Metal-deck corrosion: Three case studies

A combination of factors was found to have contributed to major, unpredictable patterns of deck corrosion

by Richard P. Canon, RRC, PE

The roofing industry has exhibited a growing concern in recent months regarding corrosion of metal decks. Several recent articles in *Professional Roofing* [1] and NRCA Bulletin 15-91 [2] have discussed a growing concern in the roofing community regarding corrosion of metal decks. During the last two years the author's roof consulting firm has investigated three projects that have experienced severe, premature corrosion of metal roof decking. Two of the decks were primed but not painted, and one was galvanized (ASTM A 446 steel with hot dipped galvanized coating conforming to ASTM A 525, G-60).

The roof assembly for each project is shown in **Figures 1, 2, and 3. Table A** summarizes the history and data regarding each project. All three used phenolic insulation as part of the system. This article will discuss the evidence that a combination of factors involving the insulation, moisture in the system and inadequate protection by the deck treatments may have contributed to deck corrosion in these three projects.

Project No. 1

The discovery of corrosion of the metal deck was initially made on the roof of Project No. 1 in 1985, about three years after construction, when several new penetrations were cut in the asphalt built-up roof (BUR). This exposed moderate-to-severe corrosion of the deck. This corrosion was initially thought to be dormant and isolated to active leaks.

Two years later a small area of corroded deck was replaced after rust was observed on the bottom of the deck over an area used to charge batteries for lift trucks. The rusting was explained as being related to battery acid fumes, a theory later invalidated. Originally, both occurrences were rationalized as localized anomalies and not a source of major concern.

In 1989, six years after construction, pieces of decking began falling to the production floor in various areas of the plant. There were numerous leaks documented in the plant with no logical pattern. Maintenance personnel also discovered several rather odd "sink

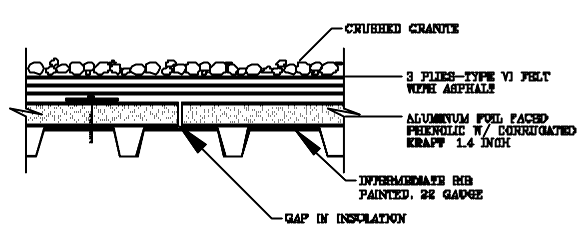

Figure 1: Project No. 1 Roof Cross Section

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TABLE A

Parameter	Project No. 1	Project No. 2	Project No. 3
Project location	Northwest South Carolina	Coastal South Carolina	Southeast Michigan
Year constructed	1982	1987	1987
Age at investigation	7 years	2 Years	4 Years
Roof age at removal	8 Years	3 Years	Pending 5 Years
Generic membrane	Aggregate surfaced BUR	Ballasted EPDM	Mechanically Fastened CSPE
Building Use	Plastic Molding	Retail Store	Office Building
Insulation Type	One layer phenolic	One layer phenolic	1 layer wood fiber 2 layers phenolic
Insulation facer	Foil over corrugated paper	Fiberglass	Fiberglass
Number of layers	1	1	3
Thicknesses	1.4 inch	2.3 inch	½ inch wood fiber 1 inch phenolic 1 inch phenolic
Unusual Interior Conditions	None	None	None
Deck Type	Metal	Metal	Metal
Deck Gauge	22	22	20
Deck configuration	Intermediate (B)	Intermediate (B)	Intermediate (B)

holes" on the roof. The owner was concerned and requested an investigation by the author to determine what was happening to the roof system, particularly the decking.

The author's first task was to determine the extent and severity of the corrosion. An infrared (IR) roof moisture survey indicated at least 6,000 square feet 2, or 11 percent of the roof, had wet insulation with varying degrees of moisture. The author also observed on an IR camera screen that nearly every board joint appeared as a white line indicating voids at insulation board joints. The same lines were visible on the roof on a frosty morning.

