Jonathan Rowley - TLAA RAI Response

From: "Mannai, David" <dmannai@entergy.com>
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Date: 12/11/2007 4:49 PM
Subject: TLAA RAI Response
CC: "Metell, Mike" <hmetell@entergy.com>, "YOUNG, GARRY G" <GYOUNG4@entergy.com>, "COX, ALAN B" <acox@entergy.com>, "Lach, David J" <DLach@entergy.com>, "Devincentis, Jim" <jdevinc@entergy.com>

Jonathon,

Here is the response to the RAI.

<<BVY 07-082.pdf>>

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<<Mannai, David.vcf>>

Mail Envelope Properties (475F05E3.F70 : 14 : 65392)

Subject:	TLAA RAI Response
Creation Date	12/11/2007 4:48:49 PM
From:	"Mannai, David" <dmannai@entergy.com>
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Junk Mail settings when this message was delivered
Junk Mail handling disabled by User
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Junk List is not enabled
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Block List is not enabled

Entergy

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December 11, 2007
BVY 07-082

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U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

References:
1) Letter, Entergy to USNRC, "Vermont Yankee Nuclear Power Station, License No. DPR-28, License Renewal Application," BVY 06-009, dated January 25, 2006.
2) Letter, Entergy to USNRC, "Update of Aging Management Program Audit Q&A Database," BVY 07-079, dated November 14, 2007.
3) Letter, USNRC to Entergy, "Update on Extension of Schedule for the Conduct of Review of the Vermont Yankee Nuclear Power Station License Renewal Application," NVY 07-157, dated November 27, 2007.

Subject: **Vermont Yankee Nuclear Power Station**
License No. DPR-28 (Docket No. 50-271)
License Renewal Application, Amendment 33

On January 25, 2006, Entergy Nuclear Operations, Inc. and Entergy Nuclear Vermont Yankee, LLC (Entergy) submitted the License Renewal Application (LRA) for the Vermont Yankee Nuclear Power Station (Reference 1).

In Reference (2), Entergy provided an update to the Aging Management Program Audit Q&A Database. In Reference (3), the NRC requested additional information relative to audit question number 387. Attachment 1 to this letter provides the additional information requested.

This letter contains no new regulatory commitments.

Should you have any questions concerning this submittal, please contact Mr. David Mannai at (802) 258-5422.

I declare under penalty of perjury that the foregoing is true and correct, executed on December 11, 2007.

Sincerely,

for T. Sullivan

Ted A. Sullivan
Site Vice President
Vermont Yankee Nuclear Power Station

Attachment (1)
cc list (next page)

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Attachment 1

Vermont Yankee Nuclear Power Station
License No. DPR-28 (Docket No. 50-271)

License Renewal Application

Amendment 33

RAI 4.3.3-2 Additional Information

RAI 4.3.3-2

Your response to audit question # 387 in your November 14, 2007, letter states that "In most cases the maximum component stress difference with time matched the maximum stress intensity calculated by ANSYS. This shows that shearing stresses are negligible for the thermal transient at that location and the maximum component stress difference is the maximum stress intensity."

Please identify the exceptions where maximum component stress difference with time did not match the maximum stress intensity calculated by ANSYS. In addition, please justify the exceptions, based on quantitative evaluations, that the shearing stresses are negligible and the maximum component stress difference is the maximum stress intensity for the branch nozzle blend radius (nozzle corner) locations with geometrical discontinuities for the applicable thermal transients. Your response should cover the shearing stress differences at the 0-180 degree axis and the 90-270 degree axis to the pipe run axis.

Vermont Yankee Response

This Request for Additional Information (RAI) addresses several topics discussed during the October 2007 NRC audit. To ensure that all the topics in the RAI are addressed this response has been formatted into several parts:

- Part 1 provides background and identifies which areas are within the scope of this RAI.
- Part 2 identifies the locations where the maximum component stress difference with time did not match the maximum stress intensity calculated by ANSYS.
- Part 3 provides the justification of the use of maximum component stress differences vs. the maximum stress intensity for input into the Green's functions.
- Part 4 identifies the nozzle blend radius (nozzle corner) locations with geometrical discontinuities and addresses the applicable thermal transients.
- Part 5 addresses the shearing stress differences at the 0-180 degree axis and the 90-270 degree axis to the pipe run axis.
- Part 6 provides a summary of this RAI response.

Part 1: Background

To address Environmentally Assisted Fatigue (EAF) for the NUREG/CR-6260 locations at Vermont Yankee, the stress inputs for the reactor vessel and nozzles were either taken from the design basis stress analyses or new stress analyses were performed. Existing stress analyses were used for the controlling locations on the vessel shell and for the Recirculation Inlet nozzles. New stress analyses were performed for the Feedwater, Reactor Recirculation Outlet, and Core Spray nozzles per ASME III, NB-3200. Updated fatigue analyses for the reactor vessel and nozzles were performed per ASME III, Subsection NB-3222.

New fatigue analyses for the Class 1 portions of the Feedwater and Reactor Recirculation/RHR piping were performed per ASME III Subsection NB-3600 since ASME fatigue analysis was not originally required for this piping.

