# Roof Leak Investigation

# Cultural Resources Center
# National Museum of the American Indian
# The Smithsonian Institution
# Suitland, Maryland

Architects Project No. 203068

11 April 2005

**Prepared for:** **Hill International, Inc.**
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**Photo 1. The north entrance to the Smithsonian Cultural Resources Center.**

## Contents

## Executive Summary

The Smithsonian's Cultural Resources Center is a complex design with many different waterproofing conditions. At this time, there are two main areas where water infiltration problems exist.

**Library/Records Room**

The first is at the Second Floor Library/Records Room # 3094. The sheet metal flashing and ductwork penetrating through the roof above this room are not installed properly. The flashing cap that rests upon the roof curb is not sufficiently sealed to keep moisture from infiltrating and dripping down into the building.

Work to repair this condition would include removal of the existing flashing and ductwork, fabrication and installation of new sheet metal ducts and flashing at and above the four penetrations of the roof above the Second Floor Library/Records Room.

Our opinion of the probable construction cost for this is …………..………………….$4,000.

**Collections Storage Area**

The water infiltration into the Collections Storage Area has presented a complex problem because of the varied locations of the leaks inside; the intermittent timing of each event; the fact that events do not synchronize with specific weather conditions; deviations between contract documents and field conditions; and the radical nature of the roof design.

The roof is less than 5 years old and would normally be covered by warranty except that the original contractor is no longer in business.

Openings and tests illustrated the free flow and distribution of subsurface water from the upper roof down the vertical wall to below the lower roof. It showed that the distribution of water leaking inside relates to the location of water insertion at the level of the upper roof and explained the abundance of leaks along the exterior wall and in areas radiating out from the gutters. The smoking gun is the presence of water at various levels under the copper roof and the presence of water bubbles under the waterproof membrane in the gutters. Surfaces below the copper roof are soaked due to condensation caused by breaks in the vapor barrier and due to penetrations through the copper pans such as holes and hairline cracks in the solder joints. Water is penetrating below the gutters through faulty seams and flashing. Under the right weather conditions, sufficient quantities of water accumulate to flow through, below the surface of the lower roof, into the Collections Storage Area.

To address the water infiltration problem, Hoffmann Architects recommends the complete removal of the copper roof and installation of a rubberized asphalt underlayment under a replacement of the flat seam lead coated copper roof. This would prevent water penetration and reduce condensation. As an alternative, the northern most quadrant of the upper copper roof could be completely sealed under liquid applied roofing but this has aesthetic drawbacks. We also recommend replacement of the gutters and as a backup measure, a system of through wall flashing and weeps at the vertical knee wall between the upper and lower roofs that would conduct water from the upper roof or gutters to the outside.

Hoffmann Architects opinion of the probable construction costs for complete replacement of the copper pan roof, installation of gutters, and the installation of through wall flashing as described herein is……………………..……………………..………………. $438,000.00

Hoffmann Architects opinion of the probable construction costs for the alternate option of covering the existing copper roof, installation of gutters, and the installation of through wall flashing as described herein is...…………………………………………….... $100,000.00

## Introduction

**Owner's Concerns**

On 28 February 2003, Mr. Ray Molano, Project Director of Hill International, Inc., contacted Richard P. Kadlubowski, AIA, of Hoffmann Architects, to discuss water infiltration conditions at the roof and second floor terrace of the Cultural Resources Center of the National Museum of the American Indian.

**Preliminary Walkthrough and Architect Retained**

On 4 March 2003, Richard Kadlubowski and David Connell of Hoffmann Architects met with David Sidbury, Assistant Building Manager of the Cultural Resources Center of the Smithsonian, to discuss the project and tour the CRC Building. Mr. Kadlubowski and Mr. Connell observed water infiltration problems at the Library/Records Room, The Collections Storage Area, the ceiling of the loading dock, and the roof hatch. Based on this walkthrough, Hoffmann Architects submitted their proposal for services on 14 March 2003, and received the authorization to proceed from Ray Molano on 26 August 2003.

**General**

The Cultural Resources Center (CRC) was constructed in 1998 as a support facility for the Smithsonian Institution's National Museum of the American Indian. It is located at 4220 Silver Hill Road in Suitland, Maryland. The building, designed by Polchek, Metcalf, Tobey and Partners in collaboration with The Native American Design Collaborative, incorporates symbolic forms reflecting the spiritual relationship of Native Americans to the Environment. It is used for research, cataloguing, and storage of artifacts among other uses.

