Exelon.
Nuclear

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Proprietary Information – Withhold From Public Disclosure Under 10 CFR 2.390

RS-12-075

10 CFR 50.55a

April 14, 2012

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

Quad Cities Nuclear Power Station, Unit 2
Renewed Facility Operating License No. DPR-30
NRC Docket No. 50-265

Subject: Response to Request for Additional Information Regarding Relief Request I4R-19, Additional Followup Question Regarding the Flaw Evaluation

References:

1) Letter from P. R. Simpson (Exelon Generation Company, LLC) to NRC, "Relief Request I4R-19 Associated with the Reactor Pressure Vessel Nozzle Repairs," dated April 6, 2012

2) Letter from D. M. Gullott (Exelon Generation Company, LLC) to NRC, "Response to Request for Additional Information Regarding Relief Request I4R-19 Associated with the Reactor Pressure Vessel Nozzle Repairs," dated April 12, 2012

3) Email from Joel Wiebe (NRC) to D. M. Gullott (Exelon Generation Company, LLC), "Quad Cities Unit 2 Relief Request I4R-19 – Additional Followup Question Regarding the Flaw Evaluation," dated April 14, 2012

In Reference 1, in accordance with 10 CFR 50.55a, "Codes and standards," paragraph (a)(3)(i), Exelon Generation Company, LLC (EGC), requested NRC approval of a relief request associated with the Fourth Inservice Inspection (ISI) Interval for Quad Cities Nuclear Power Station (QCNPS), Unit 2 . Note that the fourth interval of the QCNPS ISI program complies with the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Section XI, 1995 Edition with addenda through 1996.

During review of the subject relief request, the NRC concluded that additional information would be needed to complete their review. In Reference 2, EGC provided a portion of the requested information. In Reference 3, the NRC requested additional follow-up information to supplement the information provided in Reference 2 regarding the Flaw Evaluation. Specifically, the NRC requested the following:

<u>*Flaw Evaluation RAI-6*</u>

To support your reported operating stresses used in the flaw evaluation, provide Reference 5 of AREVA Document No. 32-9181076-001 for review.

The requested information is provided in Attachment 2 to this letter (i.e., Reference 5 of AREVA Document No. 32-9181076-001). As Attachment 2 contains information proprietary to AREVA NP Inc. (AREVA), it is supported by an affidavit (i.e., Attachment 1) signed by AREVA, the owner of the information. The affidavit sets forth the basis on which the information may be withheld from public disclosure by the NRC and addresses with specificity the considerations listed in paragraph (b)(4) of 10 CFR 2.390, "Public inspections, exemptions, requests for withholding." Accordingly, it is respectfully requested that the information which is proprietary to AREVA be withheld from public disclosure. A non-proprietary version of the information provided in Attachment 2 is provided in Attachment 3.

There are no regulatory commitments contained in this letter.

Should you have any questions concerning this letter, please contact Mr. Joseph A. Bauer at (630) 657-2804.

Respectfully,

David M. Gullott
Manager – Licensing
Exelon Generation Company, LLC

Attachment 1: AREVA NP Inc. Affidavit

Attachment 2: Reference 5 of AREVA Document No. 32-9181076-001 (Proprietary)

Attachment 3: Reference 5 of AREVA Document No. 32-9181076-001 (AREVA NP Document 32-9181208-000, "Quad Cities Unit 2 Instrument Nozzle Repair One Cycle Justification" (Non-Proprietary))

ATTACHMENT 1

Quad Cities Nuclear Power Station
Unit 2

AREVA NP Inc.

Affidavit

Supporting Response to Request for Additional Information
Flaw Evaluation RAI 6

Regarding Relief Request I4R-19
Associated with the Reactor Pressure Vessel Nozzle Repairs

AFFIDAVIT

COMMONWEALTH OF VIRGINIA)
) ss.
COUNTY OF CAMPBELL)

1. My name is Gayle F. Elliott. I am Manager, Product Licensing, for AREVA NP Inc. (AREVA NP) and as such I am authorized to execute this Affidavit.

2. I am familiar with the criteria applied by AREVA NP to determine whether certain AREVA NP information is proprietary. I am familiar with the policies established by AREVA NP to ensure the proper application of these criteria.

3. I am familiar with the AREVA NP information contained in Calculation Summary Sheet 32-9181074-000, "Quad Cities Unit 2 Instrument Nozzle Repair One Cycle Justification," dated April, 2012 and referred to herein as "Document." Information contained in this Document has been classified by AREVA NP as proprietary in accordance with the policies established by AREVA NP for the control and protection of proprietary and confidential information.

4. This Document contains information of a proprietary and confidential nature and is of the type customarily held in confidence by AREVA NP and not made available to the public. Based on my experience, I am aware that other companies regard information of the kind contained in this Document as proprietary and confidential.

5. This Document has been made available to the U.S. Nuclear Regulatory Commission in confidence with the request that the information contained in this Document be withheld from public disclosure. The request for withholding of proprietary information is made in accordance with 10 CFR 2.390. The information for which withholding from disclosure is

requested qualifies under 10 CFR 2.390(a)(4) "Trade secrets and commercial or financial information":

6. The following criteria are customarily applied by AREVA NP to determine whether information should be classified as proprietary:

(a) The information reveals details of AREVA NP's research and development plans and programs or their results.

(b) Use of the information by a competitor would permit the competitor to significantly reduce its expenditures, in time or resources, to design, produce, or market a similar product or service.

(c) The information includes test data or analytical techniques concerning a process, methodology, or component, the application of which results in a competitive advantage for AREVA NP.

(d) The information reveals certain distinguishing aspects of a process, methodology, or component, the exclusive use of which provides a competitive advantage for AREVA NP in product optimization or marketability.

(e) The information is vital to a competitive advantage held by AREVA NP, would be helpful to competitors to AREVA NP, and would likely cause substantial harm to the competitive position of AREVA NP.

The information in the Document is considered proprietary for the reasons set forth in paragraphs 6(b) and 6(c) above.

7. In accordance with AREVA NP's policies governing the protection and control of information, proprietary information contained in this Document has been made available, on a limited basis, to others outside AREVA NP only as required and under suitable agreement providing for nondisclosure and limited use of the information.

made available, on a limited basis, to others outside AREVA NP only as required and under suitable agreement providing for nondisclosure and limited use of the information.

8. AREVA NP policy requires that proprietary information be kept in a secured file or area and distributed on a need-to-know basis.

9. The foregoing statements are true and correct to the best of my knowledge, information, and belief.

SUBSCRIBED before me this 13th
day of April 2012.

Kathleen Ann Bennett
NOTARY PUBLIC, COMMONWEALTH OF VIRGINIA
MY COMMISSION EXPIRES: 8/31/15
Reg. # 110864

KATHLEEN ANN BENNETT
Notary Public
Commonwealth of Virginia
110864
My Commission Expires Aug 31, 2015

ATTACHMENT 3

Quad Cities Nuclear Power Station
Unit 2

Reference 5 of AREVA Document No. 32-9181076-001
(AREVA NP Document 32-9181208-000
"Quad Cities Unit 2 Instrument Nozzle Repair One Cycle Justification"
(Non-Proprietary))

Supporting Response to Request for Additional Information
Flaw Evaluation RAI 6

Regarding Relief Request I4R-19
Associated with the Reactor Pressure Vessel Nozzle Repairs

AREVA

CALCULATION SUMMARY SHEET (CSS)

Document No. 32 - 9181208 - 000 Safety Related: ☒ Yes ☐ No

Title Quad Cities Unit 2 Instrument Nozzle Repair One Cycle Justification (Non-Proprietary)

PURPOSE AND SUMMARY OF RESULTS:

The purpose of this calculation is to justify the operation, for one operating cycle, of Quad Cities Unit 2 with a repaired Instrument Nozzle.

The purpose of Appendix A is to provide the stresses used in the fracture mechanics analysis relevant to the repaired nozzle.

Summary of Results:

The Instrument Nozzle repair satisfies the applicable ASME Code requirements for one operating cycle.

