

PROCEEDINGS

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## WATERPROOFING AND INTEGRATION OF EXPOSED AIR HANDLING UNIT (AHU) CLADDING WITH THE BUILDING ENVELOPE

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## ABSTRACT

Large rooftop mechanical equipment, such as air handling units (AHUs), can be an important component of a building's exterior envelope. However, it is critical that the skin of this equipment be designed or constructed with principles similar to the remainder of the building envelope. This presentation will explore successes and failures in AHU cladding and roofing systems. It will also provide guidance for alternative construction techniques that can address specific issues, including removing the equipment from the building envelope.

## SPEAKER

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DAVID MARKMAN is a waterproofing consultant with Simpson Gumpertz & Heger. His experience designing and investigating the exterior envelopes of large biotechnology, university, and laboratory buildings has helped him understand how to make AHU construction and integration with the building envelope successful and where it can go wrong. He will draw on these experiences to highlight often-overlooked envelope concerns and considerations for designing these systems.

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# WATERPROOFING AND INTEGRATION OF EXPOSED AIR HANDLING UNIT (AHU) CLADDING WITH THE BUILDING ENVELOPE

The building envelope can colloquially be defined as “the part of a building that keeps the weather out.” This simple idea can focus envelope designers as they review construction documents. The most common building envelope components are walls and roofs. Our industry has developed standards, test methods, and expected behaviors of these components. Any building component that intersects or interrupts the building envelope should have the same performance as the envelope component it interrupts. This includes rooftop-mounted air handling units (AHUs), and these units are the focus of this paper.

An AHU is a piece of mechanical equipment that supplies conditioned air to a building. This can include heating, cooling, dehumidification, and purification of the air. AHUs can be installed within penthouse structures or at other locations within a building envelope. Alternatively, they can be installed in an exposed condition on a building’s roof. Typical rooftop AHU

installation involves hoisting prefabricated units onto the roof and securing them to an AHU support curb. The unit is typically hoisted from “lifting lugs” that are secured to the AHU. If the unit is too large to hoist as a single section, demount brackets are installed on each section, and these are used to secure each adjacent section.

When the AHU is placed onto a support curb, the typical waterproofing solution is to run the roof membrane up the AHU curb and terminate it at the AHU. This common method introduces a large discontinuity, in the form of the AHU, into the roof assembly at the top of the building. Because the roof membrane terminates at the base of the AHU, the AHU exterior skin becomes a de facto component of the building envelope. Therefore, to remove this discontinuity, the exterior walls, doors, and roof of the AHU should now meet the performance requirements of the remainder of the building envelope. The AHU envelope has become an integral component of the building envelope.

the watertightness of the AHU should be performed to verify the performance of the aforementioned items.

The premanufactured nature of this mechanical equipment, combined with the manufacturer’s focus on mechanical system performance, and not waterproofing performance, can lead to water intrusion. This intrusion is most commonly observed at the AHU-to-roofing transitions. With this in mind, the authors will review common AHU equipment construction in exposed conditions.

