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APR 1 6 2004

LR-N04-0175

PSEG
Nuclear LLC

U.S. Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, DC 20555-0001

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION
REGARDING RELAXATION REQUEST S1-RR-I3-B21,
FIRST REVISED NRC ORDER (EA-03-009) ON REACTOR PRESSURE VESSEL
HEAD INSPECTIONS
SALEM GENERATING STATION UNIT NO. 1
FACILITY OPERATING LICENSE NO. DPR-70
DOCKET NO. 50-272

Reference: Letter LRN-03-0329, Relaxation Request to NRC Order (EA-03-009) Interim Inspection Requirements for Reactor Pressure Vessel Heads at Pressurized Water Reactors (Relief Request S1-RR-I3-B21), dated September 24, 2003.

On February 11, 2003, the U. S. Nuclear Regulatory Commission (NRC) issued Order EA-03-009 for interim inspection requirements for reactor pressure vessel (RPV) heads at pressurized water reactor facilities. The Order required inspection of the RPV head and associated penetration nozzles. On September 24, 2003, pursuant to the procedure specified in Section IV.F of the Order, PSEG Nuclear LLC (PSEG), requested relaxation from the requirements of the Order regarding nondestructive examination of the penetration nozzles below the J-groove weld that attaches the nozzle to the head. On February 20, 2004, the NRC issued the First Revised NRC Order (EA-03-009). The revised Order modified the requirements regarding nondestructive examination of the penetration nozzles below the J-groove weld. Relaxation Request S1-RR-I3-B21 also applies to the revised Order. Additional information was requested by the NRC and submitted by PSEG letters dated March 2, 2004, (LR-N04-0040) and March 31, 2004, (LR-N04-0156).

This letter forwards Proprietary Information in accordance with 10CFR 2.390. The balance of this letter may be considered non-proprietary upon removal of Attachment 2.

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The NRC staff has reviewed the information provided by PSEG that supports the proposed relaxation request and requires additional information to clarify the submittals. This request was discussed with the NRC staff on April 8th, 12th and 14th, 2004. Attachment 1 contains PSEG's response to the request for additional information. Attachment 2 contains Westinghouse Proprietary Response to NRC RAI Question No. 2, 3, 6, and 7 Supporting Head Penetration Inspection Relaxation Request. Attachment 3 contains Westinghouse Affidavit to withhold proprietary information in accordance with 10CFR 2.390. Attachment 4 contains Westinghouse Non-Proprietary Response to NRC RAI Question No. 2, 3, 6, and 7 Supporting Head Penetration Inspection Relaxation Request.

If you have any questions or require additional information, please contact Mr. Michael Mosier at (856) 339-5434.

I declare under penalty of perjury that the foregoing is true and correct.

Executed on March 14, 2004

Sincerely,
John Carlin

Vice President – Nuclear Assessments

This letter forwards Proprietary Information in accordance with 10CFR 2.390. The balance of this letter may be considered non-proprietary upon removal of Attachment 2.

C: Mr. H. J. Miller, Administrator - Region I
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This letter forwards Proprietary Information in accordance with 10CFR 2.390. The balance of this letter may be considered non-proprietary upon removal of Attachment 2.

Attachment 1

Response to NRC Request For Additional Information
Relaxation Request S1-RR-I3-B21
First Revised NRC Order EA-03-009

**SALEM GENERATING STATION
UNIT NO. 1
FACILITY OPERATING LICENSE NO. DPR-70
DOCKET NO. 50-272
REQUEST FOR ADDITIONAL INFORMATION
RELAXATION REQUEST S1-RR-I3-B21
FIRST REVISED NRC ORDER EA-03-009**

The NRC staff has reviewed the information provided by PSEG that supports the proposed relaxation request and requires additional information to clarify the submittals. This request for additional information was discussed with the NRC staff on April 8th, 12th and 14th, 2004. The following information is PSEG's response to the request for additional information.

NRC Question 1:

The requirements of the First Revised Order in part are to examine the subject nozzles to a minimum of 1 inch below the toe of the J-groove weld encompassing all nozzle areas having stresses greater than or equal to 20 ksi. This can be accomplished using surface and/or volumetric examinations per Section IV.C.(5)(b) of the Order. Explain the basis for not supplementing the volumetric examinations with surface examinations to meet the requirements of the Order.

PSEG Response to Question 1:

All penetrations have been inspected using a volumetric ultrasonic (UT) examination including a UT leak path assessment. The UT examination covered the area from two inches above the J-groove weld down to thread relief on the outside diameter (OD) of the penetration (which is 0.75 inches from the bottom of the penetration).

Although only a relatively insignificant exam volume (i.e., 0.081 inches) was not covered by UT, subsequent analysis was performed. The analysis conservatively assumed the existence of a flaw within these regions and demonstrated that these flaws would not reach the toe of the weld in less than one operating cycle, thereby ensuring the structural integrity of the reactor pressure vessel head.

In addition, the inside surface of the CRDM nozzle was inspected with a supplemental Eddy Current Testing (ECT) surface examination. The ECT examination covered the area from two inches above the J-groove weld down to the top of the chamfer on the inside diameter (ID) of the tube (which is 0.233 inches from the bottom of the tube).

NRC Question 2:

What was the initial flaw length used in the through-wall calculations/graphs for the various angle nozzles (Figures 6-12 - Figure 6-16)?

PSEG Response to Question 2:

Summary of Initial Though-Wall Flaw Lengths in Figures 6-12 through 6-16 of WCAP-16214-P

Nozzle Angle (°)	WCAP-16214-P	Initial Flaw Length (in.)
0	Figure 6-12	0.29
26.2	Figure 6-13	0.40
44.3	Figure 6-14	0.29
45.4	Figure 6-15	0.26
48.7	Figure 6-16	0.20

NRC Question 3:

Table 4-1 Identifies various yield strengths for various nozzle material heats used at Salem Unit 1. Provide the yield strengths of the nozzles that cannot be inspected to the requirements of the Order. In addition, provide the yield strengths used in the nozzle stress calculations and note differences and provide the basis.

PSEG Response to Question 3:

See Attachment 2, Response to NRC RAI No. 2, 3, 6, and 7 Supporting Head Penetration Inspection Relaxation Request.

NRC Question 4:

As per our phone conversation on April 8, 2004, provide a table (similar to Table 3-1 in RAI response dated March 2, 2004) listing the distance below the toe of the weld that was actually volumetrically examined. Provide a minimum and a maximum. Include examination distance on the uphill and downhill side of each nozzle using UT and ECT (separate columns) examinations for nozzle numbers 74-79 and any other nozzles that did not obtain at least 1.0" below the lowest point at the toe of the J-groove weld (on a horizontal plane perpendicular to the nozzle axis).

