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OFFICE OF SECRETARY
RULEMAKINGS AND
ADJUDICATIONS STAFF

UNITED STATES
NUCLEAR REGULATORY COMMISSION

| | | |
|---|---|---|
| In the Matter of | ) | |
| | ) | |
| ENTERGY NUCLEAR VERMONT YANKEE, LLC | ) | Docket No. 50-271-LR |
| and ENTERGY NUCLEAR OPERATIONS, INC. | ) | ASLB No. 06-849-03-LR |
| | ) | |
| Vermont Yankee Nuclear Power Station | ) | |

**NEW ENGLAND COALITION, INC.'S (NEC) MOTION TO FILE A TIMELY NEW OR AMENDED CONTENTION**

The New England Coalition, Inc. (NEC) moves, pursuant to 10 C.F.R. § 2.309(f)(2) and the Initial Scheduling Order ¶ 5, for leave to file a timely new or amended contention addressing an additional analysis performed by Entergy Nuclear Vermont Yankee, LLC and Entergy Nuclear Operations, Inc. ("Entergy") to assess the impact of environmentally assisted metal fatigue (EAF) on the Vermont Yankee plant feedwater nozzle. Entergy produced its reports of this additional analysis (hereinafter referred to as "Entergy's Second CUFen Reanalysis") to NEC on February 15, 2008. These reports are attached hereto as Exhibits A-C to the Seventh Declaration of Dr. Joram Hopenfeld. *See*, Attachment 1.

NEC's proposed new or amended contention satisfies requirements of 10 C.F.R. § 2.309(f)(2). Entergy's Second CUFen Reanalysis is materially different from both the EAF analysis reported in Entergy's License Renewal Application, and the Entergy EAF analysis that NEC's Contention 2A addresses. Entergy employed different methods, and produced different results. *See,* Attachment 1, Seventh Declaration of Dr. Joram Hopenfeld. Reports of Entergy's Second CUFen Reanalysis were not available to NEC

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until Entergy produced them on February 15, 2008. NEC's filing is timely. *See,* Initial Scheduling Order ¶ 5 (a motion for a new or amended contention shall be deemed timely under 10 C.F.R. § 2.309(f)(2)(iii) if it is filed within thirty (30) days of the date when the new and material information on which it is based first becomes available); 10 C.F.R. § 2.306 ("In computing any period of time . . . . the last day of the period so computed is included unless it is a Saturday, Sunday, or legal holiday . . ., in which event the period runs until the end of the next day which is neither a Saturday, Sunday, nor holiday.").

**PROPOSED NEW OR AMENDED CONTENTION**

NEC incorporates by reference its now pending Contentions 2 and 2A (metal fatigue) and its Reply to Entergy's Answers to Contentions 2 and 2A. In addition, NEC contends the following.

(1) Statement of Issue of Law or Fact to be Raised, and Brief Explanation of Basis. 10 C.F.R. §§ 2.309(f)(i), 2.309(f)(ii). NEC's Contention 2 (metal fatigue) is that data reported in Entergy's License Renewal Application Table 4.3-3 indicate that critical reactor components may fail due to environmentally assisted metal fatigue (EAF) during the period of extended operation, and that Entergy has not proposed an adequate aging management plan addressing this issue as required pursuant to 10 C.F.R. § 54.21.[1] NEC's Contention 2A addresses a reanalysis Entergy performed of the impact of EAF on the components listed in License Renewal Application Table 4.3-3 ("Entergy's First CUFen Reanalysis"). Contention 2A is that Entergy's First CUFen Reanalysis is flawed by unjustified assumptions, uncertainties and insufficient conservatism, and fails to prove that the components assessed will not fail due to metal fatigue during the period of

[1] Per the Board's Order of November 7, 2007, NEC's Contention 2 is held in abeyance pending resolution of NEC's Contention 2A.

extended operation. NEC understands that Entergy has performed its Second CUFen Reanalysis to validate the results of its First CUFen Reanalysis.

NEC now contends, as explained in detail in the attached Seventh Declaration of Dr. Joram Hopenfeld, that Entergy's Second CUFen Reanalysis neither validates the results of Entergy's First CUFen Reanalysis, nor independently demonstrates that CUFens for all components listed in License Renewal Application Table 4.3-3 and all NUREG/CR-6260 locations are less than one. Entergy's Second CUFen Reanalysis addresses only one issue: the uncertainty in calculation of CUF values used in Entergy's First CUFen Reanalysis resulting from use of the Green Function. It does not address errors in Entergy's First CUFen Reanalysis resulting from the several other factors identified in NEC's Contention 2A and the supporting Sixth Declaration of Dr. Joram Hopenfeld. *See,* Attachment 1 ¶¶ 7-10. Further, Entergy's Second CUFen Reanalysis addresses only the feedwater nozzle, and its results are not bounding for other components. *Id.* at ¶¶ 11-12.

(2) Scope of the Proceeding and Materiality. 10 C.F.R. §§ 2.309(f)(iii), 2.309(f)(iv). This contention addresses Entergy's plan, as stated in the License Renewal Application, to monitor and manage the effects of aging on reactor components that are subject to an aging management review, pursuant to 10 C.F.R. § 54.21(a), and an evaluation of time-limited aging analysis, pursuant to 10 C.F.R. § 54.21(c). These are issues within the scope of this proceeding, and material to findings the NRC must make in this matter. *See,* 10 C.F.R. § 54.4; *Duke Energy Corp. (McGuire Nuclear Station, Units 1 and 2; Catawba Nuclear Station, Units 1, 2 and 3),* 56 NRC 358, 363-64 (2002).

(3) Expert or Factual Support. 10 C.F.R. § 2.309(f)(v). This contention is supported by the attached Declaration of NEC's expert witness, Dr. Joram Hopenfeld.

(4) Genuine Dispute of Material Law or Fact. 10 C.F.R. § 2.309(f)(vi). The attached Seventh Declaration of Dr. Joram Hopenfeld includes ample information to establish a genuine dispute with the Applicant concerning the validity of Entergy's Second CUFen Reanalysis. NEC is required to make only "a minimal showing that the material facts are in dispute, thereby demonstrating that an inquiry in depth is appropriate." *In Gulf State Utilities Co.,* 40 NRC 43, 51 (1994).

**NEC HAS CONSULTED OTHER PARTIES**

Pursuant to 10 C.F.R. § 2.323(b), NEC has consulted or attempted to consult with all parties to this proceeding concerning this motion. The State of Vermont does not object to the filing of this motion. Entergy considers NEC's motion timely, and will respond to its substance after reviewing NEC's pleading. The NRC Staff will respond after reviewing NEC's pleading. The State of New Hampshire did not take a position.

**CONCLUSION**

NEC respectfully requests that the Board grant NEC's Motion to File a Timely New or Amended Contention, and admit NEC's new or amended contention for adjudication in this proceeding.

March 17, 2008 New England Coalition

by: Karen Tyler

Andrew Raubvogel
Karen Tyler
SHEMS DUNKIEL KASSEL & SAUNDERS PLLC
For the firm

Attorneys for NEC

**ATTACHMENT 1**

UNITED STATES
NUCLEAR REGULATORY COMMISSION

| | | |
|---|---|---|
| In the Matter of | ) | |
| | ) | |
| ENTERGY NUCLEAR VERMONT YANKEE, LLC | ) | Docket No. 50-271-LR |
| and ENTERGY NUCLEAR OPERATIONS, INC. | ) | ASLB No. 06-849-03-LR |
| | ) | |
| Vermont Yankee Nuclear Power Station | ) | |

**SEVENTH DECLARATION OF DR. JORAM HOPENFELD**

1. My name is Dr. Joram Hopenfeld. The New England Coalition (NEC) has retained me as an expert witness in proceedings concerning the application of Entergy Nuclear Operations, Inc. ("Entergy") to renew its operating license for the Vermont Yankee Nuclear Power Station ("VYNPS") for twenty years beyond the current expiration date of March 21, 2012.

2. I am a mechanical engineer and hold a doctorate in engineering. I have 45 years of professional experience in the fields of instrumentation, design, project management, and nuclear safety, including 18 years in the employ of the U.S. Nuclear Regulatory Commission (NRC). My curriculum vitae was previously filed in this proceeding as an attachment to my declaration in support of NEC's Petition to Intervene.

3. I have reviewed the VYNPS License Renewal Application, submitted to the NRC in 2006, and amendments thereto. I have also reviewed the following Structural Integrity Associates, Inc. (SIA) Environmental Fatigue Analysis Calculations and Reports, which I understand that Entergy produced to New England Coalition (NEC) on February 15, 2008.

| SIA Calculation or Report No. | Title |
|---|---|
| Calculation File No. VY-19Q-301 | Design Inputs and Methodology for ASME Code Confirmatory Fatigue Usage Analysis of Reactor Feedwater Nozzle |
| Calculation File No. VY-19Q-302 | ASME Code Confirmatory Fatigue Evaluation of Reactor Feedwater Nozzle |
| Calculation File No. VY-19Q-303 | Feedwater Nozzle Environmental Fatigue Evaluation |

Copies of these calculations and reports are attached hereto as Exhibits A-C.

4. These calculations and reports describe an additional analysis Entergy has performed to assess the impact of environmentally-assisted fatigue (EAF) on the feed water nozzle ("Entergy's Second CUFen Reanalysis"). Entergy represents that this additional analysis confirms the results of Entergy's CUFen Reanalysis that is the subject of NEC's Contention 2A ("Entergy's First CUFen Reanalysis"), which I have addressed in my Declaration in support of NEC's Contention 2A. *See,* Sixth Declaration of Dr. Joram Hopenfeld (September, 2007).

5. Entergy's Second CUFen Reanalysis differs from its First CUFen Reanalysis in that it does not rely upon the Green Function methodology to obtain stress histories during plan transients. Instead, it applies the finite element model (FEM) method to calculate CUFs for plant transients. Entergy claims that this Second CUFen Reanalysis confirms that CUFs for the feedwater, spray and recirculation nozzles that were calculated by the "Green Function" method in its First CUFen Reanalysis are valid, and that CUFens for all NUREG/CR-6260 locations are less than one.

6. There are now four different CUFen values for the feedwater nozzle before the Board in this proceeding, summarized in the following Table 1.

TABLE 1- DIFFERENT CUF RESULTS FOR THE FEEDWATER NOZZLE

| REFERENCE | CUF | Fen | CUFen (Environmental) |
|---|---|---|---|
| License Renewal Application Table 4.3-3 | 0.750 | 3.81 | 2.86 |
| Entergy First CUFen Reanalysis (subject of NEC's Contention 2A) | 0.0636 | 10.05 | 0.6392 |
| Entergy Second CUFen Reanalysis | 0.0889 | 3.97 | 0.3531 |
| Joram Hopenfeld Recalculation, Sixth Declaration of Dr. Joram Hopenfeld (September, 2007) | 0.750 | 17.00 | 12.75 |

7. I do not agree that Entergy's Second CUFen Reanalysis confirms the validity of its First CUFen Reanalysis, or independently demonstrates that CUFens for all NUREG/CR-6260 locations are less than one. In my opinion, the results of Entergy's Second CUFen Reanalysis are baseless.

8. Entergy's Second CUFen Reanalysis addresses only one issue: the uncertainty in CUF values used in Entergy's First CUFen Reanalysis resulting from use of the Green Function. Entergy's Second CUFen Reanalysis does not address the errors in calculation of the environmentally corrected usage factor, CUFen, due to the several other factors I have identified in my Sixth Declaration in support of NEC's Contention 2A.

9. For instance, no matter how accurate Entergy's FEM-based calculations may be, the accuracy of the final CUFen values also depends on the accuracy of inputs such as the heat transfer coefficients, and the accuracy of the equations that describe the environmental correction factor (Fen). Even though Fen values based on more recent data would have resulted in CUFens greater than 1, Entergy still has not provided justification for using low Fen factors. *See,* Sixth Declaration of Joram Hopenfeld (September, 2007).

10. As shown in Table 1, above, the error in the CUFen due to the use of the Green Function is relatively small compared to that resulting from the uncertainties in the Fen values. The CUF as predicted by the Second CUFen Reanalysis methodology is smaller by a factor of 1.81 (0.6391/0.3531) than the CUF which was calculated using the Green Function in Entergy's First CUFen Reanalysis. On the other hand, Fen is increased by a factor of 4.3 (17/3.97) when more recent data is considered in the calculation of the Fen as described in NEC's Contention 2A. This comparison does not imply that errors in the CUF which were introduced by the Green Function are not important; it only demonstrates that the errors which are introduced by an incorrect Fen are more important.

11. Moreover, I do not agree that results of Entergy's Second CUFen Reanalysis, addressing only the feedwater nozzle, are bounding for the other components addressed by Entergy's First CUFen Reanalysis. There are considerable differences in geometry and heat transfer characteristics between the feedwater and the spray and recirculation nozzles. These differences could result in different stress distributions which could result in higher CUFs for the spray and recirculation nozzles even if the number of transients for the two nozzles is smaller than the number for the feedwater nozzle. The reports of Entergy's Second CUFen Reanalysis, Exhibits A-C hereto, do not discuss these differences. Also, in my opinion, the projection of Entergy's results for the feedwater nozzle using the FEM method to other components could only be justified if Entergy could demonstrate an understanding of the reasons for the differences in the CUFs obtained by the simplified "Green Function" analysis and those that were obtained by the FEM method. Entergy's reports of its Second CUFen Reanalysis, Exhibits A-C hereto,

do not address this issue. Therefore, Entergy's Second CUFen Reanalysis results, such as they are, should apply only to the feedwater nozzle.

