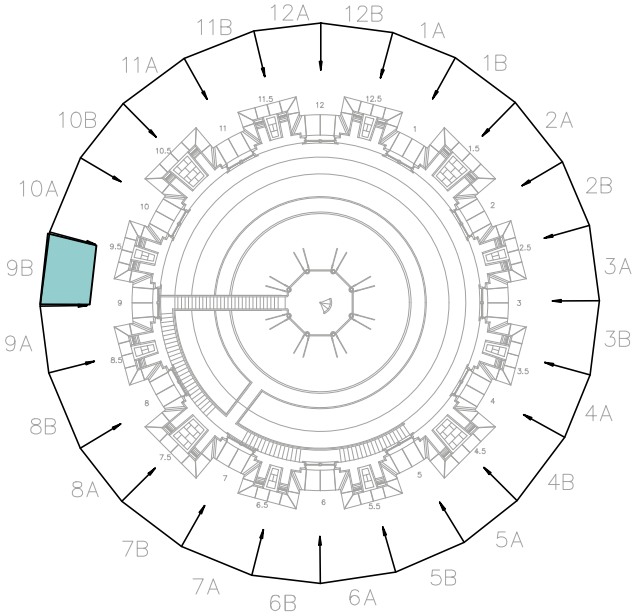
11.23.15 | 10:00 - 11:00 am

SECTION 9A

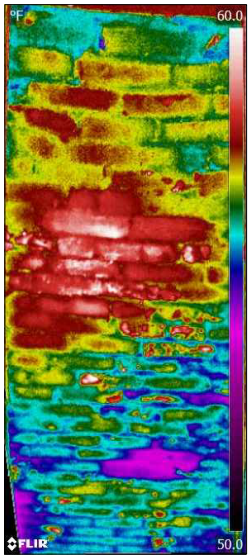


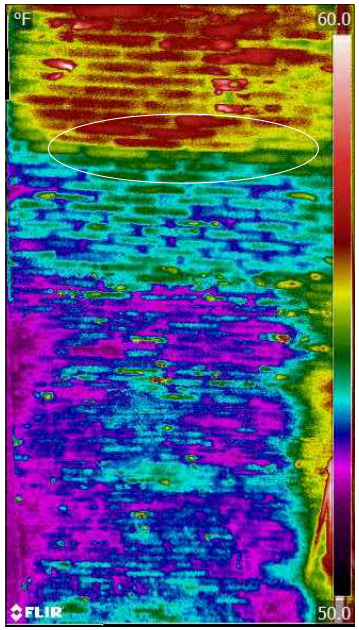
11.23.15 | 10:00 - 11:00 am





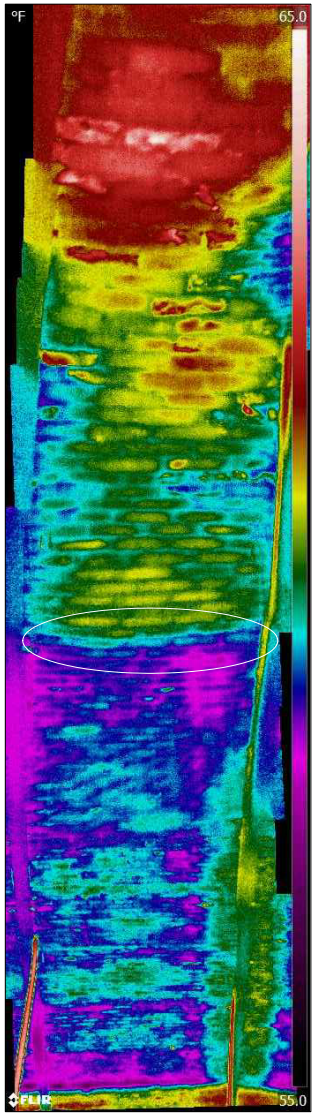
SECTION 9B



