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Mr. John White – Chief Plant Support - Branch 2
U. S. Nuclear Regulatory Commission
475 Allendale Road
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Salem Nuclear Generating Station Unit 1
Facility Operating License Nos. DPR-70
NRC Docket Nos. 50-272

Subject: Response to Unresolved Items 2005-002-03 and 2006-006-02
Salem Unit 1 Fuel Handling Building Structural Assessment

On February 28 and March 1, 2007, a meeting was held between Nuclear Regulatory Commission (NRC) and PSEG Nuclear LLC (PSEG) personnel to address the resolution of the subject unresolved items.

This letter is to provide the NRC with the following items as agreed upon as a result of the meeting:

1) A summary of the analysis that clearly identifies the existing margins,
2) The results of the surface strength test that was performed, and
3) The commitment for monitoring in accordance with standard ACI 349.

Attachment 1 summarizes the basis for the conclusion that the Salem Unit 1 Fuel Handling Building (FHB) is structurally sound and will satisfy the design basis requirements over the remaining plant life. It also addresses specific clarifications requested by the NRC during the meeting and the monitoring of the concrete.

Attachment 2 provides a brief summary of the results of the Impact Hammer Test conducted on March 21, 2007. The test was conducted to confirm that the concrete in the Salem 1 FHB sump room is sound and has not degraded significantly from exposure to boric acid leakage from the Spent Fuel Pool (SFP). The test results were shared with Mr. Suresh Chaudhary, who was on site for the performance of the test. The results of this test in conjunction with the structural assessment in MPR-2613 (*Salem Generating Station Fuel Handling Building—Evaluation of Degraded Condition*), demonstrate the structural adequacy of the FHB over the remainder of plant life.

MAR 3 0 2007

Attachment 3 provides the PSEG updated responses to the five (5) NRC questions originally provided on December 6, 2006.

Should you have any questions regarding this transmittal, please contact E. H. Villar at (856) 339-5456.

Sincerely,

T. C. Joyce

Attachments (3)

CC:

Mr. Samuel Collins, Administrator - Region I
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LIST OF REGULATORY COMMITMENTS

The following table identifies those actions committed to by PSEG in this document. Any other statements in this submittal are provided for information only purposes and are not considered to be regulatory commitments. Please direct questions regarding these commitments to Mr. Enrique Villar at (856) 339-5456.

Regulatory Commitment	Due Date/Event
PSEG has committed to revise the current monitoring procedure to include additional details regarding the benchmarking and monitoring of the FHB structure in accordance with the guidance provided in ACI 349.3R.	November 30, 2007

Attachment 1

SALEM UNIT 1
FUEL HANDLING BUILDING

SUMMARY OF BASIS FOR STRUCTURAL INTEGRITY

Introduction

Purpose

This document summarizes the basis for the conclusion that the Salem Unit 1 Fuel Handling Building (FHB) is structurally sound and will satisfy the design basis requirements over the remaining plant life. The concern regarding the structural adequacy of the FHB is that boric acid leakage from the Spent Fuel Pool (SFP) may have degraded the reinforced concrete building. PSEG Nuclear LLC (PSEG) has conducted a thorough assessment of the structure that includes the following efforts:

- A baseline inspection of the building consistent with American Concrete Institute (ACI) guidelines to assess the overall condition of the structure. PSEG has committed to continue monitoring of the structure in accordance with ACI 349.3R, and
- An assessment of the potential reduction in structural margin due to postulated degradation of the structure over the remaining plant life. This effort included testing to demonstrate the impact of boric acid on reinforced concrete and to quantify the degradation rate.

The above efforts are documented in reports that have been made available to the Nuclear Regulatory Commission (NRC) for review. Final NRC comments on the efforts were resolved at a meeting on February 28 and March 1, 2007 between PSEG, the NRC, the New Jersey Bureau of Nuclear Engineering, and MPR Associates (MPR). At that meeting, the NRC requested that PSEG summarize and clarify the basis for conclusion that the FHB is structurally adequate.

Background

On September 18, 2002, a technician working at the 78-foot elevation of the Salem Unit 1 Auxiliary Building contaminated his shoe. Investigation into the source of the contamination identified white deposits on the wall and active water leakage into the building. Further investigation determined that water from the SFP was leaking through the concrete wall into the Auxiliary Building and into the seismic gap between the buildings. Also, there was evidence of seepage into the Sump Room in the FHB via a construction joint at the base of the pool.

