Entergy

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PNP 2014-021

March 1, 2014

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

SUBJECT: Response to Request for Additional Information dated February 26, 2014, for Relief Request Number RR 4-18 – Proposed Alternative, Use of Alternate ASME Code Case N-770-1 Baseline Examination

Palisades Nuclear Plant
Docket 50-255
License No. DPR-20

References:
1. Entergy Nuclear Operations, Inc. letter PNP 2014-015, *Relief Request Number RR 4-18 - Proposed Alternative, Use of Alternate ASME Code Case N-770-1 Baseline Examination*, dated February 25, 2014
2. NRC Electronic Mail, *Request for Additional Information - Palisades - RR 4-18 - Proposed Alternative, Use of Alternate ASME Code Case N-770-1 Baseline Examination - MF3508*, dated February 26, 2014

Dear Sir or Madam:

In Reference 1, Entergy Nuclear Operations, Inc. (ENO) requested Nuclear Regulatory Commission (NRC) approval of the Request for Relief for a Proposed Alternative for the Palisades Nuclear Plant (PNP). NRC approval was requested by March 8, 2014.

Reference 1 is associated with the use of an alternative to the requirements of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Code Case N-770-1, as conditioned by 10 CFR 50.55a(g)(6)(ii)(F)(1) and 10 CFR 50.55a(g)(6)(ii)(F)(3), dated June 21, 2011.

In Reference 2, the NRC issued a request for additional information. Responses to the questions are provided in Attachments 1 and 2, and the Enclosure.

This submittal contains no proprietary information.

A047
NRR

This submittal makes no new commitments or revisions to previous commitments.

Sincerely,

owg/jse

Attachments: 1. Response to Request for Additional Information for Relief Request Number RR 4-18 – Proposed Alternative, Use of Alternate ASME Code Case N-770-1 Baseline Examination

2. Dominion Engineering, Inc. Letter No. L-4199-00-01

Enclosure: ENO Response to Question RAI-1.11

cc: Administrator, Region III, USNRC
Project Manager, Palisades, USNRC
Resident Inspector, Palisades, USNRC

ATTACHMENT 1

Response to Request for Additional Information for Relief Request Number RR 4-18 – Proposed Alternative, Use of Alternate ASME Code Case N-770-1 Baseline Examination

By letter dated February 25, 2014, Entergy Nuclear Operations (ENO) requested Nuclear Regulatory Commission (NRC) approval of the Request for Relief for a Proposed Alternative for the Palisades Nuclear Plant (PNP). By electronic mail, dated February 26, 2014, the Nuclear Regulatory Commission (NRC) requested additional information. The requested information is provided below.

1. NRC Information Request – Response to Question RAI-1.1

How was the heat treatment performed in the field?

ENO Response

All welds referenced in this relief request were post weld heat treated at the vendor's facility, during original fabrication. Per Combustion Engineering detail weld procedure (MA-41, Revision 0), heat treatment of the hot leg nozzle weld (weld number 5-675) consisted of an intermediate post weld heat treatment at 1100°F, - 0°F/+ 50°F, for 15 minutes, followed by 1150°F, +/- 25°F, for one hour per inch thickness of weld. No heat treatment was performed at the site for the subject welds.

2. NRC Information Request – Response to Question RAI-1.2

How was the heat treatment modeled?

ENO Response

The heat treatment was modeled by linearly ramping the surface temperature of the finite element analysis up and down between 70°F and 1125°F at a rate of 200°F/hour. The holding time between the heatup and cooldown ramps is four hours.

During heat treatment, creep strain relaxation modeling was included when the model temperature was above 800°F. The creep model was based on a power law:

$$\frac{d\varepsilon}{dt} = A\sigma^n$$

Material	Temperature (°F)	*A* (ksi/hr)	*n*
SA-516 Gr. 70 (Based on 1/2Mo steel)	800	1.26E-13	5.40
	900	3.59E-14	7.80
	1000	2.43E-12	10.32
	1100	2.50E-07	4.11
ER308L (Based on Type 304)	800	7.73E-19	7.95
	900	5.67E-17	7.42
	1000	1.82E-13	5.41
	1100	8.62E-12	4.78
Alloy 600 Alloy 82/182 (Based on Alloy 600)	800	1.50E-19	8.00
	900	2.87E-14	5.21
	1000	3.02E-10	3.21
	1100	1.72E-09	3.32

3. NRC Information Request – Response to Question RAI-1.3

What was the basis for the 5-cycle shakedown – typically it is not included in weld residual stress calculations?

a. Why was 5 cycles used versus two or three cycles for example?
b. How was each shakedown modeled?
c. What is the effect of the shakedowns as they were applied? (i.e. provide weld residual stresses for each application of the technique.)

ENO Response

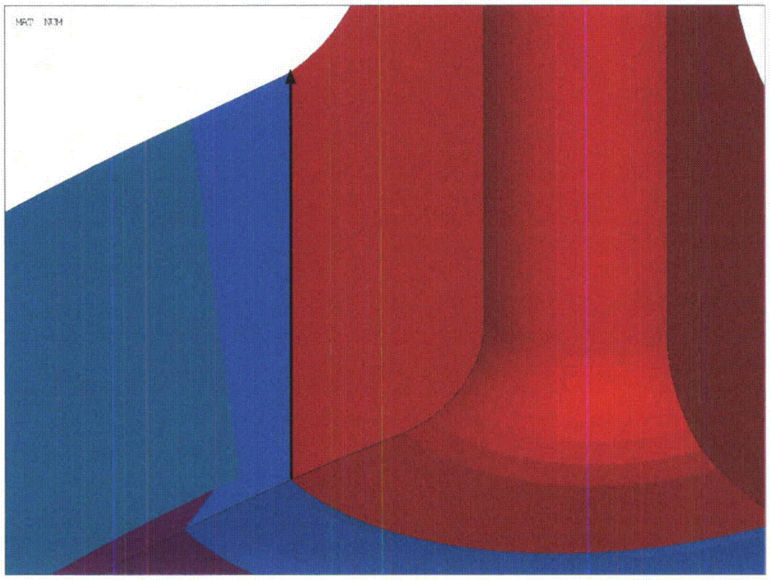
Operational cycles are frequently included in welding residual stress calculations as a part of determining the operating stress condition. In particular, the standard modeling practice adopted by the xLPR (Extremely Low Probability of Rupture) welding residual stress team, which includes the NRC, national laboratory, and industry participants, specifies that the welded configuration should be cycled between operating conditions and residual conditions to shake down the nonlinear material hardening behavior. Typically, three to five cycles are used to shake down the material's behavior.