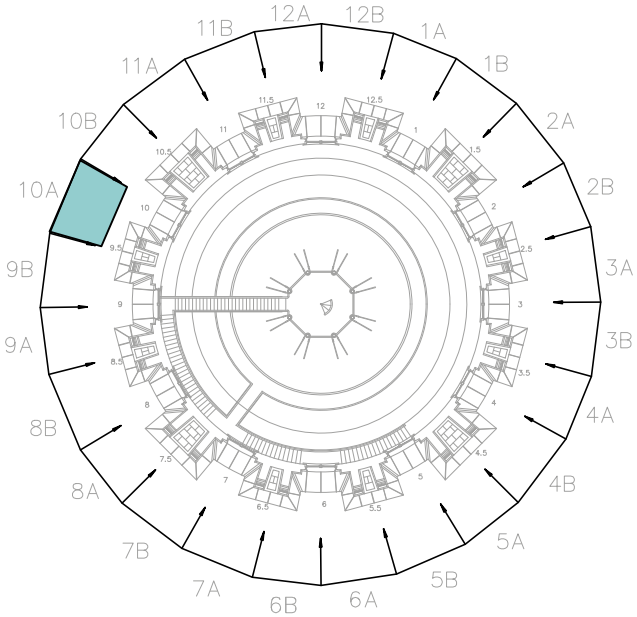


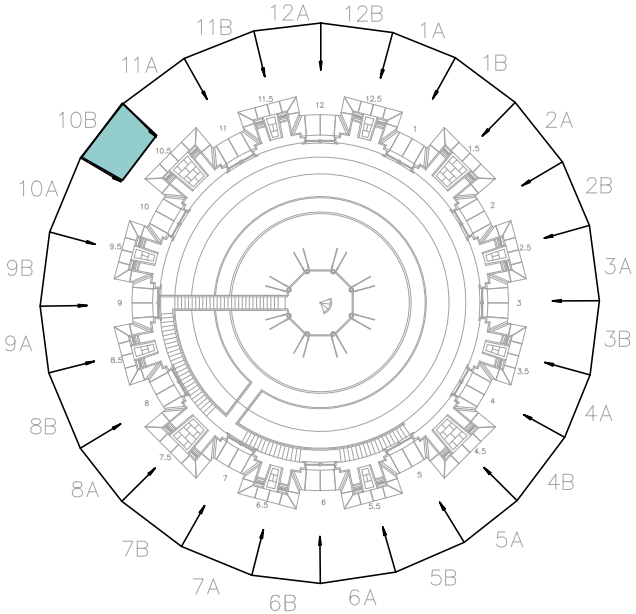
11.23.15 | 10:00 - 11:00 am

SECTION 10A

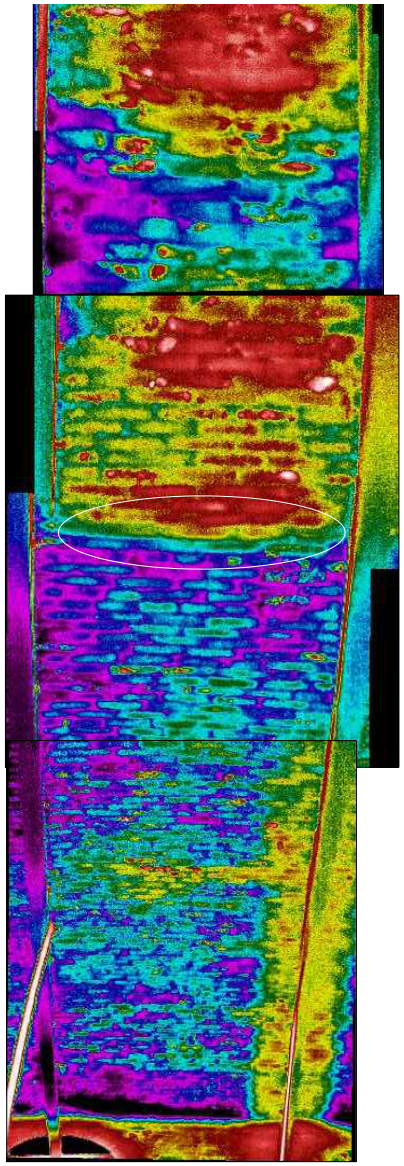


11.23.15 | 10:00 - 11:00 am



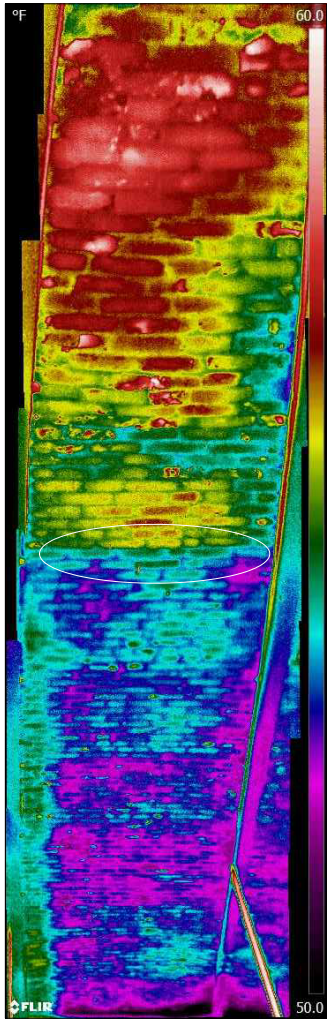


SECTION 10B

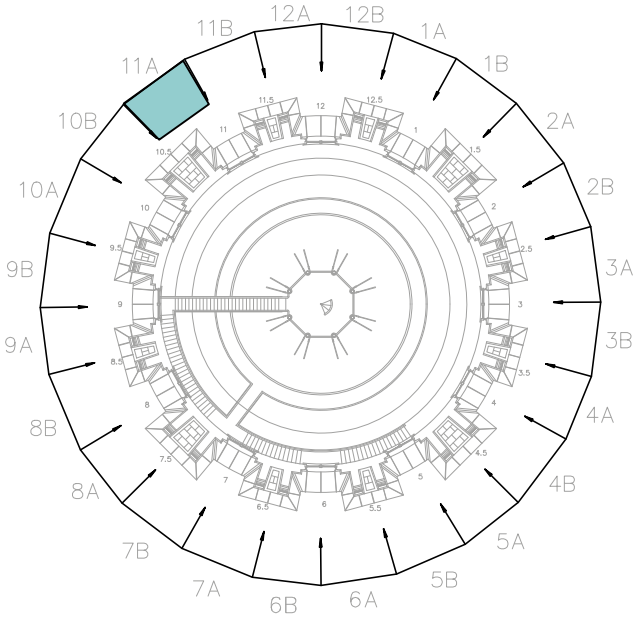


