Ziev, Tracey

From: Tsao, John NRR
Sent: Thursday, April 22, 2010 3:08 PM
To: OHara, Timothy
Cc: Lupold, Timothy; Conte, Richard; Gray, Harold; Ennis, Rick; Burritt, Arthur; Schroeder, Daniel; Cline, Leonard
Subject: RE: Scan from Salem/Hope Creek HP5035

Tim,

Thank you for forwarding Salem's AFW flaw evaluation.

This morning, Rick Ennis, forwarded us an email from the licensee that stated that all Salem Unit 1 AFW #12 and #14 buried pipes/headers will be replaced.

OK

Does this mean that the flaw evaluation for headers #12 and # 14 becomes moot? I am just wondering...

John

-----Original Message-----
From: OHara, Timothy R1
Sent: Thursday, April 22, 2010 3:00 PM
To: Tsao, John
Cc: Lupold, Timothy; Conte, Richard; Gray, Harold; Ennis, Rick; Burritt, Arthur; Schroeder, Daniel; Cline, Leonard
Subject: FW: Scan from Salem/Hope Creek HP5035

Hello John,

PSEG has provided us with a preliminary letter (attached) from SAI describing the results of the finite element analysis performed on the old Salem Unit 1 AFW buried headers #12 and #14. I'm also attaching a copy of the information which PSEG gave SAI as input to the analysis.

We don't expect to receive the final copy of the analysis until tomorrow PM so I wanted to, at least, provide this information today.

The first attachment (the letter) describes how they feel they've met the Code requirements. I'm hoping this will give you some advanced information before we get the actual FEA. Let me now if you have any questions.

Tim OHara

-----Original Message-----
From: R1Scan [mailto:R1Scan@nrc.gov]
Sent: Thursday, April 22, 2010 2:25 PM
To: OHara, Timothy
Subject: Scan from Salem/Hope Creek HP5035

Please open the attached document. This document was digitally sent to you using an HP Digital Sending device.

C/186

Unit 1 AFW Past operability evaluation

**************Long Text Object Identification**************
Order 000070108698 Operation 0110
****

70108698 0110 Unit 1 AFW Past Operability Evaluation - Engineering

Title: Salem U1 Past Operability Buried AFW Pipe - Past Operability Determination

Reason for Evaluation / Scope:

As part of planned buried pipe inspections during the Salem Unit 1 refueling outage S1R20, guided wave inspection of the buried 4 inch Auxiliary Feedwater (AFW) piping that supplies the #12 and #14 steam generators identified localized wall thinning in several regions where more detailed examination was necessary. These piping regions were excavated and revealed significant external corrosion on the AFW buried piping. Straight beam ultrasonic measurements were then taken to determine the pipe wall thickness profile. The corrosion exceeded the design minimum wall criteria. This finally lead to excavating all the AFW buried pipe, which exposed general exterior corrosion and wall thinning affecting all of the buried AFW piping.

This evaluation reviews the impact in terms of past operability of the discovery of the non-conforming Salem Unit 1 AFW buried piping that was below design minimum wall thickness.

Background Information

The buried AFW pipes that connect to the #12 and #14 main feedwater lines in the outer penetration area (OPA) travel approximately 30 feet underground along the edge of the containment building before entering the OPA at elevations 94' 8" (#12) and 96' 2" (#14).

The piping is 4-inch NPS, Schedule 80, A106 Gr B seamless carbon steel. It is classified as Nuclear 3, Seismic Category I. Per the Pipe Specification S-C-MPOO-MGS-0001, SPS 54E, the system design Pressure-Temperature limit is 1950 psi at 140 F. The nominal wall thickness is 0.337 inches ± 12.5%.

Guided Wave inspections of the Salem Unit 1 AFW buried piping revealed regions of degraded pipe wall thinning. Follow-up excavations unearthed more piping showing heavy external uniform corrosion. The apparent cause of the corrosion was the improper application (or lack) of the specified pipe coatings, X-Tru-Coat, an adhered polyethylene protection system, and Bitumastic, which was specified per drawings and pipe specifications to be applied at the welded joints. Careful visual inspections of the excavated piping revealed a lack of coating. The only remnant of coating found was a portion of coal tar which was approximately 9 inches in length and 7 inches in circumference. This piece of coating was in the shape of the 4 inch AFW piping and conformed to that same profile.

