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May 18, 2009

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

Before the Atomic Safety and Licensing Board

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

ENTERGY'S OPPOSITION TO NEC'S MOTION TO FILE A TIMELY NEW CONTENTION

I. INTRODUCTION

Applicants Entergy Nuclear Vermont Yankee, LLC and Entergy Nuclear Operations, Inc. (collectively "Entergy") submit this opposition, pursuant to 10 C.F.R. § 2.309(h)(1) and the provisions in the Board's November 24, 2008 Partial Initial Decision in this proceeding[1] and in the Board's March 9, 2009 Order (Clarifying Deadline for Filing New or Amended Contentions) ("March 9, 2009 Order"), to New England Coalition, Inc.'s ("NEC") Motion For Leave to File a Timely New Contention and Motion to Hold in Abeyance Action on this Proposed Contention Until Issuance of NRC Staff Supplemental Safety Evaluation Report, dated April 24, 2009 ("NEC Motion").[2] NEC's proposed contention is inadmissible because it contravenes the Board's admonitions that any new contention must not "rehash or renew any technical challenges that have already been raised and resolved in this proceeding" and "must specifically

[1] Partial Initial Decision (Ruling on Contentions 2A, 2B, 3 and 4), LBP-08-25, 68 N.R.C. ___ (Nov. 24, 2008) (slip op.) ("LBP-08-25").

[2] NEC's filing includes a motion asking that the Board hold in abeyance a ruling on NEC's motion for the admission of its propounded contention until the NRC Staff issues its Safety Evaluation Report Supplement and its Audit Summary relating to the Staff's review of the environmentally assisted fatigue ("EAF") calculations that are the subject of NEC's propounded contention. NEC Motion at 7-8. Entergy and the NRC Staff have filed responses opposing that motion.

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state how the new analyses are not consistent with the legal requirement and the calculations performed for the feedwater nozzle." LBP-08-25 at 67 n.95; see also March 9, 2009 Order at 3. In addition, NEC's claims are vague, are not supported by the opinion of a technically competent witness, are untimely, and are not shown to be material to the final decision the Board will make with respect to this much litigated issue. Accordingly, NEC's proposed contention must be rejected.

II. FACTUAL BACKGROUND

In August 2007, Entergy issued a set of refined calculations of environmentally assisted fatigue at nine locations. Entergy Exhs. E2-10 through E2-24. These calculations, which came to be known as the "refined fatigue calculations" or the "CUFen Reanalyses," indicated that environmentally adjusted cumulative usage factors at the nine locations would not exceed regulatory limits, and hence component failure due to metal fatigue during the period after renewal of the VY license was not a concern. LBP-08-25 at 14. On September 4, 2007, NEC filed a motion to submit a timely new or amended contention challenging Entergy's CUFen Reanalyses. On November 7, 2007, the Board admitted this contention, designating it "Contention 2A." Memorandum and Order (Ruling on NEC Motions to File and Admit New Contention), LBP-07-15, 66 N.R.C. 261, 267 (2007); LBP-08-25 at 14.

In the course of its review of the CUFen Reanalyses, the NRC Staff raised certain issues with regard to the way the "Green's Function" methodology was used in the CUFen Reanalyses to compute stresses for three reactor components: the feedwater ("FW"), core spray ("CS") and reactor recirculation outlet ("RO") nozzles. The Staff was concerned that the methodology might not lead to conservative estimates of the stress loads at certain locations in those components. To resolve the Staff's concerns, Entergy agreed to perform a confirmatory CUFen

analysis without using the Green's Function methodology on one of the three nozzles, the feedwater nozzle, which Entergy and the Staff agreed was bounding. This new environmentally assisted fatigue analysis of the feedwater nozzle was referred to as the "Confirmatory CUFen Analysis." LBP-08-25 at 15.

Entergy provided the Confirmatory CUFen Analysis to NEC in February 2008, and NEC filed a motion to amend Contention 2A to challenge the analysis. NEC asserted that the Confirmatory CUFen Analysis did not validate the results of the CUFen Reanalyses because it only resolved one of many alleged deficiencies in the CUFen Reanalyses and only addressed the feedwater nozzle, which, in NEC's view, is not bounding for the other components. Id. at 15-16. The Board admitted NEC's proposed contention, which was treated as a subset of Contention 2A and was designated "Contention 2B." Id. at 16; Order (Granting Motion to Amend NEC Contention 2A) (Apr. 24, 2008) at 2.

The Board heard extensive oral testimony on Contentions 2A and 2B at the evidentiary hearing held in Newfane, VT on July 21 and 22, 2008.[3] In particular, Messrs. Fitzpatrick and Stevens testified that the Confirmatory CuFen Analysis of the feedwater nozzle performed in early 2008 used the same finite element model, thermal transient definitions, numbers of transient cycles, and water chemistry inputs as were used in the 2007 CUFen Reanalysis for that

[3] Prior to the hearing, Entergy had submitted written direct testimony ("Fitzpatrick/Stevens Decl.") and rebuttal testimony ("Fitzpatrick/Stevens Rebuttal Decl.") on these contentions by its witnesses James C. Fitzpatrick and Gary L. Stevens. The direct and rebuttal testimony of Messrs. Fitzpatrick and Stevens, with certain corrections, were admitted into evidence and incorporated into the record of this proceeding. Fitzpatrick/Stevens Decl., Tr. at 763; Fitzpatrick/Stevens Rebuttal Decl., id.; LBP-08-25 at 20-21. Likewise, the NRC Staff had submitted, prior to the hearing, written declarations on these contentions by its witnesses Dr. Kenneth C. Chang ("Chang Decl.") and Mr. John R. Fair ("Fair Decl.") Those declarations, with certain corrections, were admitted into evidence and incorporated into the record. Chang Decl., Tr. at 1176; Fair Decl., Tr. at 766-68; LBP-08-25 at 22. Finally, NEC prefiled the direct and rebuttal testimony of its witness Dr. Joram Hopenfeld ("Hopenfeld Decl." and "Hopenfeld Rebuttal Decl.") on these contentions, and these were admitted into evidence and incorporated into the record. Hopenfeld Decl. and Hopenfeld Rebuttal Decl., Tr. at 778-79; LBP-08-25 at 23. Messrs. Fitzpatrick, Stevens and Fair and Dr. Hopenfeld presented oral testimony at the hearing. Dr. Chang was unable to testify.

nozzle. The Confirmatory CuFen Analysis differed in one respect: when the thermal transient stress histories were determined, it computed 6-component stress histories via finite element analysis for each transient, whereas the CUFen Reanalysis used a simplified single stress component difference and subsequently used Green's Functions to obtain the stress time history for all of the transients. Fitzpatrick/Stevens Decl. at A39; Tr. at 916-17, 926-32 (Stevens).[4]

At the hearing, NEC asserted a number of "errors" in Entergy's 2007 CUFen Reanalysis and the 2008 Confirmatory CUFen Analysis: (1) Entergy used "outdated" statistical equations to calculate the Fen parameters, and should have used instead the results in the 2007 guidance document NUREG/CR-6909; (2) Entergy failed to account for factors that affect the values of the Fen parameters; (3) Entergy did not provide proof that the base metal of the feedwater nozzles is not cracked; (4) Entergy used inappropriate heat transfer equations to calculate the thermal stress for each transient; (5) the number of plant transients estimated to occur during the operating life of VY is not sufficiently conservative; (6) Entergy's calculation of the Fen parameters did not appropriately account for oxygen concentrations and resulting changes in water chemistry; and (7) Entergy failed to perform an error analysis on its calculations. In addition, NEC criticized the 2007 CUFen Reanalysis because it uses a simplified Green's Function methodology. See LBP-08-25 at 32.

The Board found, after receiving extensive testimony on these issues, that NEC's claims were not meritorious and rejected them, except with respect to the use of the simplified Green's Function methodology. LBP-08-25 at 33-46. The Board determined that Entergy's

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[4] Another difference between the two sets of analyses is that, in the 2008 Confirmatory CuFen Analysis, a maximum environmental correction factor Fen is computed for each paired transient stress state point used for calculating the CUF. The contributions of all stress points are added to produce a composite CUFen. In the 2007 CUFen Reanalysis, on the other hand, a single, maximum Fen was applied to the total CUF resulting from all load pairs, based on the maximum transient temperature for all load pairs. Fitzpatrick/Stevens Decl. at A39. This difference is not relevant to the issues raised in the contention now proposed by NEC.

Confirmatory CUFen Analysis for the feedwater nozzle "is satisfactory and complies with the regulatory requirements." Id. at 54. However, the Board found that Entergy had failed to show that the Confirmatory CUFen Analysis for the feedwater nozzle proved that the metal fatigue on the CS and RO nozzles during the period of extended operation would "necessarily be below the regulatory requirement of unity." Id. at 55. The Board found that "Entergy must perform the metal fatigue analyses on the core spray and reactor recirculation nozzles (i.e., the CUFens) in compliance with the ASME Code requirements and without using the simplified Green's function methodology in order to satisfy the ASME Code requirements and 10 C.F.R. §§ 54.21(c)(1) and 54.29(a)." Id.

As a consequence of this finding, the Board concluded that the license renewal for VY can not be authorized until Entergy "either (1) properly recalculates the CS and RR outlet nozzle CUFens such that they demonstrate that these important components will not fail during the PEO (i.e., that the calculations produce a value less than unity), or (2) submits an AMP that demonstrates that aging of these components will be adequately managed during the PEO." Id. at 66. Accordingly, Entergy needs to "(1) recalculate the CUFen analyses for the CS and RR outlet nozzles, in accordance with the ASME Code, NUREG 6583 and 5704, and all other regulatory guidance, (2) resubmit these results to the NRC Staff and serve them on the other parties herein, and (3) either demonstrate that the [time limited aging analyses] are less than unity or submit an adequate [aging management program] for these components." Id. at 67.

The Board ruled that, if Entergy performed confirmatory analyses of the CS and RO nozzles, and "[i]f the CUFen analyses are (1) done in accordance with the above stated guidance and the basic approach used in the Confirmatory CUFen Analysis for the FW nozzle, (2) contain no significantly different scientific or technical judgments, and (3) demonstrate values less than

unity, then this adjudicatory proceeding terminates." Id. NEC could file a contention challenging the adequacy of those analyses, but such a contention "must specifically state how the new analyses are not consistent with the legal requirement and the calculations performed for the feedwater nozzle." Id. at 67 n.95.

Entergy proceeded to perform Confirmatory CUFen Analyses of the CS and RO nozzles utilizing the same methodology and approach used in the Confirmatory CUFen Analysis of the feedwater nozzle. On January 8, 2009, Entergy issued and provided to the parties copies of six calculations containing the Confirmatory CUFen Analyses of the CS and RO nozzles.[5] The methodology applied in these calculations was in accordance with the approach used in the Confirmatory CUFen Analyses for the feedwater nozzle, and contained no significantly different scientific or technical judgments from those used in the feedwater nozzle calculations.[6] The results of the calculations showed that the calculated CUFens for the limiting locations of both nozzles are less than unity and are therefore acceptable.[7]

The NRC Staff conducted a three-day audit of this set of calculations on February 18-20, 2009. In the course of the audit, Entergy and the NRC Staff identified certain minor discrepancies in some of the calculations. While these items did not change the final conclusions of the analyses, Entergy prepared a set of revised calculations that addressed them[8] and provided

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[5] Calculation 0801038.301, Revision 0, "Design Inputs and Methodology for ASME Code Fatigue Usage Analysis of Reactor Core Spray Nozzle;" Calculation No. 0801038.302, Revision 0, "Stress Analysis of Reactor Core Spray Nozzle;" Calculation No. 0801038.303, Revision 0, "Fatigue Analysis of Core Spray Nozzle;" Calculation No. 0801038.304, Revision 0, "Design Inputs and Methodology for ASME Code Fatigue Usage Analysis of Reactor Recirculation Outlet Nozzle;" Calculation No. 0801038.305, Revision 0, "Stress Analysis of Reactor Recirculation Outlet Nozzle;" and Calculation No. 0801038.306, Revision 0, "Fatigue Analysis of Recirculation Outlet Nozzle."

[6] Letter from Matias F. Travieso-Diaz, Esq. to the Board and the parties (January 8, 2009).

[7] Id.

