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DOCKETED
USNRC

March 10, 2009 (3:02pm)

OFFICE OF SECRETARY
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ADJUDICATIONS STAFF

March 10, 2009

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Washington, D.C. 20555-0001

In the Matter of
Entergy Nuclear Vermont Yankee, LLC, and Entergy Nuclear Operations, Inc.
(Vermont Yankee Nuclear Power Station)
Docket No. 50-271-LR; ASLBP No. 06-849-03-LR

Gentlemen:

In accordance with the provisions of the Board's Partial Initial Decision (Ruling on Contentions 2A, 2B, 3, and 4), LBP-08-25, 68 N.R.C. ___ (Nov. 24, 2008), slip op. at 67, and the Board's Order (Clarifying Deadline for Filing New or Amended Contentions) (Mar. 9, 2009), Entergy has revised and issued its final calculations of record for the confirmatory environmentally assisted fatigue (CUF_{en}) analyses on the reactor pressure vessel core spray (CS) and recirculation outlet (RO) nozzles at the Vermont Yankee Nuclear Power Station. These revised analyses are presented in the following Structural Integrity Associates, Inc. (SIA) calculations: Calculation No. 0801038.302, Revision 1, "Stress Analysis of Reactor Core Spray Nozzle;" Calculation No. 0801038.303, Revision 1, "Fatigue Analysis of Reactor Core Spray Nozzle;" Calculation No. 0801038.304, Revision 1, "Design Inputs and Methodology for ASME Code Fatigue Usage Analysis of Reactor Recirculation Outlet Nozzle;" Calculation No. 0801038.305, Revision 1, "Stress Analysis of Reactor Recirculation Outlet Nozzle;" and Calculation No. 0801038.306, Revision 1, "Fatigue Analysis of Reactor Recirculation Outlet Nozzle." Calculation 0801038.301, Revision 0, "Design Inputs and Methodology for ASME Code Fatigue Usage Analysis of Reactor Core Spray Nozzle" has not been revised so that the version sent to the parties on January 8, 2009 remains the final calculation of record.

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Entergy is serving at this time electronic copies of those analyses on the parties to the above captioned proceeding. Hard copies are also being sent today by overnight mail to the NRC Staff, the New England Coalition and the Vermont Department of Public Service.

The methodology applied in the referenced CS and RO confirmatory analyses is in accordance with the approach used in the SIA calculations for the feedwater nozzle that were introduced into evidence in this proceeding, and contains no significantly different scientific or technical judgments from those used in the feedwater nozzle calculations. See Calculation 0801038.301 at 4, n.1 and Calculation 0801038.304 at 4, n.1.

As set forth in the referenced revised calculations, the limiting calculated CUF_{en}s for the CS and RO nozzles are less than unity and are therefore acceptable.

Sincerely,

Matias F. Travieso-Diaz

Matias F. Travieso-Diaz
Counsel for Entergy

cc: Service List

CERTIFICATE OF SERVICE

I hereby certify that copies of the foregoing letter were served on the persons listed below by deposit in the U.S. Mail, first class, postage prepaid; where indicated by an asterisk, by electronic mail; and where indicated by a double asterisk, by both overnight and electronic mail, this 10th day of March, 2009.

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Structural Integrity Associates, Inc.

CALCULATION PACKAGE

File No.: 0801038.302

Project No.: 0801038
Quality Program ☒ Nuclear ☐ Commercial

PROJECT NAME:
VY Confirmatory Analysis for the CS and RO Nozzles

CONTRACT NO.:
10163217 Amendment 5

CLIENT:
Entergy Nuclear Operations, Inc

PLANT:
Vermont Yankee Nuclear Power Station

CALCULATION TITLE:
Stress Analysis of Reactor Core Spray Nozzle

Document Revision	Affected Pages	Revision Description	Project Manager Approval Signature & Date	Preparer(s) & Checker(s) Signatures & Date
0	1 - 15 Computer Files	Initial issue.	Gary L. Stevens 01/06/09	Tyler D. Novotny 01/06/09 Jennifer D. Correa 01/06/09
1	1-3, 7-8, 11 Computer Files	Revised per summary contained in Section 1.1. Changes are marked with "revision bars" in right-hand margin.	Gary L. Stevens Gary L. Stevens 03/09/09	**Preparer**: Tyler Novotny Tyler D. Novotny 03/09/09 **Checker:** Tim Gilman Tim D. Gilman 03/09/09

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1.0 OBJECTIVE

The objective of this calculation package is to obtain stress distributions for the reactor pressure vessel (RPV) core spray (CS) nozzle at the Vermont Yankee Nuclear Power Station. ANSYS [1] thermal transient and pressure stress analyses are performed, along with calculation of stresses due to attached piping loads. The stress results will be used for a subsequent ASME Code, Section III NB-3200 [2] fatigue usage calculation.

1.1 Changes Made in Revision 1 of this Calculation

Description of changes made in Revision 1 of this calculation:

a. All changes marked throughout this calculation are editorial changes made to the text of the calculation package.

2.0 METHODOLOGY

The methodology to be used for this evaluation was established in a previous calculation package [3]. A previously developed finite element model (FEM) [3] of the CS nozzle is used to perform thermal and pressure stress analyses using ANSYS [1]. A thermal transient analysis is performed for each defined transient. Concurrent with the thermal transients are pressure and piping interface loads. For these loads, unit load analyses (based on finite element analysis for pressure and manual calculations for attached piping loads) are performed. All six components of the stress tensor are determined in the stress calculations.

The fatigue usage calculation and environmental fatigue usage analysis will be performed in a separate calculation package. That subsequent calculation will utilize the thermal and pressure stresses determined in this calculation, along with stresses due to attached piping loads provided in Table 3. The stresses due to pressure and the attached piping loads will be scaled based on the temperature and pressure magnitudes during each individual transient, and the location being analyzed. From the Reference [3] calculation, the FEM includes a factor of two on the modeled RPV radius to account for the 3-D effects of two intersecting cylinders at the nozzle blend radius location.

3.0 ASSUMPTIONS / DESIGN INPUTS

Assumptions and design inputs were previously established in Section 3.1 of the Reference [3] calculation.

4.0 CALCULATIONS

4.1 Finite Element Unit Pressure Stress Analysis

A uniform pressure of 1,000 psi was applied to the FEM along the inside surface of the CS nozzle and the RPV wall (Figure 1). A pressure load of 1,000 psi was used because it is easily scaled up or down to account for different pressures that occur during transients. In addition, a membrane stress "cap load" was applied to the modeled end of the piping attached to the core spray nozzle safe end. This membrane stress was calculated as follows:

$$P_{cap} = \frac{P * D_i^2}{D_o^2 - D_i^2}$$

where:

P = Pressure = 1,000 psi unit load
D_i = Inner Diameter at end of model = 9.834 in
D_o = Outer Diameter at end of model = 10.815 in

Therefore, the membrane stress is 4,774 psi. The calculated value is given a negative sign in order for it to exert tension on the piping end of the model. The FEM geometry input file is taken from the calculation that specifies the design and methodology inputs [3, input file *VY_CSN_GEOM.INP*]. The ANSYS input file *VY_16Q_P.INP*, as obtained from Appendix A of Reference [5], contains the pressure loading. Figure 1 shows the applied 1,000 psi internal pressure distribution. At the vessel wall, a symmetric boundary condition is applied. At the piping end of the model, axial displacement is coupled to simulate the effect of the attached piping that is not modeled. Figure 2 and Figure 3 show the boundary conditions.

4.2 Thermal Transient Stress Analysis

The FEM geometry input file is taken from the calculation that specifies the design and methodology inputs [3, file *VY_CSN_GEOM.INP*], and is used as input to the files in which the thermal transient and pressure stress analyses are performed.

For the thermal transient ANSYS analyses, previously defined thermal transients [3, Table 2] are evaluated, applying heat transfer coefficients [3, Tables 4 through Table 18], as appropriate, based on the flow rates for each individual transient.

Each thermal transient is evaluated in ANSYS to determine the resulting temperature distributions. The thermal results are used as input for the stress analysis for each transient. The boundary conditions used for the pressure load case were also applied to the thermal stress cases. Figure 2 and Figure 3 show the application of these boundary conditions.

All ANSYS input files for the thermal analyses, as listed below, are saved in the project computer files:

VY_CSN_GEOM.INP: Geometry and material properties
VY_16Q_TRAN2-T.INP, VY_16Q_TRAN2-S.INP: Transient 2, thermal and stress analyses
VY_16Q_TRAN3-T.INP, VY_16Q_TRAN3-S.INP: Transient 3, thermal and stress analyses
VY_16Q_TRAN11-T.INP, VY_16Q_TRAN11-S.INP: Transient 11, thermal and stress analyses

VY_16Q_TRAN14-T.INP, VY_16Q_TRAN14-S.INP: Transient 14, thermal and stress analyses
VY_16Q_TRAN21-23-T.INP, VY_16Q_TRAN21-23-S.INP: Transient 21-23, thermal and stress analyses
VY_16Q_TRAN24-T.INP, VY_16Q_TRAN24-S.INP: Transient 24, thermal and stress analyses
VY_16Q_TRAN30-T.INP, VY_16Q_TRAN30-S.INP: Transient 30, thermal and stress analyses

4.3 Determining Critical Stress Paths

From Section 4.0 of Reference [5], the critical location in the safe end was determined to be at Node 3719. This location was selected since it possessed the highest stress intensity during the worst case thermal transient.

Also from Section 4.0 of Reference [5], the critical stress location in the nozzle blend radius was chosen based upon the highest pressure stress (which is controlling in the nozzle blend radius). The pressure stress results showed the critical location in the nozzle blend radius to be at Node 2166.

Figure 4 shows the two critical stress paths that will be used to find the linearized stresses at the safe end and nozzle blend radius.

4.4 Stress Calculation

Linearized stresses from Node 3719 (safe end inside surface) and Node 2166 (nozzle blend radius inside surface of base metal) are used for the fatigue usage analysis, as shown in Figure 4. For the nozzle blend radius location, the stresses used are for the base metal only; the cladding material is unselected prior to stress extraction.

The pressure stress intensities for the safe end and blend radius paths were extracted using the ANSYS file *VY_16Q_P.INP*. This produced one file, *PRESSURE.lin*, which contains results of the critical stress paths.

Table 1 shows the final pressure results for the safe end and blend radius. These results are slightly different from those reported in Table 14 of Reference [5] as a result of the revised material properties (i.e., temperature dependent material properties were used in the current evaluation vs. constant material properties in Reference [5]).

Table 1: Pressure Results (1,000 psi)

Location	Membrane plus Bending Stress Intensity (psi)	Total Stress Intensity (psi)
Safe End	12,030	12,070
Blend Radius	30,720	36,150

Results were also extracted from the vessel portion of the model to verify the accuracy of the results obtained from the ANSYS model, and to check the results due to the use of the 2.0 multiplier on the vessel radius. These results are contained in the file *PRESSURE.lin*. The radius of the finite element model (FEM) was multiplied by a factor of 2.0 [3] to account for the fact that the vessel portion of the axisymmetric model is a sphere, but the true geometry is the intersection of two cylinders.

The equation for the membrane hoop stress in a sphere is:

$$\sigma = \left(\frac{(pressure)\times(radius)}{2\times thickness}\right)$$

Considering a vessel base metal radius, R, of 105.906 inches increased by a factor of 2.0, a vessel base metal thickness, t, of 5.4375 inches, and an applied pressure, P, of 1,000 psi, the calculated stress for a sphere is PR/(2t) = 19,477 psi. This compares very well with the remote vessel wall membrane hoop stress from the ANSYS result file, *PRESSURE.lin*, of 18,960 psi. Thus, considering the peak total pressure stress of 36,150 psi reported above, the stress concentrating effect of the nozzle corner is 36,150/19,477 = 1.86. In other words, the peak nozzle corner stress is 1.86 times higher than nominal vessel wall stress for the axisymmetric model.

The equation for the membrane hoop stress in a cylinder is:

$$\sigma = \left(\frac{(pressure)\times(radius)}{thickness}\right).$$

Based on the previous dimensions, the calculated stress for a cylinder without the 2.0 factor is 19,477 psi. Increasing this by a factor of 1.86 yields an expected peak nozzle corner stress of 36,227 psi, which would be expected from a cylindrical geometry that is representative of the nozzle configuration. Therefore, the result from the ANSYS file for the peak nozzle corner stress (36,150 psi) is close to the peak nozzle corner stress for a cylindrical geometry because of the use of the 2.0

multiplier. This is consistent with SI's experience where a factor of two increase in radius is typical for representing the 3-D effect in an axisymmetric model.

4.5 Piping Loads

The piping loads per Reference [4] are as follows:

$F_x = 2{,}500$ lbs	$M_x = 264{,}000$ in-lb
$F_y = 4{,}600$ lbs	$M_y = 85{,}200$ in-lb
$F_z = 1{,}700$ lbs	$M_z = 105{,}600$ in-lb

The point of loads application is at the intersection between the safe end-to-pipe weld [4, 6[1]] Therefore, the safe end critical location is 0.303 inches and the nozzle blend radius is 30.817 inches from the load application point. (The nozzle blend radius location was measured from approximately the middle of the critical stress path for the blend radius and applied to the inside blend radius location along the critical stress path.) From general structural mechanics, the membrane plus bending stresses at the inside surface of a thick-walled cylinder are:

σ_{z1} = axial stress due to axial force = F_z/A
σ_{z2} = axial stress due to bending moment = $M_{xy}(ID/2)/I$
$\sigma_z = \sigma_{z1} + \sigma_{z2}$
$\tau_{r\theta}$ = shear stress due to torsion = $M_z(ID/2)/J$
τ_{rz} = shear stress due to shear force = $2F_{xy}/A$, where

F_x, F_y, F_z, M_x, M_y, and M_z are forces and moments at the pipe-to-safe end weld
M_{xL} = moment about x axis translated by length $z = -L = M_x - F_y L$
M_{yL} = moment about y axis translated by length $z = -L = M_y + F_x L$
M_{xy} = resultant bending moment = $(M_{xL}^2 + M_{yL}^2)^{0.5}$
F_{xy} = resultant shear force = $(F_x^2 + F_y^2)^{0.5}$

ID, OD = inside and outside diameters
A = area of cross section = $(\pi/4)(OD^2 - ID^2)$
I = moment of inertia = $(\pi/64)(OD^4 - ID^4)$
J = polar moment of inertia = $(\pi/32)(OD^4 - ID^4)$

The piping load stress calculations for these locations are shown in Table 3.

[1] The piping loads tabulated in and pictorially shown in Reference [4] were applied by CB&I at the safe end-to-pipe weld. Refer to Reference [6], page 9 of 13; CB&I RPV Stress Report, Section S7.

5.0 RESULTS OF ANALYSIS

A thermal transient analysis for each defined transient, as well as unit pressure stress and piping interface load analyses were performed for the CS nozzle at Vermont Yankee. All six components of the stress tensor were extracted from the ANSYS model at the two limiting path locations. Table 2 provides the unit pressure stress analysis results. The unit pressure load results are used to choose the location to analyze at the nozzle blend radius and will be scaled up or down based on applied pressures for the final fatigue analysis. Table 3 provides the piping stresses at the two critical locations. Table 4 shows an example of thermal stress results. The remaining thermal stress results are contained in the ANSYS output files, listed below, which are saved in the project computer files:

PRESSURE.lin: Unit pressure stress analysis results
VY_16Q_TRAN2-S.lin: Transient 2, thermal stress analysis results
VY_16Q_TRAN3-S.lin: Transient 3, thermal stress analysis results
VY_16Q_TRAN11-S.lin: Transient 11, thermal stress analysis results
VY_16Q_TRAN14-S.lin: Transient 14, thermal stress analysis results
VY_16Q_TRAN21-23-S.lin: Transient 21-23, thermal stress analysis results
VY_16Q_TRAN24-S.lin: Transient 24, thermal stress analysis results
VY_16Q_TRAN30-S.lin: Transient 30, thermal stress analysis results

A fatigue calculation using the methodology of Subarticle NB-3200 of Section III of the ASME Code [2] and an environmental fatigue usage analysis will be performed in a separate calculation package using the stress results from this calculation.

The results of this calculation are used in a subsequent SIA Calculation No. 0801038.303, "Fatigue Analysis of Core Spray Nozzle."

6.0 REFERENCES

1. ANSYS, Release 8.1 (w/Service Pack 1), ANSYS, Inc., June 2004.

2. ASME Boiler and Pressure Vessel Code, Section III, Subsection NB, 1998 Edition with 2000 Addenda.

3. SI Calculation No. 0801038.301, Revision 0, "Design Inputs and Methodology for ASME Code Fatigue Usage Analysis of Reactor Core Spray Nozzle."

4. VY Drawing 5920-0024, Revision 11, Sht. No. 7, "Reactor Vessel," (GE Drawing No. 919D294), SI File No. VY-05Q-241.

5. SI Calculation No. VY-16Q-309, Revision 1, "Core Spray Nozzle Green's Functions."

6. Entergy Design Input Record (DIR), Rev. 1, EC No. 1773, Rev. 0, "Environmental Fatigue Analysis for Vermont Yankee Nuclear Power Station," 7/26/07, SI File No. VY-16Q-209.

Table 2: Stresses Under Unit Pressure Load, psi

		Membrane plus Bending						Total					
	Node	S_x	S_y	S_z	S_{xy}	S_{yz}	S_{xz}	S_x	S_y	S_z	S_{xy}	S_{yz}	S_{xz}
Safe End	3719	-1011	4829	11010	-104.8	0	0	-1011	4912	11050	-85.31	0	0
Blend Radius	2166	-1052	1657	25960	4886	0	0	-1052	1720	35050	348.9	0	0

Table 3: Membrane Plus Bending Stresses Due to Piping Loads

	Safe End	Blend Radius
F_x, kip	2.5	2.5
F_y, kip	4.6	4.6
F_z, kip	1.7	1.7
M_x, kip-in	264	264
M_y, kip-in	85.2	85.2
M_z, kip-in	105.6	105.6
L, in	0.30	30.82
M_{xL}, kip-in	262.61	122.24
M_{yL}, kip-in	85.96	162.24
M_{xy}, kip-in	276.32	203.14
F_{xy}, kip-in	5.24	5.24
OD, in	10.82	24.25
ID, in	9.834	12.125
A, in^2	15.91	346.40
I, in^4	212.46	15914.32
J, in^4	424.93	31828.64
σ_{z1}, ksi	0.107	0.005
σ_{z2}, ksi	6.395	0.077
σ_z, ksi	6.502	0.082
$\tau_{r\theta}$, ksi	1.222	0.020
τ_{rz}, ksi	0.658	0.030

Note: The axial and shear stresses are expressed in a local coordinate system with r radial (X in ANSYS coordinates), θ circumferential (Z in ANSYS coordinates), and Z axial (Y in ANSYS coordinates) components with respect to the nozzle centerline.

Table 4: Example Thermal Stress Result Output, psi

Transient	Node	Time (s)	Membrane Plus Bending						Total					
			Sx	Sy	Sz	Sxy	Syz	Sxz	Sx	Sy	Sz	Sxy	Syz	Sxz
3	3719	0	48	288	696	-50	0	0	48	1	641	-86	0	0
		10.002	49	280	689	-50	0	0	49	-11	630	-86	0	0
		123.23	52	197	644	-53	0	0	52	-131	561	-89	0	0
		1716.1	124	467	1587	-123	0	0	124	-293	1413	-212	0	0
		6984.8	380	1918	5199	-385	0	0	380	-358	4733	-663	0	0
		7946.2	430	2206	5907	-436	0	0	430	-365	5384	-752	0	0
		8919	482	2506	6638	-489	0	0	482	-371	6056	-843	0	0
		16055	845	4684	11830	-857	0	0	845	-352	10830	-1487	0	0
		16164	849	4707	11880	-861	0	0	849	-352	10880	-1494	0	0
		16304	850	4831	12000	-864	0	0	850	-219	11020	-1500	0	0
		19448	851	5001	12110	-870	0	0	851	-45	11140	-1506	0	0
		20622	851	5002	12110	-870	0	0	851	-44	11140	-1506	0	0
		29155	851	5002	12110	-870	0	0	851	-44	11140	-1506	0	0
		32155	851	5002	12110	-870	0	0	851	-44	11140	-1506	0	0
		40155	851	5002	12110	-870	0	0	851	-44	11140	-1506	0	0
		50155	851	5002	12110	-870	0	0	851	-44	11140	-1506	0	0
		65155	851	5002	12110	-870	0	0	851	-44	11140	-1506	0	0
		66165	851	5002	12110	-870	0	0	851	-44	11140	-1506	0	0
	2166	0	86	-140	1025	44	0	0	87	-1084	-628	-68	0	0
		10.002	87	-141	1030	44	0	0	109	-1242	-955	-70	0	0
		123.23	109	-210	1224	60	0	0	310	-3331	-4776	-184	0	0
		1716.1	310	-1469	2676	359	0	0	794	-9114	-9547	-537	0	0
		6984.8	794	-2777	8114	775	0	0	882	-10220	-10520	-607	0	0
		7946.2	882	-3032	8912	812	0	0	973	-11350	-11470	-678	0	0
		8919	973	-3298	9762	859	0	0	1553	-18930	-18300	-1177	0	0
		16055	1553	-5119	14660	1049	0	0	1562	-19040	-18390	-1184	0	0
		16164	1562	-5143	14730	1051	0	0	1545	-18980	-18070	-1190	0	0
		16304	1545	-5079	14620	1032	0	0	1433	-18220	-14130	-1169	0	0
		19448	1433	-3608	14270	632	0	0	1422	-18180	-13900	-1169	0	0
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		50155	1409	-3452	13510	458	0	0	1409	-18140	-13810	-1173	0	0
		65155	1409	-3452	13510	458	0	0	1409	-18140	-13810	-1173	0	0
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Note: Not all time steps are listed in this table.