12. The differing results stated in the above Table 1 demonstrate that the Green's Function introduces non-quantified and poorly understood uncertainties in the calculated CUF values. I attended a meeting between Entergy and the NRC on January 8, 2008, at which Entergy's consultants presented and discussed the results of the First CUFen Reanalysis. My understanding based on the discussion at this meeting is that the NRC asked Entergy to calculate CUFen for the feedwater nozzle without using the Green Function, because Entergy's consultants were not able to justify the generic use of the Green Function for thermal transients. Until similar calculations are performed for the circulation and the spray nozzles, the associated CUFs will include unquantified errors due to the use of the Green function.

13. In conclusion, Entergy's Second CUFen Reanalysis does not address my criticisms of the First CUFen Reanalysis, validate the First CUFen Reanalysis, or independently demonstrate that CUFens for the components listed in License Renewal Application 4.3-3 are less than one. It is my opinion that acceptance of Entergy's results will lead to an unjustified reduction in the scope of fatigue monitoring at the Vermont Yankee plant.

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

Executed this 11 day of March, 2008 at Rockville, Maryland.

Joram Hopenfeld, PhD

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February 15, 2007

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**BY OVERNIGHT MAIL**

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

Re: Additional Environmentally Assisted Fatigue Calculations

Dear Ms. Baty and Ms. Tyler:

Enclosed are three additional environmentally assisted fatigue calculations recently performed by Structural Integrity Associates for Entergy relevant to New England Coalition's Contention 2A in the above captioned proceeding. The enclosed calculations are: VY-19Q-301, "Design Inputs and Methodology for ASME Code Confirmatory Fatigue Analysis of Reactor Feedwater Nozzle;" VY-19Q-302, "ASME Code Confirmatory Fatigue Analysis of Reactor Feedwater Nozzle;" and VY-19Q-303, "Feedwater Nozzle Environmental Fatigue Evaluation." Electronic copies of these calculations are also being forwarded to you today.

Copies of these calculations will be included in Entergy's March 2008 Supplemental Disclosure.

Sincerely,

Matias F. Travieso-Diaz
Counsel for Entergy

Enclosures (as noted)

**Exhibit A**

| Structural Integrity Associates, Inc. | File No.: VY-19Q-301 |
|---|---|
| CALCULATION PACKAGE | Project No.: VY-19Q |

**PROJECT NAME:**

Provide VY Support for Questions Related to Environmental Fatigue Analyses

**CONTRACT NO.:**

10163217

| **CLIENT:** | **PLANT:** |
|---|---|
| Entergy Nuclear Operations, Inc. | Vermont Yankee |

**CALCULATION TITLE:**

Design Inputs and Methodology for ASME Code Confirmatory Fatigue Usage Analysis of Reactor Feedwater Nozzle

| Document Revision | Affected Pages | Revision Description | Project Manager Approval Signature & Date | Preparer(s) & Checker(s) Signatures & Date |
|---|---|---|---|---|
| 0 | 1 – 18<br>Computer Files | Original Issue | TJ Herrmann<br>TJH 01/29/2008 | WF Weitze<br>WFW 01/29/2008<br>A. Chintapalli<br>AC 01/29/2008 |

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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) feedwater (FW) nozzle at Vermont Yankee Nuclear Power Station (VYNPS).

## 2.0 METHODOLOGY

A detailed fatigue usage analysis of the FW nozzle will be performed using the methodology of Subarticle NB-3200 of Section III of the ASME Code [1]. The analysis will be used as a confirmatory analysis for comparison with a previous fatigue usage analysis that was done using simplified methods. Therefore, only the fatigue portion of the ASME Code methodology will be used, and the analysis will be a fatigue assessment only, and not a complete ASME Code analysis.

Finite element analysis will be performed using a previously-developed axisymmetric finite element model (FEM) of the FW nozzle. 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. Additional scaling of pressure stresses will be performed to account for nozzle corner contour effects (i.e., the effects of approximating the nozzle-to-RPV intersection of two cylinders with an axisymmetric model). 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 previously-examined locations for direct comparison of results. Stresses will be linearized at these locations. 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 [15].

## 3.0 ASSUMPTIONS/DESIGN INPUTS

### 3.1 Assumptions

*3.1.1 Power uprate effects are considered as being applied to the entire period of operation. The higher pressures, flows, and temperatures at uprate conditions are used in determining and applying heat transfer coefficients [3, Section 3.2] [2, Section 3.1].*

*3.1.2 The Boltup transient [2, Tables 1 and 2] analysis does not affect the FW nozzle and is therefore excluded from the transients analyzed.*

*3.1.3 Where the flow rates in the thermal cycle diagram are at a value not calculated in Table 2, the next highest flow rate heat transfer coefficient will be used. This results in a higher heat transfer coefficient and is therefore conservative.*

*3.1.4 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 6. The smaller inner diameter (9.669") at the safe end was used to calculate heat transfer coefficients, resulting in a higher flow velocity and therefore conservative values.*

*3.1.5 The annulus leakage flow rate used is 31 GPM for EPU conditions [3, Section 3.2].*

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

*3.1.7 For purposes of linearizing stress at the nozzle corner, the effect of the cladding is conservatively neglected.*

*3.1.8 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 [2, Section 3.4].*

### 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 [2].

### 3.3 Transients

Previously developed thermal and pressure transients [2, Section 3.1 and Tables 1 and 2] are used for this analysis. The transients to be evaluated are shown in Table 1. For each transient, the time, nozzle fluid temperature ($T_{noz}$), RPV pressure, percent FW flow rate, and number of cycles are included. In some cases, flow rates and $T_{noz}$ values from the nozzle thermal cycle diagram [10, Attachment 1, p. 3] are used to reduce excess conservatism. Note that the only difference between the nozzle corner and the safe end transients in the referenced document is the length of the steady state time increment used at the end of the transients. These steady state periods are not included in Table 1; the analyst will use a value greater than or equal to the largest steady time increment from the referenced document.

At the inside surface of the RPV, the Region A temperature from the reactor thermal cycle diagram [10, Attachment 1, p. 2] shall be applied. Table 1 also includes these values as $T_{RPV}$.

## Table 1: Transients

| Transient | Time, sec | $T_{noz}$, °F | $T_{RPV}$, °F | P, psig | FW Flow, % | Cycles |
|---|---|---|---|---|---|---|
| 1. Boltup | 0 | 70 | 70 | 0 | 0% | 123 |
| 2. Design Hydrotest | 0 | 70 | 70 | 0 | 0% | 120 |
| | 1080 | 100 | 100 | 0 | 0% | |
| | 1680 | 100 | 100 | 1100 | 0% | |
| | 5280 | 100 | 100 | 1100 | 0% | |
| | 5880 | 100 | 100 | 50 | 0% | |
| 3. Startup | 0 | 100 | 100 | 50 | 0% | 300 |
| | 16164 | 549 | 549 | 1010 | 0% | |
| 4. Turbine Roll and Increased to Rated Power | 0 | 549 | 549 | 1010 | 0% | 300 |
| | 1 | 100 | 549 | 1010 | 25%* | |
| | 1801 | 100 | 549 | 1010 | 25%* | |
| | 1802 | 260 | 549 | 1010 | 25%* | |
| | 3602 | 392 | 549 | 1010 | 100% | |
| 5. Daily Reduction 75% Power | 0 | 392 | 549 | 1010 | 100% | 10,000 |
| | 900 | 310 | 549 | 1010 | 100%* | |
| | 2700 | 310 | 549 | 1010 | 100%* | |
| | 3600 | 392 | 549 | 1010 | 100% | |
| 6. Weekly Reduction 50% Power | 0 | 392 | 549 | 1010 | 100% | 2,000 |
| | 1800 | 280 | 549 | 1010 | 100%* | |
| | 3600 | 280 | 549 | 1010 | 100%* | |
| | 5400 | 392 | 549 | 1010 | 100% | |
| 9. Turbine Trip at 25% Power | 0 | 392 | 549 | 1010 | 100% | 10 |
| | 1800 | 265 | 549 | 1010 | 100% | |
| | 1980 | 265 | 549 | 1010 | 25%* | |
| | 2340 | 90 | 549 | 1010 | 25%* | |
| | 2520 | 90 | 549 | 1010 | 25%* | |
| | 3420 | 265 | 549 | 1010 | 25%* | |
| | 3600 | 265 | 549 | 1010 | 100% | |
| | 5400 | 392 | 549 | 1010 | 100% | |
| 10. FW Heater Bypass | 0 | 392 | 549 | 1010 | 100% | 70 |
| | 90 | 265 | 549 | 1010 | 100% | |
| | 1890 | 265 | 549 | 1010 | 100% | |
| | 2070 | 392 | 549 | 1010 | 100% | |

| Transient | Time, sec | $T_{noz}$, °F | $T_{RPV}$, °F | P, psig | FW Flow, % | Cycles |
|---|---|---|---|---|---|---|
| 11. Loss of FW Pumps | 0 | 392 | 549 | 1010 | 100% | 10 |
| | 1 | 565 | 565 | 1010 | 0% | |
| | 3.5 | 565 | 565 | 1190 | 0% | |
| | 4.5 | 50 | 565 | 1184.5 | 40% | |
| | 13.5 | 50 | 565 | 1135 | 40% | |
| | 184.5 | 50 | 565 | 1135 | 40% | |
| | 1564.5 | 440 | 565 | 1135 | 0% | |
| | 1565.5 | 565 | 565 | 1135 | 0% | |
| | 2165.5 | 565 | 565 | 1135 | 0% | |
| | 2166.5 | 50 | 565 | 1135 | 40%* | |
| | 2346.5 | 50 | 532 | 885 | 40%* | |
| | 5406.5 | 440 | 549 | 1055 | 0% | |
| | 5407.5 | 549 | 549 | 1055 | 0% | |
| | 6727.5 | 565 | 565 | 1135 | 0% | |
| | 6728.5 | 50 | 565 | 1135 | 25%* | |
| | 7148.5 | 50 | 502 | 675 | 25%* | |
| | 7448.5 | 300 | 502 | 675 | 0% | |
| | 11048.5 | 400 | 400 | 232 | 0% | |
| | 16411.5 | 549 | 549 | 885 | 0% | |
| | 16412.5 | 549 | 549 | 1010 | 0% | |
| | 18212.5 | 549 | 549 | 1010 | 0% | |
| | 18213.5 | 100 | 549 | 1010 | 25%* | |
| | 20013.5 | 100 | 549 | 1010 | 25%* | |
| | 20014.5 | 260 | 549 | 1010 | 25%* | |
| | 21814.5 | 392 | 549 | 1010 | 100% | |
| 12/13/15. Turbine Generator Trip, Reactor Overpressure, Other SCRAMs | 0 | 392 | 549 | 1010 | 100% | 289 |
| | 10 | 392 | 565/600** | 1135/1375** | 100% | |
| | 15 | 392 | 565/600** | 1135/1375** | 100% | |
| | 30 | 392 | 539 | 940 | 100% | |
| | 90 | 275 | 539 | 940 | 25%* | |
| | 990 | 100 | 539 | 940 | 25%* | |
| | 2790 | 100 | 539 | 940 | 25%* | |
| | 2791 | 260 | 539 | 940 | 100% | |
| | 3210 | 291 | 549 | 1010 | 100% | |
| | 4591 | 392 | 549 | 1010 | 100% | |
| 14. SRV Blowdown | 0 | 392 | 549 | 1010 | 100% | 1 |
| | 60 | 275 | 531.6 | 885 | 100% | |
| | 960 | 100 | 365 | 50 | 25%* | |
| 19. Reduction to 0% Power | 0 | 392 | 549 | 1010 | 100% | 300 |
| | 1800 | 265 | 549 | 1010 | 25%* | |
| 20. Hot Standby (Heatup Portion) | 0 | 265 | 549 | 1010 | 25%* | 300 |
| | 1 | 440 | 549 | 1010 | 0% | |
| | 3925 | 549 | 549 | 1010 | 0% | |
| 20A. Hot Standby (FW Injection Portion) | 0 | 549 | 549 | 1010 | 0% | 300 |
| | 1 | 100 | 549 | 1010 | 25% | |
| | 181 | 100 | 549 | 1010 | 25% | |
| | 241 | 290 | 549 | 1010 | 0% | |
| | 451 | 549 | 549 | 1010 | 25% | |
| 21-23. Shutdown | 0 | 549 | 549 | 1010 | 25%* | 300 |
| | 6264 | 375 | 375 | 50 | 25%* | |
| | 6864 | 330 | 330 | 50 | 25%* | |
| | 15144 | 100 | 100 | 50 | 0% | |

| Transient | Time, sec | $T_{noz}$, °F | $T_{RPV}$, °F | P, psig | FW Flow, % | Cycles |
|---|---|---|---|---|---|---|
| 24. Hydrostatic Test | 0 | 100 | 100 | 50 | 0% | 1 |
| | 600 | 100 | 100 | 1563 | 0% | |
| | 1200 | 100 | 100 | 1563 | 0% | |
| | 1800 | 100 | 100 | 50 | 0% | |
| 25. Unbolt | 0 | 100 | 100 | 0 | 0% | 123 |
| | 1080 | 70 | 70 | 0 | 0% | |

* Flow rate is conservatively rounded up to one of the three flow rates considered (25%, 40%, 100%).
** The second value applies for one cycle; the first value applies for the rest of the cycles.

