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Designated Original

Dominion®

April 4, 2008

U. S. Nuclear Regulatory Commission
Attention: Document Control Desk
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Rockville, MD 20852-2378

Serial No.: 07-0834L
NLOS/MAE: R1
Docket No.: 50-423
License No.: NPF-49

DOMINION NUCLEAR CONNECTICUT, INC.
MILLSTONE POWER STATION UNIT 3
RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION REGARDING STRETCH POWER UPRATE LICENSE AMENDMENT REQUEST
SUPPLEMENTAL RESPONSE TO QUESTION EMCB-07-0072

Dominion Nuclear Connecticut, Inc. (DNC) submitted a stretch power uprate license amendment request (LAR) for Millstone Power Station Unit 3 (MPS3) in letters dated July 13, 2007 (Serial Nos. 07-0450 and 07-0450A), and supplemented the submittal by letters dated September 12, 2007 (Serial No. 07-0450B), December 13, 2007 (Serial No. 07-0450C), March 5, 2008 (Serial No. 07-0450D) and March 27, 2008 (Serial No. 07-0450E). The NRC staff forwarded requests for additional information (RAIs) in October 29, 2007, November 26, 2007, December 14, 2007 and December 20, 2007 letters. DNC responded to the RAIs in letters dated November 19, 2007 (Serial No. 07-0751), December 17, 2007 (Serial No. 07-0799), January 10, 2008 (Serial Nos. 07-0834, 07-0834A, 07-0834C, and 07-0834F), January 11, 2008 (Serial Nos. 07-0834B, 07-0834E, 07-0834G, and 07-0834H), January 14, 2008 (Serial No. 07-0834D), January 18, 2008 (Serial Nos. 07-0846, 07-0846A, 07-0846B, 07-0846C, and 07-0846D), January 31, 2008 (Serial No. 07-0834I), February 25, 2008 (Serial Nos. 07-0799A and 07-0834J), March 10, 2008 (Serial Nos. 07-0846E and 07-0846F), and March 25, 2008 (Serial No. 07-0834K).

In a conference call with the NRC staff on February 27, 2008, the staff requested supplemental information to DNC's response to Question EMCB-07-0072, which was provided in DNC's February 25, 2008 letter (Serial No. 07-0834J). The requested information is provided in the attachment to this letter.

The information provided by this letter does not affect the conclusions of the significant hazards consideration discussion in the December 13, 2007 DNC letter (Serial No. 07-0450C).

A001 Rec'd DCD 5/21/08
Add: Erika Lee
C-RIPS

Should you have any questions in regard to this submittal, please contact Ms. Margaret Earle at 804-273-2768.

Sincerely,

Gerald T. Bischof
Vice President - Nuclear Engineering

COMMONWEALTH OF VIRGINIA)
)
COUNTY OF HENRICO)

The foregoing document was acknowledged before me, in and for the County and Commonwealth aforesaid, today by Gerald T. Bischof, who is Vice President - Nuclear Engineering of Dominion Nuclear Connecticut, Inc. He has affirmed before me that he is duly authorized to execute and file the foregoing document in behalf of that Company, and that the statements in the document are true to the best of his knowledge and belief.

Acknowledged before me this 4TH day of April, 2008.

My Commission Expires: May 31, 2010.

Vicki L. Hull
Notary Public

VICKI L. HULL
Notary Public
Commonwealth of Virginia
140842
My Commission Expires May 31, 2010

Commitments made in this letter: None

Attachment

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ATTACHMENT

LICENSE AMENDMENT REQUEST

STRETCH POWER UPRATE LICENSE AMENDMENT REQUEST

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

SUPPLEMENTAL RESPONSE TO QUESTION EMCB-07-0072

MILLSTONE POWER STATION UNIT 3
DOMINION NUCLEAR CONNECTICUT, INC.

Response to NRC Request For Additional Information
Stretch Power Uprate – Millstone Unit 3
Supplemental Responses To NRC Question EMCB-07-0072

NRC Request

The NRC staff requested Dominion Nuclear Connecticut, Inc. (DNC) provide a brief simplified plastic analysis for the following elements:

1. Table 2.2.2.3-1, "Maximum Range of Stress Intensity and Cumulative Fatigue Usage Factors."

   - Bottom Head Instrument Tubes, Location 1.