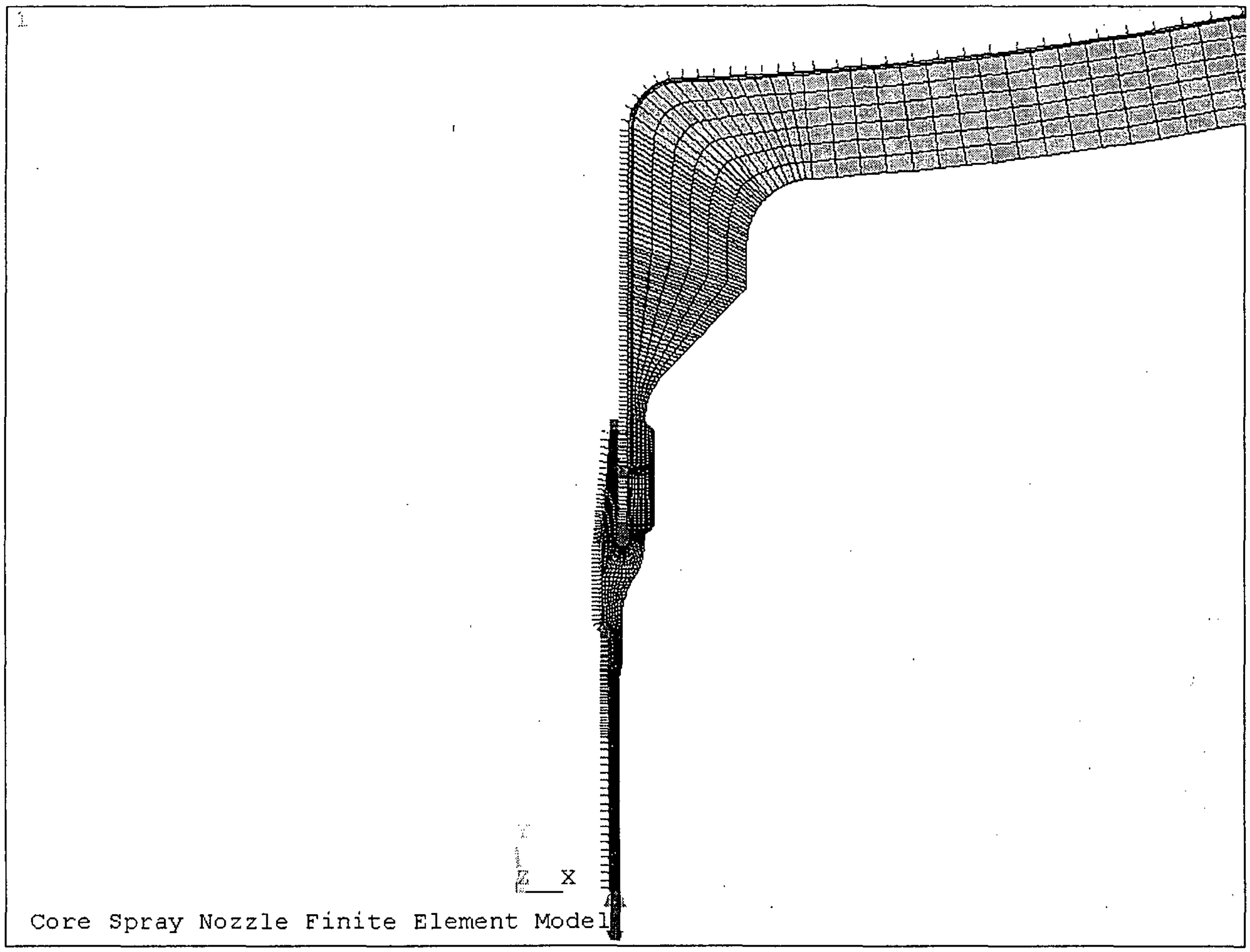

Figure 1. Core Spray Nozzle Internal Pressure Distribution

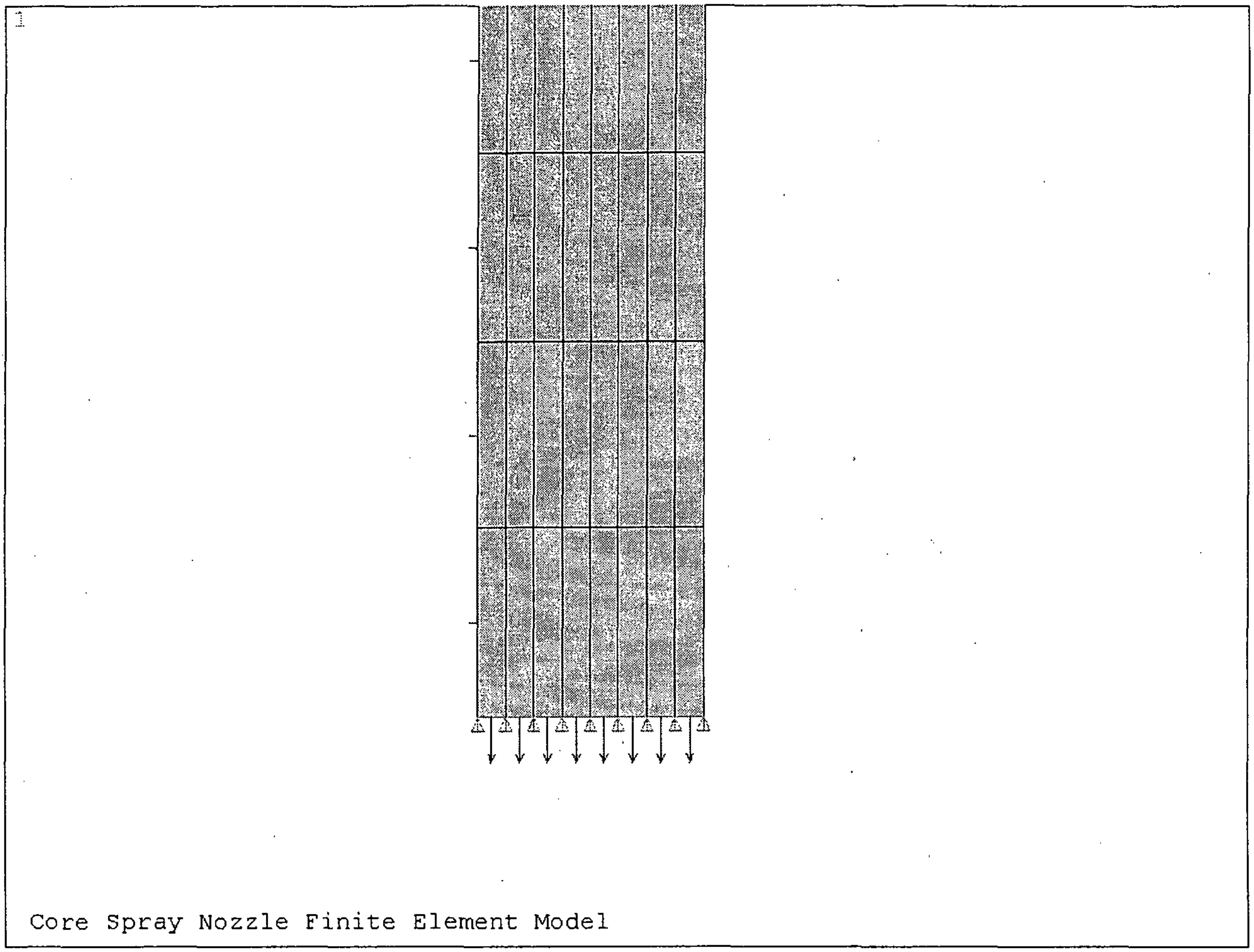

Figure 2. Core Spray Nozzle Pressure Cap Load & Boundary Condition

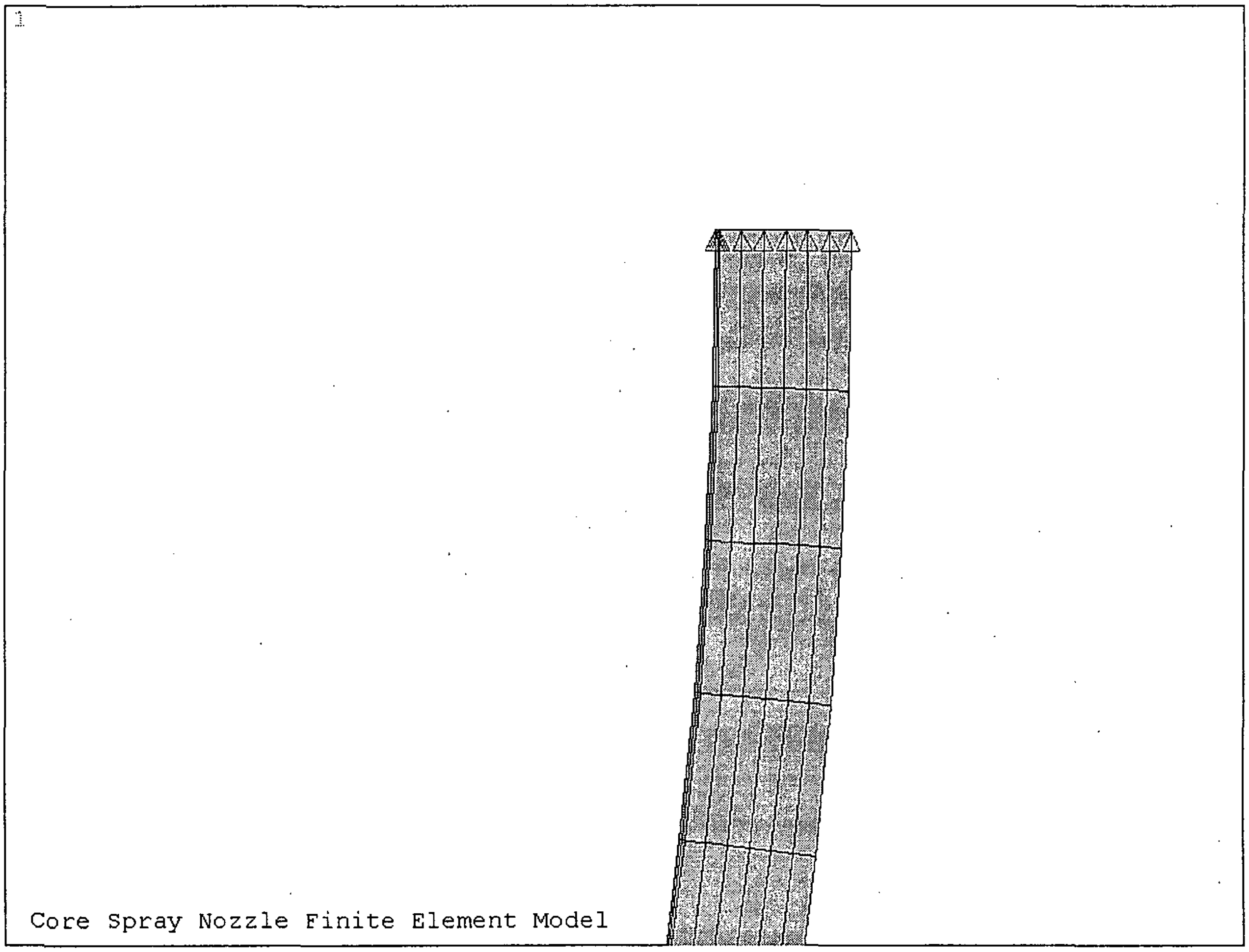

Figure 3. Core Spray Nozzle Vessel Wall Boundary Condition

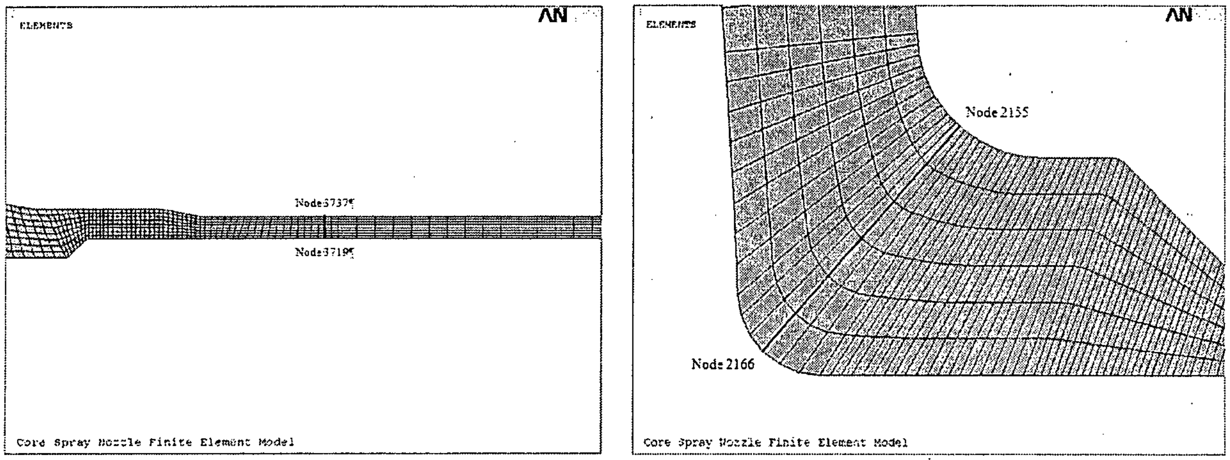

Figure 4. Limiting Stress Paths

Structural Integrity Associates, Inc.

CALCULATION PACKAGE

File No.: 0801038.303

Project No.: 0801038
Quality Program ☒ Nuclear ☐ Commercial

PROJECT NAME:
VY Confirmatory Analysis for the CS and RO Nozzles

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CALCULATION TITLE:
Fatigue Analysis of Reactor Core Spray Nozzle

Document Revision	Affected Pages	Revision Description	Project Manager Approval Signature & Date	Preparer(s) & Checker(s) Signatures & Date
0	1 - 18 Computer Files.	Initial issue.	Gary L. Stevens 01/06/09	Tyler Novotny 01/06/09 W. F. Weitze 01/06/09
1	1-3, 5-8, 11-12, 17-18 Computer Files.	Revised per summary contained in Section 1.1. Changes are marked with "revision bars" in right-hand margin.	Gary L. Stevens Gary L. Stevens 03/09/09	**Preparer**: Tyler Novotny Tyler D. Novotny 03/09/09 **Checker:** Tim Gilman Tim D. Gilman 03/09/09

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1.0 OBJECTIVE

The objective of this calculation package is to perform an ASME Code, Section III fatigue usage evaluation and a plant-specific evaluation of reactor water environmental effects for the reactor pressure vessel (RPV) core spray (CS) nozzle at the Vermont Yankee Nuclear Power Station.

1.1 Changes Made in Revision 1 of this Calculation

Description of changes made in Revision 1 of this calculation:

a. Changed Reference [1] to reflect revision of that document.
b. All other changes marked throughout this calculation are editorial changes made to the text of the calculation package.

2.0 METHODOLOGY

The methodology to be used for this evaluation was established in a previous calculation package [2]. Based on that methodology, thermal stresses, pressure stresses, and attached piping load stresses were developed in the Reference [1] calculation for use in a fatigue calculation. The thermal stresses are added to pressure stresses and attached piping load stresses[1]. Both the pressure and piping load stresses are scaled based on the magnitudes of the pressure and nozzle temperature during each transient. All six components of the stress tensor from the stress results are used in the fatigue calculation.

The fatigue calculation is performed for both of the limiting safe end and nozzle blend radius locations, as determined in the Reference [1] calculation, and uses the methodology of Subarticle NB-3200 of Section III of the ASME Code [3]. An environmental fatigue usage analysis is also performed in this calculation applying the methodology described in Reference [6].

3.0 DESIGN INPUTS

3.1 Stress Calculation

Linearized stress components at Node 3719 (limiting safe end path at inside surface) and Node 2166 (limiting nozzle blend radius path at inside surface) are used for the fatigue usage calculation, as shown in Figure 4 of Reference [1]. For the nozzle blend radius location, the stresses used in the evaluation are for the base metal only; that is, the cladding material is unselected prior to stress extraction. The stress components from the thermal stress analyses are combined with stress components due to pressure and piping loads. The linearized thermal stress components for each

[1] Stress components due to piping loads are scaled assuming no stress occurs at an ambient temperature of 70°F and the full values are reached at a reactor design temperature of 575°F [2, Assumption 3.1.7]. In addition, design seismic and deadweight loads are also included and scaled in combination with the thermal loads for each transient. This combination, coupled with assigning the stress due to these loads the same sign as the thermal stress, is considered to be a very conservative treatment of the loads overall in that deadweight and design seismic loads are considered and scaled for every transient.

transient are taken from the relevant output files associated with the Reference [1] calculation (a sample of which was provided in Table 4 of Reference [1]). The unit pressure stress component results are taken from Table 2 of Reference [1]. Piping load stress components are taken from Table 3 of the Reference [1] calculation.

3.2 Fatigue Usage Analysis, General

Structural Integrity's VESLFAT program [4] is used to perform the fatigue usage calculation in accordance with the fatigue usage portion of ASME Code Subarticle NB-3200 [3]. VESLFAT performs the analysis required by NB-3222.4(e) [3] for Service Levels A and B conditions defined by the user. The VESLFAT program computes the primary-plus-secondary and total stress ranges for all events and performs a correction for elastic-plastic analysis, if necessary.

The program computes the stress intensity range based on the stress component ranges for all event pairs [3, NB-3216.2]. The program evaluates the stress ranges for primary-plus-secondary and primary-plus-secondary-plus-peak stresses based on all six components of stress (3 normal and 3 shear stresses). If the primary-plus-secondary stress intensity range is greater than $3S_m$, the total stress range must be increased by the simplified elastic-plastic strain correction factor K_e, as described in NB-3228.5 [3]. The design stress intensity, S_m, is specified as a function of temperature. The input maximum temperature for both states of a load set pair is used to determine the temperature that S_m is determined from the user-defined values.

When more than one stress set is defined for either of the event pair loadings, the stress differences are determined for all of the potential stress pairs, saving the maximum for the event pair, based on the pair producing the largest alternating total stress intensity (S_{alt}), including any effects of K_e. The principal stresses for the stress ranges are determined by solving for the roots of the following cubic equation[2]:

$$S^3 - (\sigma_x + \sigma_y + \sigma_z)S^2 + (\sigma_x\,\sigma_y + \sigma_y\,\sigma_z + \sigma_z\,\sigma_x - \tau_{xy}^2 - \tau_{xz}^2 - \tau_{yz}^2)S$$
$$- (\sigma_x\,\sigma_y\,\sigma_z + 2\,\tau_{xy}\,\tau_{xz}\,\tau_{yz} - \sigma_z\,\tau_{xy}^2 - \sigma_y\,\tau_{xz}^2 - \sigma_x\,\tau_{yz}^2) = 0$$

The stress intensities for the event pairs are reordered in decreasing order of S_{alt}, including a correction for the ratio of modulus of elasticity (E) from the fatigue curve divided by E from the material evaluated at the maximum event temperature. This allows a fatigue table to be created to eliminate the number of cycles available for each of the transient events. This fatigue table is based on a worst-case progressive pairing of events in order of the most severe alternating stress to the least severe, allowing determination of a bounding fatigue usage per NB-3222.4(e) [3]. For each load set pair in the fatigue table, the allowable number of cycles is determined based on S_{alt}.

3.3 Event Cycles, VESLFAT

For the Vermont Yankee CS nozzle analysis, transients that consist of combined stress ramps are split so that each successive ramp is treated separately. Therefore, there are 25 load sets based on the combined stress changes for the safe end, and 27 load sets based on the combined stress changes

[2] Note that σ_x, σ_y, σ_z, etc. are used synonymously with S_x, S_y, S_z, etc., in this calculation.

for the nozzle blend radius location. The reason the number of load sets are not equal for each path is because the time history stress results of those paths differ. Tables 1 and 2 show the load sets applicable to plant operation, with cycle counts per Table 2 of Reference [2], used as input to VESLFAT for the safe end and nozzle blend radius locations, respectively. The cycle counts of Reference [2] consider 60 years of operation; see Reference [8] for the numbers of cycles. The data from Table 1 is entered into the VESLFAT input files *VY-VFAT-1I.CYC* (safe end-Inconel) and *VY-VFAT2-1I.CYC* (safe end-Stainless Steel), and the data from Table 2 is entered into the file *VY-VFAT-2I.CYC* (nozzle blend radius).

3.4 Material Properties, VESLFAT

Material properties are entered in VESLFAT input files *VY-VFAT-1I.FDT* (safe end-Inconel), VY-*VY-VFAT2-1I.FDT* (safe end-Stainless Steel) and *VY-VFAT-2I.FDT* (nozzle blend radius). Table 3 lists the temperature-dependent material properties used in the analysis [5]. Table 4 lists the fatigue curve for the nozzle and safe end materials [3, Appendix I, Table I-9.1 and Figure I-9.1 (UTS ≤ 80.0 ksi) for the nozzle blend radius, and Tables I-9.1 and I-9.2.2 (Curve C) and Figures I-9.2.1 and I-9.2.2 for both safe end locations]. Curve C is selected because it is the most conservative curve among the three extended curves for austenitic steel. VESLFAT automatically scales the stresses by the ratio of E on the fatigue curve to E in the analysis, for purposes of determining allowable numbers of cycles, as required by the ASME Code.

Other material properties are input as follows:

$m = 1.7$, $n = 0.3$, parameters used to calculate K_e for the safe end location (both materials) [3, Table NB-3228.5(b)-1]
$m = 2.0$, $n = 0.2$, parameters used to calculate K_e for the nozzle blend radius location [3, Table NB-3228.5(b)-1]
E from fatigue curve = 28,300 ksi [3, Appendix I, Figure I-9.2] for the safe end locations.
E from fatigue curve = 30,000 ksi [3, Appendix I, Figure I-9.1] for the nozzle blend radius location.

3.5 Stress Indices

Stress indices are calculated per Reference [2, Section 3.8]. For the safe end location and using the ANSYS thermal stress results, the membrane plus bending stress results are multiplied by K_3 and then are added to the peak thermal stress results to yield total thermal stress, taking guidance from Equation 11 of NB-3600 [3]. The total thermal stresses are then added to the total piping and total pressure stresses.

$C_1 = C_2 = C_3 = 1$, because the ANSYS model is sufficient to account for the effects of gross structural discontinuity. The path for Node 2166 does not contain a weld and, therefore, does not take the same guidance from NB-3600. However, the path for Node 3719 uses guidance and the following values from NB-3600 for an "as welded girth butt weld":

$K_1 = 1.2$, From Table 3681(a)-1 of NB-3600 [3]
$K_2 = 1.8$, From Table 3681(a)-1 of NB-3600 [3]
$K_3 = 1.7$, From Table 3681(a)-1 of NB-3600 [3]

The K values listed above are used to multiply the Membrane plus Bending stress results of the pressure load and piping load to yield Total Stress. So, K_1 * $(\text{Memb+Bend})_{\text{Pressure}}$ = Total $\text{Stress}_{\text{Pressure}}$ and K_2 * $(\text{Memb+Bend})_{\text{Piping}}$ = Total $\text{Stress}_{\text{Piping}}$.

4.0 CALCULATIONS

Table 5 contains the stress components at the locations of interest for the 1,000 psi unit pressure stress case [1, Table 2]. Table 5 also contains the stress components for the attached piping load unit stress case [1, Table 3], which correspond to a reactor design temperature of 575°F [2, Section 3.1.7]. The attached piping load stress components were applied assuming the same signs as the thermal stress, which yields the largest stress component ranges.

The stress indices for each location and loading scenario are calculated in the previous section. These stress indices are used in the Excel workbooks described below.

The calculations of all of the VESLFAT stress inputs are automated in Excel workbooks *VY-VFAT-1i.xls* (safe end-both materials) and *VY-VFAT-2i.xls* (nozzle blend radius). These files are organized with sheets labeled as follows:

- Overview: Contains general information.
- Other Stresses: Contains pressure and attached piping load stresses. As shown in Table 5, the pressure and thermal stresses use the membrane-plus-bending and total stress from the finite element analysis [1], and include stress indices where appropriate.
- Rearranger: There are 7 Rearranger sheets, one for each thermal transient as analyzed by ANSYS. In these sheets, thermal stresses are copied from Excel workbook *VY-StressResults.xls*, and rearranged to conform to VESLFAT input format (including switching the shear stress components S_{xz} and S_{yz} as required by VESLFAT). VY-StressResults.xls contains the results of the ANSYS stress linearization for each transient. The files contained within this workbook are shown in Table 10. Time-varying scale factors for the attached piping loads (based on path metal temperature) and pressure are determined, and used to scale the unit load case stresses, which are then added to the thermal stresses. Since the attached piping loads can act in any direction, the stresses due to the attached piping loads are assigned the same sign as the thermal stresses to maximize the component stresses. Algebraic summation of all six stress components is performed for pressure, piping loads, and thermal stresses at each transient time step. The VESLFAT stress input also includes time-varying metal temperature, as obtained from the ANSYS output, which is used to determine temperature-dependent properties from the values in Table 3.
- VESLFAT: Contains the VESLFAT stress input, as obtained from the Rearranger sheets. Load set numbers are entered on this sheet, as defined in Table 1 and Table 2. These sheets are saved to VESLFAT input files *VY-VFAT-1i.STR* (safe end-Inconel), *VY-VFAT2-1i.STR* (safe end-Stainless Steel), and *VY-VFAT-2i.STR* (nozzle blend radius).

5.0 RESULTS OF ANALYSIS

Table 6, Table 7 and Table 8 provide the detailed calculated 60-year fatigue usage, as obtained from VESLFAT output files *VY-VFAT-1I.FAT* (safe end-Inconel), *VY-VFAT2-1I.FAT* (safe end-Stainless Steel), and *VY-VFAT-2I.FAT* (nozzle blend radius). All VESLFAT input and output files are saved in the project computer files associated with this calculation.

From Table 6, the safe end (Inconel) cumulative usage factor (CUF) is 0.000174 for 60 years. From Table 7, the safe end (Stainless Steel) cumulative usage factor (CUF) is 0.000742 for 60 years. From Table 8, the nozzle blend radius CUF is 0.0171 for 60 years.

From Table 1 of Reference [6], it was determined that hydrogen water chemistry (HWC) is available for 47% of the total 60-year operating period, and normal water chemistry (NWC) is present for the remaining 53% of the total 60-year operating period. From Table 1 of Reference [6], the dissolved oxygen values for the RPV upper vessel region (which is applicable to the CS nozzles) are 97 ppb for HWC conditions and 114 ppb for NWC conditions.

For the safe end location (Inconel), the environmental fatigue factor is determined based on Alloy 600 methodology consistent with Reference [7]. The overall F_{en} (fatigue life correction factor), per Reference [7], is 1.49 and can be applied to the CS nozzle safe end (Inconel) location based on identical materials, i.e. SB-166. The resulting Environmentally Assisted Fatigue (EAF) adjusted CUF value is 0.000174 x 1.49 = 0.000259, which is less than the allowable value of 1.0 and is therefore acceptable.

For the stainless steel piping, the environmental fatigue factors for post-HWC and pre-HWC are both 8.36 from Table 4 of Reference [6]. The overall environmental multiplier is 8.36. It results in an EAF adjusted CUF of 8.36 x 0.000742 = 0.00620 for 60 years, which is acceptable (i.e., less than the allowable value of 1.0).

Based on the detailed CUF calculation shown in Table 8, a detailed EAF adjusted CUF evaluation on a load-pair basis is provided for the nozzle blend radius location in Table 9. The overall F_{en} is 8.20. The resulting EAF adjusted CUF value is 0.0171 x 8.20 = 0.140, which is less than the allowable value of 1.0 and is therefore acceptable.

6.0 CONCLUSIONS AND DISCUSSIONS

Detailed fatigue calculations for the Vermont Yankee CS nozzle were performed based on the results of stress analyses previously performed [1]. The thermal stresses were combined with stresses due to pressure and attached piping loads, both of which were scaled based on the magnitudes of the pressure and metal temperature during each thermal transient. All six components of the stress tensor were used for the fatigue calculations. The fatigue calculations were performed at previously-determined limiting locations in the safe end and nozzle blend radius, and used the methodology of Subarticle NB-3200 of Section III of the ASME Code [3].

The 60-year CUF for the safe end location (Inconel) was determined to be 0.000174, the safe end location (Stainless Steel) was determined to be 0.000742, and the CUF for the nozzle blend radius location was determined to be 0.0171. All three values are less than the ASME Code allowable value of 1.0, and are therefore acceptable.

Detailed EAF assessments were also performed for the two CS nozzle locations. The 60-year EAF CUF for the safe end location was determined to be 0.000259 using standard Alloy 600 methodology [7]. The 60-year EAF CUF for the safe end location (Stainless Steel) was determined to be 0.00620. The 60-year EAF CUF for the nozzle blend radius location was determined to be 0.140 using temperature-dependent F_{en} multipliers for each load pair. All EAF CUF values are less than the ASME Code allowable value of 1.0, and are therefore acceptable.

7.0 REFERENCES

1. Structural Integrity Associates Calculation No. 0801038.302, Revision 1, "Stress Analysis of Reactor Core Spray Nozzle."
2. Structural Integrity Associates Calculation No. 0801038.301, Revision 0, "Design Inputs and Methodology for ASME Code Fatigue Usage Analysis of Reactor Core Spray Nozzle."
3. ASME Boiler and Pressure Vessel Code, Section III, 1998 Edition with 2000 Addenda.
4. VESLFAT, Version 1.42, 02/06/07, Structural Integrity Associates.
5. ASME Boiler and Pressure Vessel Code, Section II, Part D-Properties, 1998 Edition with 2000 Addenda.
6. SI Calculation No. VY-16Q-303, Revision 0, "Environmental Fatigue Evaluation of Reactor Recirculation Inlet Nozzle and Vessel Shell/Bottom Head."
7. EPRI Report No. TR-105759, "An Environmental Factor Approach to Account for Reactor Water Effects in Light Water Reactor Pressure Vessel and Piping Fatigue Evaluations," December 1995.
8. Entergy Design Input Record (DIR) EC No. 1773, DIR. Revision 1, "Environmental Fatigue Analysis for Vermont Yankee Nuclear Power Station," 7/26/07, SI File No. VY-16Q-209.