Using the Guided Wave inspection results to target three specific areas (limiting measurements 12AF, 0.152 inch; 14AF, 0.160 inch; and 14AK, 0.166 inch wall) of buried AFW piping for excavation and examination, NDE Services initially performed confirmatory UT measurements on 378 grid areas. Approximately 76 percent of these UT measurements were non-conforming, having a minimum wall thickness less than the design minimum wall thickness of 0.278 inches. Based on these initial findings, the entire accessible portions of AFW buried pipe in Salem Unit 1 were excavated. A second set of UT measurements was then taken on a 1-inch by 1-inch grid for the full circumference of the pipe along the entire length of exposed AFW buried pipe (limiting measurement AF13T, 0.141 inch wall). The following numbers of UT readings were taken:

#14 AFW Line (Upper Pipe): 8,904 readings total. 1,194 are below 0.278"

#12 AFW Line (Lower Pipe): 8,852 readings total. 192 readings are below 0.278"

Finally a third sample set of UT measurements was taken of the bottoms of AFW buried pipe that rest on the construction aid supports (hangers), from which the overall worst case derived (14AF4T/14AF5T, 0.077 inch wall).

In summary, the worst case UT measurements, those having the least minimum wall thickness, were as follows:

For the #12 AFW buried piping, a 55 percent loss (0.152 inches).
For the #14 AFW buried piping, an approximately 78 percent loss (0.077 inches).

Removal of sections of the buried AFW piping in Salem Unit 1 during the S1R20 outage and subsequent visual examinations have validated that the identified corrosion is external.

Further examinations have also revealed evidence of the X-Tru-Coat on the through-wall portions of the buried AFW piping where it passes into the fuel transfer tube area (FTTA).

The coating system was not found on the remaining buried portions of these lines, which validates that the observed heavy general corrosion is due to a lack of coating.

The ground fill of the AFW piping is not a harsh environment (harsh with regard to coating), and there does not appear to be a correlation between the missing or deteriorated coating and the buried pipe environment.

Past Operability Evaluation

As part of the planned inspections of buried pipe, the Buried Pipe Program requested that the #12 and #14 Auxiliary Feedwater (AFW) buried piping be inspected during the Salem Unit 1 refueling outage 1R20. The buried AFW piping runs underground from the Mechanical Penetration to the Outer Penetration Area, passing alongside the west end of the Containment from north to south. [Dwg. 207483] The buried portions of AFW pipe are downstream of the AFW SG Level Control valves 12AF21 through 14AF21 for the motor-driven AFW pumps (MDAFPs) and the AFW SG Level Control valves 12AF11 through 14AF11 for the turbine-driven AFW pump (TDAFP) and are upstream of the 12AF23 through 14AF23 AFW SG Inlet Stop Check valves. [Drawing. 205236]

The minimum wall thickness (t_{min}) for the buried AFW pipe is governed by the ANSI B31.1, 1967 Edition, Power Piping code, Equation 104.1:

t_{min} = PD / 2(SE+PY)

= 1950*4.5 / 2(15000+1950*0.4) = 0.278 inches

Where pipe outside diameter (D) = 4.5 inches, design Pressure (P) = 1950 psi, and SE is the material allowable of 15000 psi for seamless pipe, and Y = 0.4 per the ANSI B31.1.

Because the buried AFW pipe is continuously supported, the deadweight and seismic loads are considered minimal. Therefore, the minimum wall thickness determined by using the design pressure is too restrictive with respect to determining operability. Instead, the Maximum Credible Operating Pressure (MCOP) was developed based on all AFW system operating conditions, and was used to evaluate t_{min} for the buried AFW pipe. Technical Evaluation 70108698-0100 determined that all AFW conditions that the MCOP for the buried Auxiliary Feedwater piping is conservatively bounded by 1275 psi. The corresponding minimum wall thickness based on a MCOP pressure of 1275 psi is 0.185 inches.