THE FOLLOWING COMPUTER CODES HAVE BEEN USED IN THIS DOCUMENT:

CODE/VERSION/REV	CODE/VERSION/REV
ANSYS 13.0	

THE DOCUMENT CONTAINS ASSUMPTIONS THAT SHALL BE VERIFIED PRIOR TO USE

☐ YES

☒ NO

Review Method: ☒ Design Review (Detailed Check)
☐ Alternate Calculation

Signature Block

Name and Title (printed or typed)	Signature	P/R/A and LP/LR	Date	Pages/Sections Prepared/Reviewed/Approved
H.T. Harrison Advisory Engineer	[signature]	LP	4/13/2012	All except Section 4.1, Section 6.0 and Appendix A
Hasan Charkas / K. Wang Engineer IV / Eng IV	[signature]	P	4/13/2012 4/13/12	Section 4.1
Martin Kolar Engineer IV	[signature]	P	04/13/12	Section 6.0 and Appendix A
Don Kim Supervisory Engineer	[signature]	LR	4/13/12	All except Section 4.1, Section 6.0 and Appendix A
Matthew Snyder Advisory Engineer	[signature]	R	4/13/2012	Section 4.1
Kaihong Wang Engineer IV	[signature]	R	4/13/12	Section 6.0 and Appendix A
Tim Wiger Manager	[signature]	A	4/13/12	All

Note: P/R/A designates Preparer (P), Reviewer (R), Approver (A);
LP/LR designates Lead Preparer (LP), Lead Reviewer (LR)

Project Manager Approval of Customer References (N/A if not applicable)

Name (printed or typed)	Title (printed or typed)	Signature	Date
N/A			

Signatures
(continued)

Mentoring Information (not required per 0402-01)

Name (printed or typed)	Title (printed or typed)	Mentor to: (P/R)	Signature	Date
N/A				

Record of Revision

Revision No.	Pages/Sections/Paragraphs Changed	Brief Description / Change Authorization
000	All	Original release

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1.0 INTRODUCTION

A [ ] Instrument Nozzle, Nozzle [ ], was found to be leaking at the Quad Cities Unit 2 plant. A [ ] repair is being performed. This calculation is to justify plant operation for one cycle with the repaired nozzle. A subsequent analysis will demonstrate acceptability of the repaired nozzle for further operation.

Nozzle [ ] is located in shell [ ] at the [ ] elevation. The original nozzle is connected to the vessel wall with a partial penetration weld made on the inside of the vessel. The repair utilized the half-nozzle approach to modify the original nozzle. The [ ] approach replaces the outer portion of the existing nozzle with a new [ ] nozzle and establishes a new pressure boundary on the outside surface of the RV shell with a partial penetration J-groove weld in a new [ ] weld pad buildup. A remnant of the original nozzle remains in place, along with the original J-groove weld. The original [ ] nozzle, stainless steel safe end, and [ ] NPS stainless steel pipe connecting to a stainless steel reducing coupling is replaced with an [ ] nozzle connected to a stainless steel reducing coupling.

2.0 METHODOLOGY

The following steps will be performed to demonstrate the acceptability of the [ ] repair:

- Acceptability of the weld configuration with respect to ASME Code requirements will be determined.
- Primary stresses will be calculated and compared to ASME Code stress criteria.
- A qualitative assessment of the secondary and peak stresses will be made, with regard to a single cycle of operation.

3.0 ASSUMPTION

There are no major assumptions. Minor assumptions are identified in the calculations as appropriate.

4.0 STRESS ANALYSIS

4.1 Primary Stresses

The purpose of this section is to verify the primary stress requirements for the design shown in ref. [1]. The verification is based on the requirements of ref. [2] and as specified in ref. [3]. More specifically the following are included in this verification:

1. Weld Pad ([ ])
2. Partial penetration J-groove weld ([ ])
3. New nozzle ([ ])

4. Weld between new nozzle and coupling ([ ])

4.1.1 Loading

The external mechanical loadings are specified in revision 000 and revision 001 of ref. [4]. The maximum internal pressure of [ ] corresponds to testing condition (Hydrostatic Pressure) specified in ref. [4]. Based on ref. [4], the external loads are applied at node 3, which is the centerline of nozzle to safe end weld. This node is located [ ] from the reactor vessel base metal internal diameter as shown in ref. [5]. These loads are given in global coordinates of the reactor vessel: X is north, Y vertical up, and Z is east. The nozzle is located at [ ] azimuth, ref. [4]. Accordingly, the loads need to be transformed to the local coordinate system of the nozzle at which x' is axial along the axis of the nozzle, y' is vertical up and z' is horizontal.

The load combinations are documented in revision 000 and revision 001 of ref. [4]. For Level D the loads from [ ] are added together to be used for faulted condition.

Service Load 1: [ ] (used for Level A)
Service Load 2: [ ] (used for Level B)
Service Load 3: [ ] (used for Level C)
Service Load 4: [ ] (used for Level D)

Table 4-1 shows the enveloping loads for each of the service loading conditions in the global coordinate system of the reactor vessel. These loads are calculated assuming conservatively that they are all positive and that all the load components pertaining to the same direction are added together (i.e. all loads and moment components are taken in an absolute sense).

The nozzle is located at the [ ]. Accordingly, the following equations are used to transform the loads from the global coordinates to the local coordinate of the nozzle:

Fx'= FX*cos([ ])+FZ*cos([ ])

Fy'= FY

Fz'= FX*cos([ ])+FZ*cos([ ])

Mx'= MX*cos([ ])+MZ*cos([ ])

My'= MY

Mz'= MX*cos([ ])+MZ*cos([ ])

Where FX, FY, FZ, MX, MY, MZ are load components in the global coordinate system of the Reactor Vessel.

Fx', Fy', Fz', Mx', My', Mz' are load components in the nozzle local coordinate system where x' is axial through the axis of the nozzle, y' is vertical up and z' is horizontal. Table 4-2 shows the external load components in the local coordinate system of the nozzle.

Table 4-1: Load Components in the Global Coordinate System of the Reactor Vessel

Service Load	FX (lbs)	FY (lbs)	FZ (lbs)	MX (lb-in)	MY (lb-in)	MZ (lb-in)
Service Level A						
Service Level B						
Service Level C						
Service Level D						

Table 4-2: Load Components in the Local Coordinate System of the Nozzle

Service Load	Fx' (lbs)	Fy' (lbs)	Fz'(lbs)	Mx' (lb-in)	My' (lb-in)	Mz' (lb-in)
Service Level A						
Service Level B						
Service Level C						
Service Level D						

Loads listed in Table 4-2 are used to calculate stresses at locations of interest using the following equations:

Axial stress: $\sigma_x = \frac{M_b * c}{I} + \frac{F_x}{A} + \frac{F_s * d_{arm} * c}{I} + \frac{P * R_i^2}{R_o^2 - R_i^2}$

Circumferential stress: $\sigma_y = \frac{P * R_i^2}{R_o^2 - R_i^2}(1 + \frac{R_o^2}{c^2})$

Radial stress: $\sigma_z = \frac{-P * R_i^2}{R_o^2 - R_i^2}(1 - \frac{R_o^2}{c^2})$

Shear stress: $\tau_{xy} = \frac{M_x * c}{J} + \frac{F_s}{A}$

Where, P = design pressure, psi

R_i = Cross section inner radius, in.

R_o = Cross section outer radius, in.

M_b = bending moment, in-lbs = $\sqrt{(M_y')^2 + (M_z')^2}$

M_x = torsional moment, in-lbs

F_x = axial load, lbs

F_s = shear load, lbs = $\sqrt{(F_y')^2 + (F_z')^2}$

d_{arm} = moment arm distance, in.

c = distance from centroid to section at which stresses are computed, in.

$I = (\pi/4)(R_o^2 - R_i^2)$, area moment of inertia, in^4.

J = I/2, polar moment of inertia, in^4.

A = cross sectional area, in^2.

Stress intensity (SI) is calculated by finding the principal stresses. Then, SI=S1-S3, where S1 is the maximum principal stress, S3 is the minimum principal stress.

4.1.2 Calculations

For the primary stress calculation, the level D loads are used conservatively to calculate stresses and is compared to the allowable stress values for level A (i.e. S_m for P_m, 1.5 for P_m+P_b). The allowable stress intensity S_m for [ ] and [ ] at [ ] is 23.3 ksi, ref. [2]. The primary stresses are calculated at the inner radius, mean radius and outer radius. The mean radius location is used to check the primary membrane limit. The maximum between the outer and inner radii locations is used to check the primary membrane plus bending limit. The mean radius is calculated using the following equation $(R_o+R_i)/2$.

