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NUCLEAR REGULATORY COMMISSION
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ELIZABETH MILLER
COMMISSIONER OF PUBLIC SERVICE
DEPT OF PUBLIC SERVICE
112 STATE ST - DRAWER 20
MONTPELIER VT 05620-2601

UNITED STATES
NUCLEAR REGULATORY COMMISSION
OFFICE OF NUCLEAR REACTOR REGULATION
WASHINGTON, DC 20555-0001

August 1, 2011

NRC INFORMATION NOTICE 2011-15: STEEL CONTAINMENT DEGRADATION AND ASSOCIATED LICENSE RENEWAL AGING MANAGEMENT ISSUES

ADDRESSEES

All holders of an operating license or construction permit for a nuclear power reactor issued under Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, "Domestic Licensing of Production and Utilization Facilities," except those who have permanently ceased operations and have certified that fuel has been permanently removed from the reactor vessel.

PURPOSE

The U.S. Nuclear Regulatory Commission (NRC) is issuing this information notice (IN) to inform addressees of recent issues identified by the NRC staff concerning degradation of nuclear power plant steel containments that could impact aging management of the containment structures during the period of extended operation of a renewed license. For the issues described below, specific commitments were made by applicants during license renewal reviews. The NRC expects recipients to review the information for applicability to their facilities and consider actions, as appropriate, to avoid similar problems. The suggestions contained in this IN are not NRC requirements; therefore, no specific action or written response is required.

DESCRIPTION OF CIRCUMSTANCES

Degraded Coatings and Corrosion of Steel Containments

<u>Duane Arnold Energy Center</u>

During its review of the Duane Arnold Energy Center license renewal application (LRA), the NRC staff noted that since 1977, when the applicant performed the first inspection of the torus after the initial coating application, the applicant has found numerous instances of localized corrosion and depletion of the coating of the torus shell (see Enclosure Figures 1 and 2) of its boiling-water reactor (BWR) Mark I containment. The applicant performed repairs in 1980 and 1983 prior to a full recoat of the suppression chamber in 1985. Since 1988, the applicant has been repairing degraded coatings and managing and tracking the effects of aging of the torus in accordance with the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code Section XI, "Rules for Inservice Inspection of Nuclear Power Plant Components," Subsection IWE, "Requirements for Class MC and Metallic Liners of Class CC Components of Light-Water Cooled Power Plants." Since 1995, the torus coating has been repaired at more than 15,000 locations, all below the water line, which is equivalent to approximately 5 percent of the underwater coating surface inside the torus. The torus steel behind the degraded coating has corroded locally at some of these locations. The applicant evaluated this degradation of

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coating of the torus and determined that the degradation has not affected the structural integrity of the torus. In addition, the applicant performed detailed analysis and determined that localized corrosion of the torus shell was acceptable without repair. The NRC staff requested that the applicant address the possibility of localized galvanic corrosion (pitting) due to degraded coatings during the period of extended operation since the normal life of the underwater zinc coating is approximately 15 to 20 years and aging management of the torus steel minimizes the potential for pitting corrosion to extend through-wall. In response to NRC requests for additional information during the license renewal review, the applicant committed to recoating the suppression pool interior surfaces below the water line prior to startup from the first refueling outage during the period of extended operation (applicant letter, dated March 9, 2010, Agencywide Documents Access and Management System (ADAMS) Accession No. ML100700248). The applicant subsequently stated that the current project plan ensures that recoating will extend well above any fluctuations in water level, including the 2-foot wide splash band at the water level (applicant letter, dated April 2, 2010, ADAMS Accession No. ML100960277).