**Methods of Investigation**

On 14 November 2003, Richard Kadlubowski and David Fede of Hoffmann Architects met with Charlie Beggs of the CRC at the site in order to inspect the interior of this building and the corresponding exterior roof surfaces where problems were reported. They also spoke with Natasha Johnson, the Operations Manager for the Collections Storage Area, about the problems she observed. The interior underside of roofs and roof structures that could be reached by direct access were inspected up close with the use of CRC lifts and ladders. Exterior roof areas were walked and conditions noted.

On 18 November 2003, Mr. Kadlubowski and Mr. Fede were accompanied by Darrel Click and Wayne Click of Commercial Roofing and Sheet Metal Co., Inc. who performed roof openings at the approximate location of the leaks. Two openings were made through the roofing system on the north segment of the lower roof. One was located roughly on top of the exterior wall near a column and a second at a gusset plate on top of the first row of beams away from the wall. A length of parapet cap in the vicinity of the leaks below was also raised for observations but these were limited when the cap could only be raised a few inches.

On 20 November 2003, Mr. Fede revisited the site in order to observe the two unit heaters that feed the exterior plenum space and to acquire drawings showing this installation. Also information concerning the history of the occurrences of leaks, the quantities of water, and atmospheric conditions when the leaks occurred was obtained from Ms. Johnson.

On 30 December 2003, Commercial Roofing and Sheet Metal performed four openings into the parapet wall and roof flashing. The first one was made into the parapet in proximity to the previous openings with a second through the vapor barrier inside the parapet down to the metal decking. The third opening was made near the second, through the roof flashing at the base of the parapet. The forth opening was located higher up the roof slope and closer to the most recent leak.

On 6 February 2004, Mr. Fede was called to the site to observe water infiltration that had just begun. Observations were made inside and outside on the roof during rainy, and icy conditions. Mr. John Standish also pointed out additional sites of water penetration.

On 24 March, 2004 water tests began on the roof above the collections storage area. These tests were completed on 6 April 2005 and culminated in a meeting to discuss results with Mr.

Rick Croson. Mr. John Standish, and other Smithsonian staff.

On 10 May, 2004 a proposal for the final water tests and openings was presented to Hill International and the architect retained on 20 August, 2004. On 15 March 2005 the final water test and investigation was performed with Wagner Roofing Company performing the openings and Mr. Mike Frazier of the Smithsonian coordinating with the contractor and with Mr. Croson in attendance for observations.

## Observations

### General

The building is a complex design of forms and materials. The northern part of the roof spirals out in a nautilus shell pattern that centers on a pyramidal skylight and rings of angled skylights. Spiraling out from this is a metal latticework that leads into a sloped portion of the roof. The slope gradually decreases as the roof spreads out clockwise to the right and the shape is accentuated by a vertical break that creates an upper outer portion and a lower inner portion. The outer ring of roof is surfaced with flat seamed, lead coated copper pans soldered together, while the roof of the inner ring is composed of overlapping modified bitumen sheets. The roof is further divided radially into segments that are defined by knee walls on the lower roof and by gutters on the upper roof. The upper and north edges of the roof are dramatically cantilevered beyond the outer walls.

The roof to the southwest over the remainder of the building is isolated from the spiraling roof and is accessed separately through the mezzanine level of the Collections Storage Area. It is a flat roof, in an IRMA configuration composed of an EPDM membrane, polystyrene insulation, and protection board, ballasted with stone.

Inside, under the western spiraling roof, is the large collections storage area. This area is used to catalogue historic artifacts. It is open and climate controlled maintaining a humidity level of about 60%. Some larger artifacts are stored on shelves and in the open while others are stored in large metal lockers. At the time of our visit, the shelves and some of the artifact storage vaults in the northern most section of the space between the exterior wall and first line of radiating roof beams were draped in plastic sheet to protect the artifacts from leaks. Other spaces inside the building include offices, conference rooms and ceremonial spaces.