### 3.4 Heat Transfer Coefficients, Condensation

When steam floods a relatively cold component, the steam condenses on the component surface. Holman [5, p. 413] gives the following equation for average heat transfer coefficient:

$$\bar{h} = 0.555\ \{\rho(\rho - \rho_v)gk^3h'_{fg}/[\mu D(T_g - T_w)]\}^{1/4}\ \text{, where}$$

$\rho$ = mass density of liquid,
$\rho_v$ = mass density of vapor,
g = acceleration of gravity,
k = conductivity of liquid at average temperature,
$h'_{fg} = h_{fg} + 0.68c(T_g - T_w)$,
$h_{fg}$ = heat of condensation at vapor temperature,
c = specific heat of liquid at average temperature,
$T_g$ = saturated vapor temperature = $T_{final}$,
$T_w$ = pipe inner wall temperature = $T_{initial}$,
$\mu$ = viscosity of liquid at average temperature
D = inner diameter of pipe

The portion of the equation inside the brackets, $\rho(\rho - \rho_v)gk^3h'_{fg}/[\mu D(T_g - T_w)]$, has the following units:

$$\frac{\cancel{(lbm)^2}\ \cancel{(ft)}\ (Btu)^3\ (Btu)\ (ft\text{-}hr)}{(ft^3)^2\ (sec^2)\ (hr\text{-}ft\text{-}°F)^3\ \cancel{(lbm)}\ \cancel{(lbm)}\ \cancel{(ft)}\ (°F)}$$

$$\frac{(Btu^4)\ (ft\text{-}\cancel{hr})\ (3600^2\ \cancel{sec^2})}{(ft^6)\ \cancel{(sec^2)}\ (hr^3\text{-}ft^3\text{-}°F^3)\ (°F)\ (hr^{\cancel{2}})}$$

$$\frac{12960000\ Btu^4}{hr^4\text{-}ft^8\text{-}°F^4}$$

After taking the fourth root, this becomes 60 Btu/hr-ft²-°F. Steam properties are interpolated at $T_g$, and water properties are interpolated at $T_f$, which is taken as the average of $T_g$ and $T_w$. Then, $h'_{fg}$ and heat transfer coefficient $\bar{h}$ are calculated for each set of steam properties, water properties, $T_g$ and $T_w$. Tables 2 and 3 list selected properties of liquid water [12, Table 1-8] and saturated steam [13], respectively.

**Table 2: Properties of Liquid Water**

| T, °F | ρ, lbm/ft$^3$ | c, Btu/lbm-°F | μ, lbm/ft-hr | ν, ft$^2$/sec | k, Btu/hr-ft-°F |
|---|---|---|---|---|---|
| 300 | 57.3 | 1.03 | 0.468 | 2.27E-06 | 0.395 |
| 400 | 53.6 | 1.08 | 0.335 | 1.74E-06 | 0.382 |
| 500 | 49.0 | 1.19 | 0.252 | 1.43E-06 | 0.349 |
| 600 | 42.4 | 1.51 | 0.208 | 1.37E-06 | 0.293 |

**Table 3: Properties of Saturated Steam**

| $T_g$, °F | $v_g$, ft$^3$/lbm | $h_{fg}$, Btu/lbm |
|---|---|---|
| 545 | 0.4449 | 649.6 |
| 550 | 0.4249 | 641.6 |
| 565 | 0.3703 | 616.4 |

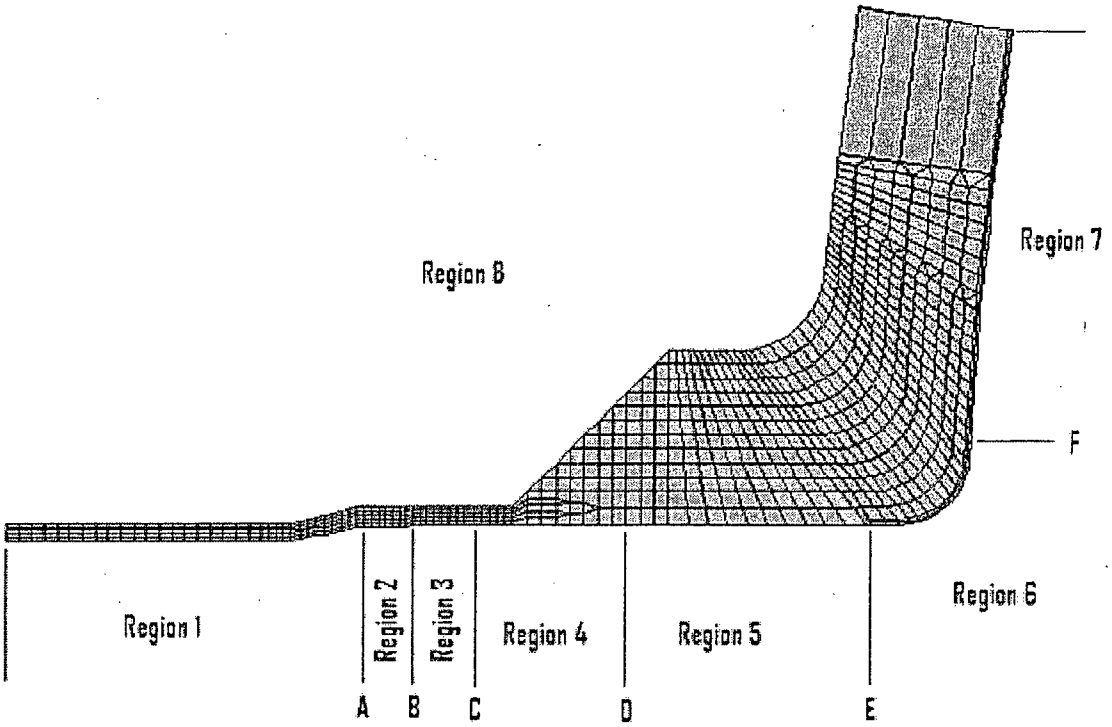
### 3.5 Heat Transfer Coefficients, Forced Flow and Natural Circulation

Table 4 summarizes the force flow and natural circulation heat transfer coefficients to be used in the analysis [3, Section 3.2.1]. For each flow rate, values are taken at 300°F as in the previous analysis. These values are within 11% of the maximum values for a given flow rate, and are more than 30% greater than the minimum values for a given flow rate [3, Table 4] [4, Tables 4 and 5]. Therefore, the use of heat transfer coefficients at 300°F is bounding for the most severe transients, which occur at a wide range of temperatures. Figure 1 illustrates the heat transfer coefficient regions [4, Figure 6].

**Table 4: Forced Flow and Natural Circulation Heat Transfer Coefficients, Btu/hr-ft$^2$-°F**

| Region | 100% flow | 40% flow | 25% flow | 0% flow, water |
|---|---|---|---|---|
| 1 | 3705 | 1780 | 1222 | 144 |
| 2 | * | * | * | * |
| 3 | 1489 | 743 | 504 | 109 |
| 4 | * | * | * | * |
| 5 | 177 | 89 | 60 | 12 |
| 6 | * | * | * | * |
| 7 | 864 | 864 | 864 | 864 |
| 8 | 0.2 | 0.2 | 0.2 | 0.2 |

* Linearly transition between the values for the adjacent regions.




Notes: Point A: End of thermal sleeve = Node 204 = 0.25" from feedwater inlet side of thermal sleeve flat.
Point B: Beginning of annulus = Node 252.
Point C: Beginning of thermal sleeve transition = approximately 4.0" from Point A = Node 294.
Point D: End of thermal sleeve transition = approximately 9.5" from Point A = Node 387.
Point E: End of inner nozzle corner (nozzle side) = Node 553.
Point F: End of inner nozzle corner (vessel wall side) = Node 779.

**Figure 1: Nozzle and Vessel Wall Thermal and Heat Transfer Boundaries**

### 3.6 Finite Element Model

The ANSYS program [6] will be used to perform the finite element analysis. A previously-developed axisymmetric model will be used [4, file FW.INP], except that temperature-dependent material properties will be used. Table 5 shows the applicable material properties [14].

**Table 5: 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 5) |
|---|---|---|---|---|---|---|---|
| 1 | SA533 Grade B, | 70 | 27.8 | 6.4 | 23.5 | 0.458 | 0.105 |
| | A508 Class II | 200 | 27.1 | 6.7 | 23.6 | 0.425 | 0.114 |
| | (see Note 2) | 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 |
| | | 600 | 25.2 | 7.4 | 22.2 | 0.336 | 0.135 |
| 2 | SS Clad | 70 | 28.3 | 8.5 | 8.6 | 0.151 | 0.116 |
| | (see Note 3) | 200 | 27.6 | 8.9 | 9.3 | 0.156 | 0.122 |
| | | 300 | 27.0 | 9.2 | 9.8 | 0.160 | 0.125 |
| | | 400 | 26.5 | 9.5 | 10.4 | 0.165 | 0.129 |
| | | 500 | 25.8 | 9.7 | 10.9 | 0.170 | 0.131 |
| | | 600 | 25.3 | 9.8 | 11.3 | 0.174 | 0.133 |
| 3 | A508 Class I | 70 | 29.3 | 6.4 | 35.1 | 0.695 | 0.103 |
| | (see Note 4) | 200 | 28.6 | 6.7 | 33.6 | 0.613 | 0.112 |
| | | 300 | 28.1 | 6.9 | 32.3 | 0.561 | 0.118 |
| | | 400 | 27.5 | 7.1 | 30.9 | 0.512 | 0.123 |
| | | 500 | 27.1 | 7.3 | 29.5 | 0.472 | 0.128 |
| | | 600 | 26.5 | 7.4 | 28.0 | 0.433 | 0.132 |
| 4 | A106 Grade B | 70 | 29.3 | 6.4 | 35.1 | 0.695 | 0.103 |
| | (see Note 4) | 200 | 28.6 | 6.7 | 33.6 | 0.613 | 0.112 |
| | | 300 | 28.1 | 6.9 | 32.3 | 0.561 | 0.118 |
| | | 400 | 27.5 | 7.1 | 30.9 | 0.512 | 0.123 |
| | | 500 | 27.1 | 7.3 | 29.5 | 0.472 | 0.128 |
| | | 600 | 26.5 | 7.4 | 28.0 | 0.433 | 0.132 |

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. Composition = C-Si; k and d for plain carbon steel are used [11].
5. Calculated as $[k/(\rho d)]/12^3$.

Stresses will be extracted and linearized at two locations, both on the inside surface. The critical safe end location is Node 192, which has the highest stress intensity due to thermal loading under high flow conditions [3, Section 4.0 and Figures 6 and 7]. The corresponding linearization path is from Node 192 to Node 187 (Figure 2 [3, Figure 7]).

The critical nozzle corner location is Node 657 at the base metal of the nozzle, chosen based upon the highest pressure stress [3, Section 4.0 and Figures 8 and 9]. The corresponding linearization path is from Node 657 to Node 645 (Figure 3 [3, Figure 9]).

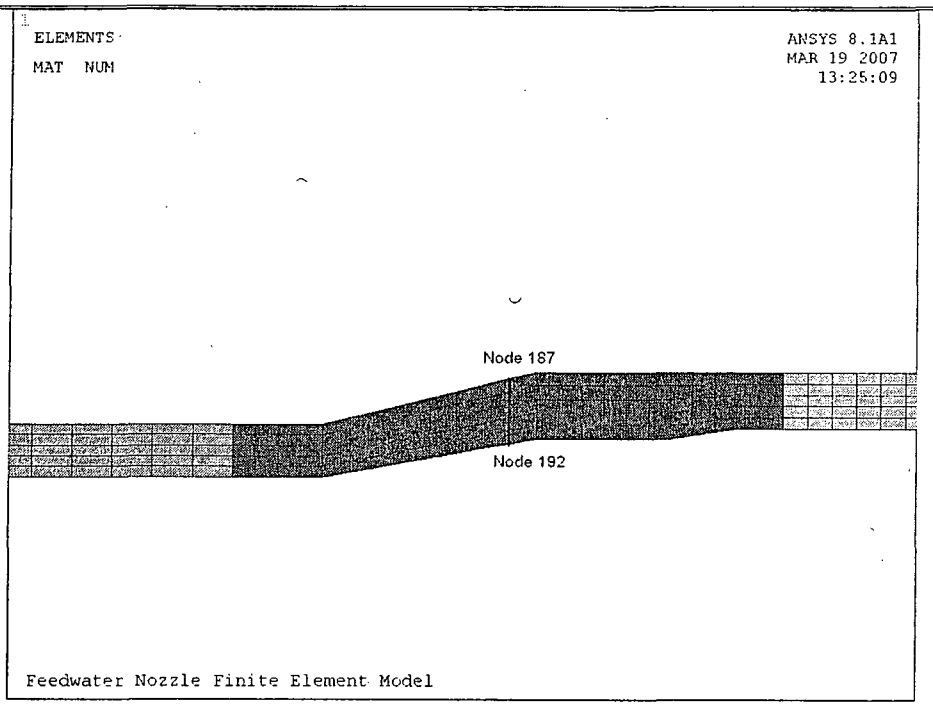



**Figure 2: Safe End Linearization Path**

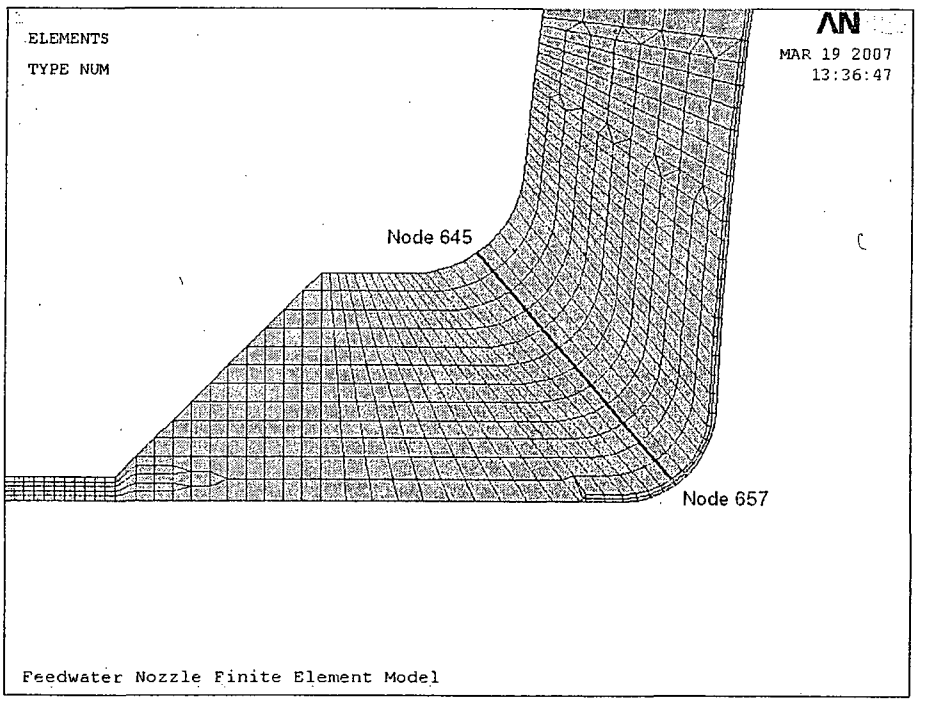



**Figure 3: Nozzle Corner Linearization Path**

### 3.7 Nozzle Corner Effects

The axisymmetric model has the effect of modeling the cylindrical RPV as spherical. To partially counter the resulting reduction in stress in the RPV wall, the radius in the model was increased by a factor of 1.5 [3, p. 8]. This yields a general membrane stress that equals the average of the hoop and axial stress for the cylinder.