PSEG Response to Question 4:

Table 1 provides all information requested. In addition, this response provides evaluation of relevant indications.

Craze Cracking Evaluation

Axial Craze Cracks

The craze cracks found in various penetration nozzles are grouped to obtain the following four bounding cases. Crack growth curves for these bounding cases are generated and shown in Figures 1 and 2. The results of the crack growth calculation in Figures 1 and 2 show that the remaining service life of these craze cracks before repair is necessary is more than one fuel cycle. This is a very conservative evaluation and in general there are no detectable depths for these craze cracks and no crack propagation due to Primary Water Stress Corrosion Cracking (PWSCC) is expected. Therefore, it can be concluded that all the craze cracks found in various penetration nozzles are acceptable.

Penetration No.	Nozzle Angle (°)	Circumferential Location	Elevation (from end of tube)	Depth (in)	Length (in)
16	18.2	Downhill (270°- 90°)	At weld 2.28" – 3.36"	< 0.040	1.08
21	18.2	Downhill (297° - 61°)	At weld 4.28" – 5.32"	< 0.040	1.04
Bounding Case 1	**26.2**	**Downhill**		**< 0.040**	**1.08**

Penetration No.	Nozzle Angle (°)	Circumferential Location	Elevation (from end of tube)	Depth (in)	Length (in)
2	8	Uphill (152° - 252°)	At Weld 1.56" – 2.68"	< 0.040	1.12
16	18.2	Uphill (132° - 220°)	At weld 2.28" – 3.36"	< 0.040	1.84
19	18.2	Uphill (145° - 205°)	At weld 2.88" – 3.48"	< 0.047	0.60
29	24.8	Uphill (138° - 231°)	At weld 2.88" – 4.0"	< 0.040	1.12
30	26.2	Uphill (153° - 219°)	At weld 2.28" – 3.2"	< 0.040	0.92
31	26.2	Uphill (132° - 220°)	At weld 2.28" – 3.36"	< 0.040	1.08
34	26.2	Uphill (174° -	At weld 2.72" –	< 0.040	0.88

		230°)	3.60"		
37	26.2	Uphill (120° - 241°)	At weld 2.08" – 3.44"	< 0.040	1.36
Bounding Case 2	**26.2**	**Uphill**		**< 0.047**	**2.16**

Penetration No.	Nozzle Angle (°)	Circumferential Location	Elevation (from end of tube)	Depth (in)	Length (in)
48	33.9	Downhill (330° 16°)	At weld 0.76" – 1.52	< 0.040	0.76
70	44.3	Downhill (298° - 54°)	At weld 4.12" – 5.12"	< 0.040	1.00
73	44.3	Downhill (286° - 72°)	At weld 3.32" – 5.92"	< 0.040	3.92
Bounding Case 3	**44.3**	**Downhill**		**< 0.040**	**3.92**

Penetration No.	Nozzle Angle (°)	Circumferential Location	Elevation (from end of weld)	Depth (in)	Length (in)
39	30.2	Uphill (234° - 120°)	At weld 3.4" – 5.8"	< 0.040	2.40
48	33.9	Uphill (102° - 246°)	At weld 2.28" – 4.24"	< 0.040	1.96
63	38.6	Uphill (136° - 238°)	At weld 2.4" – 4.64"	< 0.040	2.24
69	38.6	Uphill (123° - 228°)	At weld 2.02" – 4.86"	< 0.040	2.84
70	44.3	Uphill (138° - 222°)	At weld 3.92" – 5.6"	< 0.040	1.68
Bounding Case 4	**44.3**	**Uphill**		**< 0.040**	**2.84**

Figure 1

Bounding Crack Growth Curves for Inside Surface Axial Craze Cracks (Downhill Side of the Penetration Near the Attachment Weld)

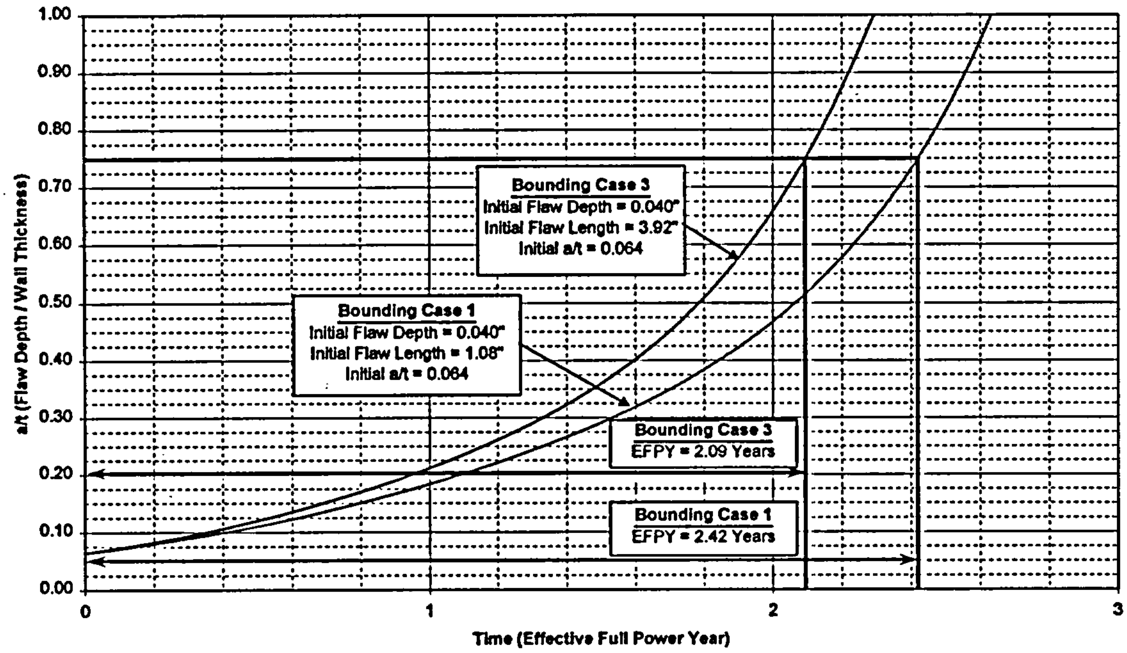
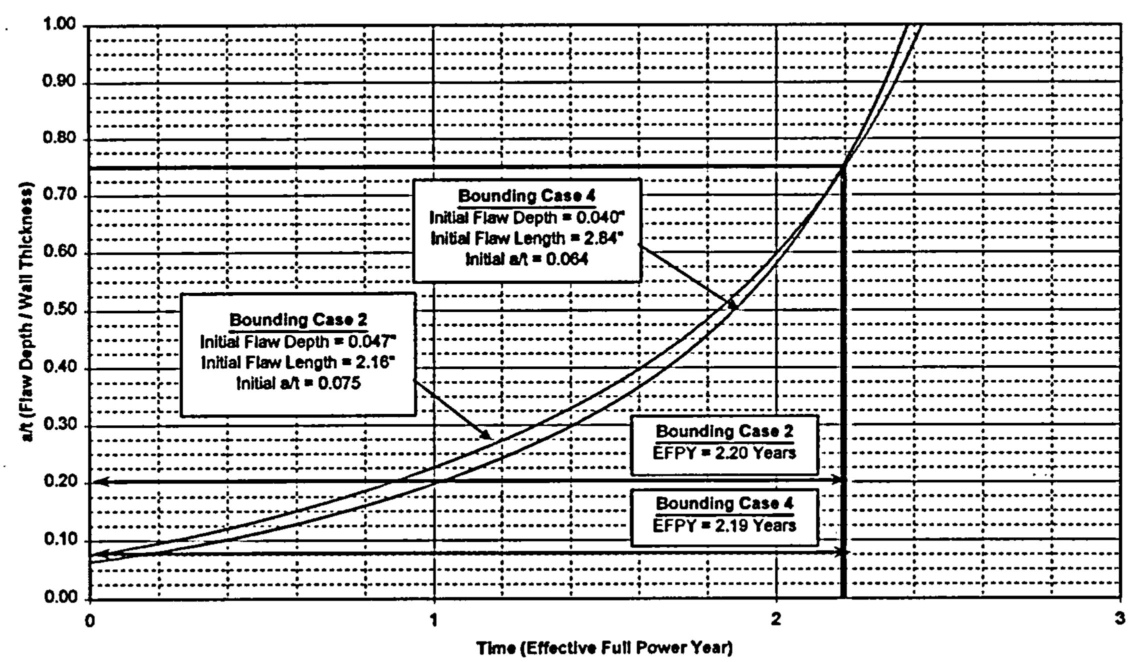