In early 2003, videoscopic inspection of the SFP telltale drains and leakage channels revealed that most of the telltale drains were blocked. The blockage caused the leakage from the pool liner to accumulate in the gap between the liner and the pool. As the water level in the gap increased, hydrostatic pressure forced water into construction joints and any cracks that might be present. PSEG cleared the telltales in early 2003 to re-establish flow and drain the stored inventory in the gap between the SFP liner and

FHB structure. PSEG monitors the telltale leak rates and performs periodic cleanings to prevent accumulation of SFP leakage behind the liner.

Long-term exposure of concrete to boric acid has the potential to degrade the structure as the acid reacts with the concrete and possibly corrodes the embedded reinforcing steel. This raised the issue of whether the potential degradation has challenged the structural adequacy of the FHB with respect to its design basis conditions.

Salem FHB Design Basis

The Salem FHB was designed, built and licensed to Standard ACI 318-63. This standard limits the stresses and loads in the structure to values well below those necessary to cause structural failure. Thus, meeting the industry standard provides significant margin to failure and ensures safe operation.

The current design analysis for the Salem FHB reports the design margin for various locations on the structure for each building load combination. Design margin is defined as the ratio of the design stress/load to the calculated stress/load. A design margin of 1.00 means that the stresses/loads in the structure are exactly equal to stress/load allowed by the ACI Code (i.e., the Code requirements are satisfied). The design analysis of the building in the "non-degraded condition" has a minimum design margin of 1.02. Therefore, the building has and additional 2% margin above that which is inherent in the ACI Code.

Basis for Salem FHB Structural Adequacy for Remaining Plant Life

The conclusion that the Salem Unit 1 FHB is structurally adequate at present and will remain so through the end of plant life is based on the following:

- A baseline inspection of the building consistent with ACI guidelines to assess the overall condition of the structure at present,
- An assessment of the potential reduction in structural margin due to postulated degradation through the end of plant life, and
- Condition monitoring of the FHB in accordance with ACI 349.3R.
- Each of these elements is discussed briefly below.

Assessment of Current Condition (based on walkdowns)

An experienced concrete structural engineer performed an independent structural assessment of the Fuel Handling Building. The assessment included review of building drawings and a visual inspection of the accessible portions of the FHB exterior walls and in the Sump Room. The checklist in ACI 201.1R-92 was used to guide the inspections. Observations were compared to limits in ACI 349.3R.

Key conclusions from the independent assessment are excerpted below:

- Overall the concrete appears to be in good structural condition.
- The appearance of leaching or chemical attack and corrosion staining of undefined source on concrete surfaces do not indicate significant structural deterioration at this time.
- There were no indications of concrete surface expansion due to reinforcing steel corrosion.

In summary, it concluded that based on a standard ACI walkdown approach, there was no reason to question the structural capacity of the Unit 1 Fuel Handling Building.

Condition Monitoring

Although PSEG performs periodic inspections of structures including the Fuel Handling Building, PSEG recognizes the need to perform specific monitoring of the FHB given the concerns regarding potential degradation due to exposure to boric acid. PSEG has committed to revise the current monitoring procedure to include additional details regarding the benchmarking and monitoring of the FHB structure in accordance with the guidance provided in ACI 349.3R. This action is being tracked in the PSEG Corrective Action Program.

Assessment of Margin Reduction from Postulated Degradation

The structural adequacy of the Salem Unit 1 FHB was assessed relative to the prolonged exposure of the concrete and reinforcing steel to boric acid, which has leaked from the SFP. This assessment evaluated:

- Conservatisms in the current Salem FHB design basis,
- Results of tests, analyses, assessments, and research documented in open literature that have reported the effects of boric acid on concrete and reinforcing steel,
- Results of evaluations of the impact of SFP leakage on the surrounding reinforced concrete structure at another nuclear power plant in the US,
- Results of testing designed to determine the effect of boric acid on concrete and reinforcing steel,

- Chemical analyses of the liquid draining from the telltales and the material that blocked the telltales, and
- The history of SFP leakage at Salem Unit 1.