Stresses from the axisymmetric analysis will need to be increased to account for the three-dimensional (3-D) geometry. A factor of 1.333 has been established in a previous calculation package that modeled the nozzle [3, p. 9], to achieve an overall pressure multiplication of 2.0. This is consistent with the maximum value used in prior VYNPS analyses [7, Appendix A, p. 4-10].

No other SCF is required at the nozzle corner inside surface, since this location has no stress riser.

### 3.8 Piping Interface Loads

The previous analysis of the FW nozzle calculated membrane axial and shear stresses due to the piping interface loads by closed form solution, then combined them into stress intensities for the two locations of interest [2, Section 3.4]. All shear stresses were treated as existing in the same plane.

In this analysis, the stress components are recalculated in Section 4.3 taking into account through-wall distribution. Forces and moments are taken from the same reference as before [8, Table 3].

### 3.9 SCFs, Safe End

In the previous analysis, an SCF of 1.34 was used for the safe end location for all load conditions [2]. That value was obtained from the original design basis evaluation for the FW nozzle. For the current analysis, the SCF is updated to reflect modern-day ASME Code fatigue usage analysis methodology for consistency with the rest of the evaluation.

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]. These rules specify stress indices $C_1$, $C_2$, and $C_3$, which are applied to nominal stress to yield primary plus secondary membrane plus bending stress (P+Q); and $K_1$, $K_2$, and $K_3$, which are applied to nominal stress along with the C factors to yield total stress (P+Q+F). The subscripts indicate the type of loading: 1 for pressure, 2 for moments, and 3 for thermal transients. Stress indices for a reducer are used.

Section 4.3 contains calculations of the safe end SCFs. For stresses due to piping loads, the moment stress indices $C_2$ and $K_2$ are applied to the nominal stress components at the safe end. For pressure stresses, the ANSYS model is sufficient to account for the effects of gross structural discontinuity such that $C_1$ is not needed. To account for the effects of local structural discontinuity, $K_1$ is applied to the linearized P+Q stress to yield P+Q+F. These factors are conservatively applied to all six components of the stress tensor.

For thermal stresses, $C_3$ and $K_3$ are given as 1.0 [1, Table NB-3681(a)-1]; therefore, no SCF is required.

### 3.10 Environmental Fatigue Multipliers

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

## 4.0 CALCULATIONS

### 4.1 Heat Transfer Coefficients, Condensation

Condensation heat transfer coefficients are calculated with the formula shown in Section 3.4 for times during which the nozzle is filled with steam at Region A temperature [10, Attachment 1, p. 3]. This is done in the sheet labeled "Condensation" in Excel workbook *VY-19Q-301.xls* in the project computer files. The highest heat transfer coefficient values for the transient temperature range are used. These are provided in Table 6.

**Table 6: Condensation Heat Transfer Coefficients, Btu/hr-ft$^2$-°F**

| Region | 0% flow, steam |
|---|---|
| 1 | 598 |
| 2 | * |
| 3 | 1515 |
| 4 | * |
| 5 | 874 |
| 6 | * |
| 7 | ** |
| 8 | ** |

* Linearly transition between the values for the adjacent regions.
** Use values from Table 4, since these are bounding and there is no change in temperature.

### 4.2 Piping Interface Loads

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

$\sigma_{z1}$ = axial stress due to axial force = $F_z/A$
$\sigma_{z2}$ = 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 = $M_z(ID/2)/J$
$\tau_{rz}$ = 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 = $(\pi/32)(OD^4 - ID^4)$

Figure 4 shows the coordinate system for the forces and moments [8, Figure 1]. 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). Table 7 shows the calculation of stresses; ID, OD, and L are taken from the previous piping load stress calculations [2, Section 3.4]. Forces and moments are taken from the same reference as before, except that signs are chosen to maximize stress [8, Table 3].

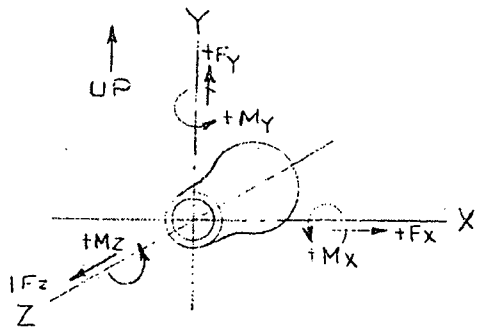



**Figure 4: Coordinate System for Forces and Moments**

**Table 7: Membrane Plus Bending Stresses Due to Piping Loads**

| | Safe End | Nozzle Corner |
|---|---|---|
| $F_x$, kip | 3.00 | 3.00 |
| $F_y$, kip | -15.00 | -15.00 |
| $F_z$, kip | 3.20 | 3.20 |
| $M_x$, kip-in | 336.00 | 336.00 |
| $M_y$, kip-in | 156.00 | 156.00 |
| $M_z$, kip-in | 480.00 | 480.00 |
| L, in | 12.09 | 27.57 |
| $M_{xL}$, kip-in | 517.31 | 749.58 |
| $M_{yL}$, kip-in | 192.26 | 238.72 |
| $M_{xy}$, kip-in | 551.88 | 786.67 |
| $F_{xy}$, kip-in | 15.30 | 15.30 |
| OD, in | 11.86 | 22.67 |
| ID, in | 10.409 | 10.750 |
| A, $in^2$ | 25.28 | 312.73 |
| I, $in^4$ | 393.28 | 12300.41 |
| J, $in^4$ | 786.55 | 24600.82 |
| $\sigma_{z1}$, ksi | 0.127 | 0.010 |
| $\sigma_{z2}$, ksi | 7.304 | 0.344 |
| $\sigma_z$, ksi | 7.430 | 0.354 |
| $\tau_{r\theta}$, ksi | 3.176 | 0.105 |
| $\tau_{rz}$, ksi | 1.210 | 0.098 |

### 4.3 SCFs, Safe End

Figure 5 shows the geometry parameters used in calculating stress indices for reducers [1, Figure NB-3683.6-1], and Figure 6 shows the feedwater nozzle safe end geometry [9]. Comparing the two figures gives the following values:

$L_1 = 0"$, $r_1 = 0.75"$, $D_1 = 12.000"$, $t_1 = (12 - 10.515)/2 = 0.7425"$
$L_2 = 0"$, $r_2 = 0.75"$, $D_2 = 10.840"$, $t_2 = (10.840 - 9.669)/2 = 0.5855"$
$\alpha = 10°$
($L_1$ and $L_2$ are taken as zero because the location of interest is on the radius of curvature.)

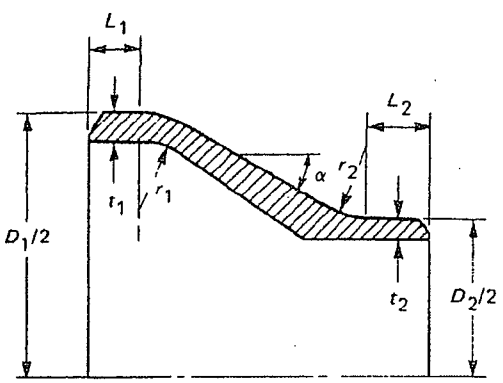



**Figure 5: Reducer Geometry Parameters**

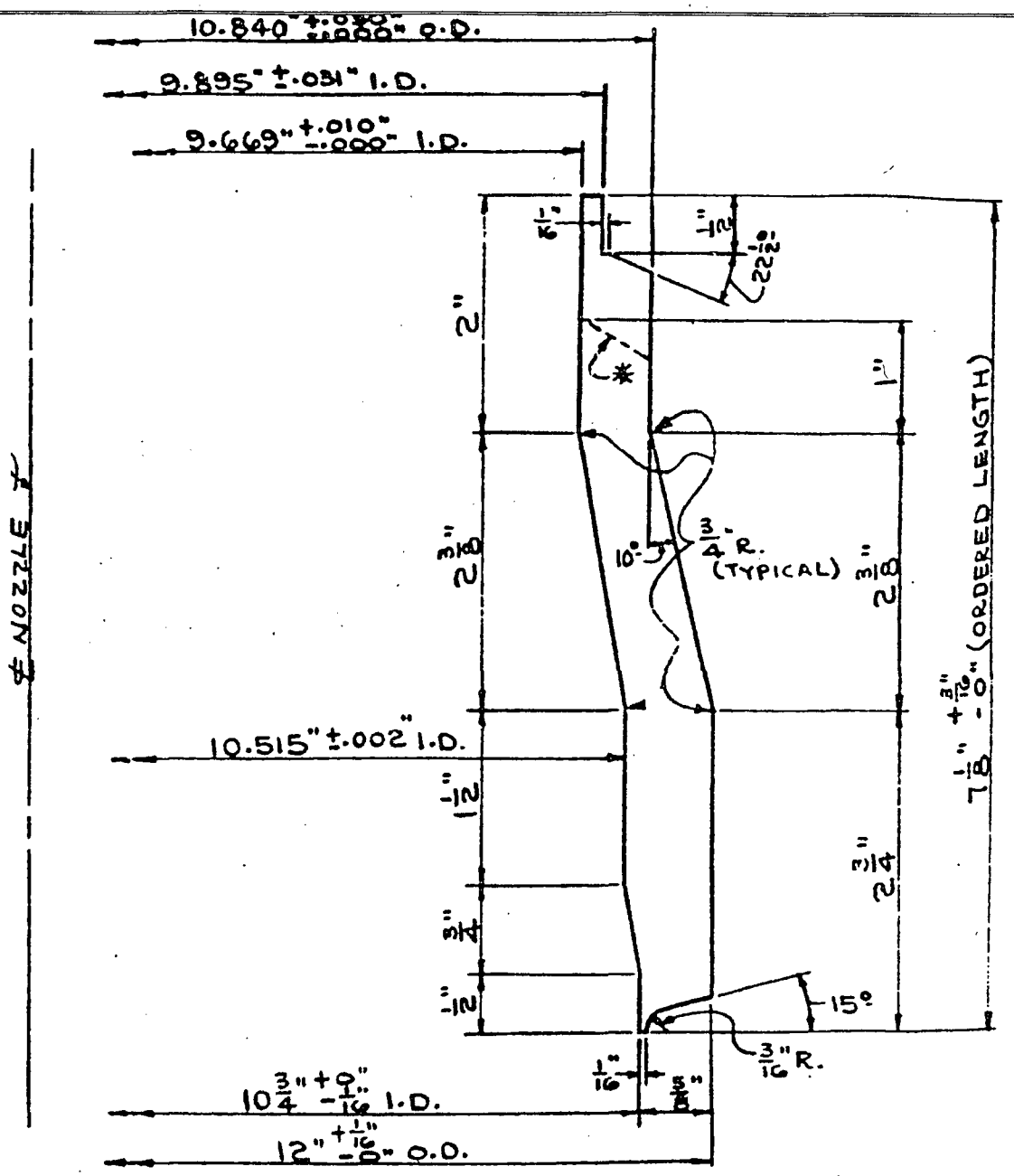



Figure 6: FW Nozzle Safe End Geometry

Equations for stress indices are taken from the ASME Code [1, NB-3683.6]. For $K_1$ and $K_2$, since the location of interest is not on a weld, the equation for flush welds is used:

$$K_1 = K_2 = 1.1 - 0.1\ L_m/(D_m\ t_m)^{0.5}, \text{ where}$$

$$L_m/(D_m\ t_m)^{0.5} = \text{the lesser of } L_1/(D_1\ t_1)^{0.5} \text{ and } L_2/(D_2\ t_2)^{0.5}$$

Since $L_1 = L_2 = 0$, one finds:

$$K_1 = K_2 = 1.1 - 0.1\ (0) = 1.1$$

Since $r_1$ and $r_2$ are less than $0.1D_1$, $C_2$ is given as:

$$C_2 = 1.0 + 0.0185\ \alpha\ (D_n/t_n)^{0.5}, \text{ where}$$

$$D_n/t_n = \text{the larger of } D_1/t_1 \text{ and } D_2/t_2$$

The bounding D/t value is $D_2/t_2 = 10.840/0.5855 = 18.514$, so that:

$$C_2 = 1.0 + 0.0185\ (10)\ (18.514)^{0.5} = 1.796$$
$$C_2\ K_2 = 1.796\ (1.1) = 1.976$$

## 5.0 RESULTS OF ANALYSIS

This calculation package specifies the ASME Code edition, finite element model, thermal and pressure transients (Table 1), and heat transfer coefficients (Tables 4 and 6) to be used in a fatigue usage analysis of the FW nozzle at VYNPS. Thermal transient and pressure stress components will be calculated using ANSYS, and piping load stress components are calculated herein using closed form solutions (Table 7).