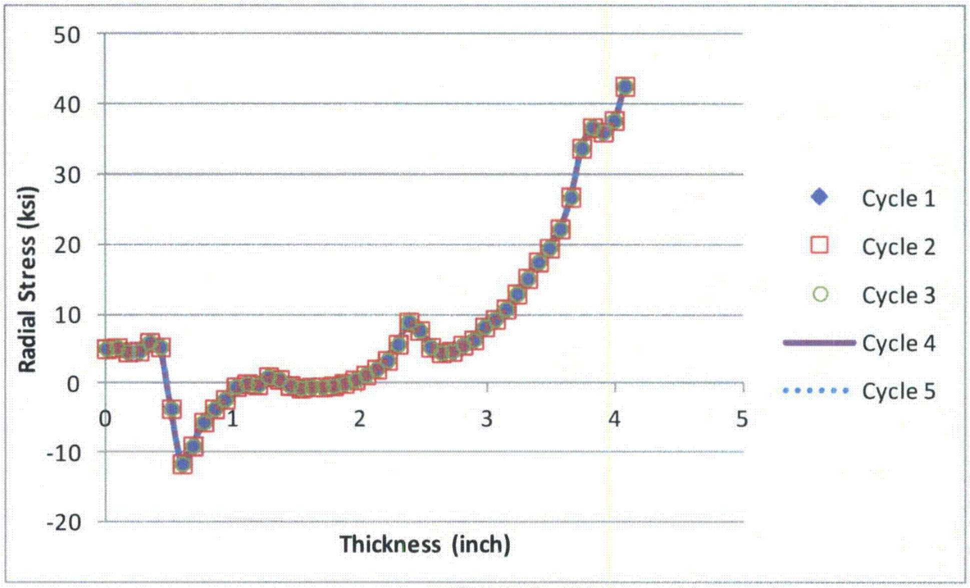
a. Since the primary interest from the residual stress analysis is to provide residual stresses for calculating stress corrosion crack growth under normal operating conditions, it is desirable to determine a stabilized residual stress state that will not change under normal operating cycles. The as-welded residual stresses usually contain localized peak stresses

at some nodal locations. Applying a few operating cycles will stabilize the stress peaks and valleys due to the slight stress redistribution at elevated temperatures. It has been determined through experience that the residual stresses will stabilize after three to five cycles. Five cycles was used for conservatism.

b. The modeling of the operating cycles involved simultaneously ramping the operating temperature and pressure between the no load and full load conditions repeatedly five times. Residual stresses at the fifth operating cycle were extracted for the crack growth calculation.

c. An example through-wall stress path at the weld/nozzle interface at the 90-degree azimuth is used to investigate the residual stresses at each operating cycle. The results show that the residual stresses are stabilized because there is virtually no change in the profiles among the five cycles. This is primarily due to the resulting stresses developed in the fabrication process.





4. NRC Information Request – Response to Question RAI-1.4

What is the basis for not including an initial weld repair, 50% through-wall?

ENO Response

The presence of an initial weld repair from plant construction (e.g., extending 50% of the wall thickness from the inside diameter (ID)) is often assumed when modeling Alloy 82/182 piping butt welds. Often for piping butt welds, the residual stress calculated for the ID is a small tensile value, or even compressive, in the absence of an assumed weld repair. In such cases, the possibility of a significant weld repair being present on the weld ID can have a relatively large effect on the calculated stresses, especially on and near the ID surface.

However, for the Alloy 82/182 branch connection welds at PNP, there are two reasons why it is not necessary to include a weld repair assumption in the analysis. First, the design for this weldment specifies a 360° backweld on the ID surfaces of the pipe that is about 0.25 inch thick. This design feature results in elevated residual stress levels at the ID surface prior to the post weld heat treatment (PWHT) being applied. The residual stress levels at the inside surface due to the presence of the backweld are similar to what would be expected due to the presence of a weld repair on the ID surface.

Second, any weld repairs would have been made prior to PHWT being applied, and would be expected to extend over a relatively limited circumferential portion of the original weld. Similar to the situation for the elevated residual stresses due to the presence of the backweld, the PWHT would relax the residual stresses in the weld repair area, including the substantial relaxation expected at the surface exposed to primary coolant. (The effect of PWHT on the likelihood of PWSCC initiation occurring on the wetted Alloy 600 and Alloy 82/182 surfaces

of the PNP branch connection weldments was assessed by Dominion Engineering, Inc. (see Attachment 2)). Moreover, in the unlikely case that initiation occurred in the area of a weld repair, the weld repair would be an additional source of non-axisymmetric crack loading that would tend to drive crack growth through-wall over a relatively local circumferential region, ultimately resulting in detection of leakage prior to the possibility of unstable pipe rupture.

5. <u>NRC Information Request – Response to Question RAI-1.5</u>

Provide the repair history on these welds during fabrication.

<u>ENO Response</u>

The manufacturing/quality plan provided in the specification for the primary coolant system piping provides instructions for performing weld repairs based on the results of NDE testing. Any defects identified in the nozzle welds would have been removed prior to final furnace heat treatment of the assembly. PNP is unable to locate post-fabrication documentation other than the weld radiographs taken after the final furnace heat treatment. These radiographs represent the condition of the subject welds at the time of installation at the site. A search of PNP records did not identify any repairs performed on the subject welds since installation.