Figure 2

Bounding Crack Growth Curves for Inside Surface Axial Craze Cracks (Uphill Side of the Penetration Near the Attachment Weld)



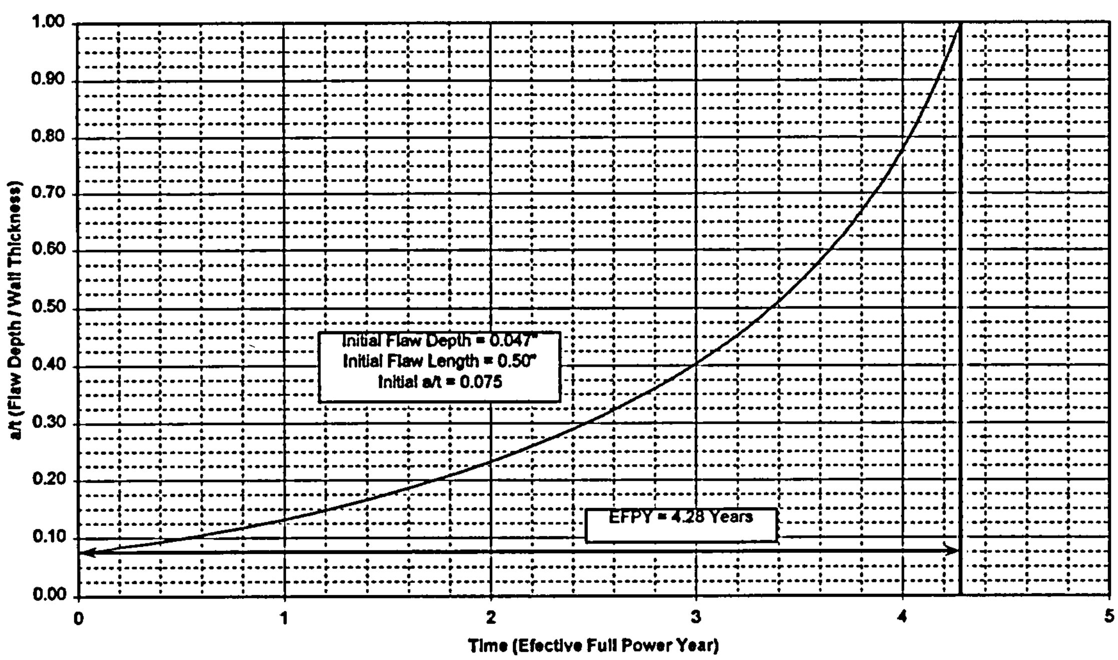
Circumferential Crack

There is a single indication on Penetration No. 19 that has been assigned a depth of 0.047" with UT. This indication is circumferentially oriented and is ½" long. There is only one circumferential indication. The indication is on the inside surface of the penetration on the uphill side. The circumferential extent is 161° - 181°. It is located 0.16" below the weld.

The crack growth curve for the as-found circumferential crack is shown in Figure 4. Based on Figure 3, it takes more than one fuel cycle (~1.5 EFPY) for the inside surface circumferential flaw to become a through-wall flaw. Based on the information specified on page 6-7 of WCAP-16214-P, circumferential flaws below the weld are acceptable for the period of service until the next inspection, regardless of depth, provided the length is less than 75% of the penetration nozzle circumference. The concern for this condition is loose parts due to a failure. Since it takes more than one fuel cycle for the inside surface circumferential flaw to become a through-wall flaw, there is no concern for loose part generation before the next inspection and the as-found circumferential flaw is acceptable.