Table 1: Safe End Load Sets as Input to VESLFAT

VESLFAT Load Set	Transient	Start Time, sec	Temp Change	Pressure Change	Cycles
1	Trn2_T1_	0	None	None	120
2	Trn2_T2_	0	None	Up	120
3	Trn2_T3_	0	None	Down	120
4	1Trn3_	0	Up	Up	300
5	2Trn3_	56.6	Up	Up	300
6	1Trn11_	0	None	Up & Down	10
7	2Trn11_	5	Down	Down	10
8	3Trn11_	26.962	Down	None	10
9	4Trn11_	207.34	Down & Up	None	10
10	5Trn11_	1734.9	Up & Down	Down	10
11	6Trn11_	2332.6	Down & Up	Down & UP	10
12	7Trn11_	5625.1	Up & Down	Up & Down	10
13	8Trn11_	7125.4	Down & Up	Down & Up	10
14	9Trn11_	14315	Up & Down	Up	10
15	10Trn11_	16749	Down	None	10
16	1Trn14_	0	Down	Down	1
17	2Trn14_	270	Down	Down	1
18	1Trn21_	0	Down	Down	300
19	2Trn21_	17.00	Down	Down	300
20	Tn24_T1_	0	None	None	1
21	Tn24_T2_	0	None	Up	1
22	Tn24_T3_	0	None	Down	1
23	1Trn30_	0	Down	Down	1
24	2Trn30_	12.2	Down	Down	1
25	3Trn30_	631	None	Down	1

Table 2: Nozzle Blend Radius Load Sets as Input to VESLFAT

VESLFAT Load Set	Transient	Start Time, sec	Temp Change	Pressure Change	Cycles
1	Trn2_T1_	0	None	None	120
2	Trn2_T2_	0	None	Up	120
3	Trn2_T3_	0	None	Down	120
4	1Trn3_	0	Up	Up	300
5	2Trn3_	56.6	Up	Up	300
6	1Trn11_	0	None	Up & Down	10
7	2Trn11_	5	Down	Down	10
8	3Trn11_	142.64	Down & Up	None	10
9	4Trn11_	1655.2	Up & Down	Down	10
10	5Trn11_	2302.7	Down & Up	Down & Up	10
11	6Trn11_	3193.7	Up & Down	Up & Down	10
12	7Trn11_	7255.1	Down & Up	Down	10
13	8Trn11_	9913	Up	Down & Up	10
14	9Trn11_	12514	Up and Down	Up	10
15	1Trn14_	0	Down	Down	1
16	2Trn14_	40	Down	Down	1
17	3Trn14_	1200	Down	Down	1
18	1Trn21_	0	Down	Down	300
19	2Trn21_	32.15	Down	Down	300
20	3Trn21_	6462.7	Down	None	300
21	Tn24_T1_	0	None	None	1
22	Tn24_T2_	0	None	Up	1
23	Tn24_T3_	0	None	Down	1
24	1Trn30_	0	None	Down	1
25	2Trn30_	1.2	Down	Down	1
26	3Trn30_	25	Down	Down	1
27	4Trn30_	3331	Down	Down	1

Table 3: Temperature-Dependent Material Properties for VESLFAT [4]

Material	T, °F	E x 10^6, psi	S_m, ksi	S_y, ksi
SB-166 Inconel (safe end[1])	70	31.0	23.3	35.0
	200	30.2	23.3	32.0
	300	29.8	23.3	31.2
	400	29.5	23.3	30.7
	500	29.0	23.3	30.3
	600	28.7	23.3	29.9
SA-508 Class 2[5] (Nozzle blend radius [2])	70	27.8	26.7	50.0
	200	27.1	26.7	47.0
	300	26.7	26.7	45.5
	400	26.1	26.7	44.2
	500	25.7	26.7	43.2
	600	25.2	26.7	42.1
SA-312 TP 304	70	28.3	20	30
(Core Spray Piping 8 x 10 Reducer [3])	200	27.6	20	25
	300	27.0	20	22.4
	400	26.5	18.7	20.7
	500	25.8	17.5	19.4
	600	25.3	16.4	18.4

Notes:

1. For the safe end material, SB-166 Inconel properties are used (72Ni-15Cr-8Fe), per Reference [2]. Annealed heat treatment is conservatively assumed for S_m and S_y values.
2. For the nozzle blend radius material, SA508 Class 2 material properties are used (3/4Ni-1/2Mo-1/3Cr-V), per Reference [2].
3. For the nozzle safe end extension material, SA-312 TP304 material properties are used (18Cr-8Ni), per Reference [2].
4. All values are taken from Reference [5].
5. SA-508 Class 2 in the Code of Construction is the same as SA-508 Gr. 2 Class 2 in the 1998 ASME Code [5]

Table 4: Carbon/Low Alloy Steel and Stainless Steel/Nickel Alloy Fatigue Curves

Number of Cycles	S_a, ksi Carbon/Low Alloy [1]	S_a, ksi Austenitic/Nickel Alloy
10	580	708
20	410	512
50	275	345
100	205	261
200	155	201
500	105	148
1000	83	119
2000	64	97
5000	48	76
10000	38	64
20000	31	55.5
50000	23	46.3
100000	20	40.8
200000	16.5	35.9
500000	13.5	31
1000000	12.5	28.2
2.E+06	N/A	22.8[2]
5.E+06	N/A	18.4[2]
1.E+07	N/A	16.4[2]
2.E+07	N/A	15.2[2]
5.E+07	N/A	14.3[2]
1.E+08	N/A	14.1[2]
1.E+09	N/A	13.9[2]
1.E+10	N/A	13.7[2]
1.E+11	N/A	13.6[2]

Note:

1. Using UTS ≤ 80 ksi curve.
2. Using Curve C for austenitic steel/nickel alloy.

Table 5: Pressure and Attached Piping Unit Load Case Stress Components

Load	Node (2)	Membrane plus Bending (1)						Total (1)					
		S_x	S_y	S_z	S_{xy}	S_{xz} (5)	S_{yz} (5)	S_x	S_y	S_z	S_{xy}	S_{xz} (5)	S_{yz} (5)
Pressure(3)	3719	-1011	4829	11010	-104.8	0	0	-1011	4912	11050	-85.31	0	0
	2166	-1052	1657	25960	4886	0	0	-1052	1720	35050	348.9	0	0
Piping(4)	3719	0	6502	0	658	1222	0	0	11704	0	1184	2200	0
	2166	0	82	0	30	20	0	0	82	0	30	20	0

Notes:
1. All stress values are in units of psi.
2. The safe end location is represented by Node 3719, and the nozzle blend radius location is represented by Node 2166.
3. The stresses for both nodes represent the stress due to an applied pressure of 1,000 psig.
4. Piping stresses for both locations represent the stress due to full attached piping loads at an RPV temperature of 575°F.
5. S_{yz} and S_{xz} components have been rearranged from the ANSYS output in order to be in correct order for VESLFAT.

Table 6: Fatigue Usage Calculation for the Safe End (Inconel)

Load #1	Desc. #1	Load #2	Desc. #2	n (cycles)	Sn (psi)	Ke	Salt (psi)	Nallow	U
24	2Trn30_	25	3Trn30_	1	67883	1	63663	10260	0.000098
17	2Trn14_	23	1Trn30_	1	44360	1	48903	37919	0.000026
5	2Trn3_	8	3Trn11_	10	26107	1	18347	5088300	0.000002
5	2Trn3_	9	4Trn11_	10	25551	1	17850	6002500	0.000002
5	2Trn3_	6	1Trn11_	10	24728	1	16797	8657500	0.000001
5	2Trn3_	7	2Trn11_	10	24429	1	16784	8698300	0.000001
5	2Trn3_	10	5Trn11_	10	23571	1	16559	9436700	0.000001
5	2Trn3_	14	9Trn11_	10	23593	1	16507	9615800	0.000001
5	2Trn3_	11	6Trn11_	10	23214	1	16399	10007000	0.000001
5	2Trn3_	15	10Trn11_	10	23358	1	16262	10800000	0.000001
5	2Trn3_	12	7Trn11_	10	23247	1	15968	12760000	0.000001
4	1Trn3_	5	2Trn3_	210	23000	1	15922	13097000	0.000016
4	1Trn3_	19	2Trn21_	90	22979	1	15914	13155000	0.000007
1	Trn2_T1_	19	2Trn21_	120	22979	1	15899	13273000	0.000009
19	2Trn21_	20	Tn24_T1_	1	22383	1	15552	16233000	0.000000
19	2Trn21_	22	Tn24_T3_	1	22383	1	15552	16233000	0.000000
3	Trn2_T3_	19	2Trn21_	88	22383	1	15552	16233000	0.000005
3	Trn2_T3_	18	1Trn21_	32	22389	1	15549	16263000	0.000002
								Total Usage =	0.000174

Note: All other load pairs have an alternating stress, Salt, that is below the endurance limit of the fatigue curve. Therefore, they do not contribute to fatigue usage.

Table 7: Fatigue Usage Calculation for the Safe End (Stainless Steel)

Load #1	Desc. #1	Load #2	Desc. #2	n (cycles)	Sn (psi)	Ke	Salt (psi)	Nallow	U
24	2Trn30_	25	3Trn30_	1	68465	1.47	101779	1699.05	0.000589
17	2Trn14_	23	1Trn30_	1	44360	1	54103	22751	0.000044
5	2Trn3_	8	3Trn11_	10	26107	1	20551	3117000	0.000003
5	2Trn3_	9	4Trn11_	10	25551	1	19856	3611400	0.000003
5	2Trn3_	6	1Trn11_	10	24728	1	18923	4435200	0.000002
5	2Trn3_	7	2Trn11_	10	24429	1	18905	4453400	0.000002
5	2Trn3_	14	9Trn11_	10	23593	1	18620	4752000	0.000002
5	2Trn3_	10	5Trn11_	10	23626	1	18525	4857700	0.000002
5	2Trn3_	15	10Trn11_	10	23358	1	18336	5106400	0.000002
5	2Trn3_	11	6Trn11_	10	23214	1	18295	5175200	0.000002
4	1Trn3_	5	2Trn3_	220	23000	1	17975	5755400	0.000038
4	1Trn3_	19	2Trn21_	80	22979	1	17967	5772000	0.000014
1	Trn2_T1_	19	2Trn21_	120	22979	1	17949	5806200	0.000021
19	2Trn21_	20	Tn24_T1_	1	22383	1	17557	6632000	0.000000
19	2Trn21_	22	Tn24_T3_	1	22383	1	17557	6632000	0.000000
3	Trn2_T3_	19	2Trn21_	98	22383	1	17557	6632000	0.000015
3	Trn2_T3_	18	1Trn21_	22	22389	1	17554	6640000	0.000003
								Total Usage =	0.000742

Note: All other load pairs have an alternating stress, Salt, that is below the endurance limit of the fatigue curve. Therefore, they do not contribute to fatigue usage.

Table 8: Fatigue Usage Calculation for the Nozzle Blend Radius

Load #1	Desc. #1	Load #2	Desc. #2	n (cycles)	S_n (psi)	Ke	Salt (psi)	N_{allow}	U
25	2Trn30_	26	3Trn30_	1	51402	1.00	44455	6278	0.0002
8	3Trn11_	13	8Trn11_	10	15961	1.00	39383	8994	0.0011
19	2Trn21_	22	Tn24_T2_	1	39644	1.00	34138	14404	0.0001
7	2Trn11_	27	4Trn30_	1	38618	1.00	27466	28999	0.0000
4	1Trn3_	7	2Trn11_	9	36665	1.00	27150	30048	0.0003
10	5Trn11_	19	2Trn21_	10	15935	1.00	26332	33005	0.0003
1	Trn2_T1_	6	1Trn11_	10	49693	1.00	25486	36486	0.0003
2	Trn2_T2_	19	2Trn21_	120	25423	1.00	24010	43822	0.0027
12	7Trn11_	19	2Trn21_	10	13983	1.00	23200	48691	0.0002
1	Trn2_T1_	9	4Trn11_	10	47005	1.00	22776	52484	0.0002
4	1Trn3_	11	6Trn11_	10	35885	1.00	22731	53008	0.0002
1	Trn2_T1_	5	2Trn3_	100	44974	1.00	22190	59737	0.0017
4	1Trn3_	5	2Trn3_	200	44974	1.00	22190	59737	0.0033
4	1Trn3_	24	1Trn30_	1	44912	1.00	22187	59767	0.0000
4	1Trn3_	18	1Trn21_	80	44912	1.00	22187	59767	0.0013
17	3Trn14_	18	1Trn21_	1	44598	1.00	21478	70216	0.0000
18	1Trn21_	20	3Trn21_	219	43608	1.00	21218	74590	0.0029
19	2Trn21_	20	3Trn21_	81	43426	1.00	21130	76147	0.0011
3	Trn2_T3_	19	2Trn21_	78	43219	1.00	21117	76367	0.0010
3	Trn2_T3_	14	9Trn11_	10	43408	1.00	21016	78221	0.0001
3	Trn2_T3_	15	1Trn14_	1	42722	1.00	20993	78639	0.0000
3	Trn2_T3_	16	2Trn14_	1	41044	1.00	20341	91957	0.0000
								Total Usage =	0.0171

Note: All other load pairs have an alternating stress, S_{alt}, that is below the endurance limit of the fatigue curve. Therefore, they do not contribute to fatigue usage.

Table 9: EAF Fatigue Usage Calculation for the Nozzle Blend Radius Location

VY CS Nozzle Corner Environmental Fatigue Calculation

CUF Calculation from file VY-VFAT-2i.fat:

Index	Load #1	Description #1	n_1 (cycles) [5]	Load #2	Description #2	n_2 (cycles) [5]	n (cycles) [5]	S_n (psi)	K_e	S_{alt} (psi)	N_{allow}	U
1	25	2Trn30_	1	26	3Trn30_	1	1	51402	1.00	44455	6278	0.0002
2	8	3Trn11_	10	13	8Trn11_	10	10	15961	1.00	39383	8994	0.0011
3	19	2Trn21_	300	22	Tn24_T2_	1	1	39644	1.00	34138	14404	0.0001
4	7	2Trn11_	10	27	4Trn30_	1	1	38618	1.00	27466	28999	0.0000
5	4	1Trn3_	300	7	2Trn11_	9	9	36665	1.00	27150	30048	0.0003
6	10	5Trn11_	10	19	2Trn21_	299	10	15935	1.00	26332	33005	0.0003
7	1	Trn2_T1_	120	6	1Trn11_	10	10	49693	1.00	25486	36486	0.0003
8	2	Trn2_T2_	120	19	2Trn21_	289	120	25423	1.00	24010	43822	0.0027
9	12	7Trn11_	10	19	2Trn21_	169	10	13983	1.00	23200	48691	0.0002
10	1	Trn2_T1_	110	9	4Trn11_	10	10	47005	1.00	22776	52484	0.0002
11	4	1Trn3_	291	11	6Trn11_	10	10	35885	1.00	22731	53008	0.0002
12	1	Trn2_T1_	100	5	2Trn3_	300	100	44974	1.00	22190	59737	0.0017
13	4	1Trn3_	281	5	2Trn3_	200	200	44974	1.00	22190	59737	0.0033
14	4	1Trn3_	81	24	1Trn30_	1	1	44912	1.00	22187	59767	0.0000
15	4	1Trn3_	80	18	1Trn21_	300	80	44912	1.00	22187	59767	0.0013
16	17	3Trn14_	1	18	1Trn21_	220	1	44598	1.00	21478	70216	0.0000
17	18	1Trn21_	219	20	3Trn21_	300	219	43608	1.00	21218	74590	0.0029
18	19	2Trn21_	159	20	3Trn21_	81	81	43426	1.00	21130	76147	0.0011
19	3	Trn2_T3_	120	19	2Trn21_	78	78	43219	1.00	21117	76367	0.0010
20	3	Trn2_T3_	42	14	9Trn11_	10	10	43408	1.00	21016	78221	0.0001
21	3	Trn2_T3_	32	15	1Trn14_	1	1	42722	1.00	20993	78639	0.0000
22	3	Trn2_T3	31	16	2Trn14	1	1	41044	1.00	20341	91957	0.0000
											Total, U =	0.0171

Table 9 (Continued): EAF Fatigue Usage Calculation for the Nozzle Blend Radius Location

		HWC DO	NWC DO	
EAF Calculations:				
(DO and HWC/NWC inputs from Table 1 of Reference [6])		97	114	ppb
	% HWC =	0.47	0.53	= % NWC

Transient Maximum Temperatures:

From "VY-VFAT-2i.ALL":

Index	Load #1	Desc. #1	Load #2	Desc. #2	Line #	T1 (4)	s1 (4)	T2 (4)	s2 (4)	Sn (psi)	T (°F) (1)
1	25	2Trn30_	26	3Trn30_	591851	25	15	26	30	51402	543
2	8	3Trn11_	13	8Trn11_	127122	8	30	13	14	15961	391
3	19	2Trn21_	22	Tn24_T2_	574637	19	20	22	1	39644	389
4	7	2Trn11_	27	4Trn30_	107543	7	32	27	17	38618	465
5	4	1Trn3_	7	2Trn11_	3921	4	1	7	32	36665	465
6	10	5Trn11_	19	2Trn21_	248706	10	67	19	20	15935	389
7	1	Trn2_T1_	6	1Trn11_	70	1	1	6	4	49693	526
8	2	Trn2_T2_	19	2Trn21_	2028	2	1	19	20	25423	389
9	12	7Trn11_	19	2Trn21_	391806	12	30	19	20	13983	389
10	1	Trn2_T1_	9	4Trn11_	161	1	1	9	1	47005	434
11	4	1Trn3_	11	6Trn11_	5546	4	1	11	1	35885	348
12	1	Trn2_T1_	5	2Trn3_	56	1	1	5	42	44974	549
13	4	1Trn3_	5	2Trn3_	3475	4	1	5	42	44974	549
14	4	1Trn3_	24	1Trn30_	10818	4	1	24	1	44912	549
15	4	1Trn3_	18	1Trn21_	10186	4	1	18	1	44912	549
16	17	3Trn14_	18	1Trn21_	536013	17	111	18	1	44598	549
17	18	1Trn21_	20	3Trn21_	571713	18	1	20	39	43608	549
18	19	2Trn21_	20	3Trn21_	573512	19	1	20	39	43426	549
19	3	Trn2_T3_	19	2Trn21_	3151	3	1	19	1	43219	549
20	3	Trn2_T3_	14	9Trn11_	2965	3	1	14	158	43408	524
21	3	Trn2_T3_	15	1Trn14_	2979	3	1	15	1	42722	526
22	3	Trn2_T3_	16	2Trn14_	2983	3	1	16	1	41044	524

TMAX (°F) (1)	TMAX (°C)	HWC Fen (2)	NWC Fen (2)	Uenv (3)
543	284	8.49	10.65	0.002
391	199	3.88	4.22	0.005
389	198	3.84	4.17	0.000
465	241	5.68	6.62	0.000
465	241	5.68	6.62	0.002
389	198	3.84	4.17	0.001
526	274	7.78	9.60	0.002
389	198	3.84	4.17	0.011
389	198	3.84	4.17	0.001
434	223	4.84	5.48	0.001
348	176	3.11	3.25	0.001
549	287	8.76	11.05	0.017
549	287	8.76	11.05	0.033
549	287	8.76	11.05	0.000
549	287	8.76	11.05	0.013
549	287	8.76	11.05	0.000
549	287	8.76	11.05	0.029
549	287	8.76	11.05	0.011
549	287	8.76	11.05	0.010
524	273	7.70	9.49	0.001
526	274	7.78	9.60	0.000
524	273	7.70	9.49	0.000
			Total, U =	*0.140*
			Overall Fen =	8.20

Notes:
1. T_{MAX} is the maximum temperature of the two paired load states, and represents the metal (nodal) temperature at the location being analyzed. This, which is included as "T" in the "Transient Maximum Temperatures" table above, determined from the VESLFAT
2. F_{en} values computed using the low alloy steel equation from Section 3.0 of Reference [6], with S* conservatively set to a maximum value of 0.015, and the transformed strain rate conservatively set to a minimum value of ln (0.001) = -6.908 for all load
3. U_{env} = [U x HWC F_{en} x % HWC] + [U x NWC F_{en} x % NWC].
4. T1 and T2 represent the load number for Load #1 and Load #2, respectively, and s1 and s2 represent the state number for each
5. For each load pair, n_1 is the number of available cycles for Load #1, n_2 is the number of available cycles for Load #2, and n is the available number of cycles for the load pair (i.e., the minimum of n_1 and n_2).

Table 10: Linearized Stress Files Compiled for *VY-StressResults.xls*

Filename	Description
vy_16q_tran2-s.csv	Transient 2 linearized stress
vy_16q_tran3-s.csv	Transient 3 linearized stress
vy_16q_tran11-s.csv	Transient 11 linearized stress
vy_16q_tran14-s.csv	Transient 14 linearized stress
vy_16q_tran21-23-s.csv	Transients 21-23 linearized stress
vy_16q_tran24-s.csv	Transient 24 linearized stress
vy_16q_tran30-s.csv	Transient 30 linearized stress

Note: All files are from the supporting computer files associated with Reference [1].

Structural Integrity Associates, Inc.

CALCULATION PACKAGE

File No.: 0801038.304

Project No.: 0801038

Quality Program: ☒ Nuclear ☐ Commercial

PROJECT NAME:
VY Confirmatory Analysis for CS and RO Nozzles

CONTRACT NO.:
10163217 Amendment 5

CLIENT:
Entergy Nuclear Operations, Inc

PLANT:
Vermont Yankee Nuclear Power Station

CALCULATION TITLE:
Design Inputs and Methodology for ASME Code Fatigue Usage Analysis of Reactor Recirculation Outlet Nozzle

Document Revision	Affected Pages	Revision Description	Project Manager Approval Signature & Date	Preparer(s) & Checker(s) Signatures & Date
0	1 - 20, Appendix: A-1 – A-23 Computer files.	Initial issue.	Gary L. Stevens 01/07/09	**Preparers:** Michael J. Minard 01/07/09 Tyler D. Novotny 01/07/09 **Checker:** Terry J. Herrmann 01/07/09
1	1-8, 10, 11, 13-20, A-2	Revised per summary contained in Section 1.1. Changes are marked with "revision bars" in right-hand margin.	Gary L. Stevens (signature) Gary L. Stevens 03/09/09	**Preparer:** (signature) Tyler D. Novotny 03/09/09 **Checker:** (signature) William Weitze 03/09/09

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1.0 OBJECTIVE

The objective of this calculation package is to establish the design inputs and methodology to be used for an ASME Code, Section III fatigue usage calculation of the reactor pressure vessel (RPV) recirculation outlet (RO) nozzle at Vermont Yankee Nuclear Power Station (VYNPS)[1].

This calculation, along with subsequent calculations for stress and fatigue, are being performed to assess the impact of using finite element analysis using all six components of stress in lieu of the Green's Function approach used in SI project VY-16Q [4, 7, and 11]. Therefore, to the extent possible, inputs from that project will be maintained and used.

1.1 Changes Made in Revision 1 of this Calculation

Description of changes made in Revision 1 of this calculation:

a. Transient 9 described in Table 1 was changed to more precisely match the Green's Function analysis.
b. All remaining changes marked throughout this calculation are editorial changes made to the text of the calculation package.

2.0 METHODOLOGY

A detailed fatigue usage calculation of the RO nozzle will be performed using the methodology of Subarticle NB-3200 of Section III of the ASME Code [1]. The 1998 Edition including the 2000 Addenda of the ASME Code [10] is also used for material properties. Only the fatigue calculation portion of the ASME Code methodology will be used and the analysis will be a fatigue assessment only, not a complete ASME Code analysis.

Finite element analysis will be performed using a previously-developed axisymmetric finite element model (FEM) of the RO nozzle [7]. Thermal transient analysis will be performed using the FEM for each defined transient. Concurrent with the thermal transients are pressure and piping interface loads; for these loads, unit load analyses (finite element analysis for pressure, and manual calculations for piping loads) will be performed. The stresses from these analyses will be scaled appropriately based on the magnitude of the pressure and piping loads during each thermal transient, and combined with stresses from the thermal transients. Other stress concentration factors (SCFs) will be applied as appropriate.

All six components of the stress tensor will be used for stress calculations. The stress components for the non-axisymmetric loads (shear and moment piping loads) can have opposite signs depending upon which side of the nozzle is being examined. Therefore, when combining stress components from these loads with stress components from thermal transients and other loads, the signs of the stress components will be adjusted to maximize the magnitude of the stress component ranges. The fatigue analysis will be performed at locations that were determined in a previous calculation [4]. Stresses will be linearized at these locations.

[1] The methodology described and applied herein and in the two additional recirculation outlet nozzle fatigue calculations is in accordance with the approach used in the SIA calculations for the feedwater nozzle [16, 17, 18] and contains no significantly different scientific or technical judgments used in those calculations.

The linearized primary plus secondary membrane plus bending stress will be used to determine the value of K_e to be used in the simplified elastic-plastic analysis in accordance with ASME Code NB-3200 methodology. Environmental fatigue multipliers will be applied in accordance with NUREG/CR-6583 [2] for the low alloy steel forging and NUREG/CR-5704 [15] for the stainless steel safe end.

3.0 ASSUMPTIONS / DESIGN INPUTS

3.1 Assumptions

1. Extended power uprate (EPU) effects are considered as being applied to the entire 60-year period of operation. The higher pressures, flows, and temperatures at uprate conditions are used in determining and applying heat transfer coefficients [4, Section 3.2] [11, Section 4.1].

2. The Boltup transient does not affect the RO nozzle because there is no pressure or temperature change, and the nozzle is sufficiently removed from the vicinity of the flange such that stresses due to head stud tensioning are insignificant at the nozzle location [8]. The Boltup transient is therefore excluded from the transients analyzed.

3. For the blend radius and safe end transient definitions, steady state condition time steps were assumed to be 5,000 seconds for Transients 3, 5, 6, 8, 9, and 40,000 seconds for Transients 1, 2, 4, 7, 10.

4. The effect of non-uniform geometries is judged to be insignificant for flow inside the safe end, because of the smooth transition and small geometry changes, as shown in Figure 3. The nominal inner diameter for all heat transfer regions was used to calculate heat transfer coefficients.

5. Density, ρ, and Poisson's ratio, ν, used in the FEM are assumed typical values of $\rho = 0.283$ lb/in^3 and $\nu = 0.3$, respectively.

6. For purposes of linearizing stress at the nozzle blend radius, the cladding is ignored.

7. Stress components due to piping loads are scaled assuming no stress occurs at an ambient temperature of 70°F and the full values are reached at reactor design temperature, 575°F, as was done in the previous analysis [11, Section 3.4].

8. Consistent with Reference [4], 12% of the available temperature difference (ΔT) between the fluid and surface was assumed for all natural convection thermal heat transfer coefficients.

9. The instant temperature change for transients is assumed as a 1-second time step.

3.2 ASME Code Edition

The analysis will be performed in a manner consistent with the fatigue usage rules in NB-3200 of Section III of the ASME Code; the 1998 Edition with Addenda through 2000 [1] will be used, for consistency with the previous analysis [11].

3.3 Transients

Previously developed thermal and pressure transients [11, Tables 2 and 3] are used for this analysis. The transients to be evaluated are shown in Table 1. For each transient, the time, nozzle fluid temperature, RPV pressure, percent reactor recirculation flow rate, and number of cycles are included. In some cases, flow rates and nozzle temperature values from the nozzle thermal cycle diagram [8, Attachment 1, p. 4] are used to reduce excess conservatism. Note that the only difference between the vessel and the safe end/nozzle transients is the temperature difference between the two regions for Transient 9.

At the inside surface of the RPV, the Region B or B1 bulk fluid temperature from the reactor thermal cycle diagram [8, Attachment 1, p. 2] shall be applied.

3.4 Heat Transfer Coefficients

Heat transfer coefficients are calculated at 300° F, as in the previous analysis [4]. The heat transfer coefficients for the 100% flow and 50% flow cases were calculated from Reference [5] as follows:

$$h_{Df} = h_{300}\left(\frac{f_{Df}}{25}\right)^{0.8}\left(\frac{26}{D_{Df}}\right)^{0.2}$$

Where:
h_{Df} = the heat transfer coefficient at a Diameter and flow rate
h_{300} = the heat transfer coefficient from Reference [5] at 300°F, f = 25 ft/sec, and D = 26" = 4,789 BTU/hr-ft^2-°F
f_{Df} = the flow velocity corresponding to h_{Df} (ft/sec)
D_{Df} = the diameter corresponding to h_{Df} (in)

The heat transfer coefficients for 0% flow were calculated in spreadsheet *HT_COEF.xls* for natural convection and are shown in Tables 6 and 7.

As shown in Figure 1, the following heat transfer coefficients were applied:

Region 1

The heat transfer coefficient, h, for 100% flow is $4789\left(\frac{17.364}{25}\right)^{0.8}\cdot\left(\frac{26}{25.8}\right)^{0.2} = 3583$ BTU/hr-ft^2-°F at 300°F, where 17.364 ft/sec is converted from 28,294 GPM and 25.8 in ID [20].

The heat transfer coefficient, h, for 50% flow is $4789\left(\frac{8.682}{25}\right)^{0.8}\cdot\left(\frac{26}{25.8}\right)^{0.2} = 2058$ BTU/hr-ft^2-°F at 300°F, where 8.682 ft/sec is converted from 14,147 GPM and 25.8 in ID [20].

The heat transfer coefficient, h, for 12% flow is $4789\left(\frac{2.084}{25}\right)^{0.8}\cdot\left(\frac{26}{25.8}\right)^{0.2} = 657$ BTU/hr-ft^2-°F at 300°F, where 2.084 ft/sec is converted from 3,395 GPM and 25.8 in ID [20].

The heat transfer coefficient, h, for 0% flow is 112 BTU/hr-ft^2-°F at 300°F. (Table 6, for natural convection)

Region 2

The heat transfer coefficient for Region 2 is linearly transitioned from the value of the heat transfer coefficient used in Region 1 to the value used for Region 3.