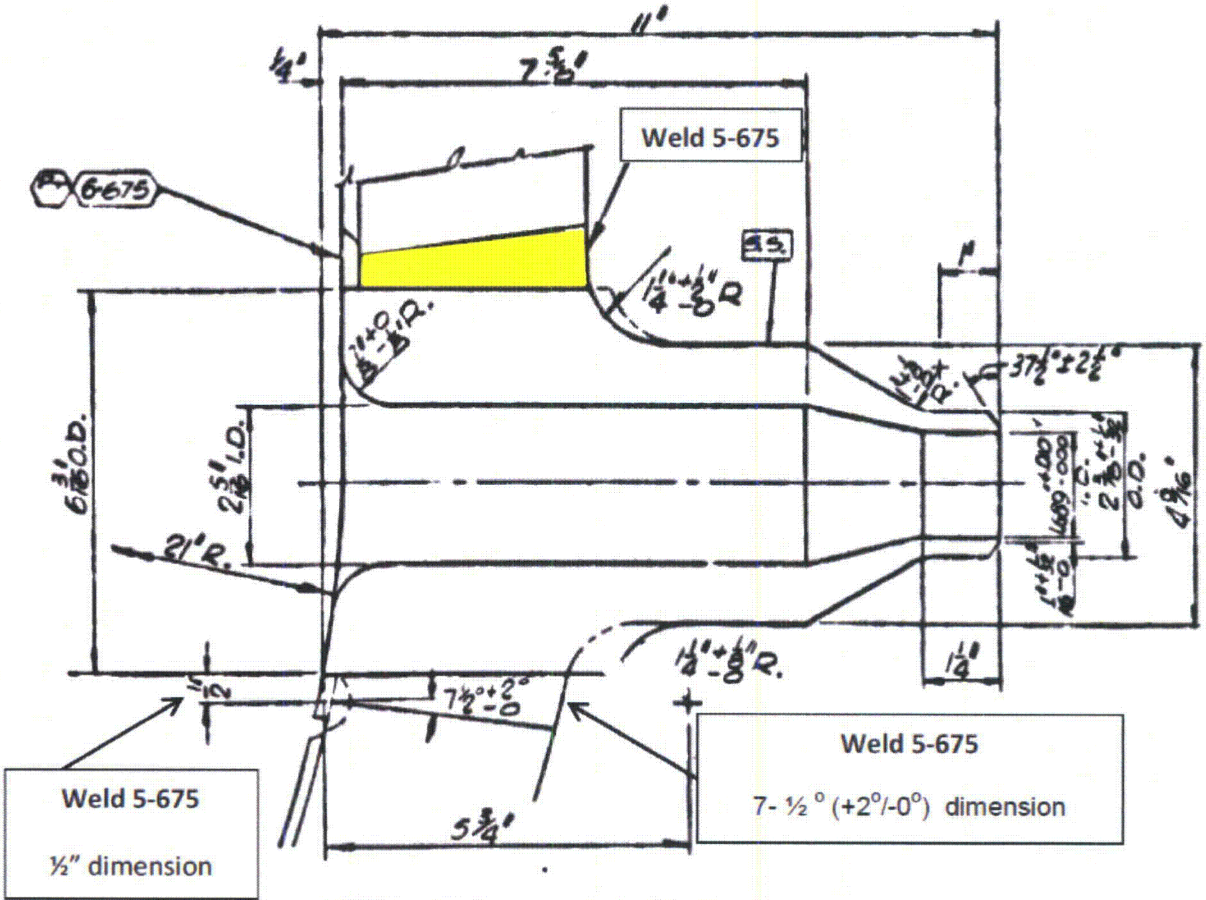
6. <u>NRC Information Request – Response to Question RAI-1.6</u>

Provide detailed geometry information of the weld, including weld thickness.

<u>ENO Response</u>

The weld is ½ inch wide at the ID of the hot leg pipe and then increases in width at a 7- ½ $^{\circ}$ (+2°/-0°) angle to the OD of the hot leg pipe. The thickness of the hot leg pipe is 3-¾ inches.

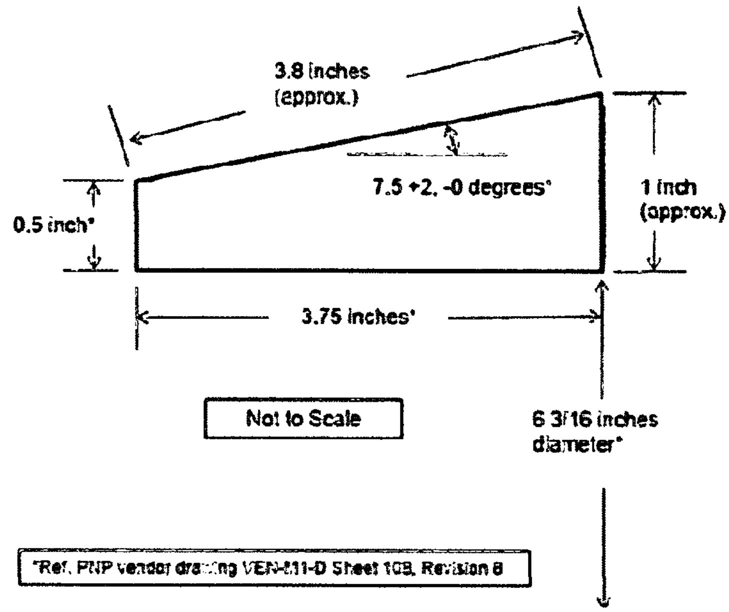
The details of the nozzle are shown on Palisades Drawing M-1D-0108. The hot leg drain nozzle is shown as part number 675-03 as shown below.