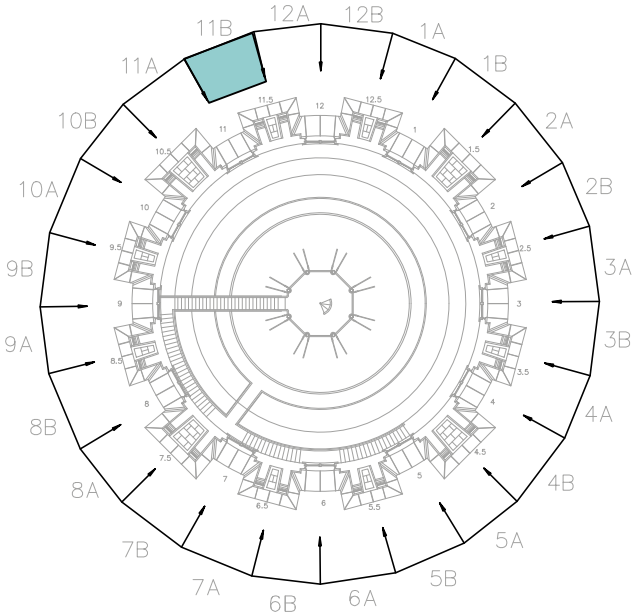
11.23.15 | 10:00 - 11:00 am

SECTION 11A

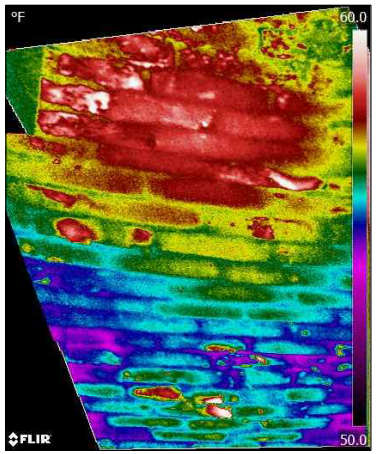


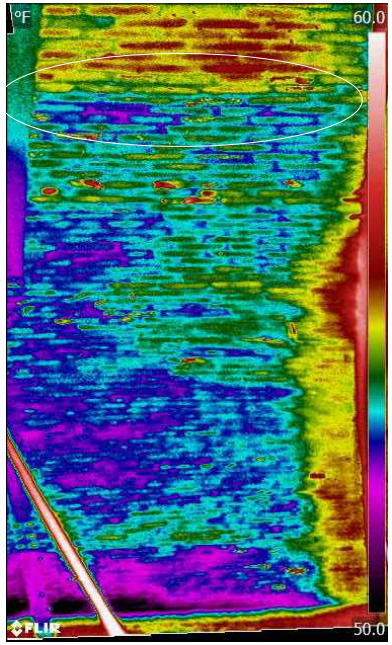
11.23.15 | 10:00 - 11:00 am





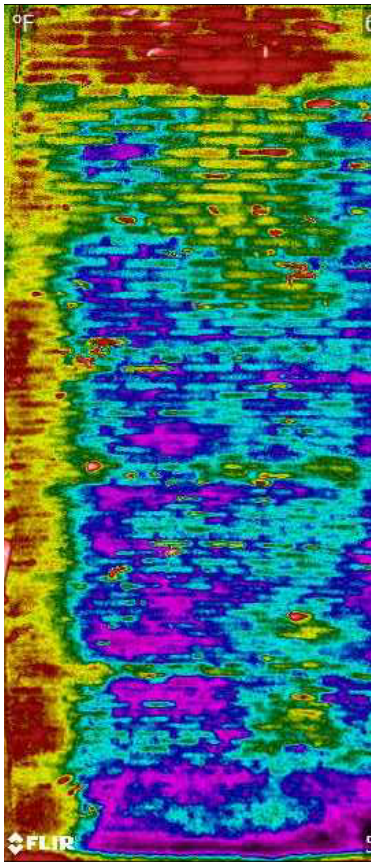
SECTION 11B