[8] 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

the revised calculations to the parties on March 10, 2009.[9] As with the original set, the revised Confirmatory CUFen Analyses of the CS and RO nozzles are done in accordance with the ASME and NRC guidance and used the same approach used in the Confirmatory CUFen Analysis for the feedwater nozzle, contain no significantly different scientific or technical judgments, and demonstrate that the CUFens for the limiting locations of both nozzles are less than unity, and are therefore acceptable.[10] These are the final CUFen analyses of record for the nozzles.

On April 24, 2009, NEC filed its Motion seeking admission of a contention challenging the Confirmatory CUFen Analyses of the CS and RO nozzles.

III. NEC'S PROPOSED CONTENTION IS INADMISSIBLE

The NEC Motion seeks admission of a contention that broadly challenges as "technically and factually flawed" the "reanalysis of environmentally assisted metal fatigue for Recirculation Outlet (RO) and Core Spray (CS) nozzles" performed by Entergy in accordance with the Board's instructions. NEC Motion at 1, 2. The Motion seeks to differentiate the proposed contention from the issues previously litigated and adjudicated in this proceeding by stating:

> NEC does not seek to "rehash technical challenges that have already been resolved in this proceeding." [NEC's witness] Dr. Hopenfeld states specifically how new analyses are not consistent with the legal requirement, the feedwater (FW) nozzle calculations, and the guidance cited in the Board's Partial Initial Decision.

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" was not revised.

[9] Letter from Matias F. Travieso-Diaz, Esq. to the Board and the parties (March 10, 2009).

[10] Id. Included as Attachments 1-3 to this response are copies of 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."

NEC Motion at 6. Notwithstanding this attempt to cast its proposed contention as new and different from previously litigated issues, the contention and the supporting Declaration of Dr. Joram Hopenfeld (Declaration of Dr. Joram Hopenfeld in Support of New England Coalition's Motion to File a Timely New or Amended Contention on Entergy's Fatigue Reanalysis (Apr. 22, 2009)) ("Hopenfeld Decl.") are concerned "primarily with"[11] two claims that were extensively discussed at the hearing and were resolved in Entergy's favor by the Board: (1) the appropriateness of the heat transfer coefficients used to compute stresses on the reactor nozzles (Tr. 1096-1127); and (2) the dissolved oxygen level in the reactor water during plant transients (Tr. 952-1031). See Hopenfeld Decl. at A5.[12]

NEC bears the burden to demonstrate that its proposed contention meets three sets of requirements for admissibility:

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[11] Hopenfeld Decl. at A5.

[12] At the end of his Declaration, Dr. Hopenfeld asserts: "Recent discoveries of large cracks in RO nozzles both at the James A Fitzpatrick Nuclear Station (ADAMS Accession Number -ML083300360 "LER 2008-002-00, November 20, 2008) and Oyster Creek Nuclear Generating Station (ADAMS Accession Number ML0090280055 [sic] " Submittal of Analytical Evaluation ...") [nozzle indication], January 21, 2009), clearly indicate that Entergy's analysis is not conservative." Hopenfeld Decl. at A24. However, the incipient crack discovered in the RO nozzle at the Fitzpatrick plant was the result of intergranular stress corrosion cracking ("ISGCC"). See James A. FitzPatrick Nuclear Power Plant, LER 2008-002-00, ADAMS Accession No. ML083300360, at 3. As discussed at the hearing in connection with another contention involving the steam dryer, IGSCC is a phenomenon that has nothing to do with environmentally assisted fatigue. See LBP-08-25 at 86 & n.110.

The incipient crack at the Oyster Creek plant occurred at the weld between the RO nozzle and the safe end; the licensee letter to the NRC does not cite fatigue as the potential cause of the crack. See letter RA-09-011 (January 21, 2009) from Exelon Nuclear to NRC, ADAMS Accession No. ML090280055. Therefore, these incidents are irrelevant to the potential vulnerability of the RO and CS nozzles at VY to environmentally assisted fatigue.

In any case, the uncontested evidence in the record demonstrates that the nozzle inspection programs at VY will be effective in detecting incipient cracks in any of the reactor nozzles and will repair them before they risk the integrity of the component. Regular and state-of-the-art ultrasonic ("UT") inspections have revealed no such cracks in the last 20 years. Entergy is obligated to continue those inspections during the period of extended operations in accord with its existing in-service inspection program, and is obliged to take corrective action if a crack is identified. Based on this record, the Board found that Entergy has appropriately addressed the possibility of cracking in the cladding inside the nozzles. LBP-08-25 at 40. Nothing in Dr. Hopenfeld's Declaration suggests otherwise. Finally, there was also uncontested testimony at the hearing that the existence of nozzle cracks is irrelevant to the EAF analysis, since such cracks are presumed identified and eliminated through the plant's ASME Section XI inspection procedures. Tr. 1058-63 (Stevens); LBP-08-25 at 40.

- First, NEC must meet the Board's specific requirements for the admissibility of contentions challenging the confirmatory RO and CS calculations. LBP-08-25 at 67.

- Second, NEC must show that its proposed contention meets the general contention admissibility requirements of 10 C.F.R. § 2.309(f)(1).

- Third, NEC must demonstrate that the "new" information upon which its proposed contention is based was not previously available, is materially different than information previously available, and was raised in a timely manner based on the availability of the information; or that it meets the admissibility criteria for nontimely filings. See 10 C.F.R. §§ 2.309(f)(2) and (c).

NEC does not – and cannot – meet *any* of these criteria for admitting its purportedly "new" contention. NEC's proposed contention is inadmissible as set forth further below.

A. NEC'S NEW CONTENTION CONTRAVENES THE BOARD'S ORDER AND IS THUS INADMISSIBLE

NEC's proposed contention is inadmissible because it contravenes the Board's specific instructions on the scope of any contention challenging the confirmatory RO and CS analyses. NEC's proposed contention must challenge whether the analyses: "are (1) done in accordance with the above stated guidance and the basic approach used in the Confirmatory CUFen Analysis for the FW nozzle, (2) contain no significantly different scientific or technical judgments, and (3) demonstrate values less than unity." LBP-08-25 at 67. NEC's challenge must not "rehash or renew any technical challenges that have already been raised and resolved in this proceeding (e.g., dissolved oxygen, outdated equations, etc.), but rather must specifically state how the new analyses are not consistent with the legal requirement and the calculations performed for the feedwater nozzle." Id. at 67 n.95.

NEC and Dr. Hopenfeld agree that the Confirmatory CUFen analyses for the RO and CS nozzles use the same methodology as that employed in the confirmatory analyses for the

feedwater nozzle.[13] Hopenfeld Decl. at A6. And, while NEC asserts that the calculations "are not performed in accordance with the ASME Code, NUREG 6583 and 5704, and all other regulatory guidance," NEC Motion at 4, this assertion is not explained or supported anywhere in the Motion or in Dr. Hopenfeld's Declaration. Therefore, the proposed contention violates one of the limitations imposed by the Board, i.e., that any contention that NEC may seek to raise must allege a failure to follow the methodology used in the confirmatory feedwater analyses or a non-compliance with NRC guidance or industry codes.

Further, all of Dr. Hopenfeld's claims were specifically addressed and resolved against NEC in the hearing. First, NEC's argument that equations used by Entergy to calculate the heat transfer coefficient longitudinally along the nozzle "are valid only when the flow inside the pipe is fully developed" (Hopenfeld Decl. at A9) is identical to NEC's argument at the hearing. See, e.g., Tr. at 1108-09 (Hopenfeld). Mr. Stevens refuted that claim by explaining that, because of the high flow velocities in the nozzle, the "entrance effects" preventing the existence of fully developed flow are not present. Tr. at 1124-25 (Stevens). Mr. Stevens referred to the very same figure that Dr. Hopenfeld includes as Attachment 2 to his Declaration, which shows that the entrance effects are not significant at high Reynolds numbers applicable to nozzle flows at issue.

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[13] Dr. Hopenfeld appears to suggest that Entergy even used the same models and inputs for the confirmatory RO nozzle analysis as it did for the feedwater nozzle analysis. Hopenfeld Decl. at A7. That is demonstrably not the case. While – as directed by the Board – Entergy used in the RO confirmatory analysis the same methodology that was upheld for the feedwater nozzle analyses, the geometries, flow conditions, and heat transfer coefficients are modeled differently for each nozzle. This is recognized in the calculation describing the detailed inputs and methodology for the confirmatory analysis of the RO nozzle, Calculation 0801038.304, Revision 1, where nozzle-specific geometry (Section 2.0 of .304, "Finite element analysis will be performed using a previously-developed axisymmetric finite element model (FEM) of the RO nozzle [7]"), transients (Section 3.3 of .304, "[p]reviously developed thermal and pressure transients [11, Tables 2 and 3] are used for this analysis"), and heat transfer coefficients (Section 3.4 of .304, "Heat transfer coefficients are calculated at 300° F, as in the previous analysis [4]") were calculated for the RO nozzle, as was done in the CUFen reanalysis for that nozzle. See Calculation VY-16Q-304, Revision 0, "Recirculation Outlet Nozzle Finite Element Model," Entergy Exh. E2-13 and Calculation VY-16Q-305, Revision 0, "Recirculation Outlet Nozzle Stress History Development for Nozzle Green Function," Entergy Exh. E2-14.

Tr. at 1123-25 (Stevens). The flows through the RO nozzle also have high Reynolds numbers, analogous to those for the feedwater nozzle. Thus, Mr. Stevens' explanation at the hearing holds true for the RO nozzle as well.[14]

Similarly, Dr. Hopenfeld's claim (Hopenfeld Decl. at A14) that it is inappropriate to use a single heat transfer coefficient for natural convection flow because the heat transfer coefficient varies circumferentially around the RO nozzle was also addressed at the hearing. Dr. Hopenfeld's claim was refuted by Mr. Stevens. See, e.g., Tr. at 1108-09 (Hopenfeld); Tr. at 1111-13 (Stevens).[15]

Finally, with respect to NEC's dissolved oxygen claim, there was testimony at the hearing on what values of dissolved oxygen were used at the RO line and other reactor locations besides the feedwater line. Entergy witnesses testified that they used the EPRI guidance document BWRVIP-120 (also known as the EPRI BWRVIA Model) to determine the dissolved oxygen values at other lines, such as the recirculation line. Entergy Exh. E2-34, Attach. 2 at 1; Fitzpatrick/Stevens Decl. at A56; Tr. at 1003-05 (Stevens); Tr. at 1030 (Fitzpatrick). The Board, citing this testimony, rejected NEC's argument and found that Entergy's use of industry guidance on dissolved oxygen values "was reasonable and appropriate." LBP-08-25 at 38. NEC's contravention of the Board's instruction not to "rehash or renew any technical challenges that have already been raised and resolved in this proceeding" (LBP-08-25 at 67 n.95) is even

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[14] See Tables 3 and 4 in Calculation VY-16Q-305, Revision 0, "Recirculation Outlet Stress History Development for Nozzle Green Function" (Entergy Exh. E2-14). Those tables include calculations of forced convection heat transfer coefficients for 100% flow for different regions of the nozzle. The Reynolds numbers for that flow are provided in the table under "Calculated Parameter." For a flow rate of over 28,000 gpm (100% rated flow), the Reynolds numbers range from 2E6 to 27E6, depending on the fluid temperature.

[15] The Board found that Dr. Hopenfeld's concern that it was inappropriate to assume that the flow at the feedwater nozzles is fully developed "has not been substantiated and instead has been fairly rebutted by the evidence presented by Mr. Stevens and Mr. Fitzpatrick." LBP-08-25 at 48. In short, despite the Board's warning, NEC is seeking to rehash a technical claim that has already been examined and rejected.

more striking because the Board specifically cited "dissolved oxygen" as one of the issues that NEC was not to raise. Id.

B. NEC'S PROPOSED CONTENTION DOES NOT MEET THE STANDARDS FOR ADMISSIBILITY IN 10 C.F.R. § 2.309(f)(1)

In addition to seeking to relitigate issues already resolved – contrary to the Board's express instructions – NEC's proposed contention is also inadmissible because it fails to meet the general admissibility standards in 10 C.F.R. § 2.309(f)(1). In particular, NEC's proposed contention is vague, immaterial, lacks expert and factual support, and fails to demonstrate the existence of a dispute with Entergy on a genuine, material issue of fact involving the VY license renewal application.