Finite element models (FEM) using ANSYS were used for the new fatigue analyses of the Feedwater, Reactor Recirculation Outlet, and Core Spray nozzles. The FEM for each nozzle is 2-D axisymmetric about the centerline of each nozzle. The geometric and material discontinuities for each nozzle configuration are included in the ANSYS FEMs.

The controlling location for thermal stresses at the safe end region of each FEM was determined using a 500°F to 100°F temperature step transient at 100% flow conditions. The controlling location in the blend radius (nozzle corner) region is the location of maximum stresses due to internal pressure.

For the Feedwater, Reactor Recirculation Outlet, and Core Spray nozzles, stress intensities for each thermal transient were determined using Green's function methodology. Stress intensities due to internal pressure were calculated directly using the ANSYS FEM models. Stress intensities from the attached piping loads at the controlling thermal stress locations were calculated from stress components per ASME Section III, Subsection NB-3215.

The total peak stress intensities for input to the ASME III fatigue analysis were determined by combining the thermal transient stress intensity values at times of maximum and minimum stress (peaks and valleys) during the transient with the stress intensities calculated for the corresponding pressure and attached piping loads at that time.

This question on the affects of the maximum component stress difference with time not matching the maximum stress intensity calculated by ANSYS only applies to the new stress and fatigue analyses performed for the Feedwater, Reactor Recirculation Outlet, and Core Spray nozzles.

Part 2: Locations where maximum component stress difference with time did not match the maximum stress intensity calculated by ANSYS:

The Green's functions at each controlling location were developed from the FEM stress results for a 500°F to 100°F temperature step transient. At each controlling location, values of the component stress differences, (SZ-SX, SY-SX, SZ-SY), were compared to the maximum stress intensity calculated from ANSYS. See Figures 1 through 6 of this response. The stress difference which most closely matched the total stress intensity calculated by ANSYS was used to determine the Green's function at each location.

The locations where maximum component stress difference with time did not match the maximum stress intensity calculated by ANSYS are as follows:

The Feedwater nozzle has the highest fatigue usage. Figures 1 and 2 show the stress response for a 500°F to 100°F temperature step transient at the nozzle safe end and blend radius locations. For both locations the SZ-SX component stress difference closely matches the maximum stress intensity calculated from ANSYS. As shown in Figure 1 for the controlling location on the safe end, the SZ-SX component stress difference is approximately 3% lower than the maximum stress intensity calculated by ANSYS for all time steps with significant (> 1000. psi.) stress values. As shown in Figure 2, for the nozzle blend radius location, the maximum component stress difference for the step transient matches the maximum stress intensity calculated by ANSYS within 1% for all times steps with significant stress response.

The Core Spray nozzle has the next highest fatigue usage. Figures 3 and 4 show the stress response for a 500°F to 100°F temperature step transient at the nozzle safe end and blend radius locations. As shown in Figure 3 for the controlling location on the safe end, the SZ-SX component stress difference matches the maximum stress intensity calculated by ANSYS within 1% for the initial rise time and peak of the stress response. In the decay portion of the stress response after approximately 25 seconds, the SZ-SX component stress difference is approximately 50% lower than the maximum stress intensity calculated by ANSYS. As shown in Figure 4 for the blend radius location, the SZ-SX component stress difference is approximately 3% lower than the maximum stress intensity calculated by ANSYS for all time steps with significant stress response.

Figures 5 and 6 show the stress response for a 500°F to 100°F temperature step transient at the nozzle safe end and blend radius for the Recirculation Outlet nozzle. As shown in Figure 5 for the safe end, the initial rise time and peak of the component stress difference match the maximum stress intensity calculated by ANSYS within 1%. In the decay portion of the transient, after approximately 220 seconds the SY-SX component stress difference is approximately 20% lower than the maximum stress intensity calculated by ANSYS.

As shown in Figure 6 for the Recirculation Outlet nozzle blend radius location, the SZ-SX component stress difference follows the maximum stress intensity calculated from ANSYS for the rise time, peak time, and decay portions of the transient. The SZ-SX component stress difference is approximately 10% lower than the maximum stress intensity calculated by ANSYS for all time steps with significant stress response.

Part 3: <u>Justification of use of maximum component stress differences vs. the maximum stress intensity</u>

The maximum stress intensity is the maximum of the principal stress differences, which are determined from the component normal and shear stresses at that location. Using strength of materials methods, the shear stresses are zero wherever the maximum component stress difference is equal to the maximum stress intensity. Table 1 shows a summary of the maximum component stress difference (SZ-SX, SY-SX, SZ-SY) versus the maximum stress intensity calculated by ANSYS for each of the nozzle controlling locations.

Two evaluations were performed to address the use of the maximum component stress difference (SZ-SX, SY-SX, SZ-SY) versus the maximum stress intensity calculated by ANSYS for input to the Green's functions development and the effect on the resulting fatigue usage.