<u>Cooper Nuclear Station</u>

During its review of the Cooper Nuclear Station LRA, the NRC staff noted that the applicant had identified pitting corrosion in its BWR Mark I containment throughout the wetted area of the torus as a result of degradation of the zinc coating (see Enclosure Figure 3). The applicant documented approximately 3,800 locations of torus degradation since 1991, covering approximately 1.1 percent of the surface area below the water line. The applicant has been tracking the effects of aging of the torus by performing augmented inspections in accordance with the ASME Subsection IWE requirements and performing coating repairs to manage torus degradation. Upon review of plant operating experience, the NRC staff requested that the applicant address the cumulative effects of pitting corrosion in its aging management program to ensure that torus degradation would be adequately managed during the period of extended operation and to minimize the potential for through-wall pits. In response, the applicant committed to inspect the wetted portion of the torus during every refueling outage from now until the wetted portion of the torus is recoated by the committed date of January 18, 2017 (applicant letter, dated May 4, 2010, ADAMS Accession No. ML101310605).

Discovery of Water in Inaccessible Areas

<u>Hope Creek Generating Station</u>

During its review of the Hope Creek Generating Station LRA, the NRC staff noted that during the 2009 refueling outage, the applicant observed in its BWR Mark I containment a small water leak from a drywell shield wall penetration sleeve J13 located in the drywell air gap region. The applicant did not observe any leakage from the drywell lower air gap drains that are located approximately 8-feet below the penetration. In its review, NRC staff identified the possibility that water might be trapped between the concrete and drywell steel below the penetration and that trapped water could lead to thinning of the drywell steel. During the subsequent 2010 refueling outage, the applicant observed leakage from the same penetration, but again no leakage was noted from the air gap drains located below the penetration. The applicant investigated and found that all four drywell air gap drains were blocked (see Enclosure Figures 4–7). The applicant subsequently performed ultrasonic testing (UT) to measure drywell thickness. The