2. Table 2.2.2.5.2.2-1, "MPS3 SPU Structural Integrity Evaluation Summary Primary Side Components."

   - Divider Plate with Hydrotest
   - Tubesheet & Shell Junction
   - Tube-to-Tubesheet Weld
   - Blowdown Pipe

3. Table 2.2.2.7.2-2, "MPS3 Primary-Plus-Secondary Stress Intensity Ranges."

   - Surge Nozzle
   - Upper Head and Shell
   - Support Skirt Near Lower Head
   - Shell at Seismic Support Lug
   - Instrument Nozzle
   - Trunnion Buildup

DNC Response

1. Table 2.2.2.3-1, "Maximum Range of Stress Intensity and Cumulative Fatigue Usage Factors."

   Bottom Head Instrument Tubes, Location 1

   According to Section NB-3228.3 of the ASME B&PV Code, the following requirements must be met:

(a) The range of primary plus secondary membrane plus bending stress intensity, excluding thermal bending stresses, shall be less than $3S_m$.

The maximum range of primary plus secondary membrane plus bending stress intensity occurs at Location 1, and has a value of 70.67 ksi, which is > $3S_m$ = 69.9 ksi.

The stress intensity with thermal bending stresses removed is 64.38 ksi, which is < $3S_m$ = 69.9 ksi

(b) The value of the alternating stress (S_a) used for entering the design fatigue curve is multiplied by the factor K_e, where:

$$K_e = 1.0 \ for \ S_n \le 3S_m$$
$$K_e = 1.0 + \frac{1-n}{n(m-1)}\left(\frac{S_n}{3S_m} - 1\right) \ for \ 3S_m < S_n \le 3mS_m$$
$$K_e = \frac{1}{n} \ for \ S_n > 3mS_m$$

where n = 0.3 and m = 1.7 for SB-166 material.

Since the stress intensity has a value of 70.67 ksi, the value of K_e to be used in the fatigue analysis for that load combination is:

$$K_e = 1.0 + \frac{0.7}{0.3(0.7)}\left(\frac{70.67}{69.9} - 1\right) = 1.04$$

(c) The cumulative fatigue usage will be determined using the K_e factor where necessary, and must have a value below 1.0.

The K_e factor was calculated for the Location 1 primary plus secondary stress intensity range that exceeded $3S_m$, and applied to the appropriate alternating stress in the fatigue evaluation.

(d) Thermal ratcheting requirements must be met.

Thermal stress ratcheting was not specifically addressed. However, progressive distortion of the instrumentation tube and weld cannot occur due to the restrictions within the penetration hole.

(e) The maximum temperature will remain below 800°F.

The maximum temperature has been calculated to be 594°F.

(f) The ratio of minimum yield strength to minimum ultimate strength must be less than 0.8.

For SB-166, minimum S_y = 35.0 ksi and minimum S_u = 80.0 ksi. Therefore,

$$\frac{S_y}{S_u} = \frac{35.0}{80.0} = 0.44 < 0.8$$

2. Table 2.2.2.5.2.2-1, "MPS3 SPU Structural Integrity Evaluation Summary Primary Side Components."

Divider Plate

Plastic Analysis

Analysis of the divider plate made use of both plastic analysis results and elastic analysis results. The $3S_m$ limit is exceeded as a result of the hydrotest transients. (Note: these transients are not affected by the uprate and so the result of the original analysis is unaffected.) The maximum stress limit, excluding the hydrotest transients, is calculated to be 61.9 ksi following the uprate versus an allowable of 69.9 ksi. Fatigue usage is calculated per the ASME B&PV Code for these hydrotest transients. These results are then combined with those calculated plastically for these transients which exceed the stress limit per Section NB-3228.1(a) of the Code.

The hydrotest transient was analyzed plastically and it was demonstrated that after five transient cycles, shakedown occurred, per NB-3228.1(b) of the Code.