Figure 3

Crack Growth Curve for Inside Surface Circumferential Crack
(Uphill Side of Penetration No. 19 Below the Attachment Weld)

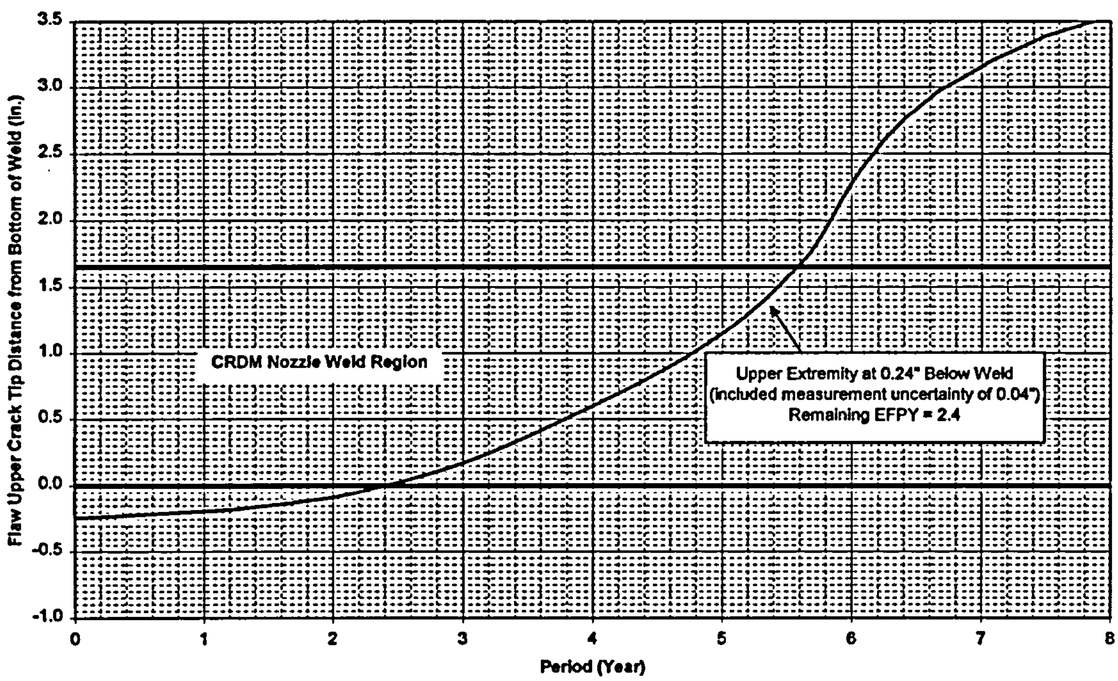


Evaluation of Inspection Coverage Achievable for Penetration No.78

The inspection coverage that is achievable below the weld on the downhill side of Penetration No. 78 is 0.28 inch. By conservatively taking into account an instrumentation uncertainty of 0.04 inch in the measurement, the upper extremity of an axial through-wall flaw is postulated to be located at 0.24 inch below the weld. The resulting crack growth curve shown in Figure 4 indicates that the period of time required for an undetected flaw, located at a distance more than 0.24 inch below the weld, to reach the bottom of the weld is 2.4 EFPY, which is more than one fuel cycle (~ 1.5 EFPY).

Figure 4

Axial Through-Wall Crack Growth Below the Weld (Penetration No. 78)



The inspection coverage achieved for penetration no. 78 is adequate to ensure that any undetected flaw would not reach the weld bottom in less than one fuel cycle. This is shown in the above analysis, which conservatively assumes the presence of a flaw within the inspected volume.

Evaluation of Inspection Coverage Achievable for Penetration No.75

Initially, the inspection coverage below the weld on penetration number 75 was reported as 0.16 inches. This was a preliminary number that was not reviewed and confirmed by our Level III NDE analyst. Penetration number 75 was rescanned because of data drop out below the J-groove weld over a wide circumferential band on the original scan. The original scan was performed with the 7010 Open Housing Scannner (OHS); while the re-scan was performed with a Trinity probe. The shoe on the trinity probe is smaller than the shoe on the 7010 scanner and provides better contact in areas where the 7010 probe may lose contact. Based on complete data below the J-groove weld on this penetration, an inspection extent of 0.74 inches below the toe of the J-groove weld has been measured and confirmed.

NRC Question 5:

What is the accuracy of the distance value measured below the toe of the J-groove weld.

PSEG Response to Question 5:

The UT probes used for the CRDM penetration inspection acquire data while moving in the axial direction. Data is sampled every 0.04" during the scan. The accuracy of our measurement from the toe of the weld to the point where we lose data is a function of the sample rate. Therefore, our measurement accuracy is ± 0.04".

NRC Question 6:

Summarize the conservatisms that are inherent in the WCAP-16214-P, Revision 0, "Structural Integrity Evaluation of Reactor Vessel Upper Head Penetrations to Support Continued Operation: Salem Units 1 and 2" as they relate to the Unit 1 evaluation.

PSEG Response to Question 6:

See Attachment 2, Response to NRC RAI No. 2, 3, 6, and 7 Supporting Head Penetration Inspection Relaxation Request.

NRC Question 7:

The staff understands that the hoop stress distribution curves provided in Appendix A of WCAP-16214-P, Revision 0 are based on the designed weld conditions. Since the field weld conditions are known now, provide discussions to show that these curves are still bounding, particularly for those nozzles that the inspections performed did not meet the order requirements.

PSEG Response to Question 7:

See Attachment 2, Response to NRC RAI No. 2, 3, 6, and 7 Supporting Head Penetration Inspection Relaxation Request.

References

1. Ball, M. G., et al., "RV Closure Head Penetration Alloy 600 PWSCC," WCAP-13525, Revision 1, Westinghouse Electric Corporation, 1992.
2. Properties and Selection: Stainless Steels, Tool Materials, and Special-Purpose Metals, ASM Materials Handbook Volume 3, Ninth Edition, p. 218, 1980.
3. Effect of Strain Rate on SCC in High Temperature Primary Water, Comparison between Alloys 690 and 600, ANS 11th Environmental Degradation Meeting, August 2003, K. M. Boursier et al (EDF).
4. WCAP-16214-P Revision 0, "Structural Integrity Evaluation of Reactor Vessel Upper Head Penetrations to Support Continued Operation: Salem Units 1 and 2" February 2004.
5. "Materials Reliability Program (MRP) Crack Growth Rates for Evaluating Primary Water Stress Corrosion Cracking (PWSCC) of Thick-wall Alloy 600 Material", EPRI MRP Report MRP-55, Revision 1, November 2002.
6. USNRC Letter, R. Barrett to A. Marion, "Flaw Evaluation Guidelines," April 11, 2003.