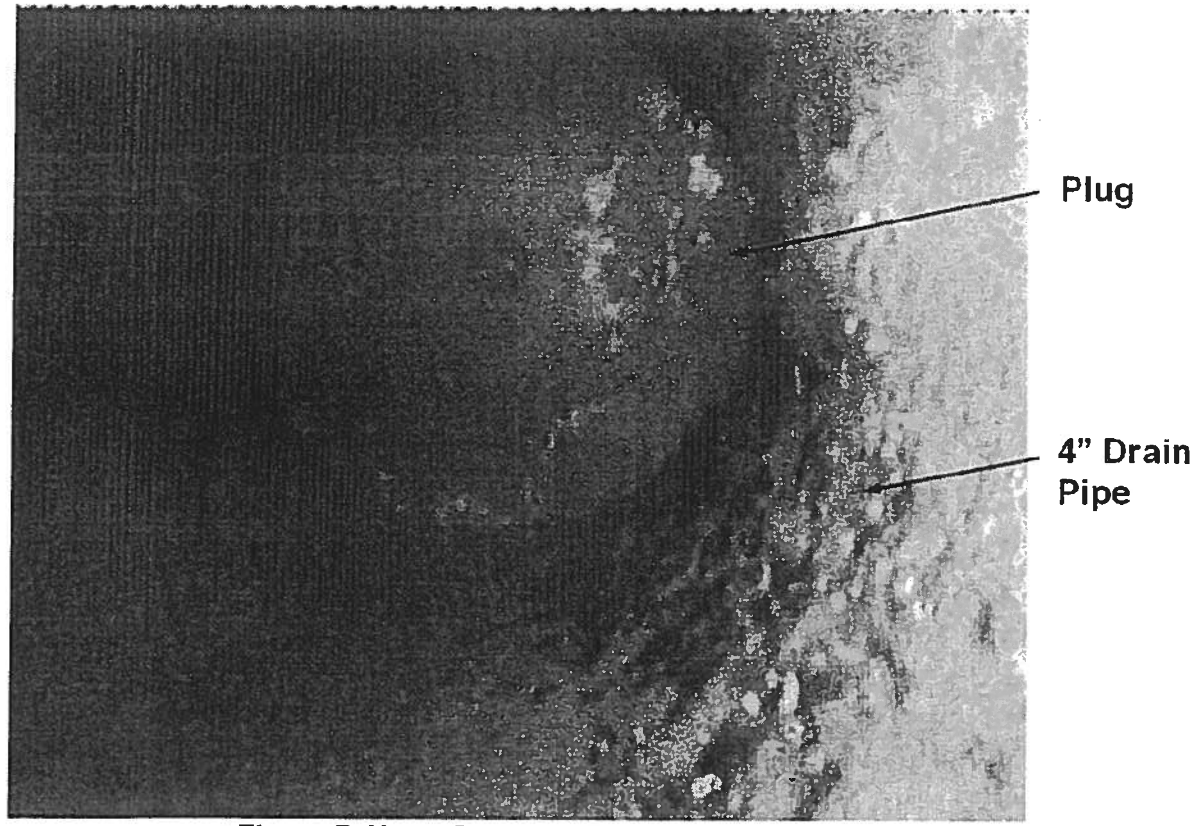

Figure 7 Hope Creek Plugged Drywell Air Gap Drain

measurements indicated greater than nominal plate thickness in all areas of drywell steel except the lower portion of the plate below the penetration. In that area, the reduced plate thickness was still greater than design requirements and was able to perform its intended function. Notwithstanding, the NRC staff requested the applicant to address the possibility that this reduced plate thickness could be the result of corrosion of the steel plate due to the presence of trapped water. The NRC staff requested that the applicant provide information on establishing a corrosion rate of the steel and projected loss of drywell thickness. In response, in its letter of January 19, 2011 (ADAMS Accession No. ML110210677), the applicant updated its commitments to perform UT thickness measurements over the next three refueling outages in the area of the drywell shell in the air gap below the penetration sleeve area and inform the NRC of its findings. The applicant will use the measurements to establish a corrosion rate and demonstrate that the effects of aging will be adequately managed such that the drywell will continue to perform its intended function for the period of extended operation.

Upon recent further investigation of the blockage in one of the drywell air gap drains, the applicant's boroscopic inspections were unable to confirm the existence of any air gap drain opening, contrary to the existing design configuration. The applicant was not able to determine the as-built configuration of the air gap drains but confirmed that there were no indications of water accumulation inside the drywell air gap space and no indications of corrosion of the containment steel shell exterior surface. In response to NRC staff questions, in its letter dated May 19, 2011 (ADAMS Accession No. ML11144A016), the applicant committed to perform UT thickness measurements during each refueling outage in the area of the drywell shell below the penetration sleeve area until drainage is established from all four drains. The licensee will ensure that the corrosion rate is such that the drywell can continue to perform its intended function for the period of extended operation. The applicant committed to document and address evidence of drywell shell degradation in the corrective action program. In addition, in response to NRC staff questions regarding the current configuration of the drywell air gap drains, the applicant revised its aging management program to establish drainage capability from the bottom of the drywell air gap through four air gap drains on or before June 30, 2015 (applicant letter, dated May 19, 2011, ADAMS Accession No. ML11144A016). The NRC included a license condition for this issue in the renewed license.

<u>Dresden Nuclear Power Station</u>

In November 2010, the licensee at Dresden Nuclear Power Station Unit 3, a BWR Mark I containment, performed UT thickness measurements of the drywell containment liner. Twenty-two core boreholes had been drilled through the bottom elevation concrete inside the drywell in 1988 to facilitate periodic thickness measurements of the drywell liner. These boreholes exposed the inner surface of the liner plate. The purpose of the UT examination was to determine the corrosion rate of the steel liner in order to verify that it would not reach the minimum allowed wall thickness and would remain within ASME Code allowable stress limits over a 60-year operating period. While performing the UT measurements, the licensee detected water in the annular region (or drywell air gap region) between the drywell wall and liner. The licensee investigated and determined that the source of the water intrusion was historic containment sump overflow, water seepage from the sump via capillary action in the concrete or other minor concrete deficiencies, and water intrusion from maintenance activities. The UT measurement results indicated that the overall degradation of the steel liner and the effect of corrosion on stresses were insignificant. At present, there is no evidence that trapped water has caused degradation of the drywell liner wall thickness. However, in accordance with the ASME Section XI, Subsection IWE aging management program, the licensee will continue to perform UT at every refueling outage and reevaluate the effects of corrosion on the steel liner and recalculate the rate of degradation of the liner, as necessary.