Using results from the above efforts, the potential degradation of the Salem Unit 1 FHB was defined and its impact on the structural capacity was assessed. The key conclusions are summarized below.

Concrete Degradation

Boric acid reacts with the alkaline constituents of cement, causing cracking and loss of bonding with the aggregate. The reacted cement is soft and porous and has no strength. There is no impact on concrete strength other than an effective reduction in thickness corresponding to the depth of the corrosion layer.

The rate of degradation is controlled by diffusion of boric acid into the concrete. Results from the long-duration testing show that degradation demonstrates square root of time behavior, which is typical for diffusion-controlled processes. Projections of concrete degradation are made using a square root of time curve fit of the test data with adjustments for temperature and uncertainty.

The slab underneath the SFP has been exposed to boric acid leakage since early in plant life. This degradation is localized to the vicinity of leaking plug welds. However, as telltales became obstructed, area exposed to boric acid increased until the entire slab was exposed. Re-establishing flow in the telltales and draining the stored inventory between the liner and concrete did not stop floor slab degradation because the leakage must still migrate from the plug welds to channels with open telltales. The projected depth of concrete degradation in the floor slab is 1.3 inches assuming exposure to boric acid over the entire plant life.

The walls surrounding the SFP were exposed to boric acid during the time period when the telltales were plugged and pool leakage accumulated in the gap between the SFP liner and the walls. The projected depth of concrete degradation in the walls is 0.44 inch.

Reinforcing Steel Corrosion

Embedded reinforcing steel can potentially corrode from exposure to boric acid that migrates through the concrete. Since the concrete cover for all walls and the slab is markedly greater than the projected depth of concrete degradation, boric acid penetration into the concrete will not reach the reinforcing steel. Hence, the only mechanism for degradation of reinforcing steel is seepage of boric acid through cracks (that may be present) or construction joints.

It is estimated that seepage through construction joints or cracks started as early as the 1995. Boric acid seepage stopped subsequent to cleaning the telltales in early 2003.

This mode of degradation is not expected to recur as PSEG has implemented multiple measures to ensure that the telltales do not become entirely blocked and boric acid leakage is not expected to enter construction joints in the future.

All evidence indicates that any degradation of reinforcing steel, particularly the outer reinforcing steel (i.e., the reinforcing steel of concern from a structural standpoint), is negligible. This evidence includes the following:

- Laboratory studies available in the literature of corrosion of embedded rebar from boric acid flow through cracks, and corrosion of mild steel in de-aerated boric acid solutions,
- Inspections of potential rebar degradation from boric acid leakage through a concrete crack at another US nuclear power plant,
- No indications of significant rebar degradation in the Salem Unit 1 FHB (i.e, lack of rust staining on the walls),
- Independent assessment of the Salem Unit 1 FHB by a concrete structural engineer per ACI guidelines (Section 3.1).
- Conservative estimates of rebar degradation from boric acid show that the reduction in rebar diameter is negligible and well within manufacturing tolerances. Further, the fact that the actual rebar strength (from review of construction records) is greater than the specified value compensates for the predicted reduction in margin by more than a factor of ten. Accordingly, there is no reduction in structural capacity from boric acid corrosion of rebar.

Although seepage through construction joints and cracks was likely a combination of boric acid leakage from the SFP and groundwater ingress, the assessment of reinforcing steel corrosion focused on corrosion from boric acid. The basis for focusing on corrosion due to boric acid was that it is the more aggressive medium. Key considerations in this regard are as follows:

- Steel corrosion is sensitive to pH and rebar is largely protected from corrosion by the alkalinity of the concrete matrix. Since the pH of the boric acid solution from the SFP is significantly lower than the pH of groundwater, it is the more aggressive condition,
- Corrosion of reinforcing steel can also be sensitive to chlorides. Chloride levels in water samples from the seismic gap, which is indicative of ground water conditions, are low (~12 ppm). The ground water is benign with regard to corrosion of embedded rebar,

- Inspections of the FHB, as well as informal walkdowns of other concrete structures at Salem and Hope Creek potentially susceptible to groundwater intrusion, show no noticeable indication of rust staining from corrosion of embedded rebar.