## AHU CONSTRUCTION

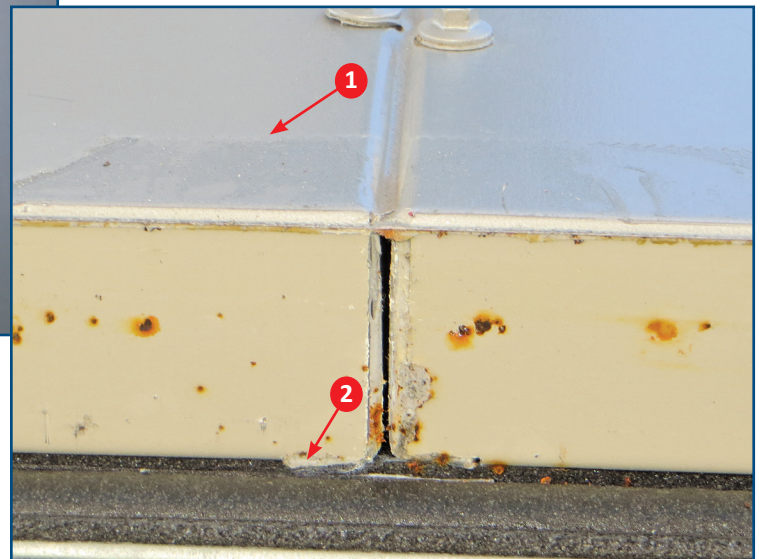
### Walls

The majority of AHUs are constructed of insulated metal wall panels. This typically takes the form of a metal skin infilled with spray polyurethane foam or fiberglass batt insulation. The metal wall panels typically are back-sealed to an interior frame with a compressed foam gasket and have a bulk water exterior-applied sealant joint placed between them as shown in *Figures 1* and *2*.

The industry standard for minimum sealant bond line and sealant joint width is 6 mm. As you can see in *Figure 2*, the joint width does not meet this requirement. The sealant joint shown in *Figure 2* acting as the primary weather seal would



**Figure 1 – Metal wall panel construction.**



**Figure 2 – Sealant joint (1) between metal wall panels and foam gasket (2).**



**Figure 3 – Single-direction roof slope.**

not be acceptable on the building envelope and should not be acceptable on an AHU that is now acting as a component of the building envelope. On many AHUs, this is just a bulk water diverting seal. However, at this size, the joint does not have the same performance as a joint designed per industry standards. In the above case, the wall panel returns are break metal with the edges butted together. The joint does not incorporate welded corners. Interior fillet sealants are installed at the factory. To speed construction, the wall panels are also fastened to the unit in the factory. This makes portions of the primary weather seal unavailable for field verification. Wall panel construction and similar joints are common across the industry. When identifying paths of water intrusion, the wall panel construction can be a common component of the path.

### Roof

On the majority of the authors' projects, the AHU is rectangular in cross section, with the top of the unit level. To address the concern of ponding water, a sloped roof is typically constructed on top of the flat top-of-unit. Depending on the width of the unit, this sloped roofing section can have single-direction slope, as shown in *Figure 3*, or a single roof ridge with two directions

of slope.

The building codes that govern a rooftop AHU include NFPA 54 ("The National Fuel Gas Code"), the International Mechanical Code (IMC), and the International Building Code (IBC), among others. The 2015 IMC, section 303.8, states, "Equipment and Appliances on Roofs...shall be designed or enclosed so as to withstand climactic conditions in the area in which they are installed." This is further reinforced in that if the building envelope terminates at the base of the AHU, the AHU's envelope becomes a portion of the building's envelope.

The IBC sets requirements for the building envelope. Specifically, the 2015 IBC (the Code) defines a roof assembly as "a system designed to provide weather protection and resistance to design loads." Therefore, if the AHU is part of the building envelope, then it forms a portion of the roof assembly. The Code goes on to state, "The system consists of a roof covering and roof deck. ...A roof assembly includes the roof deck, vapor retarder, substrate or thermal barrier, insulation, vapor retarder and roof covering," and it defines the roof deck as "the flat or sloped surface constructed on top of the exterior walls of a building or other supports for the purpose of enclosing the story below." If the AHU is a component

of the building envelope, a strict interpretation of the building code would require the roof assembly and the roof deck of the AHU to comply with the waterproofing and structural loading requirements of the Code. This would include Section 1504.1, "Wind resistance of roofs. Roof decks and roof coverings shall be designed for wind loads in accordance with Chapter 1." However, even if the interpretation that the AHU must meet the requirements for roof assemblies (as defined above) is not used, the fact of the matter is that the envelope of the AHU is exposed to the same environment and forces as the remainder of the building envelope. Therefore, the AHU envelope should perform to the same standards. The above requirements stem from the fact that when the building envelope terminates at the AHU, the AHU envelope becomes a de facto component of the building envelope. If the building envelope at the roof—commonly the roof membrane—ran continuously under

the AHU, the AHU envelope would be separated from the building envelope and the above requirements might not apply. Care should be taken by the designer to determine if the above interpretation applies to their product and their design, and steps taken to confirm that all portions of the building meet the requirements of the Code.