1275*4.5 / 2(15000 + 1275*0.4) = 0.185 inches using MCOP

The 0.185 inch minimum wall thickness was originally increased 12 mils to provide an allowance for an additional cycle of operation based on an assumed maximum corrosion rate of 8 mils per year. [Ref. NUCR 70103767] The intent was to replace any section of buried pipe that had a minimum wall less than 0.198 inches. In addition, all of the AFW buried piping, remnant and replacement, was to be re-coated before being buried again. However, as more UT measurements came in, it became clear that all of the buried AFW pipe should be replaced. DCP 80101382 was written to replace the inaccessible sections of AFW buried piping near and below the Fuel Transfer Tube and ECP 80101381 was written to replace the accessible portions of the AFW buried piping. Thus, all the AFW buried piping was replaced.

Additional UT measurements were taken from the bottom of the AFW buried pipe where it rested on carbon steel construction aides (hangers). These areas were added due to the inability of the Guided Wave technology to distinguish the boundary between the pipe and hanger metal and were thus suspect. During the inspection and UT measurements of these areas, the greatest pipe wall loss was discovered on the #14 AFW discharge line. A localized area having a minimum wall thickness measurement of 77 mils, the flaw was 0.25 inches in diameter and 0.75 inches in length before the surrounding pipe material increased to greater than 150 mils.

Upon discovery of these limited extreme localized areas of loss, Engineering requested Structural Integrity Associates, Inc. (SIA) to perform a rigorous Finite Element Analysis (FEA) of the AFW buried pipe using the most limiting cases (12AF, 14AF, 14AK, AF13T, and AF4T.AF5T) from the complete set of UT measurements. The SIA report, "ASME Code, Section III Design Analysis Evaluation of 4-inch Auxiliary Feedwater Piping," details the results of the FEA. The technical approach used was to assume that although piping may have localized thinned regions that violate the design t_{min} requirements, the non-uniform wall thickness of the pipe cross-section may still be shown to meet the design stress allowable. The approach is similar to the basis for qualifying pipe penetrations using branch reinforcement rules in the ASME Code and is possible for pipe sections exhibiting thinning when a remaining wall greater than t_{min} surrounds the thinning region. Note that the FEA did not use the Piping Specification SPS 54E design pressure for the piping but instead used the MCOP from Technical Evaluation 70108698-0100. An additional 35 psi was conservatively added to the MCOP at Design Engineering's request to provide operating margin.

The buried AFW pipe at Salem Unit 1 was designed to the t_{min} requirement given in the B31.1 Power Piping Code that does not provide specific criteria for evaluation of non-uniform wall thickness or thinning. However, guidance for stress analysis may be derived from the ASME Code, Section III, which can be used to supplement the B31.1 requirements.

Design requirements for Class 3 piping are provided in ND-3600 of the ASME Code, Section III, Division 1, 2004 Ed. Alternate methods are allowed under Section ND-3611.3, which permits use of a more rigorous piping design analysis such as NB-3200 to calculate stresses required to satisfy ND-3600 requirements. The calculated stresses must be compared to the allowable stresses in ND-3600. Thus to show acceptance of the degraded piping having a non-uniform pipe wall, the design loadings are determined using the design analysis methods in NB-3200. A finite element model is implemented incorporating the irregular pipe section profile defined by the UT thickness measurements. Current ASME Code allowable stresses are based on a factor of 3.5 on tensile strength instead of the factor of 4 as used in Salem's B31.1 Code of Construction.

<u>Summary of Structural Integrity Associates (SIA) Finite Element Analysis Report</u>

Per the ASME Code:

> *"The specific design requirements of ND-3600 are based on a simplified engineering approach. A more rigorous analysis such as described in NB-3600 or NB-3200 may be used to calculate the stresses required to satisfy these requirements. These calculated stresses must be compared to the allowable stresses in this Subsection. In such cases, the designer shall include the appropriate justification for the approach taken in the Certified Design Report."*

Thus, NB-3200 design by analysis is employed. Based on the linear-elastic finite element analysis results which showed that the thinned section of pipe (0.077 inch) was bounding, it was required to perform additional analysis only for that section of pipe in order to show operability. The more rigorous analysis employed is described in Section NB3228.1, Limit Analysis. Specifically Section NB-3228.1 states that limits on Local Membrane Stress

Intensity need not be satisfied at a specific location if it can be shown by limit analysis that the specified loadings do not exceed two-thirds of the lower bound collapse load. Also, NB-3228.1 states that the yield strength to be used in this calculation is 1.5 S_m. In this evaluation, the value of yield strength is equal to 1.5 S, where S is taken as the value of S_h, 15.0 ksi, from the original 1967 B31.1 Power Piping Code. Thus, a yield strength of 22.5 ksi is used.