1. NEC Fails to Meet Admissibility Standards with Respect to the Confirmatory CS Nozzle Analyses

Although NEC claims that its proposed contention is directed at the Confirmatory CUFen Analyses of both the RO and CS nozzles, the discussion in the NEC Motion pertains only to the RO nozzle analysis. In fact, NEC makes only three vague, non-specific references to the CS nozzle in Dr. Hopenfeld's supporting declaration. See Hopenfeld Decl. at A5 ("[m]y concerns are primarily with the lack of conservatism in the heat transfer calculations and the use of non conservative oxygen concentrations in the analysis of the CS and RO nozzles"); id. at A7 ("[t]he RO and the CS nozzles and FW nozzle are located at different sections of the reactor vessel and therefore their local coolant chemistries differ during transients"); id. at A21 ("[f]or the CS and RO nozzles, low alloy steel locations, the maximum oxygen concentrations occur at the lowest temperature during the transient").

NEC's proposed contention, as it relates to the CS confirmatory nozzle analysis, must be dismissed outright because it fails to state what factual issues are being controverted with respect

to that analysis. See 10 C.F.R. § 2.309(f)(1)(i). Also, NEC does not offer any explanation of the bases for a challenge to the CS nozzle analysis, in contravention of 10 C.F.R. § 2.309(f)(1)(ii). NEC does not make any showing that the claims against the CS nozzle analysis are material, as required by 10 C.F.R. § 2.309(f)(1)(iv). Nor does NEC provide any alleged facts or expert opinion regarding alleged deficiencies in the CS nozzle analysis, contrary to 10 C.F.R. § 2.309(f)(1)(v). Finally, the NEC Motion does not provide "sufficient information" to show that a genuine dispute exists with Entergy on a material issue of law or fact with respect to any specific aspect of the CS nozzle analysis, as required by 10 C.F.R. § 2.309(f)(1)(vi). Therefore, the proposed contention is inadmissible as it relates to the Confirmatory CuFen Analysis of the CS nozzle because it fails to satisfy the requirements of 10 C.F.R. § 2.309(f)(1).

2. NEC's Proposed Contention is Inadmissible with Respect to the Confirmatory Analyses for the RO Nozzle

a. NEC's Proposed Contention Fails to Specify the Issue of Law or Fact to be Raised

NEC fails to set forth the text of its proposed contention in the NEC Motion. Instead, NEC alleges that "Entergy has not properly recalculated the Core Spray and Recirculation Outlet nozzle CUFens." NEC Motion at 1 (emphasis in original). NEC claims that Entergy's confirmatory calculations "are technically and factually flawed and do not conform to ASME, NRC, or National Laboratory guidance, nor do they fully conform to established engineering practice, or the rules of applied physics." Id. at 2. NEC asserts – without specifying the basis for its assertion – that Entergy allegedly "has not, by this flawed reanalysis, demonstrated that the reactor components assessed will not fail due to metal fatigue during the period of extended operation," "complied with the . . . Partial Initial Decision," or "credibly demonstrated that its new calculations and analyses for the CS and RO nozzles are consistent with the intent of 10 C.F.R. § 54.21." Id. at 4.

NEC's description of its contention fails to provide the necessary "specific statement of the issue of law or fact to be raised or controverted." 10 C.F.R. § 2.309(f)(1)(i). NEC does not specify in what respect the confirmatory calculations are "technically and factually flawed" nor to what "ASME, NRC, or National Laboratory practice" they fail to conform, nor how they fail to meet "established engineering practice, or the rules of applied physics." Such vague contentions are not permissible under the Commission rules of practice. Duke Energy Corp. (Oconee Nuclear Station, Units 1, 2, and 3), CLI-99-11, 49 N.R.C. 328, 334, 338 (1999); Northeast Nuclear Energy Co. (Millstone Nuclear Power Stations, Units 2 and 3), LBP-01-10, 53 N.R.C. 273, 279, 302 (2001).[16]

b. NEC's Proposed Contention does not Demonstrate that the Issues it Raises are Material

Earlier in this proceeding, the Board defined the materiality requirements that a proposed contention must meet with respect to 10 C.F.R. § 2.309(f)(1)(iv):

> For a contention to be admissible, a petitioner must show "that the issue raised in the contention is material to the findings the NRC must make to support the action that is involved in the proceeding." 10 C.F.R. § 2.309(f)(1)(iv). An issue is only "material" if "the resolution of the dispute would make a difference in the outcome of the licensing proceeding." 54 Fed. Reg. at 33,172. This means that there must be some link between the claimed error or omission regarding the proposed licensing action and the NRC's role in protecting public health and safety or the environment. Dominion Nuclear Connecticut, Inc. (Millstone Nuclear Power Station, Units 2 and 3), LBP-04-15, 60 NRC 81, 89 (2004), aff'd, CLI-04-36, 60 NRC 631 (2004).

LBP-06-20, 64 N.R.C. 131, 149 (2006).

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[16] NEC addresses the requirements of 10 C.F.R. § 2.309(f)(1)(i) as follows: "However, NEC contends, as explained in some detail in the attached Declaration of Dr. Joram Hopenfeld (Attached as Exhibit A) that Entergy's submitted recalculations do, 'involve complex scientific and technical judgments and discretion, and are not merely ministerial,' but are not performed in [sic], 'in accordance with the ASME Code, NUREG 6583 and 5704, and all other regulatory guidance.' Thus, Entergy has not, by this flawed reanalysis, demonstrated that the reactor components assessed will not fail due to metal fatigue during the period of extended operation. Nor complied with the requirements set forth in Board's Partial Initial Decision. Nor has Entergy credibly demonstrated that its new calculations and analyses for the CS and RO nozzles are consistent with the intent of 10 C.F.R. § 54.21." NEC Motion at 4. This explanation, however, is as vague as the rest of the Motion.

(1) NEC's Proposed Changes to the RO Nozzle Confirmatory Analysis are Immaterial

NEC's proposed contention fails to satisfy 10 C.F.R. § 2.309(f)(1)(iv) with respect to the RO nozzle confirmatory analyses because neither NEC nor Dr. Hopenfeld provide any demonstration that the issues NEC raises are material to the findings that the Board must make.[17] The Confirmatory CUFen Analysis of the RO nozzle indicates that the 60-year CUFen for the safe end of the nozzle is 0.0360, and the 60-year CUFen for the nozzle blend radius is 0.111. Calculation No. 0801038.306, Revision 1, "Fatigue Analysis of Reactor Recirculation Outlet Nozzle," Attachment 3 hereto, Section 6.0 at 8. Both values are less than the ASME Code allowable value of 1.0, and are therefore acceptable. LBP-08-25 at 29. Indeed, the calculated CUFen at the limiting location – the nozzle blend radius – would have to increase by almost an order of magnitude before the ASME Code allowable was exceeded. Neither NEC nor Dr. Hopenfeld provide any sound basis to justify that an order of magnitude increase in CUFen at the nozzle's limiting location will result if a new fatigue analysis of the RO nozzle is performed along the lines that Dr. Hopenfeld suggests.[18] Because NEC has failed to demonstrate that a Confirmatory CUFen Analysis of the RO nozzle with the changes NEC suggests would result in values greater than the ASME Code allowable value, NEC has failed to demonstrate that the issues it raises are material.

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[17] All of the reasons discussed in this subsection why NEC's proposed contention lacks materiality under 10 C.F.R. § 2.309(f)(1)(iv) apply also to NEC's failure to demonstrate compliance with 10 C.F.R. § 2.309(f)(1)(vi), which requires that an admissible contention include sufficient information to show that a genuine dispute exists with the applicant/licensee on a material issue of law or fact.

[18] Dr. Hopenfeld states that using a dissolved oxygen value of 0.4 ppm to compute the environmental adjustment factor for the nozzle would result in an order of magnitude increase in the CUFen for the nozzle. Hopenfeld Decl. at A22. As further discussed below, the testimony at the hearing demonstrated that Dr. Hopenfeld's assertion was unsound. The Board rejected Dr. Hopenfeld's claim that a 0.4 ppm value should be used.

(2) NEC's Heat Transfer Coefficient Arguments are Immaterial

Dr. Hopenfeld's assertions that "fatigue life is very sensitive to even a very small change in the heat transfer coefficient" and "use of incorrect heat transfer coefficients would result in invalid fatigue life predictions," Hopenfeld Decl. at A8, do not demonstrate any material issue. First, it has already been established that "entrance effects" are insignificant for high Reynolds number conditions; therefore the heat transfer coefficients do not change. Second, as further discussed below, Dr. Hopenfeld has disclaimed expertise in the area of numerical stress analysis. Tr. at 831 (Hopenfeld). Third, Dr. Hopenfeld does not indicate what changes would need to be made to the Confirmatory CUFen Analysis of the RO nozzle to address his concerns or provide any indication that, if those changes were made, they would result in having the CUFen for the RO nozzle exceed unit at any nozzle location. Finally, Dr. Hopenfeld provides no citation or other information in support of this bald statement. This is not surprising because the statement is not true.

During the NRC's February 2009 audit of the initial version of the confirmatory analyses for the RO and CS nozzles,[19] the NRC Staff asked whether the CUFen results for those nozzles were dependent on the value of heat transfer coefficient used in the analyses. Entergy performed a sensitivity analysis, which demonstrated that the effect of changes in the heat transfer coefficient on CUFen estimates is minimal.[20] Therefore, the heat transfer analysis deficiencies

[19] Revision 0, later superseded by the March 2009 revised calculations in Revision 1.

[20] Attachment 4 hereto is a Declaration of Gary L. Stevens that describes the sensitivity analysis performed by Entergy in connection with the NRC audit that demonstrated that changes in the value of heat transfer coefficient have only a minor impact on the CUFen.

raised by Dr. Hopenfeld, even if they were correct, would have little or no impact on the value of CUFen for the RO nozzle and would raise no material issues of fact that needed adjudication.[21]

Likewise, Dr. Hopenfeld's claim that, for natural convection flow, the heat transfer coefficient varies circumferentially around the pipe is immaterial. As further discussed below, the calculations show that convection flow (as opposed to the forced flow that occurs during some transients) does not contribute significantly to the component stress.

Neither NEC nor Dr. Hopenfeld have provided any indication that the alleged deficiencies in the heat transfer equations for the RO nozzle make a material difference in the value of CUFen for the RO nozzle. Dr. Hopenfeld vaguely asserts:

> I believe that Entergy should be required to demonstrate that the incorrect heat transfer equations that they used actually result in conservative CUFens. This can be done by repeating the calculations with heat transfer equations which are valid for the nozzle geometries and which take into account the local variation in the heat transfer instead of using average values. I believe that such calculations will show that the present results are not conservative.

Hopenfeld Decl. at A17 (emphases in original). Dr. Hopenfeld does not quantify by how much he claims the CUFen computations for the RO nozzle are not conservative, nor does he claim that he has performed (or is able to perform) such a computation. In the absence of such a quantification, his claim that Entergy's calculation is non-conservative does not rise above mere speculation. Dr. Hopenfeld furthermore does not identify what changes would need to be made

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[21] Table 6 on p. 15 of the confirmatory CUFen calculation for the RO nozzle (Calculation No. 0801038.306, Revision 1, "Fatigue Analysis of Reactor Recirculation Outlet Nozzle," Attachment 3 hereto) shows that for the safe end of the RO nozzle the main contributor to fatigue is the first load pair combination (loads 47 and 48), which occurs during transient 9 (see Table 1 on p. 10 of the same calculation). As shown in Table 1 on p. 10 of Calculation No. 0801038.304, Revision 1, "Design Inputs and Methodology for ASME Code Fatigue Usage Analysis of Reactor Recirculation Outlet Nozzle" (Attachment 1 hereto), Transient 9 occurs during forced flow conditions. Thus, for the safe end of the nozzle, convection flow is only a minor contributor to fatigue, and the circumferential variation on heat transfer coefficient alleged by Dr. Hopenfeld is of no consequence. Also, the main contributor to fatigue in the nozzle corner region occurs during pressure, not temperature, transients; so Dr. Hopenfeld's allegation is immaterial for that nozzle as well. See Calculation No. 0801038.305, Revision 1, "Stress Analysis of Reactor Recirculation Outlet Nozzle" (Attachment 2 hereto), Section 4.3 at p. 6.

to the Confirmatory CUFen Analysis of the RO nozzle to address his concerns or provide any indication that, if those changes were made, they would result in having the CUFen for the RO nozzle exceed unity at any nozzle location. NEC has provided no evidence that the deficiencies that Dr. Hopenfeld alleges raise a material issue, as required by 10 C.F.R. § 2.309(f)(1)(iv).