4.1.2.1 Reinforcement Area Required

The maximum overbore diameter in the reactor vessel due to this repair is [ ] in. This overbore is small compared to the available thickness of the reactor vessel. Therefore, this requirement is satisfied.

4.1.2.2 Weld Pad

At the centerline of the weld pad the following section properties are calculated:

Dw_o = ([ ])/2 = [ ] in. = outer diameter at the centerline of the weld pad, thus Rw_o = [ ] in. (ref. [1])

Dw_i = [ ] = [ ] in. = maximum inner diameter for the weld pad, thus Rw_i = [ ] in. (ref. [1])

Moment of Inertia of the cross section at the Centerline of weld pad: $\frac{\pi(Dw_o^4 - Dw_i^4)}{64}$ = [ ] in^4

Area of the cross section at the Centerline of weld pad: $\frac{\pi(Dw_o^2 - Dw_i^2)}{4}$ = [ ] in^2

Polar moment of inertia at the Centerline of weld pad: $\frac{\pi(Dw_o^4 - Dw_i^4)}{32}$ = [ ] in^4

Distance between the location of loads applied to centerline of weld pad considering reactor vessel thickness ([ ] in) and weld pad thickness ([ ] in) is ([ ]) = [ ] in. Therefore, d_{arm} = [ ] in. The [ ] in is the distance between location of loads application to the reactor vessel base metal, ref. [5]

All stress calculations are documented in MathCAD sheet "Primary Stress Calculation_WeldPad.xmcd".

Stress intensity at Rw_o = [ ] ksi < 1.5 (23.3) = 34.95 ksi, Ok.

Stress intensity at Rw_m = [ ] ksi < 23.3 ksi, Ok.

Stress intensity at Rw_i = [ ] ksi < 34.95 ksi, Ok.

The primary stress requirements for the weld pad are satisfied.

4.1.2.3 New Nozzle

The following section properties are for the new nozzle:

Dn_o = [ ] in, outer diameter of the new nozzle near the weld pad, R_o = [ ] in. (ref. [1])

Dn_i = [ ] in, inner diameter of the new nozzle, R_i = [ ] in. (ref. [6])

Moment of Inertia = [ ] in^4

Area of the cross-section = [ ] in^2

Polar moment of inertia = [ ] in^4

Minimum required thickness:

$$t = \frac{PR}{S_m - 0.5} = \left[\quad \right] \text{in.}$$

Available thickness using the minimum thickness of the nozzle (ref. [6]) is ([ ] in. Therefore, the thickness requirement is met.

All stress calculations are documented in MathCAD sheet "Primary Stress Calculation_NewNozzle.xmcd".

Stress intensity at Rn_o = [ ] ksi < 1.5 (23.3) = 34.95 ksi, Ok.

Stress intensity at Rn_m = [ ] ksi < 23.3 ksi, Ok.

Stress intensity at Rn_i = [ ] ksi < 34.95 ksi, Ok.

The primary stress requirements for the replacement nozzle are satisfied.

4.1.2.4 Weld between New Nozzle and Weld Pad

This weld needs to satisfy the minimum dimension requirements of FIG. NB-4244(d)-1e of ref. [2].

For this evaluation, the thickest section of the nozzle before machining is used conservatively. That is [ ] in. The available length is [ ] in.; therefore, this requirement is satisfied.

Total weld length is [ ] in > 1.5 t_n = 0.748 in. This requirement is satisfied.

Pure shear stress due to pressure:

Pressure area = $\frac{\pi(d^2)}{4}$ = [ ] = [ ] in^2, where [ ] in is the nozzle OD at the J-groove weld.

Force as a result of pressure = [ ] lbs.

Total axial force = [ ] lbs.

Shear area = [ ] = [ ] in^2

Shear stress due to pressure and piping axial load = [ ] psi

Pure shear stress due to piping torsional load:

R_o = ([ ] in

R_i = [ ] in

J = $\pi(R_o^4 - R_i^4)/$ = [ ] in^4

Shear stress = [ ] psi

Therefore total shear stress = [ ]

Using the same R_o and R_i for the weld throat cross section, other stress calculations are documented in MathCAD sheet "Primary Stress Calculation_JWeld.xmcd".

Stress intensity at Rn_o = [ ] Ok.

Stress intensity at Rn_m = [ ] Ok.

Stress intensity at Rn_i = [ ] Ok.

The primary stress requirements for the J-groove weld are satisfied.

4.1.2.5 Weld between New Nozzle and Coupling

This weld needs to satisfy the minimum dimension requirements of FIG. 1(3) of ref. [7].

$t_c$min = [ ] = [ ] in. The available weld throat thickness is [ ] in. Therefore this requirement is satisfied.

Pressure area = [ ] in is the nozzle OD at the weld.

Force as a result of pressure = [ ] lbs.

Shear area = [ ] (note that 0.25 is a conservative dimension)

Shear stress = [ ] psi.

Similarly, pure shear stress due to piping torsional load:

R_o = [ ] in

R_i = [ ] in

J = [ ] in^4

Shear stress = [ ] psi

Therefore total shear stress = [ ] , ok.

Distance between the location of loads applied to centerline of weld is [ ] in. This distance is calculated as follows:

Distance between OD of Reactor Vessel to weld is [ ] in. (ref. [1])

Distance between OD of Reactor Vessel to location of load application is [ ] (half of weld pad thickness) = [ ] in.

Therefore, d_{arm} for this weld is [ ] in.

All stress calculations are documented in MathCAD sheet "Primary Stress Calculation_FilletWeld.xmcd".

Stress intensity at Rnc_o = [ ] ksi < 1.5 (23.3) = 34.95 ksi, Ok.

Stress intensity at Rnc_m = [ ] ksi < 23.3 ksi, Ok.

Stress intensity at Rnc_i = [ ] ksi < 34.95 ksi, Ok.

4.2 Interference Check

There is a minimum [ ] gap between the end of the original nozzle remnant and the replacement nozzle. A conservative calculation will be done to verify that this gap is sufficient to accommodate thermal growth, ΔL.

Original Nozzle material: [ ]
Nozzle thermal expansion coefficient: $\alpha = 7.7\text{x}10^{-6}$ °F^{-1} (rev. 000 of ref. [4])
Nozzle length: L = [ ] (use full thickness of shell and cladding), ref. [6]
Nozzle temperature: T = [ ] (use operating temperature), (rev. 000 of ref. [4])

ΔL = L* α* ΔT = ([ ])*(7.7x10^{-6})*([ ] -70) = [ ]

The nozzle thermal growth of [ ] in. is less than the minimum gap of [ ] in., so the gap is sufficient to prevent interference.

4.3 Secondary and Peak Stresses

The ASME Code places a limit on secondary stresses in order to prevent failure by excessive distortion caused by the repeated application of loads. The Code also limits peak stresses, through the cumulative fatigue usage factor, in order to prevent failure by fatigue.

A fatigue usage factor of [ ] for the [ ] instrument nozzle was calculated in the original stress report (rev. 000 of ref. [4]) considering heatup, cooldown and pressure test transients. Additional fatigue usage was calculated in a later analysis (rev. 000 of ref. [4]) which considered additional transients and an increased number of cycles. The results of this analysis increased the usage factor from the original stress report by [ ] due to an increase of [ ] in the number of heatup and cooldown cycles. [ ] cycles of the SCRAM transient added an additional [ ] to the usage factor. The SRVB transient was also included; fatigue usage for this transient was calculated as [ ] for 12 cycles. Design cycles for this transient are now [ ], so the additional usage for SRVB transient is [ ]. The result is a cumulative usage factor of [ ] for the 40 year design life of the [ ] instrument nozzle. This corresponds to fatigue usage of [ ] during a single [ ] fuel cycle.

The repair weld and replacement nozzle are subject to the same transients as the original design. The geometries are similar; however the original weld was on the ID of the vessel. The repair weld is located on the OD of the vessel, which is not exposed to reactor water or steam, and would therefore experience less severe transient thermal stresses. It can be concluded that the single cycle fatigue usage for the repair is conservatively estimated by the original nozzle single cycle fatigue usage of [ ].