Test cuts and cores confirmed the observations of the IR survey. Areas of phenolic insulation interpreted to be wet were very wet. **M**oisture **C**ontent **B**y **W**eight (MCBW) was measured up to 1,025 percent. Most wet material was found to contain about 250 percent MCBW. Compare these values with the equilibrium moisture content for phenolic insulation, which has been determined to be 23.4 percent (at 90 percent relative humidity and 68E F)[3].

Dry insulation extracted fromsome of the areas we had interpreted to be dry were found to contain as little as 1.6 percent MCBW.

The roof membrane had numerous deficiencies, which had resulted in more than 100 documented leaks since occupancy. The author also found evidence from the test cuts that the joints in the phenolic foam had been butted, or up to ¼ inches wide, at the time of construction. They were now up to 1½ inches wide with an average width of 1 inch. *[WE ESTIMATED THE TOTAL CUMULATIVE AREA WHERE THERE IS NO INSULATION DUE TO OPEN BOARD JOINTS WAS 2,465 FT². **THIS MEANT THAT ABOUT 5% OF THE INSULATED ROOF AREA WAS NOT INSULATED!**]*

This was concluded, by observation, to be the result of shrinkage (i.e. due to dimensional instability) of the insulation, not improper placement. The author believes the resulting gap could have contributed to the corrosion in two possible ways:

! First, as the insulation shrank it placed the membrane under tension in the region above the joints. This may have resulted in water infiltration through the membrane in this region.

! Second, at the wide joints, water vapor would have been allowed to rise freely. It thus could have condensed in those joints on the underside of the membrane or near the top of the insulation's sidewalls. This would have led to wetting of the edges of the insulation in the wide joints as moisture dripped from the top of the roof assembly in those areas.

At the test-cut locations, the author observed the aluminum foil facer was in varying states of decomposition. However, metallurgical and chemical analysis concluded the foil was not a factor in the corrosion. The foam was typically crushed, broken, and fractured. Many of the insulation fasteners in the test-cut locations had corroded from 0.172 inches diameter down to 0.05" diameter. Most of these fasteners had some scaly rust. Corrosion was typically most severe on the top flange of

Figure 2: From Project No. 1, severe corrosion of deck, plate, and fastener.

the deck. In the most heavily corroded areas, all surfaces were corroded: flange, web, and flute. **Numerous galvanizedinsulation fastener plates were heavily pitted and corroded.**

The author determined that the interior conditions were such that a vapor retarder would not typically be deemed necessary. Relative humidity during the heating season is generally about 40 percent. The bottom of deck temperature is about 75E F. But since there was no vapor retarder, condensation was determined to be a significant factor in the corrosion analysis. The reason for this is that during the winter months, the dew point would fall within the insulation (which is where it should be), and most critically could have occurred, under certain conditions, in close proximity to the deck-to-insulation interface. When it occurred close enough to the deck, this phenomenon could result in a leaching effect.

After extensive study, the author concluded that water had entered the insulation from four sources:

! Leakage through the membrane.

! Condensation within the roof insulation.

! Condensation in the areas of wide board joints.

It is the author's opinion that the presence of the moisture seems to have resulted in serious, accelerated corrosion of the metal deck, possibly because it caused an acid to leach from the insulation (which will be discussed later in this article).

From the IR survey, visual inspection of the underside of the deck and test-cut data, the author projected that 13 percent of the roof deck would have to be removed and replaced. Further, the author estimated that about 30 percent of the deck would be lightly to moderately corroded and would require field coating.

The physical condition of the insulation and the extent of corrosion, however, led the author to recommend a total removal of the roof system to the deck. It would then be necessary to replace seriously deteriorated deck and to coat moderately corroded deck with a high-solids epoxy coating system. After this preparation, a new roof system would be installed.

During the demolition the author found the IR and interior survey techniques assisted in predicting areas of corrosion in some areas but were of little value in most others. Although the process gave the author an *indication* of the problem and assisted in developing a basic magnitude of the extent of the corrosion, it was not as dependable as he would have hoped.