The authors have seen two primary methods of rooftop AHU construction: a standing seam metal roof with battens over the seams, or a single-ply thermoplastic roof membrane over tapered insulation. When a metal roof is installed, it leads to inaccessible interstitial space between the top-of-unit and the metal roof. The design and construction of the AHU roof—be it standing seam metal or thermoplastic—can suffer from the same failure mechanisms as the corresponding roofing components installed in a more conventional manner. For thermoplastic roof systems on AHUs, roof edge securement, positive slope, and membrane welds are potential weak links. With AHU standing seam metal roofs, the integration of the rooftop end caps, the end of the standing seam battens, corrosion potential, and deterioration of metal panel coatings have all led to water intrusion or leakage. In the authors' observations, each of these items can lead to water intrusion of rooftop AHUs. However, if good design



**Figure 4 –  
AHU mounted  
on posts.**

**Figure 5 –  
Close-up of  
unit mounted  
on posts.**

practice is followed, both the standing seam metal roof and the thermoplastic membrane roof can provide appropriate protection.

### Roof-to-AHU Integration

The most common method of transitioning from the building envelope to the AHU envelope is to place the AHU on a curb. The roofing membrane terminates at the top of the curb, and the AHU is placed above. The AHU now becomes a component of the building envelope, and the continuity of the building envelope must be maintained. Commonly, the AHU has a perimeter structural base frame taking the form of a structural C-channel (*Figure 5*). If the unit comes in one single section, joints in the C-channel can be fully welded in the factory. This maintains the continuity of the building envelope. If the unit comes in multiple sections, the joint where sections come together is often referred to as the demount joint. Joints in the perimeter structural support—either at demount joints or joints in the structural support—should be sealed. However, this may not occur. This is primarily due to the AHU manufacturer’s installation of a sheet metal counterflashing that extends from the AHU wall down over the structural channel and counterflashes the roof membrane termination. If this flashing is installed in the factory, then this flashing will be discontinuous at the demount lines and will prevent sealing of the perimeter structural support joints. Water can still bypass this flashing—either through unsealed laps in the flashing or by



wind-driven rain passing up and under the bottom of the base-of-wall flashing. An alternative to providing a continuously welded or sealed structural channel is to extend the roof membrane to the top of the C-channel and integrate it to the base of the wall panels with a sheet metal Z-flashing or liquid-applied self-terminating membrane.

Joints in the bottom structural support are one common area of concern; however, additional care must be taken at the wall-to-wall joints, and the base of the wall panels are primarily sealed with a back gasket to a primary frame, this demount joint introduces a seam in the gasket. Removing the panels

on either side of the demount joint can allow inspection of the manufacturer’s proposed sealing system at this joint. Introducing a form of sill flashing with a back upturned leg between the back of the panel and the primary structural frame would kick out water that tries to bypass this joint and would have the added benefit of directing water away from the joint in the C-channel.

### Roof-to-AHU Separation and Isolation

As an alternative to the conventional AHU installation on curbs, the AHU’s envelope can be isolated from the building envelope by mounting the unit on cantilevered steel columns acting as support posts.



**Figure 6 – Typical duct penetration.**

As shown in *Figures 4 and 5*, with the unit mounted on posts, the contractor can install the roof membrane under the AHU. In this way, the only discontinuities introduced in the building envelope are the posts and any potential ductwork under the unit. Depending on where the AHU exhaust and supply ducting are routed, any duct openings that occur below the AHU will still require curbs; however, the overall discontinuity created by the AHU is reduced. In our review of five projects, the surface area of these discontinuities can be as little as 5% of the typical footprint plan area of the unit. Installing the unit on posts as shown in *Figure 5* effectively removes the rooftop AHU from the building envelope. The AHU becomes an isolated piece of rooftop equipment whose function as equipment will continue to have an effect on the building, but its impact on the building envelope is reduced. In addition to reducing the impact of the AHU on the building envelope by extending the building envelope continuously under the AHU, the ponding and roof slope cricketing is avoided because water can flow directly under the units. Complete reroofing does require the space below the unit to be tall enough to facilitate construction. These tangible benefits to the building do come with some drawbacks. The cost of posts is often higher than the cost of curbs. Additionally, the installation of the posts can take longer than the installation of curbs.