Once the strain range was calculated, a strain concentration factor equal to 2.0 was applied to all locations of interest except at the central drain cutout where a factor of 3.0 was applied. The maximum strain intensity was then multiplied by one-half of the modulus of elasticity to calculate the stress range, per NB-3228.1(c) of the Code. The maximum alternating stress calculated from the plastic analysis is 82.6 ksi and results in a maximum fatigue usage of 0.005 for the 10 cycles of the hydrotest transient. The maximum fatigue usage -doesn't occur at the point of maximum plastic stress. Further, the remaining locations evaluated produce a fatigue usage of 0.0001. The appropriate fatigue usage resulting from the plastic analysis was added to the fatigue usage calculated for the remaining transients calculated elastically.

Cumulative Usage Factor

$U = U_1 + U_2 + U_3 + U_4 + \ldots + U_{28}$

$U = 0.0136 + 0.0097 + 0.0067 + \ldots + 0.0001 = 0.072$

It is shown that the cumulative fatigue usage factor for the divider plate is less than 10% of the allowable.

Tubesheet and Shell Junction

According to Section NB-3228.3, the $3S_m$ limit may be exceeded, provided that the requirements listed in that section are met,

NB-3228.3 (a) The range of primary-plus-secondary membrane plus bending stress intensity, excluding thermal bending stresses, shall be $\leq 3S_m$.

The stress intensity is 56.5 ksi, which is $< 3S_m = 90$ ksi

NB-3228.3 (b) The value of S_a *used for entering the design fatigue curve is multiplied by the factor* K_e, *…*

The K_e factor as defined for this requirement is calculated for all stress ranges that exceed the $3S_m$ limit. S_a is multiplied by the K_e factor and this product is used to enter the design fatigue curve. This is done for all components where a simplified-elastic plastic analysis is performed.

$$K_e = 1.0 \text{ for } S_n \leq 3S_m$$

$$= 1.0 + \frac{(1-n)}{n(m-1)}\left(\frac{S_n}{3S_m} - 1\right) \text{ for } 3S_m < S_n < 3mS_m$$

$$= 1/n \text{ for } S_n \geq 3mS_m$$

S_n = range of primary-plus-secondary stress intensity.

where: $n = 0.2$ and $m = 2.0$ for low alloy steel.

Since the stress intensity (S_n) was determined as 98.6 ksi, the value of K_e to be used in the fatigue analysis is:

$K_e = 1.0 + 4\ (98.6/90.0 - 1) = 1.382$

NB-3228.3 (c) The rest of the fatigue evaluation stays the same as required in NB-3222.4, except that the procedure of NB-3227.6 need not be used.

The fatigue analysis for all components is performed per the Code. Where $3S_m$ is exceeded, the S_a used to enter the fatigue curve is multiplied by K_e and the fatigue usage for that combination is calculated. Otherwise there is no change to the methodology used to calculate the fatigue usage factor for the components.

NB-3228.3 (d) The component meets the thermal ratcheting requirement of NB-3222.5.

The components listed as applying the simplified elastic-plastic analysis methodology meet this condition either because the component is not subject to internal steady state pressure loading (blowdown pipe) or because the stress has been shown to meet the Code requirements for thermal stress ratchet.

NB-3228.3 (e) The temperature does not exceed those listed in the above table for the various classes of Code materials.

Since the maximum temperatures specified in the table of "m" and "n" parameters for various classes of Code materials, Item (b), is 700 and 800 degrees F, and none of the steam generator components exceed 700 degrees F, this requirement is met for all steam generator components.

NB-3228.3 (f) The material shall have a minimum specified yield strength to minimum specified ultimate strength ratio of less than 0.80.

Steam generator materials used within the Millstone steam generators have a minimum specified yield strength to minimum specified ultimate strength ratio less than 0.70 for the range of materials and temperatures. This is less than the maximum of 0.80 required by the Code. Therefore, this requirement is met for all of the components considered.