BACKGROUND

Regulation 10 CFR 50.55a, "Codes and Standards," requires that licensees implement the inservice inspection program for steel and concrete containments in accordance with Subsection IWE and Subsection IWL, respectively, of Section XI of the ASME Boiler and Pressure Vessel Code, which is incorporated by reference therein with certain conditions. Paragraph (a)(1) of 10 CFR 54.29, "Standards for Issuance of a Renewed License," requires that applicants for a renewed license will manage the effects of aging during the period of extended operation on the functionality of structures and components that require review under 10 CFR 54.21(a)(1). NUREG-1801, "Generic Aging Lessons Learned (GALL) Report," recommends that ASME Section XI, Subsection IWE, be used to manage aging of steel containments through the period of extended operation.

During license renewal reviews, NRC staff noted similar containment degradation issues and identified the need for License Renewal Interim Staff Guidance (LR-ISG)-2006-01, "Plant-Specific Aging Management Program for Inaccessible Areas of Boiling-Water Reactor Mark I Steel Containment Drywell Shell," dated November 24, 2006 (ADAMS Accession No. ML063210041), which recommends a plant-specific aging management review of inaccessible areas of BWR Mark I steel containment drywell shells in addition to the visual inspection recommended in NUREG-1801. LR-ISG-2006-01 recommends that licensees implement augmented inspections for the period of extended operation in accordance with ASME Section XI, IWE-1240, Examination Category E-C, if moisture has been detected or suspected in the inaccessible area on the exterior drywell shell, and demonstrate that corrosion is not occurring, or that corrosion is progressing so slowly that the age-related degradation will not jeopardize the intended function of the drywell shell through the period of extended operation.

DISCUSSION

Design stress criteria dictate the minimum allowable plate thickness required for steel containments. Coatings applied to the steel containment serve to prevent or minimize loss of material thickness due to corrosion. Torus coatings are typically expected to last less than 20 years. Once the coating material begins to degrade, the steel is susceptible to moisture which can lead to corrosion. The degradation and repair of torus coatings at Duane Arnold Energy Center and Cooper Nuclear Station, over the years, collectively involved approximately 5 percent and 1.1 percent, respectively, of the torus wetted surface. In these cases, degraded torus coatings resulted in corrosion of the steel substrate, which in some instances involved localized galvanic corrosion (pitting). The pitting corrosion rate can be 5 to 15 times faster than that of generalized (uniform) corrosion and is less predictable. If left unmonitored, pitting corrosion in containment steel can more quickly reach a depth that reduces plate thickness below its minimum design value or progress through-wall, which could compromise containment reliability. In the cases discussed, the corrosion did not reduce the steel thickness below its design thickness limits, and the applicants were managing aging of the coatings by repairing areas of coating degradation. Notwithstanding, the NRC identified concerns in its license