The final area of demolition was 12,250 square feet or 23 percent of the project, compared to an initial estimate of 13 percent. The area coated with epoxy was 6,250 square feet or 12 percent.

The corrosion patterns were unpredictable. The author found the severity of corrosion could change from board to board. In this case, total removal of the roof to the deck exposure was essential in order to accurately assess the extent of corrosion and the need for replacement or field coating. There does not appear to be a viable non-destructive technique that would have differentiated accurately the "good" deck from the "bad" in such a situation.

Project No. 2

On September 22, 1989, South Carolina was visited by a very unpleasant Hurricane Hugo. The roof on this project, which is located near the coast, was exposed to some of Hugo's higher winds. The ballasted EPDM roof billowed and was ripped in several places. The owner arranged for emergency repairs soon after the hurricane. During final repairs three months later, extensive corrosion of the primed deck was observed. After 1,710 square feet of steel deck had been replaced, with more replacement anticipated, the author was requested to review the situation and provide recommendations.

The author extracted numerous test cuts from the roof to observe the decking: several were taken in storm-damaged wet areas; most were in areas not known to have been damaged during Hugo.

The results were of great concern. Out of nine test cuts, eight had moderate-to-full penetration rusting of the decking. The flange was typically much more severely corroded than the webs or flute. In the most severe areas all surfaces of the deck were seriously corroded.

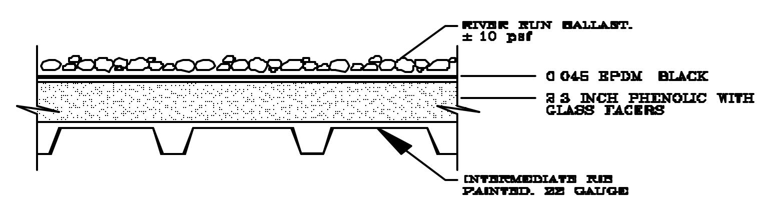

Figure 3: Project No. 2 Cross Section

Phenolic insulation with a fiberglass facer was in contact with the deck. In many locations, the facer had become firmly adhered to the corroded deck. When the insulation was removed, the deck came up with it in strips the width of the flange. The association of the fiberglass as a reactant in the corrosion process has not been fully investigated, but is currently not felt by the author to be significant.

The author examined the EPDM membrane for evidence of factory deficiencies or deficient field seams or flashings. No serious problems were found that could explain the extent of observed corrosion.

The owner reported that prior to Hugo, he had only one persistent leak in the store. There was nothing in the history of the roof to indicate that the deck was rusting except for some orange stains observed on the end walls immediately after Hugo. Despite the disappointing results on Project No. 1 with non-destructive testing to locate corroded decking, procedures for infrared, nuclear and capacitance testing were reviewed.

Because the roof system was ballasted EPDM, the author ruled out the

IR camera and capacitance meter. The moisture readings from a nuclear gauge were questionable, because the author got low readings on all test-cut locations except one where the insulation was found to contain 1,980 percent MCBW. Here the nuclear count was 19, which is not a high reading for 2 inches of insulation that was found to be soaking wet.

In other test cuts where rust was observed, the foam was found to contain only 3.8 percent to 11.4 percent MCBW and nuclear counts were all only four. **Therefore, for ballasted EPDM, non-destructive testing was concluded to be of little to no value in correlating wet insulation to areas of rusted deck.**

Visually surveying the bottom side of the deck was misleading too, because only about 5 percent of the deck exhibited visible pitting. In these areas, the moisture contents were found to be about 1,980 percent.

An orange stain was visible at numerous flute lines at end laps in the deck and the exterior end walls. This orange stain was found to be rust that had been carried to the flutes of the deck and flowed in the building after Hugo. The staining was not found to be a reliable indicator of rusted decking.

The author saw no option but to recommend again **complete removal of the roof system to the deck**, for two reasons: We had to visually inspect the top surface of the deck for rust, and we were concerned that the continued presence of wet insulation could pose potential future corrosion problems.