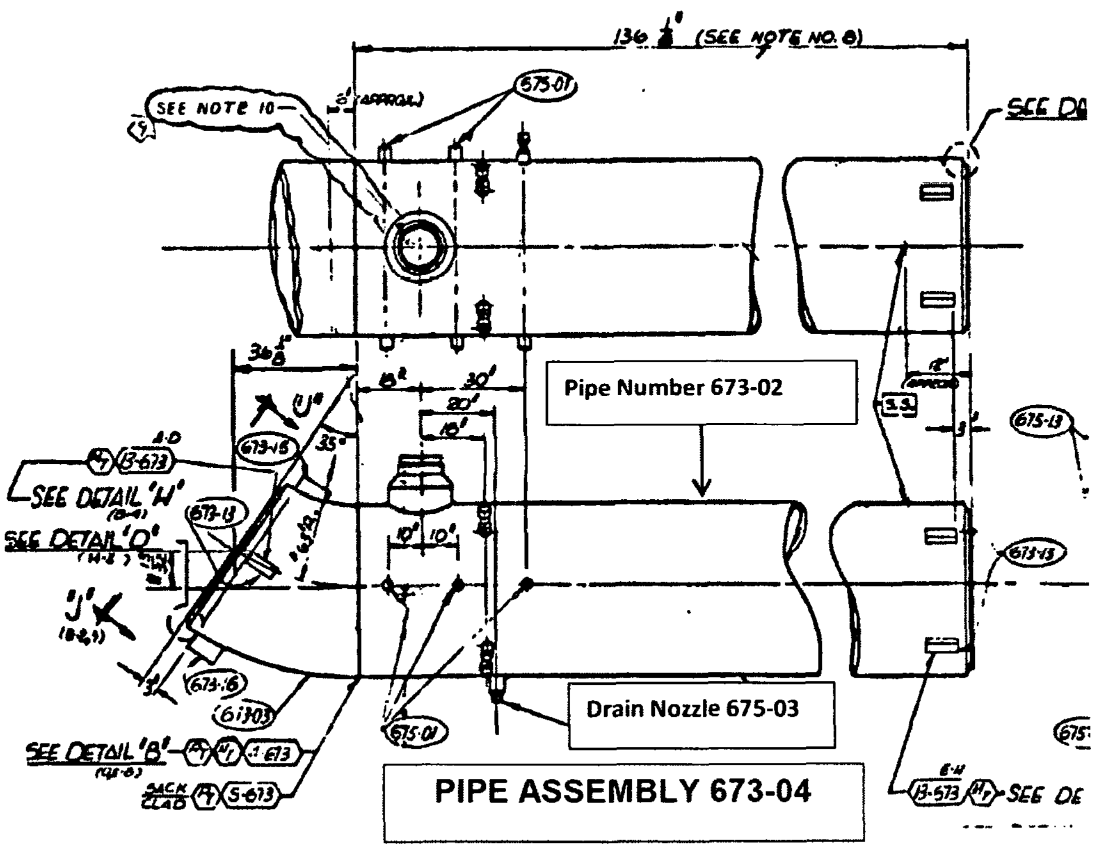
67503 DRAIN NOZZLE

The weld number in question is designated as 5-675 on the drawing. The details show that it is ½ inch wide at the ID of the hotleg pipe and then increases in width at a 7- ½ ° (+2°/-0°) angle to the OD of the hot leg pipe.

An exploded view of weld 5-675 follows, showing the additional calculated dimensions, based on a 7.5 degree angle.



Weld 5-675 width of 3.75 inches was obtained from the hot leg drain nozzle (675-03) installation drawing. The hot leg drain nozzle is located in pipe assembly 673-04 and is attached to pipe number 673-02 as detailed on Palisades drawing M0001D-0106 and shown below.



Pipe Number 673-02 has a specified minimum thickness of 3- ¾ inches as shown in the material table from Palisades drawing M0001D-0106.

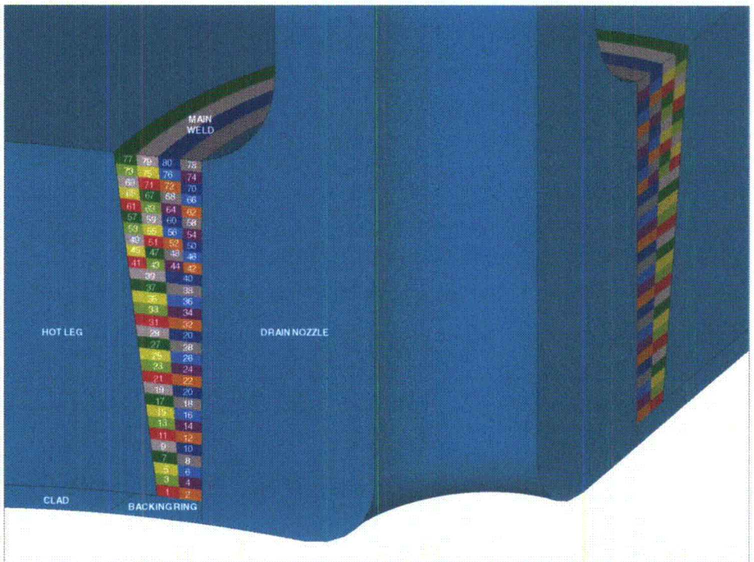
ASSY NO.	PC. NO.	NO. REQD.	NOMENCLATURE	MATERIAL	MATERIAL SPEC.	MAT'L NOTES
	673-02	1	PIPE			
673-04		1	PIPE ASSEMBLY - CONSISTING OF:			
	675-13	5	SAFE END			
	675-02	5	PRESS MEASUREMENT & SAMPLING NOZZLE			
675-06		1	SHUTDOWN COOLING OUTLET NOZZLE ASSEMBLY			
	675-01	5	R.T.D. NOZZLE			
	673-16	1	LUG 3 7/16" × 6" × 2"			
	673-15	1	LUG 3" × 6" × 2"			
	673-13	6	LUG - 3" × 6" × 2"	C.S.	SA516 GR70	'B'
	673-03	1	ELL 42" I.D. × 4 5/16" MIN. BASE METAL WALL × 35°, 63" R.			'A'
	673-02	1	PIPE ?$1\frac{3}{8}$" I.D. × 3 ¾" MIN. BASE METAL WALL × 136 ⅛" LG.	[illegible] STEEL CLAD	SA 264	'A'
673-01		1	PIPE ASSEMBLY —— CONSISTING OF:			
LIST OF MATERIAL - QUANTITIES FOR ONE (1) UNIT, ONE UNIT ON CONTRACT.						

