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21PF OVERPACKS: PHENOLIC-FOAM INDUCED CORROSION

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ABSTRACT

The 21PF overpack was developed in the 1960s and approved for use in the 1970s by the U.S. Department of Transportation (DOT). This package, which is used for the transport of uranium hexafluoride enriched >1%, has had a history of severe metal corrosion, water ingress, and subsequent leakage.

Problems associated with corrosion and water leaking from 21PF overpacks caused the DOT to seek public comments and to undertake rulemaking action. As a result, the DOT required modifications and refurbishment of existing overpacks, and specification changes for the fabrication of new 21PF overpacks. Recent studies conducted by the roofing industry indicate that phenolic foam has caused severe corrosion in metal roofing structures, and its use is being curtailed. These findings need to be explored in order to determine if phenolic foam in 21PF overpacks causes corrosion and compromises the package integrity.

Metallic corrosion induced by phenolic foam may affect the continued use of the 21PF overpack because damage to the structural integrity of the metal parts of the packaging will affect its ability to meet design specifications.

INTRODUCTION

The U.S. Department of Transportation (DOT) specification package 21PF-1 was developed during the 1960s and approved during the 1970s to transport uranium hexafluoride (UF_6). The package uses phenolic foam as an impact and a thermal protective material to meet fissile package test requirements. Packages of this design have had a history of severe metal corrosion and have leaked water intermittently, thus resulting in emergency response situations. Regulatory agencies have responded to these problems by issuing information to the package users. Following are excerpts from some of these documents.

REGULATORY AGENCY NOTICES The U.S. Nuclear Regulatory Commission issued an Information Notice on July 20, 1982, which states: "This notice provides information concerning incidents where water was found leaking from uranium hexafluoride overpacks during shipment from Department of Energy (DOE) facilities to NRC uranium hexafluoride processors. . . . This water may leak from the overpack during transportation through loose bolts, defective seals or rusted through areas." [1]

The DOE Oak Ridge Operations office sent UF_6 customers a letter on July 30, 1982, which states: "Today we are receiving at our toll enrichment facilities many overpacks in deteriorated conditions, particularly the DOT Specification 21PF-1 overpack . . . . Some overpacks have been rejected due to their extremely poor physical condition. In most cases, there appears not to be any maintenance of the overpacks between shipments. In addition, there have been several cases recently where water was found to be leaking out of the overpack while in transit."

"There are three principal categories whereby overpacks are not being properly maintained. These are as follows: (1) corrosion, (2) accumulation of moisture within the insulation, and (3) condition of overpack tie-down supports." [2]

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The International Atomic Energy Agency (IAEA) Symposium on the Packaging and Transport of Radioactive Materials, PATRAM '86, included a presentation which states: "Protective shipping packages show deterioration with extended service, principally structural damage from rough handling and rust damage from exposure to weather and from storage practices which may promote absorption of water by the insulating foam . . . . Used protective shipping packages have . . . permitted water absorption by the insulating foam in amounts approaching 1,000 pounds per container. . . . Some of the overpacks . . . showed severe rust damage to the steel cover and around the joint plane at the package centerline." [3]

<u>DOCUMENTED STUDIES OF PHENOLIC FOAM CORROSION</u> Report K/SS-471 was issued November 1986; it states: "The DOT Specification 21PF-1 protective overpack has been in use . . . since 1968, during which time thousands of overpacks have been manufactured and placed into service. Many of the packages have been damaged and many others have shown apparently serious deterioration. Service damage . . . has allowed moisture to infiltrate the phenolic foam structure." [4]

Report K-2057 was issued November 1986; it states: "Protective shipping packages . . . show deterioration with extended service, principally, structural damage from rough handling, and rust damage from exposure to weather and from storage practices which may promote absorption of water by the insulating foam."

"Foam in the overpack is effective as an insulator even while wet, but considerations of metal corrosion and structural wood deterioration dictate that the overpacks should be maintained in as dry a state as practical."

"These packages . . . showed rust penetration through the 14-gauge shell in several areas, in one package totaling more than 20 square inches. The containers were observed to contain salt water . . . and when selected for the drying tests were weighed at an average of 840 pounds above a nominal 1,750 pound new weight." [5]

American National Standards Institute, Inc., (ANSI) N14.1 — 1990 states: "Each protective packaging shall be recertified every 5 years . . . . Outer protective packaging shall receive a full visual inspection for rusting and the presence of corrosion." [6]

<u>DOT RULE-MAKING</u> The DOT Research and Special Programs Administration recognized the problems of metal corrosion and leaking water from 21PF-1 overpacks and initiated procedures for "Modification to DOT Specification 21PF-1 Overpacks" on September 20, 1988.