Linearized stress components at Nodes 192 (safe end inside surface) and 657 (nozzle corner inside surface) will be used for the fatigue usage analysis. At the nozzle corner, P+Q and P+Q+F pressure stress components will be increased by a factor of 1.333. For the nozzle corner location, the stresses used in the evaluation shall be for the base metal only; that is, the cladding material should be unselected prior to stress extraction. At the safe end, linearized P+Q pressure stress components will be multiplied by 1.1 to yield P+Q+F pressure stress components, and nominal stress components due to piping loads are multiplied by 1.796 to yield P+Q stress components and 1.976 to yield P+Q+F stress components.

The fatigue usage analysis will consider all six stress components, and will be performed using the NB-3200 rules of Section III of the ASME Code [1]. Calculated fatigue usage factors will be multiplied by the overall $F_{en}$ of 1.74 for the safe end [2, Section 5.0] and values to be developed in a subsequent calculation package, to be assigned file number VY-19Q-303, for the nozzle corner.

## 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. SI Calculation Package, *Fatigue Analysis of Feedwater Nozzle*, Revision 0, SI File No. VY-16Q-302.

3. SI Calculation Package, *Feedwater Nozzle Stress History Development for Greens Functions*, Revision 0, SI File No. VY-16Q-301.

4. SI Calculation Package, *Feedwater Nozzle Finite Element Model and Heat Transfer Coefficients*, Revision 0, SI File No. VY-10Q-301.

5. Holman, J.P., *Heat Transfer*, Fifth Edition, McGraw-Hill, 1981.

6. ANSYS, Release 8.1 (w/Service Pack 1), ANSYS, Inc., June 2004. (Listed for reference only; this program is not used in this calculation package.)

7. Entergy Document VYC-378, Revision 0, *Vermont Yankee Reactor Cyclic Limits for Transient Events*, SI File No. VY-05Q-211.

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

9. Ebasco Drawing 5920-234R1, 08/03/67, *Safe End Detail for Nozzles MK. N4A THRU N4D*, (CB&I Contract 9-6201, Drawing #M14, Revision 0, 05/02/67), SI File No. VY-05Q-215.

10. Entergy Document EC No. 1773, Revision 0 (Design Input Revision 1), *Environmental Fatigue Analysis for Vermont Yankee Nuclear Power Station*, SI File No. VY-16Q-209.

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

**Exhibit B**

| Structural Integrity Associates, Inc. | File No.: VY-19Q-302 |
|---|---|
| **CALCULATION PACKAGE** | Project No.: VY-19Q |

**PROJECT NAME:**

Provide VY Support for Questions Related to Environmental Fatigue Analyses

**CONTRACT NO.:**

10163217

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

**CALCULATION TITLE:**

ASME Code Confirmatory Fatigue Evaluation of Reactor Feedwater Nozzle

| Document Revision | Affected Pages | Revision Description | Project Manager Approval Signature & Date | Preparer(s) & Checker(s) Signatures & Date |
|---|---|---|---|---|
| 0 | 1 – 12<br>Computer Files | Original Issue | TJ Herrmann<br>TJH 01/30/2008 | WF Weitze<br>WFW 01/30/2008<br>CS Lohse<br>CSL 01/30/2008 |

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## 1.0 OBJECTIVE

The objective of this calculation package is to perform an ASME Code, Section III fatigue usage calculation for the reactor pressure vessel (RPV) feedwater (FW) nozzle at Vermont Yankee Nuclear Power Station (VYNPS).

## 2.0 METHODOLOGY

The methodology to be used for this evaluation was established in a previous calculation package [1], and is summarized herein. A previously-developed finite element model (FEM) is analyzed using the ANSYS program [2]. Thermal transient analysis is performed for each defined transient, and the thermal stresses are added to stresses due to pressure and piping loads, which are scaled based on the magnitudes of the pressure and piping loads. Stress concentration factors (SCFs) are applied as appropriate. All six components of the stress tensor are used for stress calculations.

The fatigue calculation is performed at previously-examined locations, and uses the methodology of Subarticle NB-3200 of Section III of the ASME Code [3]. Environmental fatigue usage analysis will be performed in a separate calculation package.

## 3.0 DESIGN INPUTS

### 3.1 Finite Element Analysis

A previous calculation package specifies all design input [1]. The FEM input file is taken from the previous analysis of the FW nozzle [4, file *FW.INP*], and modified to include temperature-dependent properties [1, Table 5]. The modified file is named *FW-GEOM.INP*, and is used as input to the files in which the thermal transient and stress analyses are performed. Figure 1 shows the FEM [4, Figure 4].

For the thermal transient ANSYS analysis, previously defined thermal transients [1, Table 1] are analyzed, applying heat transfer coefficients [1, Tables 4 and 6] as appropriate based on flow rate. Bounding reactor temperature is used for Transients 12/13/15 [1, Table 1], called Transient 13 herein. (In VESLFAT, Transient 13 is run separately since it has a higher reactor pressure.) For ramps during which the flow rate undergoes a ramp change [5, Attachment 1, p. 3], the set of heat transfer coefficients with the largest values is used. This is done because ANSYS always applies changes to the heat transfer coefficients as step changes, even if the temperature undergoes a ramp change.

Note that, for three time periods during Transient 11 [1, Table 1], the nozzle is filled with steam at Region A temperature [5, Attachment 1, p. 3, Note 1], such that heat transfer coefficients for condensation apply [1, Table 6]. Since it takes a finite amount of time for the water to drain and condensation to begin, the condensation heat transfer coefficients are not applied until the load step after the Region A temperature is reached.

Stress analysis is performed using the temperature distributions calculated in the thermal transient ANSYS analysis as input. At the vessel wall, Y displacement is set to zero, and X displacement is

unconstrained, as was previously done [6, Figure 4]. At the FW pipe, Y displacement is coupled to account for the adjacent piping, as was previously done [6, files *FWS_VY_25.INP*, *FWS_VY_40.INP*, and *FWS_VY_100.INP*]. Figure 1 shows the locations of these boundary conditions.

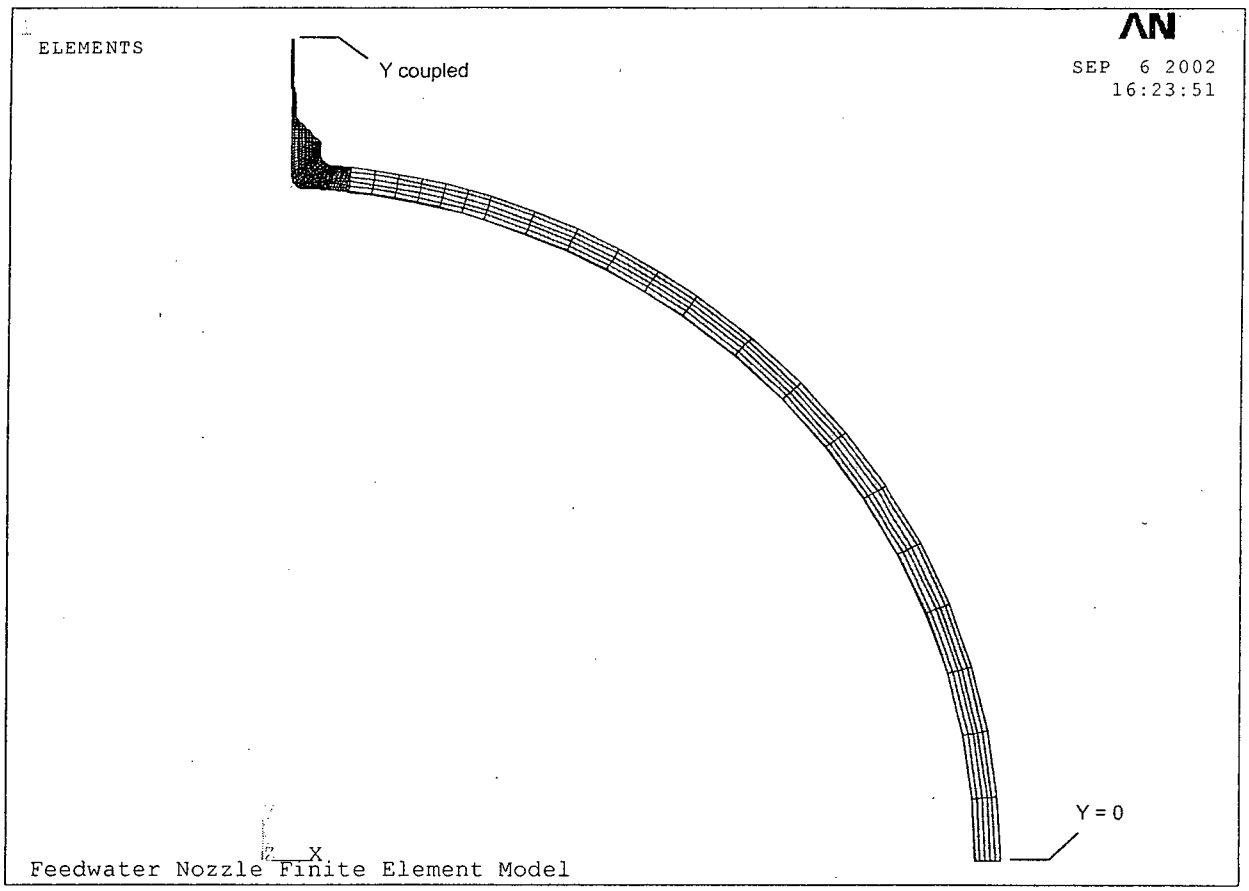


**Figure 1: ANSYS Finite Element Model**

All ANSYS input files, listed below, are saved in the project computer files:

*FW-GEOM.INP*: Geometry and material properties
*FW-HTBC.INP*: Set heat transfer boundary conditions
*TRAN02-T.INP, TRAN02-S.INP*: Transient 2, thermal and stress analysis
*TRAN03-T.INP, TRAN03-S.INP*: Transient 3, thermal and stress analysis
*TRAN04-T.INP, TRAN04-S.INP*: Transient 4, thermal and stress analysis
*TRAN05-T.INP, TRAN05-S.INP*: Transient 5, thermal and stress analysis
*TRAN06-T.INP, TRAN06-S.INP*: Transient 6, thermal and stress analysis
*TRAN09-T.INP, TRAN09-S.INP*: Transient 9, thermal and stress analysis
*TRAN10-T.INP, TRAN10-S.INP*: Transient 10, thermal and stress analysis
*TRAN11-T.INP, TRAN11-S.INP*: Transient 11, thermal and stress analysis
*TRAN13-T.INP, TRAN13-S.INP*: Transient 12/13/15, thermal and stress analysis

*TRAN14-T.INP, TRAN14-S.INP*: Transient 14, thermal and stress analysis
*TRAN19-T.INP, TRAN19-S.INP*: Transient 19, thermal and stress analysis
*TRAN20-T.INP, TRAN20-S.INP*: Transient 20, thermal and stress analysis
*TRAN20AT.INP, TRAN20AS.INP*: Transient 20A, thermal and stress analysis
*TRAN21-T.INP, TRAN21-S.INP*: Transient 21, thermal and stress analysis
*TRAN25-T.INP, TRAN25-S.INP*: Transient 25, thermal and stress analysis

### 3.2 Stress Calculation

Linearized stress components at Nodes 192 (safe end inside surface) and 657 (nozzle corner inside surface) are used for the fatigue usage analysis [1, Section 3.6], as shown in Figure 2 [6, Figures 7 and 9]. For the nozzle corner 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. A unit pressure stress analysis was performed using ANSYS in a previous calculation package [6], and stress component results are taken from that analysis [6, files *PSE.OUT* and *PBLEND.OUT*]. Piping load stress components are taken from previous calculations using closed form solutions [1, Table 7].

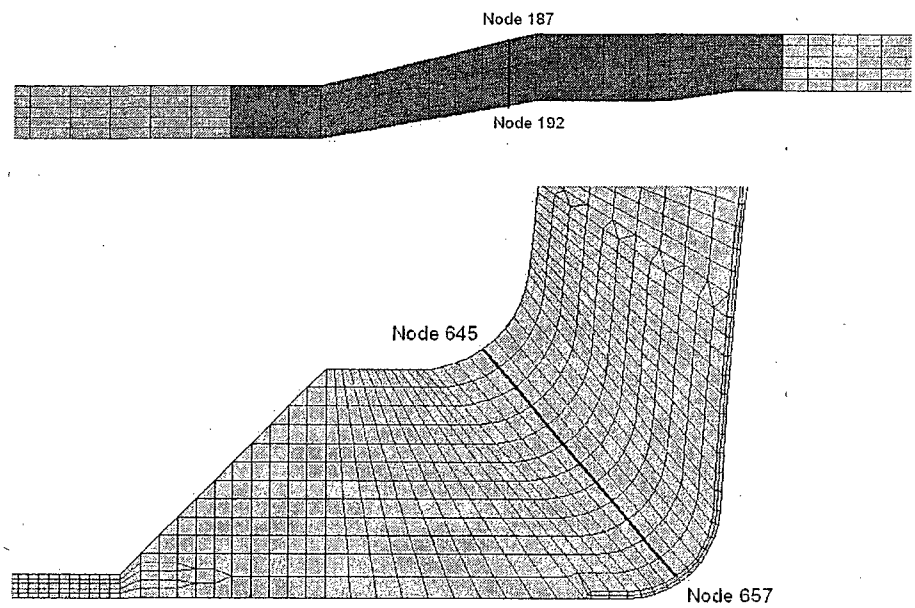


**Figure 2: Linearization Paths**

SCFs are applied to the pressure and piping load stress components to yield primary plus secondary membrane plus bending stress components (P+Q) and the total (primary plus secondary plus peak) stress components (P+Q+F) as specified in the methodology calculation package [1].