During the demolition, there was a full-time observer on site to collect samples, to log and map the demolished areas, to take photographs and to observe the installation of the new roof. A total of 14,900 square feet, or 17 percent of the roof deck, was replaced and 52,094 square feet or 60 percent, was coated with epoxy. Prior to coating, the deck was carefully prepared. **The use of epoxy requires applicators who are trained in the proper techniques for this type of coating**.

The demolition daily exposed random, and extensive, corrosion of the decking that the author would not have known about if the roof system had not removed. To have followed a course other than total removal of the roof system would have been a very serious mistake. **Total removal is required to assure all corroded deck is removed.**

During the course of the retrofit, the author made several observations.

The foam was heavily damaged from compression failure. The author believes most of this occurred during the placement of the ballast. Obviously, there was also some damage done during the repairs. The insulation did not display any instability problems; i.e., there was no shrinkage. There were some areas where perlite was in contact with the deck adjacent to phenolic foam in these locations. In these locations there was no rust under the perlite but there was severe rust only inches away under the phenolic. *[WE ALSO NOTICE LESS CORROSION UNDER LOCATIONS WHERE TAPERED EDGE STRIPS WERE INSTALLED OVER THE PHENOLIC FOAM. IN THESE CASES, CORROSION STARTED AT THE TOE OF THE TAPERED EDGE STRIP.

IN ASSESSING THE SOURCE OF THE EXTENSIVE CORROSION ON THIS PROJECT WE AGAIN CONCLUDED THE PHENOLIC FOAM WAS THE CULPRIT. THE BASIC EQUATION FOR CORROSION WAS:

PHENOLIC FOAM + WATER = CORROSION]*

The author concluded there were four "sources" of the **water** that entered the system and initiated the corrosion. In order of significance they are:

! Condensation on the bottom of the membrane.

! Condensation near the deck-to-insulation interface.

! Condensation at insulation joints.

! Leaks prior to Hugo.

! Leaks from Hugo damage.

It was observed by the author that the **corrosion was more severe at damp areas compared to very wet areas**. The acidity of the insulation was tested in different locations using a pH meter, and was found to range from 4.3 pH in the very wet insulation to a highly acidic 1.6 pH in the damp insulation. (The pH scale is from 0-14, with 0 being acidic, 7 being neutral and 14 being caustic.)

This finding initially seems contrary to logic, until you consider that the concentration of an acid is diluted as more water is added to it, and thus its pH is closer to neutral. Therefore, acidity can be affected by the quantity of water present, but perhaps not in ways you might expect.

PROJECT NO. 3

The author was recently requested to consult on a third project that exhibited corrosion of the metal deck. This roof was about four years old and the deck had a G-60 galvanized coating. The insulation consisted of two layers of 1-inch phenolic foam covered by half-inch wood-fiber board. As shown in Table C, the membrane was a CSPE mechanically attached system.

Leaks were reported soon after occupancy. There were numerous deficiencies in the installation of the membrane. The persistence of the leakage led to initiating a partial replacement program with the boundaries for replacement based in large part on the results of an IR survey. As the replacement progressed, it became apparent that there was significantly more wet insulation than the IR had indicated. Also during the replacement, a more disturbing fact surfaced: The galvanized decking was corroding under the areas of wet insulation.