The first evaluation was for the Recirculation Outlet blend radius. This is the location with the largest difference between the maximum component stress difference (SZ-SX) and the maximum stress intensity calculated by ANSYS for all time steps with significant stress response. See Figure 6.

The second evaluation was for the Core Spray safe end. This is the location with the largest difference between the maximum component stress difference (SZ-SX) and the maximum stress intensity calculated by ANSYS for the decay portion of the transient stress response. See Figure 3.

For the Recirculation Outlet blend radius location, new Green's functions were developed using the maximum stress intensity calculated from ANSYS. Stresses for the thermal transients evaluated in calculation VY-16Q-306 Revision 0 were re-calculated using the new Green's functions. The thermal transient stress intensities were combined with the appropriate stress intensities from pressure and attached piping loads and an ASME III fatigue analysis was performed. This analysis repeated the analysis performed in calculation VY-16Q-306 Revision 0 for the blend radius location with only one difference in inputs. The Green's functions based on maximum stress intensities versus the component stress intensities were used. A comparison of the results is shown in Table 2.

Table 2 shows less than a 4% increase in calculated fatigue usage for the location with the largest difference in maximum component stress difference (SZ-SX, SY-SX, SZ-SY) versus the use of maximum stress intensity calculated by ANSYS. The cumulative usage factor (CUF) for 60 years including the environmental multiplier increases from 0.084 to 0.087.

For the Core Spray safe end radius location, new Green's functions were developed using the maximum stress intensity calculated from ANSYS. Stresses for the thermal transients evaluated in calculation VY-16Q-310 Revision 1 were re-calculated using the new Green's functions. The thermal transient stress intensities were combined with the appropriate stress intensities from pressure and attached piping loads and an ASME III fatigue analysis was performed. This analysis repeated the analysis performed in calculation VY-16Q-310 Revision 1 for the safe end location with only one difference in inputs. The Green's functions based on maximum stress intensities versus the component stress intensities were used. A comparison of the results is shown in Table 3.

Table 3 shows less than a 5% increase in calculated fatigue usage for the location with the largest difference in maximum component stress difference (SZ-SX, SY-SX, SZ-SY) versus the use of maximum stress intensity calculated by ANSYS. The cumulative usage factor (CUF) for 60 years including the environmental multiplier increases from 0.059 to 0.062.

As shown in Tables 2 and 3 the overall change in the calculated cumulative usage factors (CUFs) for 60 years including environmental effects is 0.003 for both of the locations.

The calculated cumulative usage factors (CUFs) for 60 years including environmental effects are based on the use of design transients, conservative projections of the numbers of transients, and bounding environmental multipliers (F_{en} factors). As shown in Table 1, the maximum environmentally adjusted CUF for 60 years for all of the affected locations is 0.256.

Since the changes in calculated fatigue usage for the locations with the largest differences in component stress difference (SZ-SX, SY-SX, SZ-SY) versus maximum stress intensity calculated by ANSYS are less than 5%, an increase of 10% in calculated cumulative usage conservatively bounds the effect. This would result in a calculated 60 year environmentally adjusted CUF of 0.282.

All of the affected locations shown in Table 1 have significant margin to unity for calculated fatigue usage. The limiting margin exceeds 70%. The affects of using maximum component stress difference with time not matching the maximum stress intensity calculated by ANSYS only impacts the calculated fatigue usage at non-limiting locations.

Part 4: Nozzle blend radius (nozzle corner) locations with geometrical discontinuities for the applicable thermal transients:

The geometric and material discontinuities for each nozzle configuration are included in the ANSYS finite element model of each nozzle. The ANSYS stress results from the 400°F (500°F to 100°F) step change transient applied to each model are used to determine the controlling locations for fatigue as well as input to defining the Green's functions. As identified in the calculations, the controlling locations for the fatigue analysis are based on the locations of maximum thermal stresses from the step change transient for the safe ends and the location of maximum pressures stress in the nozzle blend radius. See the following figures in the calculations:

Feedwater Nozzle: Calculation VY-16Q-301 Rev. 0, Figures 6 & 7 for the Safe End & Figure 8 & 9 for the Blend Radius

Recirculation Outlet Nozzle: Calculation VY-16Q-305 Rev. 0, Figures 6 & 7 for Safe End & Figures 8 & 9 for Blend Radius

Core Spray Nozzle: Calculation VY-16Q-309, Rev.0, Figure 6 for Safe End & Figure 7 for Blend Radius (Note: Figures 6 & 7 in Revision 1 are the same.)

The controlling locations are at discontinuities. For the safe end, the controlling locations are either at a geometric discontinuity such as the start or end of a taper transition or at a material discontinuity such as a dissimilar weld location. For the blend radius, the location of maximum stress due to pressure was chosen based on previous nozzle analyses showing that the pressure stresses are the largest contributor to the total stresses. At the blend radius region the thermal stresses resulting from the nozzle flow transients are mitigated by mixing with the large volume of the water flowing in the reactor. A comparison with the previous ASME stress and fatigue analysis of the VY feedwater nozzle (VY-10Q-303) shows that the locations chosen for the safe end and the blend radius using the methodology described above are the same as the critical locations from the full ASME stress and fatigue analysis.