**Photo 2. The main roof centers on a pyramidal skylight surrounded by rings of flat roof and skylights.**

## Library/Records Room

### Interior Condition

The Second Floor Library/Records Room #3094 has water infiltration problems in the ceiling adjacent to the north wall. Water stains on suspended acoustical ceiling tiles indicate where water has dripped from above. The maintenance staff has recently replaced these tiles and therefore the damage we observed was new.

In the ceiling directly above the damaged ceiling tiles there is metal ductwork with rust and watermarks. During the initial visit, there was water present on the ductwork and on the bottom of the concrete structure.

**Photo 3. Rust and watermarks on the penetrating ductwork above the Library/Conference Room #3094.**

### Exterior Condition

The roof structure over the Library / Records room is a concrete waffle slab type of construction. The concrete is covered with ridged insulation, a waterproof elastomeric membrane, and stone ballast. Metal ducts penetrate the roof structure at four locations. Three of these ducts tie into air-handling units on the roof above and the forth is a vent.

The metal ductwork and flashing on the roof above the Library/Records Room show signs of after installation attempts to seal the joints. The flashing and ductwork has wide bands of sealant over the outside of the corner joints and some of that sealant is cracked and pulling loose. Directly above the most active leak there are open joints in the metal cap flashing and water is present in the cracked corner seals. The third unit from the east was the only one running during the November investigation and it draws in air through the base flashing.

**Photo 4. Four ductwork penetrations through the roof. Three lead to air handling units.**

**Photo 5. The duct penetrates the slab at the base flashing of the roof top air-handling unit. Tool shows open corner joints.**

## Collections Storage Area

The first signs of water infiltration were reported during the first week of December 2002. On four occasions that winter, approximately 1-1/2 inches (less than one-quart) of water was collected in a bucket. Water infiltration was not apparent in warmer months but began again in early December 2003, with the reported collection of more than one gallon of water. Again on 5 January 2004, at least one- quart of water was collected. Episodes of other occasional drips have been reported but they were lesser in volume.

Generally the leaks occur during cold but not necessarily freezing weather, during or shortly after a period of precipitation but not on a regular basis. There were no leaks reported during the warmer months including during extreme weather events of the year such as tropical storms. The leaks also do not directly correlate to the occurrence of snow and rain, happening sometimes when there is precipitation but more often, days after the last rain or snow. The 2004 – 2005 winter season has had only minimal reports of leaks.

**Photo 6. Shelving and artifact storage cases in the Collections Storage Area covered with plastic sheet.**

## Interior Conditions

The greatest concentration of water infiltrations and the greatest volume of water collected are located halfway along the exterior wall (structural grid number R-16). However, water infiltrations have been reported further along the wall toward the mezzanine and even at random locations further away from the exterior wall. On 6 February 2004, Hoffmann Architects witnessed an ongoing leak located at the head of the second structural column along the exterior wall. At the flange of the beam attached to this column, a steady flow of water was observed that flowed down the inside face of the wall into the collections storage area and also appeared to flow into the wall cavity. About two-quarts of water were collected on one day and the leaks continue sporadically up to the date of this report.

Close examination revealed watermarks on the flanges of beams along the exterior wall. Tape marks on the floor indicate where in the past water drops have fallen. There are also signs of rust at the gusset plates that are attached on top of the steel beams and break the surface of the metal roof decking.

**Photo 7. Rust marks at the breaks in the metal decking.**

**Photo 8. Watermarks along the beam flanges and column head in the collections storage area.**

## Exterior Conditions

All sections of the spiral roof, upper and lower, were observed and we found that generally the lower roof, the cant, and the flashing show little signs of wear. There were one or two spots on some of the southern segments of the lower roof where foot traffic had disturbed the abrasive surface but these areas did not penetrate the surface.

We focused on the northern most segment of roof, which is above the portion of the Collections Storage Area where water infiltration occurs. In this area water flows diagonally across the surface toward the parapet. After a snow there is some build-up mainly along the south and west sides in the shadow of the parapets, knee walls, and in the gutter.

**Photo 9. The northern segment of the lower roof drains diagonally toward the parapet on the northern edge**

There are two locations on the surface of the roof down the slope further than the observed interior leaks, with slight ridges where the rolled bituminous material is not laid down flat however they do not show cracks or signs of openings. There is slight abrasion and damming at the splash blocks below the drain trough outlets in the corner along the outside parapet wall. The flashing in the corner above the splash block is not tight but it is sealed and protected by the overhang of the upper roof. On the field of the roof there are three round patches from openings made prior to this investigation.