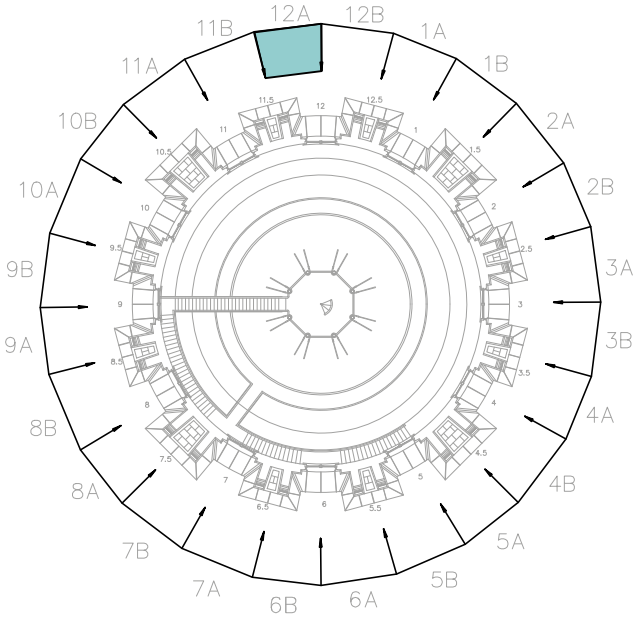


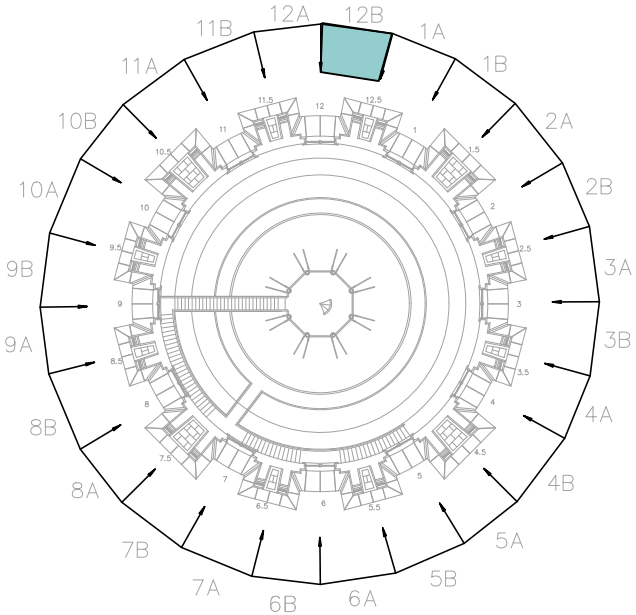
11.23.15 | 10:00 - 11:00 am

SECTION 12A

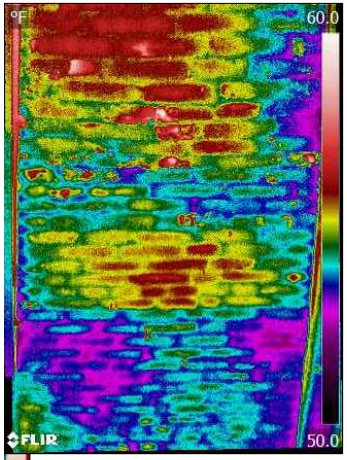


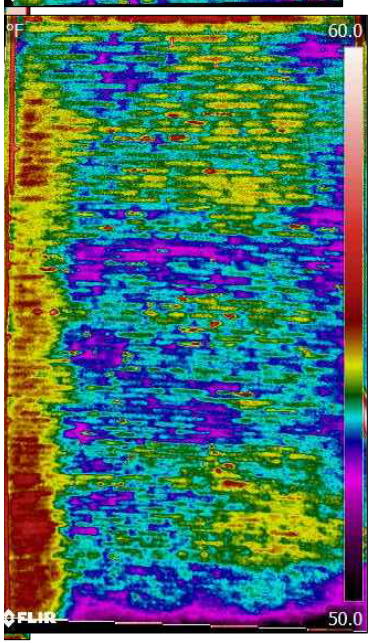
11.23.15 | 10:00 - 11:00 am





SECTION 12B





11.23.15 | 10:00 - 11:00 am

*Analysis of mechanical system is included in Design Cost. Any modifications to current mechanical system are not currently included in this budget. It is anticipated that only minor modifications may be necessary and they can be accommodated through the current contingency.