Salem FHB Structural Capacity

The foregoing discussion shows that projected degradation through the end of plant life is minor and would have a small impact on available structural margin. Projected degradation through the end of plant life reduces the available margin in the limiting section by less than half percentage point to 1.6% (i.e., a design margin ratio of 1.016). Therefore, the conservative design basis analysis of record is not invalidated by the postulated degradation.

Conclusion

The efforts summarized above demonstrate that structural adequacy of the Salem Unit 1 FHB is maintained through the end of plant life even with consideration of prolonged exposure to boric acid.

The inspection performed by an experienced concrete engineer using ACI guidance concludes that the structural capacity of the building has not been compromised.

The assessment of the structure based on projected degradation through the end of plant life indicates that the reduction in structural capacity is minor. The projected design margin at the end of plant life is reduced slightly, but still greater than 1.00. Recall that a design margin ratio greater than 1.00 indicates that the structure has additional margin beyond that inherent in the Code.

PSEG has committed to monitor the condition of the FHB in accordance with ACI 349.3R to ensure that any changes in condition are trended and evaluated appropriately.

Attachment 2

SALEM UNIT 1
FUEL HANDLING BUILDING

STRUCTURAL INTEGRITY ASSESSMENT TEST RESULTS

Test Objective

The objective of the test was to confirm the concrete in the Salem 1 Fuel Handling Building Sump Room is sound.

Test Overview

The concept for the test was to perform an in-situ test of the compressive strength of the portion of the Unit 1 FHB west wall accessible from the Sump Room. The test was intended to be a comparative test between an area that appeared to be "wet" and a control area on the same wall that appeared to be dry. The test was a Rebound Hammer test in accordance with ASTM C805 (*Standard Test Method for Rebound Number of Hardened Concrete*). Use of this test standard is consistent with ACI 349.3R.

The testing was performed by PSEG Power's Maplewood Testing Services on March 21, 2007 using a new Digi-Schmidt 2000 Model ND rebound hammer. Testing was performed using ASTM-C805-02 and the rebound hammer manual for guidance. The two areas tested were on the Sump Room wall that faces the west wall of the SFP (i.e., the wall with the telltale drains) at an elevation consistent with the construction joint at the base of the pool. Within the areas to be tested, the paint and smoothing layer of concrete were removed.

Because a limited number of tests were to be performed with a new rebound hammer, calibration against a hardened steel anvil was not required or necessary.

Test Results

Rebound Number

Results from the test are tabulated below. Ten measurements were taken in each of the two areas tested.

Test Location	Test Results	
	Mean	Range
"Dry" Area	45.9	44 – 48
"Wet" Area	47.0	44 – 60

As shown above, the results for the two areas are essentially the same. That is, there is no substantive difference between a "dry" area and a "wet" area. This suggests that the portions of the Sump Room wall that appear to be wet have not undergone degradation relative to the portions of the wall that are dry.

Approximate Compressive Strength

Rebound numbers can provide an estimate of the compressive strength of the concrete. Such conversions are approximate as the results can vary due to the non-homogeneity of concrete and stiffness of concrete. The table below shows the approximate compressive strength of the FHB concrete using the Digi-Schmidt 2000 manual.

Test Location	Compressive Strength (psi)	
	Compressive Strength	Uncertainty
"Dry" Area	6300	±1000
"Wet" Area	6600	±1000

The design analysis of the Fuel Handling Building credits a compressive strength of only 3500 psi. Further, compressive strength testing for concrete specimens prepared using the same mix design and same material sources as the concrete used in the FHB showed that the concrete mixture used at Salem has a compressive strength of about 6,000 psi.

Conclusions

The rebound hammer test results for the "dry" and "wet" areas on the wall were essentially the same. Further, the approximate compressive strengths are consistent with those for laboratory specimens prepared using the same mix design and same material sources. The estimated compressive strengths are well above the value used in the FHB design analyses. These results demonstrate that the "wet" areas of the Sump Room wall have not degraded relative to the "dry" areas and that the design basis analyses remain valid.