Region 3 (the point between Region 2 and Region 4)

The inside diameter of Region 3, as measured on the ANSYS model, is 35.49 inches.

The heat transfer coefficient, h, for 100% flow is $4789\left(\frac{9.176}{25}\right)^{0.8}\cdot\left(\frac{26}{35.49}\right)^{0.2}=2018$ BTU/hr-ft^2-°F at 300°F, where 9.176 ft/sec is converted from 28,294 GPM and 35.49 in. ID.

The heat transfer coefficient, h, for 50% flow is $4789\left(\frac{4.588}{25}\right)^{0.8}\cdot\left(\frac{26}{35.49}\right)^{0.2}=1159$ BTU/hr-ft^2-°F at 300°F, where 4.588 ft/sec is converted from 14,147 GPM and 35.49 in. ID.

The heat transfer coefficient, h, for 12% flow is $4789\left(\frac{1.101}{25}\right)^{0.8}\cdot\left(\frac{26}{35.49}\right)^{0.2}=370$ BTU/hr-ft^2-°F at 300°F, where 1.101 ft/sec is converted from 3,395 GPM and 35.49 in. ID.

The heat transfer coefficient, h, for 0% flow is 112 BTU/hr-ft^2-°F at 300°F. using the same HTC as Region 1 (Table 6, for natural convection)

Region 4

The heat transfer coefficient for Region 4 (Nozzle Blend Radius).is linearly transitioned from the value of the heat transfer coefficient used in Region 3 to the value used in Region 5.

Region 5

A value of 0.5 × Region 1 HTC from Reference [5, page I-T9-4, 6] is used to simulate the interior of the RPV shell for all conditions.

The heat transfer coefficient, h, for 100% flow is 0.5 x 3583.3 = 1,792 BTU/hr-ft^2-°F at 300°F.

The heat transfer coefficient, h, for 50% flow is 0.5 x 2058.1= 1029 BTU/hr-ft^2-°F at 300°F.

The heat transfer coefficient, h, for 12% flow is 0.5 x 657.2= 329 BTU/hr-ft^2-°F at 300°F.

The heat transfer coefficient, h, for 0% flow is 101 BTU/hr-ft^2-°F at 300°F. (Table 7, for natural convection) by using 40 in. hydraulic diameter [5].

Region 6

The heat transfer coefficient, h, is 0.4 BTU/hr-ft^2-°F [5].

A summary of the heat transfer coefficients (HTC) to be used is shown in Table 2.

3.5 Finite Element Model

The ANSYS program [6] will be used to perform the finite element analysis. A previously developed axisymmetric model will be used [7, file *RON_VY.INP*], except that temperature-dependent material properties will be used. Table 3 shows the applicable material properties [10].

Stresses will be extracted and linearized at two locations, both on the inside surface of the model, one at the safe end, and one at the blend radius, as was done previously [4].

3.6 Nozzle Blend Radius Pressure Stress

The axisymmetric model has the effect of modeling the cylindrical RPV as spherical. The following paragraphs describe the details of the modeling used to account for the differences in this approximation and the actual geometry of two intersecting cylinders.

The radius of the vessel in the finite element model was multiplied by a factor of 2 to account for the fact that the vessel portion of the axisymmetric model is a sphere, but the true geometry is a cylinder. The equation for the membrane hoop stress for a sphere is:

$$\sigma = \frac{(pressure) \times (radius)}{2 \times thickness}$$

The equation for the membrane hoop stress in a cylinder is:

$$\sigma = \frac{(pressure) \times (radius)}{thickness}$$

The factor of two was verified in Reference [4], where actual stress results were compared to the results of this analytical form.

The pressure stress components for the safe end and blend radius paths will be extracted using ANSYS [6].

3.7 Piping Interface Loads

Per Reference [9, 11], the RO nozzle piping loads, which conservatively use the design loads for the seismic, thermal and deadweight load combination, are stated in Table 4 along with relevant dimensions. The coordinate system used for these are shown in Figure 2 and is consistent with Reference [9]. The finite element model coordinate system is shown in Figure 1.

3.8 SCFs, Safe End

At the safe end inside surface, guidance is taken from the piping analysis rules in Subarticle NB-3600 of Section III of the ASME Code [1]. The stresses caused by the piping will be hand calculated and require a stress concentration factor, if appropriate. The stress concentration factor for the safe end location is 1.53 [5, page I-S9-4E, Table 5]. This value is conservatively used for both the C_2 and K_2 values required by the ASME code [1, NB-3600]. The piping loads are relatively minor in comparison to the other loads this nozzle experiences so the conservative C_2 and K_2 values will have a small impact on the analysis. These factors are conservatively applied to all six components of the stress tensor.

3.9 Environmental Fatigue Multipliers

The environmental fatigue multipliers for the safe end will be calculated in accordance with NUREG/CR-5704 methodology [15], and the environmental fatigue multipliers for the nozzle blend radius will be calculated in accordance with NUREG/CR-6583 methodology [2].

Table 1: Vessel and Nozzle/Safe End Transients

Transient Number	Time (s)	Temp (°F)	Time Step (s)	Pressure (psig)	Flow Rate (GPM)
1. Normal Startup with Heatup at 100°F/hr 300 Cycles (2)	0	100		0	14147.0
	16164	549	16164	1010	(50%)
	56164	549	40000	1010	
2. Turbine Roll and Increase to Rated Power 300 Cycles (1, 2)	0	549		1010	28294
	1	542	1	1010	(100%)
	601	542	600	1010	
	602	526	1	1010	
	40602	526	40000	1010	
3. Loss of Feedwater Heaters Turbine Trip 25% Power 10 Cycles (2)	0	526		1010	28294
	1800	542	1800	1010	(100%)
	2100	542	300	1010	
	2460	526	360	1010	
	3060	526	600	1010	
	3960	542	900	1010	
	4260	542	300	1010	
	6060	526	1800	1010	
	11060	526	5000	1010	
4. Loss of Feedwater Pumps 10 Cycles (1, 2)	0	526		1010	0
	3	526	3	1190	(0%)
	13	526	10	1135	
	233	300	220	1135	
	2213	500	1980	1135	
	2393	300	180	885	
	6773	500	4380	1135	
	7193	300	420	675	14147
	7493	300	300	675	(50%)
	11093	400	3600	240	
	16457	549	5364	1010	
	16517	549	60	1010	
	16518	542	1	1010	28294
	17118	542	600	1010	(100%)
	17119	526	1	1010	
	57119	526	40000	1010	
5. Turbine Generator Trip 60 Cycles (1, 2)	0	526		1010	28294
	10	526	10	1135	(100%)
	15	526	5	1135	
	30	526	15	940	
	1830	526	1800	940	
	2250	549	420	1010	
	2310	549	60	1010	
	2311	542	1	1010	
	2911	542	600	1010	
	2912	526	1	1010	
	7912	526	5000	1010	

Transient Number	Time (s)	Temp (°F)	Time Step (s)	Pressure (psig)	Flow Rate (GPM)
6. Reactor Overpressure 1 Cycle (1, 2)	0	526		1010	28294
	2	526	2	1375	(100%)
	32	526	30	940	
	1832	526	1800	940	
	2252	549	420	1010	
	2312	549	60	1010	
	2313	542	1	1010	
	2913	542	600	1010	
	2914	526	1	1010	
	7914	526	5000	1010	
7. SRV Blowdown 1 Cycle (2)	0	526		1010	28294
	600	375	600	170	(100%)
	11580	70	10980	50	
	51580	70	40000	50	
8. SCRAM Other 228 Cycles (1, 2)	0	526		1010	28294
	15	526	15	940	(100%)
	1815	526	1800	940	
	2235	549	420	1010	
	2295	549	60	1010	
	2296	542	1	1010	
	2356	542	60	1010	
	2357	526	1	1010	
	7357	526	5000	1010	
9. Improper Startup 1 Cycle (1, 2)	0	526		1010	3395
	1	130 [3]	1	1010	(12%)
	27	130 [3]	26	1010	
	28	526	1	1010	
	5028	526	5000	1010	
10. Shutdown 300 Cycles (2)	0	549		1010	14147
	6264	375	6264	170	(50%)
	6864	330	600	88	
	16224	70	9360	50	
	56224	70	40000	50	
11. Design Hydrostatic Test 120 Cycles (2)	---	100	---	0	1981
				1100	(7%)
				50	
12. Hydrostatic Test 1 Cycle (2)	—	100	—	50	1981
				1563	(7%)
				50	

1. The instant temperature change is assumed as 1-second time step.
2. The number of cycles is for 60 years [8].
3. 130°F is the Region 1 temperature for Transient 9, whereas the blend radius is at 268°F and the vessel is at 268°F, as was modeled previously [11].

Table 2: Heat Transfer Coefficients

Thermal Region	Flow Rate			
	100%	50%	12%	0% (Natural Convection)
Region 1	3583	2058	657	112
Region 2		Linear transition from Region 1 and Region 3 values		
Region 3	2018	1159	370	112
Region 4		Linear transition from Region 3 and Region 5 values		
Region 5	1792	1029	329	101
Region 6		0.4 for all flow rates		

Note: All Heat transfer coefficients are in units of BTU/hr-ft^2-°F and are evaluated at 300°F.

Table 3: Temperature-Dependent Material Properties

Material No.	Description	Temperature, °F	Young's Modulus, E x 10^6 (psi)	Mean Coefficient of Thermal Expansion, α x 10^{-6} (in/in-°F)	Conductivity, k (BTU/hr-ft-°F) (see Note 1)	Diffusivity, d (ft^2/hr)	Specific Heat, c_p (BTU/lbm-°F) (see Note 4)
4	SA533 Grade B,	70	29.2	7.0	23.5	0.458	0.105
	[Vessel Wall]	200	28.5	7.3	23.6	0.425	0.114
	(Mn-½Mo-½Ni)	300	28.0	7.4	23.4	0.401	0.119
		400	27.4	7.6	23.1	0.378	0.125
		500	27.0	7.7	22.7	0.356	0.130
		600	26.4	7.8	22.2	0.336	0.135
2	SA-508 Class 2	70	27.8	6.4	23.5	0.458	0.105
	[Nozzle Forging]	200	27.1	6.7	23.6	0.425	0.114
		300	26.7	6.9	23.4	0.401	0.119
		400	26.1	7.1	23.1	0.378	0.125
		500	25.7	7.3	22.7	0.356	0.130
	(See Note 2)	600	25.2	7.4	22.2	0.336	0.135
1, 3	SA 240 Type	70	28.3	8.5	8.6	0.151	0.116
	304, SS Clad,	200	27.6	8.9	9.3	0.156	0.122
	SA182 Type	300	27.0	9.2	9.8	0.160	0.125
	F316	400	26.5	9.5	10.4	0.165	0.129
	[Clad, Safe End]	500	25.8	9.7	10.9	0.170	0.131
	(see Note 3)	600	25.3	9.8	11.3	0.174	0.133

Notes:
1. Convert to BTU/sec-in-°F for input to ANSYS.
2. Properties of A508 Class II are used (3/4Ni-1/2Mo-1/3Cr-V).
3. Properties of 18Cr - 8Ni austenitic stainless steel are used.
4. Calculated as $[k/(\rho d)]/12^3$.

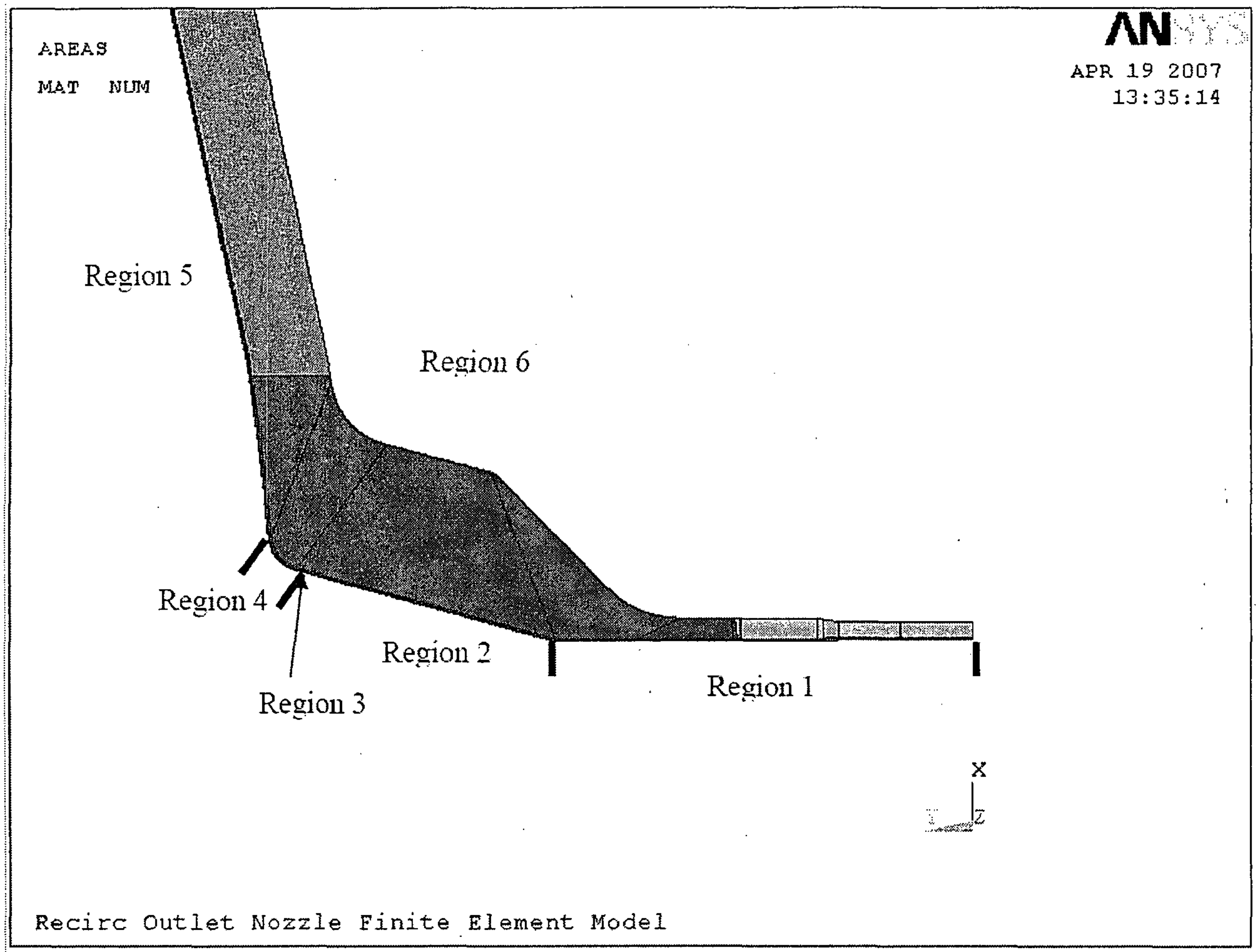

Figure 1: Nozzle and Vessel Wall Thermal Boundaries

4.0 CALCULATIONS

4.1 Piping Interface Loads

From general structural mechanics [14], the membrane plus bending stresses at the inside surface of a thick-walled cylinder are:

σ_{z1} = axial stress due to axial force = F_z/A
σ_{z2} = axial stress due to bending moment = $M_{xy}(ID/2)/I$
$\sigma_z = \sigma z1 + \sigma z2$
$\tau_{r\theta}$ = shear stress due to torsion = $M_z(ID/2)/J$
τ_{rz} = shear stress due to shear force = $2F_{xy}/A$, where

F_x, F_y, F_z, M_x, M_y, and M_z are forces and moments at the pipe-to-safe end weld
M_{xL} = moment about x axis translated by length z = -L = $M_x - F_y L$
M_{yL} = moment about y axis translated by length z = -L = $M_y + F_x L$
M_{xy} = resultant bending moment = $(M_{xL}^2 + M_{yL}^2)^{0.5}$
F_{xy} = resultant shear force = $(F_x^2 + F_y^2)^{0.5}$

ID, OD = inside and outside diameters
A = area of cross section = $(\pi/4)(OD^2 - ID^2)$

I = moment of inertia = $(\pi/64)(OD^4 - ID^4)$
J = polar moment of inertia = $(\pi/32)(OD^4 - ID^4)$

The shear stresses are expressed in a local coordinate system with r radial (X in ANSYS coordinates), θ circumferential (Z in ANSYS coordinates), and Z axial (Y in ANSYS coordinates). Tables 4 and 5 show the calculation of stresses; ID, OD, and L are taken from the previous piping load stress calculations [11, Section 3.4]. Forces and moments are taken from Reference 11, Table 1. Note that the IDs shown in Table 4 for the safe end and nozzle blend radius (25.938" and 37.368", respectively) represent the two most limiting locations for the nozzle (See Figure 3), and therefore do not represent the ID values where the HTCs were calculated.

Table 4: Recirculation Outlet Nozzle Attached Piping Loads and Dimensions [9, 11]

	Safe End	Nozzle Blend Radius
F_x, kip	20.0	20.0
F_y, kip	20.0	20.0
F_z, kip	30.0	30.0
M_x, kip-in	2004.0	2004.0
M_y, kip-in	3000.0	3000.0
M_z, kip-in	2004.0	2004.0
L, in	4.25	42.77
OD, in	28.38	55.88
ID, in	25.938	37.368

Table 5: Membrane Plus Bending Stresses Due to Piping Loads

	Safe End	Blend Radius
M_{xL}, kip-in	1919.00	1148.60
M_{yL}, kip-in	3085.00	3855.40
M_{xy}, kip-in	3633.15	4022.86
F_{xy}, kip-in	28.28	28.28
A, in^2	104.18	1355.76
I, in^4	9624.85	382912.48
J, in^4	19249.69	765824.95
σ_{z1}, ksi	0.288	0.022
σ_{z2}, ksi	4.895	0.196
σ_z, ksi	5.183	0.218
$\tau_{r\theta}$, ksi	1.350	0.049
τ_{rz}, ksi	0.543	0.042

Table 6: 0% Flow Regions 1 and 3 Heat Transfer Coefficients

Pipe Inside Diameter, D =	25.800	inches =	2.150	ft		
		=	0.655	m		
Outer Pipe, Inside radius, r_o =	12.9	inches =	1.075	ft		
			0.328	m		
Inner Pipe Outside Diameter, D =	n/a	inches =	0.000	ft		
		=	0.000	m		0.000
Inner Pipe, Outside radius, r_i =	0	inches =	0.000	ft		
			0.000	m		
Fluid Velocity, V =	0.000	ft/sec =	0.000	gpm=	0	Mlb/hr
Characteristic Length, L = D =	2.150	ft =	0.655	m		

$T_{fluid} - T_{surface}$, ΔT = assumed to be 12% of fluid temperature =	8.40	12.00	24.00	36.00	48.00	60.00	72.00	°F
=	4.67	6.67	13.33	20.00	26.67	33.33	40.00	°C

		Value at Fluid Temperature, T [12]							Units
Water Property	Conversion Factor [19]	70 21.11	100 37.78	200 93.33	300 148.89	400 204.44	500 260.00	600 315.56	°F °C
k	1.7307	0.5997	0.6300	0.6784	0.6836	0.6611	0.6040	0.5071	W/m-°C
(Thermal Conductivity)		0.3465	0.3640	0.3920	0.3950	0.3820	0.3490	0.2930	Btu/hr-ft-°F
c_p	4.1869	4.185	4.179	4.229	4.313	4.522	4.982	6.322	kJ/kg-°C
(Specific Heat)		1.000	0.998	1.010	1.030	1.080	1.190	1.510	Btu/lbm-°F
ρ	16.018	997.1	994.7	962.7	917.8	858.6	784.9	679.2	kg/m^3
(Density)		62.3	62.1	60.1	57.3	53.6	49.0	42.4	lbm/ft^3
β	1.8	1.89E-04	3.24E-04	6.66E-04	1.01E-03	1.40E-03	1.98E-03	3.15E-03	m^3/m^3-°C
(Volumetric Rate of Expansion)		1.05E-04	1.80E-04	3.70E-04	5.60E-04	7.80E-04	1.10E-03	1.75E-03	ft^3/ft^3-°F
g	0.3048	9.806	9.806	9.806	9.806	9.806	9.806	9.806	m/s^2
(Gravitational Constant)		32.17	32.17	32.17	32.17	32.17	32.17	32.17	ft/s^2
μ	1.4881	9.96E-04	6.82E-04	3.07E-04	1.93E-04	1.38E-04	1.04E-04	8.62E-05	kg/m-s
(Dynamic Viscosity)		6.69E-04	4.58E-04	2.06E-04	1.30E-04	9.30E-05	7.00E-05	5.79E-05	lbm/ft-s
Pr (Prandtl Number)		6.980	4.510	1.910	1.220	0.950	0.859	1.070	—
Calculated Parameter	**Formula**	**70**	**100**	**200**	**300**	**400**	**500**	**600**	**°F**
Reynold's Number, Re	$\rho VD/\mu$	0	0	0	0	0	0	0	—
Grashof Number, Gr	$g\beta\Delta TL^3/(\mu/\rho)^2$	2441754517	1.2697E+10	2.417E+11	1.252E+12	3.9766E+12	1.034E+13	2.16049E+13	—
Grashof Number, Gr_δ	$g\beta\Delta T(r_o-r_i)^3/(\mu/\rho)^2$	3.05E+08	1.59E+09	3.02E+10	1.57E+11	4.97E+11	1.29E+12	2.70E+12	—
Rayleigh Number, Ra	GrPr	17043446531	5.7265E+10	4.616E+11	1.528E+12	3.7777E+12	8.883E+12	2.31172E+13	—
Rayleigh Number, Ra	$Gr_\delta Pr$	2.13E+09	7.16E+09	5.77E+10	1.91E+11	4.72E+11	1.11E+12	2.89E+12	—

From [19]:

Inside Surface Natural Convection Heat Transfer Coefficient:

Case:	Enclosed cylinder		C =	0.55	n =	0.25	(see page 289 of [3])		
H_{free}	$C(GrPr)^n k/L$	181.85	258.65	469.34	637.89	773.57	875.17	933.22	W/m^2-°C
		32.03	45.55	82.66	112.34	136.24	154.13	164.35	$Btu/hr\text{-}ft^2$-°F

Table 7: 0% Flow Region 5 Heat Transfer Coefficient

Pipe Inside Diameter, D = 40.000 inches = 3.333 ft
= 1.016 m
Outer Pipe, Inside radius, r_o = 20 inches = 1.667 ft
0.508 m
Inner Pipe Outside Diameter, D = n/a inches = 0.000 ft
= 0.000 m 0.000
Inner Pipe, Outside radius, r_i = 0 inches = 0.000 ft
0.000 m
Fluid Velocity, V = 0.000 ft/sec = 0.000 gpm= 0 Mlb/hr
Characteristic Length, L = D = 3.333 ft = 1.016 m

$T_{fluid} - T_{surface}$, ΔT = assumed to be 12% of fluid temperature =	8.40	12.00	24.00	36.00	48.00	60.00	72.00	°F
=	4.67	6.67	13.33	20.00	26.67	33.33	40.00	°C

Water Property	Conversion Factor [19]	Value at Fluid Temperature, T [12]							Units
		70	100	200	300	400	500	600	°F
		21.11	37.78	93.33	148.89	204.44	260.00	315.56	°C
k (Thermal Conductivity)	1.7307	0.5997	0.6300	0.6784	0.6836	0.6611	0.6040	0.5071	W/m-°C
		0.3465	0.3640	0.3920	0.3950	0.3820	0.3490	0.2930	Btu/hr-ft-°F
c_p (Specific Heat)	4.1869	4.185	4.179	4.229	4.313	4.522	4.982	6.322	kJ/kg-°C
		1.000	0.998	1.010	1.030	1.080	1.190	1.510	Btu/lbm-°F
ρ (Density)	16.018	997.1	994.7	962.7	917.8	858.6	784.9	679.2	kg/m³
		62.3	62.1	60.1	57.3	53.6	49.0	42.4	lbm/ft³
β (Volumetric Rate of Expansion)	1.8	1.89E-04	3.24E-04	6.66E-04	1.01E-03	1.40E-03	1.98E-03	3.15E-03	m³/m³-°C
		1.05E-04	1.80E-04	3.70E-04	5.60E-04	7.80E-04	1.10E-03	1.75E-03	ft³/ft³-°F
g (Gravitational Constant)	0.3048	9.806	9.806	9.806	9.806	9.806	9.806	9.806	m/s²
		32.17	32.17	32.17	32.17	32.17	32.17	32.17	ft/s²
μ (Dynamic Viscosity)	1.4881	9.96E-04	6.82E-04	3.07E-04	1.93E-04	1.38E-04	1.04E-04	8.62E-05	kg/m-s
		6.69E-04	4.58E-04	2.06E-04	1.30E-04	9.30E-05	7.00E-05	5.79E-05	lbm/ft-s
Pr (Prandtl Number)		6.980	4.510	1.910	1.220	0.950	0.859	1.070	—
Calculated Parameter	**Formula**	**70**	**100**	**200**	**300**	**400**	**500**	**600**	°F
Reynold's Number, Re	$\rho VD/\mu$	0	0	0	0	0	0	0	—
Grashof Number, Gr	$g\beta\Delta TL^3/(\mu/\rho)^2$	9099611606	4.7319E+10	9.006E+11	4.667E+12	1.4819E+13	3.854E+13	8.05143E+13	—
Grashof Number, Gr_δ	$g\beta\Delta T(r_o-r_i)^3/(\mu/\rho)^2$	1.14E+09	5.91E+09	1.13E+11	5.83E+11	1.85E+12	4.82E+12	1.01E+13	—
Rayleigh Number, Ra	GrPr	63515269008	2.1341E+11	1.72E+12	5.6938E+12	1.4078E+13	3.31E+13	8.61503E+13	—
Rayleigh Number, Ra	$Gr_\delta Pr$	7.94E+09	2.67E+10	2.15E+11	7.12E+11	1.76E+12	4.14E+12	1.08E+13	—

From [19]:

Inside Surface Natural Convection Heat Transfer Coefficient:

Case:	Enclosed cylinder	C =	0.55	n =	0.25	(see page 289 of [3])			
H_{free}	$C(GrPr)^n k/L$	162.97	231.79	420.60	571.66	693.25	784.30	836.32	W/m²-°C
		28.70	40.82	74.07	100.68	122.09	138.13	147.29	Btu/hr-ft²-°F

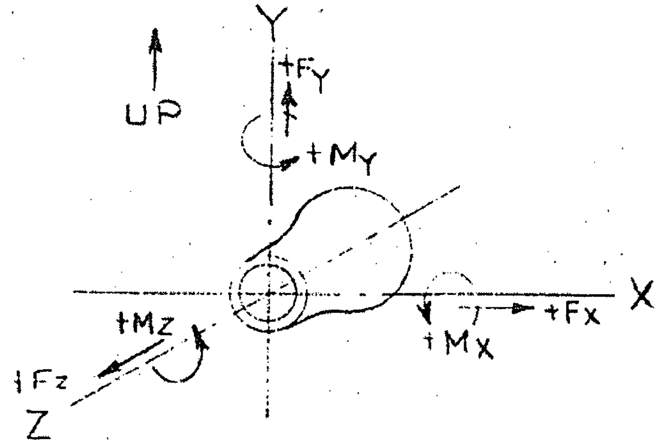

Figure 2: Coordinate System for Forces and Moments

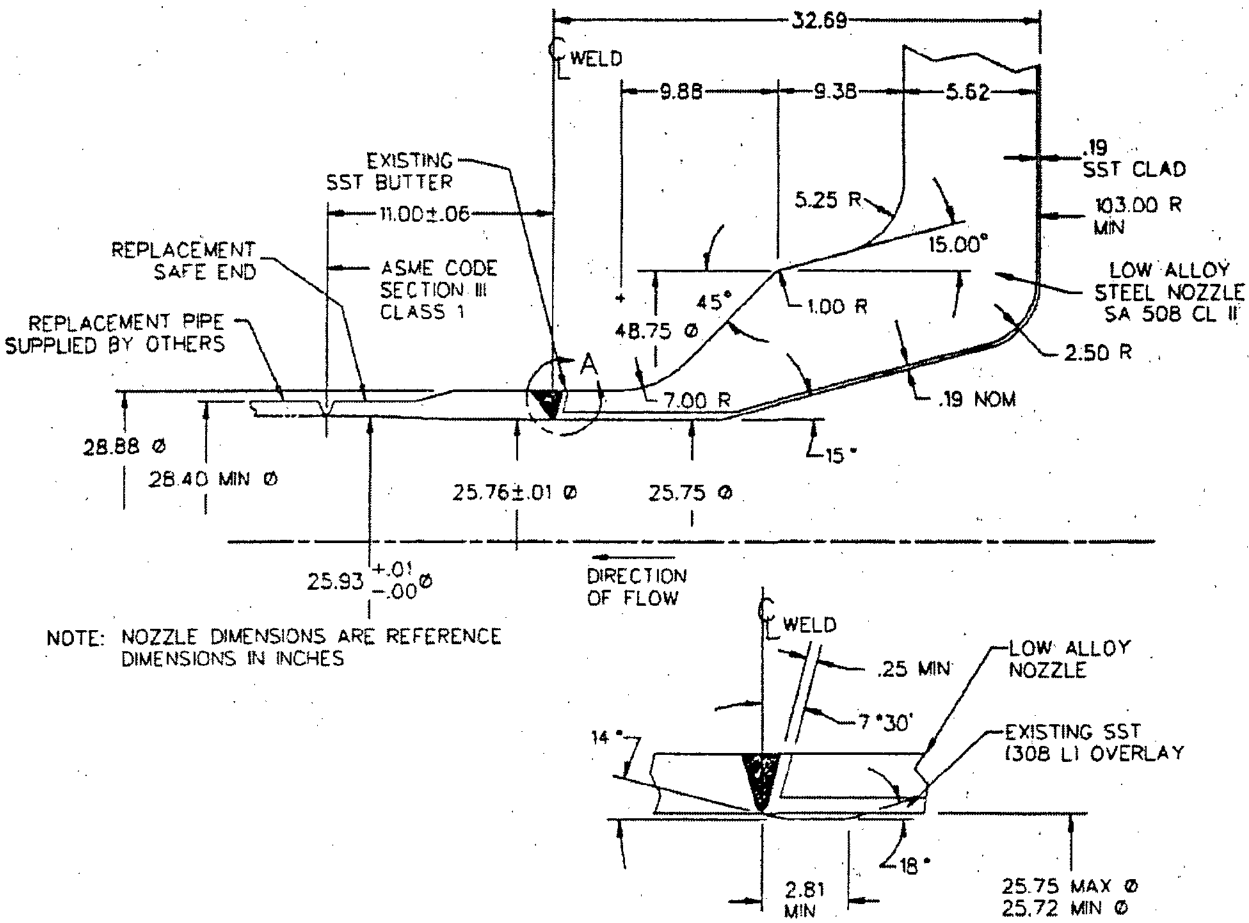

Figure 3: RO Nozzle and Safe End Geometry [20]

5.0 RESULTS OF ANALYSIS

This calculation package specifies the ASME Code Edition, finite element model, thermal and pressure transients (Table 1), and HTCs (Table 2) to be used in a fatigue usage calculation of the RO nozzle at Vermont Yankee. Thermal transient and pressure stress components will be calculated using ANSYS [6] and will be combined with piping loads in subsequent calculations.