Item	Quantity	Cost Per	Total	Notes
Lantern Level L - Scaffolding - 6 mo	732	$190.00	$139,080	C.C.F. = One hundred Square Feet
Lantern Level L - Window repaint 40 sf of opening	8	$1,600.00	$12,800	Lump sum
Lantern Level L - Window repair and new glazing	8	$12,000.00	$96,000	Lump sum
Lantern Level L - Cast iron deck removal/repair	16	$3,000.00	$48,000	Lump sum
Lantern Level L - Structural repair under deck	1	$40,000.00	$40,000	Lump sum
Lantern Level L - Waterproofing under deck	1	$5,000.00	$5,000	Lump sum
Lantern Level L - Door repair	1	$10,000.00	$10,000	Lump sum
Lantern Level L - Vents	8	$3,000.00	$24,000	Lump sum
Lantern Level L - Demo Exterior lighting	8	$1,000.00	$8,000	Lump sum
Lantern Level L - Exterior and Interior lighting	8	$15,000.00	$120,000	Lump sum
Lantern Level L - Paint interior	644	$12.00	$7,728	square foot
Lantern Level L - Paint exterior	2826	$12.00	$33,912	square foot
Lantern Dome - Copper repairs	8	$2,000.00	$16,000	Lump sum
Dome Level K - Copper repairs	32	$2,758.69	$88,278	per square
Dome Interior Level K - Skydome protection	1	$30,000.00	$30,000	Lump sum
Dome Interior Level K - window removal and replace	12	$1,000.00	$12,000	Lump sum
Dome Level K - Window repaint - 15 sf of opening	12	$600.00	$7,200	Lump sum
Dome Interior Level K - Working platform structure	12	$4,500.00	$54,000	Lump sum
Dome Interior Level K - Grating platform	2826	$50.00	$141,300	square foot
Dome Interior Level K - railing	45	$40.00	$1,800	linear foot
Dome Interior Level K - ladder	1	$7,500.00	$7,500	Lump sum
Dome Interior Level K - Brick Masonry Demo/repair	1505	$215.00	$323,575	square foot
Dome Interior Level K - Brick Masonry Poultice	7608	$21.12	$160,706	square foot
Dome Interior Level K - Repointing Brick Masonry	7608	$12.67	$96,424	square foot
Dome Interior Level K - Consolidate Brick Masonry	7608	$8.50	$64,668	square foot
Exterior Drum Level J - Window repaint - 50 sf opening	12	$2,000.00	$24,000	square foot
Exterior Drum Level H & J - scaffolding of drum 13 mo. 96' Dia x 82' high	4820	$155.00	$747,102	C.C.F. = One hundred Square Feet
Exterior Drum Level H & J - Stone resurfacing	650	$100.00	$65,000	square foot
Exterior Drum Level H & J - Copper repairs	32	$2,758.69	$88,278	per square
Exterior Drum Level H & J - clean top of skydome	1	$10,000.00	$10,000	Lump sum
Exterior Drum Level H & J - Stone Cleaning - limestone	25174	$8.87	$223,339	square foot
Interior Drum Level H & J - scaffolding of drum 6 mo. 64' Dia x 66' High	1194	$225.00	$268,596	C.C.F. = One hundred Square Feet
Interior Drum Level H & J - Brick Masonry Poultice	7121	$21.12	$150,419	square foot
Interior Drum Level H & J - Repointing Brick Masonry	7121	$12.67	$90,252	square foot
Interior Drum Level H & J - Consolidate Brick Masonry	7121	$8.50	$60,529	square foot
Interior Drum Level H & J - Platform install factor with restricted access	24	$10,000.00	$240,000	Lump sum
Dome Level H - Window repaint - 132 sf of opening	12	$5,280.00	$63,360	Lump sum
Stylobate Flat lock joint repairs	35	$800.00	$27,600	per square
Stylobate Copper flashing repairs	307	$36.44	$11,194	linear foot
Stylobate Copper expansion joint repairs	136	$174.90	$23,787	linear foot
Stylobate Sealant remove and replace	384	$8.00	$3,072	linear foot
Stylobate Copper expansion joint extensions	96	$160.00	$15,360	linear foot
Stylobate protection for flatlock	4580	$4.00	$18,320	square foot
Stylobate - Load distribution for scaffolding	1.00	$30,000	$30,000	lump sum
Attic Level - Scaffolding to brick arch - 4 mo - access to brick arch in attic	320	$100.00	$32,000	C.C.F. = One hundred Square Feet
Attic Level - Poultice	990	$21.12	$20,912	square foot
Attic Level - Point brick	990	$33.80	$33,459	square foot
Lab work for salt extraction	1	$7,500.00	$7,500	lump sum
Wash down of dome by rope access	12	$1,500.00	$18,000	Lump sum
Crane time	1	$675,000.00	$675,000	Lump sum
Building/Site Protection/Construction Fence	1	$150,000.00	$150,000	Lump sum
Site repair due to construction access	4	$25,000.00	$100,000	Lump sum
Subtotal			$4,745,049	
Overhead & Profit		15%	$711,757.35	
General Conditions		8.5%	$463,829	
Building Cost Index projected to 4th Quarter of 2017 (9 quarters) and with Des Moines Construction Factor (12% + 6% = 18%)		18%	$1,065,714	
Subtotal			$6,986,349	
Contingency		15%	$1,047,952	
Total			$8,034,301	Statement of Probable Construction Cost
			$888,259	Design Fee *
			$7,632	Design Reimbursables
			$100,000	DAS - Owner's Representative fee
			$80,343	DAS - Builders Risk
			$8,775	DAS - EADOC project management software
			$871,589	Construction Manager fee
			$9,990,899	Project Cost

Click the links below to view video footage of the dome descent. The password for each is “Iowa”, case sensitive.

- Iowa State Capitol Dome
- Lantern Dome
- North
- East
- South
- West