Attachment 3

SALEM UNIT 1
FUEL HANDLING BUILDING

REVISED RESPONSES TO NRC QUESTIONS

Question 1

1. Use of Industry Codes and Standards to Assess Condition of FHB:

Background

The S&L Survey used the American Concrete Institute (ACI) Standard ACI 349.3R, "Evaluation of Existing Nuclear Safety-Related Concrete Structures," to assess the condition of the FHB. The S&L survey stated that the SFP structure did not pass the First-Tier limits of Section 5.1 of ACI 349.3R due to observation of apparent leaching. The S&L Survey also stated that the Second-Tier limits of Section 5.2 may be used to assist in rendering a judgment of the structural condition. The S&L Survey further indicated that the Second-Tier limits apply to degraded conditions that are deemed to be inactive, and that the recognition of a state of inactivity requires comparison of present conditions with those in a previous examination. However, the S&L survey stated that such a comparison was not possible in this case because no previous structural examination data were available. The S&L Survey also reported that the conditions observed relative to the appearance of leaching or chemical attack and corrosion staining on the concrete surfaces did not indicate significant structural deterioration.

Since the determination of whether the conditions are active or inactive cannot be made without data comparisons, the S&L Survey recommended that FHB be observed at regular future intervals and the results compared with those of preceding examinations to assess the progression of degradation, if any. Accordingly, the contractor's recommendation was to defer determination until a later date as to whether the conditions met Second Tier limits of Section 5.2 or should be handled in accordance with Section 5.2, "Conditions Requiring Further Evaluation," of ACI 349.3R.

NRC Observations

The NRR staff noted that the Second-Tier limits of Section 5.2 that are used to judge the structural condition require additional data collection that is not reported as accomplished in the S&L survey.

Further, the staff noted that the S&L Survey cited ACI 349.3R-02 as the standard for the examination; however, there was no evidence that the specific procedure cited in the standard was completely applied. As a result, the information presented in the S&L Survey appears incomplete with respect to Section 5.2 of ACI 349.3R, and the recommendation to defer the determination does not appear to have a sound basis.

Required Information

PSEG (PSEG) should reach a conclusion IAW ACI 349.3R, or any other standard that is deemed appropriate, with regards to the condition of the FHB. IF ACI 349.3R is used, PSEG should complete the application of the criteria to determine whether the degradation is active or inactive, and determine whether further actions are warranted.

PSEG Response

An independent assessment of the FHB concrete structure by Sargent & Lundy (S&L) engineers was conducted. The S&L Survey used the American Concrete Institute (ACI) Standard ACI 349.3R, "Evaluation of Existing Nuclear Safety-Related Concrete Structures," to assess the condition of the FHB. The SFP structure did not pass the First-Tier limits of Section 5.1 of ACI 349.3R due to observation of apparent leaching. The Second-Tier limits of Section 5 were used to assist in rendering a judgment of the structural condition.

The S&L survey indicated that the Second-Tier limits apply to degraded conditions that are deemed to be inactive, and that the recognition of a state of inactivity requires comparison of present conditions with those in a previous examination. The S&L survey stated that such a comparison was not possible in this case because no previous structural examination data were available. The S&L Survey reported that the conditions observed relative to the appearance of leaching or chemical attack and corrosion staining on the concrete surfaces did not indicate significant structural deterioration. Further, the S&L Survey stated that there were no indications of structural spalling, bulging, gross distortion or differential settlement in any of the areas exhibiting deposits or stains.

Based on the independent S&L structural survey conducted, PSEG's assessment is that the FHB structure is in good structural condition. PSEG also recognizes the need to perform a structural survey of the FHB on a periodic basis.

Question 2

2. Historical Condition of FHB:

Background

The S&L Survey noted a number of areas of apparent water migration through the wall between the SFP and the sump room; however, these areas were dry at the time of inspection. Further, the S&L Survey also documented that there is a layer of surface patching approximately 5 feet above the sump room floor extending nearly the entire length of the sump troughs, with an approximately ½ inch deviation in vertical surface alignment across the patch.

NRC Observations

None

Required Information

PSEG should provide information that describes the as-built configuration of the FHB wall between the SFP and the sump room, and if that configuration has changed over time. To this end, PSEG is requested to establish, relative to this wall, a timeline indicating the dates that: (1) the leaks/seepages were observed, (2) the ½ inch deviation in vertical alignment was observed, (3) the patch applied, and (4) the paint was applied.