The primary plus secondary stress intensity range calculated for the original nozzle was [ ] ksi, with an allowable value of 70 ksi. For the reasons given above this is also considered to be a conservative estimate for the primary plus secondary stress intensity range of the repair nozzle.

4.4 Corrosion Evaluation

Corrosion effects have been evaluated in ref. [8] and have an insignificant effect on the stress calculations.

5.0 ASME CODE RECONCILIATION

The original code of construction for Quad Cities Unit 2 is:

ASME Section III, 1965 edition with Summer 65 Addenda.

The code specified for the nozzle repair is:

ASME Section III, 2007 edition with 2008 Addenda.

The stress criteria are the same in both Code editions with the following exceptions:

A. In Table N-413 of the original Construction Code, the bending stress due to a through-wall thermal gradient is classified as a peak stress. In Table NB-3217-1 of the 2007 edition of ASME Section III, this stress, the equivalent linear stress, is classified as a secondary stress and therefore it must be included in the calculation of the primary plus secondary stress intensity range per NB-3222.2. The criteria of the 2007 edition is more restrictive than that of the 1965 edition, therefore satisfying the 2007 edition criteria ensures satisfaction of the 1965 edition criteria.

B. The procedure for a detailed fatigue analysis in the 2007 edition of ASME Section III includes a provision for adjustment of the calculated alternating stress intensity by the ratio of the modulus of elasticity on the design fatigue curve to the modulus of elasticity used in the analysis (NB-3222.4(e)(4)). The 1965 edition of ASME Section III does not require this adjustment. The adjustment results in an increase in the alternating stress intensity used in the fatigue analysis. Therefore the criteria of the 2007 edition is more restrictive than that of the 1965 edition, so satisfying the 2007 edition criteria ensures satisfaction of the 1965 edition criteria.

6.0 COMPUTER AND SOFTWARE USAGE

The EASI List computer program ANSYS Release 13.0 (ref. [9]) is used to generate data in Appendix A of this document.

The list of ANSYS verification run output files is found in Table 6-2. The verification runs were submitted for the following element types used in the analysis: PLANE183, SURF153, PLANE77, CONTA172, TARGE169 and SURF151. Error notices for ANSYS Release 13.0 are reviewed and none apply for this analysis.

For the files in Table 6-1:

- Computer hardware used: Dell Precision T5400 (Service Tag #: BYZS7J1) with Intel® Xeon® CPU E5420 @ 2.49GHz, 3.25GB of RAM and Operating System is Windows XP Professional Version 2002 Service Pack 3. The files were run by preparer of Section 4.1.

For the files in Table 6-2:

- Computer hardware used: Dell Precision T5400 (Service Tag #: G238PJ1) with Intel® Xeon® CPU E5420 @ 2.50GHz, 3.25GB of RAM and Operating System is Microsoft Windows XP Professional Version 2002 Service Pack 3. Test run by the preparer of Appendix A. Date of tests: April 11, 2012

- Acceptability: Results shown in files VM38.out, VM147.out, VM211.out and VM227.out show that the test runs are acceptable.

6.1 Computer Output Files

The computer output files used in the main body of this document are located in ColdStor at: /cold/41304/32-9181074-000/official and shown in Table 6-1. The computer output files used in Appendix A of this document are located at /cold/41304/32-9181074-000/official/AppendixA and shown in Table 6-2.

Table 6-1: Calculation Computer Output Files

Name	Size	Date/Time Modified	CRC
Primary Stress Calculation_FilletWeld.xmcd	145267	Apr 13 2012 17:28:05	38427
Primary Stress Calculation_JWeld.xmcd	145965	Apr 13 2012 17:29:48	31182
Primary Stress Calculation_NewNozzle.xmcd	145028	Apr 13 2012 17:30:34	12919
Primary Stress Calculation_WeldPad.xmcd	146368	Apr 13 2012 16:42:32	54870

Table 6-2: Appendix A Computer Output Files

File Name	Date	Time	Size
.../BlowDown			
BlowDown_dT.mac	4/8/2012	8:54 PM	139
BlowDown_dT.out	4/10/2012	12:48 PM	30,315
BlowDown_stRun.mac	4/10/2012	1:01 PM	1,304
BlowDown_stRun.out	4/10/2012	1:01 PM	57,503
BlowDown_thRun.mac	4/10/2012	12:37 PM	1,094
BlowDown_thRun.out	4/10/2012	12:48 PM	90,151
BlowDown_ThStress.mac	4/10/2012	1:01 PM	1,329
BlowDown_ThStress.out	4/10/2012	1:02 PM	49,177
BlowDown_TrDef.mac	4/10/2012	12:37 PM	526

File Name	Date	Time	Size
.../DesignCase			
dCase_stRun.mac	4/11/2012	2:22 PM	1,243
dCase_stRun.out	4/11/2012	2:23 PM	29,645

File Name	Date	Time	Size
.../FractureData			
FractureData.mac	4/11/2012	5:48 PM	2,270
FractureData.out	4/11/2012	5:48 PM	246,860

File Name	Date	Time	Size
.../HeatCool			

HeatCool_dT.mac	4/8/2012	8:54 PM	139
HeatCool_dT.out	4/10/2012	1:54 PM	61,279
HeatCool_stRun.mac	4/10/2012	1:59 PM	1,424
HeatCool_stRun.out	4/10/2012	2:00 PM	72,921
HeatCool_thRun.mac	4/10/2012	12:39 PM	1,351
HeatCool_thRun.out	4/10/2012	1:54 PM	248,888
HeatCool_ThStress.mac	4/10/2012	1:59 PM	1,449
HeatCool_ThStress.out	4/10/2012	2:00 PM	61,324
HeatCool_TrDef.mac	4/10/2012	1:52 PM	984

File Name	Date	Time	Size
.../Scram			
Scram_dT.mac	4/8/2012	8:54 PM	139
Scram_dT.out	4/10/2012	10:37 AM	39,360
Scram_stRun.mac	4/10/2012	10:50 AM	1,193
Scram_stRun.out	4/10/2012	10:52 AM	42,710
Scram_thRun.mac	4/10/2012	10:33 AM	1,171
Scram_thRun.out	4/10/2012	10:37 AM	138,113
Scram_ThStress.mac	4/10/2012	10:50 AM	1,218
Scram_ThStress.out	4/10/2012	10:52 AM	37,655
Scram_trDef.mac	4/9/2012	10:17 AM	612
File Name	Date	Time	Size
.../StructuralModel			
QcStructuralModel.inp	4/9/2012	10:24 PM	1,084,851
StructuralModel.mac	4/8/2012	6:24 PM	559
StructuralModel.out	4/10/2012	10:34 AM	38,979

Table 6-2: Appendix A Computer Output Files (cont'd)

File Name	Date	Time	Size
.../ThermalModel			
QcThermalModel.inp	4/9/2012	2:27 PM	1,100,368
ThermalModel.mac	4/8/2012	6:24 PM	553
ThermalModel.out	4/10/2012	10:34 AM	40,036

File Name	Date	Time	Size
.../ToolboxFiles			
dTpostProcessing.mac	4/9/2012	10:31 AM	7,405
MaterialProperties.mac	4/10/2012	9:36 AM	7,609

File Name	Date	Time	Size
.../Verification			
vm147.inp	4/11/2012	5:25 PM	2,263
vm147.out	4/11/2012	5:29 PM	23,029
vm211.inp	4/11/2012	5:26 PM	8,534
vm211.out	4/11/2012	5:34 PM	223,632
vm227.inp	4/11/2012	5:26 PM	2,639
vm227.out	4/11/2012	5:34 PM	43,984
vm38.inp	4/11/2012	5:24 PM	5,183
vm38.out	4/11/2012	5:29 PM	76,847

7.0 CONCLUSION

The repair of nozzle [ ] is acceptable for one cycle of operation.