(3) NEC's Dissolved Oxygen Claim is Immaterial

Dr. Hopenfeld's assertions (Hopenfeld Decl. at A22) that Entergy should have used a 0.4 ppm concentration for dissolved oxygen at the RO nozzle, as "dictated by ANL," and that had it done so, the CUFen "would have been increased by an order of magnitude" lack a factual foundation for the premise that a 0.4 ppm dissolved oxygen concentration should have been used anywhere in the RO nozzle area. The Board heard extensive testimony at the hearing on the significance of the 0.4 ppm figure in the ANL report, NUREG/CR-6909, which it summarized as follows: "With regard to Dr. Hopenfeld's argument that Entergy should have used the DO values of 0.4 ppm for carbon and low-alloy steels and 0.05 ppm for austenitic stainless steels specified in NUREG/CR-6909, Mr. Fitzpatrick pointed out that the NUREG statement was not prescriptive. Tr. at 997-98 (Fitzpatrick). Mr. Fair clarified that NUREG/CR-6909 calls for the use of the DO values of 0.4 ppm and 0.05 ppm only as default values." Tr. at 998 (Fair); LBP-08-25 at 37. Dr. Hopenfeld's dissolved oxygen claim lacks materiality, a fact that he conceded at the hearing. When asked about his concerns regarding the dissolved oxygen issue, he testified: "First of all, I would like to comment that this is not a major concern." Tr. at 959 (Hopenfeld). See also, LBP-08-25 at 39.

c. NEC's Proposed Contention Fails to Include a Concise Statement of Supportive Alleged Facts or Expert Opinions

The Board has described the requirements of 10 C.F.R. § 2.309(f)(1)(v) as follows:

> Contentions must be supported by "a concise statement of the alleged facts or expert opinions which support the . . . petitioner's position on the issue . . . together with references to the specific sources and documents on which [it] intends to rely to support its position." 10 C.F.R. § 2.309(f)(1)(v). It is the obligation of the petitioner to present the factual information or expert opinions necessary to support its contention adequately. Yankee Atomic Electric Co. (Yankee Nuclear Power Station), CLI-96-7, 43 NRC 235, 262 (1996). Failure to do so requires that the contention be rejected. Arizona Public Service Co. (Palo Verde Nuclear Generating Station, Units 1, 2, and 3), CLI-91-12, 34 NRC 149, 155 (1991).

LBP-06-20, 64 N.R.C. at 150. The information, facts, and expert opinion alleged by the petitioner will be examined by the Board to confirm that it does indeed supply adequate support for the contention. Vermont Yankee Nuclear Power Corp. (Vermont Yankee Nuclear Power Station), ALAB-919, 30 N.R.C. 29, 48 (1989), vacated in part on other grounds and remanded, CLI-90-04, 31 N.R.C. 333 (1990). NEC's proposed contention fails to meet the requirements of 10 C.F.R. § 2.309(f)(1)(v).

(1) NEC's Proposed Changes to the RO Nozzle Confirmatory Analysis Lack Support from Adequate Expert Testimony

Dr. Hopenfeld admitted that he lacks expertise on the very issue that NEC raises in its proposed contention – CUF analytical computations. NEC's arguments concerning the appropriateness of the heat transfer coefficients used in the confirmatory RO nozzle analyses relate solely to the calculation of CUF values (i.e., they are not related to the Fen environmental multipliers). When the Board asked Dr. Hopenfeld whether he agreed with Entergy's methodology for performing stress analyses of reactor components, he admitted: "With respect to the specific numerical analysis, I am not an expert in stress numerical analysis." Tr. at 831 (Hopenfeld). In fact, Dr. Hopenfeld does not claim to have ever performed a fatigue analysis of reactor components comparable to Entergy's analysis. The Board has emphasized that proper performance of stress analysis computations requires "technical and scientific judgment, the

construction of a complex finite element model, running 20 different kinds of transients through the model, and performing quality assurance." LBP-08-25 at 62-63. Because Dr. Hopenfeld admittedly lacks the expertise to perform these computations, he is not qualified to render an expert opinion in support of NEC's proposed contention that challenges them.[22]

(2) NEC's Dissolved Oxygen Argument Lacks Expert or Factual Support

As previously stated, Entergy used the EPRI guidance document BWRVIP-120 (also known as the EPRI BWRVIA Model) to determine the dissolved oxygen values. Entergy Exh. E2-34, Attach. 2 at 1; Fitzpatrick/Stevens Decl. at A56; Tr. at 1003-05 (Stevens); Tr. at 1030 (Fitzpatrick). Citing this testimony, the Board found that Entergy's use of industry guidance on dissolved oxygen values "was reasonable and appropriate." LBP-08-25 at 38. Nowhere in NEC's contention or Dr. Hopenfeld's Declaration are there new facts that would properly challenge the dissolved oxygen values derived from BWRVIP-120.

Dr. Hopenfeld's suggestion that Entergy should have used different dissolved oxygen concentrations at two different locations in the same RO nozzle – the safe end and the forging end – is likewise unsupported. Dr. Hopenfeld does not explain why the dissolved oxygen concentration in the water to which a nozzle is exposed would vary depending the nozzle material. Neither his Declaration, nor his testimony at the hearing, nor any of the references he cites supports his proposition.

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[22] Indeed, the Board flatly rejected Dr. Hopenfeld's "recalculation" of the CUFens for the VY reactor components: "The Board finds that Dr. Hopenfeld's CUFen recalculations are unsound. The recalculations use ASME default values for the CUF calculation, despite the fact that actual values and conditions are known and available. The recalculations inappropriately use an isolated portion of the NUREG/CR-6909 approach, without applying the other necessary components of that NUREG. And the recalculations use the worst-case Fen values from NUREG/CR-6909 without valid justification. As was elicited in testimony during the hearing, Dr. Hopenfeld's recalculations predict that the regulatory requirement (i.e., unity) would have been exceeded within 4.63 years after the VYNPS commenced operations, and it is obvious to the Board that this did not occur. Tr. at 1129-30." LBP-08-25 at 56-57.

Not only does NEC fail to support its proposition that Entergy should have used different dissolved oxygen concentrations at the two nozzle locations even though they are exposed to the same water, the proposition is unsound. In the case of the feedwater nozzle, the flow direction is inward toward the reactor pressure vessel and a thermal sleeve separates the safe end fluid flow from the nozzle corner fluid flow. Tr. at 955-56 (Stevens). For those conditions, it is appropriate and conservative to use different water chemistries for each of the two nozzle locations. This is shown in Section 3.0 of Calculation VY-19Q-303, Revision 0 (Entergy Exh. E2-27), at pages 4 and 5. However, in the case of the RO nozzle, flow is outward from the reactor pressure vessel and there is no thermal sleeve present as in the feedwater nozzle. See Calculation No. 0801038.304, Revision 1 (Attachment 1 hereto), Fig. 3 at p. 17. Accordingly, both the nozzle corner and safe end locations of the RO nozzle are exposed to the same water with the same dissolved oxygen content. Because of their exposure to the same dissolved oxygen concentrations, Entergy used the same concentration of dissolved oxygen in the recirculation line at both locations of the RO nozzle. See Section 5.0 and Table 8 of Calculation 0801038.306, Revision 1 (Attachment 3 hereto) at pages 6-7 and 16-17.[23] NEC's claims regarding dissolved oxygen are not supported by credible expert testimony; thus, NEC fails to meet the requirements of 10 C.F.R. § 2.309(f)(1)(v).

d. NEC's Proposed Contention Fails to Demonstrate a Genuine Dispute on a Material Issue

The Board has stated with respect to 10 C.F.R. § 2.309(f)(1)(vi):

[23] Moreover, Entergy's conservative decision to lower the assumed oxygen level at the stainless steel safe end of the feedwater nozzle still resulted in a computed CUFen of 0.0994, over an order of magnitude less than the allowable value of unity. See Entergy Exh. E2-27, Section 4.0 at 5. NEC provides no evidence that a different result would obtain for the RO nozzle, whose CUF (0.00308) is an order of magnitude less than that for the feedwater nozzle (0.0571). Compare Calculation No. 0801038.306, Revision 1, "Fatigue Analysis of Reactor Recirculation Outlet Nozzle" (Attachment 3 hereto), Section 6.0 at 8 with Entergy Exh. E2-27, Section 4.0 at 5.

> A properly pled contention must contain "sufficient information to show that a genuine dispute exists with the applicant/licensee on a material issue of law or fact." 10 C.F.R. § 2.309(f)(1)(vi). Specifically, a contention "must include references to specific portions of the application . . . that the petitioner disputes and the supporting reasons for each dispute, or, if the petitioner believes that the application fails to contain information on a relevant matter as required by law, the identification of each failure and the supporting reasons for the petitioner's belief." 10 C.F.R. § 2.309(f)(1)(vi). In contrast to subparagraph (v), which focuses on the need for some factual support for the contention, subparagraph (vi) requires that there be a concrete and genuine dispute worth litigating. Making a "bald or conclusory allegation that such a dispute exists" is not sufficient, as a petitioner "must make a minimal showing that material facts are in dispute, thereby demonstrating that an 'inquiry in depth' is appropriate." 54 Fed. Reg. at 33,171 (quoting Connecticut Bankers Ass'n v. Board of Governors, 627 F.2d 245, 251 (D.C. Cir. 1980)).

LBP-06-20, 64 N.R.C. at 151.

NEC's proposed contention fails to meet the standards in 10 C.F.R. § 2.309(f)(1)(vi). First, as discussed above with respect to 10 C.F.R. § 2.309(f)(1)(iv), NEC has not demonstrated that any of its allegations are material. Moreover, NEC fails to reference the specific portions of Entergy's confirmatory calculations that it disputes, and fails to indicate the supporting reasons for each dispute. NEC has ignored the portions of the confirmatory calculations that address NEC's allegations.

(1) NEC's Heat Transfer Coefficient Claim Fails to Demonstrate a Genuine Dispute on a Material Fact

Dr. Hopenfeld ignores statements in Entergy's confirmatory calculations that belie his concerns. Dr. Hopenfeld seeks to establish a difference between the feedwater nozzle and the RO nozzle in that the flow direction is inward (i.e., into the reactor pressure vessel) for the feedwater nozzle and outward for the RO nozzle. However, Entergy explicitly took into account such a difference in flow direction in the both the 2007 CUFen Reanalysis of the RO nozzle and the 2009 Confirmatory Analysis of the RO nozzle. As discussed in Section 3.4 of Calculation 0801038.304, Revision 1 (Attachment 1 hereto), the methods and equations used for calculating

the heat transfer coefficients for the RO nozzle differ appropriately from those used for the feedwater nozzle, including the use of a different equation for forced flow heat transfer coefficient, as well as different geometry inputs specific for each nozzle. Compare the equation for "h_{DF}" in Section 3.4 of Calculation 0801038.304 with the equation for "H_{forced}" in Table 4 of Calculation VY-16Q-301, "Feedwater Nozzle Stress History Development for Green Functions," Entergy Exh. E2-10 at 11. Therefore, NEC's allegation regarding heat transfer during forced flow ignores and thus fails to challenge – contrary to 10 C.F.R. § 2.309(f)(1)(vi) – the calculation that addresses the issue that NEC seeks to raise.

Similarly, Dr. Hopenfeld's claim that, for natural convection flow, the heat transfer coefficient varies circumferentially around the RO nozzle (Hopenfeld Decl. at A14) ignores the calculation that addresses the natural convection flow. Diameter effects on heat transfer coefficients were considered in the Confirmatory CUFen Analysis of the RO nozzle. For example, Calculation 0801038.304 (Revision 1) includes an equation for calculating heat transfer coefficient at a given "Diameter and flow rate." (Emphasis added). The equation includes a diameter term (D_{Df}), which adjusts the heat transfer coefficient to accommodate the diameter of the region of interest. See Calculation 0801038.304, Revision 1 (Attachment 1 hereto) at Section 3.4. The calculations that follow in Section 3.4 use the appropriate diameter of each region evaluated. NEC does not address or challenge Entergy's equations used in the calculations of the heat transfer coefficient for natural convection flow for the RO nozzle, and thus fails to comply with 10 C.F.R. § 2.309(f)(1)(vi).