PSEG Response

The configuration of the wall has not changed over time. There have been intermittent leakages/seepages of ground water into this area of the building throughout the life of the plant. The ½ inch deviation in vertical alignment was identified as a pour seam. The "surface patching" referred to in the S&L survey was not a patch, but a cementitious coating, not for structural restoration, but as a leveling compound to provide a smooth, even surface, for epoxy paint. A major building painting project occurred in the summer 2001 timeframe and the FHB was part of this project's scope.

Question 3

3. Confirmation of mathematical Model used in FHB Structural Evaluation

Background

The S&L Survey reported evidence of leaching and stains on the wall between the sump room and the SFP. The NRC staff also noticed this occurrence. PSEG also reported that SFP water had leaked out of the FHB structure into the on-site environment. The leaching and SFP water leakage from the structure could indicate potential wall degradation at or near the construction joints between the SFP walls and base slab.

NRC Observations

The design basis evaluation for the SFP/FHB is reported in MPR-1863, Revision 0, "Salem Generating Station Spent Fuel Pool Building Structural Design Analysis," dated December 1997. This analysis assumes continuity between the walls and the slab such that the walls and the slab move as a unit during a design-basis event (DBE), such as a seismic event. However, this mathematical model may not represent the current condition of the SFP structure if there are discontinuities at or near the construction joint, as could be caused by the leakage of borated water through the joint. ACI 349.3R, Section 3.5 - Evaluation techniques, provides methods for estimating the possibility and extent of concrete degradation.

Required Information

PSEG should evaluate the condition of the concrete at or near the construction joint to confirm that the mathematical model used in its design-basis analysis will remain valid for the life of the plant, or revise the analyses, accordingly.

PSEG Response

The design basis analysis in MPR-1863 as supplemented by the margin reduction based on postulated degradation in MPR-2613 is considered valid for the life of the plant. Hence, no revision to the analyses is necessary. Key points in this conclusion are as follows:

- The FHB structural analysis documented in MPR-1863 (*Salem Generating Station Spent Fuel Pool Building Structural Design Analysis*), Revision 0 uses standard concrete analysis methods defined in ACI-318-63, which inherently assume that the concrete contains cracks. Further, as explicitly stated in MPR-1863 and the calculations contained therein, crack section properties are considered in determining the effective elastic modulus.

- Possible concrete degradation in the construction joint between the walls and the slab is analogous to a crack. Transport of boric acid through the concrete walls preferentially occurs at a construction joints because local voids and mini-discontinuities between the concrete pours create a transport path with decreased resistance. Accordingly, degradation in the joint is localized to the migration path, not uniform across the joint. ACI 349.3R, Section 3.5 provides guidelines for evaluating degradation of nuclear safety-related concrete structures. It covers the following techniques: (1) visual inspection or condition survey; (2) nondestructive testing; (3) destructive testing; and (4) analytical methods.

PSEG's efforts on the assessment of potential degradation have included several of these techniques.

PSEG had an experienced concrete structural engineer performed an independent structural assessment of the FHB. The checklist in ACI 201.1R-92 was used to guide the inspections and observations were compared to limits in ACI 349.3R.

PSEG conducted testing on concrete bores removed from the Salem Auxiliary Building (which has an identical mix design to the FHB and was constructed about the same time) and on concrete materials prepared to match the FHB concrete as closely as possible.

PSEG performed structural analyses to assess the impact of conservative predictions of degradation on the available structural margin. The laboratory testing conducted as part of these efforts is a substitute for non-destructive testing of the FHB or destructive testing of samples removed from the FHB. It is noted that ACI 349.3R, Section 3.5 recognizes that are limitations on the use of non-destructive and destructive testing of nuclear safety related structures due to radiological considerations and outage considerations.

At the February 28/March 1 meeting, PSEG agreed to the NRC's request to perform a Rebound Hammer test on the portion of the west wall accessible in the Sump Room to demonstrate that the concrete is sound. The test results for the "dry" and "wet" areas on the wall were essentially the same. Further, the approximate compressive strengths are consistent with those for laboratory specimens prepared using the same mix design and material sources as used in original construction. The estimated compressive strengths are well above the value used in the FHB design analyses. These results demonstrate that the "wet" areas of the Sump Room wall have not degraded relative to the "dry" areas and that the design basis analyses remain valid.