The DOT rule-making states: "Many of these overpacks have been damaged during the course of transport, or have deteriorated in service. Problems have centered around corrosion of the external skin and warping of the wooden step joint, allowing in-leakage of rainwater and ocean spray. The primary difficulty encountered is a tendency for these overpacks to collect and retain water during normal use. This water, especially salt (ocean) water, accelerates the corrosion of metal parts and the decay of wooden parts. The water collects inside the overpacks during rainy weather or during ocean voyages from salt spray, and then leaks or sloshes out during dry weather. Although the water has not been contaminated with radioactive material, liquid leakage from a package marked and labeled "RADIOACTIVE" may cause considerable alarm." [7]

Overpack owners complied with these regulations and inspected their overpacks to determine which packages were to be scrapped or to be refurbished. Modified overpacks were designated as "DOT 21PF-1A overpacks."

<u>UF_6 CONFERENCE DISCUSSIONS</u> At the Second Uranium Hexafluoride Handling Conference, held October 1991, in Oak Ridge, Tennessee, a breakout session was held to discuss ongoing problems with overpacks. A number of overpack owners expressed concern about new 304 stainless steel overpacks that were less than one year old and used minimally, but were exhibiting severe pitting on the interior surfaces. It was mentioned that possibly this pitting was a result of a chemical reaction between the phenolic foam and the metal parts.

During the ensuing discussion, a container manufacturer's representative stated that one of the last steps in making the phenolic resin was to neutralize the resin pH using hydrochloric acid. Typically, concentrations of 0.5% chloride occurred in the finished foam. [8]

PHENOLIC FOAM INSULATION PROBLEMS IDENTIFIED IN ROOFING SYSTEMS Concurrently and independently, building contractors began to discuss and to document problems occurring with metal roofing structures using phenolic foam insulation.

The National Insulation and Abatement Contractors (NIAC) magazine, *Outlook*, published in March 1991, contains an article by John W. Kalis, Jr., Principal Engineer with E.I. DuPont Company. He reports the results of a DuPont engineering department Committee on Corrosion Under Insulation: "The number one enemy of thermal insulation is water. Water in insulation increases heat loss and deteriorates the insulation. It can also cause corrosion to carbon steel and cause chloride-stress-corrosion cracking of austenitic stainless steel. The study also indicated that the corrosion was more extensive where the water was higher in chlorides .... All insulations contain chlorides or acid in some amount. I believe that the chlorides or acids in the water are the major troublemakers, since they are able to position themselves properly on the metal surface. In addition, once moisture has entered the insulation system, it is just a matter of time until corrosion begins." [9]

The March 1991 *National Roofing Contractors Association NEWS* reports: "**Phenolic insulation and steel deck corrosion** [emphasis in original]. Severe deck corrosion has been associated with phenolic foam insulation. It is speculated that water-leached chemicals from the insulation are highly corrosive. It is also believed that prime-coated deck finishes offer very little corrosive protection to the steel deck." [10]

The *National Roofing Contractors Association* periodical, *Professional Roofing*, published August 1991, contains an article by Ruben G. Garcia, director of research for roofing products at Manville's Roofing System Division. The article discusses "... results of an investigation of how steel roof decks were performing in service, as well as the basic mechanism of corrosion as it applies to roofing."

"During this laboratory study, a test was developed to screen various insulation and painted steel deck types. The conditions of the test called for putting the insulation and steel deck systems together with Factory Mutual approved fasteners and subjecting these assemblies to a continuous environment of 90 degrees F and 90 percent relative humidity."

"This severe environment was run for three weeks, after which the systems were removed from the test chamber and opened up. The deck surface was evaluated visually. These tests indicated that insulations that contained acidic components (i.e perlite, wood fiber, fiberglass and phenolic foam) all showed some level of surface corrosion in this environment." [11]

PHENOLIC FOAM METAL DECK CORROSION STUDIES *Professional Roofing*, published August 1991, contains an article, by Richard P. Cannon. The "author's roof-consulting firm investigated three projects that have experienced severe, premature corrosion of metal roof decking. Two of the decks were primed but not field-painted, and one was galvanized ASTM A 446 steel with hot-dipped galvanized coating .... 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."

[The article continues.] Project No. 1. The first test used 1.4-in. phenolic foam with an insulation facer of foil corrugated paper. "Corrosion was typically most severe on the top .... In the most heavily corroded areas, all surfaces were corroded .... **Numerous galvanized insulation fastener plates were heavily pitted and corroded.** [Emphasis in original] ... Condensation was determined to be a significant factor in the corrosion analysis .... The presence of moisture seems to have resulted in serious, accelerated corrosion of the metal deck, possibly because it caused an acid to leach from the insulation."