Moreover, even if the circumferential variations in heat transfer coefficient during the convection mode had been neglected, the effect on the overall heat transfer coefficient would have been negligible. Dr. Hopenfeld ignores the portion of the Entergy calculations showing

that, for natural convection, the heat transfer coefficient is much lower than that for forced flow, so that the contribution of heat transfer to fatigue is much smaller than for forced flow (one order of magnitude, compared to full flow conditions for the significant transients). This can be seen in Section 3.4 of Calculation 0801038.304, Revision 1 where, for example, in Region 1 the 100% flow heat transfer coefficient is 3583, whereas the 0% (convection flow) heat transfer coefficient is 112, i.e., 30 times lower. A similar difference exists in the remaining regions.

Dr. Hopenfeld tries to demonstrate his claim that the circumferential effects on the heat transfer coefficient will be more pronounced at the RO nozzle because it has a larger diameter than the feedwater nozzle by referring to one of the equations in Calculation 0801038.301, "Design Inputs and Methodology for ASME Code Fatigue Usage Analysis of Reactor Core Spray Nozzle." Hopenfeld Decl. at A13 - A14. Apart from the fact that the calculation he cites is for the wrong nozzle, Dr. Hopenfeld's analysis is based on obviously incorrect mathematics. He quotes equation "1" from Entergy's Calculation 0801038.301, page 9, which reads: $h = C(GrPr)^n k/x$, where x is the inside diameter of the nozzle, and using Entergy's value for "n" of 0.25, he concludes that the heat transfer coefficient for the RO nozzle would vary with the vertical distance as $1/x^{0.25}$, causing a the heat transfer coefficient to "vary by a factor of 2.5 $(36/1)^{0.25}$ around the circumference of the RO nozzle, i.e. 240% variation vs. 140% for the FW nozzle." Id. at A13. However, in equation "1," the "n" exponent applies only to the parenthetical term (GrPr). Dr. Hopenfeld's analysis is invalid on its face.

(2) NEC's Dissolved Oxygen Argument Fails to Demonstrate a Genuine Dispute on a Material Issue

Similarly, Dr. Hopenfeld's claims concerning dissolved oxygen fail to satisfy the requirements of 10 C.F.FR. § 2.309(f)(1)(vi). The dissolved oxygen levels in the recirculation line that were used in the RO nozzle fatigue calculations were identified in Table 1 and

Appendix A of Calculation VY-16Q-303 (Entergy Exh. E2-12). The same inputs were used in the Confirmatory CUFen Analysis for the RO nozzle. See Calculation 0801038.306, Revision 1, Section 5.0 at 6. NEC does not refer to, or take issue with, this calculation.

In short, not only are NEC's claims in its proposed contention lacking in materiality, but they do not controvert – or even refer to – the portions of the Confirmatory CUFen Analysis of the RO nozzle that address the issues that NEC seeks to raise. NEC's proposed contention fails to establish the existence of a dispute on a material issue of fact involving VY's license renewal application, contrary to 10 C.F.R. § 2.309(f)(1)(vi).

C. NEC'S PROPOSED CONTENTION DOES NOT MEET THE STANDARDS FOR ADMISSIBILITY IN 10 C.F.R. § 2.309(f)(2)

1. The Heat Transfer Coefficient Claims are not Timely

In its March 9, 2009 Order, the Board indicated that it would only allow NEC to file "new or amended contentions, meeting the requirements of 10 C.F.R. § 2.309(f)(1) and (2) and the criteria set forth in the PID at page 67." March 9, 2009 Order at 3. Despite the Board's directive, NEC has failed to address the requirements of 10 C.F.R. § 2.309(f) (2), which states that to be timely, NEC must show that its proposed contention: (i) is based on information "not previously available"; (ii) is based on information "materially different than information previously available"; and (iii) "has been submitted in a timely fashion based on the availability of the subsequent information."

The purportedly "new" information that NEC relies upon for its proposed contention was previously available almost two years ago, but NEC failed to challenge it until now. NEC does not – and cannot – demonstrate timeliness as required by the regulation. NEC's omission in itself should be sufficient to require that its proposed contention be rejected.

Dr. Hopenfeld alleges that: (1) the heat transfer coefficients for forced convection flow for the RO nozzle were derived from equations which are inapplicable to the RO nozzle because they are valid only when the flow inside the pipe is fully developed; (2) the heat transfer coefficient during natural convection varies considerably more around the circumference of the RO nozzle than around the circumference of the feedwater nozzle because the RO nozzle has a larger diameter than the feedwater nozzle; and (3) that Entergy should have used different dissolved oxygen concentrations at two different locations in the RO nozzle – the safe end and the forging end. Hopenfeld Decl. at A9 and A18. However, NEC received calculations that included each of these features as part Entergy's 2007 CUFen Reanalysis almost two years ago, but declined to challenge them until now.

With respect to the equations used to obtain heat transfer coefficient for the RO nozzle analysis for forced flow conditions, Entergy's equations to obtain the heat transfer coefficient for the RO nozzle were contained in the 2007 CUFen Reanalysis for that nozzle. See Calculation VY-16Q-305, Revision 0 (Recirculation Outlet Stress History Development for Nozzle Green Function) (July 18, 2007), Section 3.2, Entergy Exh. E2-14 at 5-7. The same equations were used, unchanged, in the confirmatory analysis of the nozzle. See Calculation 0801038.304, Revision 1 (Design Inputs and Methodology for ASME Code Confirmatory Fatigue Usage Analysis of Reactor Recirculation Outlet Nozzle), Attachment 1 hereto, Section 3.4 at 6.

Regarding the heat transfer coefficient used around the circumference of the RO nozzle during natural convection, Entergy's assumption of uniform value for the heat transfer coefficient around the circumference of the nozzle was reflected in constant values of the heat transfer coefficient for each region of the nozzle in the 2007 CUFen Reanalyses. See Section 3.2.1 of Entergy Exh. E2-14 at 5-7. The very same assumption was used in the confirmatory

analysis of the nozzle. See Calculation 0801038.304, Revision 1, Section 3.4 at 6-8 and Table 2 at 11.

Finally, with regard to the dissolved oxygen levels to which the RO nozzle would be exposed, the dissolved oxygen levels in the recirculation line that were used in the RO nozzle fatigue calculations were identified in 2007 in Table 1 and Appendix A of Calculation VY-16Q-303 (Entergy Exh. E2-12). The same inputs were used in the Confirmatory CUFen Analysis for the RO nozzle. See Calculation 0801038.306, Revision 1, Section 5.0 at 7.

Because NEC was aware of the alleged deficiencies in 2007, NEC cannot show that its proposed contention is based on information "not previously available" or "materially different than information previously available." 10 C.F.R. § 2.309(f)(2). NEC was free to raise any of these alleged deficiencies in 2007, and thus cannot demonstrate that its proposed contention "has been submitted in a timely fashion based on the availability of the subsequent information." Id. NEC's proposed contention is therefore nontimely.

2. There is no Justification for the Contention's Nontimeliness

Since NEC cannot show that its proposed contention is timely, it must "address the factors in paragraphs (c)(1)(i) through (c)(1)(viii)" of 10 C.F.R. § 2.309(c)(1). 10 C.F.R. § 2.309(c)(2). NEC has failed to comply with 10 C.F.R. § 2.309(c)(2) because it has failed to specify any reason whatsoever for why it is now challenging the heat transfer coefficient analysis for the RO nozzle, almost two years after obtaining the information containing the features it attacks. Accordingly, the proposed contention should be denied.

Even if NEC had tried to apply the eight factor balancing test of 10 C.F.R. § 2.309(c)(1), its challenge to the heat transfer coefficients in the RO calculation would be inadmissible because NEC fails to meet the most important factor in the balancing test – showing "[g]ood

cause, if any, for failure to file on time." 10 C.F.R. § 2.309(c)(1)(i). Dominion Nuclear Connecticut, Inc. (Millstone Nuclear Power Station, Units 2 and 3), CLI-05-24, 62 N.R.C. 551, 563 (2005); State of New Jersey (Department of Law and Public Safety's Request Dated October 8, 1993), CLI-93-25, 38 N.R.C. 289, 296 (1993). Furthermore, admission of NEC's nontimely contention would unduly prolong a proceeding that has been ongoing for several years and which would draw to a close were the contention to be rejected, in contravention of 10 C.F.R. § 2.309(c)(1)(vii). LBP-08-25 at 67-68.

NEC has failed to show good cause for its failure to raise its heat transfer coefficient and dissolved oxygen claims for the RO nozzle in a timely manner, and admission of the contention would significantly and unreasonably delay this proceeding. Accordingly, NEC's proposed contention should be rejected as nontimely.

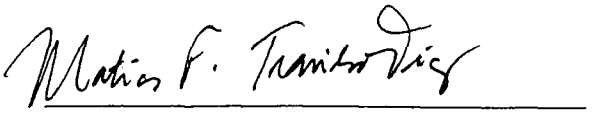
IV. CONCLUSION

NEC's proposed fatigue contention (1) fails to meet the conditions set by the Board for the submittal of contentions challenging the Confirmatory CUFen Analyses of the RO and CS nozzles; (2) fails to meet the admissibility standards in 10 C.F.R. § 2.309(f)(1); and (3) is not timely. For these reasons, NEC's proposed contention should be denied.

Because Entergy has demonstrated that its Confirmatory CUFen Analyses have been "(1) done in accordance with the above stated guidance and the basic approach used in the Confirmatory CUFen Analysis for the FW nozzle, (2) contain no significantly different scientific

or technical judgments, and (3) demonstrate values less than unity," LBP-08-25 at 67, Entergy respectfully requests that this adjudicatory proceeding be terminated.

Respectfully Submitted,



David R. Lewis
Matias F. Travieso-Diaz
Blake J. Nelson
PILLSBURY WINTHROP SHAW PITTMAN LLP
2300 N Street, NW
Washington, DC 20037-1128
Tel. (202) 663-8000

Dated: May 18, 2009

Counsel for Entergy

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

Before the Atomic Safety and Licensing Board

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

CERTIFICATE OF SERVICE

I hereby certify that copies of the foregoing "Entergy's Opposition to NEC's Motion to File a Timely New Contention" were served on the persons listed below by deposit in the U.S. Mail, first class, postage prepaid, and where indicated by an asterisk by electronic mail, this 18th day of May 2009.

*Administrative Judge
Alex S. Karlin, Esq., Chairman
Atomic Safety and Licensing Board
Mail Stop T-3 F23
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001
ask2@nrc.gov

*Administrative Judge
Dr. Richard E. Wardwell
Atomic Safety and Licensing Board
Mail Stop T-3 F23
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001
rew@nrc.gov

*Administrative Judge
William H. Reed
1819 Edgewood Lane
Charlottesville, VA 22902
whrcville@embarqmail.com

*Secretary
Att'n: Rulemakings and Adjudications Staff
Mail Stop O-16 C1
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001
hearingdocket@nrc.gov

*Office of Commission Appellate Adjudication
Mail Stop O-16 C1
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001
OCAAmail@nrc.gov

Atomic Safety and Licensing Board
Mail Stop T-3 F23
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

*Lloyd Subin, Esq.
*Susan L. Uttal, Esq.
*Maxwell C. Smith, Esq.
Office of the General Counsel
Mail Stop O-15-D21
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001
LBS3@nrc.gov; susan.uttal@nrc.gov;
maxwell.smith@nrc.gov

*Sarah Hofmann, Esq.
Director of Public Advocacy
Department of Public Service
112 State Street – Drawer 20
Montpelier, VT 05620-2601
Sarah.hofmann@state.vt.us

*Anthony Z. Roisman, Esq.
National Legal Scholars Law Firm
84 East Thetford Road
Lyme, NH 03768
aroisman@nationallegalscholars.com

* Matthew Brock
Assistant Attorney General
Office of the Attorney General
One Ashburton Place, 18th Floor
Boston, MA 02108
Matthew.Brock@state.ma.us

*Peter L. Roth, Esq.
Office of the New Hampshire Attorney General
33 Capitol Street
Concord, NH 03301
Peter.roth@doj.nh.gov

* Zachary Kahn
Atomic Safety and Licensing Board Panel
Mail Stop T-3 F23
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001
zachary.kahn@nrc.gov

Raymond Shadis
New England Coalition Pro Se Representative
Post Office Box 98
Edgecomb, ME 04556
shadis@prexar.com

* Lauren Bregman
Atomic Safety and Licensing Board Panel
Mail Stop T-3 F23
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001
lauren.bregman@nrc.gov

Matias F. Travieso-Diaz

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

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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 (50%)
	16164	549	16164	1010	
	56164	549	40000	1010	
2. Turbine Roll and Increase to Rated Power 300 Cycles (1, 2)	0	549		1010	28294 (100%)
	1	542	1	1010	
	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 (100%)
	1800	542	1800	1010	
	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 (0%)
	3	526	3	1190	
	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 (50%)
	7493	300	300	675	
	11093	400	3600	240	
	16457	549	5364	1010	
	16517	549	60	1010	
	16518	542	1	1010	28294 (100%)
	17118	542	600	1010	
	17119	526	1	1010	
	57119	526	40000	1010	
5. Turbine Generator Trip 60 Cycles (1, 2)	0	526		1010	28294 (100%)
	10	526	10	1135	
	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 (100%)
	2	526	2	1375	
	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 (100%)
	600	375	600	170	
	11580	70	10980	50	
	51580	70	40000	50	
8. SCRAM Other 228 Cycles (1, 2)	0	526		1010	28294 (100%)
	15	526	15	940	
	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 (12%)
	1	130 (3)	1	1010	
	27	130 (3)	26	1010	
	28	526	1	1010	
	5028	526	5000	1010	
10. Shutdown 300 Cycles (2)	0	549		1010	14147 (50%)
	6264	375	6264	170	
	6864	330	600	88	
	16224	70	9360	50	
	56224	70	40000	50	
11. Design Hydrostatic Test 120 Cycles (2)	---	100	---	0	1981 (7%)
				1100	
				50	
12. Hydrostatic Test 1 Cycle (2)	---	100	---	50	1981 (7%)
				1563	
				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	Tempera-ture, °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 $[k/(\rho d)]/12^3$.