Question 4

4. Condition of the Reinforcing Bar

Background

The S&L Survey noted staining on the wall between the sump room and the SFP. The NRC noticed the same rust stains during its inspection. The NRC staff also observed rust stains in the telltale drain trough, which appeared to be emanating from the telltale drain lines, along length of the trough. This staining could indicate corrosion of the reinforcing bar.

NRC Observation

The strength of the reinforcing bar is an important parameter in the FHB structural analyses. A significant reduction in the strength of the reinforcing bar could invalidate the structural analyses of the FHB. Corrosion of the reinforcing bar would reduce its cross sectional area and, thus, its tensile force carrying capacity. Reinforcing bar corrosion is expected to be highest at the locations where water flows through the concrete, such as at the construction joint between the SFP walls and base slab. ACI 349.3R, Section 3.5 - Evaluation techniques, provides methods for estimating the possibility and extent of corrosion activity of steel reinforcing bars.

Required Information

PSEG should justify that the reinforcing bar in the FHB has, and will maintain for the life of the plant, the tensile load carrying capacity assumed in the structural analysis, or revise the analysis, accordingly.

PSEG Response

The design basis analysis, as supplemented by the margin reduction based on postulated rebar degradation, is considered valid for the life of the plant. Hence, no revision to the analyses is necessary. Key points in this conclusion are as follows.

- PSEG documented an independent assessment of the FHB by an experienced concrete structural engineer. The assessment was guided by the checklist from ACI 201.1R-92 and the limits in ACI 349.3R. It concluded that the concrete was in "good structural condition" and that the "appearance of leaching or chemical attack and corrosion staining of undefined source on concrete surfaces do not indicate significant structural deterioration at this time." Further, it notes that there were "no indications of concrete surface expansion due to reinforcing steel corrosion." In short, it concluded that based on a standard ACI walkdown approach, there was no reason to question the structural capacity of the building. It recommends periodic inspections to trend the building (see response to NRC Item 1).

- MPR-2613 (*Salem Generating Station Fuel Handling Building Evaluation of Degraded Condition*) discusses potential degradation of rebar from boric acid seepage through the construction joint; the degradation mode of concern for the rebar. It concludes that "reinforcing steel degradation in the FHB is minimal and structural capacity has not been impacted." Key points cited in this discussion include the following:

- The rebar of concern is the outer rebar as the limiting margin cases involve compression on the poolside and tension on the outside. Accordingly, the boric acid has to transit through several feet of concrete before reaching the rebar. The boric acid would react with concrete along the transit path and not be as acidic. The corrosion rate of carbon steel in de-aerated boric acid is 0.004 mm/year in a 2400 ppm solution. However, this rate is conservative with regard to the situation in the FHB because the pH when the boric acid reaches the rebar will increase from the reaction with the concrete.

- A study from Germany published in a reputable journal documented a carefully controlled study of corrosion of embedded rebar from flow of boric acid through a simulated crack. It showed negligible corrosion for the most aggressive conditions after a period of two years.

- Experience at another US PWR showed no visible corrosion of embedded reinforcing steel from boric acid flow through a crack over several years. Rust staining on the sump room walls is very minor and the result of small amounts of iron oxide.

- The NRC's observation of rust stains in the telltale drain trough in the sump room is not necessarily indicative of rebar corrosion, particularly the outer rebar that is the rebar of interest.

For corrosion products from the rebar to reach the sump, the liquid flow in the joint would have to be from the outside back toward to the pool and the iron would have to be transported through concrete walls to the gap between the liner and the concrete. In the case of the outer rebar, the iron would have to be transported through concrete several feet thick to reach the gap. Any iron would likely be deposited inside the concrete.

The most likely source of the iron is construction debris and wastes on top of the slab or behind the liner. Chemical analyses of the liquid from the telltales show chemicals such as zinc that suggest some housekeeping issues during plant construction.

A walkdown of the Sump Room was conducted during the visit to the site on February 28th and March 1st of 2007. There was no rust staining on the wall that was observed by the inspection team. The only apparent rust stains related to fittings from injection repairs at past leak locations.

PSEG has considered the non-destructive testing methods identified in ACI 349.3R, Section 3.5 and concluded that non-destructive testing is both impractical and unlikely to yield meaningful insights. For example, half cell potential tests are impractical because the rebar is not exposed so that an electrode can be attached. Also, methods that verify rebar size and location are not sufficiently accurate to confirm the expected negligible extent of degradation. Finally, due to access limitations, any non-destructive testing to establish whether the outer rebar is corroding is limited to the sump room; potential rebar degradation in the sump room may or may not be representative.