Each location was evaluated for the thermal transients defined in Attachment 1 to the Design Input Record (DIR) Revision 1 for EC 1773 dated 7/26/07. The thermal transient stress intensity values at times of maximum and minimum stress (peaks and valleys) during each transient are combined with the stress intensities calculated for the corresponding pressure and attached piping loads at that time to determine the total peak stress intensities for input to the ASME III fatigue analysis.

In addition "fatigue strength reduction factors" (K_t) based on the surface profile at the controlling locations are applied to the total alternating stress inputs to the ASME fatigue analysis. These values are either the same values used in the design analysis stress reports for the vessel nozzles and safe ends or if not available, they are based on the ASME code. See the following tables in the calculations:

Feedwater Nozzle: Calculation VY-16Q-302 Rev. 0, Table 6 for the Blend Radius and Table 7 for Safe End

Recirculation Outlet Nozzle: Calculation VY-16Q-306 Rev. 0, Table 6 for Blend Radius
Table 7 for Safe End

Core Spray Nozzle: Calculation VY-16Q-310, Rev. 0, Table 7 the Blend Radius, Table 8 for the Safe End, Table 9 for the CS Pipe. (Note: K_t values did not change in Revision 1)

Part 5: Shearing stress differences at the 0-180 degree axis and the 90-270 degree axis to the pipe run axis:

The blend radius dimensions for each nozzle are axisymmetric about the centerline of the nozzle and are the same at the 0-180 degree axis and the 90-270 degree axis except for the tangent angle intercepting the inside radius of the vessel shell at the outer end of the blend radius. A two dimensional (2-D) axisymmetric model is appropriate to evaluate local stresses in the nozzle since the loadings are localized and axisymmetric to the nozzle centerline. The geometric and material discontinuities for the blend radius region of each nozzle configuration are included in the ANSYS finite element model of each nozzle.

In BWR Vessel and Internals Project (BWRVIP) study EPRI Report No. 1003557, "BWRVIP-108: BWR Vessel and Internals Project, Technical Basis for the Reduction of Inspection Requirements for the Boiling Water Reactor Nozzle-to-Vessel Shell Welds and Nozzle Blend Radii," Final Report, October 2002, Figures 4-30 to 4-33 show a significant variation of pressure stress around the centerline of the nozzle with the peak hoop pressure stresses occurring at the +90° (top) and -90° (bottom) azimuths. This is due to the differences in hoop and axial stresses in a cylindrical vessel. The new FEMs used in the Vermont Yankee environmentally assisted fatigue (EAF) evaluations were 2-D axisymmetric about the centerline of each nozzle. As discussed in the response to data base question No. 387 in Entergy letter (BVY 07-079), November 14, 2007, the radius of the vessel in the FEM or the pressure stress was multiplied by a factor to account for variation in pressure stress for a nozzle oriented normal to the cylindrical vessel shell.

Figures 4-30 to 4-33 in BWRVIP-108 also show no significant variance in steady state thermal stresses at the nozzle. The figures show the magnitude of axial stress at the 0° & 180° azimuths is equal to the magnitude of the hoop stress at 90° and -90° azimuths. The figures show the thermal stress in the blend radius oriented normal to the axis of the nozzle is constant. Thermal transients used in the EAF evaluations are axisymmetric and localized to the nozzle safe end, bore, and blend radius regions. Therefore, the use of 2-D axisymmetric modeling vs. the use of a 3-D FEM is adequate to determine thermal transient stresses in both the safe end and blend radius locations. Shearing stress differences in the thermal transient analyses were addressed in Part 3 above.

Part 6: Summary

Table 1 shows a summary of the differences in the maximum component stress difference (SZ-SX, SY-SX, SZ-SY) vs. the of maximum stress intensity calculated by ANSYS for each of the nozzle controlling locations.

Two evaluations were performed to address the use of the maximum component stress difference (SZ-SX, SY-SX, SZ-SY) versus the maximum stress intensity calculated by ANSYS for input to the Green's functions development and the effect on the resulting fatigue usage.

- The first evaluation was for the Recirculation Outlet blend radius which is the location with the largest difference in component stress difference vs. maximum stress intensity calculated by ANSYS for all time steps with significant stress response. As shown in Table 2 there is less than a 4% increase in calculated fatigue usage for this location. The cumulative usage factor (CUF) for 60 years including environmental multiplier increases from 0.084 to 0.087.

- The second evaluation was for the Core Spray safe end which is the location with the largest difference in component stress difference vs. maximum stress intensity calculated by ANSYS for the decay portion stress response. As shown in Table 3 there is less than a 5% increase in calculated fatigue usage for this location. The cumulative usage factor (CUF) for 60 years including environmental multiplier increases from 0.059 to 0.062.

As shown in Tables 2 and 3 the overall change in the calculated cumulative usage factors (CUFs) for 60 years including environmental effects is 0.003 for both of the locations.