Attachment 3

Affidavit to withhold proprietary information in accordance with 10CFR 2.390

CAW-04-1814

AFFIDAVIT

COMMONWEALTH OF PENNSYLVANIA:

ss

COUNTY OF ALLEGHENY:

Before me, the undersigned authority, personally appeared J. A. Gresham, who, being by me duly sworn according to law, deposes and says that he is authorized to execute this Affidavit on behalf of Westinghouse Electric Company LLC (Westinghouse), and that the averments of fact set forth in this Affidavit are true and correct to the best of his knowledge, information, and belief:

J. A. Gresham, Manager
Regulatory Compliance and Plant Licensing

Sworn to and subscribed
before me this 15th day
of April, 2004

Notary Public

Notarial Seal
Margaret L. Gonano, Notary Public
Monroeville Boro, Allegheny County
My Commission Expires Jan. 3, 2006
Member, Pennsylvania Association Of Notaries

(1) I am Manager, Regulatory Compliance and Plant Licensing, in Nuclear Services, Westinghouse Electric Company LLC (Westinghouse), and as such, I have been specifically delegated the function of reviewing the proprietary information sought to be withheld from public disclosure in connection with nuclear power plant licensing and rule making proceedings, and am authorized to apply for its withholding on behalf of Westinghouse.

(2) I am making this Affidavit in conformance with the provisions of 10 CFR Section 2.390 of the Commission's regulations and in conjunction with the Westinghouse "Application for Withholding" accompanying this Affidavit.

(3) I have personal knowledge of the criteria and procedures utilized by Westinghouse in designating information as a trade secret, privileged or as confidential commercial or financial information.

(4) Pursuant to the provisions of paragraph (b)(4) of Section 2.390 of the Commission's regulations, the following is furnished for consideration by the Commission in determining whether the information sought to be withheld from public disclosure should be withheld.

(i) The information sought to be withheld from public disclosure is owned and has been held in confidence by Westinghouse.

(ii) The information is of a type customarily held in confidence by Westinghouse and not customarily disclosed to the public. Westinghouse has a rational basis for determining the types of information customarily held in confidence by it and, in that connection, utilizes a system to determine when and whether to hold certain types of information in confidence. The application of that system and the substance of that system constitute Westinghouse policy and provides the rational basis required.

Under that system, information is held in confidence if it falls in one or more of several types, the release of which might result in the loss of an existing or potential competitive advantage, as follows:

(a) The information reveals the distinguishing aspects of a process (or component, structure, tool, method, etc.) where prevention of its use by any of

Westinghouse's competitors without license from Westinghouse constitutes a competitive economic advantage over other companies.

(b) It consists of supporting data, including test data, relative to a process (or component, structure, tool, method, etc.), the application of which data secures a competitive economic advantage, e.g., by optimization or improved marketability.

(c) Its use by a competitor would reduce his expenditure of resources or improve his competitive position in the design, manufacture, shipment, installation, assurance of quality, or licensing a similar product.

(d) It reveals cost or price information, production capacities, budget levels, or commercial strategies of Westinghouse, its customers or suppliers.

(e) It reveals aspects of past, present, or future Westinghouse or customer funded development plans and programs of potential commercial value to Westinghouse.

(f) It contains patentable ideas, for which patent protection may be desirable.

There are sound policy reasons behind the Westinghouse system which include the following:

(a) The use of such information by Westinghouse gives Westinghouse a competitive advantage over its competitors. It is, therefore, withheld from disclosure to protect the Westinghouse competitive position.

(b) It is information that is marketable in many ways. The extent to which such information is available to competitors diminishes the Westinghouse ability to sell products and services involving the use of the information.

(c) Use by our competitor would put Westinghouse at a competitive disadvantage by reducing his expenditure of resources at our expense.

(d) Each component of proprietary information pertinent to a particular competitive advantage is potentially as valuable as the total competitive advantage. If competitors acquire components of proprietary information, any one component may be the key to the entire puzzle, thereby depriving Westinghouse of a competitive advantage.

(e) Unrestricted disclosure would jeopardize the position of prominence of Westinghouse in the world market, and thereby give a market advantage to the competition of those countries.

(f) The Westinghouse capacity to invest corporate assets in research and development depends upon the success in obtaining and maintaining a competitive advantage.

(iii) The information is being transmitted to the Commission in confidence and, under the provisions of 10 CFR Section 2.390, it is to be received in confidence by the Commission.

(iv) The information sought to be protected is not available in public sources or available information has not been previously employed in the same original manner or method to the best of our knowledge and belief.

(v) The proprietary information sought to be withheld in this submittal is that which is appropriately marked in Project Letter PSE-04-44, "Response to NRC RAI No. 2, 3, 6 and 7 Supporting Head Penetration Inspection Relaxation Request" (Proprietary) dated April 15, 2004, being transmitted by the Public Service Electric & Gas Company letter and Application for Withholding Proprietary Information from Public Disclosure, to the Document Control Desk. The proprietary information as submitted for use by Westinghouse for the Salem Unit 1 is expected to be applicable for other licensee submittals in response to certain NRC requirements for justification of relaxation request for the head vent nozzle from the NRC Revised Order EA-03-009 issued on February 20, 2004.

This information is part of that which will enable Westinghouse to:

(a) Determine the allowable time of safe operation if cracks are found.

(b) Assist the customer to obtain NRC approval.

Further this information has substantial commercial value as follows:

(a) Westinghouse plans to sell the use of similar information to its customers for purposes of meeting NRC requirements for licensing documentation.

(b) Westinghouse can sell support and defense of continued safe operation with the presence of cracks in the upper head penetration.

(c) The information requested to be withheld reveals the distinguishing aspects of a methodology which was developed by Westinghouse.

Public disclosure of this proprietary information is likely to cause substantial harm to the competitive position of Westinghouse because it would enhance the ability of competitors to provide similar calculations and licensing defense services for commercial power reactors without commensurate expenses. Also, public disclosure of the information would enable others to use the information to meet NRC requirements for licensing documentation without purchasing the right to use the information.

The development of the technology described in part by the information is the result of applying the results of many years of experience in an intensive Westinghouse effort and the expenditure of a considerable sum of money.

In order for competitors of Westinghouse to duplicate this information, similar technical programs would have to be performed and a significant manpower effort, having the requisite talent and experience, would have to be expended.

Further the deponent sayeth not.

PROPRIETARY INFORMATION NOTICE

Transmitted herewith are proprietary and/or non-proprietary versions of documents furnished to the NRC in connection with requests for generic and/or plant-specific review and approval.