### AHU Ductwork

The primary purpose of an AHU is to condition air for a building. This requires airflow into the unit (air intake) and airflow out of the unit (exhaust). Depending on the mechanical system used on the project, the intake air can be 100% outside air, or some percentage of the intake air can be ducted into the unit from the building. All of the exhaust air is ducted into the

building. The intake and exhaust ducts that connect the AHU to the building can occur directly below the unit or they can duct to the sides of the unit and enter the building away from the AHU. Care must be taken with these duct penetrations, similarly to all other rooftop penetrations. The duct penetration is typically offset from the top of the roof by placing the duct on curbs (*Figure 6*).

AHUs often come as individual units that are connected at demount joints. Ductwork and duct penetrations do not have the same segmentation concerns. This is primarily due to the continuous sheet metal construction. The omission of demount joints simplifies the construction and reduces the risk of water intrusion. However, water that does enter an AHU runs the risk of flowing into the building through the ductwork. Addressing the waterproofing requirements of ductwork is outside the scope of this paper.

## CASE STUDIES

### Unique Concerns: Rooftop AHU leakage

There are two unique features of AHUs that make leakage investigation more complicated compared to leakage investigation of other building envelope components. The first is that there is often minimal redundancy built into the HVAC system. This means that when an AHU is shut down for maintenance, the entire building may lose its conditioned air. Therefore, localized

sources of water intrusion can now lead to a global impact on a building. For continuously occupied buildings, this can have an unacceptable negative impact on building operations. This can lead to costly temporary cooling systems and ducting to serve the building while the unit is offline for the investigation.

The second unique concern is that AHUs can pack a significant amount of equipment into a very small space. A single AHU can incorporate a fan wall to push air, an ultraviolet light chamber to disinfect the air, multiple cooling chambers, dampers to control airflow, and additional fans for exhausting air. In addition to these components, all of the water, gas, electrical, and waste infrastructure must also be incorporated into a small space. This condensed equipment makes observing, tracking, and localizing a leak location very time-consuming, difficult, and, therefore, expensive.

### Case Study A

The authors were called in to assist a building owner during construction. Construction was nearly complete. The building had rooftop-mounted AHUs. These units were recently installed, and during the first rain event, water was observed within the interstitial space below the units and within the occupied space on the floor below. Additional investigation after the initial event found water within the AHU unit and within the insulated metal wall panels. The following investigation discovered water intrusion through portions of the AHU wall assembly, door assemblies, and standing seam metal roofs. The integration of the unit to the primary roof membrane was tested and performed appropriately. After the investigation, repair procedures were agreed upon that required installing preformed silicone tape over all exterior joints in the unit roofs and walls (*Figure 8*).

### Case Study B

As shown in *Figure 9*, this rooftop AHU showed significant corrosion on top of the standing seam metal roof. The combination of water ponding and a marine environment were the primary sources of corrosion. However, other units on the same building, exposed to a similar environment and of a similar vintage, did not exhibit this corrosion. This was primarily an anti-corrosion coating failure, and the repair was to re-coat the standing seam metal roof.