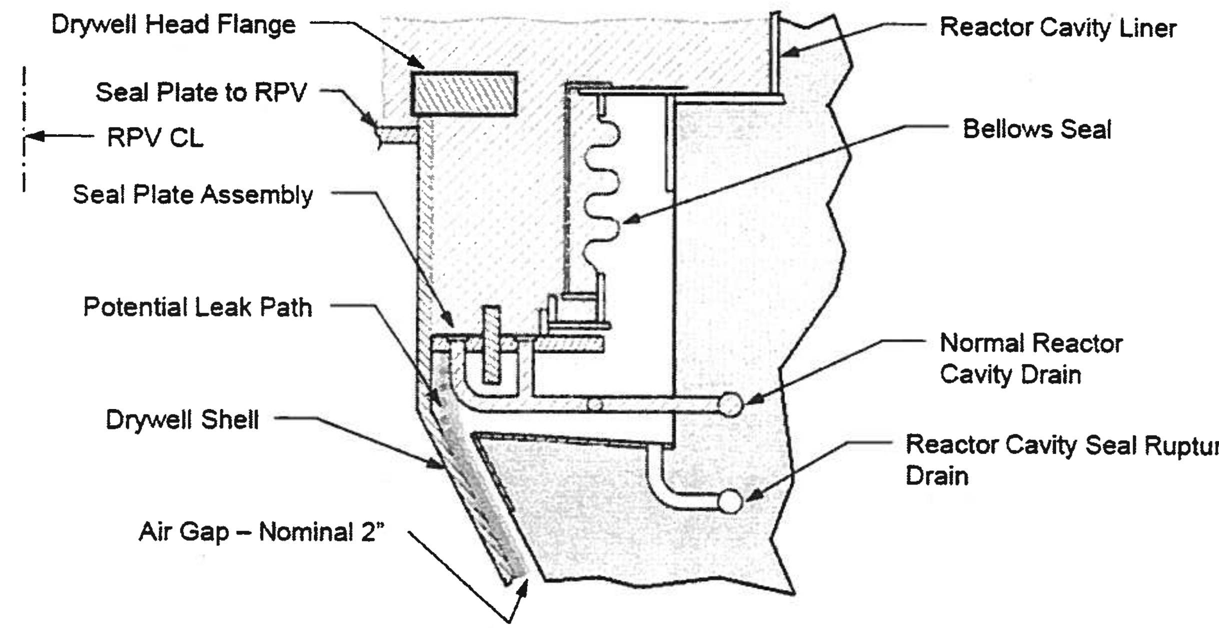

Figure 5 Detail A: Configuration of Hope Creek Reactor Cavity Seal Area During Refueling Operation