8.0 REFERENCES

1. AREVA Document 02-9180863E-002, Quad Cities 2 Inch Instrumentation Nozzle Replacement Implementation
2. ASME B&PV Code, Rules for Construction of Nuclear Facility Components, Division 1, 2007 Edition, including Addenda through 2008
3. AREVA Document 08-9180860-001, Modification of the N11-B Reactor Vessel at Quad Cities Unit 2
4. AREVA Document 38-9180939-002, Design Inputs for Quad Cities Unit 2 Reactor Vessel N11B Instrument Nozzle Modification
5. B&W drawing 02-151837E-00, 2" & 3" Nozzles
6. AREVA Document 02-9180866C-001, Quad Cities 2 Inch Instrumentation Replacement Nozzle
7. ASME B&PV Code Case N-405-1, Socket Welds, Section III, Division 1
8. AREVA Document # 51-9180975-000, Corrosion Evaluation of the Quad Cities Unit 2 N11-B Reactor Vessel Nozzle Modification
9. ANSYS FE Computer Code, Version 13.0, ANSYS Inc, Canonsburg PA
10. AREVA Document NPGD-TM-500 RevD, 'NPGMat', NPGD Material Properties Program User Manual (03-1985)

APPENDIX A: DATA FOR FRACTURE MECHANICS EVALUATION

A.1 Purpose

The purpose of this appendix is to describe the development of the finite element model, the loads applied to the FE model, and obtaining the stresses to support the fracture analysis, which is performed in separate document.

A.2 Methodology

The methodology consists of:

1. Building an axially symmetric FE model which includes a section of the RV base material, a section of the original nozzle, the original J-groove weld, cladding, the new replacement nozzle, weld build-up and weld between replacement nozzle and weld build-up. The radius of the RV in the FE axi-symmetrical model was magnified by 2.5 to account for difference in the membrane stresses between the sphere and cylinder of the same thickness and radius. There are two models with identical mesh: one for thermal analysis and one for structural analysis.

2. Applying the temperature and heat transfer coefficient of applicable transients (heat up, cool down, blow down and s.c.r.a.m. transients) on thermal FE model.

3. Defining the locations of interest for thermal gradients within the structure, obtaining values of thermal gradients for entire transient from runs on thermal model and selecting the time points for structural runs.

4. Applying pressure and temperature on the structural model for the time points identified in the previous step to obtain stresses resulting from pressure and thermal gradients. Submitting the structural run for identical time points but without applying pressure to obtain only the thermal stresses.

5. Defining one stress classification line across the thickness of the RV, away from discontinuity and listing component stresses to support fracture mechanics analysis.

A.3 Design Inputs

The geometry is based on reference [1]. The thickness of the weld build-up in FE model is approximate. The discrepancy between modeled and actual geometry is considered insignificant for the stresses in the section of the RV used for fracture mechanics analysis.

Material designations for the FE model can be found in Table A-1 and Figure A-1. Table A-1 is based on information available in references [1], [6] and rev. 000 of ref. [4]. The following engineering judgment was made: filler ERNiCrFe-7A as shown on drawing [1] has chemical composition equivalent to Alloy 690.

Table A-1: Material Designation

Item	Material Designation	Reference
Reactor Vessel, Base Material		[1]
Reactor Vessel, Cladding		Page 221 of rev. 000 of ref. [4]
Original Nozzle		[1]
Original J-groove Weld		[1]
Repair Nozzle		[6]
Repair Weld Build Up		Equivalent

Table A-2: Base Material, [ ]

Temp	E	μ	ρ	α	k	C
°F	psi		lb/in^3	in/in/°F	Btu/hr-in-°F	Btu/lb-°F
70						
100						
200						
300						
400						
500						
600						
650						
700						
Ref:	[2]	[2]	[10]	[2]	[2]	[2], [10]

Table A-3: Cladding, Type [ ]

Temp	E	μ	ρ	α	k	C
°F	psi		lb/in^3	in/in/°F	Btu/hr-in-°F	Btu/lb-°F
70						
100						
200						
300						
400						
500						
600						
650						
700						
Ref:	[2]	[2]	[10]	[2]	[2]	[2], [10]

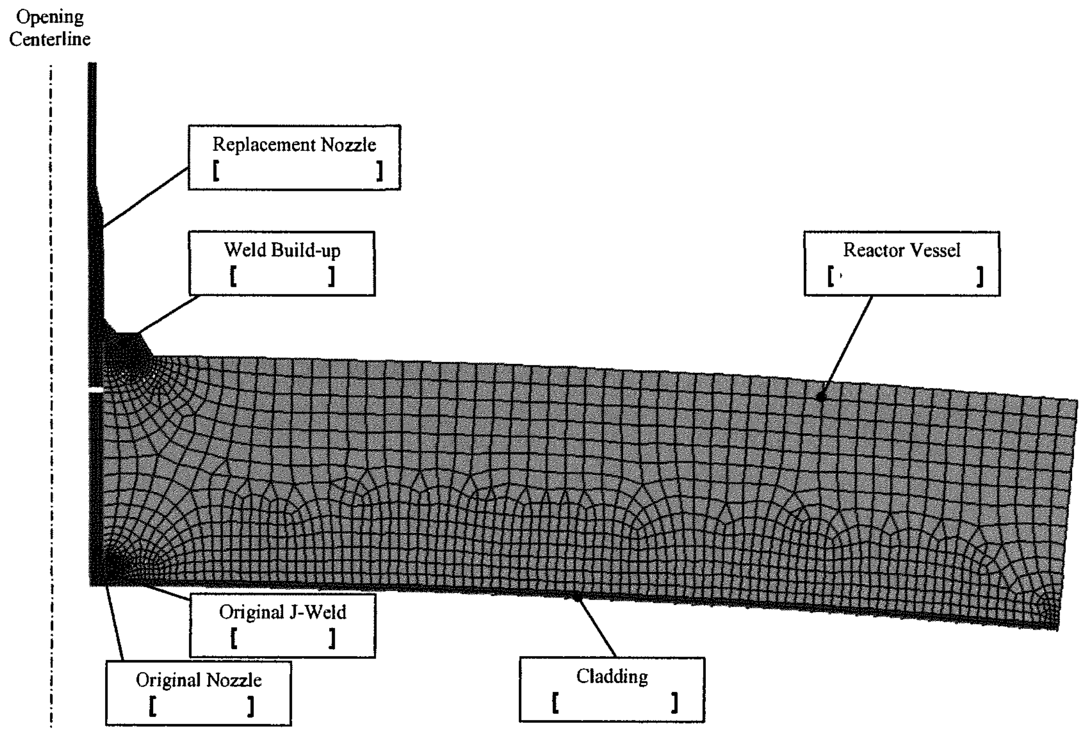
Table A-4: Original Nozzle and Weld, [ ]

Temp	E	μ	ρ	α	k	C
°F	psi		lb/in^3	in/in/°F	Btu/hr-in-°F	Btu/lb-°F
70						
100						
200						
300						
400						
500						
600						
650						
700						
Ref:	[2]	[2]	[10]	[2]	[2]	[2], [10]

Table A-5: Replacement Nozzle and Weld, [ ]

Temp	E	μ	ρ	α	k	C
°F	psi		lb/in^3	in/in/°F	Btu/hr-in-°F	Btu/lb-°F
70						
100						
200						
300						
400						
500						
600						
650						
700						
Ref:	[2]	[2]	[10]	[2]	[2]	[2], [10]

Figure A-1: FE Model, Material Designation



A.3.1 Thermal and Structural Loads

There are three transients considered in this appendix: Heat up/Cool Down, Blow Down and S.C.R.A.M. The time dependent pressure and temperature for each transient can be found in Table A-6 through Table A-8. The tables were developed based on information from pages 87, 122 and 196 of rev. 000 of ref. [4].

The heat transfer coefficient for vessel wetted surface: [ ], for nozzle wetted surface: [ ] (page 129 of rev. 000 of ref. [4]). The vessel and nozzle outer surfaces (dry) are considered insulated. The heat transfer coefficient of [ ] is considered appropriate for such condition. The outside ambient temperature is set to 120°F at all time points of transients listed in Table A-6 through Table A-8.

The post pressure test flush transient is not time dependent. The pressure is set to 0 psi, temperature of the RV shell is set 40°F higher than the body temperature of nozzles, welds, and cladding (page 122 of rev. 000 of ref. [4]).