Cumulative Usage Factor

$$U = U_1 + U_2 + U_3 + U_4 + \ldots + U_{13}$$

$$U = 0.0025 + 0.0525 + 0.2571 + 0.0695 + 0.0249 + 0.0112 + 0.1875 + 0.2153 + 0.0007 + 0.1059 + 0.0006 + 0.0006 + 0.01 = 0.938$$

It is shown that the cumulative fatigue usage factor for the tube sheet and shell junction is less than the allowable of 1.0.

Tube-to-Tubesheet Weld

Analysis of the tube-to-tubesheet weld made use of both plastic analysis results and elastic analysis results. Exceeding the $3S_m$ limit was the result of some normal, upset and test transients. The original analysis evaluated all primary-plus-secondary stress intensities exceeding $3S_m$ inelastically in a manner similar to what was done for the divider plate above.

Based on geometry considerations (i.e., the tube is restrained by the tubesheet), and because there are no significant temperature gradients that occur in the vicinity of the tube-to-tubesheet weld, the requirements of Code paragraph NB-3222.5 are implicitly satisfied.

Inelastic analyses were performed for Primary Hydrotest, Secondary Hydrotest, Primary Leak Test, Tube Leak Test, Loss of Power, and Inadvertent Startup of an Inactive Loop in order to obtain plastic strains to show conformance with the Code. However, fatigue calculations based on linearized elastic stresses and a fatigue strength reduction factor of 4.0 to the linearized in-plane stresses and a factor of 1.215 to the tangential stresses proved more conservative, and that method was chosen for the tube-to-tubesheet weld fatigue analysis.

<u>Cumulative Usage Factor</u>

$U = U_1 + U_2 + \ldots + U_6$

$U = 0.0500 + 0.4839 + 0.1905 + 0.0201 + 0.0639 + 0.079 = 0.887$

It is shown that the cumulative fatigue usage factor for the tube-to-tubesheet weld is less than the allowable of 1.0.

Blowdown Pipe

The significant transient group used plastic analysis to evaluate the stress per the requirements of NB-3228.1 similar to what was done for the Divider Plate and Tube-to-Tubesheet Weld above. The calculated plastic stress was 140.5 ksi. The strain level calculated is within the limits of the material, which is 30 to 40% for Inconel. The next highest stress level was 74.8 ksi which is below the $3S_m$ limit.

For conservatism, the stress groups for the uprate were evaluated using NB-3228.3. This results in the increase of the maximum stress level, calculated plastically, by the K_e multiplier which leads to the calculation of a conservative fatigue usage for that transient group. Therefore, although the primary-plus-secondary stress was calculated in accordance with NB-3228.1, and thus did not require that K_e be applied to the resulting stress for the fatigue usage calculations, the plastic calculated stress meets NB-3228.3(a) of the Code and a K_e factor was calculated and applied to the stress. This conservatively results in a higher fatigue usage for that transient combination since no factor would have to be applied to a stress calculated from a plastic analysis. The following discussion addresses the requirements associated with performing a simplified elastic-plastic analysis.

Note that the discussion below for NB-3228.3(a) makes mention of the plastic analysis performed in the baseline analysis and how the requirements of NB-3228.1 were met. Conservatively, performing an elastic-plastic evaluation per NB-3228.3 would lead to a conservative calculation of the fatigue usage for this combination and this approach was used. Therefore the baseline analysis made use of both types of analysis methods in the qualification of the blowdown pipe. The uprate analysis evaluated the critical component in a conservative fashion through an adjustment of the calculated alternating stress to account for changes resulting from the uprate. An evaluation of the fatigue usage used the simplified elastic-plastic analysis methodology per NB-3228.3 to calculate the fatigue usage for the transient combination under consideration.

According to Section NB-3228.3, the $3S_m$ limit may be exceeded, provided that the requirements listed in that section are met,

NB-3228.3 (a) The range of primary-plus-secondary membrane plus bending stress intensity, excluding thermal bending stresses, shall be $\leq 3S_m$.