Coming off the edge of the upper roof especially from the area of the ribs, water pours onto the roof below. Generally this falls away from the vertical flashing but was observed to splash and blow back onto the adjacent wall.

The roof on the north side cantilevers beyond the exterior wall. A lower and upper plenum space exist in the area between the parapet that runs along the top edge and the soffit below. The lower plenum contains a duct fed from two heater/blower units located above the mezzanine. These units were not connected for the first two years after construction. Water was observed dripping from the soffit during water tests and there are stains and cracks indicating previous leaks.

Openings confirmed that the lower roof is composed of two layers of overlapping rolled modified bituminous waterproofing nailed to 3/4-inch plywood. The outer layers of roofing do not appear to be heat applied. Below this an air space is formed from non-continuous, 2 by 4-inch sleepers that rest on 2 layers of 2-inch polystyrene insulation, separated by a 3/4-inch layer of plywood. The lower vapor barrier is composed of a self-adhering rubberized asphalt membrane, adhered to 3/4-inch gypsum board. This is fastened to the structural metal decking visible from below. Subsequent openings and water tests showed that water flows freely through all levels of the roof, traveling in the interface between materials, down the slope of the roof and down through joints between the boards to the vapor barrier.

**Photo 10. During water tests water was observed flowing freely through all layers of the roofing system.**

**The Parapet**

The parapets are finished with lead-coated copper flashing and are vented at the cap on both the inside and outside faces. The cap has overlapping expansion joints at 30-foot intervals and soldered flat seam joints between. Many of the solder joints have hairline cracks and the sealant at the expansion joints is failing. Below the metal cap there is a layer of rosin paper that is soaked with water, sitting on top of elastomeric flashing. We observed only minor traces of rust on the internal framing within the parapet. The flashing on the roof side of the parapet is fastened on top at the vent and at the bottom above the cant with a screwed in termination bar. When the termination bar was removed the roof flashing was not adhered consistently to the plywood substrate.

The roof vapor barrier extends under the parapet to the outer wall, where it turns down over the edge of the plenum. The structure of the parapet on the roof side consists of metal framing, on a runner that is fastened through the vapor barrier to the metal deck at regular intervals. Plywood is attached to the framing and runs down to the vapor barrier of the roof adjacent to the cant. Tests showed that water below the surface of the roof flows along the base behind the cant where it seeps under the runner.

**Photo 11. Sealant on parapet at expansion joints is open.**

**Photo 12. During tests, an opening in the cant at the base of the parapet wall shows water flowing along the base of the wall and seeping under the base runner.**

**The Upper Roof**

The upper portion of the spiraling exterior roof is broken into segments by drain troughs and ribs that serve as expansion joints. This roof is finished with lead-coated copper pans, soldered together with flat lock seams. Nail hole size punctures were noted in a few locations throughout the roof and there are hairline cracks in many of the solder joints. The area of the field of copper pans between ribs and the gutters is largest on this segment of roof and on hot days the roof buckles as it expands. Joints on the ribs are sealed with large amounts of sealant that is cracked and unbonded.

**Photo 13. The upper roof area is finished with a field of lead coated copper pans divided by metal-capped ribs and drain troughs. Water drains off the end at the vertical knee wall to the lower roof.**

An opening in one of the copper pans on this roof revealed that below the copper is a layer of rosin paper, and then a layer of heavy weight asphalt impregnated roofing felt. Below this the construction is the same as the lower roof with a three quarter inch thick plywood substrate airspace created with wood sleepers, two inches of polystyrene insulation, three quarter inch plywood board, another two inch thick layer of polystyrene insulation, and a vapor barrier on gypsum board fastened to the metal deck. From the vapor barrier to the top of the copper pan roof is approximately seven and a half inches.

When the opening was made the rosin paper was found to be soaked as were areas on both levels of plywood. The vapor barrier was wet to the touch. Screws that connect the plywood down through the vapor barrier were damp and rusted. After periods of rain, water has been observed coming out from below the metal surface of the upper roof in spots along the edge above the vertical break to the lower roof. Closer examination revealed holes in the seams where the metal tucks under.