### 3.3 Fatigue Usage Analysis, General

The VESLFAT program [7] is used to perform the fatigue usage analysis in accordance with the fatigue usage portion of 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 appropriate.

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 stress based upon six components of stress (3 direct and 3 shear stresses). If the primary plus secondary stress intensity range is greater than $3S_m$, then the total stress range is increased by the factor $K_e$, as described in NB-3228.5 [3]. The value of $S_m$ is specified as a function of temperature. The input maximum temperature for both states of a load set pair is used to determine the temperature upon which $S_m$ is determined from the user-defined values.

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

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

The stress intensities for the event pairs are reordered in decreasing order of $S_{alt}$, including a correction for the ratio of modulus of elasticity (E) from the fatigue curve divided by E from the analysis. This allows a fatigue table to be created to eliminate the number of cycles available for each of the events of an event pair, allowing determination of 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 $S_{alt}$.

For the VYNPS FW nozzle analysis, transients that consist of both upward and downward temperature and pressure ramps are split so that each successive ramp is treated separately. Table 1 shows the transients as input to VESLFAT [1, Table 1]. The numbers of cycles in Table 1 are entered in VESLFAT input files *VFAT-1I.CYC* (safe end) and *VFAT-2I.CYC* (nozzle corner).

**Table 1: Transients as Input to VESLFAT**

| VESLFAT Load Set | Transient | Start Time, sec** | Temp. Change | Pressure Change | Cycles |
|---|---|---|---|---|---|
| 1 | 1_Boltup | 0 | None | None | * |
| 2 | 2_DesHydro1 | 0 | Upward | Upward | 120 |
| 3 | 2_DesHydro2 | 5280 | None | Downward | 120 |
| 4 | 3_Startup | 0 | Upward | Upward | 300 |
| 5 | 4_TurbRoll1 | 0 | Downward | None | 300 |
| 6 | 4_TurbRoll2 | 1801 | Upward | None | 300 |
| 7 | 5_DailyRed1 | 0 | Downward | None | 10,000 |
| 8 | 5_DailyRed2 | 2700 | Upward | None | 10,000 |
| 9 | 6_WklyRed1 | 0 | Downward | None | 2,000 |
| 10 | 6_WklyRed2 | 3600 | Upward | None | 2,000 |
| 11 | 9_TurbTrip1 | 0 | Downward | None | 10 |
| 12 | 9_TurbTrip2 | 2520 | Upward | None | 10 |
| 13 | 10_FWHByp1 | 0 | Downward | None | 70 |
| 14 | 10_FWHByp2 | 1890 | Upward | None | 70 |
| 15 | 11_LoFP1 | 0 | Upward | Upward | 10 |
| 16 | 11_LoFP2 | 3.5 | Downward | Downward | 10 |
| 17 | 11_LoFP3 | 184.5 | Upward | None | 10 |
| 18 | 11_LoFP4 | 2165.5 | Downward | Downward | 10 |
| 19 | 11_LoFP5 | 2346.5 | Upward | Upward | 10 |
| 20 | 11_LoFP6 | 6727.5 | Downward | Downward | 10 |
| 21 | 11_LoFP7 | 7148.5 | Upward | Downward | 10 |
| 22 | 11_LoFP8 | 11048.5 | Upward | Upward | 10 |
| 23 | 11_LoFP9 | 18212.5 | Downward | None | 10 |
| 24 | 11_LoFP10 | 20013.5 | Upward | None | 10 |
| 25 | 12_TGTrip1 | 0 | None | Upward | 288 |
| 26 | 12_TGTrip2 | 15 | Downward | Downward | 288 |
| 27 | 12_TGTrip3 | 2790 | Upward | Upward | 288 |
| 28 | 13_Overpr1 | 0 | None | Upward | 1 |
| 29 | 13_Overpr2 | 15 | Downward | Downward | 1 |
| 30 | 13_Overpr3 | 2790 | Upward | Upward | 1 |
| 31 | 14_SRVBlwdn | 0 | Downward | Downward | 1 |
| 32 | 19_RedTo0pct | 0 | Downward | None | 300 |
| 33 | 20_HSHeatup | 0 | Upward | None | 300 |
| 34 | 20A_HSFWInj1 | 0 | Downward | None | 300 |
| 35 | 20A_HSFWInj2 | 181 | Upward | None | 300 |
| 36 | 21_Shutdown | 0 | Downward | Downward | 300 |
| 37 | 24_HydroTest1 | 0 | None | Upward | 1 |
| 38 | 24_HydroTest2 | 1200 | None | Downward | 1 |
| 39 | 25_Unbolt | 0 | Downward | None | 123 |

* Since this transient does not affect the FW nozzle, it is not considered in the cyclic evaluation.
** Note that stress peaks may occur after the start of the subsequent ramp.

## 3.4 Material Properties, VESLFAT

Material properties are entered in VESLFAT input files *VFAT-1I.FDT* (safe end) and *VFAT-2I.FDT* (nozzle corner). Table 2 lists the temperature-dependent material properties used in the analysis [1, Table 5] [8], and Table 3 lists the fatigue curve for the nozzle and safe end materials [3, Appendix I, Table I-9.1 and Figure I-9.1]. VESLFAT automatically scales the stresses by the ratio of E on the fatigue curve to E in the analysis, for purposes of determining allowable numbers of cycles, as required by the ASME Code.

Other material properties are input as follows:

m = 3.0, n = 0.2, parameters used to calculate factor $K_e$, safe end [9]
m = 2.0, n = 0.2, parameters used to calculate factor $K_e$, nozzle corner [9]
E from fatigue curve = 30,000 ksi [3, Appendix I, Table I-9.1 and Figure I-9.1] [9]

**Table 2: Temperature-Dependent Material Properties, VESLFAT**

| Material | T, °F | E, psi | $S_m$, ksi | $S_y$, ksi |
|---|---|---|---|---|
| A508 Class I | 70 | $29.3(10)^6$ | 23.3 | 36.0 |
| (safe end) | 200 | $28.6(10)^6$ | 21.9 | 33.0 |
| | 300 | $28.1(10)^6$ | 21.3 | 31.8 |
| | 400 | $27.5(10)^6$ | 20.6 | 30.8 |
| | 500 | $27.1(10)^6$ | 19.4 | 29.3 |
| | 600 | $26.5(10)^6$ | 17.8 | 27.6 |
| A508 Class II | 70 | $27.8(10)^6$ | 26.7 | 50.0 |
| (nozzle) | 200 | $27.1(10)^6$ | 26.7 | 47.0 |
| | 300 | $26.7(10)^6$ | 26.7 | 45.5 |
| | 400 | $26.1(10)^6$ | 26.7 | 44.2 |
| | 500 | $25.7(10)^6$ | 26.7 | 43.2 |
| | 600 | $25.2(10)^6$ | 26.7 | 42.1 |

**Table 3: Carbon/Low Alloy Steel Fatigue Curve**

| Number of Cycles | $S_a$, ksi |
|---|---|
| 10 | 580 |
| 20 | 410 |
| 50 | 275 |
| 100 | 205 |
| 200 | 155 |
| 500 | 105 |
| 1,000 | 83 |
| 2,000 | 64 |
| 5,000 | 48 |
| 10,000 | 38 |
| 20,000 | 31 |
| 50,000 | 23 |
| 100,000 | 20 |
| 200,000 | 16.5 |
| 500,000 | 13.5 |
| 1,000,000 | 12.5 |

## 4.0 CALCULATIONS

Table 4 contains the stress components at the locations of interest for the 1,000 psi pressure case [6, files *PSE.OUT* and *PBLEND.OUT*] and for the piping loads [1, Table 7], corresponding to a reactor temperature of 575°F [1, Section 3.1.8].

**Table 4: Stress Components Before SCF, psi**

| Loading | Type | Node | $S_x$ | $S_y$ | $S_z$ | $S_{xy}$ | $S_{xz}$ | $S_{yz}$ |
|---|---|---|---|---|---|---|---|---|
| Unit | Membrane | 192 | -810.7 | 6116 | 7853 | -450.1 | 0 | 0 |
| Pressure, | plus Bending | 657 | -705.2 | 1198 | 24020 | -3590 | 0 | 0 |
| 1,000 psi | Total | 657 | -705.2 | 985.5 | 27590 | -121.1 | 0 | 0 |
| Piping Loads | Nominal | 192 | 0 | 7430 | 0 | 1210 | 3176 | 0 |
| at 575°F | | 657 | 0 | 354 | 0 | 98 | 105 | 0 |

SCFs are applied to the pressure and piping load stress components to yield P+Q and P+Q+F stress components as follows [1]:

Pressure:

Safe end (Node 192):

Membrane plus bending from ANSYS equals P+Q

Membrane plus bending from ANSYS is multiplied by 1.1 to yield P+Q+F

Nozzle corner (Node 657):

Membrane plus bending from ANSYS is multiplied by 1.333 to yield P+Q

Total stress from ANSYS is multiplied by 1.333 to yield P+Q+F

Piping Loads:

Safe end (Node 192):

Nominal stresses are multiplied by 1.796 to yield P+Q

Nominal stresses are multiplied by 1.976 to yield P+Q+F

Nozzle corner (Node 657):

Nominal stresses are used as is for P+Q and P+Q+F

Table 5 shows the stress components with SCFs. The piping load stress components are applied as having negative signs, to yield the largest stress component ranges.

**Table 5: Stress Components With SCF, psi**

| | | Membrane plus Bending | | | | | | Total | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Load | Node | $S_x$ | $S_y$ | $S_z$ | $S_{xy}$ | $S_{xz}$ | $S_{yz}$ | $S_x$ | $S_y$ | $S_z$ | $S_{xy}$ | $S_{xz}$ | $S_{yz}$ |
| Pressure | 192 | -811 | 6116 | 7853 | -450 | 0 | 0 | -892 | 6728 | 8638 | -495 | 0 | 0 |
| | 657 | -940 | 1597 | 32019 | -4785 | 0 | 0 | -940 | 1314 | 36777 | -161 | 0 | 0 |
| Piping | 192 | 0 | 13344 | 0 | 2173 | 5704 | 0 | 0 | 14682 | 0 | 2391 | 6276 | 0 |
| | 657 | 0 | 354 | 0 | 98 | 105 | 0 | 0 | 354 | 0 | 98 | 105 | 0 |

The calculations of VESLFAT stress input are automated in Excel workbooks *VFAT-1I.XLS* (safe end) and *VFAT-2I.XLS* (nozzle). These files are organized with sheets labeled as follows:

- Overview: Contains general information.

- Other Stresses: Contains calculation of pressure and piping load as shown in Tables 4 and 5.
- Rearranger: There are 16 Rearranger sheets, one for each transient as analyzed by ANSYS. In these sheets, thermal stresses are copied from Excel workbook *StressResults.xls*, which contains the results of the ANSYS stress linearization for each transient, and rearranged to conform to VESLFAT input format (including switching the shear stress components $S_{xz}$ and $S_{yz}$ as required by VESLFAT). Time-varying scale factors for the piping loads (based on FW nozzle fluid temperature) and pressure are determined, and used to scale the unit load stresses, which are then added to the thermal stresses. Time-varying pressure is also included in the VESLFAT stress input. The VESLFAT stress input also includes time-varying metal temperature, from the ANSYS output, which is used to determine temperature-dependent properties from the values in Table 2.
- VESLFAT: Contains the VESLFAT stress input, obtained from sheets named Rearranger. Load set numbers are entered on this sheet, as defined in Table 1. These sheets are saved to VESLFAT input files *VFAT-1I.STR* (safe end) and *VFAT-2I.STR* (nozzle corner). To avoid double counting of stress states, the initial time steps of each load set before the first stress peak are not included.

The files with extension STR are edited if necessary to remove some intermediate stress points, since VESLFAT has a limit of 3,000 total stress states.

## 5.0 RESULTS OF ANALYSIS

Tables 6 and 7 give the detailed fatigue usage results for the safe end and the nozzle corner, respectively, from VESLFAT output files *VFAT-1I.FAT* (safe end) and *VFAT-2I.FAT* (nozzle corner). All VESLFAT input and output files are saved in the project computer files.