As shown in Table 1, the highest environmentally adjusted CUF for 60 years for all of the affected locations is 0.256. An increase of 10% in calculated cumulative usage conservatively bounds the effect. This would result in a calculated 60 year environmentally adjusted CUF of 0.282. The limiting margin exceeds 70%. The affects of using maximum component stress difference with time not matching the maximum stress intensity calculated by ANSYS only impacts the calculated fatigue usage at non-limiting locations.

The geometric and material discontinuities for each nozzle configuration are included in the ANSYS finite element model of each nozzle. There is significant variation in pressure stress around the centerline of the nozzle with the peak hoop pressure stresses occurring at the +90° (top) and -90° (bottom) azimuths. This is due to the differences in hoop and axial stresses in a cylindrical vessel. The new FEMs account for the variation in pressure stress for a nozzle oriented normal to the cylindrical vessel shell.

The thermal transients used in the EAF evaluations are axisymmetric and localized to the nozzle safe end, bore, and blend radius (nozzle corner) regions. Thermal stresses in the blend radius oriented normal to the axis of the nozzle are constant regardless of azimuth.

The effect of shearing stress differences in the thermal transient analyses were addressed by performing two evaluations using the maximum stress intensity calculated by ANSYS for input into the Green's functions. As shown in Tables 2 and 3 the contribution of shearing stresses resulted in less than a 5% increase in the calculated fatigue usage.

The overall change in the calculated cumulative usage factors for 60 years including environmental effects (CUF_{en}) is 0.003 for the locations with the largest differences. The 0.003 difference in calculated CUF_{en} is well within the accuracy of ASME fatigue analyses and is considered negligible.

Table 1: Summary of Maximum Component Stress Difference vs. Maximum Stress Intensity Calculated By ANSYS and Calculated Fatigue Usage.

Nozzle – Location	Maximum Component Stress Difference compared to ANSYS Maximum Stress Intensity	ASME 60Yr CUF	EAF Multiplier	EAF 60 yr CUFen	References (Green' function / CUFs)
Feedwater – Blend Radius	Same*	0.0636	10.05	0.639	VY-16Q-301 Rev. 0 / VY-16Q-302 Rev. 0
Feedwater – Safe End	Max. component stress difference is approx. 3% less	0.1471	1.74	0.256	VY-16Q-301 Rev. 0 / VY-16Q-302 Rev. 0
Core Spray – Blend Radius	Max. component stress difference is approx. 3% less	0.0166	10.05	0.167	VY-16Q-309 Rev. 1 / VY-16Q-310 Rev. 1
Core Spray – Safe End	<u>Same* for rise time and peak response</u>. Decay approx. 50% less after 25 sec.	0.0398	1.49	0.059	VY-16Q-309 Rev. 1 / VY-16Q-310 Rev. 1
Core Spray – Piping	<u>Same* for rise time and peak response</u>. Decay approx. 50% less after 25 sec.	0.0017	8.36	0.009	VY-16Q-309 Rev. 1 / VY-16Q-310 Rev. 1
Recirculation Outlet – Blend Radius	Max. component stress difference is approx. 10% less	0.0108	7.74	0.084	VY-16Q-305 Rev. 0 / VY-16Q-306 Rev. 0
Recirculation Outlet – Safe End	<u>Same* for rise time and peak response</u>. Decay approx. 20% less after 220 sec.	0.0015	11.65	0.018	VY-16Q-305 Rev. 0 / VY-16Q-306 Rev. 0

* Within 1% for all time steps with significant (>1000. psi.) stress response

Table 2:

Comparison of Results for the Recirculation Outlet Nozzle Blend Radius Fatigue Usage

Recirculation Outlet Nozzle – Blend Radius	ASME 60Yr CUF	EAF Multiplier	EAF 60 yr CUFen
Calculation VY-16Q-306 Rev. 0	0.0108	7.74	0.084
New Analysis with Green's functions based on Maximum ANSYS Stress Intensity	0.0112	7.74	0.087
Difference	+3.7%	No change	+3.7%

Table 3:

Comparison of Results for the Core Spray Nozzle Safe End Fatigue Usage

Core Spray Nozzle – Safe End	ASME 60Yr CUF	EAF Multiplier Safe End	EAF 60 yr CUFen
Calculation VY-16Q-310 Rev. 1	0.0398	1.49	0.059
New Analysis with Green's functions based on Maximum ANSYS Stress Intensity	0.0417	1.49	0.062
Difference	+4.8%	No change	+4.8%