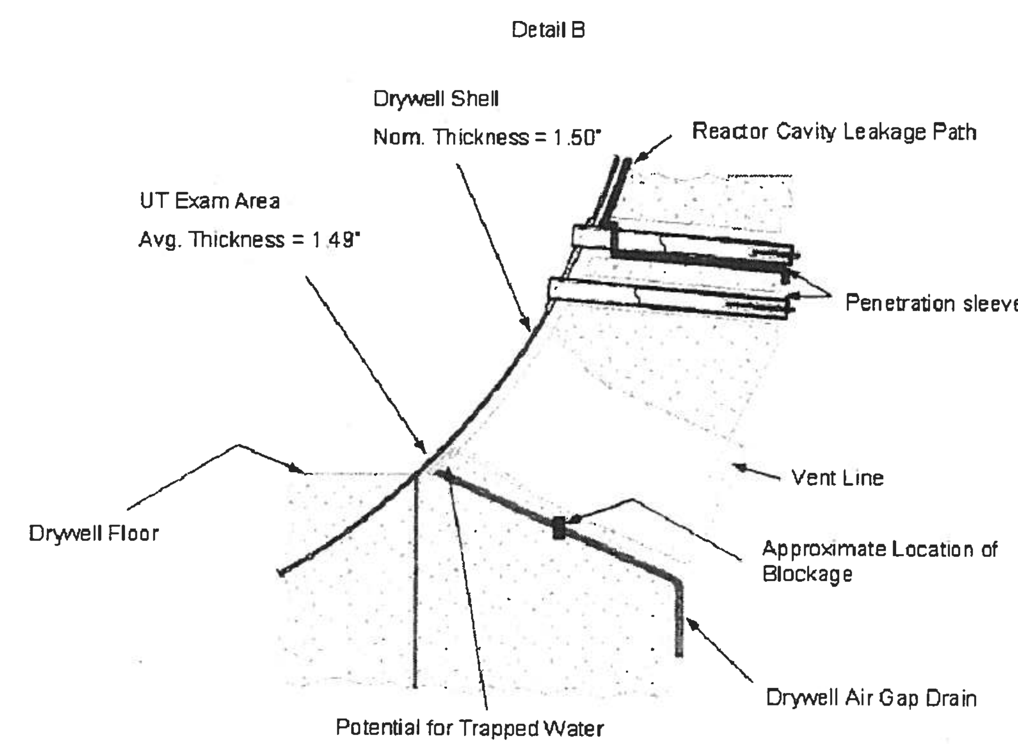

Figure 6 Detail B: Hope Creek Lower Drywell Area

Figure 3 Cooper Nuclear Station—Pitting Corrosion of Torus Steel

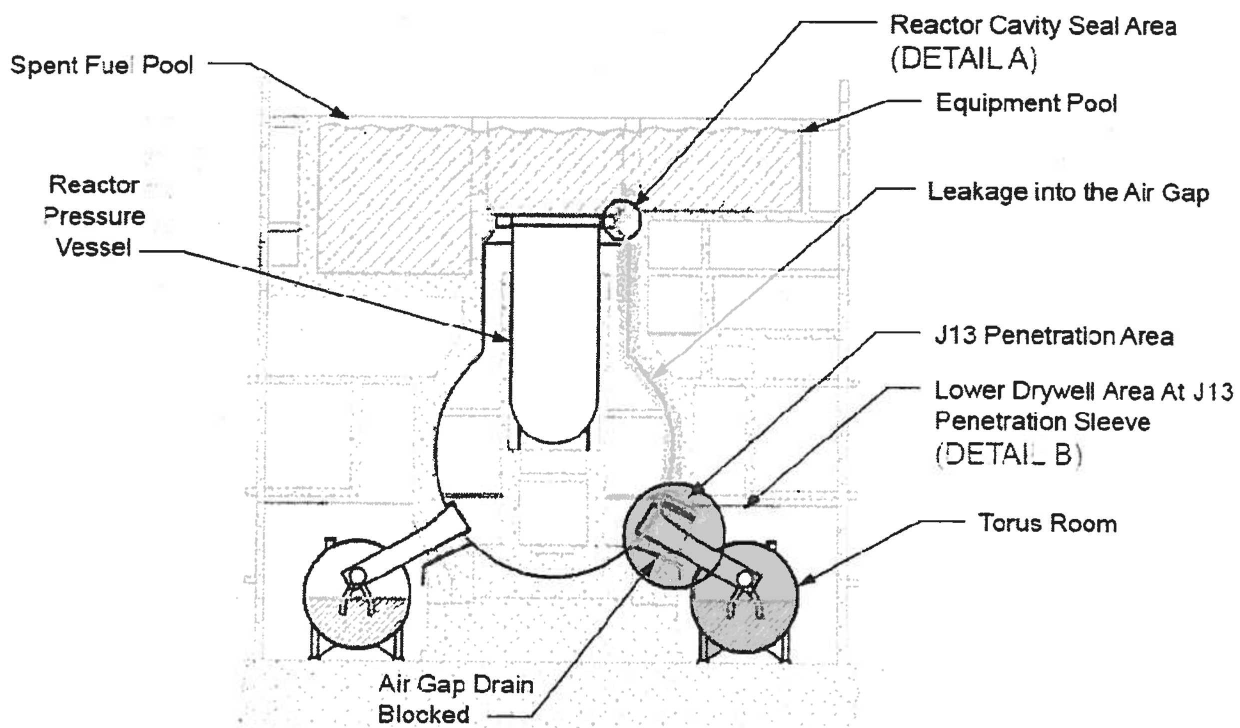

Figure 4 Hope Creek Mark I Containment During Refueling Operation

renewal reviews with the sizable area of torus coating degradation and repair with respect to aging management of the steel, particularly regarding the instances of pitting. Although there is no regulatory requirement to do so, several BWR Mark I licensees have chosen to schedule a complete recoating of the torus, instead of repairing areas of degraded coatings, as an aging management measure to minimize future containment corrosion.