**Table 6: Fatigue Usage Results for Safe End**

| Load Set A | Load Set B | n | $S_n$, psi | $K_e$ | $S_{alt}$, psi | N | Usage |
|---|---|---|---|---|---|---|---|
| 15 11_LoFP1 | 18 11_LoFP4 | 10 | 61435 | 1.115 | 57352 | 2836.19 | 0.0035 |
| 20 11_LoFP6 | 27 12_TGTrip3 | 10 | 49698 | 1 | 40800 | 8098.01 | 0.0012 |
| 27 12_TGTrip3 | 34 20A_HSFWInj1 | 278 | 42194 | 1 | 37182 | 10769 | 0.0258 |
| 30 13_Overpr3 | 34 20A_HSFWInj1 | 1 | 42194 | 1 | 37182 | 10769 | 0.0001 |
| 33 20_HSHeatup | 34 20A_HSFWInj1 | 21 | 42563 | 1 | 35966 | 12060 | 0.0017 |
| 5 4_TurbRoll1 | 33 20_HSHeatup | 279 | 43986 | 1 | 35597 | 12491 | 0.0223 |
| 6 4_TurbRoll2 | 23 11_LoFP9 | 10 | 39882 | 1 | 32197 | 17579 | 0.0006 |
| 5 4_TurbRoll1 | 6 4_TurbRoll2 | 21 | 39842 | 1 | 32178 | 17615 | 0.0012 |
| 16 11_LoFP2 | 35 20A_HSFWInj2 | 10 | 40708 | 1 | 31762 | 18413 | 0.0005 |
| 35 20A_HSFWInj2 | 37 24_HydroTest1 | 1 | 20956 | 1 | 13081 | 664055 | 0.0000 |
| 17 11_LoFP3 | 35 20A_HSFWInj2 | 10 | 20399 | 1 | 12667 | 887275 | 0.0000 |
| 19 11_LoFP5 | 35 20A_HSFWInj2 | 10 | 19602 | 1 | 12135 | infinite | 0.0000 |
| | | | | | | TOTAL = | 0.0571 |

**Table 7: Fatigue Usage Results for Nozzle Corner**

| Load Set A | Load Set B | n | $S_n$, psi | $K_e$ | $S_{alt}$, psi | N | Usage |
|---|---|---|---|---|---|---|---|
| 2 2_DesHydro1 | 16 11_LoFP2 | 10 | 65109 | 1 | 46047 | 5655.78 | 0.0018 |
| 2 2_DesHydro1 | 20 11_LoFP6 | 10 | 50344 | 1 | 43990 | 6477.19 | 0.0015 |
| 2 2_DesHydro1 | 18 11_LoFP4 | 10 | 50150 | 1 | 43205 | 6832.83 | 0.0015 |
| 2 2_DesHydro1 | 11 9_TurbTrip1 | 10 | 65712 | 1 | 43011 | 6924.58 | 0.0014 |
| 2 2_DesHydro1 | 5 4_TurbRoll1 | 80 | 64296 | 1 | 43008 | 6925.97 | 0.0116 |
| 5 4_TurbRoll1 | 39 25_Unbolt | 123 | 63308 | 1 | 41430 | 7738.36 | 0.0159 |
| 3 2_DesHydro2 | 5 4_TurbRoll1 | 97 | 61437 | 1 | 40391 | 8343.98 | 0.0116 |
| 3 2_DesHydro2 | 23 11_LoFP9 | 10 | 63138 | 1 | 40101 | 8524.36 | 0.0012 |
| 3 2_DesHydro2 | 34 20A_HSFWInj1 | 13 | 49069 | 1 | 39657 | 8810.73 | 0.0015 |
| 34 20A_HSFWInj1 | 38 24_HydroTest2 | 1 | 49097 | 1 | 39622 | 8833.38 | 0.0001 |
| 34 20A_HSFWInj1 | 36 21_Shutdown | 286 | 49111 | 1 | 39616 | 8837.88 | 0.0324 |
| 26 12_TGTrip2 | 36 21_Shutdown | 14 | 60379 | 1 | 38556 | 9578.4 | 0.0015 |
| 21 11_LoFP7 | 26 12_TGTrip2 | 10 | 49395 | 1 | 33091 | 16015 | 0.0006 |
| 26 12_TGTrip2 | 31 14_SRVBlwdn | 1 | 42902 | 1 | 27518 | 28831 | 0.0000 |
| 22 11_LoFP8 | 26 12_TGTrip2 | 10 | 32212 | 1 | 24687 | 40237 | 0.0002 |
| 4 3_Startup | 26 12_TGTrip2 | 253 | 30212 | 1 | 23513 | 46728 | 0.0054 |
| 4 3_Startup | 29 13_Overpr2 | 1 | 30212 | 1 | 23513 | 46728 | 0.0000 |
| 4 3_Startup | 28 13_Overpr1 | 1 | 28966 | 1 | 19423 | 111118 | 0.0000 |
| 4 3_Startup | 32 19_RedTo0pct | 45 | 24083 | 1 | 17665 | 156402 | 0.0003 |
| 32 19_RedTo0pct | 33 20_HSHeatup | 255 | 18765 | 1 | 12883 | 761835 | 0.0003 |
| 13 10_FWHByp1 | 33 20_HSHeatup | 45 | 19637 | 1 | 12679 | 879615 | 0.0001 |
| 13 10_FWHByp1 | 35 20A_HSFWInj2 | 25 | 20388 | 1 | 12624 | 914934 | 0.0000 |
| 35 20A_HSFWInj2 | 37 24_HydroTest1 | 1 | 19850 | 1 | 12359 | infinite | 0.0000 |
| 9 6_WklyRed1 | 35 20A_HSFWInj2 | 274 | 19341 | 1 | 11952 | infinite | 0.0000 |
| | | | | | | TOTAL = | 0.0889 |

## 6.0 CONCLUSIONS AND DISCUSSIONS

A previously-developed FEM was analyzed using the ANSYS program. Thermal transient analysis was performed for each defined transient, and the thermal stresses were added to stresses due to pressure and piping loads, which were scaled based on the magnitudes of the pressure and piping loads. SCFs were applied as appropriate. All six components of the stress tensor were used for stress calculations. The fatigue calculation was performed at previously-examined locations, and used the methodology of Subarticle NB-3200 of Section III of the ASME Code.

The 60-year CUF for the safe end location was determined to be 0.0571, and the CUF for the nozzle corner location was determined to be 0.0889. Both values are less than the ASME Code allowable value of 1.0.

Environmental fatigue usage analysis will be performed in a separate calculation package.

## 7.0 REFERENCES


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

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

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

4. SI Calculation Package, *Feedwater Nozzle Finite Element Model and Heat Transfer Coefficients*, Revision 0, SI File No. VY-10Q-301.

5. Entergy Document EC No. 1773, Revision 0 (Design Input Revision 1), *Environmental Fatigue Analysis for Vermont Yankee Nuclear Power Station*, SI File No. VY-16Q-209.

6. SI Calculation Package, *Feedwater Nozzle Stress History Development for Green Functions*, Revision 0, SI File No. VY-16Q-301.

7. VESLFAT, Version 1.42, 02/06/07, Structural Integrity Associates.

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

9. SI Calculation Package, *Fatigue Analysis of Feedwater Nozzle*, Revision 0, SI File No. VY-16Q-302.

**Exhibit C**

| Structural Integrity Associates, Inc. | File No.: VY-19Q-303 |
|---|---|
| **CALCULATION PACKAGE** | **Project No.:** VY-19Q |

**PROJECT NAME:**

Provide VY Support for Questions Related to Environmental Fatigue Analyses

**CONTRACT NO.:**

10163217

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

**CALCULATION TITLE:**

Feedwater Nozzle Environmental Fatigue Evaluation

| Document Revision | Affected Pages | Revision Description | Project Manager Approval Signature & Date | Preparer(s) & Checker(s) Signatures & Date |
|---|---|---|---|---|
| 0 | 1 - 7 | Initial issue. | Terry J. Herrmann<br>01/30/2008 | Gary L. Stevens<br>01/30/2008<br>Gary L. Stevens<br><br>Terry J. Herrmann<br>01/30/2008 |

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## 1.0 INTRODUCTION

The purpose of this calculation is to perform a plant-specific evaluation of reactor water environmental effects for the reactor pressure vessel (RPV) feedwater nozzle identified in NUREG/CR-6260 [1] for the older vintage General Electric (GE) plant for the Vermont Yankee Nuclear Power Station (VY).

## 2.0 APPROACH

Per Chapter X, "Time-Limited Aging Analyses Evaluation of Aging Management Programs Under 10 CFR 54.21(c)(1)(iii)," Section X.M1, "Metal Fatigue of Reactor Coolant Pressure Boundary," of the Generic Aging Lessons Learned (GALL) Report [2], detailed, vintage-specific, fatigue calculations are required for plants applying for license renewal for the locations identified for the appropriate vintage plant in NUREG/CR-6260.

In this calculation, detailed environmentally assisted fatigue (EAF) calculations are performed for VY for one of the locations associated with the older vintage GE plant in NUREG/CR-6260. The older-vintage GE plant is the appropriate comparison to VY since the original piping design at VY was in accordance with USAS B31.1 [3], as well as the fact that the older-vintage boiling water reactor (BWR) in NUREG/CR-6260 was a BWR-4 plant, which is the same as VY.

Entergy performed an initial assessment of EAF effects for VY in their License Renewal Application (LRA) that was submitted to the NRC in January 2006. Table 4.3-3 of the VY LRA provides the results of those evaluations. All but two of the VY locations evaluated for EAF in the LRA did not yield acceptable results for 60 years of operation, as they were based on generic analysis results from NUREG/CR-6260 that were not VY-specific. Plant-specific analyses have been recently completed to address those components for VY. Relevant chemistry input for this calculation is contained in Reference [5]. This calculation documents the EAF evaluation for the feedwater nozzle locations.

## 3.0 METHODOLOGY

Per Section X.M1 of the GALL Report [2], the EAF evaluation must use the appropriate $F_{en}$ relationships from NUREG/CR-6583 [4] (for carbon/low alloy steels), which are the materials under consideration for the feedwater nozzle. Per Figure 2 and Table 2 of Reference [6], the two locations being evaluated are the feedwater nozzle safe end (carbon steel) and the feedwater nozzle forging corner (low alloy steel). Based on the materials of these locations, the appropriate expressions are:

*For Carbon Steel [4, p. 69]:* $$F_{en} = \exp(0.585 - 0.00124T' - 0.101S^*T^*O^*\dot{\varepsilon}^*) \quad (1)$$

Substituting T' = 25°C in the above expression, as required by NUREG/CR-6583 to relate room temperature air data to service temperature data in water [7], the following is obtained:

$$F_{en} = \exp(0.585 - 0.00124(25°C) - 0.101\ S^*\ T^*\ O^*\dot{\varepsilon}^*) \quad (2)$$

$$= \exp(0.554 - 0.101\ S^*\ T^*\ O^*\ \dot{\varepsilon}^*) \quad (3)$$

*For Low Alloy Steel [4, p. 69]:* $$F_{en} = \exp(0.929 - 0.00124T' - 0.101S^*T^*O^*\dot{\varepsilon}^*) \quad (4)$$

Substituting T' = 25°C in the above expression, as required by NUREG/CR-6583 to relate room temperature air data to service temperature data in water [7], the following is obtained:

$$F_{en} = \exp(0.929 - 0.00124(25°C) - 0.101\ S^*\ T^*\ O^*\dot{\varepsilon}^*) \quad (5)$$

$$= \exp(0.898 - 0.101\ S^*\ T^*\ O^*\dot{\varepsilon}^*) \quad (6)$$

where [4, pp. 60 and 65]:

| | | |
|---|---|---|
| $F_{en}$ | = | fatigue life correction factor |
| $S^*$ | = | S for 0 < sulfur content, S ≤ 0.015 wt. % |
| | = | 0.015 for S > 0.015 wt. % |
| $T^*$ | = | 0 for T < 150°C |
| | = | (T - 150) for 150 ≤ T ≤ 350°C |
| T | = | fluid service temperature (°C) |
| $O^*$ | = | 0 for dissolved oxygen, DO < 0.05 parts per million (ppm) |
| | = | ln(DO/0.04) for 0.05 ppm ≤ DO ≤ 0.5 ppm |
| | = | ln(12.5) for DO > 0.5 ppm |
| $\dot{\varepsilon}^*$ | = | 0 for strain rate, $\dot{\varepsilon}^*$ > 1%/sec |
| | = | ln($\dot{\varepsilon}^*$) for 0.001 ≤ $\dot{\varepsilon}^*$ ≤ 1%/sec |
| | = | ln(0.001) for $\dot{\varepsilon}^*$ < 0.001%/sec |

Bounding $F_{en}$ values were determined in Reference [5]. The values determined in Table 3 of Reference [5] will be used for the carbon steel feedwater nozzle safe end location, where feedwater DO levels are low and the $F_{en}$ value is a constant value of 1.74 for all temperatures for both hydrogen water chemistry (HWC) and normal water chemistry (NWC) conditions. For the low alloy steel

nozzle corner location, the applicable $F_{en}$ values are shown in Table 4 of Reference [5]. Since there is a significant variation in values with temperature, $F_{en}$ values will be computed for each load pair in the detailed fatigue calculation for this location.

The environmental fatigue is determined as $U_{env} = (U)(F_{en})$, where U is the original fatigue usage and $U_{env}$ is the environmentally assisted fatigue (EAF) usage factor. All calculations can be found in Excel spreadsheet "*VY-19Q-303 (Env. Fat. Calcs).xls*" associated with this calculation.

From Table 1 of Reference [5], the following water chemistry input applies for the low alloy steel nozzle corner location:

- Over the 60-year operating life of the plant, HWC conditions exist for 47% of the time, and NWC conditions exist for 53% of the time.
- For the RPV Upper Region, which is applicable to the nozzle corner location, DO is 114 ppb pre-HWC and 97 ppb post-HWC.

With these assumptions, the cumulative usage factor (CUF) values documented in this calculation are considered applicable for sixty years of operation including all relevant EAF and EPU effects.

## 4.0 CALCULATIONS

From Table 6 of Reference [6], the CUF for the safe end for 60 years of operation is 0.0571. Thus, the EAF CUF for 60 years is 0.0571 x 1.74 = 0.0994, which is less than the allowable value of 1.0 and is therefore acceptable.

The CUF for the nozzle corner for 60 years of operation is shown in Table 7 of Reference [6], and has a value of 0.0889. This calculation is reproduced in Table 1, along with EAF calculations on a load pair basis using the $F_{en}$ expression in Equation (6) above for low alloy steel. The final EAF CUF for 60 years is 0.3531, which is less than the allowable value of 1.0 and is therefore acceptable. The overall Fen multiplier for this location is 3.97.

## 5.0 CONCLUSIONS

In this calculation, EAF calculations were performed in accordance with the GALL Report [2] for the feedwater nozzle safe end (carbon steel) and nozzle corner (low alloy steel) locations. These locations were selected based on the locations identified in NUREG/CR-6260 for the older vintage GE plant and plant-specific fatigue calculations that determined the limiting locations for VY. Calculations for the remaining NUREG/CR-6260 locations are documented in other calculations.