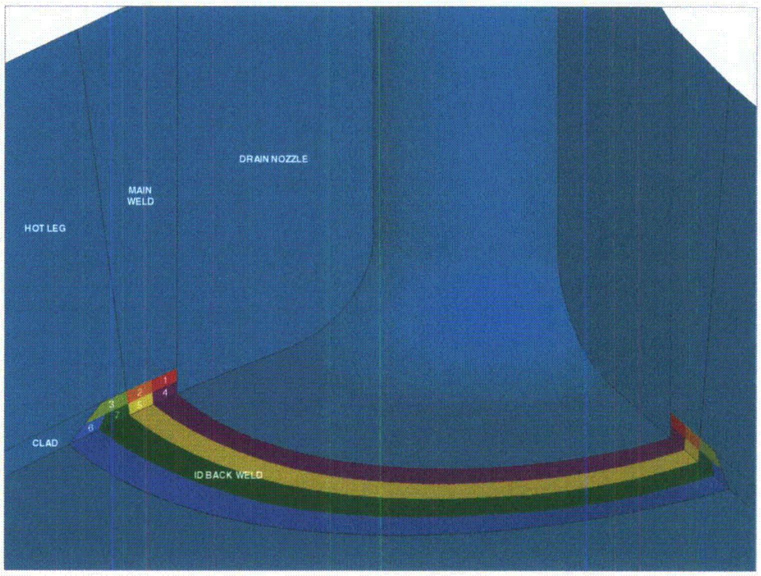
7. NRC Information Request – Response to Question RAI-1.7

Provide weld bead application sequence.

ENO Response

The weld beads were modeled as full bead rings, with 80 bead rings defined for the main weld, and seven bead rings defined for the inside diameter patch weld per the labeled sequence shown in the figures below.





8. NRC Information Request – Response to Question RAI-1.8

Provide hardening law chosen in model.

ENO Response

Multilinear isotropic hardening (MISO) modeling was used in ANSYS. The material stress-strain curves were derived using the Ramberg-Osgood curve fit with the maximum stress modified to be at the flow stress, which is defined as the average of the yield strength and tensile strength. The approach is a standard practice at Structural Integrity Associates (SI) for weld residual stress finite element analyses, including the results submitted to the NRC for the International Weld Residual Stress Round Robin Phase 2a study, where the SI results were shown to compare well with the measurements.

9. NRC Information Request – Response to Question RAI-1.9

Provide weld parameters chosen in model.

ENO Response

The welding parameters used in the ANSYS finite element analyses are as follows:

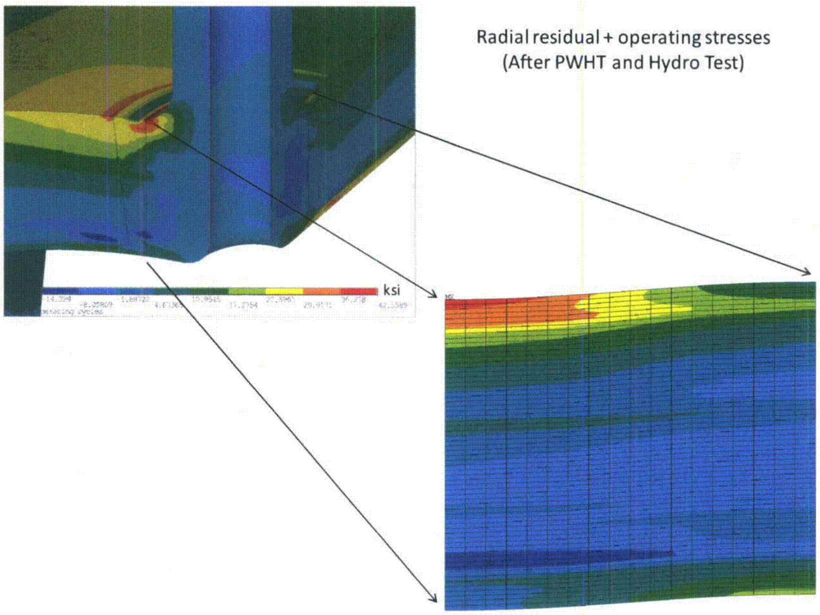
Interpass temperature	=	350°F
Melting temperature	=	2500°F
Ambient temperature	=	70°F
Heat input both welds	=	28 kJ/in
Heat efficiency both welds	=	0.8
Inside/Outside heat transfer coefficient	=	5 Btu/hr/ft^2
Inside/Outside temperature	=	70°F

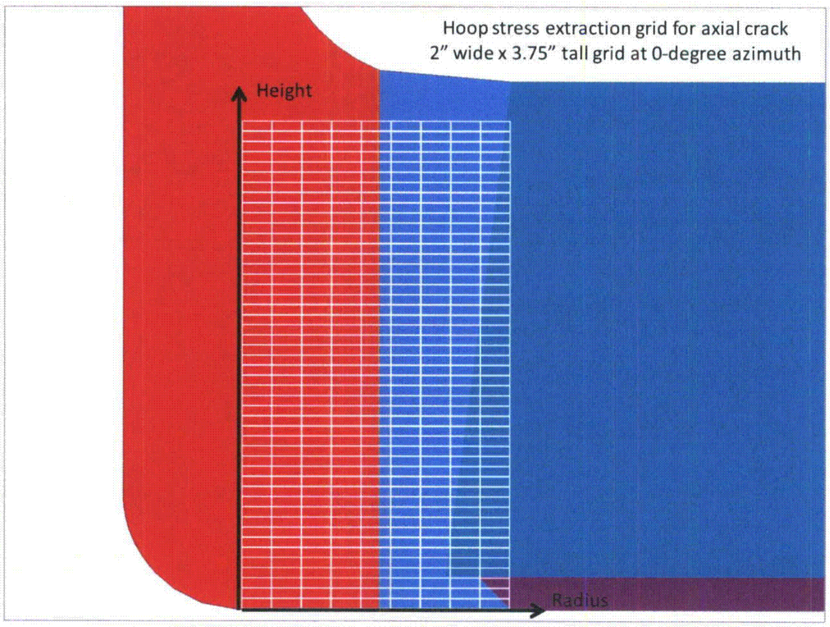
10. NRC Information Request – Response to Question RAI-1.10

Provide extraction path of WRS profile.

ENO Response

The stress extraction path for the circumferential crack was the radial stresses on the entire weld/nozzle interface area. The stress extraction path for the axial crack was the hoop stresses within a rectangular 2 inch x 3.75 inch grid located on the axial cut plane of the hot leg (i.e., at the 0-degree azimuth).





11. NRC Information Request – Response to Question RAI-1.11

Provide weld residual stresses for profiles chosen.

ENO Response

Requested stress outputs are included in the supporting file RAI_SupportFiles.zip, which are provided in the Enclosure.

Radial stresses (SX) for the circumferential crack analysis were extracted at the element face centroid location for each element on the crack face. The outputs were saved to two files:

Crack6_COORD1.txt contains the element face centroid location.