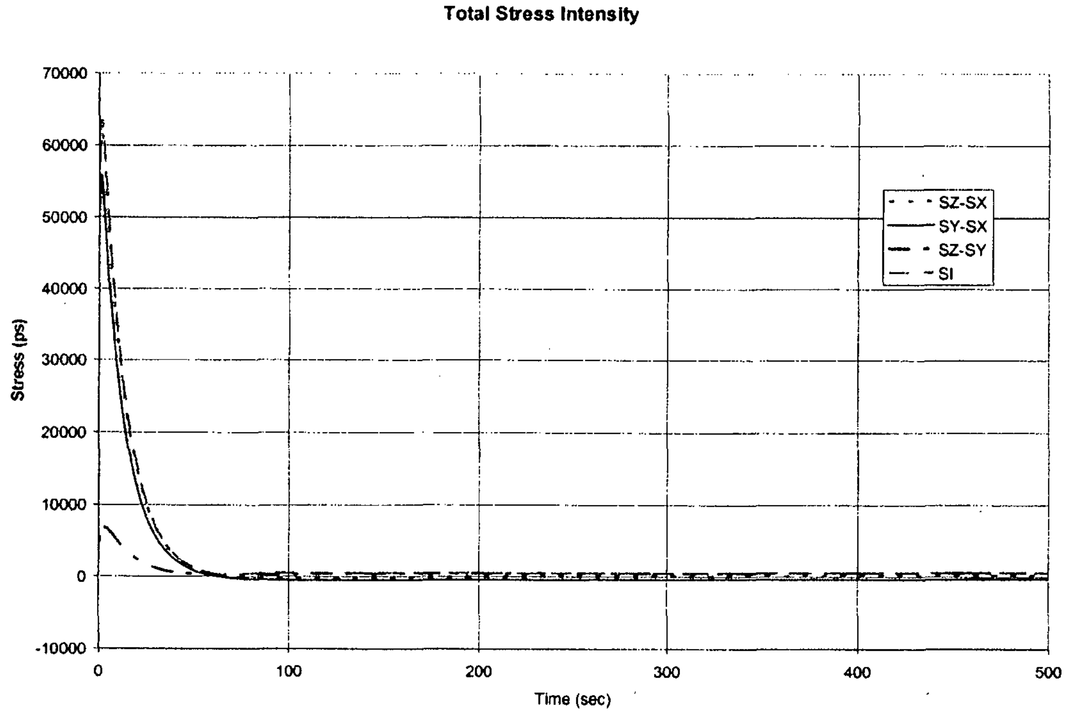

Figure 1: Feedwater Nozzle - Safe End 100% Flow Total Stress Intensity Reference: VY-16Q-301 Revision 0

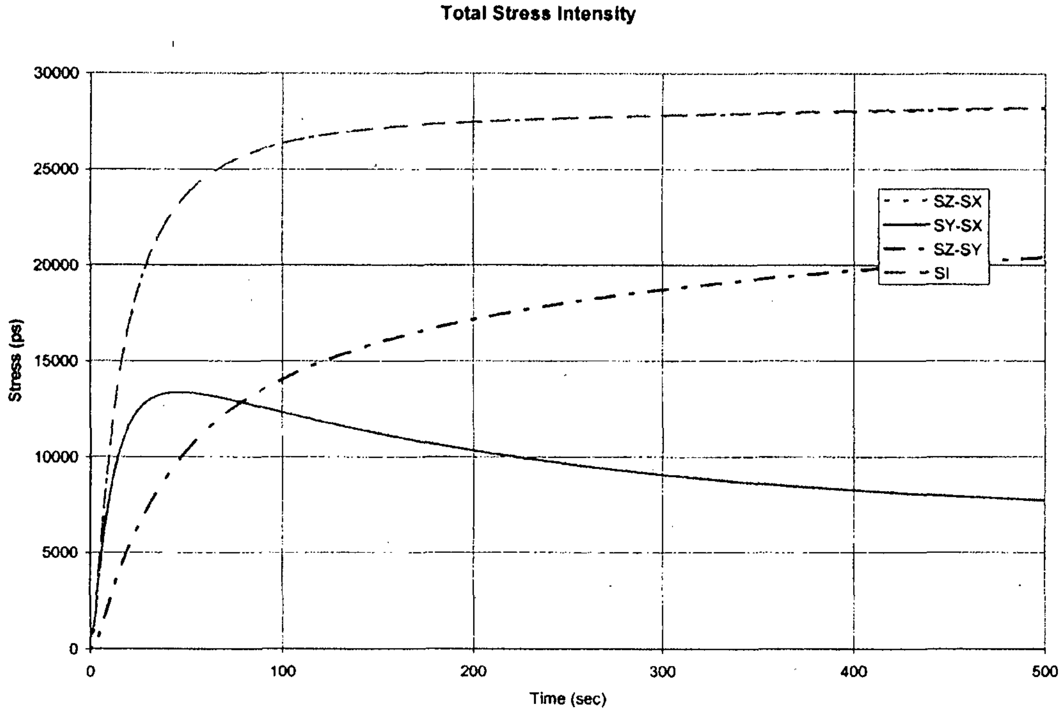

Figure 2: Feedwater Nozzle - Blend Radius 100% Flow Total Stress Intensity Reference: VY-16Q-301 Revision 0