Project No. 2. The second test used 2.3-in. phenolic foam with a fiberglass insulation facer. "Corrosion was more severe at damp areas compared to very wet areas. The acidity of the insulation was tested ... 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 third test used 2 layers of 1-in. phenolic foam covered by 0.5-in. wood-fiber board. The "roof was about four years old and the deck had a G-60 galvanized coating . . . . Leaks were reported soon after occupancy . . . The galvanized decking was corroding under the areas of wet insulation."

"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."

"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 . . . acid, forming an acidic environment which contacts the roof decking."

"Accelerated corrosion of the bare steel ensues. While it is acknowledged that the available quantity of acidity in a given volume of 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 . . . . Acids released by moisture from the phenolic foam therefore act as both an initiator of corrosion and as a catalyst for further corrosion." [12]

<u>ROOFING MANUFACTURERS REPORT PHENOLIC FOAM CORROSION</u> On March 30, 1992, Manville Roofing Systems released Marketing Bulletin 52A4-396 which states: "In Manville's Marketing Bulletin 52A4-373A, dated September 14, 1990, we reported that under certain conditions . . . phenolic foam roof insulation can react with the paint used on painted steel decks allowing a surface layer of corrosion to form on the steel. This bulletin serves to update you regarding our latest knowledge of the potential for phenolic foam roof insulations to contribute to the corrosion of steel roof decks."

"Observations of . . . phenolic foam . . . suggest that the corrosion phenomenon can occur under certain circumstances on galvanized as well as painted steel decks. The ultimate severity of corrosion associated with phenolic insulation, and its potential effect on the performance of a steel deck, cannot be predicted in all field conditions. However, . . . where insulation is wet or damaged, we now believe that there is a potential that the corrosion reaction could progress to a point which could weaken or penetrate an area in a metal deck." [13]

On March 31, 1992, Beazer East, Inc., of Pittsburgh, Pennsylvania, sent to "Former Distributors of Koppers RX Insulation" a product alert bulletin, "Koppers RX All-Purpose Insulation Board." This bulletin states:

"During the past year, Beazer has been receiving reports of steel deck corrosion . . . The possibility of roof deck corrosion appears to be limited to single-ply roof systems where RX phenolic insulation is in contact with the metal roof deck." [14]

<u>ROOFING CONFERENCE PHENOLIC FOAM CORROSION STUDY REPORT</u> The 10th Conference of Roofing Technology, which was held April 22-23, 1993, in Gaithersburg, Maryland, included a presentation, "Steel Deck Corrosion Associated with Phenolic Roof Insulation: Problem Causes, Prevention, Damage Assessment and Corrective Action." The presenter states:

"In 1990 and early 1991, the National Roofing Contractors Association (NRCA) received an increased number of reports of severe deck corrosion. All of the jobs utilized . . . phenolic foam roof insulation. Because of the serious ramifications of severe deck corrosion, NRCA surveyed its contractor membership, commissioned several laboratory evaluations and began an in-situ corrosion research program."

"Domestic production of phenolic roof insulation ceased in early 1992 . . . . The concern regarding phenolic foam corrosion is primarily related to existing roof systems that have phenolic foam insulation adjacent to steel decks, and the potential problems that may occur if deck corrosion compromises the deck's structural integrity."

"In a 1982 article, the issue of phenolic insulation and corrosion was briefly discussed. In the article, a person states: 'Acids used in the manufacturing process can combine with moisture after the product is installed.' He states that this can create an acidic solution and cause a corrosion problem around fasteners .... In the same article Stuart Smith states that he '... knows of phenolic foams on the market that contain *free acids*.' And he states that there was only a remote possibility of phenolic corroding a metal deck, but that 'it can eat nails and aluminum facers right up.'"

"A 1985 document by J. M. Blizzard reported on a laboratory evaluation for a phenolic foam manufacturer. The report presented several findings, including the following: For the wet insulation test series, 'the phenolic foams were more likely to cause paint damage than most other test materials with initially wet insulation .... Pitting, however, became a significant factor in several tests.'"

"For the continuously wet test series (in which water was periodically added), 'with few exceptions, the phenolic foam samples were more damaging to the painted panels in this test series than the other insulations.'"

"'Pitting corrosion became more of a factor on both steel and galvanized surfaces in the long-term (200 day) tests with the wet and continuously wet exposure. It is important to note that the rate at which a pit can penetrate a metal surface is not necessarily or typically related to the corrosion rate .... The most significant thing to note is that pitting can occur under a specific set of conditions which could reach serious proportions.'"