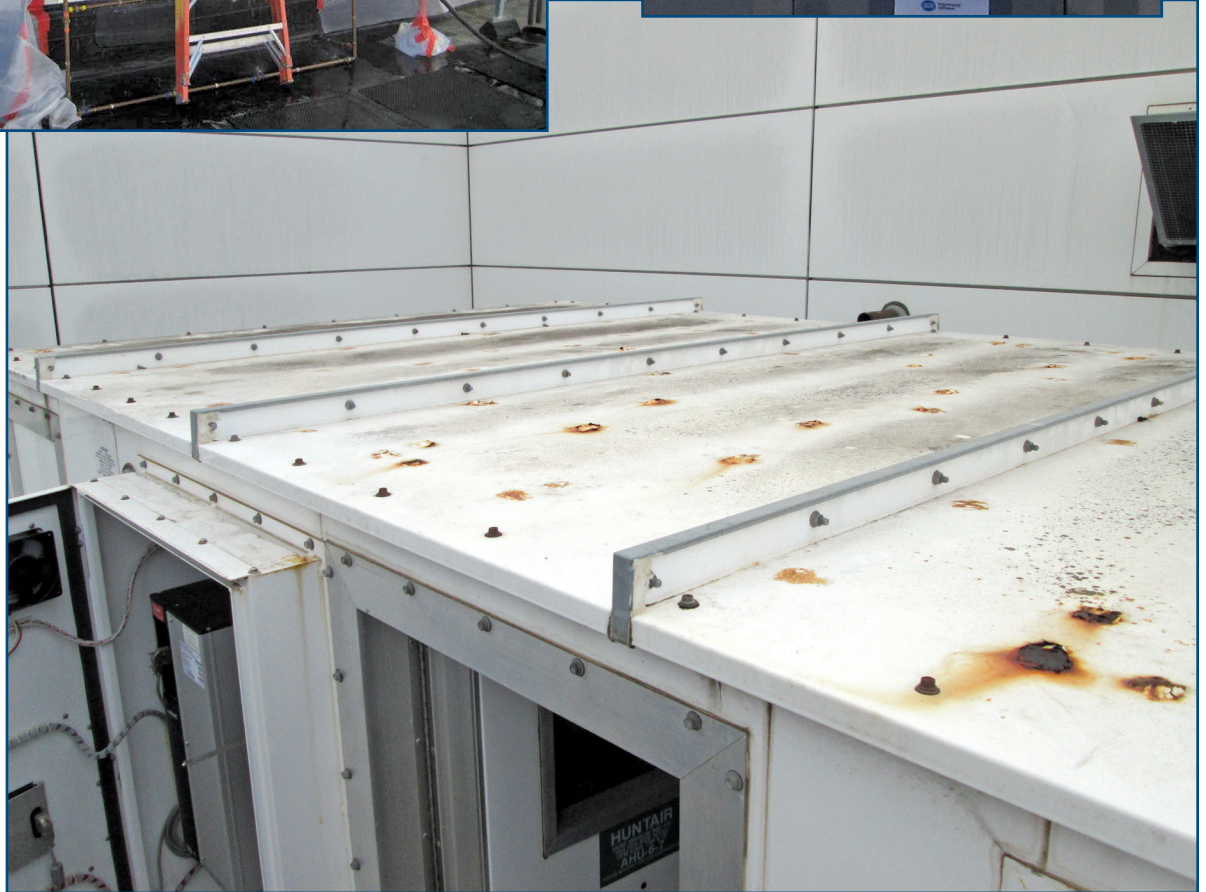
**Figure 8 – Preformed silicone tape over all joints in AHU.**