STR_FieldOper_61.txt contains the stresses for each element on the crack face, where the radial component (SX) was used in the circumferential crack analysis.

Hoop stresses (S_hoop) for the axial crack analysis were output in a tabular format in terms of Radius, Height, S_hoop, in the attached computer file Hoop_0.csv.

12. <u>NRC Information Request – Response to Question RAI-1.12</u>

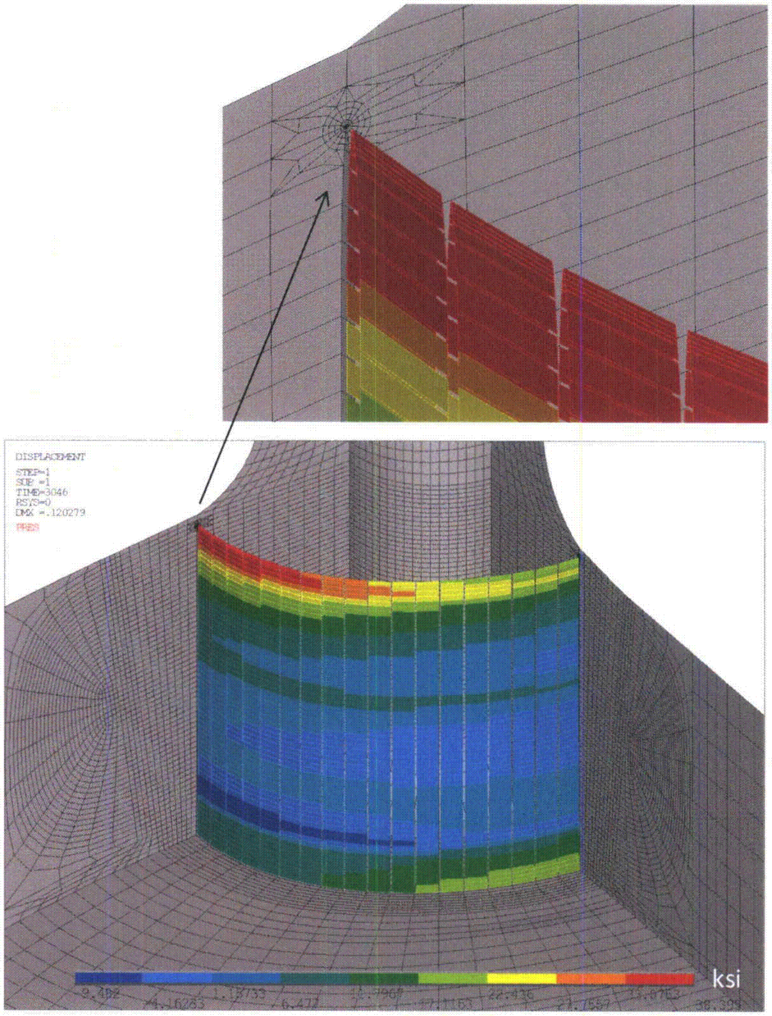
Was the WRS profile fit with a polynomial? If so, what order was the polynomial? If not, how were K values derived?

<u>ENO Response</u>

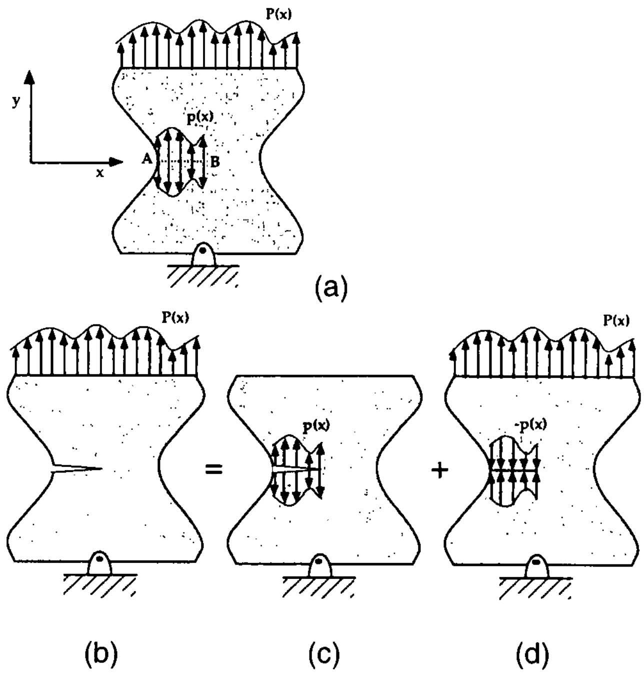
For the circumferential crack, the stress intensity factors, including the residual stresses, were calculated via deterministic finite element analyses using linear elastic fracture mechanics (LEFM) principles. Seven fracture mechanics finite element models are derived to include "collapsed" crack meshing that represent full circumferential flaws surrounding the nozzle at various depths within the boss weld. The depths vary from 0.13 inch to 3.95 inch.

High order SOLID95 elements in ANSYS were used around the crack tips, with the mid-side nodes shifted to the "quarter point" locations to properly capture the singularities at the crack tips. The 3.95 inches deep crack is shown as an example.

In order to determine the "Ks," the radial component (relative to the nozzle) residual stresses, plus operating stresses at the boss weld/nozzle interface, were extracted from the residual stress analysis and reapplied on the crack face as surface pressure loading. The transferred radial stresses onto the crack face are also shown in the figure below.



The crack face pressure transfer approach is based on the load superposition principle: Anderson, T. L., “Fracture Mechanics Fundamentals and Applications,” Second Edition, CRC Press, 1995. The superposition technique is based on the principle that, in the linear elastic regime, stress intensity factors of the same mode, which are due to different loads, are additive (similar to stress components in the same direction). The superposition method can be summarized with the following sketches:



A load p(x) on an uncracked body, Sketch (a), produces a normal stress distribution p(x) on Plane A-B. The superposition principle is illustrated by Sketches (b), (c), and (d) of the same body with a crack at Plane A-B. The stress intensity factors resulting from these loading cases are such that:

KI(b) = KI(c) + KI(d)

Thus, KI(d) = 0 because the crack is closed, and:

KI(b) = KI(c)

This means that the stress intensity factor obtained from subjecting the cracked body to a nominal load p(x) is equal to the stress intensity factor resulting from loading the crack faces with the same stress distribution p(x) at the crack location in the uncracked body.