 

**Photo 14. Opening in the upper roof revealed moisture at all levels, from the rosin paper down through the insulation and plywood to the vapor barrier.**

**Photo 15. Water is coming out from below the copper pans along the seams at the edge of the upper roof.**

**Photo 16. Cracks in the solder joints along the upper edge of the copper roof.**

**Photo 17. Sealant at expansion joints on the ribs is open, allowing backflow of water under the copper pans.**

**Drain Troughs**

The drain troughs on the upper roof divide the spiraled roof into segments. The drain troughs are lined with an EPDM membrane and metal flashing from the knee wall wraps into the gutter at the outlet. Water is allowed to fall from the outlet onto a concrete splash block on the lower roof.

The trough lining has blisters filled with water that are more than eight inches long, and there are openings in some of the seams within the two troughs observed. The flashing at the second drain trough outlet from the northern edge is bent and pulled away from the sidewall. Ice dams with backed up water were observed at the outlet of this drain trough during freezing weather.

**Photo 18. Ice dam in the drain trough of the upper roof.**

**Photo 19. Openings in splice joint of the water proof liner of the drainage trough.**

**Photo 20. Water bubble under the membrane in the drainage trough.**

### Concrete Façade Panels On Flat Roof

Beyond the spiral roof is a lower flat roof that covers the remainder of the building. The parapet around this roof is formed by the continuation of the concrete facade panels above the roof. The sealant between the concrete panels is cracked in most locations.

There are holes in the concrete that have been previously patched but the patches are loose or missing. There are also areas near the top of this parapet where there are cracks and spalling is beginning.

**Photo 21. Deteriorated sealant between sections of the concrete parapet walls.**

### Other Areas of Reported Leaks

During the initial pre-contract walkthrough certain conditions were noted that were resolved prior to this report or did not appear in subsequent investigations. One item was the water penetration into the loading area from the west terrace wall of the library/patio area above. The owners have sealed this leak.

Another concern that appeared in the initial walkthrough is moisture on the inside face of the roof hatch. In our opinion this was a condensation problem caused by an air leak in the seal at the hatch. This was not apparent in latter investigations and does not seem to be repetitive enough to be a concern to the users.

Since the survey phase of this report other areas where there is water infiltration have been reported. New leaks have been reported in the “Textile Paper Lab” (E-3096) and in the “Open Offices” (E-3017). It appears that these water infiltrations are neither substantial nor regular in occurrence. Both are in proximity to the HVAC Units on the roof and may be similar to the leak at the Library Records Room. Further investigation and evaluation of the newer water penetrations is beyond the scope of this report but may warrant a new study if they persist.

## Evaluations

**Library/Records Room**

The leaks in the ceiling of the Library/Conference Room #3094 are a result of poor workmanship in the construction and installation of the sheet metal ductwork and flashing at four locations where the roof is penetrated above this space. The duct penetrations from these units allow water infiltration in a number of ways.

First water is seeping in through the seams at the corners of the metal cap flashing. The sealant on these units is insufficient and there are clearly cracks in the sealant that allow water to seep in. The vibration of the mechanical units exasperates this problem.

A second source of leaks is the result of water being sucked in between the roof curb and base flashing into the ceiling plenum below.

The third source of water in this area is a result of condensation. The metal ductwork and flashing through the roof is not thermally broken or properly insulated and it is therefore significantly cooler in wintertime than the room temperature. Warm moist air inside the building condenses on the cold metal surface and the condensate water drips down to the ceiling below.

**Collections Storage Area**

The water infiltration into the Collections Storage Area is a complex problem because of the bi-level, nautilus design of the roof. There is a weakness in the design of the roof that is most apparent in the northern most segment of roof. This segment has the least slope of the roof system and at the same time has the broadest area. This creates conditions where water drains more slowly and there is the greatest stress on the roof due to thermal movement.

The source of the water originates in the upper roof, in the drainage troughs bordering the upper roof, and at the expansion joints. The lower roof over the collections storage area is not believed to be a source of water, but the design is such that it provides an easy conduit for water to flow to any location on this segment of the roof. There are penetrations below this roof surface, through the layers of insulation, plywood, vapor barrier, and metal decking, that allows water to infiltrate into the space below.