**Figure 7 – Using an ASTM E1105 spray rack to test base of unit flashing.**

### Case Study C

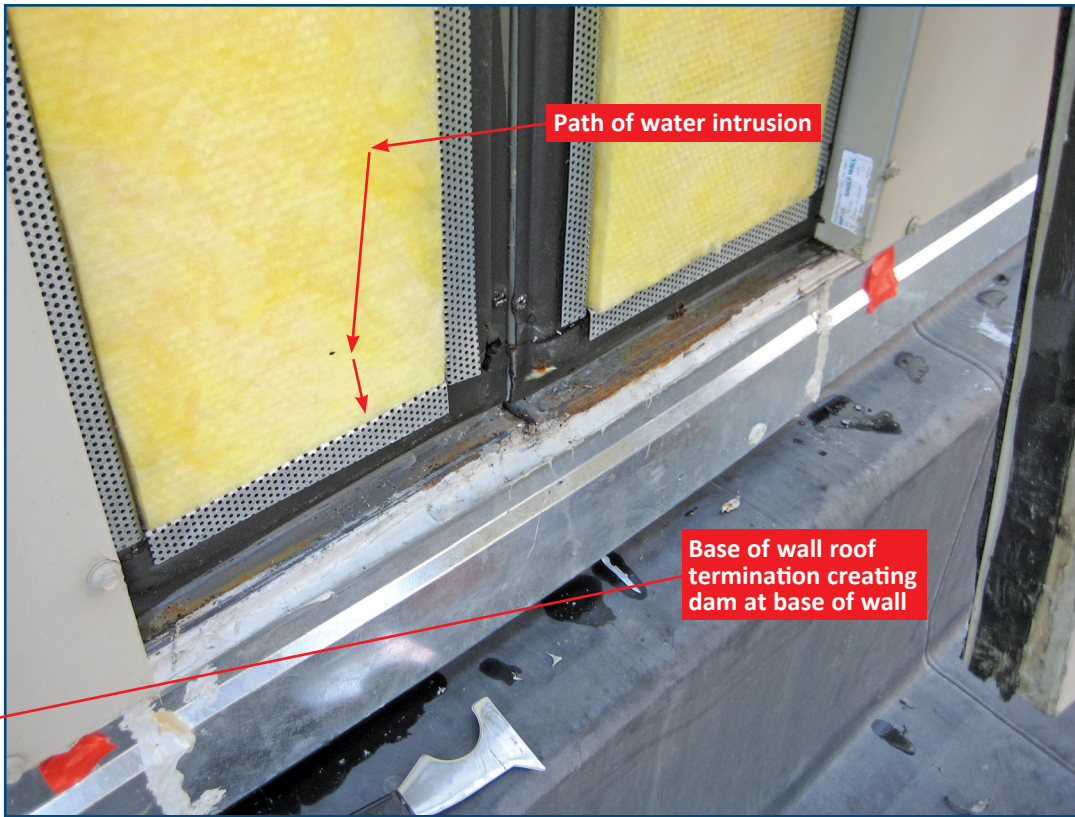
The author was called out by a general contractor to investigate leakage that was directly below multiple air-handling units. The roofing system was a black EPDM membrane over tapered polyisocyanurate insulation. The initial site walk showed ponding water within the building directly below the units and also showed evidence of water intrusion below the AHU, but above the structural deck. Care was taken to determine if the space below the units qualified as a permit-required confined space. This additional safety check increased the cost and decreased the speed of the investigation. As shown in Figure 7, the authors used a calibrated spray rack similar to that used in ASTM E1105, *Standard Test Method for Field Determination of Water Penetration of Installed Exterior Windows, Skylights,*



**Figure 9 – Coating failure on metal roof.**

*Doors, and Curtain Wall by Uniform or Cyclic Static Air Pressure*, to subject different sections of the AHU to sustained water spray. After each test, the wall panels were removed to check for water intrusion (Figure 10). Figure 10 also shows the condition where two wall panels from different AHU sections come together at the demount line. Above the stainless steel counterflashing, you can see the gap between the units. The exterior wall panels are designed to

seal at the black gasket. This makes the area outboard of the gasket the wet zone. Water draining down the panel joint is directed into the joint at the demount line and thus into the building. See the arrow in Figure 10. In addition to water leakage at some of the demount lines, the original roofing system terminated onto the base of the exterior AHU wall panels. These panels are not barrier wall panels that are



*Figure 10 - Wall panels removed after water test.*

*Figure 11 - Roof membrane terminated to base of wall panel.*



designed to seal at the face of the panel, but they are a modified drainage system that has the primary seal back at the gasket-to-frame joint. As shown in *Figure 11*, the roofing membrane terminated onto the face of the wall panels. This effectively created a dam at the front face of the panels at the base of the wall. This dam prevented water from flowing out of the wall panels. *Figure 11* also shows the new repair counterflashing and roof termination installed below the base-of-wall panels to remove the dam created by the original roofing.

## CONCLUSION

A rooftop AHU can be a difficult, complicated, and expensive component of the building envelope to install and maintain. When the building envelope terminates at the base of the AHU, the unit's waterproofing envelope becomes a de facto portion of the building envelope. This may

require it to meet the building code requirements for a building envelope. However, the discontinuity in the building envelope cre-

ated by the AHU can be removed if the unit is placed on posts and the building envelope (roofing) is run continuously below it. 