RAI B.2.1.29-2

Background:

GALL Report (NUREG-1801), AMP XI.S2, "ASME Section XI, Subsection IWL," Program Element 10 states that implementation of ASME Section XI, Subsection IWL, in accordance with 10 CFR 50.55a, is a necessary element of aging management for concrete containments through the period of extended operation.

Issue:

Program Element 10 for the Salem ASME Section XI, Subsection IWL aging management program describes results of concrete inspections conducted in April 2001 and October 2005 for Unit 1, and November 2000, May 2005, and August 2009 for Unit 2. In addition to isolated areas of physical damage to concrete surfaces on both units, normal shrinkage cracking was also observed. Salem Units 1 and 2 containments are constructed from reinforced (non-prestressed) concrete; therefore, cracking of the concrete in some areas is likely and is expected over the 60-year operating life. In Notification 000020234570, the applicant reported cracks in the concrete coating over the entire outside of the Unit 2 containment. Long-term exposure of concrete cracks to salt spray originating from the Delaware Bay could result in corrosion of the embedded steel reinforcing bars located nearest to the outer surface of the containment concrete during the extended period of operation.

Request:

The applicant is requested to provide the following:

1. The extent and maximum width of the cracks observed in Salem Unit 1 and 2 containments.

2. Actions that are planned to mitigate the consequences of chloride ion penetration to the level of the embedded steel reinforcing bars over the period of extended operation. This may be necessary since the Salem Units 1 and 2 concrete containment surface inspection reports documented scaling and spalling of up to 3 inches.

3. If no actions are anticipated to mitigate the consequences of chloride ion penetration to the level of the embedded steel reinforcing bars, the applicant is requested to provide an assessment of this time-dependent phenomenon and the basis for this decision.

The staff needs the above information to confirm that the effects of aging of the concrete containment will be adequately managed so that it's intended function will be maintained consistent with the current licensing basis for the period of extended operation, as required by 10 CFR 54.21(a)(3).

PSE&G Response:

1. Concrete inspections for both Salem Unit 1 and Unit 2 Containment structures were completed in April 2010 using the ACI 349.3R tiered acceptance criteria. Examination results have been reviewed by the site Responsible Professional Engineer, and found acceptable, meeting ACI 349.3R acceptance criteria. These results, including extent and maximum width of cracks, are summarized below:

   General:
   The overall crack patterns are very similar for both Unit 1 and Unit 2 containments. The concrete surfaces exhibit general pattern cracking over the entire surface as well as cracking at random areas of mortar patches. The mortar patches were originally applied at the construction joints. Minor degradation of the mortar patches was noted.

   Cylindrical walls:
   Pattern cracking on about a 15" by 15" grid is evident over most of the cylindrical walls, with crack widths of about 0.015".

   Dome:
   There is similar pattern cracking on the tops of the Unit 1 and Unit 2 domes. The crack widths across most of the domes are about 0.015" wide with some areas at the top having cracks up to 0.040" wide.

   Maximum width and extent of cracking:
   - At the Unit 2 Containment, El. 130' airlock, some of the cracks were 0.0625" wide at the surface.
   - At the Unit 1 Containment, inside the Penetration area, above the floor at elevation 78', a circumferential crack 0.032" wide was noted.

   Comparison to original structural integrity tests:
   The above conditions were compared to those found during the original start-up structural integrity tests. The cracks are characterized as passive and inactive. The extent of the cracking and maximum crack widths is expected and consistent with the crack patterns exhibited following the original start-up structural integrity tests. Widening of cracks at the surface was identified and evaluated as part of the original structural integrity tests and accepted as a shallow, surface condition that was acceptable.

2. Salem will continue to monitor the condition of Unit 1 and Unit 2 containment concrete surfaces for spalling, scaling, cracking, and rust stains which are indicative of reinforcing bars corrosion. The monitoring activities will be in accordance with the applicable edition and addenda of ASME Section XI, Subsection IWL, as approved in 10 CFR 50.55a and recommended in the GALL Report, Rev. 1. Inspection and acceptance criteria will be in accordance with ACI 349.3R as described in LRA Section B.2.1.29. If acceptance criteria specified in ACI 349.3R for spalling, scaling, and cracking cannot be met, corrective actions will be implemented as required by the corrective action process to address corrosion of reinforcing bars. These actions may include mitigative measures, such as repairs to scaled and spalled

areas of concrete, and sealing of cracks to minimize penetration of chloride ions. If corrosion staining of reinforcing steel is observed on containment concrete surfaces, an engineering evaluation will be conducted to assess the condition of reinforcing bars and the impact of rebar corrosion on containment structural integrity. As described in the response to item 1 above, the Unit 1 and Unit 2 concrete containment surfaces were not spalled up to 3 inches, but rather had minor scaling and spalling. Therefore, there is currently no need for specific mitigative actions to prevent the potential of chloride ion penetration to the level of embedded reinforcing bars.