Linearized stress components will be used for the fatigue usage calculation. For the nozzle blend radius location, the stresses used in the evaluation will be for the base metal only; that is, the cladding material will be unselected prior to stress extraction consistent with ASME Code rules and Reference [13].

The fatigue usage calculation will consider all six stress components, and will be performed using the rules of Subarticle NB-3200 of Section III of the ASME Code [1]. Calculated fatigue usage factors will be multiplied by the appropriate environmental fatigue multipliers computed for each location.

The results of this calculation are to be used in SIA calculations: No. 081038.305, Stress Analysis of Reactor Recirculation Outlet Nozzle and No. 081038.306, Fatigue Analysis of Recirculation Outlet Nozzle

6.0 REFERENCES

1. American Society of Mechanical Engineers, Boiler and Pressure Vessel Code, Section III, Subsection NB, 1998 Edition, with Addenda through year 2000.

2. NUREG/CR-6583 (ANL-97/18), "Effects of LWR Coolant Environments on Fatigue Design Curves of Carbon and Low-Alloy Steels," March 1998.

3. J. P. Holman, "Heat Transfer," 5th Edition, McGraw Hill Inc., 1981.

4. Structural Integrity Associates Calculation No. VY-16Q-305, Revision 0, "Recirculation Outlet Stress History Development for Nozzle Green Function."

5. CB&I, RPV Stress Report Sections S9 "Stress Analysis Recirculation Outlet Nozzle Vermont Yankee Reactor Vessel." and T9 "Thermal Analysis Recirculation Outlet Nozzle Vermont Yankee Reactor Vessel." CB&I Contract 9-6201, SI File No. VY-16Q-204.

6. ANSYS, Release 8.1 (w/Service Pack 1), ANSYS, Inc., June 2004.

7. Structural Integrity Associates Calculation No. VY-16Q-304, Revision 0, "Recirculation Outlet Nozzle Finite Element Model."

8. Entergy Design Input Record (DIR), Rev. 1, EC No. 1773, Rev. 0, "Environmental Fatigue Analysis for Vermont Yankee Nuclear Power Station," 7/26/07, SI File No. VY-16Q-209.

9. GE Drawing No. 919D294, Revision 11, Sheet 7, "Reactor Vessel, Spec. Control," SI File No. VY-05Q-241.

10. American Society of Mechanical Engineers, Boiler and Pressure Vessel Code, Section II, Part D, 1998 Edition, with Addenda through year 2000.

11. Structural Integrity Associates Calculation No. VY-16Q-306, Revision 0, "Fatigue Analysis of Recirculation Outlet Nozzle."

12. N. P. Cheremisinoff, "Heat Transfer Pocket Handbook," Gulf Publishing Co., 1984.

13. NUREG/CR-6260 (INEL-95/0045), "Application of NUREG/CR-5999 Interim Fatigue Curves to Selected Nuclear Power Plant Components," March 1995.

14. Warren C. Young, "Roark's Formulas for Stress & Strain," Sixth Edition, McGraw – Hill Book Company, 1989.

15. NUREG/CR-5704, "Effects of LWR Coolant Environments on Fatigue Design Curves of Austenitic Stainless Steels," April, 1999.

16. SI Calculation No. VY-19Q-301, Revision 0, "Design Inputs and Methodology for ASME Code Confirmatory Fatigue Usage Analysis of Reactor Feedwater Nozzle."

17. SI Calculation No. VY-19Q-302, Revision 0, "ASME Code Confirmatory Fatigue Evaluation of Reactor Feedwater Nozzle."

18. SI Calculation No. VY-19Q-303, Revision 0, "Feedwater Nozzle Environmental Fatigue Evaluation."

19. J. P. Holman, "Heat Transfer," 4th Edition, McGraw Hill Inc., 1976.

20. GE Stress Report 23A4316, Revision 0, "Stress Report-Reactor Vessel Recirculation Outlet Safe End," SI File No. VY-16-204.

APPENDIX A:

ANSYS Input File: RON_VY.INP

ANSYS Input File: RON_VY.INP

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finish
/clear,start
/prep7
/title, Recirc Outlet Nozzle Finite Element Model

/com, PLANE42, 2-D Solid
et,1,PLANE42,,,1    !Axisymmetric

/com, ***************************
/com, Material Properties
/com, ***************************

MPTEMP, , 70,200,300,400,500,600
tmp = 3600*12       ! hr-ft to sec-in

/COM, Material #1 Safe-End and Portion of Piping (SA-182 F316)  (18Cr-
8Ni)
MPDATA,EX  ,1, , 28.3e6,  27.6e6,  27.0e6,  26.5e6,   25.8e6,   25.3e6
MPDATA,ALPX,1, , 8.5e-6,   8.9e-6,   9.2e-6,   9.5e-6,   9.7e-6,   9.8e-
6
MPDATA, KXX,1, , 8.6/tmp, 9.3/tmp, 9.8/tmp, 10.4/tmp, 10.9/tmp, 11.3/tmp
MPDATA,   C,1, , 0.116,    0.122,    0.125,    0.129,    0.131,    0.133
mp,nuxy,1,0.3
mp,dens,1,0.283

/COM, Material #2 (Nozzle Forging) SA-508 Class 2 (3/4Ni-1/2Mo-1/3Cr-V)
MPDATA,EX  ,2, , 27.8e6,  27.1e6,  26.7e6,  26.1e6,   25.7e6,   25.2e6
MPDATA,ALPX,2, , 6.4e-6,   6.7e-6,   6.9e-6,   7.1e-6,   7.3e-6,   7.4e-
6
MPDATA, KXX,2, , 23.5/tmp, 23.6/tmp, 23.4/tmp, 23.1/tmp, 22.7/tmp,
22.2/tmp
MPDATA,   C,2, , 0.105,    0.114,    0.119,    0.125,    0.130,    0.135
mp,nuxy,2,0.3
mp,dens,2,0.283

/COM, Material #3 (Cladding) SA-240 Type 304 (18Cr-8Ni)
MPDATA,EX  ,3, , 28.3e6,  27.6e6,  27.0e6,  26.5e6,   25.8e6,   25.3e6
MPDATA,ALPX,3, , 8.5e-6,   8.9e-6,   9.2e-6,   9.5e-6,   9.7e-6,   9.8e-
6
MPDATA, KXX,3, , 8.6/tmp, 9.3/tmp, 9.8/tmp, 10.4/tmp, 10.9/tmp, 11.3/tmp
MPDATA,   C,3, , 0.116,    0.122,    0.125,    0.129,    0.131,    0.133
mp,nuxy,3,0.3
```

```
mp,dens,3,0.283

/COM, Material #4 (Vessel) SA-533, GR. B (Mn-1/2Mo-1/2Ni)
MPDATA,EX   ,4, , 29.2e6,  28.5e6,  28.0e6,  27.4e6,   27.0e6,   26.4e6
MPDATA,ALPX,4, , 7.0e-6,   7.3e-6,   7.4e-6,   7.6e-6,   7.7e-6,   7.8e-6
MPDATA, KXX,4, , 23.5/tmp, 23.6/tmp, 23.4/tmp, 23.1/tmp, 22.7/tmp, 22.2/tmp
MPDATA,   C,4, , 0.105,    0.114,    0.119,    0.125,    0.130,    0.135
mp,nuxy,4,0.3
mp,dens,4,0.283

*AFUN,DEG
/com, *** Geometric Parameters ***
*set,vira,(103+3/16)        !Actual Vessel Inner Radius to base metal used for model
*set,vir,2.0*vira                             !2.0 time of  Vessel Inner Radius to base metal used for model
*set,tvw,5+5/8-3/16         !Vessel Wall Thickness
*set,ri1,25.75/2
*set,ro1,28.375/2
*set,L1,5
*set,ro2,28.375/2
*set,L2,4.25
*set,ro3,28.875/2
*set,ro4,48.75/2
*set,L3,1.5
*set,L4,5.25
*set,L5,7+1/16
*set,L6,12+13/16
*set,L7,9+7/8
*set,L8,9+3/8
*set,L9,31+15/16
*set,L10,L9-12-13/16-tvw
*set,ra,7
*set,rb,1
*set,rc,5.25
*set,rd,2.5
*set,tv,3/16
*set,dimA,vir-(tv*2.0)+L9+11+L1  !Vessel Centerline to End of Safe End used for model
*set,L21,1
*set,L22,4.25
*set,ri21,(25+15/16)/2

/com,*******************************************************************
/com, Geometry
```

```
/com,*********************************************************************
local,13,0,,dimA,,,,

csys,13

/com, Begin at end of Safe-End - Carbon Section

k, 1, ri1, -1*(dimA)
k, 2, ri1+tv, -1*(dimA)
k, 3, ro1, -1*(dimA)
k, 4, ri1, -1*(dimA-L1)
k, 5, ri1+tv, -1*(dimA-L1)
k, 6, ro1, -1*(dimA-L1)
k, 7, ri1, -1*(dimA-L1-L2)
k, 8, ri1+tv, -1*(dimA-L1-L2)
k, 9, ro2, -1*(dimA-L1-L2)
k, 10, ri1, -1*(dimA-L1-L2-L3)
k, 11, ri1+tv, -1*(dimA-L1-L2-L3)
k, 12, ro3, -1*(dimA-L1-L2-L3)
k, 13, ri1, -1*(dimA-L1-L2-L3-L4)
k, 14, ri1+tv, -1*(dimA-L1-L2-L3-L4)
k, 15, ro3, -1*(dimA-L1-L2-L3-L4)
k, 16, ri1, -1*(dimA-L1-L2-L3-L4-L5)
k, 17, ri1+tv, -1*(dimA-L1-L2-L3-L4-L5)
k, 18, ro3, -1*(dimA-L1-L2-L3-L4-L5)

k,19,     ro4, -1*(dimA-L1-L2-L3-L4-L5-L7)! Temporary Point
l,19,18
l,18,15
lfillt,1,2,ra
k,22,     ro4+(L8+6)*tan(15), -1*(dimA-L1-L2-L3-L4-L5-L7-(L8+6))
l,19,22
LFILLT,1,4,rb

k, 25, ri1, -1*(dimA-L1-L2-L3-L4-L6)
k, 26, ri1+tv, -1*(dimA-L1-L2-L3-L4-L6)

k, 27, ri1+(L10+tvw+tv+4)*tan(15), -1*(vir-tv-4)
k, 28, ri1+tv+(L10+tvw+tv+4)*tan(15), -1*(vir-tv-4)

k,29,     (vir+tvw+tv)*sin(45), -1*(vir+tvw+tv)*cos(45)
k,30,     0, -1*(vir+tvw+tv)   ! Temporary Point
k,31,     0, 0 ! Temporary Point

larc,29,30,31,vir+tvw+tv

k,32,     (vir+tv)*sin(45), -1*(vir+tv)*cos(45)
```

```
k,33,     0, -1*(vir+tv)    ! Temporary Point
larc,32,33,31,vir+tv

k,34,     vir*sin(45), -1*vir*cos(45)
k,35,     0, -1*vir    ! Temporary Point
larc,34,35,31,vir

LSTR,       4,       5
LSTR,       5,       6
LSTR,       6,       9
LSTR,       9,      12
LSTR,      12,      15
LSTR,       5,       8
LSTR,       4,       7
LSTR,       7,      10
LSTR,       8,      11
LSTR,      11,      14
LSTR,      10,      13
LSTR,      13,      16
LSTR,      14,      17
LSTR,      16,      25
LSTR,      17,      26
LSTR,      26,      28
LSTR,      25,      27
LSTR,       4,       1
LSTR,       1,       2
LSTR,       2,       3
LSTR,       3,       6
LSTR,       5,       2
LSTR,       7,       8
LSTR,       8,       9
LSTR,      12,      11
LSTR,      11,      10
LSTR,      13,      14
LSTR,      14,      15

FLST,2,2,4,ORDE,2
FITEM,2,4
FITEM,2,6
LPTN,P51X

FLST,2,2,4,ORDE,2
FITEM,2,8
FITEM,2,25
LPTN,P51X

FLST,2,2,4,ORDE,2
```

```
FITEM,2,7
FITEM,2,24
LPTN,P51X

FLST,2,6,4,ORDE,6
FITEM,2,6
FITEM,2,25
FITEM,2,37
FITEM,2,40
FITEM,2,42
FITEM,2,44
LDELE,P51X, , ,1

!*
LFILLT,4,41,rd, ,
!*
LFILLT,43,8,rd, ,
!*
LFILLT,39,38,rc, ,

FLST,2,3,4,ORDE,3
FITEM,2,1
FITEM,2,3
FITEM,2,5
LCOMB,P51X, ,0
LSTR,       16,       17
LSTR,       17,       21
LSTR,       25,       26
LSTR,       26,       24
LSTR,       22,       30
LSTR,       30,       35
LSTR,       27,       28
LSTR,       28,       33
LSTR,       29,       32
LSTR,       32,       34

k,39,      0, -1*(vir+tvw+tv)

!Create Areas
FLST,2,4,4
FITEM,2,27
FITEM,2,30
FITEM,2,26
FITEM,2,9
AL,P51X
FLST,2,4,4
FITEM,2,28
```

```
FITEM,2,29
FITEM,2,10
FITEM,2,30
AL,P51X
FLST,2,4,4
FITEM,2,11
FITEM,2,32
FITEM,2,10
FITEM,2,14
AL,P51X
FLST,2,4,4
FITEM,2,15
FITEM,2,14
FITEM,2,9
FITEM,2,31
AL,P51X
FLST,2,4,4
FITEM,2,32
FITEM,2,33
FITEM,2,12
FITEM,2,17
AL,P51X
FLST,2,4,4
FITEM,2,16
FITEM,2,17
FITEM,2,31
FITEM,2,34
AL,P51X
FLST,2,4,4
FITEM,2,36
FITEM,2,13
FITEM,2,33
FITEM,2,18
AL,P51X
FLST,2,4,4
FITEM,2,19
FITEM,2,18
FITEM,2,35
FITEM,2,34
AL,P51X
FLST,2,4,4
FITEM,2,2
FITEM,2,5
FITEM,2,36
FITEM,2,21
AL,P51X
FLST,2,4,4
```

```
FITEM,2,20
FITEM,2,21
FITEM,2,3
FITEM,2,35
AL,P51X
FLST,2,4,4
FITEM,2,1
FITEM,2,37
FITEM,2,23
FITEM,2,5
AL,P51X
FLST,2,4,4
FITEM,2,22
FITEM,2,23
FITEM,2,25
FITEM,2,3
AL,P51X
FLST,2,4,4
FITEM,2,38
FITEM,2,42
FITEM,2,37
FITEM,2,8
AL,P51X
FLST,2,4,4
FITEM,2,4
FITEM,2,8
FITEM,2,25
FITEM,2,40
AL,P51X
FLST,2,4,4
FITEM,2,24
FITEM,2,45
FITEM,2,7
FITEM,2,42
AL,P51X
FLST,2,4,4
FITEM,2,6
FITEM,2,7
FITEM,2,44
FITEM,2,40
AL,P51X
FLST,2,4,4
FITEM,2,41
FITEM,2,43
FITEM,2,47
FITEM,2,44
AL,P51X
```

```
FLST,2,4,4
FITEM,2,39
FITEM,2,46
FITEM,2,45
FITEM,2,43
AL,P51X

! define materials
FLST,5,8,5,ORDE,2
FITEM,5,1
FITEM,5,-8
CM,_Y,AREA
ASEL, , , ,P51X
CM,_Y1,AREA
CMSEL,S,_Y
!*
CMSEL,S,_Y1
AATT,       1, ,   1,       0,
CMSEL,S,_Y
CMDELE,_Y
CMDELE,_Y1
!*
FLST,5,5,5,ORDE,5
FITEM,5,9
FITEM,5,11
FITEM,5,13
FITEM,5,15
FITEM,5,18
CM,_Y,AREA
ASEL, , , ,P51X
CM,_Y1,AREA
CMSEL,S,_Y
!*
CMSEL,S,_Y1
AATT,       2, ,   1,       0,
CMSEL,S,_Y
CMDELE,_Y
CMDELE,_Y1
!*
FLST,5,5,5,ORDE,5
FITEM,5,10
FITEM,5,12
FITEM,5,14
FITEM,5,16
FITEM,5,-17
CM,_Y,AREA
ASEL, , , ,P51X
```

```
CM,_Y1,AREA
CMSEL,S,_Y
!*
CMSEL,S,_Y1
AATT,       3, ,    1,        0,
CMSEL,S,_Y
CMDELE,_Y
CMDELE,_Y1
!*

!/com, Map mesh areas
FLST,5,10,4,ORDE,10
FITEM,5,5
FITEM,5,10
FITEM,5,28
FITEM,5,32
FITEM,5,-33
FITEM,5,36
FITEM,5,-37
FITEM,5,42
FITEM,5,45
FITEM,5,-46
CM,_Y,LINE
LSEL, , , ,P51X
CM,_Y1,LINE
CMSEL,,_Y
!*
LESIZE,_Y1, , ,15, , , , ,1
!*
FLST,5,10,4,ORDE,10
FITEM,5,3
FITEM,5,9
FITEM,5,25
FITEM,5,27
FITEM,5,31
FITEM,5,34
FITEM,5,-35
FITEM,5,40
FITEM,5,44
FITEM,5,47
CM,_Y,LINE
LSEL, , , ,P51X
CM,_Y1,LINE
CMSEL,,_Y
!*
LESIZE,_Y1, , ,2, , , , ,1
!*
```

```
FLST,5,3,4,ORDE,3
FITEM,5,39
FITEM,5,41
FITEM,5,43
CM,_Y,LINE
LSEL, , , ,P51X
CM,_Y1,LINE
CMSEL,,_Y
!*
LESIZE,_Y1, , ,80, , , ,1
!*
FLST,5,3,4,ORDE,3
FITEM,5,6
FITEM,5,-7
FITEM,5,24
CM,_Y,LINE
LSEL, , , ,P51X
CM,_Y1,LINE
CMSEL,,_Y
!*
LESIZE,_Y1, , ,20, , , ,1
!*
FLST,5,3,4,ORDE,3
FITEM,5,4
FITEM,5,8
FITEM,5,38
CM,_Y,LINE
LSEL, , , ,P51X
CM,_Y1,LINE
CMSEL,,_Y
!*
LESIZE,_Y1, , ,40, , , ,1
!*
FLST,5,3,4,ORDE,3
FITEM,5,1
FITEM,5,22
FITEM,5,-23
CM,_Y,LINE
LSEL, , , ,P51X
CM,_Y1,LINE
CMSEL,,_Y
!*
LESIZE,_Y1, , ,30, , , ,1
!*
FLST,5,6,4,ORDE,6
FITEM,5,2
FITEM,5,20
```

```
FITEM,5,-21
FITEM,5,26
FITEM,5,29
FITEM,5,-30
CM,_Y,LINE
LSEL, , , ,P51X
CM,_Y1,LINE
CMSEL,,_Y
!*
LESIZE,_Y1, , ,40, , , , ,1
!*
FLST,5,9,4,ORDE,2
FITEM,5,11
FITEM,5,-19
CM,_Y,LINE
LSEL, , , ,P51X
CM,_Y1,LINE
CMSEL,,_Y
!*
LESIZE,_Y1, , ,20, , , , ,1
!*

! Meshing
FLST,5,18,5,ORDE,2
FITEM,5,1
FITEM,5,-18
CM,_Y,AREA
ASEL, , , ,P51X
CM,_Y1,AREA
CHKMSH,'AREA'
CMSEL,S,_Y
!*
MSHKEY,1
AMESH,_Y1
MSHKEY,0
!*
CMDELE,_Y
CMDELE,_Y1
CMDELE,_Y2
!*

!Modify the safe end ID
FLST,2,6,5,ORDE,2
FITEM,2,1
FITEM,2,-6
ACLEAR,P51X
FLST,2,6,5,ORDE,2
```

```
FITEM,2,1
FITEM,2,-6
ADELE,P51X
FLST,2,9,4,ORDE,7
FITEM,2,9
FITEM,2,14
FITEM,2,-17
FITEM,2,26
FITEM,2,-27
FITEM,2,30
FITEM,2,-31
LDELE,P51X, , ,1

FLST,2,3,4,ORDE,3
FITEM,2,10
FITEM,2,28
FITEM,2,32
LDELE,P51X, , ,1
FLST,3,2,3,ORDE,2
FITEM,3,3
FITEM,3,6
KGEN,2,P51X, , ,-ro2+ri21, , , ,0
FLST,3,1,3,ORDE,1
FITEM,3,2
KGEN,2,P51X, , , ,L22, , ,0
FLST,3,3,3,ORDE,3
FITEM,3,1
FITEM,3,-2
FITEM,3,4
KGEN,2,P51X, , ,tv, , , ,0
FLST,3,2,3,ORDE,2
FITEM,3,10
FITEM,3,-11
KGEN,2,P51X, , , ,-(L3-L21), , ,0
FLST,3,1,3,ORDE,1
FITEM,3,23
KGEN,2,P51X, , ,5, , , ,0
LSTR,      23,      40
FLST,2,2,4,ORDE,2
FITEM,2,9
FITEM,2,12
LPTN,P51X
LDELE,      16, , ,1
FLST,2,4,3
FITEM,2,11
FITEM,2,23
FITEM,2,41
```

```
FITEM,2,12
A,P51X
FLST,2,4,3
FITEM,2,23
FITEM,2,8
FITEM,2,9
FITEM,2,41
A,P51X
FLST,2,4,3
FITEM,2,8
FITEM,2,7
FITEM,2,6
FITEM,2,9
A,P51X
FLST,2,4,3
FITEM,2,7
FITEM,2,5
FITEM,2,3
FITEM,2,6
A,P51X
FLST,2,4,3
FITEM,2,10
FITEM,2,20
FITEM,2,23
FITEM,2,11
A,P51X
FLST,2,4,3
FITEM,2,20
FITEM,2,4
FITEM,2,8
FITEM,2,23
A,P51X
FLST,2,4,3
FITEM,2,4
FITEM,2,2
FITEM,2,7
FITEM,2,8
A,P51X
FLST,2,4,3
FITEM,2,2
FITEM,2,1
FITEM,2,5
FITEM,2,7
A,P51X
FLST,5,8,5,ORDE,4
FITEM,5,1
FITEM,5,-6
```

```
FITEM,5,19
FITEM,5,-20
CM,_Y,AREA
ASEL, , , ,P51X
CM,_Y1,AREA
CMSEL,S,_Y
!*
CMSEL,S,_Y1
AATT,       1, ,   1,       0,
CMSEL,S,_Y
CMDELE,_Y
CMDELE,_Y1
!*
FLST,5,4,4,ORDE,4
FITEM,5,15
FITEM,5,-16
FITEM,5,26
FITEM,5,28
CM,_Y,LINE
LSEL, , , ,P51X
CM,_Y1,LINE
CMSEL,,_Y
!*
LESIZE,_Y1, , ,15, , , , ,1
!*
FLST,5,4,4,ORDE,4
FITEM,5,31
FITEM,5,48
FITEM,5,50
FITEM,5,52
CM,_Y,LINE
LSEL, , , ,P51X
CM,_Y1,LINE
CMSEL,,_Y
!*
LESIZE,_Y1, , ,2, , , , ,1
!*
FLST,5,6,4,ORDE,6
FITEM,5,9
FITEM,5,-10
FITEM,5,12
FITEM,5,14
FITEM,5,30
FITEM,5,32
CM,_Y,LINE
LSEL, , , ,P51X
CM,_Y1,LINE
```