The baseline analysis identified that the critical stress combination exceeded $3S_m$ after excluding the thermal bending stress contribution. A plastic analysis was performed for these transients per Section NB-3228.1 of the Code. Results of the evaluation demonstrated that there are only secondary and peak stresses at the location in question, therefore the requirements of NB-3228.1(a) are satisfied. The load cycle has only 20 occurrences which limit the total accumulated plastic strain to a tolerable level and the total displacement of the structure is limited by the tubesheet displacements. Therefore, it can be concluded that shakedown, or limited deformation, will occur because the total deformation is strictly limited. Consequently, the requirements of NB-3228.1(b) are satisfied. To satisfy the requirements of NB-3228.1(c), the total strain was calculated and shown to be within the expected limits of the material.

The evaluation made use of the elastically calculated alternating stress, which is higher than the plastically calculated stress, increased by K_e for the purpose of calculating the fatigue usage. This produced a conservative estimate of the fatigue usage for these stress combinations. The results of the evaluation were shown to meet the fatigue usage allowable of 1.0 and no refinement of the calculation was required. The following discussion shows how the remaining requirements of NB-3228.3 were met.

NB-3228.3 (b) The value of S_a used for entering the design fatigue curve is multiplied by the factor K_e, ...

The K_e factor as defined for this requirement is calculated for all stress ranges that exceed the $3S_m$ limit. S_a is multiplied by the K_e factor and this product is used to enter the design fatigue curve. This is done for all components where a simplified-elastic plastic analysis is performed.

$K_e = 1.0$ for $S_n \leq 3S_m$

$$= 1.0 + \frac{(1-n)}{n(m-1)}\left(\frac{S_n}{3S_m} - 1\right) \text{ for } 3S_m < S_n < 3mS_m$$

$= 1/n$ for $S_n \geq 3mS_m$

S_n = range of primary-plus-secondary stress intensity.

where: $n = 0.3$ and $m = 1.7$ for stainless steel.

Since the stress intensity (S_n) was determined as 140.5 ksi, the value of K_e to be used in the fatigue analysis is:

$K_e = 1.0 + 3.333\ (140.5/90.0 - 1) = 2.87$

NB-3228.3 (c) The rest of the fatigue evaluation stays the same as required in NB-3222.4, except that the procedure of NB-3227.6 need not be used.

The fatigue analysis for all components is performed per the Code. Where $3S_m$ is exceeded, the S_a used to enter the fatigue curve is multiplied by K_e and the fatigue usage for that combination is calculated. Otherwise, there was no change to the methodology used to calculate the fatigue usage factor for the components.

NB-3228.3 (d) The component meets the thermal ratcheting requirement of NB-3222.5.

The components listed as applying the simplified elastic-plastic analysis methodology meet this condition either because the component is not subject to internal steady state pressure loading (blowdown pipe) or because the stress has been shown to meet the Code requirements for thermal stress ratchet.

NB-3228.3 (e) The temperature does not exceed those listed in the above table for the various classes of Code materials.

Since the maximum temperatures specified in the table of "m" and "n" parameters for various classes of Code materials, Item (b), is 700 and 800 degrees F, and none of the steam generator components exceed 700 degrees F, this requirement is met for all steam generator components.

NB-3228.3 (f) The material shall have a minimum specified yield strength to minimum specified ultimate strength ratio of less than 0.80.

Steam generator materials used within the Millstone steam generators have a minimum specified yield strength to minimum specified ultimate strength ratio less than 0.70 for the range of materials and temperatures. This is less than the maximum of 0.80 required by the Code. Therefore, this requirement is met for all of the components considered.

Cumulative Usage Factor

$$U = U_1 + U_2 + U_3 + U_4 + \ldots + U_{10}$$

$$U = 0.7713 + 0.0333 + 0.0751 + 0.0182 + 0.0101 + 0.0227 + 0.0001 + $$

$$+ 0.0031 + 0.0025 + 0.030 = 0.966$$

It is shown that the cumulative fatigue usage factor for the blowdown pipe is less than the allowable of 1.0.

3. Table 2.2.2.7.2-2, "MPS3 Primary-Plus-Secondary Stress Intensity Ranges."

Surge Nozzle

According to Section NB-3228.3, the following requirements must be met:

(a) The range of primary plus secondary membrane plus bending stress intensity, excluding thermal bending stresses, shall be less than $3S_m$.