In order to conform to the requirements of 10 CFR 2.390 of the Commission's regulations concerning the protection of proprietary information so submitted to the NRC, the information which is proprietary in the proprietary versions is contained within brackets, and where the proprietary information has been deleted in the non-proprietary versions, only the brackets remain (the information that was contained within the brackets in the proprietary versions having been deleted). The justification for claiming the information so designated as proprietary is indicated in both versions by means of lower case letters (a) through (f) located as a superscript immediately following the brackets enclosing each item of information being identified as proprietary or in the margin opposite such information. These lower case letters refer to the types of information Westinghouse customarily holds in confidence identified in Sections (4)(ii)(a) through (4)(ii)(f) of the affidavit accompanying this transmittal pursuant to 10 CFR 2.390(b)(1).

Attachment 4

Redacted version of Response to NRC RAI No. 2, 3, 6, and 7 Supporting Head Penetration Inspection Relaxation Request.
(Westinghouse Non- Proprietary Class 3 Version)

Response to NRC RAI No. 2, 3, 6 and 7 Supporting Head Penetration Inspection Relaxation Request (Westinghouse Non- Proprietary Class 3 Version)

Response to RAI No. 2

Summary of Initial Though-Wall Flaw Lengths in Figures 6-12 through 6-16 of WCAP-16214-P

Nozzle Angle (°)	WCAP-16214-P	Initial Flaw Length (in.)
0	Figure 6-12	0.29
26.2	Figure 6-13	0.40
44.3	Figure 6-14	0.29
45.4	Figure 6-15	0.26
48.7	Figure 6-16	0.20

Response to RAI No. 3

The nozzles that did not have one inch of examinable volume below the J grove welds are denoted on Table 1. The yield strength range of the Salem Unit 1 nozzles is delineated in response to RAI No. 6.

The stress-strain curve used in the finite element stress analysis for the penetration nozzle is provided in Figure 1. The nozzle is assumed to be stress free at room temperature at the start of the analysis (i.e., the effects of tubing fabrication are not reflected in the model). This assumption is made because the effects of tubing fabrication are not known with certainty. The Alloy 600 nozzle material is assumed to strain-harden isotropically using the von Mises yield criterion with a multi-linear input curve. The shape of the Alloy 600 input curve is based on the data for cyclic stress-strain properties of Alloy 600, presented in Reference 1. The test data was obtained from cyclic stress strain tests on test samples taken from an actual head penetration tube in a reactor vessel closure head located at the Westinghouse's Waltz Mill facility.

The stress strain curve given in Reference 1 is for the material at 600°F; scaling to other temperatures is accomplished using the following scaling factors, taken from high-temperature yield strength data for Alloy 600 material in Reference 2:

- 70 °F: 1.15
- 600 °F: 1.00
- 1,200 °F: 0.83
- 1,600 °F: 0.29
- 2,300 °F: 0.05
- 3,500 °F: 0.05

The cyclic stress-strain data are yield-strength independent; therefore, one curve can be used for all the analysis models.

Table 1
Scan Extents Above and Below Welds at Downhill and Uphill Sides Salem Unit 1*

Pen No	Intersection Angle (Degrees)	OHS** (O) or Trinity (T) Probe	Downhill side of weld				Uphill side of weld				UT Call ***	ECT Call ***
			Lower UT extent	Lower ECT extent	Upper UT extent	Upper ECT extent	Lower UT extent	Lower ECT extent	Upper UT extent	Upper ECT extent		
1	0	T	1.30	2.04	2.28	2.58	1.34	2.08	2.24	2.54	NDD	NDD
2	8	O	1.08	1.72	3.68	3.08	1.84	2.48	3.00	2.40	NDD	MAI
3	8	O	1.28	1.84	3.84	3.24	1.92	2.48	3.16	2.56	NDD	NDD
4	8	O	0.92	1.48	3.68	3.08	1.88	2.44	3.16	2.56	NDD	NDD
5	8	O	0.68	1.44	3.68	3.08	1.56	2.32	3.00	2.40	NDD	NDD
6	11.4	T	1.22	2.04	3.16	3.46	1.94	2.76	2.52	2.82	NDD	NDD
7	11.4	T	1.22	2.00	3.36	3.66	1.90	2.68	2.72	3.02	NDD	NDD
8	11.4	T	1.10	1.76	3.44	3.74	2.06	2.72	2.72	3.02	NDD	NDD
9	11.4	T	0.86	1.66	3.40	3.70	1.62	2.42	2.72	3.02	NDD	NDD
10	16.2	T	1.10	1.86	3.76	4.06	2.18	2.94	2.60	2.90	NDD	NDD
11	16.2	T	1.06	1.59	3.73	4.02	2.67	3.20	2.36	2.66	NDD	NDD
12	16.2	T	1.18	1.94	3.84	4.14	2.22	2.98	2.64	2.94	NDD	NDD
13	16.2	T	0.70	1.40	3.52	3.82	2.02	2.72	2.28	2.58	NDD	NDD
14	18.2	T	0.90	1.32	4.24	4.54	2.42	2.84	2.88	3.18	NDD	NDD
15	18.2	O	0.92	1.56	4.88	4.28	2.52	3.16	3.56	2.96	NDD	NDD
16	18.2	T	1.26	1.74	3.76	4.06	2.54	3.02	2.36	2.66	NDD	MAI
17	18.2	O	0.92	1.60	4.80	4.20	2.44	3.12	3.48	2.88	NDD	NDD
18	18.2	T	0.62	1.24	3.88	4.18	2.58	3.20	2.56	2.86	NDD	NDD
19	18.2	O	0.84	1.56	4.92	4.32	2.40	3.12	3.56	2.96	PTI	MAI
20	18.2	T	0.74	1.10	3.92	4.22	2.10	2.46	3.04	3.34	NDD	NDD
21	18.2	O	1.00	1.80	4.56	3.96	2.48	3.28	3.32	2.72	NDD	MAI
22	23.3	T	0.94	1.68	4.40	4.70	2.70	3.44	2.64	2.94	NDD	NDD
23	23.3	T	0.98	1.34	4.12	4.42	2.86	3.22	2.64	2.94	NDD	NDD
24	23.3	T	0.90	1.44	4.28	4.58	3.02	3.56	2.48	2.78	NDD	NDD
25	23.3	T	0.50	0.92	4.48	4.78	2.62	3.04	2.84	3.14	NDD	NDD
26	24.8	O	0.60	1.24	5.28	4.68	3.08	3.72	3.48	2.88	NDD	NDD
27	24.8	O	0.88	1.92	5.12	4.52	2.92	3.96	3.04	2.44	NDD	NDD
28	24.8	O	1.00	1.67	4.28	3.68	3.20	3.87	2.52	1.92	NDD	NDD
29	24.8	O	0.64	1.36	5.48	4.88	2.88	3.60	3.60	3.00	NDD	MAI