The upper roof over the mezzanine storage area has water present below the copper pans and it has been observed in all layers of the roofing system. The source of this water appears to be a combination of penetrations and condensation. The penetrations are a combination of pinholes, hairline cracks, and open joints. There are a limited number of pinholes and most are associated with impact marks that appear to be the result of damage during construction. More widespread are the hairline cracks in the solder joints. These are primarily the result of movement due to expansion and contraction of the copper pans over a large field of roof. Warm weather makes the roof material bulge slightly. Cold weather shrinks the roof, pulling on the seams and opening cracks that are then vulnerable to water penetration through capillary action.

A lesser source of water below the copper pans is the flashing that covers the expansion joint. The lap joints between sections are not properly sealed and many present an opening for wind driven water and capillary action to draw water into the roof system.

The water infiltration problem is often a cold weather phenomenon for which condensation is a contributing factor. The water vapor that condenses comes from two sources, interior air penetrating the roof system from below and moist air entering through the vents at the ends of the roof cavities. The vapor barrier has unsealed screw penetrations and positive air pressure in the collections storage area forces high humidity interior air through any breech in the barrier. Vents are intended to dry that vapor however if outside air is also laden with moisture it can contribute to the problem. The distance to the openings and outside conditions such as rain and wind are factors in the effectiveness of a vent.

Another source of water is the gutter that is lined with an EPDM membrane. There is water below that membrane that entered through a combination of broken seams, condensation and improperly designed flashings that allows water in from below the adjacent roof. Once water is below the membrane it seeps down to the end of the gutter where it enters the vertical wall cavity between the upper and lower roof and continues through the lower roofing system.

An inherent problem with the gutters on this segment of roof is the propensity to allow the build up of ice dams toward their ends. This happens because of the shallow slope, which is unique to this segment of roof, a combination of snow buildup braced by the metal flashing, and a sequence of freeze and thaw cycles, which seals the snow pack. Tests have shown that when a dam occurs and the water backs up high enough, it will over flow the adjacent flashing and enter the vertical wall cavity and roof system below

The path of water travel once it is below the outer roof surface determines the location of the leaks inside and this varies depending upon where the source water is entering the lower roof system. The downhill path of travel is generally northeast toward the edge parapet and below this within the channels of the metal support decking the water flows back toward the southeast. Water tests made at the gutter on the southern edge of the segment resulted in leaks inside starting closest to the stair and proceeded through the middle of the space to the end wall. The quantity of water determined how far down the roof leaks appeared. Water tests on the northern edge of the upper roof and gutter developed leaks inside on the outer wall of the collections storage area starting at the mezzanine and under the soffit out side.

Openings and tests have proved that water flows readily through the layers of the roof system below the finished roof. From the air cavity it can flow along the first insulation board, through seams to the plywood and though joints to the lower insulation board and to the vapor barrier below. The vapor barrier has been penetrated many times by screws holding down the middle layer of plywood, which provides a conduit for water travel to the channels of the metal deck below. Another location where the vapor barrier is penetrated is under the outside parapet wall. Water flows along the base of this wall behind the cant and it was observed soaking under the runner where screw penetrations occur.

The spots inside the Collections Storage Area where the leaks are most prevalent are along the north exterior wall near the structural piers and at the first major beam parallel to the outside wall. The worst occurrences involve steady drips off of structural elements and streams down the exterior wall. Water that has penetrated the vapor barrier through screw holes connecting the parapet wall above, flows into the metal deck channels and flows back into the Collections Storage Area. The metal decking is not continuous and water comes out at the first available opening. Drips correspond to brakes and penetrations in the metal decking such as where the splice plate of a beam breaks the decking or where screws protrude. In some instances water will then travel along the beam flanges until it drips off at random locations or it is channeled to lower features such as secondary beams, light fixtures, or pipes before dripping to the ground.

The intermittent timing and varied locations of the water infiltration into the Collections Storage Area suggests a complex relationship between the source of the water and its appearance inside. There are reservoirs on different parts of the roof where the water must first accumulate and then drain from, to supply water to the leaks. Some of these reservoirs are the bubbles under the membrane in the gutter, others include the area under the copper pans where water was observed coming back out of holes and cracks in the copper pans. Joints in the insulation and substrate material also provide areas for ponding and parts of the vertical knee wall under freezing conditions would provide a significant reservoir of water. Accumulation and draining of these reservoirs regulates the timing and location of the leaks.