```
CMSEL,,_Y
!*
LESIZE,_Y1, , ,6, , , , ,1
!*
FLST,5,3,4,ORDE,3
FITEM,5,11
FITEM,5,17
FITEM,5,49
CM,_Y,LINE
LSEL, , , ,P51X
CM,_Y1,LINE
CMSEL,,_Y
!*
LESIZE,_Y1, , ,12, , , , ,1
!*
FLST,5,3,4,ORDE,3
FITEM,5,27
FITEM,5,29
FITEM,5,51
CM,_Y,LINE
LSEL, , , ,P51X
CM,_Y1,LINE
CMSEL,,_Y
!*
LESIZE,_Y1, , ,25, , , , ,1
!*
FLST,5,8,5,ORDE,4
FITEM,5,1
FITEM,5,-6
FITEM,5,19
FITEM,5,-20
CM,_Y,AREA
ASEL, , , ,P51X
CM,_Y1,AREA
CHKMSH,'AREA'
CMSEL,S,_Y
!*
MSHKEY,1
AMESH,_Y1
MSHKEY,0
!*
CMDELE,_Y
CMDELE,_Y1
CMDELE,_Y2
!*

FLST,2,2,5,ORDE,2
```

```
FITEM,2,17
FITEM,2,-18
ACLEAR,P51X

csys,0
k, 51,62/2,0,0
k, 52,62/2,60,0
LSTR,       51,       52
FLST,2,2,5,ORDE,2
FITEM,2,17
FITEM,2,-18
ADELE,P51X
lplo
FLST,2,4,4,ORDE,4
FITEM,2,39
FITEM,2,41
FITEM,2,43
FITEM,2,53
LPTN,P51X
FLST,2,2,4,ORDE,2
FITEM,2,60
FITEM,2,-61
LDELE,P51X, , ,1
FLST,2,4,4
FITEM,2,54
FITEM,2,62
FITEM,2,55
FITEM,2,44
AL,P51X
FLST,2,4,4
FITEM,2,55
FITEM,2,63
FITEM,2,58
FITEM,2,45
AL,P51X
FLST,2,4,4
FITEM,2,63
FITEM,2,56
FITEM,2,57
FITEM,2,46
AL,P51X
FLST,2,4,4
FITEM,2,47
FITEM,2,59
FITEM,2,57
FITEM,2,62
AL,P51X
```

```
CM,_Y,AREA
ASEL, , , ,       18
CM,_Y1,AREA
CMSEL,S,_Y
!*
CMSEL,S,_Y1
AATT,        2, ,   1,       0,
CMSEL,S,_Y
CMDELE,_Y
CMDELE,_Y1
!*
FLST,5,2,5,ORDE,2
FITEM,5,17
FITEM,5,22
CM,_Y,AREA
ASEL, , , ,P51X
CM,_Y1,AREA
CMSEL,S,_Y
!*
CMSEL,S,_Y1
AATT,        3, ,   1,       0,
CMSEL,S,_Y
CMDELE,_Y
CMDELE,_Y1
!*
CM,_Y,AREA
ASEL, , , ,       21
CM,_Y1,AREA
CMSEL,S,_Y
!*
CMSEL,S,_Y1
AATT,        4, ,   1,       0,
CMSEL,S,_Y
CMDELE,_Y
CMDELE,_Y1
!*
FLST,5,3,4,ORDE,3
FITEM,5,54
FITEM,5,-55
FITEM,5,58
CM,_Y,LINE
LSEL, , , ,P51X
CM,_Y1,LINE
CMSEL,,_Y
!*
LESIZE,_Y1, , ,8, , , , ,1
```

```
!*
FLST,5,3,4,ORDE,3
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FITEM,5,59
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LSTR,       46,       47
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LSTR,       46,       44
LSTR,       45,       47
LSTR,       13,       16
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LSTR,       49,       47
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FITEM,2,-65
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FITEM,2,69
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FITEM,2,69
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LSEL, , , ,P51X
```