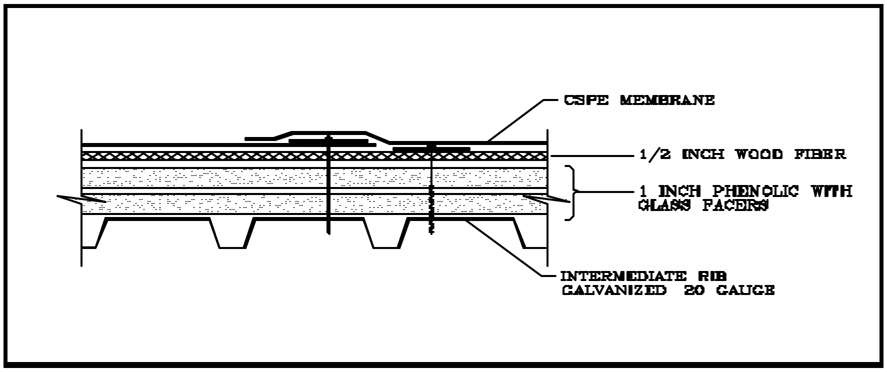

Figure 4: Project No. 3 Roof Cross Section

The author visited the site on a cold, late winter morning and extracted three exploratory test cuts. Two were in known wet areas (from the IR) and one was in an area interpreted to be dry. The moisture profile in the wet area is interesting:

! Wood fiber = 356 percent MCBW.
! Top layer phenolic foam = 1,734 percent MCBW.
! Bottom layer of phenolic foam = 551 percent MCBW.

The equilibrium moisture content of the wood fiber is 15 percent and of phenolic is 23.4 percent, so these insulation samples were very wet.

On the dry test cut, the wood fiber was 51 percent MCBW in the upper half of the board and 33 percent MCBW in the lower half. The top layer of the phenolic contained 9.4 percent MCBW and the bottom layer 6.9 percent MCBW. The author believes this stratification of moisture is significant, as it indicates moisture accumulation related to the drive of moisture from an area of high vapor pressure to an area of low vapor pressure. Condensation on the bottom of the CSPE membrane was observed by the author at the two cuts made in wet areas. The galvanized fastener plates were slightly corroded but all of the screws appeared free of rust. The author found a saturated area around the fasteners, which may have been an indication of a thermal bridge (short circuit) at the screws.

Upon exposing the galvanized deck, the author's worst expectations were confirmed. There was aggressive corrosion on the deck, primarily at the joints in the lowest insulation board and on the deck at the fastener penetration point. There was also a precipitate on the webs of the deck. The flange of the deck was corroded, but there was little to no corrosion on the web or the bottom of the flute. This has been a common phenomenon observed on the three projects.

The corrosion had progressed all the way through the G-60 coating on the top flange and was attacking the base metal. No full-penetration rust was observed. *[The corrosion of the galvanized coated decking was predicted from research gathered on Project No. 1, but now it was confirmed.]* Although the corrosion was not as severe as on Project 2 (both were the same vintage foam) there was a basis for serious concern.

*[Another interesting observation was made where a deck weld had been painted. This protected the metal deck from corrosion despite abutting corrosion on the bare deck. **It appeared that a good coat of paint out performed the galvanize .**]*

The extent of the corrosion on this project is currently not known pending possible demolition of the system (which the author has recommended). The author does not anticipate there will be much if any deck replacement, but does expect a significant area will have to be field-coated.

On this project there had been no firm determination at this time of the source of the water that triggered the corrosion, but the following are our prime candidates:

! Condensation on the bottom of the billowed membrane during positive-pressure operation of the HVAC system.

! Condensation within the roof assembly with a fluctuating dew-point location.

! Top-side leakage through membrane deficiencies.

! Damage to the membrane from other trades.

The author has recommended the

Metal Decks: More than a place to hang your roof

On each of the projects described in the accompanying article, the metal deck was designed as more than just a platform for the roof. The deck in such a design serves three primary functions:

! Supporting vertical dead and live loads.

! Providing a wind uplift resistance component.

! Providing resistance to lateral (sideways) wind loads striking the building. This is referred to as diaphragm action.

When a steel roof deck is seriously corroded, its capacity to resist these loads is compromised. The deck may no longer be capable of supporting snow loads, the dead load of the roof system, foot traffic, etc. The wind resistance for an adhered system and a mechanically attached system are provide by screwing the insulation or membrane to the metal deck.