Design conditions: pressure [ ] psig, temperature [ ] (page 210 of rev. 000 of ref. [4]).

Normal operating condition: pressure [ ] psig, temperature [ ] (page 210 of rev. 000 of ref. [4]).

Test condition: pressure [ ] psi (page 152 of rev. 000 of ref. [4]).

No external piping loads are considered in this appendix.

Table A-6: Heat Up / Cool Down Transient

Time [hour]	Temperature [°F]	Pressure [psi]
0.0003		
0.0836		
2.0800		
4.5400		
5.0000		
10.0000		
11.8600		
12.0267		
13.8267		
15.0000		

Figure A-2: Heat Up / Cool Down Transient

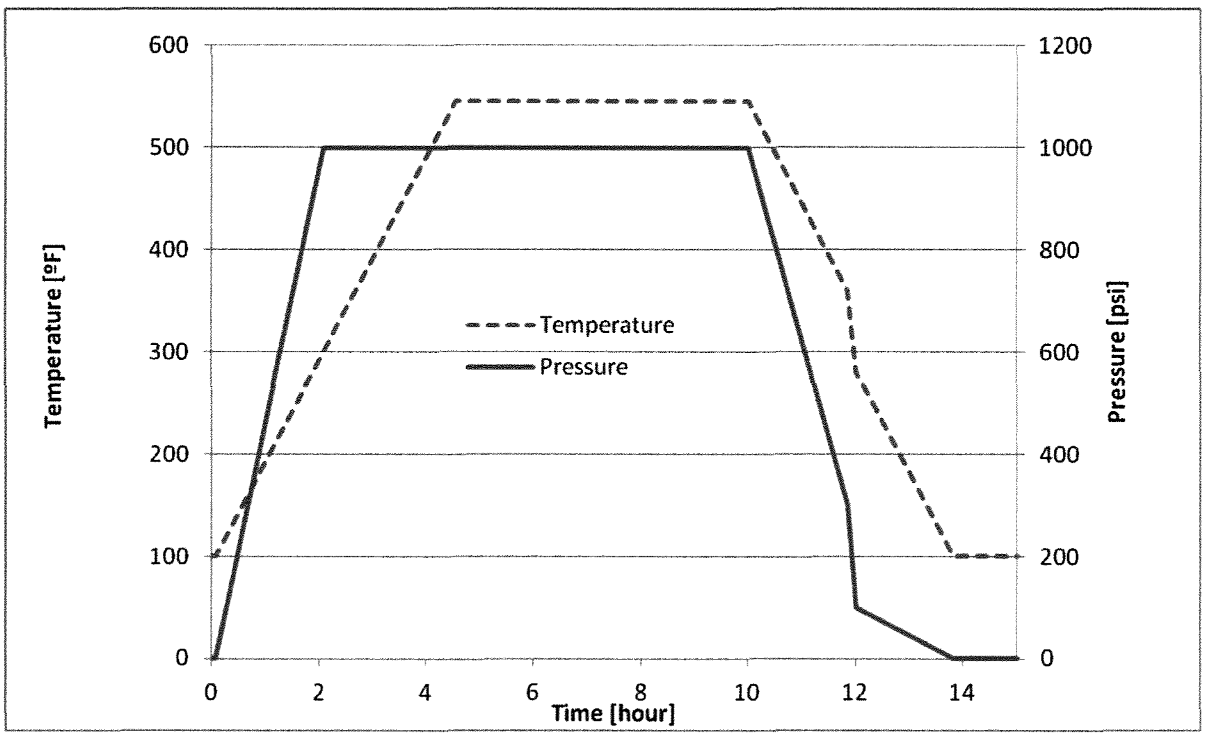


Table A-7: Blow Down Transient

Time [hour]	Temperature [°F]	Pressure [psi]
0.0003		
0.0836		
0.2503		
3.0003		
4.0000		

Figure A-3: Blow Down Transient

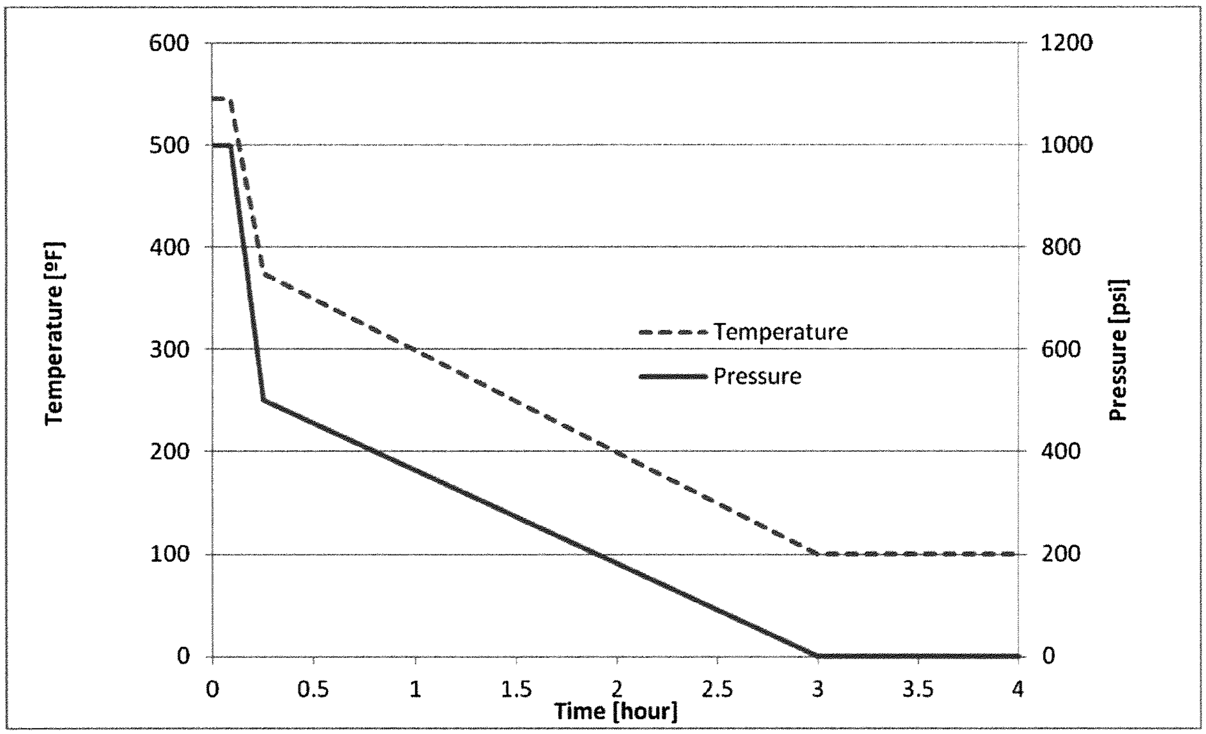
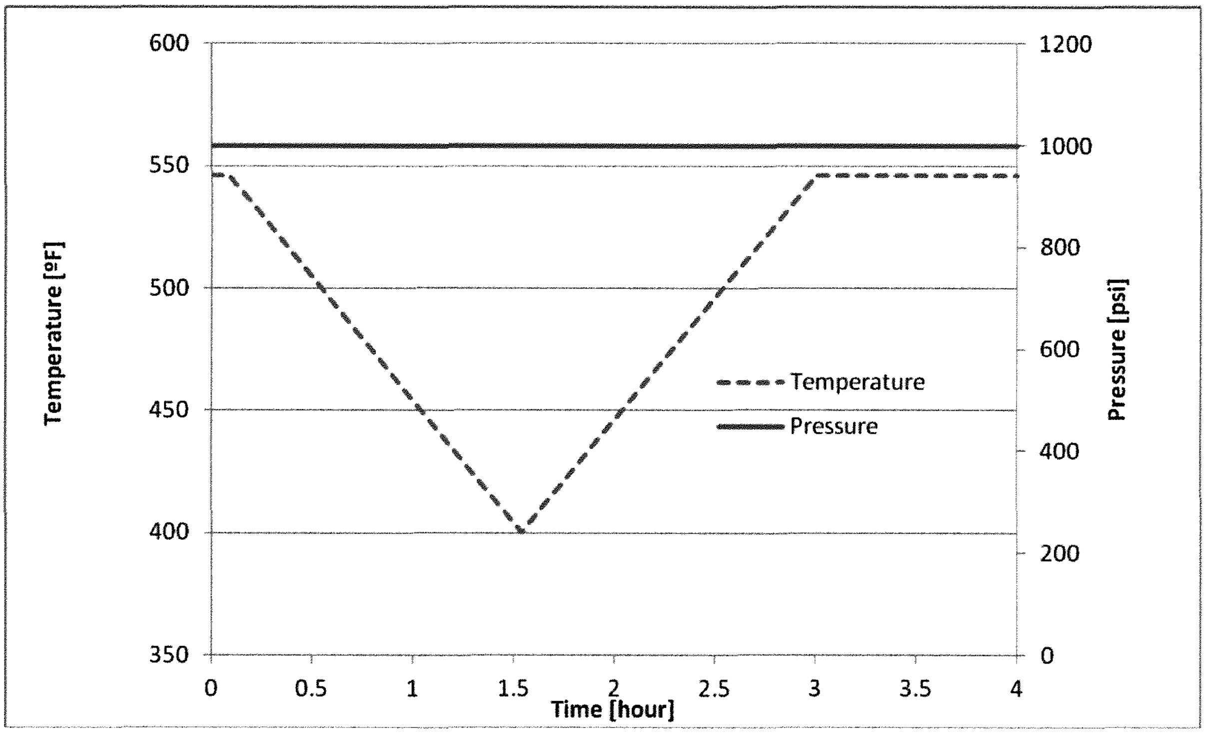