```
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CMDELE,_Y2
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save
finish
```

Structural Integrity Associates, Inc.	File No.: 0801038.305
CALCULATION PACKAGE	**Project No.: 0801038** Quality Program ☒ Nuclear ☐ Commercial

PROJECT NAME:

VY Confirmatory Analysis for the CS and RO Nozzles

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CLIENT:	**PLANT:**
Entergy Nuclear Operations, Inc	Vermont Yankee Nuclear Power Station

CALCULATION TITLE:

Stress Analysis of Reactor Recirculation Outlet Nozzle

Document Revision	Affected Pages	Revision Description	Project Manager Approval Signature & Date	Preparer(s) & Checker(s) Signatures & Date
0	1 - 16 Computer Files	Initial issue.	Gary L. Stevens 01/07/09	**Preparer:** Tyler Novotny 01/07/09 **Checker:** R. D. Dixon 01/07/09
1	1-9, 11, 15	Revised per summary contained in Section 1.1. Changes are marked with "revision bars" in right-hand margin.	Gary L. Stevens 03/09/09	**Preparer:** Tyler D. Novotny 03/09/09 **Checker:** Tim D. Gilman 03/09/09

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1.0 OBJECTIVE

The objective of this calculation package is to obtain stress distributions for the reactor pressure vessel (RPV) recirculation outlet (RO) nozzle at the Vermont Yankee Nuclear Power Station. ANSYS [1] thermal transient and pressure stress analyses are performed, along with calculation of stresses due to attached piping loads. The stress results will be used for a subsequent ASME Code, Section III NB-3200 [2] fatigue usage calculation.

1.1 Changes Made in Revision 1 of this Calculation

Description of changes made in Revision 1 of this calculation:

a. Transient 9 described in Section 4.3 was changed to more precisely match the Green's Function analysis. This also required modification of the input files *VY_RON_TRAN9-T.INP* and *VY_RON_TRAN9-S.INP*.
b. The input files *VY_RON_TRAN2-T.INP* and *VY_RON_TRAN2-S.INP* were modified to include a finer time step around 601 seconds.
c. A K_t value of 1.53 that was conservatively applied to piping loads at blend radius was changed to $K_t = 1.0$ to match the Green's Function analysis .
d. Table 3 was revised because the input file *VY_RON_TRAN4-T.INP* was updated to correct a conservative misapplication of a temperature ramp rate.
e. Figure 4 was revised because Transient 9, which produced Figure 4, was modified.
f. All remaining changes marked throughout this calculation are editorial changes made to the text of the calculation package.

2.0 METHODOLOGY

The methodology to be used for this evaluation was established in a previous calculation package [3]. A previously developed finite element model (FEM) [3] of the RO nozzle is used to perform thermal and pressure stress analyses using ANSYS [1]. A thermal transient analysis is performed for each defined transient. Concurrent with the thermal transients are pressure and piping interface loads. For these loads, unit load analyses (based on finite element analysis for pressure and manual calculations for attached piping loads) are performed. All six components of the stress tensor are determined in the stress calculations.

The fatigue usage calculation and environmental fatigue usage analysis will be performed in a separate calculation package. That subsequent calculation will utilize the thermal and pressure stresses determined in this calculation, along with stresses due to attached piping loads provided in Tables 4 and 5 of Reference [3]. The stresses due to pressure and the attached piping loads will be scaled based on the temperature and pressure magnitudes during each individual transient, and the location being analyzed. The appropriate nozzle blend radius effects factor will also be applied to the total stresses for the nozzle blend radius location.

3.0 ASSUMPTIONS / DESIGN INPUTS

Assumptions and design inputs were previously established in Section 3.0 of the Reference [3] calculation. Assumption 3.1.3 of Reference [3] was verified in this calculation package by plotting the stress components of each transient in ANSYS. If the stress components plot did not contain a step change at the end of the transient, the steady state portion, the steady state time step assumed was determined to be adequate.

4.0 CALCULATIONS

4.1 Finite Element Unit Pressure Stress Analysis

A uniform pressure of 1,000 psi was applied to the FEM along the inside surface of the RO nozzle and the RPV wall (Figure 1). A pressure load of 1,000 psi was used because it is easily scaled up or down to account for different pressures that occur during transients. In addition, a membrane stress "cap load" was applied to the modeled end of the piping attached to the RO nozzle safe end. This membrane stress was calculated as follows:

$$P_{cap} = \frac{P D_i^2}{D_o^2 - D_i^2}$$

where:

P = Pressure = 1,000 psi unit load
D_i = Inner Diameter at end of model = 25.9375 in
D_o = Outer Diameter at end of model = 28.375 in

Therefore, the membrane stress is 5,082 psi. The calculated value is given a negative sign in order for it to exert tension on the piping end of the model. The FEM geometry input file is taken from the calculation that specifies the design and methodology inputs [3, input file *RON_VY.INP*]. The ANSYS input file *VY_RON_P.INP* contains the pressure loading. Figure 1 shows the applied 1,000 psi internal pressure distribution. At the vessel wall, a symmetric boundary condition is applied. At the piping end of the model, axial displacement is coupled to simulate the effect of the attached piping that is not modeled. Figure 2 and Figure 3 show the boundary conditions.

4.2 Thermal Transient Stress Analysis

The FEM geometry input file is taken from the calculation that specifies the design and methodology inputs [3, file *RON_VY.INP*], and is used as input to the files in which the thermal transient and pressure stress analyses are performed.

For the thermal transient ANSYS analyses, previously defined thermal transients [3, Table 1] are evaluated, applying heat transfer coefficients [3, Table 2], as appropriate, based on the flow rates for each individual transient.

Each thermal transient is evaluated in ANSYS to determine the resulting temperature distributions. The thermal results are used as input for the stress analysis for each transient. The boundary conditions used for the pressure load case were also applied to the thermal stress cases. Figure 2 and Figure 3 show the application of these boundary conditions.

All ANSYS input files for the thermal analyses, as listed below, are saved in the project computer files:

RON_VY.INP: Geometry and material properties
VY_RON_TRAN1-T.INP, VY_RON_TRAN1-S.INP: Transient 1, thermal and stress analyses
VY_RON_TRAN2-T.INP, VY_RON_TRAN2-S.INP: Transient 2, thermal and stress analyses
VY_RON_TRAN3-T.INP, VY_RON_TRAN3-S.INP: Transient 3, thermal and stress analyses
VY_RON_TRAN4-T.INP, VY_RON_TRAN4-S.INP: Transient 4, thermal and stress analyses
VY_RON_TRAN5-T.INP, VY_RON_TRAN5-S.INP: Transient 5, thermal and stress analyses
VY_RON_TRAN6-T.INP, VY_RON_TRAN6-S.INP: Transient 6, thermal and stress analyses
VY_RON_TRAN7-T.INP, VY_RON_TRAN7-S.INP: Transient 7, thermal and stress analyses
VY_RON_TRAN8-T.INP, VY_RON_TRAN8-S.INP: Transient 8, thermal and stress analyses
VY_RON_TRAN9-T.INP, VY_RON_TRAN9-S.INP: Transient 9, thermal and stress analyses
VY_RON_TRAN10-T.INP, VY_RON_TRAN10-S.INP: Transient 10, thermal and stress analyses
VY_RON_TRAN11-T.INP, VY_RON_TRAN11-S.INP: Transient 11, thermal and stress analyses
VY_RON_TRAN12-T.INP, VY_RON_TRAN12-S.INP: Transient 12, thermal and stress analyses

4.3 Determining Critical Stress Paths

The thermal transient that is to be used in determining the critical stress path at the safe end was determined by the most severe temperature difference over the shortest amount of time. This transient, Transient 9, is intended to represent the worst case thermal transient. This occurs during the Improper Startup cycle per Reference [3, Table 1]. The thermal transient conditions are:

- 12% flow rate heat transfer coefficients.
- Thermal shock from 526°F to 130°F along the inside surface of the nozzle safe end and piping and a blend radius and lower vessel thermal shock from 526°F to 268°F.
- Constant temperatures from previous step for 26 seconds
- Thermal shock from 130°F to 526°F along the inside surface of the nozzle safe end and piping and a blend radius and lower vessel thermal shock from 268°F to 526°F.
- Steady state temperature conditions following thermal shocks.
- Constant temperature of 120°F on the outside surface of the model.

The ANSYS input files for the analysis, as listed below, are saved in the project computer files:

RON_VY.INP. Geometry and material properties
VY_RON_TRAN9-T.INP, VY_RON_TRAN9-S.INP: Thermal and stress analysis for the worst case transient for the safe end

An interactive review of the worst case thermal stress results (which are controlling for the safe end) showed the critical location in the model to be at Node 6395. The location of Node 6395 is shown in

Figure 4. This location was selected since it possessed the highest stress intensity during the worst case thermal transient. This is the same location evaluated in Reference [4].

A critical stress location in the nozzle blend radius will also be analyzed. This location is chosen based upon the highest pressure stress (which is controlling in the nozzle blend radius) in the base metal. An interactive review of the pressure stress intensity results showed the critical location in the nozzle blend radius to be at Node 3829 (Figure 5). This is the same location evaluated in Reference [4].

Figure 6 shows the two critical stress paths that will be used to extract the linearized stresses at the safe end and nozzle blend radius.

4.4 Stress Calculation

Linearized stresses from Node 6395 (safe end inside surface) and Node 3829 (nozzle blend radius inside surface of base metal) are used for the fatigue usage analysis, as shown in Figure 6. For the nozzle blend radius location, the stresses used are for the base metal only; since the cladding is of the integrally bonded type and is less than 10% of the total thickness of the section the material is unselected prior to stress extraction, per NB-3122.3 [2].

The pressure stress intensities for the safe end and blend radius paths were extracted using the ANSYS file *VY_RON_P.INP*. This produced one file, *RO_PRESSURE.lin*, that contains results of the critical stress paths.

Table 1 shows the final pressure stress intensity results for the safe end and blend radius. The results at the blend radius are slightly different from those reported in Table 2 of Reference [4] as a result of the revised material properties (i.e., temperature dependent material properties were used in the current evaluation vs. constant material properties in Reference [4]).

Results were also extracted from the vessel portion of the model to verify the accuracy of the results obtained from the ANSYS model, and to check the results due to the use of the 2.0 multiplier on the vessel radius. These results are contained in the file *RO_PRESSURE.lin*. The radius of the finite element model (FEM) was multiplied by a factor of 2.0 [4] to account for the fact that the vessel portion of the axisymmetric model is a sphere, but the true geometry is the intersection of two cylinders.

The equation for the membrane hoop stress in a thin wall sphere is:

$$\sigma = \left(\frac{(pressure) \times (radius)}{2 \times thickness} \right)$$

Considering an actual vessel base metal radius, R, of 105.906 inches increased by a factor of 2.0, a vessel base metal thickness, t, of 5.4375 inches, and an applied pressure, P, of 1,000 psi, the calculated stress for a thin wall sphere is PR/(2t) = 19,477 psi. This compares very well with the remote vessel wall membrane hoop stress from the ANSYS result file, *RO_PRESSURE.lin*, of

18,070 psi. Thus, considering the peak total pressure stress of 31,270 psi, the stress concentrating effect of the nozzle blend radius is 31,270/19,477 = 1.61. In other words, the peak nozzle blend radius stress is 1.61 times higher than nominal vessel wall stress for the axisymmetric model.

The equation for the membrane hoop stress in a thin wall cylinder is:

$$\sigma = \left(\frac{(pressure) \times (radius)}{thickness} \right).$$

Based on the previous dimensions, the calculated stress for a cylinder without the 2.0 factor is 19,477 psi. Increasing this by a factor of 1.61 yields an expected peak nozzle blend radius stress of 31,358 psi, which would be expected from a cylindrical geometry that is representative of the nozzle configuration. Therefore, the result from the ANSYS file for the peak nozzle blend radius stress (31,270 psi) is close to the peak nozzle blend radius stress for a cylindrical geometry because of the use of the 2.0 multiplier. This is consistent with SI's experience where a factor of two increase in radius is typical for representing the 3-D effect in an axisymmetric model.

4.5 Piping Loads

The piping loads were taken from Table 4 of Reference [3]. To determine the piping load stresses, the distances from the applied piping loads to the limiting stress locations were first determined. The limiting stress path locations from Section 4.3 are in the same locations assumed in Table 4 of Reference [3]; this means that no reconciliation of the lengths in Table 4 of Reference [3] is needed. Reference [3, Section 4.1] methodology was used to calculate the piping load stresses. The piping loads and piping load stresses are found in Table 4 and Table 5 of Reference [3].

Table 1: Pressure Stress Intensity Results (1,000 psi)

Location	Membrane plus Bending Stress Intensity (psi)	Total Stress Intensity (psi)
Safe End (Path 1 Inside)	11,350	11,490
Blend Radius (Path 2 Inside)	30,540	31,270

5.0 RESULTS OF ANALYSIS

A thermal transient analysis for each defined transient, as well as unit pressure stress and piping interface load analyses were performed for the RO nozzle at Vermont Yankee. All six components of the stress tensor were extracted from the ANSYS model at the two limiting path locations, which are the same two locations previously evaluated [4]. Table 2 provides the unit (1,000 psig) pressure stress analysis results. The unit pressure load results are used to choose the location to analyze at the nozzle blend radius and will be scaled up or down based on applied pressures in the fatigue analysis. Table 5 of Reference [3] provides the piping stresses at the two critical locations. Table 3 shows an example of thermal stress results. The remaining thermal stress results are contained in the ANSYS output files, listed below, which are saved in the project computer files:

RO_PRESSURE.lin: Unit pressure stress analysis results
VY_RON_TRAN1-S.lin: Transient 1, thermal stress analysis results
VY_RON_TRAN2-S.lin: Transient 2, thermal stress analysis results
VY_RON_TRAN3-S.lin: Transient 3, thermal stress analysis results
VY_RON_TRAN4-S.lin: Transient 4, thermal stress analysis results
VY_RON_TRAN5-S.lin: Transient 5, thermal stress analysis results
VY_RON_TRAN6-S.lin: Transient 6, thermal stress analysis results
VY_RON_TRAN7-S.lin: Transient 7, thermal stress analysis results
VY_RON_TRAN8-S.lin: Transient 8, thermal stress analysis results
VY_RON_TRAN9-S.lin: Transient 9, thermal stress analysis results
VY_RON_TRAN10-S.lin: Transient 10, thermal stress analysis results
VY_RON_TRAN11-S.lin: Transient 11, thermal stress analysis results
VY_RON_TRAN12-S.lin: Transient 12, thermal stress analysis results

A fatigue calculation using the methodology of Subarticle NB-3200 of Section III of the ASME Code [2] and an environmental fatigue usage analysis will be performed in a separate calculation package using the stress results from this calculation.

The results of this calculation are to be used in SI Calculation No. 081038.306, "Fatigue Analysis of Recirculation Outlet Nozzle."

6.0 REFERENCES

1. ANSYS, Release 8.1 (w/Service Pack 1), ANSYS, Inc., June 2004.

2. ASME Boiler and Pressure Vessel Code, Section III, Subsection NB, 1998 Edition with 2000 Addenda.

3. SI Calculation No. 0801038.304, Revision 1, "Design Inputs and Methodology for ASME Code Confirmatory Fatigue Usage Analysis of Reactor Recirculation Outlet Nozzle."

4. SI Calculation No. VY-16Q-305, Revision 0, "Recirculation Outlet Stress History Development for Nozzle Green Function."

Table 2: Stresses Under Unit Pressure Load, psi

	Node	Membrane plus Bending						Total					
		S_x	S_y	S_z	S_{xy}	S_{yz}	S_{xz}	S_x	S_y	S_z	S_{xy}	S_{yz}	S_{xz}
SE	6395	-955.2	4420	10390	15.26	0	0	-955.2	4912	10530	-222.6	0	0
BR	3829	-718.7	-951.7	25000	4708	0	0	-718.7	206.2	30150	733.2	0	0

Table 3: Example Thermal Stress Result Output, psi

Transient	Node	Time (s)	Membrane Plus Bending						Total					
			Sx	Sy	Sz	Sxy	Syz	Sxz	Sx	Sy	Sz	Sxy	Syz	Sxz
4	6395	0	-33	-3379	196	351	0	0	-33	-3539	139	209	0	0
		3	-33	-3367	207	351	0	0	-33	-3518	160	209	0	0
		13	-33	-3340	231	350	0	0	-33	-3493	180	208	0	0
		233	180	11400	12840	210	0	0	180	16290	17350	-536	0	0
		2213	-74	-5983	-2660	293	0	0	-74	-7056	-3558	322	0	0
		2393	149	8475	9884	164	0	0	149	12580	13670	-416	0	0
		6773	-51	-4443	-1020	320	0	0	-51	-5018	-1463	256	0	0
		7193	231	12680	13780	145	0	0	231	17340	18140	-588	0	0
		7493	10	-142	2054	221	0	0	10	164	2398	45	0	0
		11093	-40	-3276	-654	256	0	0	-40	-3669	-954	192	0	0
		16457	-47	-4080	-479	352	0	0	-47	-4491	-773	244	0	0
		16517	-41	-3813	-231	351	0	0	-41	-4095	-404	230	0	0
		16518	-28	-3689	-110	350	0	0	-28	-3383	297	199	0	0
		17118	-33	-3241	307	349	0	0	-33	-3393	255	204	0	0
		17119	3	-2918	623	348	0	0	3	-1521	2098	125	0	0
		57120	-33	-3283	279	350	0	0	-33	-3439	223	206	0	0
	3829	0	3078	2100	4262	554	0	0	3078	4281	5859	577	0	0
		3	3078	2100	4262	554	0	0	3078	4280	5856	577	0	0
		13	3078	2099	4263	554	0	0	3078	4278	5853	576	0	0
		233	823	6811	-8426	-847	0	0	823	12480	38540	5953	0	0
		2213	3002	-447	2916	683	0	0	3002	1782	-3944	-735	0	0
		2393	799	3298	-10540	-506	0	0	799	9988	25870	4515	0	0
		6773	2953	-85	3049	980	0	0	2953	2409	-2931	-397	0	0
		7193	1539	6354	-2971	49	0	0	1539	9542	24620	4575	0	0
		7493	1642	7294	6946	137	0	0	1642	6282	20660	2675	0	0
		11093	2290	364	2825	500	0	0	2290	2225	882	-131	0	0
		16457	3195	285	3758	754	0	0	3195	3045	526	-230	0	0
		16517	3191	304	3705	753	0	0	3191	3131	687	-181	0	0
		16518	3182	300	3699	752	0	0	3182	3120	680	-180	0	0
		17118	3157	1120	3848	706	0	0	3157	3802	3273	233	0	0
		17119	3127	1109	3832	704	0	0	3127	3771	3247	235	0	0
		57120	3077	2085	4216	543	0	0	3077	4274	5877	573	0	0

Note: Not all time steps are listed in this table.

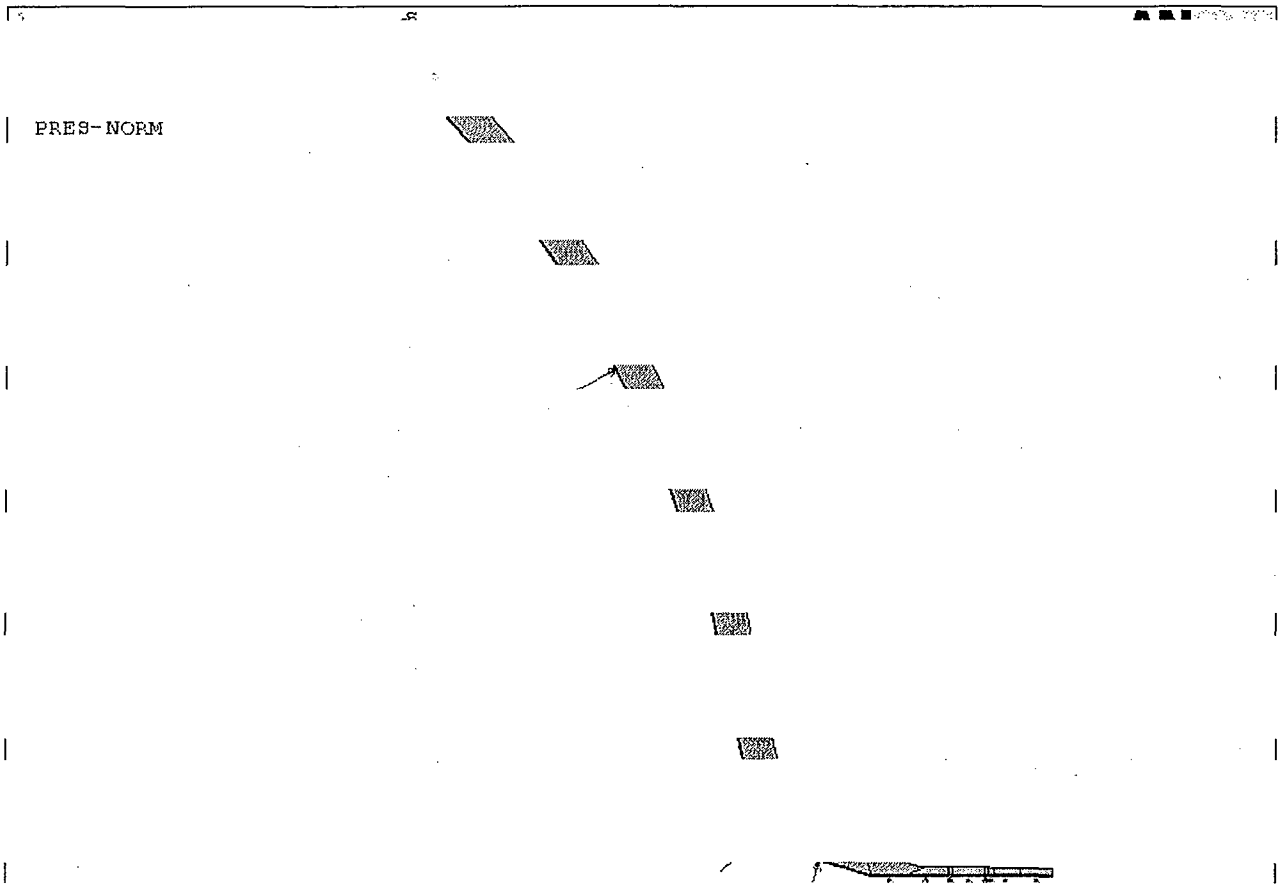

Figure 1. RO Nozzle Internal Pressure Distribution

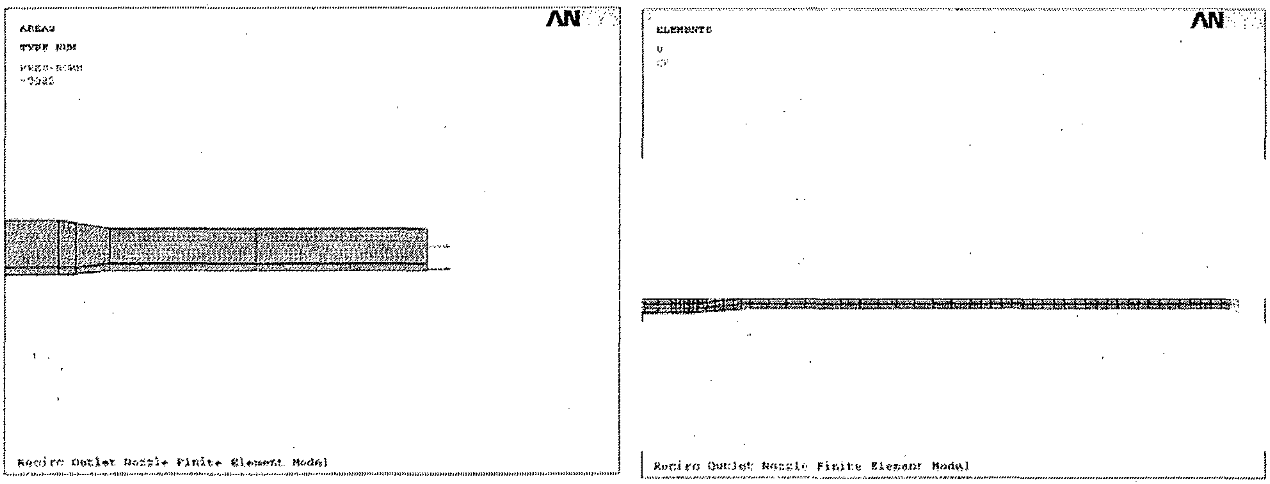

Figure 2. RO Nozzle Pressure Cap Load & Boundary Condition

Figure 3. RO Nozzle Vessel Wall Boundary Condition

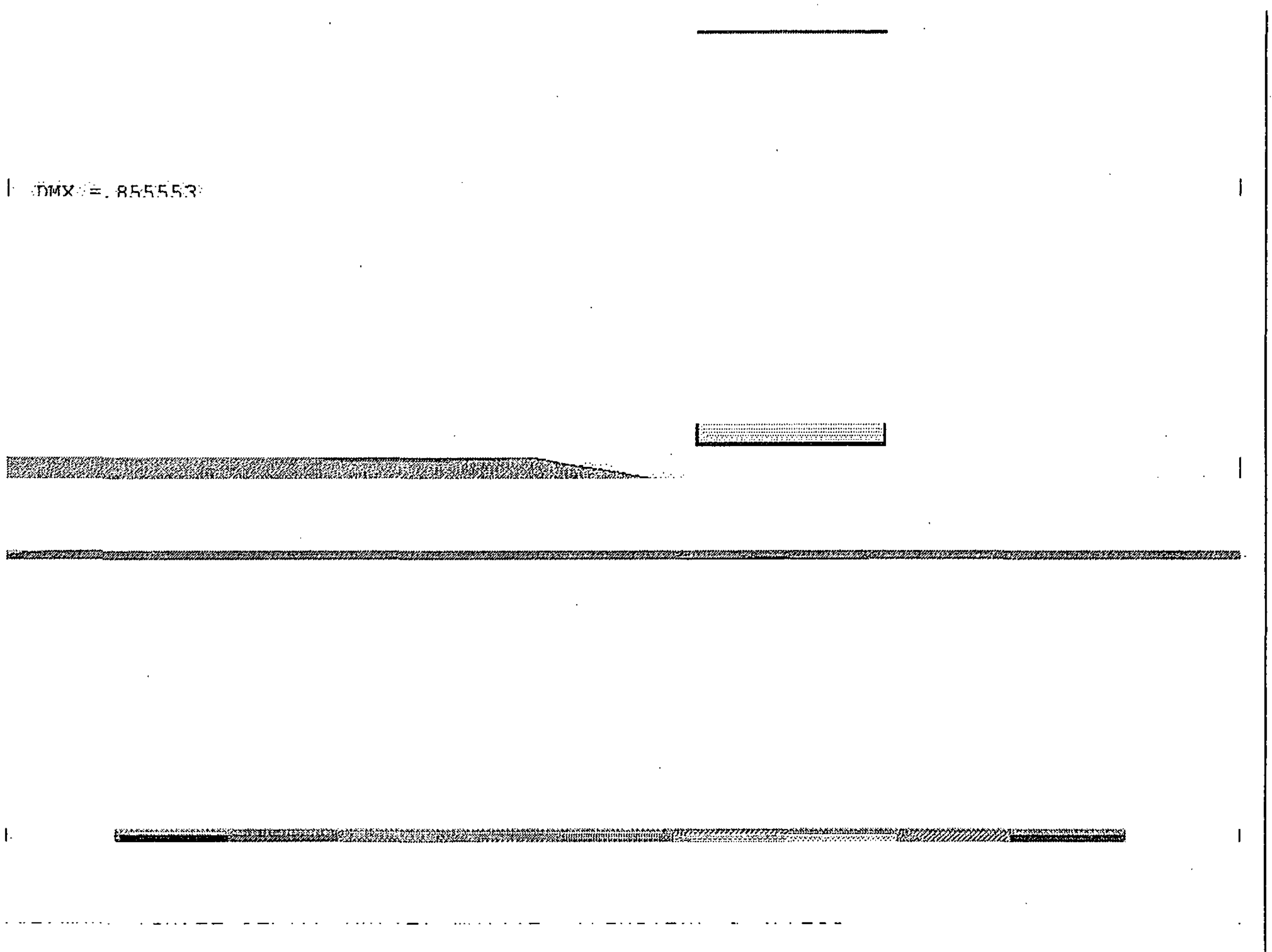

Figure 4. Safe End Critical Thermal Stress Intensity Location

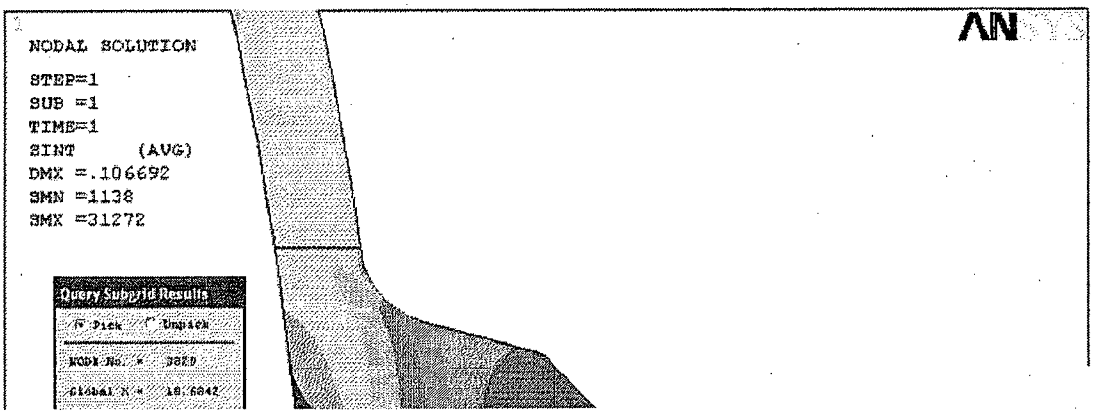

Figure 5. Nozzle Blend Radius Limiting Pressure Stress Intensity Location

Figure 6. Limiting Stress Paths

Structural Integrity Associates, Inc. **CALCULATION PACKAGE**	**File No.:** 0801038.306 **Project No.: 0801038** Quality Program ☒ Nuclear ☐ Commercial

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CLIENT:	**PLANT:**
Entergy Nuclear Operations, Inc.	Vermont Yankee Nuclear Power Station

CALCULATION TITLE:

Fatigue Analysis of Reactor Recirculation Outlet Nozzle

Document Revision	Affected Pages	Revision Description	Project Manager Approval Signature & Date	Preparer(s) & Checker(s) Signatures & Date
0	1 - 18 Computer Files	Initial issue.	Gary L. Stevens 01/07/09	Tyler Novotny 01/07/09 Jennifer E. Smith 01/07/09
1	1-4, 6-12, 14-19 Computer Files	Revised per summary contained in Section 1.1. Changes are marked with "revision bars" in right-hand margin.	Gary L Stevens 03/09/09	**Preparer:** Tyler D. Novotny 03/09/09 **Checker:** William F. Weitze 03/09/09

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1.0 OBJECTIVE

The objective of this calculation package is to perform an ASME Code, Section III fatigue usage evaluation and a plant-specific evaluation of reactor water environmental effects for the reactor pressure vessel (RPV) recirculation outlet (RO) nozzle at the Vermont Yankee Nuclear Power Station.

1.1 Changes Made in Revision 1 of this Calculation

Description of changes made in Revision 1 of this calculation:

a. Editorial changes were made to Table 1 to more precisely describe the transient load sets.
b. All but one of the changes made to Table 2 were editorial to more precisely describe the portions of the transients. The one non-editorial change was to move a time split in Transient 9 to better catch a stress peak or stress valley.
c. Table 3 and the corresponding VESLFAT input file were revised to reflect actual material properties for the safe end. Revision 0 of this calculation tabulated SA-182 F304 (18Cr -8Ni) properties, but actually used properties for an Alloy 600 material.
d. Table 5 was changed to eliminate the application of $K_t = 1.53$ to the nozzle corner piping loads.
e. Tables 6, 7, and 8 were revised to reflect the new fatigue usage and environmental assisted fatigue summaries as a result of the changes associated with Bullets b and c above.
f. Table 8 was revised for editorial changes.
g. The results of various sensitivity studies on fatigue usage were added to Section 5.0.
h. Revision of CUF values in Sections 5.0 and 6.0 to reflect revised analyses.
i. All remaining changes marked throughout this calculation are editorial changes made to the text of the calculation package.

2.0 METHODOLOGY

The methodology to be used for this evaluation was established in a previous calculation package [2]. Based on that methodology, thermal stresses, pressure stresses, and attached piping load stresses were developed in the Reference [1] calculation for use in this fatigue calculation. The thermal stresses are added to pressure stresses and attached piping load stresses[1]. Both the pressure and piping load stresses are scaled based on the magnitudes of the pressure and nozzle fluid temperature during each transient. All six components of the stress tensor from the stress results are used in the fatigue calculation.

[1] Stress components due to piping loads are scaled assuming no stress occurs at an ambient temperature of 70°F and the full values are reached at a reactor design temperature of 575°F [2, Assumption 3.1.7]. In addition, design seismic and deadweight loads are also included and scaled in combination with the thermal loads for each transient. This combination, coupled with assigning the stress due to these loads the same sign as the thermal stress, is considered to be a very conservative treatment of the loads overall in that deadweight and design seismic loads are considered and scaled for every transient.

The fatigue calculation is performed for both the limiting safe end and nozzle blend radius locations, as determined in the Reference [1] calculation, and uses the methodology of Subarticle NB-3200 of Section III of the ASME Code [3]. An environmental fatigue usage analysis is also performed in this calculation applying the methodology and associated environmental fatigue multipliers described in Reference [6].

3.0 DESIGN INPUTS

3.1 Stress Calculation

Linearized stress components at Node 6395 (limiting safe end path at inside surface) and Node 3829 (limiting nozzle blend radius path at inside surface) are used for the fatigue usage calculation, as shown in Figure 6 of Reference [1]. For the nozzle blend radius location, the stresses used in the evaluation are for the base metal only; that is, the cladding material is unselected prior to stress extraction. The stress components from the thermal stress analyses are combined with stress components due to pressure and piping loads. The linearized thermal stress components for each transient are taken from the relevant output files in the Reference [1] calculation (a sample of which was provided in Table 3 of Reference [1]). The unit pressure stress component results are taken from Table 2 of Reference [1]. Piping load stress components are taken from Table 5 of the Reference [2] calculation.

3.2 Fatigue Usage Analysis, General

Structural Integrity's VESLFAT program [4] is used to perform the fatigue usage calculation in accordance with the fatigue usage portion of ASME Code, Section III, Subarticle NB-3200 [3]. VESLFAT performs the analysis required by NB-3222.4(e) [3] for Service Levels A and B conditions defined by the user. The VESLFAT program computes the primary-plus-secondary and total stress ranges for all events and performs a correction for elastic-plastic analysis, if necessary.

The program computes the stress intensity range based on the stress component ranges for all event pairs [3, NB-3216.2]. The program evaluates the stress ranges for primary-plus-secondary and primary-plus-secondary-plus-peak stresses based on all six components of stress (3 normal and 3 shear stresses). If the primary-plus-secondary stress intensity range is greater than $3S_m$, the total stress range must be increased by the simplified elastic-plastic strain correction factor, K_e, as described in NB-3228.5 [3]. The design stress intensity, S_m, is specified as a function of temperature. The input maximum temperature for both states of a load set pair is used to establish the S_m value used in the fatigue calculations from the user-defined input values.

When more than one stress set is defined for either of the event pair loadings, the stress differences are determined for all of the potential stress pairs, and the pair producing the largest alternating total stress intensity (S_{alt}), including any effects of K_e, is used. The principal stresses for the stress ranges are determined by solving for the roots of the following cubic equation[2]:

$$S^3 - (\sigma_x + \sigma_y + \sigma_z)S^2 + (\sigma_x \sigma_y + \sigma_y \sigma_z + \sigma_z \sigma_x - \tau_{xy}^2 - \tau_{xz}^2 - \tau_{yz}^2)S$$

[2] Note that σ_x, σ_y, σ_z, etc. are used synonymously with S_x, S_y, S_z, etc., in this calculation.

$$- (\sigma_x \sigma_y \sigma_z + 2 \tau_{xy} \tau_{xz} \tau_{yz} - \sigma_z \tau_{xy}^2 - \sigma_y \tau_{xz}^2 - \sigma_x \tau_{yz}^2) = 0$$

The stress intensities for the event pairs are reordered in decreasing order of S_{alt}, including a correction for the ratio of modulus of elasticity (E) from the fatigue curve divided by E from the material evaluated at the maximum event temperature. This allows a fatigue table to be created to eliminate the number of cycles available for each of the transient events. This fatigue table is based on a worst-case progressive pairing of events in order of the most severe alternating stress to the least severe, allowing determination of a bounding fatigue usage per NB-3222.4(e) [3]. For each load set pair in the fatigue table, the allowable number of cycles is determined based on S_{alt}.

3.3 Event Cycles, VESLFAT

For the Vermont Yankee RO nozzle analysis, transients that consist of combined stress peaks or valleys are split so that each successive peak or valley is treated separately. Therefore, there are 61 load sets based on the combined stress changes for the safe end, and 46 load sets based on the combined stress changes for the nozzle blend radius location. The reason the number of load sets are not equal for each path is because the time history stress results of those paths differ. Tables 1 and 2 show the load sets applicable to plant operation, with cycle counts per Table 1 of Reference [2]. These are used as input to VESLFAT for the safe end and nozzle blend radius locations, respectively. The cycle counts of Reference [2, 7] consider 60 years of operation. The data from Table 1 is entered into the VESLFAT input files *VY-RO-VFAT-1I.CYC* (safe end) and the data from Table 2 is entered into the file *VY-RO-VFAT-2I.CYC* (nozzle blend radius).

3.4 Material Properties, VESLFAT

Material properties are entered in VESLFAT input files *VY-RO-VFAT-1I.FDT* (safe end) and *VY-RO-VFAT-2I.FDT* (nozzle blend radius). Table 3 lists the temperature-dependent material properties used in the analysis [5]. Table 4 lists the fatigue curve for the nozzle blend radius and safe end materials [3, Appendix I, Table I-9.1 and Figure I-9.1 (UTS ≤ 80.0 ksi) for the nozzle blend radius, and Tables I-9.1 and I-9.2.2 (Curve C) and Figures I-9.2.1 and I-9.2.2 for the safe end location]. Curve C is selected for the safe end location because it is the most conservative curve among the three extended curves for austenitic steel. VESLFAT automatically scales the stresses by the ratio of E on the fatigue curve to E in the analysis, for the purposes of determining allowable numbers of cycles, as required by the ASME Code.

Other material properties are input as follows:

m = 1.7, n = 0.3, parameters used to calculate K_e for the safe end location [3, Table NB-3228.5(b)-1]
m = 2.0, n = 0.2, parameters used to calculate K_e for the nozzle blend radius location [3, Table NB-3228.5(b)-1]
E from fatigue curve = 28,300 ksi [3, Appendix I, Figure I-9.2] for the safe end location.
E from fatigue curve = 30,000 ksi [3, Appendix I, Figure I-9.1] for the nozzle blend radius location.

3.5 Stress Indices