If, for example, 50 percent of the deck has turned to *[CRUSTED]* rust, the uplift resistance of its attachment to joists or beams - and the pull-out resistance of insulation fasteners - is reduced proportionately to the reduction of metal thickness. When wind strikes a building that was designed to transfer wind loads (shear loads) through a diaphragm, the wind load is transferred from the windward wall to the roof deck and out to the walls parallel to the wind direction.

This transfer is accomplished by attaching the deck to the structural supports (joists or beams) with welds or screws. If the decking has either rusted away from the fasteners or has corroded to the point it is no longer a monolithic plate capable of distributing loads (a diaphragm), the structure could receive extensive damage or possibly rack or collapse during a wind that is within the structure's design load, or even less.

Note: The assessment of loss of structural integrity should be made by a structural engineer who is knowledgeable regarding deck corrosion and its effects.

As a critical component of such structures, metal roof decks are anticipated in the design to serve the life of the building - which in most cases is 50, 75, or even 100 years. A building owner may expect to have to replace localized areas of rusted deck when he replaces his roof, but should not expect to replace his entire roof deck, or large portions of it when doing so.

inclusion of an air retarder or a change to a fully adhered system in the replacement to reduce or eliminate any problems with the HVAC positive pressure.

Chemical Analysis

What is going on in the roof system to propagate such aggressive corrosion in such a short time? The common denominators in these projects were **phenolic foam insulation in contact with a metal deck and the presence of water *[MOISTURE]***.

During the author's investigation of Projects 1 and 2 he worked with a metallurgist/chemist, Dr. John E. Slater of INVETECH, Houston, Texas in analyzing the chemical reactions related to the corrosion process. Product literature and his research indicated that the phenolic foam contained an aromatic sulfonic acid as a catalyst used to create the cells of the foam.

Slater found that the deck primer was a purely organic coating. Chloride was present in the corrosion product with 0.001 percent to 0.01 percent by weight. Sulfur content, on the other hand, was found to be in the range of 0.01 percent to 0.24 percent by weight (i.e., from 10 to 200 times more sulfur than chloride).

Slater's report stated:

"It is considered axiomatic that water will find its way into a roofing system, either due to leaks or to condensation. Water absorption by the phenolic foam can be extremely high. The water dissolves the sulfonic acid, forming an acidic environment which contacts the roof decking. The organic materials used to coat the deck (primer) and protect from atmospheric corrosion are unable to withstand these acidic environments and quickly break down.

Accelerated corrosion of the bare steel ensues. While it is acknowledged that the available quantity of acidity in a given volume of the foam is limited, and thus cannot by itself sustain accelerated corrosion indefinitely, the salts produced during the initial corrosion process will remain within the corrosion product (rust), rendering its conductivity high. Thus, continued high corrosion rates occur in the presence of moisture trapped in the foam and atmospheric oxygen. The sulfonic acids released by moisture from the phenolic foam therefore act as both an initiator of corrosion and as a catalyst for further corrosion."

Regarding the use of galvanized decking, Slater's report states:

"It has been suggested that galvanized decking is more resistant to atmospheric corrosion and hence more resistant to the type of attack found on the (investigated) roof. The corrosion rate test data clearly indicate that the galvanizing cannot be relied upon to protect against the sulfonic acid attack. Furthermore, the sulfonates can be anticipated to catalyze atmospheric corrosion of the galvanized layer which remains after the initial acid attack, in the same way as for the ungalvanized steel. *[THUS GALVANIZING IS NOT CONSIDERED TO BE THE PROTECTIVE COATING OF CHOICE IN THIS APPLICATION.]*"

*[TESTS WHICH WERE CONDUCTED AND REPORTED BY A PHENOLIC FOAM MANUFACTURER STATED THE FOLLOWING:

"UNDER THE MOST SEVERE POSSIBLE TEST EXPOSURES, I.E. UNPROTECTED STEEL, ACCELERATED TEST CONDITIONS, AND CONTINUOUSLY WET (PHENOLIC FOAM) INSULATION, MEASURED CORROSION RATES WERE BELOW 2 (1.8) MILS PER YEAR AFTER 200 DAYS ......"