 

## Recommendations

**Library/Records Room**

Our opinion of the source of the water infiltration problem in the Library/Conference Room (#3094) is the flashing and ductwork penetrating the roof above. It is recommended that for all four penetrations the flashing and ductwork be removed and new ductwork and flashing be fabricated and installed. The ductwork should be disconnected from other ductwork on the roof and replaced with a new hood that is properly designed and constructed. Attention should be given to sizing, the avoidance of thermal sinks, the construction of joints and laps, and the connection and sealing of the units at the curb.

Hoffmann Architects opinion of the probable construction costs for the removal of ductwork and flashing and the installation of new ductwork and flashing is …………………….$4,000.

**Collections Storage Area**

Hoffmann Architects recommends a program of repairs beginning with the upper roof. Water must be stopped from penetrating the flat seam copper pan roofing. The solder joint between pans have been damaged in many locations and there is no effective means of resoldering those joints. Nor is the application of a sealant over the joints only, feasible since this would be both laborious and a maintenance problem that would have to be repeated frequently.

We recommend instead the removal of existing copper pans, rosin paper, and felt underlayment and replacement with new soldered lead coated copper pans with a rubberized asphaltic sheet and rosin paper underlayment. The copper pans would form the primary roof barrier while the underlayment would ensure that there is a vapor and moisture barrier to prevent condensation under the copper and as a backup for moisture penetration at this level. Expansion joint battens and flashing at the gutters would be detailed appropriately. The finished appearance would match the other roof segments. To further mitigate the effects of condensation we recommend a further analysis of mechanical options for dehumidifying the vent space within the roofing layers.

Hoffmann Architects opinion of the probable construction costs for the removal of the existing copper pan roof, batten cover, edge flashing and vapor barrier, and the installation of new vapor barrier, flashing, and lead coated copper pan roof is ……………….. $400,000.00

An alternate option for repair would be to completely cover the copper roof with another roof surface such as a fluid applied reinforced elastimeric coating. This would seal all joints including the expansion joint battens. This is available in many colors to match adjacent surfaces however the appearance would be monolithic and therefore would contrast with other segments of the copper roof.

Hoffmann Architects opinion of the probable construction costs for the preparation and installation of new liquid applied acrylic coating is ………………………….. $62,000.00

The gutters on either side of this roof segment also need to be replaced. The membrane lining the gutters and flashing up and under the roof must be removed and any damage to the wood substrate repaired. The nature of this repair will require pealing back the copper roof and replacing the roof and parapet flashing on both sides adjacent to the two gutters. A new rubberized asphaltic sheet underlayment would be installed as a vapor barrier and a new continuous copper trough would be installed and flashed into the roof.

Hoffmann Architects opinion of the probable construction costs for the removal of the existing gutter and related adjacent materials, limited repair of the trough substrate, the installation of new vapor barrier, gutter, and flashing is ………………...…….. $28,000.00

Finally as a precaution against future leaks that involve water below the surface of the roof traveling from the upper to the lower roof through the knee wall we recommend the installation of continuous through wall flashing. The flashing needs to be continuous from gutter to gutter across this segment and it must span through the wall from the vapor barrier to the outer surface of the wall, where it would weep onto the roof. The flashing needs to accommodate the studs that form the internal structure of the wall. The existing cant and base flashing on this wall should remain intact.

Hoffmann Architects opinion of the probable construction costs for the removal of the existing vertical exterior flashing and the installation of new through wall flashing, weeps and exterior face patch materials and flashing is ……………………………….. $10,000.00

Hoffmann Architects opinion of the total probable construction costs for the above-mentioned repairs involving complete replacement of the copper pan roof is ………………………………………………………………..………………. **$438,000.00**

Hoffmann Architects opinion of the total probable construction costs for the above-mentioned repairs based upon the alternate option for coating the existing copper roof is ……………………………………………………………………………….. **$100,000.00**

 

## General Information

**Construction Costs**

Statements of opinion of probable construction costs given in this report do not include professional fees for consultants concerning repair procedures, preparation of construction documents, assistance with bidding, construction contract administration, or on-site observation of construction. Construction costs projected in this report represent our opinion as to what the probable costs, in today's dollars, might be to implement the recommendations. They are based on our experience supplemented by published cost estimating sources. They reflect preliminary data and have not been derived from accurate quantities, drawings, details, or specifications. Actual construction costs may therefore vary from the costs in this report.

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