"In 1985, a membrane manufacturer issued a technical note that stated 'test results have indicated that some phenolic foam insulations can contribute significantly to corrosion of metals in certain environments.'"

"In 1989, the American Society for Testing and Materials (ASTM) material standard C 1126 for phenolic insulation was issued. Section 11.3 states '. . . phenolic foams may contain some compounds which may promote corrosion in the presence of liquid water.'" [15]

CONCLUSION

Diverse users of phenolic foam in contact with metal surfaces have experienced corrosion and pitting of the metal surfaces in contact with the phenolic foam. Users of radioactive material packages and metal roofing systems have completed studies verifying that a chemical reaction of phenolic foam and a metal surface occurs which can compromise the structural integrity of the metal surface. United States manufacturers of phenolic foam metal-insulating systems have ceased production of phenolic foam for metal decks and metal roofs.

Five years have lapsed since DOT required modifications to 21PF overpacks. ANSI N14.1—1990, "Uranium Hexafluoride-Packaging for Transport," states "each protective packaging shall be recertified every 5 years .... Outer protective packaging shall receive a full visual inspection for rusting and the presence of corrosion. This inspection shall include the assurance that corrosion has not reduced the skin wall thickness by 10%."

As 21PF overpacks are recertified under ANSI N14.1-1990, it is essential that definitive qualitative tests be used to determine if corrosion or other package deterioration has occurred to cause an overpack to be scrapped instead of being recertified.

It appears that a formal study is needed to determine the seriousness of phenolic foam induced corrosion in 21PF overpacks. Studies made for the roofing industry should be reviewed and documented to determine any applicability to radioactive material packages using phenolic foam as a thermal insulation. The results should be reviewed, and recommendations should be made based on the implications for radioactive material packages and the nuclear industry.

REFERENCES

1. U.S. Nuclear Regulatory Commission, IE Information Notice No. 82-24: Water

Leaking from Uranium Hexafluoride Overpacks, July 20, 1982.

2. H. Doran Fletcher, "DOT Specification Overpacks for Packaging 235 U Enriched UF_6, U.S. Department of Energy, Oak Ridge, Tennessee, July 30, 1981.

3. C. R. Barlow, K. T. Ziehlke, W. A. Pryor, W. R. Householder, "Testing and Evaluation of Used UF_6 Shipping Packages," *IAEA International Symposium on the Packaging and Transport of Radioactive Materials (PATRAM '86)* Vol. 2, IAEA-SM-286/230P, 1986.

4. C. R. Barlow et al., "Proposal for Modifications to U.S. Department of Transportation Specification 21PF-1 Fire and Shock Resistant Phenolic Foam-Insulated Metal Overpack," K/SS-471, Martin Marietta Energy Systems, November 1986, Portsmouth Gaseous Diffusion Plant.

5. C. R. Barlow et al., *Renovation of DOT Specification 21PF-1 Protective Shipping Packages*, K-2057, Martin Marietta Energy Systems, Inc., Oak Ridge, Tennessee, November 21, 1986.

6. American National Standards Institute, "American National Standard for Nuclear Materials — Uranium Hexafluoride-Packaging for Transport," ANSI NI14.1, New York, 1990.

7. *Federal Register*, "Modifications to DOT Specification 21PF-1 Overpacks," 49 CFR Parts 171, 173, and 178, September 20, 1988.

8. W. M. Arnold, letter to Marvin Burger, "Pitting Problem with Stainless Steel Overpacks," Nuclear Containers, Inc., Elizabethton, Tennessee, dated September 1, 1993.

9. J. W. Kalis, Jr., "Corrosion Under Insulation," NIAC's *Overlook*, Alexandria, Virginia, March 1991.

10. "NRCA Tech Department Evaluates Problems," *NEWS*, NRCA, Rosemont, Illinois, March 1991.

11. R. G. Garcia, "Better Finish is Key to Avoiding Corrosion," *Professional Roofing*, National Roofing Contractors Association, Rosemont, Illinois, August 1991.

12. R. P. Cannon, "Metal-deck Corrosion: Three Case Studies," *Professional Roofing*, National Roofing contractors Association, Rosemont, Illinois, August 1991.

13. Manville Marketing Bulletin, "Steel Roof Deck Corrosion—Roof Insulations," Bulletin 52A4-373A, Denver, Colorado, September 14, 1990.

14. J. D. Gallie, Beazer East, Inc.,letter to Former Distributors of Koppers RX Insulation," March 31, 1992.

15. T. L. Smith, J. D. Carlson, T. L. Walzak, "Steel Deck Corrosion Associated with Phenolic Roof Insulation: Problem Causes, Prevention, Damage Assessment and Corrective Action," *10th Conference on Roofing Technology*, 1993, p. 108.

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