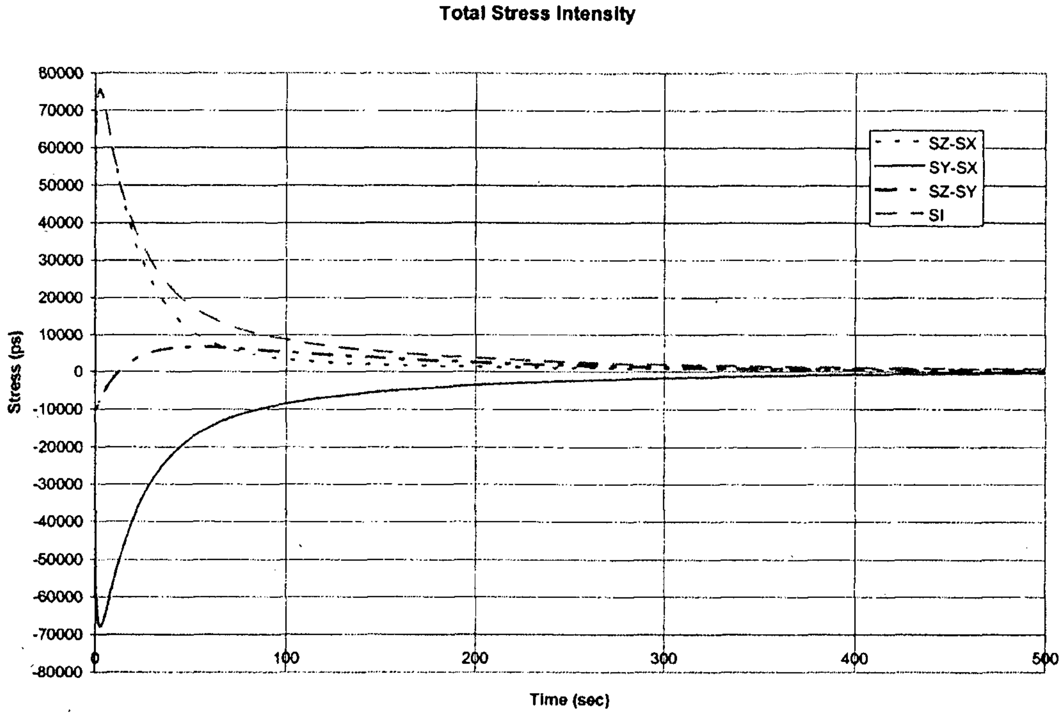

Figure 3: Core Spray Nozzle - Safe End 100% Flow Total Stress Intensity Reference: VY-16Q-309 Revision 1

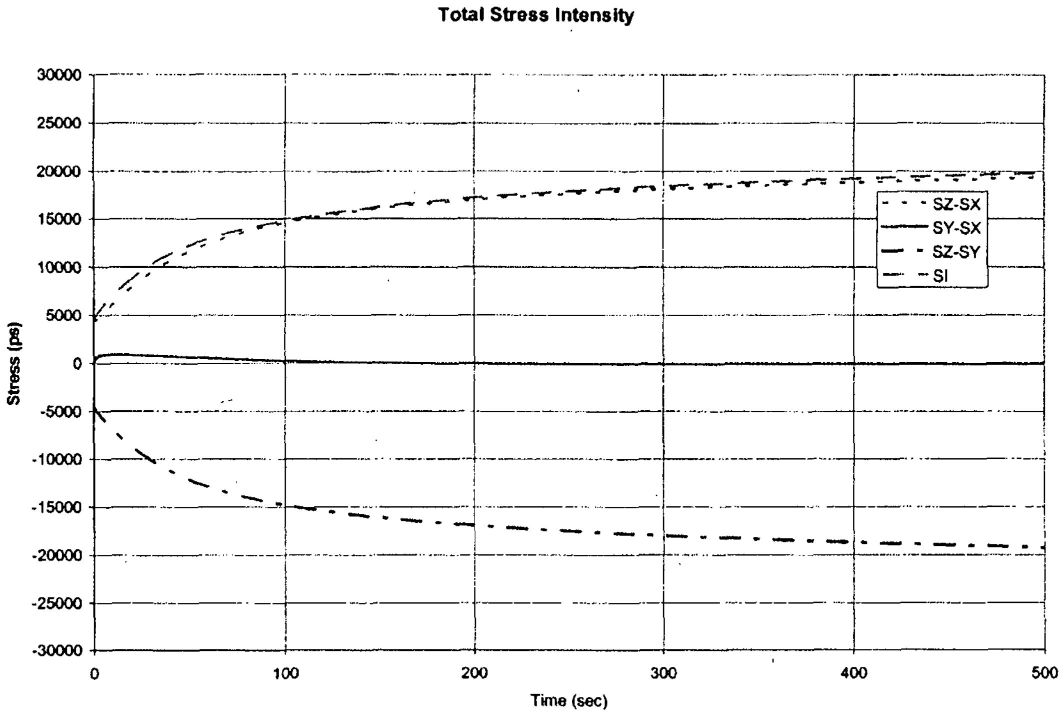

Figure 4: Core Spray Nozzle - Blend Radius 100% Flow Total Stress Intensity Reference: VY-16Q-309 Revision 1