The maximum range of primary plus secondary membrane plus bending stress intensity occurs at the outside surface of Section A-A, and has a value of 60.84 ksi, which is > $3S_m$ = 38.9 ksi.

The stress intensity with thermal bending stresses removed is 24.7 ksi, which is < $3S_m$ = 38.9 ksi

(b) The value of S_a used for entering the design fatigue curve is multiplied by the factor K_e, where:

$$K_e = 1.0 \; for \; S_n \leq 3S_m$$

$$K_e = 1.0 + \frac{1-n}{n(m-1)}\left(\frac{S_n}{3S_m} - 1\right) for \; 3S_m < S_n \leq 3mS_m$$

$$K_e = \frac{1}{n} \; for \; S_n > 3mS_m$$

where n = 0.3 and m = 1.7 for stainless steel.

Since the stress intensity had a value of 60.84 ksi, the value of K_e to be used in the fatigue analysis for that load combination is:

$$K_e = 1.0 + \frac{0.7}{0.3(0.7)}\left(\frac{60.84}{38.9} - 1\right) = 2.88$$

(c) The cumulative fatigue usage will be determined using the K_e factor where necessary, and must have a value below 1.0.

K_e factors were calculated for all primary plus secondary stress intensity ranges that exceeded $3S_m$, and applied to the appropriate alternating stress in the fatigue evaluation.

(d) Thermal ratcheting requirements must be met.

The thermal stress range was 43.11 ksi vs. an allowable thermal stress range of 43.66 ksi for section A-A.

(e) The maximum temperature will remain below 800°F.

All temperatures remain below 700°F.

(f) The ratio of minimum yield strength to minimum ultimate strength must be less than 0.8.

For stainless steel, S_y = 14.42 ksi and S_u = 57.2 ksi at the design temperature of 680°F. Therefore,

$$\frac{S_y}{S_u} = \frac{14.42}{57.2} = 0.252 < 0.8$$

Upper Head and Shell

According to Section NB-3228.3, the following requirements must be met:

(a) The range of primary plus secondary membrane plus bending stress intensity, excluding thermal bending stresses, shall be less than $3S_m$.

The maximum range of primary plus secondary membrane plus bending stress intensity occurs at the inside base metal surface of Section C-C, and has a value of 106 ksi, which is > $3S_m$ = 90 ksi.

The stress intensity with thermal bending stresses removed is 22.1 ksi, which is < $3S_m$ = 90 ksi

(b) The value of S_a used for entering the design fatigue curve is multiplied by the factor K_e, where:

$$K_e = 1.0 \; for \; S_n \le 3S_m$$

$$K_e = 1.0 + \frac{1-n}{n(m-1)}\left(\frac{S_n}{3S_m} - 1\right) \; for \; 3S_m < S_n \le 3mS_m$$

$$K_e = \frac{1}{n} \; for \; S_n > 3mS_m$$

where n = 0.2 and m = 2.0 for low alloy steel.

Since the stress intensity had a value of 106 ksi, the value of K_e to be used in the fatigue analysis for that load combination is:

$$K_e = 1.0 + \frac{0.8}{0.2(1.0)}\left(\frac{106}{90} - 1\right) = 1.71$$

(c) The cumulative fatigue usage will be determined using the K_e factor where necessary, and must have a value below 1.0.

The above K_e factor was applied to the appropriate alternating stress in the fatigue evaluation.

(d) Thermal ratcheting requirements must be met.

The thermal stress range was 99.3 ksi vs. an allowable thermal stress range of 153.4 ksi for section C-C.

(e) The maximum temperature will remain below 700°F for low alloy steel.

All temperatures remain below 700°F.

(f) The ratio of minimum yield strength to minimum ultimate strength must be less than 0.8.

For low alloy steel, S_y = 60 ksi and S_u = 90 ksi at a temperature of 700°F. Therefore,

$$\frac{S_y}{S_u} = \frac{60}{90} = 0.67 < 0.8$$

Support Skirt Near Lower Head

According to Section NB-3228.3, the following requirements must be met:

(a) The range of primary plus secondary membrane plus bending stress intensity, excluding thermal bending stresses, shall be less than $3S_m$.