3. Chloride ions are common in nature and small amounts can be unintentionally contained in the concrete mixture ingredients. Potential external sources of chlorides include exposure to seawater or spray, deicing salts, or those from accelerating admixtures. The penetration and diffusion of chloride ions in concrete and their impact on reinforced concrete has been a subject of tests and studies as documented in the American Concrete Institute (ACI) ACI 222R, *"Protection of Metals in Concrete Against Corrosion",* ACI 349.3R, *"Evaluation of Existing Nuclear Safety-Related Concrete Structures"*, ACI 365.1R, *"Service Life Prediction---State-of-the-Art Report"*, NUREG/CR-6927, *"Primer on Durability of Nuclear Power Plant Reinforced Concrete Structures – A Review of Pertinent Factors",* and other literature. NUREG/CR-6927 also includes the results of concrete condition surveys in ten nuclear power plants. The review of ACI 222R, ACI 349.3R, ACI 365.1R, and NUREG/CR-6927 indicates that chloride ion penetration and diffusion in concrete depends on concrete durability and serviceability which have been incorporated into codes such as ACI 318, "*Building Code Requirements for Structural Concrete".* Durability of concrete has been included in ACI 318 through specification of maximum water-cement ratios, cement content, type of cement, entrained air, minimum cover over the reinforcing bars, and control of cracks. The Salem Containments are constructed of concrete that conforms to the applicable ACI 318 requirements. The minimum concrete clear cover over the reinforcing bars shown on the design drawings is $3^3/_8$ inches nominal which is greater than the 2 inch cover required by ACI 318 for concrete exposed to weather. Recent examinations of Unit 1 and Unit 2 Containment concrete surfaces using procedures that are based on ACI 349.3R inspection and acceptance criteria identified only minor spalling and scaling, but none that reduce the concrete cover over the reinforcing bars below the 2 inches required by ACI 318. Cracking is minor as described in the response to the item 1 of this RAI. In addition, the Containment concrete is observed to be free of large penetrating cracks that could permit significant chloride ion penetration to reach the level of reinforcing bars.

   The primary concern associated with penetration and concentration of chloride ions over time is that it can lead to corrosion of the reinforcing bars. Reinforcing bars with adequate concrete cover should not be susceptible to corrosion because the highly alkaline conditions present within concrete cause a passive iron-oxide film to form on the surface of the reinforcing bars. Chloride ions, however, can destroy this passive film and initiate corrosion. Corrosion of reinforcing bars (i.e., the transformation of metallic iron to ferric oxide, or rust) is accompanied by an increase in volume of the metallic iron. The volume increase can cause cracking, spalling, and delamination of the concrete that can be visible in the form of loss of concrete material, rust spots and stains, and cracks in the concrete cover along the reinforcing bars. Visual inspection required to be conducted in accordance with ASME Section XI,

Subsection IWL, would detect such conditions before the loss of containment intended function. To date, corrosion of containment concrete reinforcing bars has not been identified as a concern by Salem or industry operating experience.

In summary, chloride ion penetration and diffusion in concrete has been a subject of extensive research and studies. The extent of the penetration and diffusion depend on concrete durability, permeability, and cracking, which have been considered in concrete design codes and standards. Salem conforms to the applicable concrete codes and standards. In the event this time dependent phenomenon penetrates to the level of reinforcing bars and initiates corrosion, the increase in volume of the steel due to the creation of rust will result in spalling, cracking, delamination of concrete, and staining of concrete surfaces. Implementation of ASME Section XI, Subsection IWL, aging management program described in LRA B.2.1.29 is considered to provide reasonable assurance that these aging effects will be detected and corrective actions will be taken prior to the loss of the Containment intended function.