Table A-8: S.C.R.A.M. Transient

Time [hour]	Temperature [°F]	Pressure [psi]
0.0003		
0.0836		
1.5436		
3.0036		
3.0870		
4.0000		

Figure A-4: S.C.R.A.M. Transient



A.4 Calculations

Finite Element Model: The axially symmetric finite element model was built in ANSYS R13.0. The dimensions of the weld build-up are approximate. When the vessel is modeled being axially symmetric to the nozzle centerline, the inside radius of the reactor vessel must be increased in order to obtain the actual value of membrane stress in the hoop direction. The scaling factor was in this particular case 2.5. This value is based on experience with modeling similar geometries.

A.4.1 Thermal Analysis

The temperature listed in Table A-6 through Table A-8 was applied on all wetted surfaces. The outer surfaces of the replacement nozzle and the part of original nozzle inserted into the RV were thermally coupled with inner surface of the opening bore. Input data for transient thermal analyses are listed in Section A.3.1. The thermal runs are documented in computer output files with names '*_thRun.out'.

A.4.2 Structural Analysis

The time-points for structural runs were selected based on the pressure transients (listed in Table A-6 through Table A-8) and thermal gradients (temperature differences) between locations of interest (as listed in Table A-9). The approximate location for thermal gradients can be also found on Figure A-5. The thermal gradient listing can be found in computer files '*_dT.out'.

A list of time-points for which the structural runs were submitted can be found in Table A-10 through Table A-12. The pressure was applied on all wetted surfaces, including outer surface of original nozzle and inner surface of shell hole (also shown on Figure A-6). Nodes on the outer edge of the shell were fixed in hoop direction, the cap force was applied for all structural runs on the end of replacement nozzle. The body temperature corresponding to the time of the transient is applied to the structural model from result file from thermal transient analysis of Section A.4.1. The structural runs are documented in computer files '*_stRun.out'.

The computer output files '*_ThStress.out' document stress runs which do not have any pressure applied, therefore calculate pure thermal stresses.

Computer output file 'dCase_stRun.out' documents: the design case run (the pressure is in this case set to [ ] psi which is higher than actual design pressure of [ ] psi); the test case run (with pressure of [ ] psi); and 'post test flush' transient with 40°F difference between shell temperature and nozzle temperature.

Table A-9: Locations for Thermal Gradients

Item #	Location	Node #	Node #
1	Vessel Thickness	1858	2484
2	Original Weld to Vessel	1340	570
3	Original Weld to Original Nozzle	2070	8307
4	Replacement Nozzle to Build Up Weld	1701	2608
5	Replacement Nozzle Transition	1566	1706
6	Replacement Weld to Vessel	2610	1031
7	Build Up Weld to Vessel	2662	568

Figure A-5: Locations for Thermal Gradients

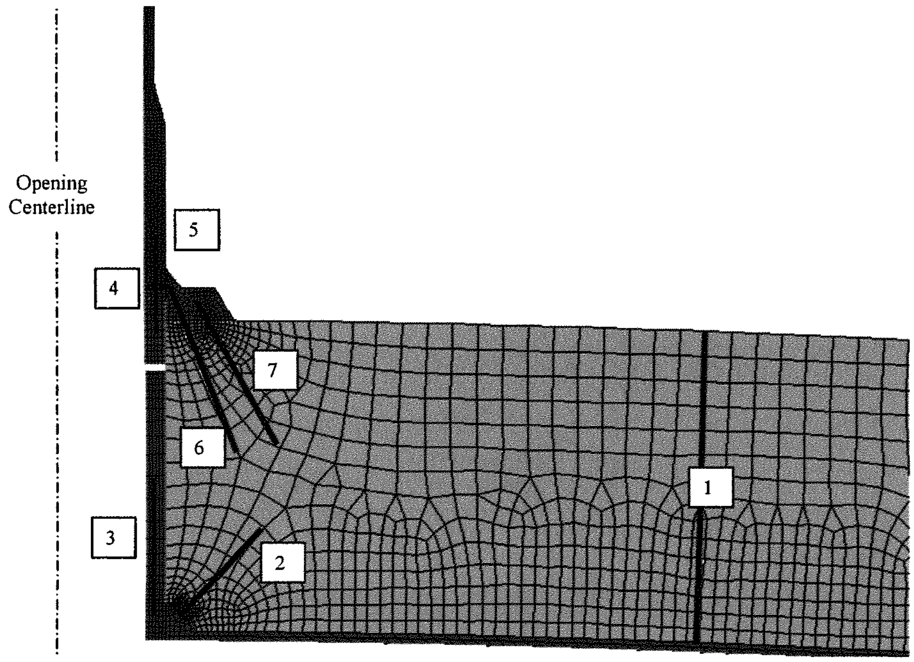


Figure A-6: FE Model, Crevice Boundary Conditions

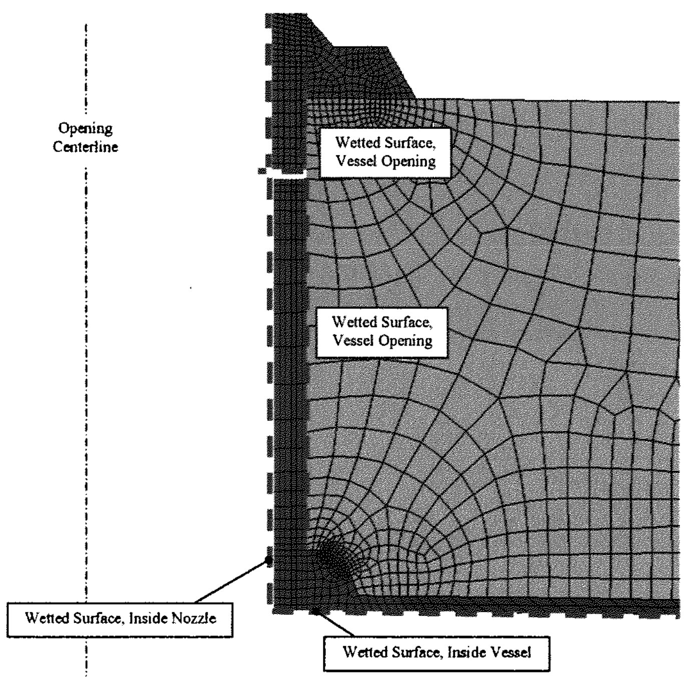


Table A-10: Stress Run, Heat Up / Cool Down Transient Time-points

#	time [hour]
1	0.0003
2	0.0836
3	2.0800
4	4.5400
5	5.0000
6	10.0000
7	11.6219
8	11.8600
9	12.0267
10	13.2724
11	13.5052
12	13.6216
13	13.8267
14	15.0000