THE THICKNESS OF 22 GAUGE PRIMED METAL DECKING IS ABOUT 0.0295" THICK. IF WE CAN EXPECT CORROSION TO REMOVE 2 MILS (0.002") PER YEAR, THE ANTICIPATED DECK LIFE WILL BE ONLY 15 YEARS! BASED ON OUR OBSERVATIONS OF THE ROOF ON PROJECT NO. 1 WHICH WAS EIGHT YEARS OLD AT REPLACEMENT AND ON PROJECT NO. 2 WHICH WAS TWO YEARS OLD, THE ACTUAL CORROSION RATE WAS 3.5 TO 14 MILS PER YEAR (0.0295" ÷ 8 YEARS = 3.6 MILS PER YEAR AND 0.0295" ÷ 2 YEARS = 15 MILS PER YEAR). THIS IS HARDLY AN ACCEPTABLE CONDITION.]*

<u>Recommendations</u>

What can be done to avoid or minimize deck corrosion under the conditions described in these case studies? The author suggests these as possible preventative steps:

*[! ISOLATE PHENOLIC FOAM FROM METAL DECK WITH A SEPARATOR BOARD

! INSTALL A "PERFECT" ROOF THAT HAS NOT NOR WILL LEAK DURING ITS LIFE (NOT A PRACTICAL EXPECTATION)]*

! Use epoxy coating or equivalent applied to prime-coated metal deck.

! Use G-90 galvanize coating, not G-60, for longer resistance to corrosion.

*[! HAVE THE INSULATION MANUFACTURER WARRANT DAMAGE TO DECK FROM CORROSION FOR "X" YEARS

! USE A ROOF SYSTEM THAT IS EASY TO VISUALLY INSPECT FOR PHYSICAL DAMAGE

! USE STAINLESS STEEL SCREWS

! CONSIDER USING ANOTHER INSULATION

UNLESS THERE HAS BEEN OR WILL BE A MAJOR CHANGE IN THE CHEMICAL COMPOSITION OF PHENOLIC FOAM (NOT THE FACERS OR AN INCREASE IN THE COMPRESSIVE STRENGTH), WE HAVE NO ASSURANCE THAT THE PRESENCE OF PHENOLIC FOAM ON A PRIMED OR GALVANIZED DECK WILL NOT CORRODE THE DECK.]*

The author believes that his investigation on these projects has raised certain points that require further study and discussion within the roofing industry.

First, more designers and contractors should be aware that phenolic foam insulation is vapor-permeable and therefore capable of absorbing water. This has ramifications relative to: material storage (that is, stored in a place with low humidity); possible inclusion of a vapor retarder in situations not normally requiring one; application of this insulation during hot, humid weather, and design considerations due to the additional weight of absorbed moisture.

The industry also needs a better method to determine the absorption potential of phenolic insulation. ASTM C1126 is the "Standard Specification for Faced or Unfaced Rigid Cellular Phenolic Thermal Insulation." This standard refers to ASTM C209, which includes a moisture absorption test. This test does not adequately model the conditions to which a roof insulation will be exposed. **The test measures the percentage water absorption increase by volume with a <u>two-hour</u> immersion**. For one manufacturer, this was 2.0 percent by volume. With a density of the foam of 2.7 pounds per cubic foot that is 46 percent MCBW. Further, immersion does not model a vapor drive to which in-service insulation is exposed. *[THE INDUSTRY NEEDS A BETTER TEST.]*

*[This leads us then to a second

point. The industry must acknowledge that phenolic foam is not "closed-cell" relative to **moisture**. When the product can absorb 46% in two hours and ultimately nearly 2,000% MCBW, it ain't closed-cell! This is important during the design stage. Structural engineers base their designs and size structural members on the assumption that the insulation is dry and will remain dry, not that **someday it may weigh 20 times more** than they were told it would. Mechanical engineers base their heating and cooling loads on dry material with a stated "R" value, not a depreciated, lower value as a result of moisture absorption. These are important liabilities that must considered.]*

In addition, the matter of positive pressure from an HVAC system billowing a single-ply membrane is a situation that is not receiving adequate attention from manufactures, designers, or contractors. The requirement for roof pressure relief valves, air retarders or fully adhered systems needs further study and consideration in the design process. With the exception of only a few manufacturers, air infiltration remains a non-issue.