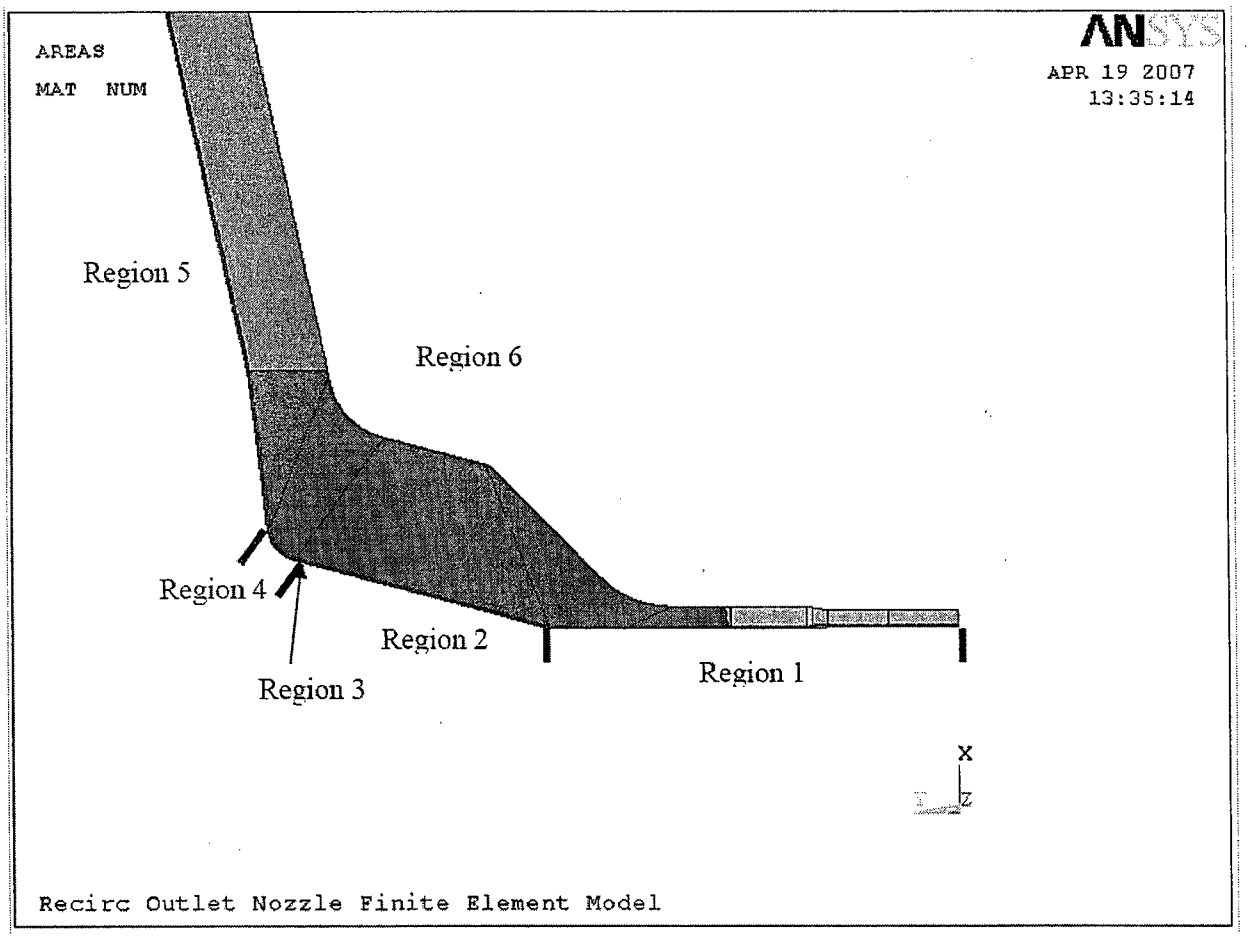

Figure 1: Nozzle and Vessel Wall Thermal Boundaries

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	100	200	300	400	500	600	°F
		21.11	37.78	93.33	148.89	204.44	260.00	315.56	°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	982.7	917.8	858.6	784.9	679.2	kg/m³
(Density)		62.3	62.1	60.1	57.3	53.6	49.0	42.4	lbm/ft³
β	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
(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	ft³/ft³-°F
g	0.3048	9.806	9.806	9.806	9.806	9.806	9.806	9.806	m/s²
(Gravitational Constant)		32.17	32.17	32.17	32.17	32.17	32.17	32.17	ft/s²
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		6.980	4.510	1.910	1.220	0.950	0.859	1.070	—
(Prandtl Number)									
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_c	$g\beta\Delta T(r_o-r_i)^3/(\mu/\rho)^2$	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_c	Gr_cPr	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/m²-°C
		32.03	45.55	82.66	112.34	136.24	154.13	164.35	Btu/hr-ft²-°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

		Value at Fluid Temperature, T [12]							Units
Water Property	Conversion Factor [19]	70	100	200	300	400	500	600	°F
		21.11	37.78	93.33	148.89	204.44	260.00	315.56	°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/m³
(Density)		62.3	62.1	60.1	57.3	53.6	49.0	42.4	lbm/ft³
β	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
(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	ft³/ft³-°F
g	0.3048	9.806	9.806	9.806	9.806	9.806	9.806	9.806	m/s²
(Gravitational Constant)		32.17	32.17	32.17	32.17	32.17	32.17	32.17	ft/s²
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		6.980	4.510	1.910	1.220	0.950	0.859	1.070	—
(Prandtl Number)									
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	1.4619E+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	63515289008	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

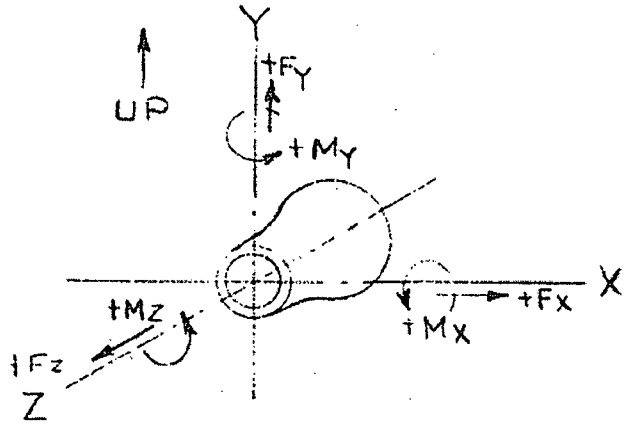

Figure 2: Coordinate System for Forces and Moments

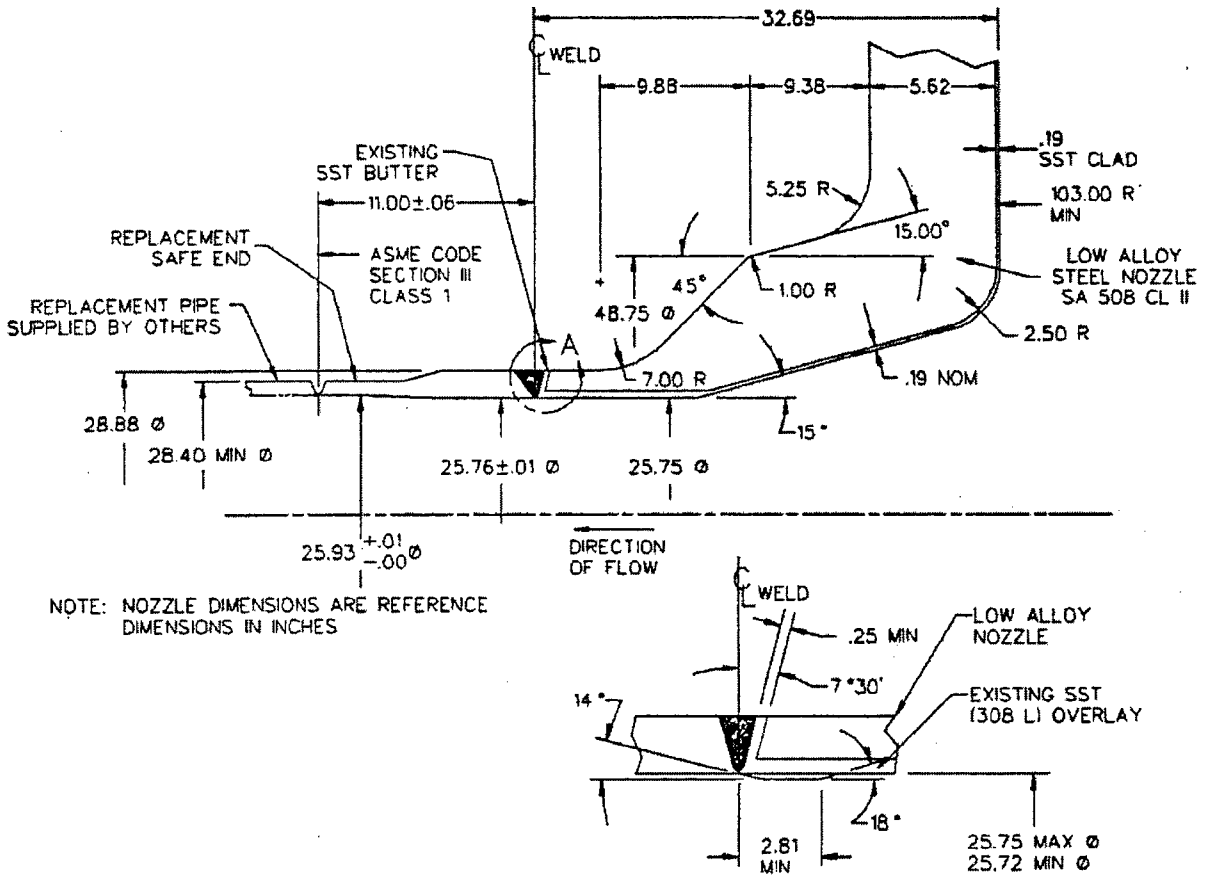

Figure 3: RO Nozzle and Safe End Geometry [20]

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

```
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
```