The maximum range of primary plus secondary membrane plus bending stress intensity occurs at the outside surface of Section C-C, and has a value of 73.6 ksi, which is > $3S_m$ = 54.9 ksi.

The stress intensity with thermal bending stresses removed is 25.6 ksi, which is < $3S_m$ = 54.9 ksi

(b) The value of S_a used for entering the design fatigue curve is multiplied by the factor K_e, where:

$$K_e = 1.0 \text{ for } S_n \le 3S_m$$

$$K_e = 1.0 + \frac{1-n}{n(m-1)}\left(\frac{S_n}{3S_m} - 1\right) \text{ for } 3S_m < S_n \le 3mS_m$$

$$K_e = \frac{1}{n} \text{ for } S_n > 3mS_m$$

where n = 0.2 and m = 3.0 for carbon steel.

Since the stress intensity had a value of 73.6 ksi, the value of K_e to be used in the fatigue analysis for that load combination is:

$$K_e = 1.0 + \frac{0.8}{0.2(2.0)}\left(\frac{73.6}{54.9} - 1\right) = 1.68$$

(c) The cumulative fatigue usage will be determined using the K_e factor where necessary, and must have a value below 1.0.

The above K_e factor was applied to the appropriate alternating stress in the fatigue evaluation.

(d) Thermal ratcheting requirements must be met.

The thermal stress range was 15.1 ksi vs. an allowable thermal stress range of 77.3 ksi for section C-C.

(e) The maximum temperature will remain below 700°F for carbon steel.

All temperatures remain below 700°F.

(f) The ratio of minimum yield strength to minimum ultimate strength must be less than 0.8.

For carbon steel, S_y = 27.4 ksi and S_u = 70 ksi at the design temperature of 680°F. Therefore,

$$\frac{S_y}{S_u} = \frac{27.4}{70} = 0.39 < 0.8$$

Shell at Seismic Support Lug

According to Section NB-3228.3, the following requirements must be met:

(a) The range of primary plus secondary membrane plus bending stress intensity, excluding thermal bending stresses, shall be less than $3S_m$.

The maximum range of primary plus secondary membrane plus bending stress intensity occurs at the inside surface of the shell, and has a value of 103.2 ksi, which is > $3S_m$ = 90 ksi.

The stress intensity with thermal bending stresses removed is 72.75 ksi, which is < $3S_m$ = 90 ksi

(b) The value of S_a used for entering the design fatigue curve is multiplied by the factor K_e, where:

$$K_e = 1.0 \ for \ S_n \le 3S_m$$

$$K_e = 1.0 + \frac{1-n}{n(m-1)}\left(\frac{S_n}{3S_m} - 1\right) for \ 3S_m < S_n \le 3mS_m$$

$$K_e = \frac{1}{n} \ for \ S_n > 3mS_m$$

where n = 0.2 and m = 2.0 for low alloy steel.

Since the stress intensity had a value of 103.2 ksi, the value of K_e to be used in the fatigue analysis for that load combination is:

$$K_e = 1.0 + \frac{0.8}{0.2(1.0)}\left(\frac{103.2}{90} - 1\right) = 1.59$$

(c) The cumulative fatigue usage will be determined using the K_e factor where necessary, and must have a value below 1.0.

The above K_e factor was applied to the appropriate alternating stress in the fatigue evaluation.

(d) Thermal ratcheting requirements must be met.

The thermal stress range was 96.3 ksi vs. an allowable thermal stress range of 147.5 ksi for section E-E (closest to the location of the seismic lug).

(e) The maximum temperature will remain below 700°F for low alloy steel.

All temperatures remain below 700°F.

(f) The ratio of minimum yield strength to minimum ultimate strength must be less than 0.8.

For low alloy steel, S_y = 60 ksi and S_u = 90 ksi at a temperature of 700°F. Therefore,

$$\frac{S_y}{S_u} = \frac{60}{90} = 0.67 < 0.8$$

Instrument Nozzle

According to Section NB-3228.3, the following requirements must be met:

(a) The range of primary plus secondary membrane plus bending stress intensity, excluding thermal bending stresses, shall be less than $3S_m$.