This IN also addresses the discovery of water in the drywell air gap region in two other plants, Hope Creek Nuclear Generating Station and Dresden Nuclear Power Station. A similar issue involving the presence of water in inaccessible areas was documented in IN 86-99, "Degradation of Steel Containments," dated December 8, 1986, and its corresponding Supplement 1, dated February 14, 1991. This generic communication informed licensees that significant corrosion was discovered in the inaccessible sand-bed region of the drywell shell at Oyster Creek Nuclear Generating Station. The IN supplement noted that the corrosion was likely caused by water in the gap between the drywell and the concrete shield. The source of water was noted as leakage through the seal between the drywell and the refueling cavity. The licensee used UT thickness measurements to detect wall thinning and determine corrosion rates.

Water that is in contact with the steel drywell liner can cause corrosion that may result in wall thinning. Routine inspection of the drainage capability of air gap drains in BWR containments (with or without sand pockets) decreases the likelihood of water being trapped. Inaccessible areas are of particular concern because corrosion could go undetected for years and possibly result in wall thinning to less than the minimum design thickness. ASME Code Section XI, Subsection IWE, requires evaluation of the acceptability of inaccessible areas when conditions are found in accessible areas that could indicate the presence of or result in degradation to inaccessible areas. The NRC Generic Aging Lessons Learned Report recommends that applicants for license renewal for plants with BWR Mark I containments should augment the monitoring and trending requirements of their IWE aging management program to address inaccessible areas of the drywell.

Although this IN describes corrosion due to presence of water in inaccessible areas and degradation of coatings and pitting corrosion of the torus steel shell of BWR Mark I containments, there have also been instances of corrosion and pitting of pressurized-water reactor (PWR) and other BWR containments due to long term exposure to water and moisture, including that in inaccessible areas. During license renewal reviews, NRC staff has identified operating experience involving corrosion due to presence of trapped water at moisture barriers in PWR and BWR containments. Other potential locations for water to accumulate and potentially result in uniform or pitting corrosion of the steel include but are not limited to: the junction of the containment cylinder and intermediate floors and basemat concrete of PWRs and Mark III BWRs, the areas adjacent to crane girder rails and supports attached to steel liner plates of concrete containments, and behind ice condenser baskets. Similar instances have been identified at plants with a variety of containment designs as described in NRC IN 88-82, "Torus Shells with Corrosion and Degraded Coatings in BWR Containments," NRC IN 89-79, "Degraded Coatings and Corrosion of Steel Containment Vessels," NRC IN 97-10, "Liner Plate Corrosion in Concrete Containments," and NRC IN 2004-09, "Corrosion of Steel Containment and Containment Liner."

Issues involving the degradation of coatings and corrosion of steel containments and liner plates due to presence of water in inaccessible areas continue to be of concern for aging management. Implementation of the in-service inspection requirements of ASME Code Section XI, Subsection IWE for steel components of steel and concrete containments is necessary in order to ensure the containment will be able to perform its intended functions through the period of extended operation.

CONTACT

This IN requires no specific action or written response. Please direct any questions about this matter to the technical contacts listed below or to the appropriate Office of Nuclear Reactor Regulation (NRR) project manager.

Timothy J. McGinty, Director
Division of Policy and Rulemaking
Office of Nuclear Reactor Regulation

Technical Contacts: Angela Buford, NRR
301-415-3166
E-mail: angela.buford@nrc.gov

Abdul Sheikh, NRR
301-415-6004
E-mail: abdul.sheikh@nrc.gov

Enclosure: Photographs and Illustrations of Degradation of BWR Containment Torus Shell and Drywell Due to Corrosion

Note: NRC generic communications may be found on the NRC public Web site, http://www.nrc.gov, under NRC Library.