Regardless of the type of insulation to be used, there needs to be a thorough, industry wide review of metal decks and corrosion. The industry needs to know what the deck manufactures can and will provide to the end user. *[The Steel Deck Institute recommends field painting the deck because they say the factory primer is "an impermanent and provisional coating." Would it be possible or practical for the metal deck supplier to furnish a prepainted product with more than a "provisional coating"? If not, then the choices are: a G-90 galvanized coating; an aluminum zinc alloy coating; a field applied paint or coating; or changing to another decking system.

WHAT CAN YOU DO?

During our investigations we have conducted a simple test to monitor phenolic foam corrosion properties and moisture absorption. You may want to perform your own tests to see what happens when a 2" cube of dry phenolic foam is placed in about 150 ml of distilled water. Every 24 hour period measure the pH with indicator paper or a pH meter. Also accurately weigh the samples. We found the pH dropped from 6.6 to 3.3 in only 48 hours. The MCBW increased to over 200% in the same time period. (That is five times the two-hour immersion value of 47% MCBW.) Next remove the foam from the container. Place a few small strips of metal decking in the soak water and monitor for a week or so. We observed rust on the exposed cut edges of the strips in about 48 hours. When we checked the pH after the metal had been in the solution for a week, we found the pH had risen due to the chemical reaction taking pace in the corrosion process.

More sophisticated tests can be run but we have found these simple tests are quite informative. You may want to run similar test on other insulations for your information.

For those who have in-place phenolic foam, it may be prudent to determine if a problem currently exists and then recheck occasionally. Take a few exploratory test cuts and **see** if there is a problem. On our Project No. 1, 35% of the deck had to be either replaced or coated after only eight years. On Project No. 2, 77% had to be replaced or coated after only two years. Time may be your enemy if the deck is corroding. Damage may be minimized if caught early enough.]*

BY THE TIME RUST IS OBSERVED ON THE BOTTOM SIDE OF THE DECK IT IS TOO LATE. THE CORROSION HAS PROGRESSED TO A POINT OF COMPONENT FAILURE.

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* READER NOTE: The text enclosed by asterisks and brackets *[in small caps]* was in the author's original manuscript, but omitted in the published article by the Editor.

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ADDITIONAL PHOTOGRAPHS OF MISCELLANEOUS PROJECTS

Figure 5: Project 1, view of wet insulation.

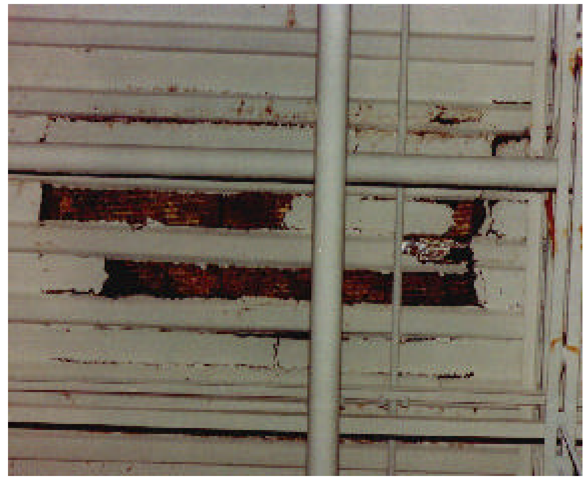

Figure 6: Project 1 interior view of corrosion

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