The limiting stress path for the RO nozzle safe end is defined in Reference [1]. The stresses caused by the piping were hand calculated and do require a stress concentration factor, if appropriate. The stress concentration factor for the safe end location is 1.53 [2, Section 3.8]. This value is conservatively used for both the C_2 and K_2 values required by the ASME Code [3, NB-3600]. The piping loads are relatively minor in comparison to the other loads this nozzle experiences so the conservative C_2 and K_2 values will have a small impact on the analysis. Table 5 shows the piping loads after applying the C_2 and K_2 values as appropriate.

4.0 CALCULATIONS

Table 5 contains the stress components at the locations of interest for the 1,000 psi unit pressure stress case [1, Table 2]. Table 5 also contains the stress components for the attached piping load unit stress case [2, Table 5], which correspond to a reactor design temperature of 575°F [2, Section 3.1.7]. The attached piping load stress components were applied assuming the same signs as the thermal stress, which yields the largest stress component ranges.

The calculations of all of the VESLFAT stress inputs are automated in Excel workbooks *VY-RO-VFAT-1i.xls* (safe end) and *VY-RO-VFAT-2i.xls* (nozzle blend radius). These files are organized with sheets labeled as follows:

- Overview: Contains general information.
- Other Stresses: Contains pressure and attached piping load stresses. As shown in Table 5, the pressure stresses use the membrane-plus-bending and total stress from the finite element analysis [1].
- Rearranger: There are 12 Rearranger sheets, one for each thermal transient as analyzed by ANSYS. In these sheets, thermal stresses are copied from Excel workbook *VY-RO-StressResults.xls*, and rearranged to conform to VESLFAT input format (including switching the shear stress components S_{xz} and S_{yz} as required by VESLFAT). *VY-RO-StressResults.xls* contains the results of the ANSYS stress linearization for each transient. The files contained within this workbook are shown in Table 9. Time-varying scale factors for the attached piping loads (based on path metal temperature) and pressure are determined, and used to scale the unit load case stresses, which are then added to the thermal stresses. Since the attached piping loads can act in any direction, the stresses due to the attached piping loads are assigned the same sign as the thermal stresses to maximize the component stresses. Algebraic summation of all six stress components is performed for pressure, piping loads, and thermal stresses at each transient time step. The VESLFAT stress input also includes time-varying metal temperature, as obtained from the ANSYS output, which is used to determine temperature-dependent properties from the values in Table 3.
- VESLFAT: Contains the VESLFAT stress input, as obtained from the Rearranger sheets. Load set numbers are entered on this sheet, as defined in Table 1 and Table 2. These sheets are saved to VESLFAT input files *VY-RO-VFAT-1i.STR* (safe end) and *VY-RO-VFAT-2i.STR* (nozzle blend radius).

5.0 RESULTS OF ANALYSIS

Table 6 and Table 7 provide the detailed calculated 60-year fatigue usage, as obtained from VESLFAT output files *VY-RO-VFAT-1I.FAT* (safe end) and *VY-RO-VFAT-2I.FAT* (nozzle blend radius). All VESLFAT input and output files are saved in the project computer files associated with this calculation.

From Table 6, the safe end cumulative usage factor (CUF) is 0.00308 for 60 years. From Table 7, the nozzle blend radius CUF is 0.0175 for 60 years.

From Table 1 of Reference [6], it was determined that hydrogen water chemistry (HWC) is available for 47% of the total 60-year operating period, and normal water chemistry (NWC) is present for the remaining 53% of the total 60-year operating period. From Table 1 of Reference [6], the dissolved oxygen values for the recirculation line (which is applicable to the RO nozzle) are 48 ppb for HWC conditions and 122 ppb for NWC conditions.

For the stainless steel piping, the environmental fatigue factors for post-HWC and pre-HWC are 15.35 and 8.36 from Table 2 of Reference [6]. The overall environmental multiplier is found by (15.35 x 47% + 8.36 x 53%), which equals 11.645, conservatively rounded up to 11.7. Therefore, the overall environmental multiplier is 11.7, which results in an EAF adjusted CUF of 11.7 x 0.00308 = 0.0360 for 60 years, which is acceptable (i.e., less than the allowable value of 1.0).

Based on the detailed CUF calculation shown in Table 7, a detailed EAF adjusted CUF evaluation on a load-pair basis is provided for the nozzle blend radius location in Table 8. The EAF usage from Table 8 is 0.111 for 60 years, which is less than the allowable value of 1.0 and is therefore acceptable. The effective overall Fen is 0.111/0.0175 = 6.32.

As a part of fatigue analysis calculations, it was noted that using F_y = -20 kips in the piping loads caused a slightly higher total stress intensity. However, the change was determined to have an insignificant effect on fatigue usage results. In addition, the effect of modeling the distinct material properties of both Type F304 and Type F316 in the ANSYS analysis (as opposed to using 18Cr-8Ni properties) was determined to have an insignificant effect on fatigue usage results. Finally, the effect of applying a minimum temperature of 130°F for thermal boundary Region 2 (see Figure 1 of Reference [2]) was determined to have an insignificant effect on fatigue usage results. These investigations and associated results are contained in the project files.

6.0 CONCLUSIONS AND DISCUSSIONS

Detailed fatigue calculations for the Vermont Yankee RO nozzle were performed based on the results of stress analyses previously performed [1]. The thermal stresses were combined with stresses due to pressure and attached piping loads, both of which were scaled based on the magnitudes of the pressure and metal temperature during each thermal transient. All six components of the stress tensor were used for the fatigue calculations. The fatigue calculations were performed at previously-determined limiting locations in the safe end and nozzle blend radius, and used the methodology of Subarticle NB-3200 of Section III of the ASME Code [3].

The 60-year CUF for the safe end location was determined to be 0.00308 and the CUF for the nozzle blend radius location was determined to be 0.0175. Both values are less than the ASME Code allowable value of 1.0, and are therefore acceptable.

Detailed EAF assessments were also performed for the two RO nozzle locations. The 60-year EAF CUF for the safe end location was determined to be 0.0360. The 60-year EAF CUF for the nozzle blend radius location was determined to be 0.111 using temperature-dependent F_{en} multipliers for each load pair. Both values are less than the ASME Code allowable value of 1.0, and are therefore acceptable.

7.0 REFERENCES

1. Structural Integrity Associates Calculation No. 0801038.305, Revision 1, "Stress Analysis of Reactor Recirculation Outlet Nozzle."
2. Structural Integrity Associates Calculation No. 0801038.304, Revision 1, "Design Inputs and Methodology for ASME Code Fatigue Usage Analysis of Reactor Recirculation Outlet Nozzle."
3. ASME Boiler and Pressure Vessel Code, Section III, 1998 Edition with 2000 Addenda.
4. VESLFAT, Version 1.42, 02/06/07, Structural Integrity Associates.
5. ASME Boiler and Pressure Vessel Code, Section II, Part D-Properties, 1998 Edition with 2000 Addenda.
6. SI Calculation No. VY-16Q-303, Revision 0, "Environmental Fatigue Evaluation of Reactor Recirculation Inlet Nozzle and Vessel Shell/Bottom Head."
7. Entergy Design Input Record (DIR) EC No. 1773, DIR. Revision 1, "Environmental Fatigue Analysis for Vermont Yankee Nuclear Power Station," 7/26/07, SI File No. VY-16Q-209.
8. Deleted (not used in this calculation).

Table 1: Safe End Load Sets as Input to VESLFAT

VESLFAT Load Set	Transient	Start Time, sec	Temp Change	Pressure Change	Cycles
1	1Trn1_	0	Up	Up	300
2	2Trn1_	1616.4	Up	Up	300
3	1Trn2_	0	Down	None	300
4	2Trn2_	0.4	Down	None	300
5	3Trn2_	301	Down	None	300
6	4Trn2_	601.4	Down	None	300
7	1Trn3_	0	Up	None	10
8	2Trn3_	250	Up	None	10
9	3Trn3_	2050	Down	None	10
10	4Trn3_	2960	Up & Down	None	10
11	5Trn3_	5560	Down	None	10
12	1Trn4_	0	None	Up	10
13	2Trn4_	2	None	Up & Down	10
14	3Trn4_	7	Down	Down	10
15	4Trn4_	46	Down & Up	None	10
16	5Trn4_	992	Up & Down	Down	10
17	6Trn4_	2294	Down & Up	Down & Up	10
18	7Trn4_	3050	Up & Down	Up & Down	10
19	8Trn4_	6899	Down & Up	Down	10
20	9Trn4_	7745	Up	Down	10
21	10Trn4_	8645	Up	Down	10
22	11Trn4_	11057	Up	Up	10
23	12Trn4_	16166	Up & Down	Up	10
24	13Trn4_	16818	None	None	10
25	14Trn4_	17118	Down	None	10
26	1Trn5_	0	None	Up	60
27	2Trn5_	1.5	None	Up & Down	60
28	3Trn5_	24	Up	Down & Up	60
29	4Trn5_	2310	Down	None	60
30	5Trn5_	2611	None	None	60
31	6Trn5_	2911.4	Down	None	60
32	1Trn6_	0	None	Up	1
33	2Trn6_	0.6	None	Up & Down	1
34	3Trn6_	20	Up	Down & Up	1
35	4Trn6_	2312	Down	None	1
36	5Trn6_	2613	None	None	1
37	6Trn6_	2913.6	Down	None	1

Table 1 (continued): Safe End Load Sets as Input to VESLFAT

VESLFAT Load Set	Transient	Start Time, sec	Temp Change	Pressure Change	Cycles
38	1Trn7_	0	Down	Down	1
39	2Trn7_	37.5	Down	Down	1
40	3Trn7_	600	Down	Down	1
41	4Trn7_	4443	Down	Down	1
42	1Trn8_	0	None	Down	228
43	2Trn8_	3	Up	Down & Up	228
44	3Trn8_	2295	Down	None	228
45	4Trn8_	3927	None	None	228
46	1Trn9_	0	Down	None	1
47	2Trn9_	0.12	Down & Up	None	1
48	3Trn9_	27.92	Up	None	1
49	4Trn9_	290.15	None	None	1
50	1Trn10_	0	Down	Down	300
51	2Trn10_	730.8	Down	Down	300
52	3Trn10_	6314	Down	Down	300
53	4Trn10_	6844	Down	Down	300
54	5Trn10_	9555	Down	Down	300
55	6Trn10_	14937	Down	Down	300
56	1Trn11_	0	None	None	120
57	2Trn11_	0	None	Up	120
58	3Trn11_	0	None	Down	120
59	1Trn12_	0	None	None	1
60	2Trn12_	0	None	Up	1
61	3Trn12_	0	None	Down	1

Table 2: Nozzle Blend Radius Load Sets as Input to VESLFAT

VESLFAT Load Set	Transient	Start Time, sec	Temp Change	Pressure Change	Cycles
1	1Trn1_	0	Up	Up	300
2	2Trn1_	808.2	Up	Up	300
3	1Trn2_	0	Down	None	300
4	2Trn2_	0.4	Down	None	300
5	3Trn2_	401	Down	None	300
6	1Trn3_	0	Up	None	10
7	2Trn3_	250	Up & Down	None	10
8	3Trn3_	2325	Down & Up	None	10
9	4Trn3_	3510	Up & Down	None	10
10	5Trn3_	5060	Down	None	10
11	1Trn4_	0	None	Up	10
12	2Trn4_	2	None	Up & Down	10
13	3Trn4_	7	Down	Down	10
14	4Trn4_	46	Down & Up	None	10
15	5Trn4_	1091	Up & Down	Down	10
16	6Trn4_	2348	Down & Up	Down & Up	10
17	7Trn4_	3269	Up & Down	Up & Down	10
18	8Trn4_	6983	Down & Up	Down	10
19	9Trn4_	7745	Up	Down & Up	10
20	10Trn4_	13839	Up & Down	Up	10
21	11Trn4_	16918	Down	None	10
22	12Trn4_	18986	None	None	10
23	1Trn5_	0	None	Up & Down	60
24	2Trn5_	24	Up & Down	Down & Up	60
25	3Trn5_	2611	Down	None	60
26	1Trn6_	0	None	Up	1
27	2Trn6_	0.6	None	Up & Down	1
28	3Trn6_	20	Up & Down	Down & Up	1
29	4Trn6_	2663	Down	None	1
30	1Trn7_	0	Down	Down	1
31	2Trn7_	37.5	Down	Down	1
32	3Trn7_	2247	Down	Down	1
33	1Trn8_	0	None	Down	228

Table 2 (continued): Nozzle Blend Radius Load Sets as Input to VESLFAT

VESLFAT Load Set	Transient	Start Time, sec	Temp Change	Pressure Change	Cycles
34	2Trn8_	3	Up & Down	Down & Up	228
35	3Trn8_	2025	Down	None	228
36	1Trn9_	0	Down	None	1
37	2Trn9_	9	Up	None	1
38	3Trn9_	58	None	None	1
39	1Trn10_	0	Down	Down	300
40	2Trn10_	313.2	Down	Down	300
41	1Trn11_	0	None	None	120
42	2Trn11_	0	None	Up	120
43	3Trn11_	0	None	Down	120
44	1Trn12_	0	None	None	1
45	2Trn12_	0	None	Up	1
46	3Trn12_	0	None	Down	1

Table 3: Temperature-Dependent Material Properties for VESLFAT (3)

Material	T, °F	E x 10^6, psi	S_m, ksi	S_y, ksi
SA-508 Class 2	70	27.8	26.7	50.0
(nozzle blend radius(2))	200	27.1	26.7	47.0
	300	26.7	26.7	45.5
	400	26.1	26.7	44.2
	500	25.7	26.7	43.2
	600	25.2	26.7	42.1
SA-182 F316	70	28.3	20	30
(Safe End (1))	200	27.6	20	25.9
	300	27.0	20	23.4
	400	26.5	19.3	21.4
	500	25.8	18.0	20.0
	600	25.3	17.0	18.9

Notes:
1. For the safe end material, SA-182 F316 (16Cr – 12Ni – 2Mo) austenitic stainless steel properties are used.
2. For the nozzle blend radius material, SA508 Class 2 material properties are used (3/4Ni-1/2Mo-1/3Cr-V), per Reference [2].
3. All values are taken from Reference [5].
4. SA-508 Class 2 in the Code of Construction is the same as SA-508 Gr. 2 Class 2 in the 1998 ASME Code [5].

Table 4: Carbon/Low Alloy Steel and Stainless Steel Fatigue Curves

Number of Cycles	S_a, ksi Carbon/Low Alloy [(1)]	S_a, ksi Austenitic
10	580	708
20	410	512
50	275	345
100	205	261
200	155	201
500	105	148
1000	83	119
2000	64	97
5000	48	76
10000	38	64
20000	31	55.5
50000	23	46.3
100000	20	40.8
200000	16.5	35.9
500000	13.5	31
1000000	12.5	28.2
2.E+06	N/A	22.8[(2)]
5.E+06	N/A	18.4[(2)]
1.E+07	N/A	16.4[(2)]
2.E+07	N/A	15.2[(2)]
5.E+07	N/A	14.3[(2)]
1.E+08	N/A	14.1[(2)]
1.E+09	N/A	13.9[(2)]
1.E+10	N/A	13.7[(2)]
1.E+11	N/A	13.6[(2)]

Note:

1. Using UTS ≤ 80 ksi curve.
2. Using Curve C for austenitic steel.

Table 5: Pressure and Attached Piping Unit Load Case Stress Components

Load	Node (2)	Membrane plus Bending (1)						Total (1)					
		S_x	S_y	S_z	S_{xy}	S_{xz} (5)	S_{yz} (5)	S_x	S_y	S_z	S_{xy}	S_{xz} (5)	S_{yz} (5)
Pressure (3)	6395	-955.2	4420	10390	15.26	0	0	-955.2	4912	10530	-222.6	0	0
	3829	-718.7	-951.7	25000	4708	0	0	-718.7	206.2	30150	733.2	0	0
Piping (4)	6395	0	7930	0	831	2066	0	0	12133	0	1271	3160	0
	3829	0	218	0	42	49	0	0	218	0	42	49	0

Notes:
1. All stress values are in units of psi.
2. The safe end location is represented by Node 6395, and the nozzle blend radius location is represented by Node 3829.
3. The stresses for both nodes represent the stress due to an applied pressure of 1,000 psig.
4. Piping stresses for both locations represent the stress due to full attached piping loads at an RPV temperature of 575°F.
5. S_{yz} and S_{xz} components have been rearranged from the ANSYS output in order to be in correct order for VESLFAT.

Table 6: Fatigue Usage Calculation for the Safe End

Load #1	Desc. #1	Load #2	Desc. #2	n (cycles)	Sn (psi)	Ke	Salt (psi)	Nallow	U
47	2Trn9_	48	3Trn9_	1	79715	2.62	169777	331.52	0.00302
15	4Trn4_	49	4Trn9_	1	30275	1	23722	1757500	0.00000
15	4Trn4_	28	3Trn5_	9	29755	1	23610	1784800	0.00001
19	8Trn4_	28	3Trn5_	10	26926	1	21352	2647400	0.00000
17	6Trn4_	28	3Trn5_	10	25213	1	20492	3155800	0.00000
28	3Trn5_	39	2Trn7_	1	20321	1	16926	8269400	0.00000
18	7Trn4_	28	3Trn5_	10	19961	1	16731	8866300	0.00000
28	3Trn5_	44	3Trn8_	20	4606	1	16450	9819700	0.00000
34	3Trn6_	44	3Trn8_	1	4606	1	16450	9819700	0.00000
43	2Trn8_	44	3Trn8_	207	4606	1	16450	9819700	0.00002
6	4Trn2_	43	2Trn8_	21	4028	1	16176	11335000	0.00000
6	4Trn2_	35	4Trn6_	1	3519	1	15752	14441000	0.00000
6	4Trn2_	29	4Trn5_	60	3484	1	15637	15446000	0.00000
6	4Trn2_	22	11Trn4_	10	11783	1	15613	15666000	0.00000
6	4Trn2_	23	12Trn4_	10	3202	1	15588	15895000	0.00000
2	2Trn1_	6	4Trn2_	198	3193	1	15583	15936000	0.00001
2	2Trn1_	31	6Trn5_	60	3319	1	15531	16430000	0.00000
2	2Trn1_	37	6Trn6_	1	3319	1	15531	16430000	0.00000
2	2Trn1_	25	14Trn4_	10	1702	1	15055	23098000	0.00000
2	2Trn1_	40	3Trn7_	1	18894	1	14987	24732000	0.00000
2	2Trn1_	16	5Trn4_	10	5069	1	14487	41157000	0.00000
33	2Trn6_	52	3Trn10_	1	12380	1	14460	42317000	0.00000
13	2Trn4_	52	3Trn10_	10	10470	1	13875	1.336E+09	0.00000
50	1Trn10_	52	3Trn10_	289	9634	1	13841	1.968E+09	0.00000
50	1Trn10_	53	4Trn10_	11	18796	1	13770	4.465E+09	0.00000
3	1Trn2_	53	4Trn10_	289	18795	1	13769	4.491E+09	0.00000
								Total Usage =	0.00308

Note: All other load pairs have an alternating stress, S_{alt}, that is below the endurance limit of the fatigue curve. Therefore, they do not contribute to fatigue usage.

Table 7: Fatigue Usage Calculation for the Nozzle Blend Radius

Load #1	Desc. #1	Load #2	Desc. #2	n (cycles)	S_n (psi)	Ke	Salt (psi)	N_{allow}	U
1	1Trn1_	14	4Trn4_	10	21902	1.00	43085	6889	0.0015
1	1Trn1_	37	2Trn9_	1	21390	1.00	32177	17617	0.0001
1	1Trn1_	16	6Trn4_	10	15100	1.00	31137	19701	0.0005
1	1Trn1_	27	2Trn6_	1	42381	1.00	27020	30496	0.0000
2	2Trn1_	45	2Trn12_	1	45773	1.00	26852	31084	0.0000
1	1Trn1_	15	5Trn4_	10	18457	1.00	26707	31604	0.0003
1	1Trn1_	18	8Trn4_	10	13066	1.00	26562	32139	0.0003
1	1Trn1_	36	1Trn9_	1	28617	1.00	24546	40947	0.0000
1	1Trn1_	13	3Trn4_	10	34179	1.00	24042	43643	0.0002
1	1Trn1_	38	3Trn9_	1	25904	1.00	23939	44218	0.0000
1	1Trn1_	12	2Trn4_	10	36762	1.00	23612	46129	0.0002
1	1Trn1_	23	1Trn5_	60	35051	1.00	22617	54348	0.0011
1	1Trn1_	17	7Trn4_	10	22210	1.00	22533	55358	0.0002
1	1Trn1_	5	3Trn2_	166	29847	1.00	22312	58126	0.0029
2	2Trn1_	5	3Trn2_	134	29301	1.00	22309	58168	0.0023
2	2Trn1_	28	3Trn6_	1	33856	1.00	22227	59234	0.0000
2	2Trn1_	11	1Trn4_	10	33460	1.00	21959	62919	0.0002
2	2Trn1_	26	1Trn6_	1	32908	1.00	21661	67330	0.0000
2	2Trn1_	25	3Trn5_	60	29068	1.00	21226	74454	0.0008
2	2Trn1_	29	4Trn6_	1	29068	1.00	21226	74454	0.0000
2	2Trn1_	8	3Trn3_	10	29847	1.00	21214	74661	0.0001
2	2Trn1_	4	2Trn2_	82	30245	1.00	21092	76819	0.0011
4	2Trn2_	41	1Trn11_	120	32229	1.00	20851	81328	0.0015
4	2Trn2_	32	3Trn7_	1	30983	1.00	20125	96967	0.0000
4	2Trn2_	40	2Trn10_	97	30982	1.00	20124	96981	0.0010
10	5Trn3_	40	2Trn10_	10	31344	1.00	20033	99198	0.0001
35	3Trn8_	40	2Trn10_	193	29931	1.00	19888	102050	0.0019
35	3Trn8_	43	3Trn11_	35	29651	1.00	19696	105678	0.0003
9	4Trn3_	43	3Trn11_	10	30915	1.00	19357	112494	0.0001
7	2Trn3_	46	3Trn12_	1	30523	1.00	19349	112655	0.0000
7	2Trn3_	44	1Trn12_	1	30523	1.00	19349	112655	0.0000
7	2Trn3_	43	3Trn11_	8	30523	1.00	19349	112655	0.0001
3	1Trn2_	43	3Trn11_	67	31236	1.00	19331	113042	0.0006
3	1Trn2_	19	9Trn4_	10	23810	1.00	16958	181219	0.0001
31	2Trn7_	42	2Trn11_	1	27376	1.00	11515	infinite	0.0000
								Total Usage =	0.0175

Note: All other load pairs have an alternating stress, S_{alt}, that is below the endurance limit of the fatigue curve. Therefore, they do not contribute to fatigue usage.

Table 8: EAF Fatigue Usage Calculation for the Nozzle Blend Radius Location

VY RO Nozzle Corner Environmental Fatigue Calculation
CUF Calculation from file VY-RO-VFAT-2i.fat:

Index	Load #1	Description #1	n_1 (cycles) (5)	Load #2	Description #2	n_2 (cycles) (5)	n (cycles) (5)	S_p (psi)	K_e	S_{alt} (psi)	N_{allow}	U
1	1	1Trn1_	300	14	4Trn4_	10	10	21902	1.00	43085	6889	0.0015
2	1	1Trn1_	290	37	2Trn9_	1	1	21390	1.00	32177	17617	0.0001
3	1	1Trn1_	289	16	6Trn4_	10	10	15100	1.00	31137	19701	0.0005
4	1	1Trn1_	279	27	2Trn6_	1	1	42381	1.00	27020	30496	0.0000
5	2	2Trn1_	300	45	2Trn12_	1	1	45773	1.00	26852	31084	0.0000
6	1	1Trn1_	278	15	5Trn4_	10	10	18457	1.00	26707	31604	0.0003
7	1	1Trn1_	268	18	8Trn4_	10	10	13066	1.00	26562	32139	0.0003
8	1	1Trn1_	258	36	1Trn9_	1	1	28617	1.00	24546	40947	0.0000
9	1	1Trn1_	257	13	3Trn4_	10	10	34179	1.00	24042	43643	0.0002
10	1	1Trn1_	247	38	3Trn9_	1	1	25904	1.00	23939	44218	0.0000
11	1	1Trn1_	246	12	2Trn4_	10	10	36762	1.00	23612	46129	0.0002
12	1	1Trn1_	236	23	1Trn5_	60	60	35051	1.00	22617	54348	0.0011
13	1	1Trn1_	176	17	7Trn4_	10	10	22210	1.00	22533	55358	0.0002
14	1	1Trn1_	166	5	3Trn2_	300	166	29847	1.00	22312	58126	0.0029
15	2	2Trn1_	299	5	3Trn2_	134	134	29301	1.00	22309	58168	0.0023
16	2	2Trn1_	165	28	3Trn6_	1	1	33856	1.00	22227	59234	0.0000
17	2	2Trn1_	164	11	1Trn4_	10	10	33460	1.00	21959	62919	0.0002
18	2	2Trn1_	154	26	1Trn6_	1	1	32908	1.00	21661	67330	0.0000
19	2	2Trn1_	153	25	3Trn5_	60	60	29068	1.00	21226	74454	0.0008
20	2	2Trn1_	93	29	4Trn6_	1	1	29068	1.00	21226	74454	0.0000
21	2	2Trn1_	92	8	3Trn3_	10	10	29847	1.00	21214	74661	0.0001
22	2	2Trn1_	82	4	2Trn2_	300	82	30245	1.00	21092	76819	0.0011
23	4	2Trn2_	218	41	1Trn11_	120	120	32229	1.00	20851	81328	0.0015
24	4	2Trn2_	98	32	3Trn7_	1	1	30983	1.00	20125	96967	0.0000
25	4	2Trn2_	97	40	2Trn10_	300	97	30982	1.00	20124	96981	0.0010
26	10	5Trn3_	10	40	2Trn10_	203	10	31344	1.00	20033	99198	0.0001
27	35	3Trn8_	228	40	2Trn10_	193	193	29931	1.00	19888	102050	0.0019
28	35	3Trn8_	35	43	3Trn11_	120	35	29651	1.00	19696	105678	0.0003
29	9	4Trn3_	10	43	3Trn11_	85	10	30915	1.00	19357	112494	0.0001
30	7	2Trn3_	10	46	3Trn12_	1	1	30523	1.00	19349	112655	0.0000
31	7	2Trn3_	9	44	1Trn12_	1	1	30523	1.00	19349	112655	0.0000
32	7	2Trn3_	8	43	3Trn11_	75	8	30523	1.00	19349	112655	0.0001
33	3	1Trn2_	300	43	3Trn11_	67	67	31236	1.00	19331	113042	0.0006
34	3	1Trn2_	233	19	9Trn4_	10	10	23810	1.00	16958	181219	0.0001
35	31	2Trn7_	1	42	2Trn11_	120	1	27376	1.00	11515	infinite	0.0000
											Total, U =	0.0175

Table 8 (continued): EAF Fatigue Usage Calculation for the Nozzle Blend Radius Location

Transient Maximum Temperatures:

From "VY-RO-VFAT-2i.ALL":

Index	Load #1	Desc. #1	Load #2	Desc. #2	Line #	T1 (4)	s1 (4)	T2 (4)	s2 (4)	Sn (psi)	T (°F) (1)
1	1	1Trn1_	14	4Trn4_	1756	1	3	14	19	21902	339
2	1	1Trn1_	37	2Trn9_	6065	1	3	37	62	21390	437
3	1	1Trn1_	16	6Trn4_	1968	1	3	16	7	15100	329
4	1	1Trn1_	27	2Trn6_	3734	1	3	27	8	42381	526
5	2	2Trn1_	45	2Trn12_	201558	2	1	45	1	45773	120
6	1	1Trn1_	15	5Trn4_	1927	1	3	15	49	18457	394
7	1	1Trn1_	18	8Trn4_	2236	1	3	18	10	13068	335
8	1	1Trn1_	36	1Trn9_	5857	1	3	36	41	28617	495
9	1	1Trn1_	13	3Trn4_	1651	1	3	13	15	34179	516
10	1	1Trn1_	38	3Trn9_	6657	1	3	38	1	25904	490
11	1	1Trn1_	12	2Trn4_	1599	1	3	12	3	36762	526
12	1	1Trn1_	23	1Trn5_	3115	1	3	23	27	35051	526
13	1	1Trn1_	17	7Trn4_	2152	1	3	17	58	22210	426
14	1	1Trn1_	5	3Trn2_	952	1	3	5	80	29847	530
15	2	2Trn1_	5	3Trn2_	8718	2	1	5	79	29301	530
16	2	2Trn1_	28	3Trn6_	99727	2	1	28	1	33856	526
17	2	2Trn1_	11	1Trn4_	42455	2	1	11	4	33460	526
18	2	2Trn1_	26	1Trn6_	98465	2	1	26	3	32908	526
19	2	2Trn1_	25	3Trn5_	89557	2	1	25	22	29068	529
20	2	2Trn1_	29	4Trn6_	105593	2	1	29	21	29068	529
21	2	2Trn1_	8	3Trn3_	35741	2	1	8	5	29847	528
22	2	2Trn1_	4	2Trn2_	7777	2	1	4	7	30245	543
23	4	2Trn2_	41	1Trn11_	233450	4	7	41	1	32229	543
24	4	2Trn2_	32	3Trn7_	223647	4	7	32	126	30983	543
25	4	2Trn2_	40	2Trn10_	232587	4	7	40	209	30982	543
26	10	5Trn3_	40	2Trn10_	1138571	10	21	40	209	31344	527
27	35	3Trn8_	40	2Trn10_	2891140	35	51	40	209	29931	528
28	35	3Trn8_	43	3Trn11_	2910647	35	51	43	1	29651	528
29	9	4Trn3_	43	3Trn11_	1069326	9	28	43	1	30915	536
30	7	2Trn3_	46	3Trn12_	968274	7	42	46	1	30523	536
31	7	2Trn3_	44	1Trn12_	968190	7	42	44	1	30523	536
32	7	2Trn3_	43	3Trn11_	968148	7	42	43	1	30523	536
33	3	1Trn2_	43	3Trn11_	206818	3	1	43	1	31236	549
34	3	1Trn2_	19	9Trn4_	203153	3	1	19	94	23810	549
35	31	2Trn7_	42	2Trn11_	2625522	31	90	42	1	27376	339

EAF Calculations:

	HWC DO	NWC DO	
(DO and HWC/NWC inputs from Table 1 of Reference [6])	48	122	ppb
% HWC =	47%	53%	= % NWC

TMAX (°F) (1)	TMAX (°C)	HWC Fen (2)	NWC Fen (2)	Uenv (3)
339	171	2.45	3.12	0.004
437	225	2.45	5.89	0.000
329	165	2.45	2.92	0.001
526	274	2.45	10.49	0.000
120	49	2.45	2.45	0.000
394	201	2.45	4.46	0.001
335	168	2.45	3.04	0.001
495	257	2.45	8.56	0.000
516	269	2.45	9.83	0.001
490	254	2.45	8.31	0.000
526	274	2.45	10.49	0.001
526	274	2.45	10.49	0.007
426	219	2.45	5.48	0.001
530	277	2.45	10.76	0.020
530	277	2.45	10.76	0.016
526	274	2.45	10.49	0.000
526	274	2.45	10.49	0.001
525	274	2.45	10.49	0.000
529	276	2.45	10.69	0.005
529	275	2.45	10.59	0.000
528	276	2.45	10.63	0.001
543	284	2.45	11.71	0.008
543	284	2.45	11.71	0.011
543	284	2.45	11.71	0.000
543	284	2.45	11.71	0.007
527	275	2.45	10.56	0.001
528	276	2.45	10.63	0.013
528	276	2.45	10.63	0.002
536	280	2.45	11.19	0.001
536	280	2.45	11.19	0.000
536	280	2.45	11.19	0.000
536	280	2.45	11.19	0.001
549	287	2.45	12.18	0.005
549	287	2.45	12.18	0.000
339	171	2.45	3.12	0.000
			Total, U =	0.111
			Overall Fen =	6.32

Notes:

1. T_{MAX} is the maximum temperature of the two paired load states, and represents the metal (nodal) temperature at the location being analyzed. This, which is included as "T" in the "Transient Maximum Temperatures" table above, determined from the VESLFAT output.
2. F_{en} values computed using the low alloy steel equation from Section 3.0 of Reference [6], with S* conservatively set to a maximum value of 0.015, and the transformed strain rate conservatively set to a minimum value of ln (0.001) = -6.908 for all load pairs.
3. U_{env} = [U x HWC F_{en} x % HWC] + [U x NWC F_{en} x % NWC].
4. T1 and T2 represent the load number for Load #1 and Load #2, respectively, and s1 and s2 represent the state number for each of those loads.
5. For each load pair, n_1 is the number of available cycles for Load #1, n_2 is the number of available cycles for Load #2, and n is the available number of cycles for the load pair (i.e., the minimum of n_1 and n_2).

Table 9: Linearized Stress Files Compiled for *VY-RO-StressResults.xls*

Filename	Description
VY_RON_TRAN1-S.csv	Transient 1 linearized stress
VY_RON_TRAN2-S.csv	Transient 2 linearized stress
VY_RON_TRAN3-S.csv	Transient 3 linearized stress
VY_RON_TRAN4-S.csv	Transient 4 linearized stress
VY_RON_TRAN5-S.csv	Transient 5 linearized stress
VY_RON_TRAN6-S.csv	Transient 6 linearized stress
VY_RON_TRAN7-S.csv	Transient 7 linearized stress
VY_RON_TRAN8-S.csv	Transient 8 linearized stress
VY_RON_TRAN9-S.csv	Transient 9 linearized stress
VY_RON_TRAN10-S.csv	Transient 10 linearized stress
VY_RON_TRAN11-S.csv	Transient 11 linearized stress
VY_RON_TRAN12-S.csv	Transient 12 linearized stress

Note: All files are from the Reference [1] supporting computer files.

Hearing Docket

From: Travieso-Diaz, Matias F. [matias.travieso-diaz@pillsburylaw.com]
Sent: Tuesday, March 10, 2009 3:02 PM
To: Alex Karlin; Richard Wardwell; whrcville@embarqmail.com; secy@nrc.gov; Hearing Docket; Susan Uttal; Lloyd Subin; Maxwell Smith; Sarah.hofmann@state.vt.us; aroisman@nationallegalscholars.com; peter.roth@doj.nh.gov; Matthew.Brock@state.ma.us; Zachary Kahn; Mr. Raymond Shadis; OCAAMAIL Resource
Cc: Lewis, David R.; Nelson, Blake J.
Subject: Entergy Nuclear Vermont Yankee, LLC, and Entergy Nuclear Operations, Inc. (Vermont Yankee Nuclear Power Station), Docket No. 50-271-LR, ASLBP No. No. 06-849-03-LR (Part 1 of 3)
Attachments: Letter to ASLB enclosing revised calculations .pdf

In accordance with the provisions of the Board's Partial Initial Decision (Ruling on Contentions 2A, 2B, 3, and 4), LBP-08-25, 68 N.R.C. ___ (Nov. 24, 2008), slip op. at 67, and the Board's Order (Clarifying Deadline for Filing New or Amended Contentions) (Mar. 9, 2009), Entergy has revised and issued its final calculations of record for the confirmatory environmentally assisted fatigue (CUF_{en}) analyses on the reactor pressure vessel core spray (CS) and recirculation outlet (RO) nozzles at the Vermont Yankee Nuclear Power Station. These revised analyses are presented in the following Structural Integrity Associates, Inc. (SIA) calculations: Calculation No. 0801038.302, Revision 1, "Stress Analysis of Reactor Core Spray Nozzle;" Calculation No. 0801038.303, Revision 1, "Fatigue Analysis of Reactor Core Spray Nozzle;" Calculation No. 0801038.304, Revision 1, "Design Inputs and Methodology for ASME Code Fatigue Usage Analysis of Reactor Recirculation Outlet Nozzle;" Calculation No. 0801038.305, Revision 1, "Stress Analysis of Reactor Recirculation Outlet Nozzle;" and Calculation No. 0801038.306, Revision 1, "Fatigue Analysis of Reactor Recirculation Outlet Nozzle." Calculation 0801038.301, Revision 0, "Design Inputs and Methodology for ASME Code Fatigue Usage Analysis of Reactor Core Spray Nozzle" has not been revised so that the version sent to the parties on January 8, 2009 remains the final calculation of record. Entergy is serving at this time electronic copies of those analyses on the parties to the above captioned proceeding.

The methodology applied in the referenced CS and RO confirmatory analyses is in accordance with the approach used in the SIA calculations for the feedwater nozzle that were introduced into evidence in this proceeding, and contains no significantly different scientific or technical judgments from those used in the feedwater nozzle calculations. <u>See</u> Calculation 0801038.301 at 4, n.1 and Calculation 0801038.304 at 4, n.1.

As set forth in the referenced revised calculations, the limiting calculated CUF_{en}s for the CS and RO nozzles are less than unity and are therefore acceptable.

Hard copies are also being sent today by overnight mail to the NRC Staff, the New England Coalition and the Vermont Department of Public Service.

This submittal comprises three electronic messages. This first message, attaching Entergy's cover letter, is being transmitted to the entire service list. The second message, comprising the calculation package for the CS nozzle, is being transmitted only to the parties (including interested States). The third message, comprising the calculation package for the RO nozzle, is being forwarded only to the parties (including interested States).

If you have any difficulty opening this attachment, please contact me at the number below.

Matias F. Travieso-Diaz | Pillsbury Winthrop Shaw Pittman LLP

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Mar 2009 12:01:37 -0700
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Return-Receipt-To: "Travieso-Diaz, Matias F."
<matias.travieso-diaz@pillsburylaw.com>
MIME-Version: 1.0
Disposition-Notification-To: "Travieso-Diaz, Matias F."
<matias.travieso-diaz@pillsburylaw.com>
Subject: Entergy Nuclear Vermont Yankee, LLC, and Entergy Nuclear
Operations, Inc. (Vermont Yankee Nuclear Power Station), Docket No.
50-271-LR, ASLBP No. No. 06-849-03-LR (Part 1 of 3)
Date: Tue, 10 Mar 2009 15:01:32 -0400
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X-MS-Has-Attach:
X-MS-TNEF-Correlator:
Thread-Topic: Entergy Nuclear Vermont Yankee, LLC, and Entergy Nuclear
Operations, Inc. (Vermont Yankee Nuclear Power Station), Docket No.
50-271-LR, ASLBP No. No. 06-849-03-LR (Part 1 of 3)
Thread-Index: AcmhsqBNE1E/xb+NRnSr5e7LFNXrig==
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