Photographs and Illustrations of Degradation of BWR Containment Torus Shell and Drywell Due to Corrosion

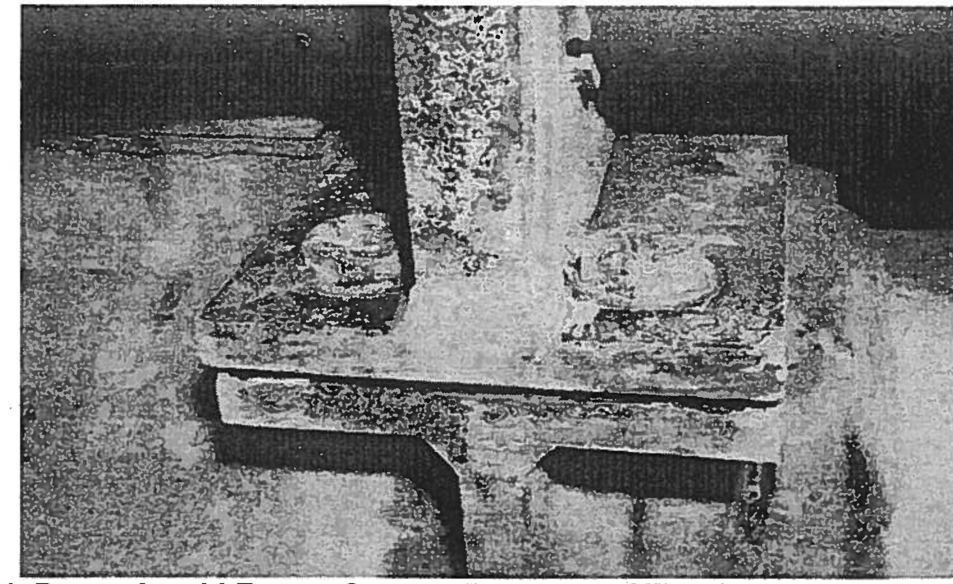

Figure 1 Duane Arnold Energy Center—Depletion of Zinc Coating on Torus Shell and Supporting Steel

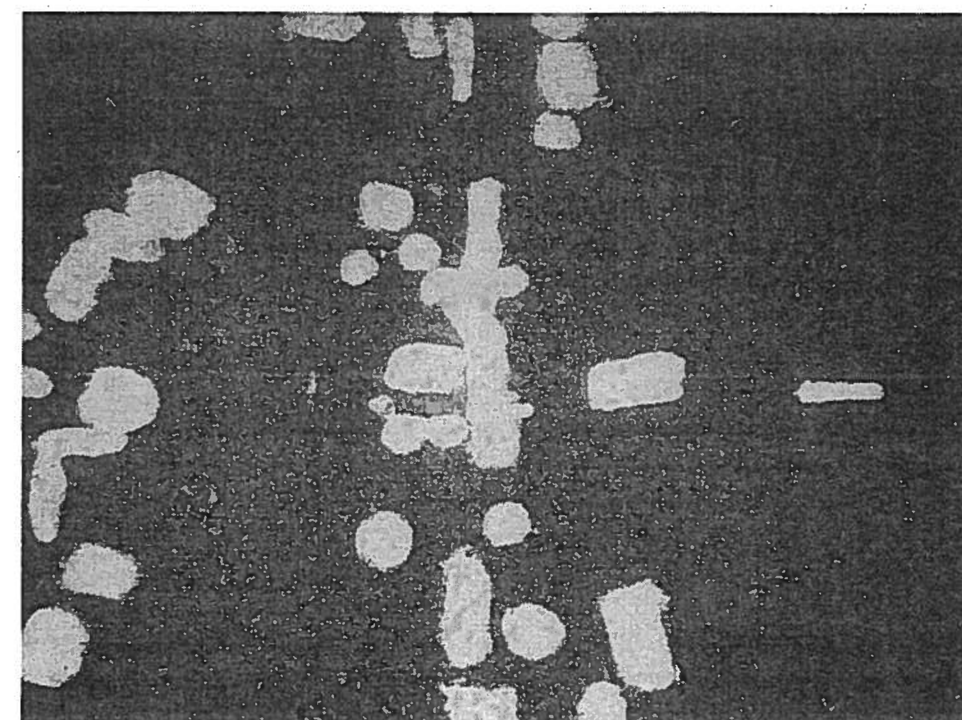

Figure 2 Duane Arnold Energy Center—Torus Coating Repairs