Question 5

5. Boric Acid Effects on Concrete Slab

Background

With regards to the concrete slab below the pool, Report MPR-2613, Rev. 0. "Salem Generating Station Fuel Handling Building Evaluation of Degraded Condition," states "... the boric acid attacks the cement paste, weakening it and causing it to de-bond from the coarse and fine aggregate. As the degradation progresses, a rubble bed of coarse and fine aggregate is formed on the top of the remaining concrete. The debris (cement paste and fine aggregate) is found to be the cause that blocked the telltales drains. The degradation, most likely, initiated prior to 1995 and is ongoing."

NRC Observations

PSEG has assumed that long term exposure to boric acid will cause a uniform layer (bed) of rubble on the top of the slab. The NRC staff considers that, if it occurred, uneven settling or debris bed generation may impact the structural analysis of the spent fuel racks.

Required Information

PSEG should address the potential for uneven degradation of the slab and any resulting impact on the spent fuel rack structural analysis. PSEG should justify that the structural analyses of the spent fuel racks remain valid for the life of the plant, or revise the analyses accordingly.

PSEG Response

The design basis analysis for the fuel racks is considered valid for the life of the plant as the potential differential settlement of the racks is expected to be very minimal and within the leveling tolerance for the racks. Hence, no revision to the analyses is necessary. Key points in this conclusion are as follows:

- The "void" under the liner that could result from postulated concrete degradation is very small. An estimated depth is on the order of 0.07 inch or less. This void depth was based on the following assumptions.
- The depth of concrete degradation is 1.31 inches, which is the anticipated depth of affected paste assuming the concrete, is exposed to boric acid for the entire plant life and 10 years after cessation of operations.

- It is assumed that, within the depth of affected paste, all cement is lost. This is conservative, as only the very topmost portion may have lost a significant portion of the cement paste from the reaction with boric acid.

- The coarse and fine aggregate constitutes 95% by volume of concrete and 80% by mass. Assuming cement paste is 5% of the concrete volume yields a reduction in concrete thickness of only 0.066 inch.

- No credit is taken for the fact that the cement paste fills the voids between aggregate particles. Hence, dissolution of cement into the boric acid solution does not impact the structural skeleton of aggregate particles. Therefore, the actual volume reduction will be less than 5% (i.e., less than 0.066 inches).

Any slab degradation that occurred prior to installation of the new racks in 1994/1995 was addressed as part of leveling the new racks during installation. Therefore, the concern regarding differential settlement relates only to any degradation that occurs subsequent to rack installation (i.e., degradation from rack installation to present and future degradation).

Leakage initiated early in plant life (as early as 1980) and the pool was re-racked in 1994/1995.

Using the square root of time formulation for a diffusion-controlled process, 46% of the degradation expected over a over the life of the plant (including 10 years after cessation of operations) occurs in the first 15 years. Therefore, only about half of the expected degradation occurs over the remainder of plant life. Differential settlement after rack installation could be half of that estimated above.

The Salem re-racking project provided (±) 1/8" of leveling tolerance during the installation of Salem new spent fuel racks. The estimated differential settlement is well within this value.

As discussed in MPR-2613, the most likely source of SFP leakage is considered to be the plug welds between the liner and the embeds. While plug weld leakage could cause localized degradation, degradation of the slab is expected to cover large areas and likely the entire slab. This reduces the potential for localized degradation that could cause differential settling.

Leakage is most likely through a series of small tight cracks in a number of the 1400 plug welds. All plug welds, (those in the walls and those in the floor), are highly stressed from thermal loads.

Leakage from a plug weld collects on the slab and migrates over the slab to a leakage channel with an open telltale. As the telltales became obstructed, the boric acid would have to migrate longer distances over the slab to an open telltale. Hence, the wetted portion of the slab increased as telltales became obstructed.

During the time that the telltales were essentially blocked and leakage accumulated in the gap between the liner and the concrete, virtually all of the slab would have been wetted and subject to degradation.

Even with periodic cleanings, not all telltales are equally open. As such, plug weld leakage will still migrate a significant difference to a leakage channel with an open telltale.