For the axial crack, all the stresses (including residual) were calculated using finite element analyses. These stresses were then used to calculate stress intensity factors using a buried elliptical crack model by use of influence functions. Fitting stresses to polynomials was not required. A published K solution was used: P. M. Besuner, "Residual Life Estimates for Structures with Partial Thickness Cracks," ASTM STP 590, 1974. This K solution is available in two commercial software packages – NASCRAC and SmartCrack. SmartCrack was used for the analysis herein.

13. <u>NRC Information Request – Response to Question RAI-1.13</u>

Provide the Structural Integrity Associates report for the flaw evaluation for these nozzle welds.

<u>ENO Response</u>

The Structural Integrity Associates, Inc. calculations will be provided in a supplemental RAI response letter.

ATTACHMENT 2

Dominion Engineering, Inc.
Letter No. L-4199-00-01

Effect of Post-Weld Heat Treatment Applied to Alloy 82/182 Full-Penetration Branch Pipe Connection Welds at Palisades

February 25, 2014

5 Pages Follow

Dominion Engineering, Inc.

February 25, 2014
L-4199-00-01, Rev. 0

Mr. William Sims
Entergy Operations, Inc.
1340 Echelon Parkway
Jackson, MS 39213

Subject: Effect of Post-Weld Heat Treatment Applied to Alloy 82/182 Full-Penetration Branch Pipe Connection Welds at Palisades

Dear Mr. Sims:

Introduction

At Palisades, Alloy 82/182 full-penetration dissimilar metal V-welds were used for installation of Alloy 600 branch connection nozzles on the hot-leg and cold-leg piping. Subsequent to installation of these nozzles, a post-weld heat treatment (PWHT) was performed of the adjacent carbon steel material. Because the PWHT was performed subsequent to installation of these nozzles, the Alloy 82/182 and Alloy 600 materials also were exposed to this heat treatment. There is one such nozzle on the hot-leg piping at Palisades (2-inch Hot Leg Drain Nozzle) and eight such nozzles on the cold-leg piping at Palisades (six 2-inch nozzles and two 3-inch nozzles). Direct visual examinations of all these weldments for evidence of leakage have been previously performed per the requirements of ASME Code Case N-722-1 [1] for each location, with no such evidence reported.

The purpose of this letter is to assess the effect of the PWHT on the susceptibility of the nickel-base Alloy 82/182 weld metal and Alloy 600 base metal to primary water stress corrosion cracking (PWSCC).

Benefit of Post-Weld Heat Treatment (PWHT) for Resistance to PWSCC Initiation

Testing and extensive plant experience demonstrate that Alloy 600 weldments that have been exposed to PWHT after welding have greatly reduced susceptibility to occurrence of PWSCC:

- In 2007, Scott ([2] and [3]) reported that PWHT of test samples of Alloy 182 welds was found to greatly delay occurrence of PWSCC. This work included detailed laboratory investigation of the effect of the PWHT on residual stresses and the material microstructure of the nickel-base weld, including stress measurements on mockups. Scott [2] concluded that the large benefit of PWHT is due to the reduction in residual stress levels it produces, including very significant relaxation of the residual stress in the surface layer of the weldment, and that the reason for "the strong favorable effect on surface residual stresses and consequently on PWSCC initiation resistance" is that the PWHT causes recrystallization of the surface cold-worked layer produced by grinding.

- Consistent with the laboratory work, PWR plant experience shows hundreds of cases of PWSCC when the Alloy 82/182 or Alloy 600 material was not exposed to PWHT, but extremely few cases when the material was exposed to PWHT subsequent to welding:

- There have been more than 120 cases of PWSCC detected in small-diameter Alloy 600 instrumentation nozzles and pressurizer heater sleeves in plants designed by Combustion Engineering ([4], [5], and [6]). These nozzles in CE-designed plants were not exposed to PWHT after installation. On the other hand, small-diameter Alloy 600 instrumentation nozzles are also used extensively in B&W-designed PWRs, and there have been extremely few cases of PWSCC reported for these components, which were installed prior to PWHT being performed [4]. The limited cases of PWSCC reported for a component exposed to PWHT include one reactor vessel bottom-mounted nozzle at Gravelines Unit 1 in France [7]. In 2011, PWSCC was reported for one bottom-mounted nozzle at this plant associated with pre-existing base metal manufacturing defects.

- In a 2007 paper, Scott, et al., [2] cited the very favorable plant experience that there had been no occurrences of PWSCC in Alloy 600 weldments in France where the weldment had been subjected to a PWHT.

- Bartsch, et al., reported in 2003 that no PWSCC had been detected in the CRDM nozzles at Obrigheim, despite their having been made of Alloy 600 and being welded with Alloy 82/182 J-groove welds similar to those that had cracked at plants in other countries and for which PWHT was not applied subsequent to nozzle installation [8]. The freedom from cracking was attributed to the reactor vessel head having been PWHT after installation of the CRDM nozzles.

- Papers by Bibollet, et al., [9] and Verdière, et al. [10] in 2006 describe the occurrence of PWSCC in a few steam generator divider plates in France. A main observation regarding this PWSCC is that it has essentially all been associated with the divider plate to stub weld, which is the only weld in the divider plate assembly that was not given a PWHT. An exception is for one case where PWSCC occurred as a result of cold work due to impacts by a large loose part.

Based on the favorable test data and plant experience for Alloy 600/82/182 components exposed to PWHT, it is unlikely that PWSCC initiation of a flaw of engineering size (i.e. depth of 1 or 2 millimeters) has occurred on the Alloy 82/182 full-penetration branch pipe connection welds at Palisades. Eight of these nine locations operate at reactor cold-leg temperature, and the other at reactor hot-leg temperature. None of them operates at pressurizer temperature. Because of the relatively large effect of operating temperature on PWSCC susceptibility (e.g., [11]), the operating temperatures applicable to these components add confidence to the conclusion that PWSCC initiation is unlikely to have occurred.