The EAF results for the locations identified above indicate that the fatigue usage factors, including environmental effects, are within the allowable value for 60 years of operation. The calculations for both locations make use of the 60-year projected cycles for VY and incorporate EPU effects

(conservatively assumed to apply for all 60 years of operation). Therefore, no additional evaluation is required for these components, and the GALL requirements are satisfied.

## 6.0 REFERENCES


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

2. NUREG-1801, Revision 1, "Generic Aging Lessons Learned (GALL) Report," U. S. Nuclear Regulatory Commission, September 2005.

3. USAS B31.1.0 – 1967, USA Standard Code for Pressure Piping, "Power Piping," American Society of Mechanical Engineers, New York.

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

5. SI Calculation Package, *Environmental Fatigue Evaluation of Reactor Recirculation Inlet Nozzle and Vessel Shell/Bottom Head*, Revision 0, SI File No. VY-16Q-303.

6. SI Calculation Package, *ASME Code Confirmatory Fatigue Evaluation of Reactor Feedwater Nozzle*, Revision 0, SI File No. VY-19Q-302.

7. EPRI/BWRVIP Memo No. 2005-271, "Potential Error in Existing Fatigue Reactor Water Environmental Effects Analyses," July 1, 2005.

# Table 1: EAF Calculations for the Feedwater Nozzle Corner

CUF Calculation from Table 7 of Reference [6]:

| Index | Load #1 | Description #1 | $n_1$ (cycles) | Load #2 | Description #2 | $n_2$ (cycles) | n (cycles) | $S_n$ (psi) | $K_e$ | $S_{alt}$ (psi) | $N_{allow}$ | U |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 2_DesHydro1 | 120 | 16 | 11_LoFP2 | 10 | 10 | 65,109 | 1.000 | 46,047 | 5,655.78 | 0.00177 |
| 2 | 2 | 2_DesHydro1 | 110 | 20 | 11_LoFP6 | 10 | 10 | 50,344 | 1.000 | 43,990 | 6,477.19 | 0.00154 |
| 3 | 2 | 2_DesHydro1 | 100 | 18 | 11_LoFP4 | 10 | 10 | 50,150 | 1.000 | 43,204 | 6,632.83 | 0.00146 |
| 4 | 2 | 2_DesHydro1 | 90 | 11 | 9_TurbTrip1 | 10 | 10 | 65,712 | 1.000 | 43,011 | 6,924.58 | 0.00144 |
| 5 | 2 | 2_DesHydro1 | 80 | 5 | 4_TurbRoll1 | 300 | 80 | 64,296 | 1.000 | 43,008 | 6,925.97 | 0.01155 |
| 6 | 5 | 4_TurbRoll1 | 220 | 39 | 25_Unbolt | 123 | 123 | 63,308 | 1.000 | 41,430 | 7,738.36 | 0.01589 |
| 7 | 3 | 2_DesHydro2 | 120 | 5 | 4_TurbRoll1 | 97 | 97 | 61,437 | 1.000 | 40,391 | 8,343.98 | 0.01163 |
| 8 | 3 | 2_DesHydro2 | 23 | 23 | 11_LoFP9 | 10 | 10 | 63,138 | 1.000 | 40,101 | 8,524.36 | 0.00117 |
| 9 | 3 | 2_DesHydro2 | 13 | 34 | 20A_HSFWInj1 | 300 | 13 | 49,069 | 1.000 | 39,657 | 8,810.73 | 0.00148 |
| 10 | 34 | 20A_HSFWInj1 | 287 | 38 | 24_HydroTest2 | 1 | 1 | 49,097 | 1.000 | 39,622 | 8,833.38 | 0.00011 |
| 11 | 34 | 20A_HSFWInj1 | 286 | 36 | 21_Shutdown | 300 | 286 | 49,111 | 1.000 | 39,616 | 8,837.88 | 0.03236 |
| 12 | 26 | 12_TGTrip2 | 288 | 36 | 21_Shutdown | 14 | 14 | 60,379 | 1.000 | 38,556 | 9,578.40 | 0.00146 |
| 13 | 21 | 11_LoFP7 | 10 | 26 | 12_TGTrip2 | 274 | 10 | 49,395 | 1.000 | 33,091 | 16,015.00 | 0.00062 |
| 14 | 26 | 12_TGTrip2 | 264 | 31 | 14_SRVBlwdn | 1 | 1 | 42,902 | 1.000 | 27,518 | 28,831.00 | 0.00003 |
| 15 | 22 | 11_LoFP8 | 10 | 26 | 12_TGTrip2 | 263 | 10 | 32,212 | 1.000 | 24,667 | 40,237.00 | 0.00025 |
| 16 | 4 | 3_Startup | 300 | 26 | 12_TGTrip2 | 253 | 253 | 30,212 | 1.000 | 23,513 | 46,728.00 | 0.00541 |
| 17 | 4 | 3_Startup | 47 | 29 | 13_Overpr2 | 1 | 1 | 30,212 | 1.000 | 23,513 | 46,728.00 | 0.00002 |
| 18 | 4 | 3_Startup | 46 | 28 | 13_Overpr1 | 1 | 1 | 28,966 | 1.000 | 19,423 | 111,118.00 | 0.00001 |
| 19 | 4 | 3_Startup | 45 | 32 | 19_RedTo0pct | 300 | 45 | 24,083 | 1.000 | 17,665 | 156,402.00 | 0.00029 |
| 20 | 32 | 19_RedTo0pct | 255 | 33 | 20_HSHeatup | 300 | 255 | 18,765 | 1.000 | 12,883 | 761,835.00 | 0.00033 |
| 21 | 13 | 10_FWHByp1 | 70 | 33 | 20_HSHeatup | 45 | 45 | 19,637 | 1.000 | 12,679 | 879,615.00 | 0.00005 |
| 22 | 13 | 10_FWHByp1 | 25 | 35 | 20A_HSFWInj2 | 300 | 25 | 20,388 | 1.000 | 12,624 | 914,934.00 | 0.00003 |
| 23 | 35 | 20A_HSFWInj2 | 275 | 37 | 24_HydroTest1 | 1 | 1 | 19,850 | 1.000 | 12,359 | infinite | 0.00000 |
| 24 | 9 | 6_WklyRed1 | 2000 | 35 | 20A_HSFWInj2 | 274 | 274 | 19,341 | 1.000 | 11,952 | infinite | 0.00000 |
| | | | | | | | | | | | Total, $U_{59}$ = | 0.08893 |

EAF Calculations:

| | HWC DO | NWC DO | |
|---|---|---|---|
| | 97 | 114 | ppb |
| % HWC = | 47% | 53% | = % NWC |

| $T_{MAX}$ (°F) [1] | $T_{MAX}$ (°C) | HWC $F_{en}$ [2] | NWC $F_{en}$ [2] | $U_{env}$ [3] |
|---|---|---|---|---|
| 356.0 | 180.0 | 3.242 | 3.410 | 0.00589 |
| 381.0 | 193.9 | 3.687 | 3.971 | 0.00592 |
| 389.0 | 198.3 | 3.842 | 4.169 | 0.00588 |
| 351.0 | 177.2 | 3.159 | 3.308 | 0.00468 |
| 360.0 | 182.2 | 3.309 | 3.494 | 0.03936 |
| 360.0 | 182.2 | 3.309 | 3.494 | 0.05416 |
| 360.0 | 182.2 | 3.309 | 3.494 | 0.03961 |
| 353.0 | 178.3 | 3.192 | 3.349 | 0.00384 |
| 388.0 | 197.8 | 3.823 | 4.144 | 0.00589 |
| 388.0 | 197.8 | 3.823 | 4.144 | 0.00045 |
| 388.0 | 197.8 | 3.823 | 4.144 | 0.12921 |
| 349.0 | 176.1 | 3.127 | 3.268 | 0.00468 |
| 424.0 | 217.8 | 4.601 | 5.160 | 0.00306 |
| 349.0 | 176.1 | 3.127 | 3.268 | 0.00011 |
| 538.0 | 281.1 | 8.277 | 10.330 | 0.00233 |
| 503.0 | 261.7 | 6.912 | 8.347 | 0.04154 |
| 503.0 | 261.7 | 6.912 | 8.347 | 0.00016 |
| 503.0 | 261.7 | 6.912 | 8.347 | 0.00007 |
| 503.0 | 261.7 | 6.912 | 8.347 | 0.00221 |
| 543.0 | 283.9 | 8.493 | 10.649 | 0.00323 |
| 548.0 | 286.7 | 8.714 | 10.978 | 0.00051 |
| 549.0 | 287.2 | 8.759 | 11.045 | 0.00027 |
| 548.0 | 286.7 | 8.714 | 10.978 | 0.00000 |
| 548.0 | 286.7 | 8.714 | 10.978 | 0.00000 |
| | | | Total, $U_{59\text{-}env}$ = | 0.35306 |
| | | | Overall $F_{en}$ = | 3.970 |

Transient Maximum Temperatures:

| Index | Load #1 | Description #1 | $n_1$ (cycles) | Load #2 | Description #2 | From "Mat-2i.ALL": Index | T1 [4] | s1 [4] | T2 [4] | s2 [4] | $S_n$ (psi) | T (°F) [1] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 2_DesHydro1 | 120 | 16 | 11_LoFP2 | 1 | 2 | 30 | 16 | 14 | 65,109 | 356 |
| 2 | 2 | 2_DesHydro1 | 110 | 20 | 11_LoFP6 | 2 | 2 | 30 | 20 | 3 | 50,344 | 381 |
| 3 | 2 | 2_DesHydro1 | 100 | 18 | 11_LoFP4 | 3 | 2 | 30 | 18 | 7 | 50,150 | 389 |
| 4 | 2 | 2_DesHydro1 | 90 | 11 | 9_TurbTrip1 | 4 | 2 | 30 | 11 | 6 | 65,712 | 351 |
| 5 | 2 | 2_DesHydro1 | 80 | 5 | 4_TurbRoll1 | 5 | 2 | 30 | 5 | 12 | 64,296 | 360 |
| 6 | 5 | 4_TurbRoll1 | 220 | 39 | 25_Unbolt | 6 | 5 | 12 | 39 | 23 | 63,308 | 360 |
| 7 | 3 | 2_DesHydro2 | 120 | 5 | 4_TurbRoll1 | 7 | 3 | 1 | 5 | 12 | 61,437 | 360 |
| 8 | 3 | 2_DesHydro2 | 23 | 23 | 11_LoFP9 | 8 | 3 | 1 | 23 | 7 | 63,138 | 353 |
| 9 | 3 | 2_DesHydro2 | 13 | 34 | 20A_HSFWInj1 | 9 | 3 | 1 | 34 | 21 | 49,069 | 388 |
| 10 | 34 | 20A_HSFWInj1 | 287 | 38 | 24_HydroTest2 | 10 | 34 | 21 | 38 | 1 | 49,097 | 388 |
| 11 | 34 | 20A_HSFWInj1 | 286 | 36 | 21_Shutdown | 11 | 34 | 21 | 36 | 156 | 49,111 | 388 |
| 12 | 26 | 12_TGTrip2 | 288 | 36 | 21_Shutdown | 12 | 26 | 6 | 36 | 156 | 60,379 | 349 |
| 13 | 21 | 11_LoFP7 | 10 | 26 | 12_TGTrip2 | 13 | 21 | 68 | 26 | 7 | 49,395 | 424 |
| 14 | 26 | 12_TGTrip2 | 264 | 31 | 14_SRVBlwdn | 14 | 26 | 6 | 31 | 41 | 42,902 | 349 |
| 15 | 22 | 11_LoFP8 | 10 | 26 | 12_TGTrip2 | 15 | 22 | 1 | 26 | 7 | 32,212 | 538 |
| 16 | 4 | 3_Startup | 300 | 26 | 12_TGTrip2 | 16 | 4 | 1 | 26 | 7 | 30,212 | 503 |
| 17 | 4 | 3_Startup | 47 | 29 | 13_Overpr2 | 17 | 4 | 1 | 29 | 7 | 30,212 | 503 |
| 18 | 4 | 3_Startup | 46 | 28 | 13_Overpr1 | 18 | 4 | 1 | 28 | 1 | 28,966 | 503 |
| 19 | 4 | 3_Startup | 45 | 32 | 19_RedTo0pct | 19 | 4 | 1 | 32 | 45 | 24,083 | 503 |
| 20 | 32 | 19_RedTo0pct | 255 | 33 | 20_HSHeatup | 20 | 32 | 45 | 33 | 26 | 18,765 | 543 |
| 21 | 13 | 10_FWHByp1 | 70 | 33 | 20_HSHeatup | 21 | 13 | 23 | 33 | 26 | 19,637 | 548 |
| 22 | 13 | 10_FWHByp1 | 25 | 35 | 20A_HSFWInj2 | 22 | 13 | 23 | 35 | 14 | 20,388 | 549 |
| 23 | 35 | 20A_HSFWInj2 | 275 | 37 | 24_HydroTest1 | 23 | 35 | 14 | 37 | 1 | 19,850 | 548 |
| 24 | 9 | 6_WklyRed1 | 2000 | 35 | 20A_HSFWInj2 | 24 | 9 | 10 | 35 | 14 | 19,341 | 548 |

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 is determined from the VESLFAT output from Reference [6], which is included as "T" in the "Transient Maximum Temperatures" table above.
2. $F_{en}$ values computed using Equation (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.

**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, Clara Cavitt, hereby certify that copies of NEW ENGLAND COALITION, INC.'S (NEC) MOTION TO FILE A TIMELY NEW OR AMENDED CONTENTION in the above-captioned proceeding were served on the persons listed below, by U.S. Mail, first class, postage prepaid; and, where indicated by an e-mail address below, by electronic mail, on March 17, 2008.

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