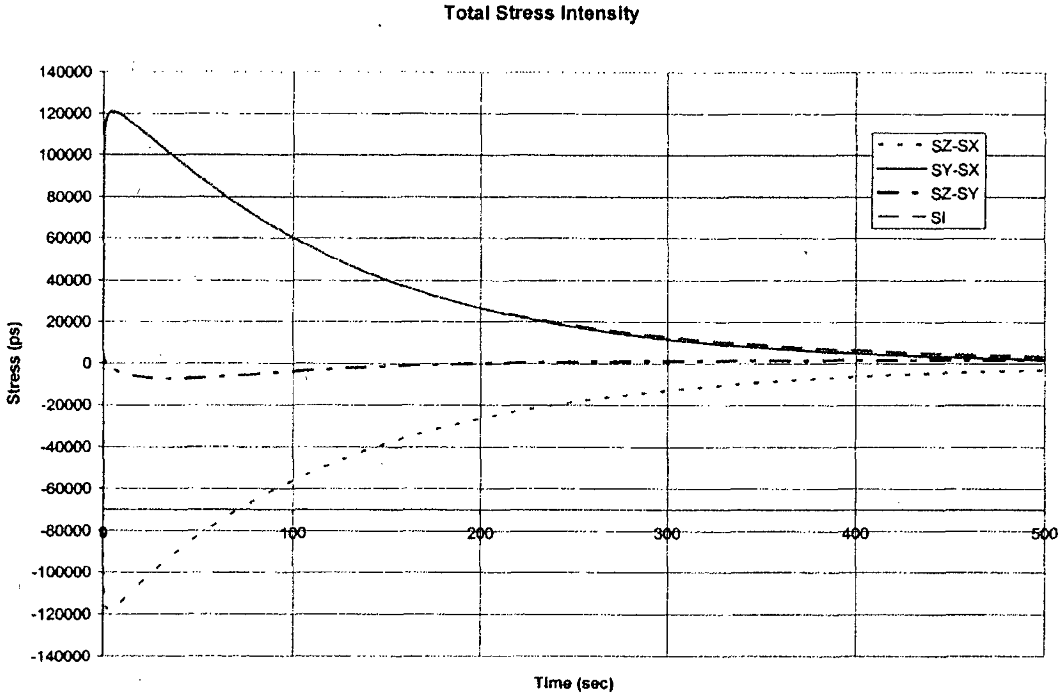

Figure 5: Recirculation Outlet Nozzle - Safe End 100% Flow Total Stress Intensity
Reference: VY-16Q-305 Revision 0

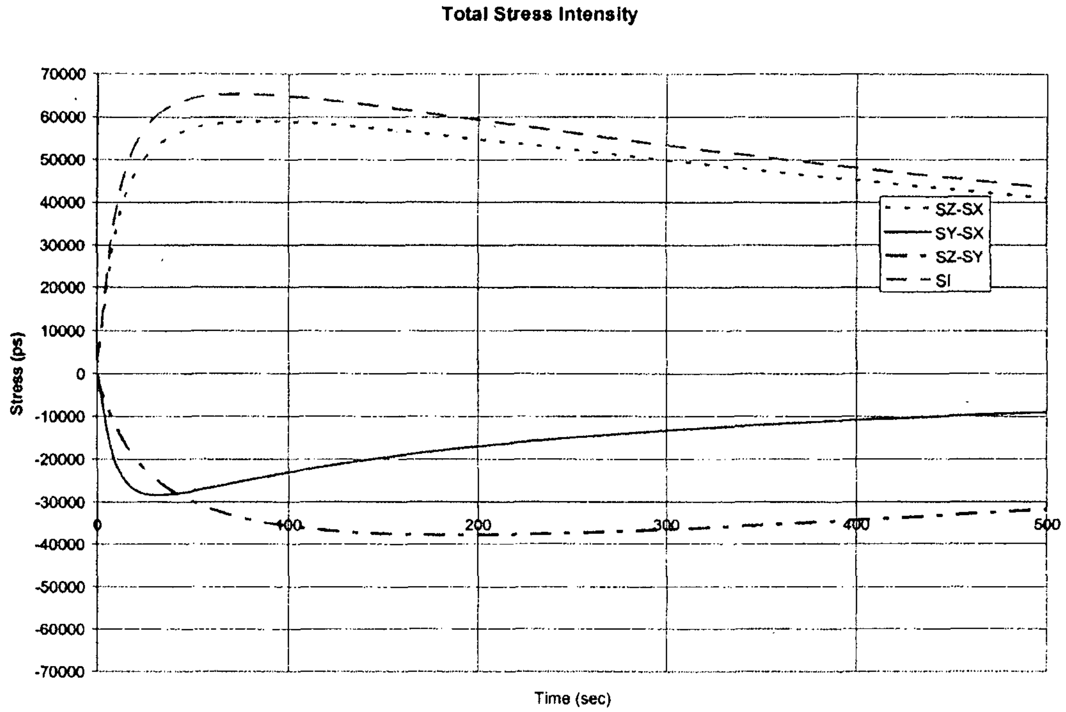

Figure 6: Recirculation Outlet Nozzle - Blend Radius 100% Flow Total Stress Intensity
Reference: VY-16Q-305 Revision 0