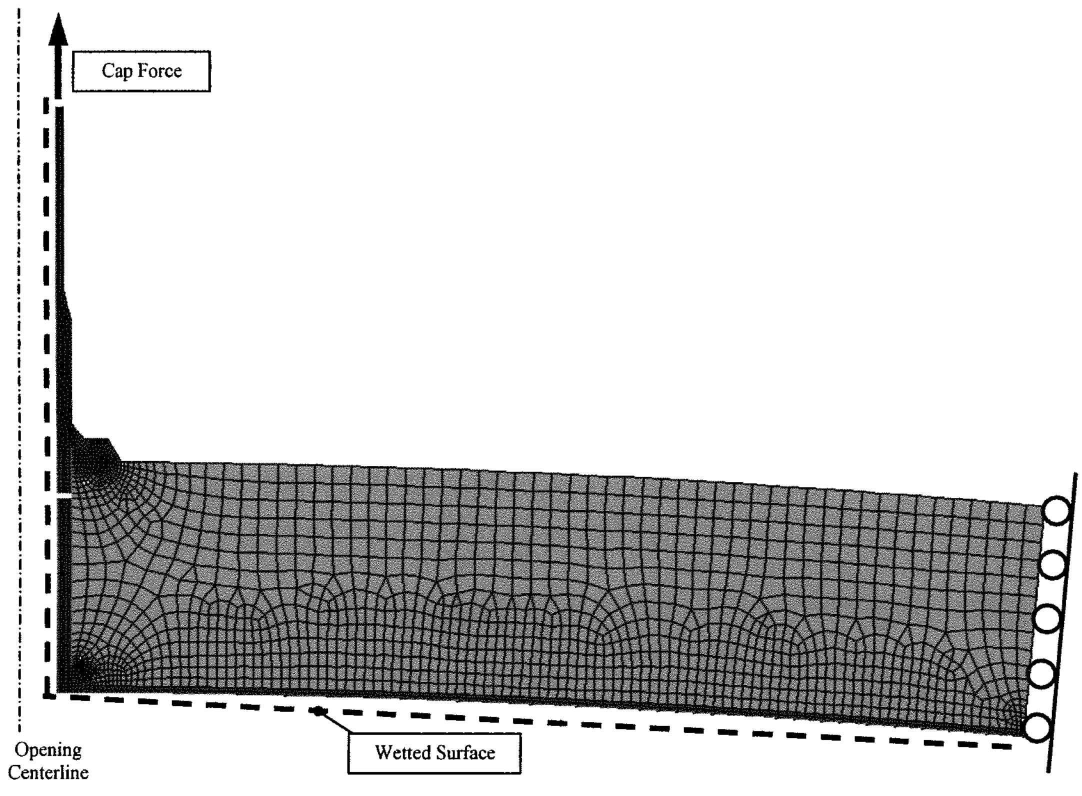
Table A-11: Stress Run, Blow Down Transient Time-points

#	time [hour]
1	0.0003
2	0.0836
3	0.2503
4	0.2670
5	0.2836
6	1.8571
7	2.1067
8	2.1899
9	3.0003
10	4.0000

Table A-12: Stress Run, S.C.R.A.M Transient Time-points

#	time [hour]
1	0.0003
2	0.0836
3	1.5436
4	3.0036
5	3.0870
6	4.0000

Figure A-7: Structural Run, Boundary Condition



A.5 Results

The computer output file 'FractureData.out' contains seven formatted tables. Each table lists the transient time points, metal temperature at the location of original weld, along with membrane and bending hoop and radial component stresses at the stress classification line away from the opening discontinuity. Refer to the header of each table (in file 'FractureData.out') for the origin of stresses. The 'thStRun' in the header of the table is the designation for thermal stresses only; 'StRun' refers to the 'thermal plus pressure' origin of reported stresses. Refer to Table A-13 and Table A-14 for the description of listing as it appears in output file 'FractureData.out'

Table A-13: Stress Origin Description

Table Header	Reported Stresses from the Structural Runs
../DesignCase/dCase_Run	Design Case, Pressure Case, Post Pressure Test Flush
../HeatCool/HC_StRun	Heat Up/Cool Down, Pressure + Thermal
../HeatCool/HC_thStRun	Heat Up/Cool Down, Thermal Only
../BlowDown/BD_StRun	Blow Down, Pressure + Thermal
../BlowDown/BD_thStRun	Blow Down, Thermal Only
../Scram/SC_StRun	Scram, Pressure + Thermal
../Scram/SC_thStRun	Scram, Thermal Only

Table A-14: Column Description

#	Item
1	table line number
2	time in the transient
3	temperature at location of original J-groove weld (shell material)
4	radial membrane stress
5	radial bending stress, shell inner surface
6	radial bending stress, shell outer surface
7	hoop membrane stress
8	hoop bending stress, shell inner surface
9	hoop bending stress, shell outer surface

Stress components are listed in the cylindrical coordinate system with the RV shell centerline being the axis of rotation, meaning hoop is the circumferential direction of entire RV shell and radial direction is radial direction of entire RV shell. Also refer to Figure A-8 for approximate location of the stress classification line 'FrPath'. Table A-15 through Table A-17 list the membrane hoop and bending hoop (at RV shell ID) stress components from selected stress runs (reference: output file 'FractureData.out').

Figure A-8: Results, Reported Location

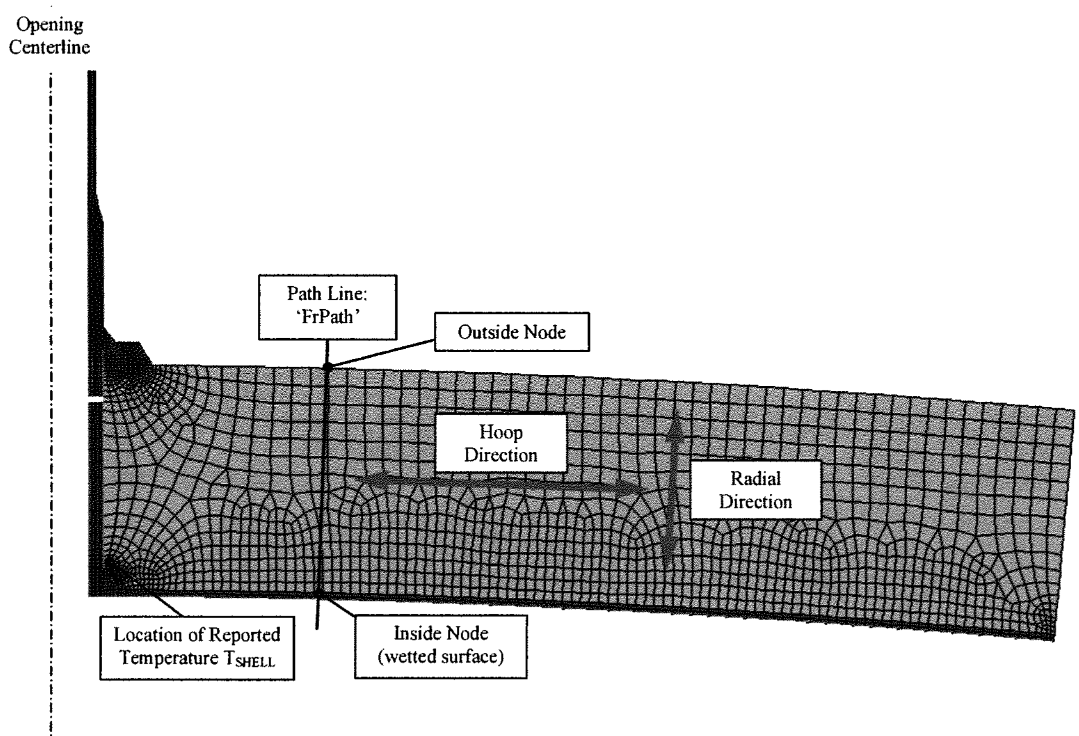


Table A-15: Heat Up / Cool Down Thermal + Pressure Stresses

[ ]

Table A-16: Blow Down Thermal + Pressure Stresses

[ ]

Table A-17: S.C.R.A.M. Thermal + Pressure Stresses

[ ]