Pen No	Intersection Angle (Degrees)	OHS** (O) or Trinity (T) Probe	Downhill side of weld				Uphill side of weld				UT Call ***	ECT Call ***
			Lower UT extent	Lower ECT extent	Upper UT extent	Upper ECT extent	Lower UT extent	Lower ECT extent	Upper UT extent	Upper ECT extent		
30	26.2	T	0.74	1.32	5.56	5.86	2.66	3.24	3.92	4.22	NDD	MAI
31	26.2	T	0.86	1.52	5.64	5.94	2.58	3.24	3.96	4.26	NDD	MAI
32	26.2	T	1.02	1.67	5.48	5.78	2.70	3.35	3.80	4.10	NDD	NDD
33	26.2	T	0.82	1.32	5.28	5.58	2.94	3.44	3.48	3.78	NDD	NDD
34	26.2	O	0.76	1.36	5.92	5.32	3.00	3.60	3.80	3.20	NDD	MAI
35	26.2	T	0.94	1.48	5.44	5.74	2.62	3.16	3.76	4.06	NDD	NDD
36	26.2	T	0.78	1.36	5.60	5.90	2.66	3.24	3.92	4.22	NDD	NDD
37	26.2	T	0.58	1.16	5.56	5.86	2.46	3.04	3.88	4.18	NDD	MAI
38	30.2	T	0.94	1.48	5.16	5.46	2.98	3.52	3.28	3.58	NDD	NDD
39	30.2	T	0.82	1.28	4.92	5.22	3.26	3.72	3.00	3.30	NDD	MAI
40	30.2	T	0.78	1.36	5.00	5.30	3.30	3.88	2.96	3.26	NDD	NDD
41	30.2	T	0.82	1.60	4.72	5.02	3.26	4.04	2.64	2.94	NDD	NDD
42	30.2	T	0.86	1.35	5.08	5.38	3.54	4.03	2.88	3.18	NDD	NDD
43	30.2	T	0.78	1.52	4.72	5.02	3.62	4.36	2.32	2.62	NDD	NDD
44	30.2	T	0.82	1.48	4.95	5.25	3.57	4.23	2.68	2.98	NDD	NDD
45	30.2	T	0.74	1.16	5.24	5.54	3.74	4.16	2.64	2.94	NDD	NDD
46	33.9	T	0.86	1.36	5.44	5.74	3.78	4.28	2.80	3.10	NDD	NDD
47	33.9	T	0.66	1.08	5.20	5.50	3.38	3.80	2.84	3.14	NDD	NDD
48	33.9	T	0.66	1.32	5.32	5.62	3.42	4.08	2.88	3.18	NDD	MAI
49	33.9	T	0.54	0.72	6.02	6.32	3.82	4.00	2.96	3.26	NDD	NDD
50	35.1	T	0.62	1.68	5.16	5.46	3.66	4.20	3.00	3.30	NDD	NDD
51	35.1	T	0.62	0.84	5.80	6.10	3.90	4.12	3.16	3.46	NDD	NDD
52	35.1	T	1.14	1.60	5.60	5.90	3.62	4.08	2.88	3.18	NDD	NDD
53	35.1	T	0.58	1.12	5.52	5.82	3.78	4.32	2.92	3.22	NDD	NDD
54	35.1	T	0.94	1.42	5.38	5.68	3.70	4.18	2.74	3.04	NDD	NDD
55	35.1	T	0.74	1.50	5.24	5.54	3.34	4.10	3.00	3.30	NDD	NDD
56	35.1	T	0.78	1.14	5.68	5.98	3.70	4.06	3.12	3.42	NDD	NDD
57	35.1	T	0.74	1.14	5.68	5.98	3.90	4.30	3.12	3.42	NDD	NDD
58	36.3	T	0.62	1.10	5.60	5.90	3.78	4.26	2.96	3.26	NDD	NDD
59	36.3	T	1.10	1.48	5.80	6.10	3.98	4.36	3.00	3.30	NDD	NDD
60	36.3	T	1.18	1.70	5.76	6.06	4.18	4.70	2.80	3.10	NDD	NDD
61	36.3	T	0.82	1.62	5.52	5.82	3.98	4.78	2.72	3.02	NDD	NDD

Pen No	Intersection Angle (Degrees)	OHS** (O) or Trinity (T) Probe	Downhill side of weld				Uphill side of weld				UT Call ***	ECT Call ***
			Lower UT extent	Lower ECT extent	Upper UT extent	Upper ECT extent	Lower UT extent	Lower ECT extent	Upper UT extent	Upper ECT extent		
62	38.6	T	0.66	1.28	5.64	5.94	4.30	4.92	2.36	2.66	NDD	NDD
63	38.6	T	0.74	1.24	6.24	6.54	4.26	4.76	3.08	3.38	NDD	MAI
64	38.6	T	0.78	1.32	6.08	6.38	3.86	4.40	2.92	3.22	NDD	NDD
65	38.6	T	0.58	1.10	6.04	6.34	4.30	4.82	2.84	3.14	NDD	NDD
66	38.6	T	0.74	1.18	5.84	6.14	4.10	4.54	2.80	3.10	NDD	NDD
67	38.6	T	0.50	1.30	5.60	5.90	4.06	4.86	2.64	2.94	NDD	NDD
68	38.6	T	0.70	1.14	6.00	6.30	4.46	4.90	2.80	3.10	NDD	NDD
69	38.6	T	0.78	1.10	6.04	6.34	3.90	4.22	3.08	3.38	NDD	MAI
70	44.3	T	0.86	1.40	6.40	6.70	4.62	5.16	2.96	3.26	PTI (<0.04")	MAI
71	44.3	T	0.98	1.48	6.40	6.70	4.98	5.48	2.48	2.78	NDD	NDD
72	44.3	T	0.62	1.04	6.76	7.06	4.98	5.40	2.80	3.10	NDD	NDD
73	44.3	T	0.50	1.12	6.40	6.70	4.82	5.44	3.00	3.30	PTI (<0.04")	MAI
74	48.7	O	0.64	1.43	7.68	7.08	5.88	6.67	2.96	2.36	NDD	NDD
75	48.7	T	0.74	1.48	6.64	6.94	5.74	6.48	2.20	2.50	NDD	NDD
76	48.7	O	0.94	1.44	7.00	6.40	6.06	6.56	2.20	1.60	NDD	NDD
77	48.7	O	0.54	1.04	6.80	6.20	5.78	6.28	2.08	1.48	NDD	NDD
78	48.7	O	0.28	0.83	7.44	6.84	5.80	6.35	2.64	2.04	NDD	NDD
79	48.7	O	0.90	1.28	7.00	6.40	5.94	6.32	2.52	1.92	NDD	NDD

* Lower extents are measured from the toe of the J-groove weld. Upper extents are measured from the root of the J-groove weld.