In the case of the single nozzle operating at reactor hot-leg temperature, detailed weld residual stress calculations have been performed simulating the effect of welding and the other sources of stress applicable to normal operating conditions. The finite-element simulation also considers the effect of the PWHT applied subsequent to installation of the nozzle. We understand that these results show a maximum tensile radial stress over the wetted surface of the nickel-base materials of 30.4 ksi, and a maximum tensile hoop stress over the wetted surface of the nickel-base materials of 24.3 ksi.

These calculated stresses are relatively modest compared to the surface stresses of 40 to 60 ksi that are typically predicted for components that have been reported to experience PWSCC. Laboratory work shows that the time to PWSCC initiation is sensitive to the surface stress level,

with the sensitivity typically described using an exponent on the stress in the range of 4 to 7 [12]. Furthermore, while it is considered that there is no firm "threshold" below which PWSCC will never occur, from a practical experience perspective a tensile stress of about 20 ksi (138 MPa) is considered a conservative lower bound estimate of a stress level below which PWSCC initiation will not occur during plant lifetimes [13]. (The 20 ksi threshold stress corresponds to about 80% of the lower bound yield strength for Alloy 600 materials at operating temperatures.)

Thus, the weld residual stress results specific to the single nozzle operating at reactor hot-leg temperature further supports plant experience and test data. Given that the calculated peak surface stress is reasonably close to the expected threshold for initiation during plant timescales and given the large demonstrated sensitivity of initiation time to surface stress, there is a low probability that PWSCC initiation of a flaw of engineering size has occurred on the single Alloy 82/182 full-penetration branch pipe connection weld at Palisades. Because of the cold-leg operating temperature of the nozzles located on the Palisades cold legs and because the weld residual stress is expected to be similar for the cold-leg locations, this conclusion extends to the eight cold-leg nozzles.

Benefit of PWHT for Resistance to PWSCC Growth Rate

In the unlikely case that crack initiation has occurred, the effect of PWHT on the resistance to PWSCC crack growth would become a factor. Section 3.1.8 of MRP-115 [14] discusses the effect of PWHT on the PWSCC crack growth rate. Cassagne et al. [15] reported that there was a beneficial effect of PWHT (by a factor between two and four) on CGRs measured for four weld metals with various carbon and silicon contents. Based primarily on these data, Le Hong et al. [16] recommend that crack growth rates be reduced by a factor of 2.0 for stress relieved specimens compared to otherwise similar as-received specimens.

The standard deterministic crack growth rate equation for Alloy 182 weld metal in MRP-115 [14] was developed on the basis of specimens that were not exposed to PWHT. Thus, calculations performed using the deterministic MRP-115 equation tends to result in conservatively high crack growth rates when applied to welds that were exposed to a PWHT. This level of conservatism can be considered in terms of the statistical variability in crack growth rates exhibited in MRP-115 across different test welds for equivalent temperature and stress conditions. The deterministic equation for Alloy 182 corresponds to the 75^{th} percentile of the log-normal distribution describing this material variability. The 95^{th} percentile of this distribution corresponds to a crack growth rate that is 1.77 times the 75^{th} percentile value. Thus, in effect the deterministic crack growth rate equation for Alloy 182 corresponds to a crack growth rate above the 95^{th} percentile of behavior if the effect of PWHT is credited.

Conclusions

In summary, there is a low probability that a PWSCC crack of engineering size has initiated on the Alloy 82/182 full-penetration branch pipe connection welds at Palisades. Confidence in this conclusion is provided by a combination of laboratory investigations, extensive plant experience, the favorable operating temperatures, and finite-element weld residual stress calculations specific to Palisades.

In the unlikely case that crack initiation were to occur, there is expected to be a significant beneficial effect of the PWHT on the crack growth rate. Furthermore, in the unlikely event that circumferential PWSCC were to occur in the Alloy 82/182 full-penetration weld, the significant

variability in residual stress with azimuthal position around the nozzle (for the geometry of a nozzle welded into a cylindrical pipe) would tend to drive crack growth through-wall along part of the circumference, tending to support detection of leakage prior to the possibility of unstable pipe rupture. The periodic visual examinations for evidence of leakage that are performed for each location per ASME Code Case N-722-1 [1], including during every refueling outage for the single hot-leg nozzle, are direct examinations of the metal surface that are capable of detecting small amounts of pressure boundary leakage. In the unlikely event that axial PWSCC were to occur in the Alloy 82/182 full-penetration weld and the adjoining Alloy 600 nozzle, the structural stability provided by the pipe branch connection geometry would also tend to support detection of leakage prior to the possibility of unstable pipe rupture.

Finally, the potential presence of weld repairs made during plant construction would not affect these conclusions. Any such weld repairs would have been made prior to PHWT being applied, and would be expected to extend over a relatively limited circumferential portion of the original weld. The PWHT would relax the residual stresses in the weld repair area, including the substantial relaxation expected at the surface exposed to primary coolant. Moreover, in the unlikely case that initiation occurred in the area of a weld repair, the weld repair would be an additional source of nonaxisymmetric crack loading that would tend to drive crack growth through-wall over a relatively local circumferential region, again tending to support detection of leakage prior to the possibility of unstable pipe rupture.

If you have any questions regarding this topic, please do not hesitate to contact me at (703) 657-7315 or gwhite@domeng.com, or Mr. John Broussard at (703) 657-7316 or jbroussard@domeng.com.

Sincerely,

Glenn A. White, P.E.
Principal Engineer

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ENCLOSURE

ENO Response to Question RAI-1.11

The files discussed in the ENO response to RAI-1.11 (repeated below) in Attachment 1 are provided in this Enclosure.

11. <u>NRC Information Request – Response to Question RAI-1.11</u>

Provide weld residual stresses for profiles chosen.

<u>ENO Response</u>

Requested stress outputs are included in the supporting file AI_SupportFiles.zip and are transmitted via the enclosure.

Radial stresses (SX) for the circumferential crack analysis were extracted at the element face centroid location for each element on the crack face. The outputs were saved to two files:

Crack6_COORD1.txt contains the element face centroid location.

STR_FieldOper_61.txt contains the stresses for each element on the crack face, where the radial component (SX) was used in the circumferential crack analysis.

Hoop stresses (S_hoop) for the axial crack analysis were output in a tabular format in terms of Radius, Height, S_hoop in the attached computer file Hoop_0.csv.

(Electronic Files Enclosed)