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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
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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
```

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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
FITEM,5,56
FITEM,5,-57
FITEM,5,59
CM,_Y,LINE
LSEL, , , ,P51X
CM,_Y1,LINE
CMSEL,,_Y
!*
LESIZE,_Y1, , ,40, , , , ,1
!*
FLST,5,2,5,ORDE,2
FITEM,5,17
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
!*
FLST,5,2,5,ORDE,2
FITEM,5,21
FITEM,5,-22
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
!*
```

```
!Simulating Butter
FLST,2,2,5,ORDE,2
FITEM,2,9
FITEM,2,-10
ACLEAR,P51X
FLST,2,2,5,ORDE,2
FITEM,2,9
FITEM,2,-10
ADELE,P51X

KGEN,2,15, , , ,11/16, , ,0
KGEN,2,44, , , ,-0.25, , ,0
KGEN,2,14, , , ,11/16-1.375*tan(7.5), , ,0
KGEN,2,46, , , ,-0.25, , ,0

FLST,2,3,4,ORDE,3
FITEM,2,2
FITEM,2,20
FITEM,2,-21
LDELE,P51X
LSTR,       21,       44
LSTR,       44,       45
LSTR,       45,       15
LSTR,       17,       46
LSTR,       46,       47
LSTR,       47,       14
LSTR,       46,       44
LSTR,       45,       47
LSTR,       13,       16
FLST,3,2,3,ORDE,2
FITEM,3,46
FITEM,3,-47
KGEN,2,P51X, , ,-0.25, , , ,0
LSTR,       48,       46
LSTR,       49,       47
FLST,2,3,4,ORDE,3
FITEM,2,61
FITEM,2,64
FITEM,2,-65
LPTN,P51X
FLST,2,2,4,ORDE,2
FITEM,2,70
FITEM,2,-71
LDELE,P51X, , ,1
FLST,2,4,4
FITEM,2,67
FITEM,2,39
```

```
FITEM,2,68
FITEM,2,3
AL,P51X
FLST,2,4,4
FITEM,2,39
FITEM,2,5
FITEM,2,2
FITEM,2,53
AL,P51X
FLST,2,4,4
FITEM,2,20
FITEM,2,60
FITEM,2,53
FITEM,2,41
AL,P51X
FLST,2,4,4
FITEM,2,72
FITEM,2,68
FITEM,2,69
FITEM,2,41
AL,P51X
FLST,2,4,4
FITEM,2,21
FITEM,2,60
FITEM,2,36
FITEM,2,43
AL,P51X
FLST,2,4,4
FITEM,2,66
FITEM,2,69
FITEM,2,35
FITEM,2,43
AL,P51X

CM,_Y,AREA
ASEL, , , ,       10
CM,_Y1,AREA
CMSEL,S,_Y
!*
CMSEL,S,_Y1
AATT,       2, ,   1,       0,
CMSEL,S,_Y
CMDELE,_Y
CMDELE,_Y1
!*
FLST,5,3,5,ORDE,3
FITEM,5,9
```

```
FITEM,5,23
FITEM,5,-24
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
!*
FLST,5,2,5,ORDE,2
FITEM,5,25
FITEM,5,-26
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,5,3,4,ORDE,3
FITEM,5,2
FITEM,5,39
FITEM,5,67
CM,_Y,LINE
LSEL, , , ,P51X
CM,_Y1,LINE
CMSEL,,_Y
!*
LESIZE,_Y1, , ,10, , , , ,1
!*
FLST,5,6,4,ORDE,6
FITEM,5,20
FITEM,5,-21
FITEM,5,41
FITEM,5,43
FITEM,5,66
FITEM,5,72
CM,_Y,LINE
LSEL, , , ,P51X
```

```
CM,_Y1,LINE
CMSEL,,_Y
!*
LESIZE,_Y1, , ,2, , , , ,1
!*
FLST,5,2,5,ORDE,2
FITEM,5,9
FITEM,5,-10
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,5,4,5,ORDE,2
FITEM,5,23
FITEM,5,-26
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
!*

save
finish
```

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CALCULATION PACKAGE	Project No.: 0801038 Quality Program ☒ Nuclear ☐ Commercial

PROJECT NAME:

VY Confirmatory Analysis for the CS and RO Nozzles

CONTRACT NO.:

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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 Gary L. Stevens 03/09/09	**Preparer:** Tyler Novotny Tyler D. Novotny 03/09/09 **Checker:** Jim 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) 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

		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}
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.