** OHS = Open Housing Scanner (7010 scanner)

*** NDD = No Detectable Degradation MAI = Multiple Axial Indications PTI = Parent Tube Indication

Figure 1
Stress-Strain Curves for Penetration Nozzle

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Response to RAI No. 6

The major inherent conservatisms in WCAP-16214-P Revision 0 are summarized below:

Conservatism in Assumed Crack Geometry

There is nearly universal agreement that high stresses, on the order of the material yield strength, are necessary to initiate Primary Water Stress Corrosion Cracking (PWSCC). There is no known case of stress corrosion cracking of Alloy 600 below the yield stress (Reference 3). The yield strengths for wrought Alloy 600 head penetration nozzles are in the range of 37 ksi to 65 ksi. Weld metal yield strengths are generally higher. The yield strength of the head penetration nozzles for Salem Unit 1 varies from 35 ksi to 63 ksi (Reference 4) which is a room temperature value obtained using a 0.2% offset. The stress level of 20 ksi is a conservative value below which PWSCC initiation is extremely unlikely. Therefore the assumption of any PWSCC crack initiation in the region of the penetration nozzle with a stress level of 20 ksi or less is conservative. The assumption of a through-wall flaw in these unlikely PWSCC crack initiation regions of the head penetration is an important additional conservatism, since the penetration tubes were inspected with maximum achievable coverage on the tube ID, and no indications were found.

Conservatism in Recommended PWSCC Crack Growth Rate

From Table 5-3 of MRP-55 Rev. 1 (Reference 5), the mean crack growth amplitude (α) for each Huntington Alloy 600 heat is summarized below:

Heat	Material Supplier	Mean α (SI units)
NX8101	Huntington	$1.37x10^{-12}$
NX8664	Huntington	$1.29x10^{-12}$
NX6420G	Huntington	$7.21x10^{-13}$
NX9240	Huntington	$4.97x10^{-13}$
NX8168G	Huntington	$1.93x10^{-13}$

Huntington is the material supplier for the head penetrations for Salem Unit 1. Since the recommended crack growth amplitude (α) from the NRC flaw evaluation guidelines (Reference 6) is $2.67x10^{-12}$ in SI units, the recommended PWSCC crack growth rate is about a factor of 1.9 higher than that obtained from the test data for any of the Huntington material heats.

Conservatism in the As-Designed J-Weld Configuration

See Response to RAI No. 7

Response to RAI No. 7

Scan limits for CRDM examinations are determined in advance based upon design dimensions. In accordance with the revised NRC Order, upper scan limits are set to assure that scanning is conducted to at least 2.0" above the highest point of the root of the J-groove weld. In experience at over 30 head penetration examinations in the US, there have not been any observed instances where the size (thickness measured through the reactor vessel head) of the J-Groove weld varied significantly from the design dimensions.

Recent experience with vessel head examinations has shown that the calculated tube lengths inside the vessel head are not always representative of the dimensions found in the vessel head as-built condition. In most instances, the tube lengths are calculated based on the elevation where the tube intersects the vessel head and does not take into account the fillet weld on the tube.

During the manufacturing of the reactor vessel, the length of the fillet weld was not a controlled dimension and could vary from tube to tube. The as-built geometry, taking into account the presence of the weld fillet, has been found to have created an accessibility impact for inspecting the outside surface of the tube, by reducing the length of inspectable surface. This constraint is especially prevalent on the downhill side of the weld.

Recent evaluations of the as-built weld configurations for two other power plants have shown that the additional weld metal deposited on the tube below the as-designed weld acts to reduce the stresses below the weld. There is a logical explanation for this result. The weld is designed to connect the tube to the vessel head, and as it cools, it contracts by pulling at both the vessel head and the tube. The portion of the weld on the tube below the vessel head is only in contact with the tube, so it does not contribute to additional stresses. Instead it results in compressive stresses imparted on the tube due to shrinkage during weld solidification.

To investigate the impact of larger fillet weld sizes in the as-built configuration, finite element analysis results were obtained for an outermost penetration row (46°) from a representative power plant. The results are reviewed here. [

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In order to determine the applicability of the results shown in Figure 2 to Salem Unit 1, a comparison was made between the as-designed weld configuration hoop stress distribution for the Salem Unit 1 outermost penetration row (48.7°) and that shown for the 46° penetration row in Figure 2. The comparison is shown in Figure 3. It can be seen that the hoop stress distributions between the two as-designed weld configurations are similar. This is not surprising since the vessel manufacturer for Salem Unit 1 and the representative power plant is the same and the penetration nozzle angle is very similar. It is therefore expected that the as-built configuration hoop stress distribution for the 48.7° penetration row is also very similar to that shown for the 46° penetration row in Figure 2 and that the larger as-built weld configuration tends to reduce the stresses below the weld for the penetration nozzle.

Figure 2
Downhill Side Hoop Stress Distributions for As-built vs As-Design Weld Configurations
(46° Penetration From a Representative Power Plant)

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Figure 3
Comparison of Downhill Side Hoop Stress Distribution - Salem (48.7° Penetration) vs Figure 2 (46° Penetration)

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References

1. Ball, M. G., et al., "RV Closure Head Penetration Alloy 600 PWSCC," WCAP-13525, Revision 1, Westinghouse Electric Corporation, 1992.
2. Properties and Selection: Stainless Steels, Tool Materials, and Special-Purpose Metals, ASM Materials Handbook Volume 3, Ninth Edition, p. 218, 1980.
3. Effect of Strain Rate on SCC in High Temperature Primary Water, Comparison between Alloys 690 and 600, ANS 11th Environmental Degradation Meeting, August 2003, K. M. Boursier et al (EDF).
4. WCAP-16214-P Revision 0, "Structural Integrity Evaluation of Reactor Vessel Upper Head Penetrations to Support Continued Operation: Salem Units 1 and 2" February 2004.
5. "Materials Reliability Program (MRP) Crack Growth Rates for Evaluating Primary Water Stress Corrosion Cracking (PWSCC) of Thick-wall Alloy 600 Material", EPRI MRP Report MRP-55, Revision 1, November 2002.
6. USNRC Letter, R. Barrett to A. Marion, "Flaw Evaluation Guidelines," April 11, 2003.