The maximum range of primary plus secondary membrane plus bending stress intensity occurs at the outside surface of Section A-A, and has a value of 75.34 ksi, which is > $3S_m$ = 49.8 ksi.

The stress intensity with thermal bending stresses removed is 15.33 ksi, which is < $3S_m$ = 49.8 ksi

(b) The value of S_a used for entering the design fatigue curve is multiplied by the factor K_e, where:

$$K_e = 1.0 \; for \; S_n \leq 3S_m$$

$$K_e = 1.0 + \frac{1-n}{n(m-1)}\left(\frac{S_n}{3S_m} - 1\right) for \; 3S_m < S_n \leq 3mS_m$$

$$K_e = \frac{1}{n} for \; S_n > 3mS_m$$

where n = 0.3 and m = 1.7 for stainless steel.

Since the stress intensity had a value of 75.34 ksi, the value of K_e to be used in the fatigue analysis for that load combination is:

$$K_e = 1.0 + \frac{0.7}{0.3(0.7)}\left(\frac{75.34}{49.8} - 1\right) = 2.71$$

(c) The cumulative fatigue usage will be determined using the K_e factor where necessary, and must have a value below 1.0.

The instrument nozzle analysis satisfied the fatigue exemption requirements of NB-3222.4(d). The K_e factor was incorporated in that evaluation by multiplying the value of alternating stress used for entering the design fatigue curve by K_e.

(d) Thermal ratcheting requirements must be met.

The instrument nozzle is rolled into the shell. The constraint provided by the shell prevents thermal ratcheting of the instrument nozzle.

(e) The maximum temperature will remain below 800°F.

All temperatures remain below 700°F.

(f) The ratio of minimum yield strength to minimum ultimate strength must be less than 0.8.

For stainless steel, S_y = 18.1 ksi and S_u = 71.8 ksi at the design temperature of 680°F. Therefore,

$$\frac{S_y}{S_u} = \frac{18.1}{71.8} = 0.252 < 0.8$$

Trunnion Buildup

According to Section NB-3228.3, the following requirements must be met:

(a) The range of primary plus secondary membrane plus bending stress intensity, excluding thermal bending stresses, shall be less than $3S_m$.

The maximum range of primary plus secondary membrane plus bending stress intensity occurs at the inside base metal surface of Section C-C, and has a value of 93.6 ksi, which is > $3S_m$ = 90 ksi.

The stress intensity with thermal bending stresses removed is <14.7 ksi, which is < $3S_m$ = 90 ksi

(b) The value of S_a used for entering the design fatigue curve is multiplied by the factor K_e, where:

$$K_e = 1.0 \text{ for } S_n \leq 3S_m$$

$$K_e = 1.0 + \frac{1-n}{n(m-1)}\left(\frac{S_n}{3S_m} - 1\right) \text{ for } 3S_m < S_n \leq 3mS_m$$

$$K_e = \frac{1}{n} \text{ for } S_n > 3mS_m$$

where n = 0.2 and m = 2.0 for low alloy steel.

Since the stress intensity had a value of 93.6 ksi, the value of K_e to be used in the fatigue analysis for that load combination is:

$$K_e = 1.0 + \frac{0.8}{0.2(1.0)}\left(\frac{93.6}{90} - 1\right) = 1.16$$

(c) The cumulative fatigue usage will be determined using the K_e factor where necessary, and must have a value below 1.0.

The above K_e factor was applied to the appropriate alternating stress in the fatigue evaluation.

(d) Thermal ratcheting requirements must be met.

The thermal stress range was 97.4 ksi vs. an allowable thermal stress range of 156.92 ksi.

(e) The maximum temperature will remain below 700°F for low alloy steel.

All temperatures remain below 700°F.

(f) The ratio of minimum yield strength to minimum ultimate strength must be less than 0.8.

For low alloy steel, S_y = 60 ksi and S_u = 90 ksi at a temperature of 700°F. Therefore,

$$\frac{S_y}{S_u} = \frac{60}{90} = 0.67 < 0.8$$