The thinned section of pipe is modeled using the as-found wall thickness values for the region specified in S-TODI-2010-0005 which includes a minimum wall thickness of 0.077 inches. A pressure load of 1.5 times the PSEG specified operating pressure is applied (1943 psi = 1.5*[1310psia-14.7psi]) to the pipe per the more rigorous methodology to ensure that the operating pressure remains less than two-thirds of the failure pressure (1943 * 0.667 = 1295 psi).

The results of the finite element analysis show that the thinned pipe in this section remains structurally stable at 1.5 times the PSEG specified operating pressure and therefore passes the limit load analysis.

<u>MPR's independent Review of SIA's Finite Element Analysis Report</u>

MPR Associates was contracted to perform an independent, third party review of SIA's Finite Element Analysis that was performed to address external wall thinning of buried Auxiliary Feedwater (AF) piping at Salem Unit 1. The SIA calculation concludes that the degraded piping was operable prior to replacement during the current refueling outage. MPR's review focused on the approach, bases for assumptions and design inputs, and conclusions of the SIA calculation. MPR found the approach and conclusions of the subject calculation to be reasonable, and concur with the calculation conclusion that the degraded AF piping was operable prior to its recent replacement.

Extent of Condition

Because the Salem Unit 1 AFW discharge piping to the #11 and #13 steam generators runs from Containment to the Mechanical Penetration to the Pipe Alley to the Auxiliary Building, it is neither buried nor subject to the same corrosive environment as the AFW discharge lines to the #12 and #14 Steam Generators. The Buried Pipe Program inspection examined the Control Air (CA) and Station Air (SA) piping buried with the AFW pipe. A small pinhole leak was found in the CA pipe and was repaired to original condition. The overall condition of the CA and SA pipe was found with the protective coating intact and not degraded in the fashion as seen by the AFW pipe.

In operating Modes 5, 6, and Defueled, AFWS has no required safety function. The decay heat removal safety function is provided by the Residual Heat Removal (RHR) system. The AFWS does provide a means for refilling the secondary side of the SGs after eddy current testing and removal of the SG nozzle dams is complete. The secondary side water provides an additional heat sink in case of a loss of RHR cooling. In Mode 4 when RCS temperature is greater than 212°F but less than 350°F, the SGs can provide for decay heat removal if shutdown cooling is lost. Finally, in Modes 1 through 3, Technical Specification 3/4.7 Plant Systems, LCO 3.7.1.2, Auxiliary Feedwater System, requires at least three independent Auxiliary Feedwater pumps and their flow paths be operable to ensure that the RCS can be cooled down to a hot leg temperature less than 350°F in the event of a loss of offsite power (LOOP). This permits entry into the shutdown cooling mode of operation for the RHR system if RCS pressure is less than 340 psig.

Conclusions / Findings:

Despite being found in a degraded condition, the AFWS has always performed its safety and design functions in the past. No evidence has been found of a through wall flaw in the piping surveyed. The piping has maintained structural integrity during normal operation. The limiting design basis accident, the steam line break (SLB) inside containment event from which the MCOP pressure is derived, has yet to occur. The results of the SIA FEA support the conclusion that the generalized corrosion observed has not yet degraded the pipe wall below a minimum thickness that would make it inoperable or subject to failure. The system is degraded but operable. Per the SIA analysis, the existing AFWS #12 and #14 buried pipe is capable of operating for one more cycle if re-coated properly to ensure a minimal, near zero corrosion rate. MPR's independent Review of SIA's Finite Element Analysis Report on past-operability found the approach and conclusions of the subject calculation to be reasonable,