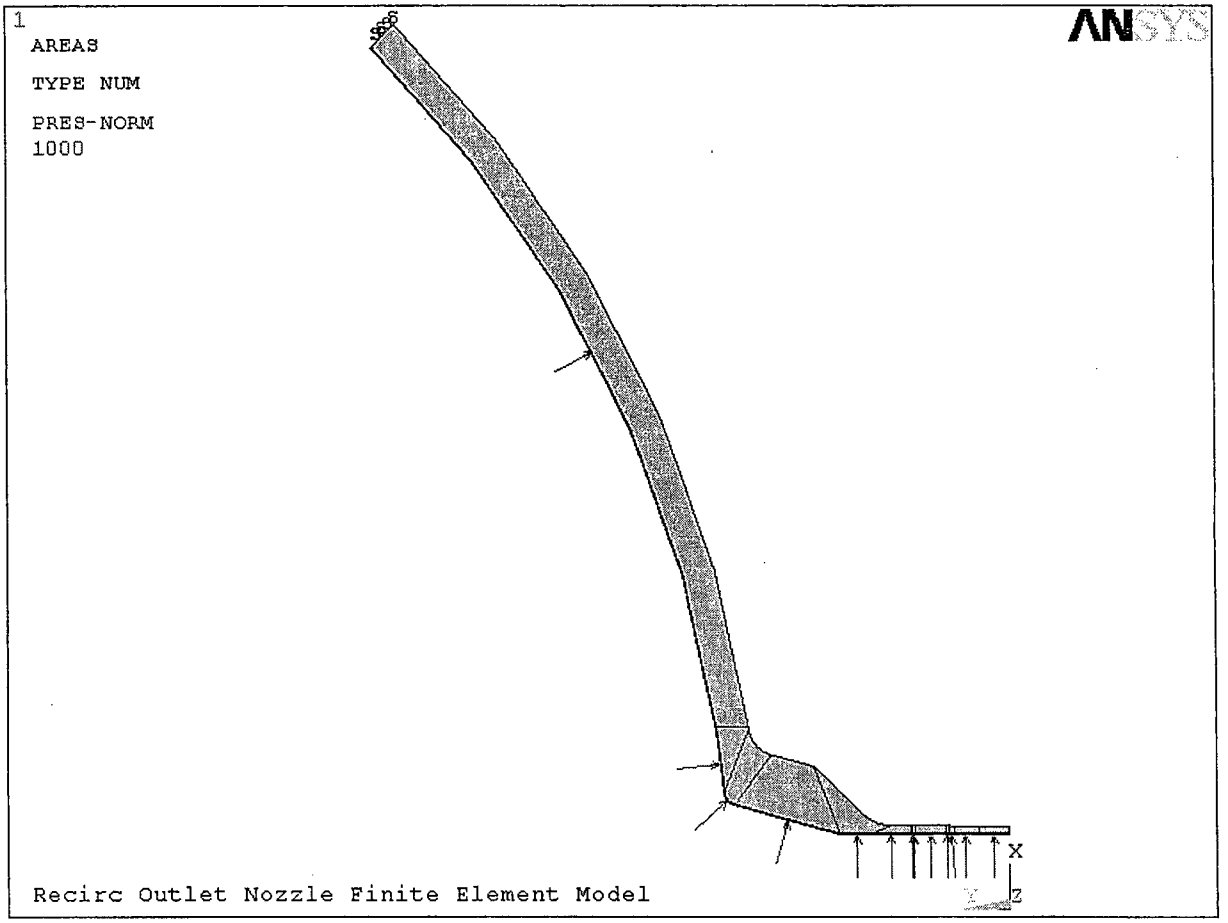

Figure 1. RO Nozzle Internal Pressure Distribution

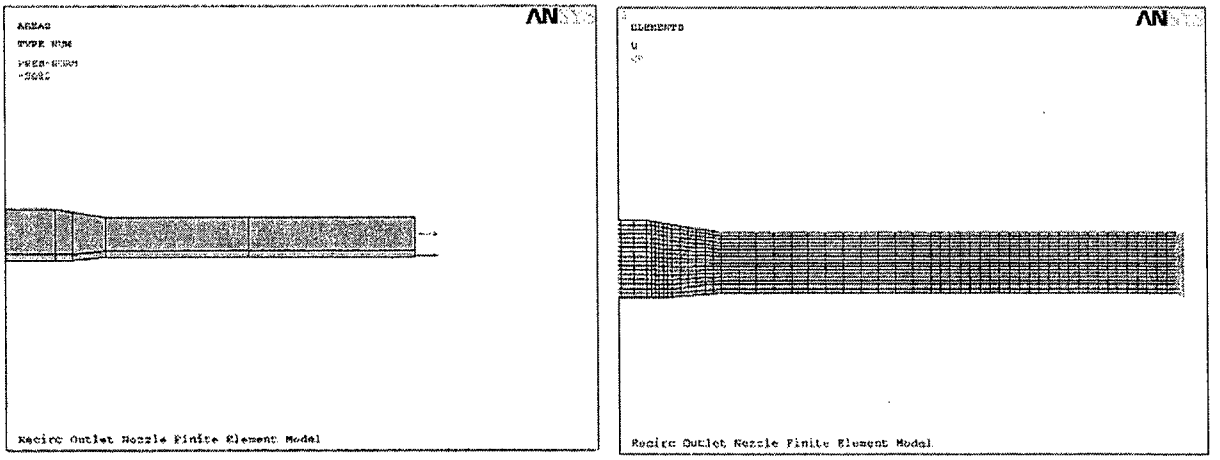

Figure 2. RO Nozzle Pressure Cap Load & Boundary Condition

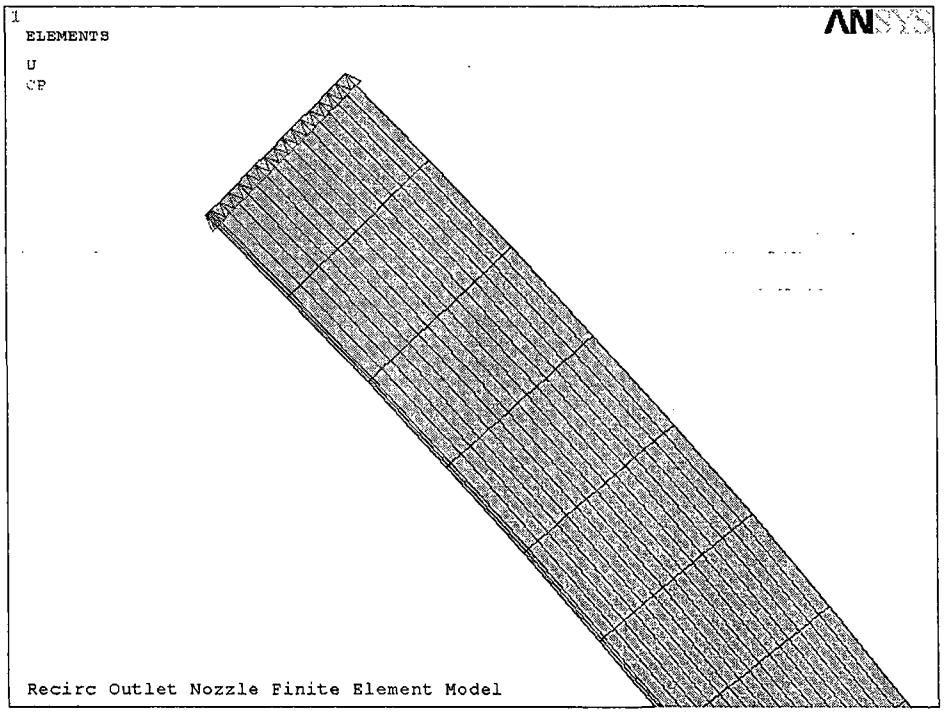

Figure 3. RO Nozzle Vessel Wall Boundary Condition

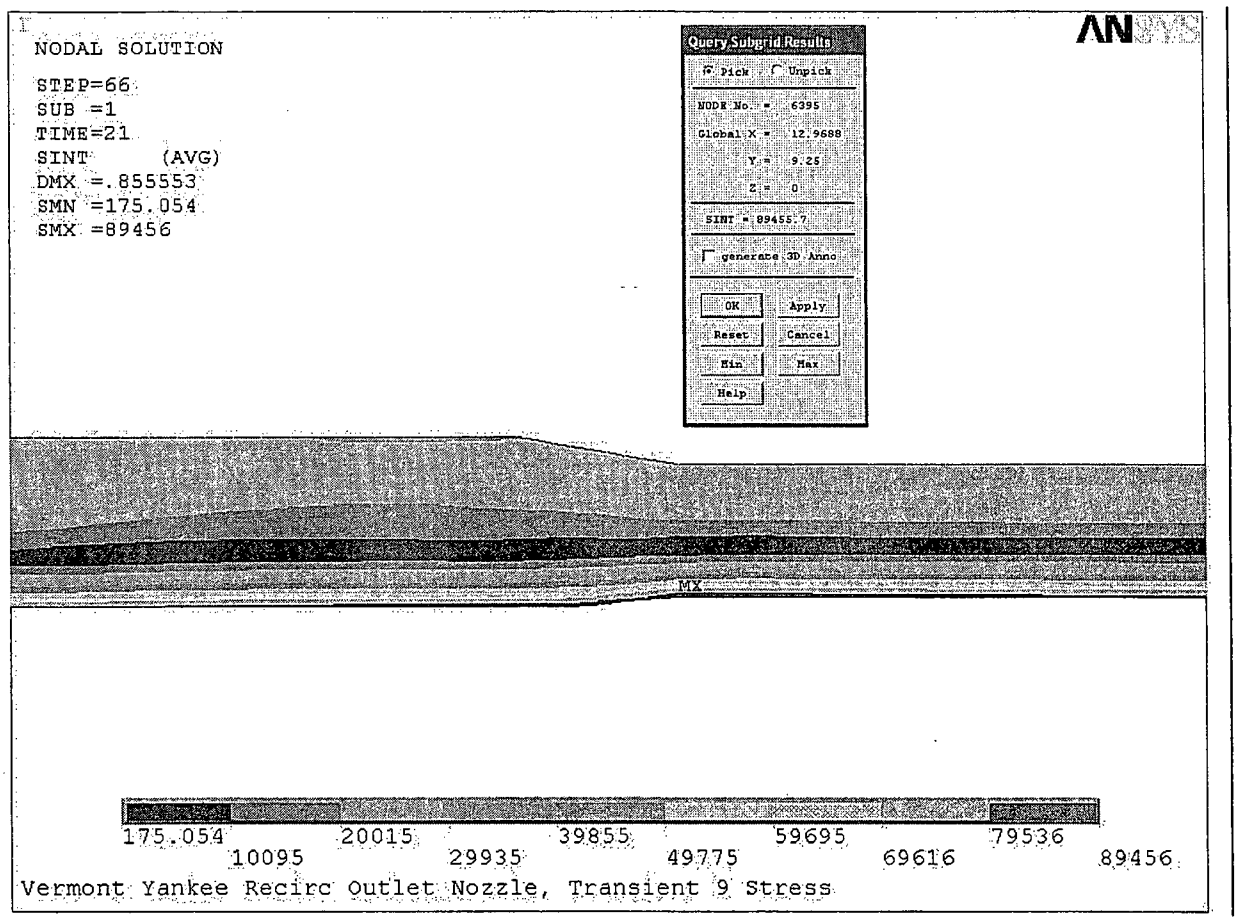

Figure 4. Safe End Critical Thermal Stress Intensity Location

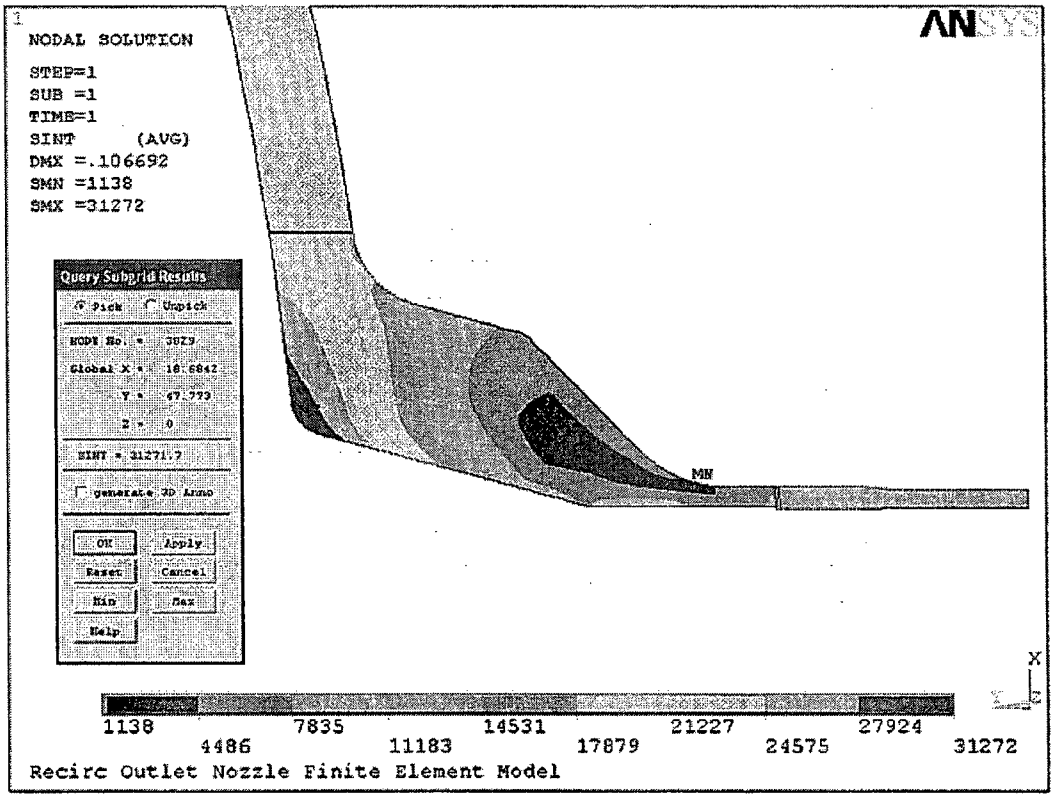

Figure 5. Nozzle Blend Radius Limiting Pressure Stress Intensity Location

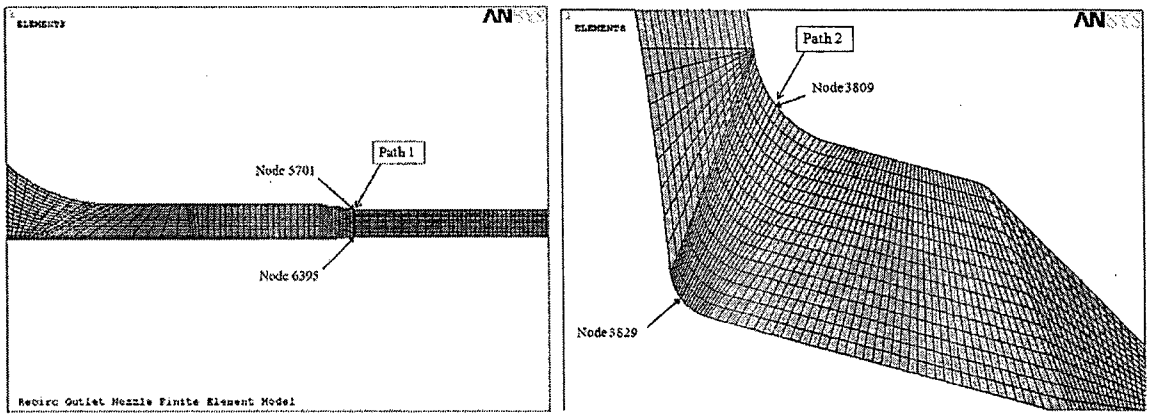

Figure 6. Limiting Stress Paths

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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 Gary L Stevens 03/09/09	**Preparer:** Tyler Novotny Tyler D. Novotny 03/09/09 **Checker:** William F. Weitze 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 $\leq$ 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_a (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	38762	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-2LALL":

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	13066	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_	8713	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:

[DO and HWC/NWC inputs from Table 1 of Reference [5]]

	HWC DO	NWC DO	
	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	8.58	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
526	274	2.45	10.49	0.000
529	276	2.45	10.69	0.005
529	276	2.45	10.69	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.

ATTACHMENT 4

May 15, 2009

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

Before the Atomic Safety and Licensing Board

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

DECLARATION OF GARY L. STEVENS

Gary L. Stevens states as follows under penalty of perjury:

1. My name is Gary Lance Stevens. I am a Senior Associate at Structural Integrity Associates, Inc. ("SIA"). I have previously testified on behalf of Applicants Entergy Nuclear Vermont Yankee, LLC and Entergy Nuclear Operations, Inc. ("Entergy") in this proceeding.

2. I led the SIA team that prepared in January 2009 a set of Confirmatory Environmentally Assisted Fatigue Analyses ("CUFen Analyses") of the Core Spray ("CS") and Recirculation Outlet ("RO") reactor nozzles at the Vermont Yankee Nuclear Power Station ("VY") utilizing the same methodology and approach SIA had used in the Confirmatory CUFen Analysis of another reactor nozzle, the feedwater nozzle. These analyses were reflected in the following calculations: Calculation 0801038.301, Revision 0, "Design Inputs and Methodology for ASME Code Fatigue Usage Analysis of Reactor Core Spray Nozzle;" Calculation No. 0801038.302, Revision 0, "Stress Analysis of Reactor Core Spray Nozzle;" Calculation No. 0801038.303, Revision 0, "Fatigue Analysis of Core Spray Nozzle;" Calculation No. 0801038.304, Revision 0, "Design Inputs and Methodology for ASME Code Fatigue Usage Analysis of Reactor

Recirculation Outlet Nozzle;" Calculation No. 0801038.305, Revision 0, "Stress Analysis of Reactor Recirculation Outlet Nozzle;" and Calculation No. 0801038.306, Revision 0, "Fatigue Analysis of Recirculation Outlet Nozzle" (collectively referred to as "the initial CS and RO confirmatory calculations"). I also led the SIA team that prepared, in March 2009, a set of revised Confirmatory CUFen calculations for the CS and RO nozzles, i.e., 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."

3. Entergy provided copies of the initial CS and RO confirmatory calculations to the Staff of the U.S. Nuclear Regulatory Commission ("NRC"), who performed a technical audit of the calculations. During the course of the audit, the NRC Staff asked whether the CUFen results for those nozzles were dependent on the value of heat transfer coefficient used in the analyses. SIA staff, under my supervision, performed a sensitivity analysis of the effect of variations in the nozzle corner heat transfer coefficients on the CUFen for the CS nozzle. The analysis was completed in March 2009.

4. A copy of a table prepared by SIA that tabulates the CUFen for the CS nozzle as a function of heat transfer coefficient is enclosed as Exhibit A. The table demonstrates that the effect of changes in the heat transfer coefficient on CUFen estimates is minimal. While the sensitivity analysis focused on the CS nozzle, its results are applicable to the RO nozzle as well, since the forced convection heat transfer coefficients for the CS nozzle are higher (and therefore bound) the heat transfer coefficients calculated for the RO nozzle. Refer to Table 3 of Exh. E2-14 (VY-16Q-305, Rev. 0) at p. 12 (H_{forced} = 2713 Btu/hr-ft^2-°F at 300°F for Region 3 (near nozzle corner)) vs. Table 19 of 0801038.301, Rev. 0 at p. 40 (H_{forced} = 3921 Btu/hr-ft^2-°F for Region 9 (near nozzle corner)).

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

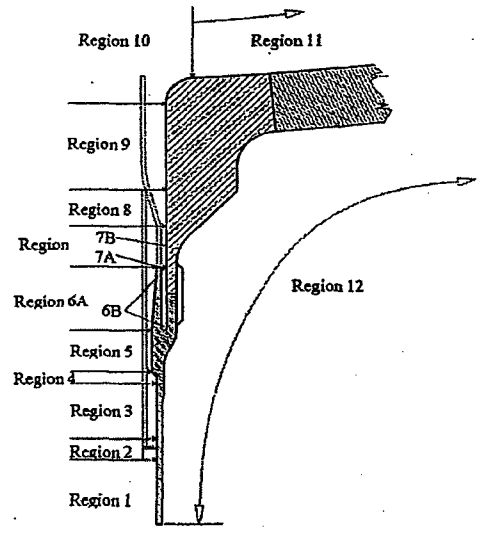
Gary L. Stevens

Gary L. Stevens

Executed on May 15, 2009

EXHIBIT A

0801038-307

CS Nozzle	1	2	CUF Difference
Safe End Material 1(Inconel)	0.0001740	0.0001740	0.000000
Safe End Material 2 (S.S.)	0.0007422	0.0007422	0.000000
Blend Radius	0.0171387	0.0155733	-0.0015654

1. The results of 0801038.303.R0
2. For this iteration 0801038.302.R0 ANSYS input files for all transients were modified by changing the Region 9 heat transfer coefficient to 500Btu/hr-ft^2-°F for all flow cases. This change then forces Region 9, 10 and 11 to have a heat transfer coefficient of 500Btu/hr-ft^2-°F for all flow cases.