Jonathan Rowley - final Section 4.3.3 for VY SER

From: Jonathan Rowley
To: Charles Hammer; Christopher Brown
Date: 02/22/2008 3:29 PM
Subject: final Section 4.3.3 for VY SER
CC: Frank Gillespie; Kenneth Chang ; Lloyd Subin; Mary Baty; Pao-Tsin Kuo; Samson Lee

Attached is the version of Section 4.3.3 of the VY SER. With this, the VY SER is complete. The compiled version of the SER will be provided to you on Monday.

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Subject: final Section 4.3.3 for VY SER
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From: Jonathan Rowley

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4.3.3 Effects of Reactor Water Environment on Fatigue Life

4.3.3.1 Summary of Technical Information in the Application

LRA Section 4.3.3 summarizes the evaluation of effects of reactor water environment on fatigue life for the period of extended operation. NUREG/CR-6260 applies fatigue design curves incorporating environmental effects on several plants and identifies locations of interest for consideration of environmental effects with the following six component locations as most sensitive to them:

(1) reactor vessel shell and lower head
(2) reactor vessel feedwater nozzle
(3) reactor recirculation piping (including inlet and outlet nozzles)
(4) core spray line reactor vessel nozzle and associated piping
(5) RHR return piping
(6) feedwater piping

Entergy evaluated the limiting locations (a total of nine components corresponding to the six most sensitive locations) with the guidance of the GALL Report, Volume 2, Section X.M.1. Seven of nine components evaluated have an environmentally adjusted CUF of greater than 1.0. The ASME Code does not require environmental adjustment for fatigue analyses.

Considering environmental effects prior to the period of extended operation, for each location that may exceed a 1.0 CUF the applicant will implement one or more of the following: (1) further refinement of the fatigue analyses to lower the predicted CUFs to less than 1.0; (2) management of fatigue at the affected locations by an inspection program reviewed and approved by the staff; or (3) repair or replacement of the affected components.

Should VYNPS select the option to manage environmental-assisted fatigue during the period of extended operation, details of the aging management program such as scope, qualification, method, and frequency will be provided to the NRC prior to the period of extended operation. The effects of environmental-assisted thermal fatigue for the limiting locations identified in NUREG-6260 have been evaluated. Cracking by environmentally-assisted fatigue of these locations will be addressed by one or more of these three approaches in compliance with 10 CFR 54.21(c)(1).

4.3.3.2 Staff Evaluation

The staff reviewed LRA Section 4.3.3 to verify: (1) in accordance with 10 CFR 54.21(c)(1)(i), that the analyses remain valid for the period of extended operation; (2) in accordance with 10 CFR 54.21(c)(1)(ii), that the analyses have been projected to the end of the period of extended operation; or (3) in accordance with 10 CFR 54.21(c)(1)(iii), that the effects of aging on the intended function(s) will be adequately managed for the period of extended operation.

The staff reviewed the technical information in LRA Section 4.3.3, pertaining to the effect of reactor water environment on the fatigue analysis of components and piping, against the criteria contained in SRP-LR Section 4.3.3.2.

SRP-LR Section 4.3.3.2 states that the applicant must address the staff recommendation for closure of General Safety Issue (GSI)-190 and also address the effects of the coolant environment on component fatigue life when aging management programs are formulated to support license renewal. If an applicant has chosen to assess the impact of the reactor coolant environment on a sample of critical components, the applicant should:

(a) Address critical components including, as a minimum, those selected in NUREG/CR-6260.

(b) Demonstrate that the sample of critical components has been evaluated by applying environmental correction factors, F_{en}, to the existing ASME Code fatigue usage factor.

(c) Demonstrate that the formulas for calculating the environmental life correction factors are those contained in NUREG/CR-6583 for carbon and low-alloy steels, and in NUREG/CR-5704 for austenitic stainless steels (SSs), or an approved technical equivalent.

The staff verified that the applicant included into the environmental assisted fatigue evaluation all the critical components selected in NUREG/CR-6260. LRA Table 4.3-3 indicated that the sample of critical components has been evaluated by applying environmental correction factors to the existing ASME Code fatigue analysis, except for reactor recirculation (RR) piping tee, core spray (CS) safe end, RHR return piping, and feedwater (FW) piping. The staff also verified the formulas for calculating the environmental life correction factors. Since the formulas follow SRP-LR guidance, they are acceptable.

During the audit and review, the staff noted that the CUFs for the components of CS safe end, FW piping, RHR return piping, and RR piping tee, in LRA Tables 4.3-1 and 4.3-3, are taken from NUREG/CR-6260 and not based on plant-specific analysis results. Staff requested that the applicant provide justification for not using plant-specific analysis results. In a letter dated July 14, 2006, the applicant revised its LRA to address this issue. In this letter, the applicant stated that LRA Table 4.3-1 has been revised to remove the NUREG/CR-6260 values for CS safe end, FW piping, RHR return piping, and RR piping tee and replaced them with "not applicable." The staff finds that CUFs for these four locations are required to address the effects of reactor coolant environment on fatigue as mentioned above.

The staff reviewed the applicant's Commitment #27, which was provided in a letter dated July 6, 2006, and LRA question and answer (Q&A) database Item 318. In the LRA Q&A database Item 318, the applicant stated that the more limiting, VYNPS-specific locations, with a valid CUF may be substituted for the NUREG/CR-6260 locations. The staff did not find the substitution proposed by the applicant acceptable since SRP-LR clearly stated that "the critical components include, as a minimum, those selected in NUREG/CR-6260." The staff asked whether the applicant will address all nine locations instead of substitutions. In a letter dated January 4, 2007, the applicant provided its revised Commitment #27. The applicant stated that more limiting VYNPS-specific locations with a valid CUFs may be added in addition to the NUREG/CR-6260 locations to address the effects of the coolant environment. Since the applicant will address more locations than the minimum required by NUREG/CR-6260, the staff finds applicant's response acceptable.

The staff requested that the applicant clarify whether oxygen concentrations derived from implementation of normal water chemistry (NWC) were factored in the environmental fatigue life correction factor (F_{en}) calculations for those operational periods when NWC was implemented instead of hydrogen water chemistry (HWC). The applicant stated that the F_{en} was estimated based on HWC oxygen concentration. Prior to the period of extended operation, VYNPS will perform fatigue analyses and an appropriate F_{en} will be used to account for operating times when both HWC and NWC are implemented. On the basis of its review, the staff finds this acceptable because both NWC and HWC will be accounted for in the fatigue analyses.

The applicant indicated that seven of nine components reviewed have an environmentally adjusted CUF of greater than 1.0 as indicated in LRA Table 4.3-3. For each location that may exceed a CUF of 1.0 when considering environmental effects prior to entering the period of extended operation, VYNPS will implement one or more of the following options:

(1) further refinement of the fatigue analyses to lower the predicted CUFs to less than 1.0;

(2) management of fatigue at the affected locations by an inspection program that has been reviewed and approved by the NRC (e.g., periodic non-destructive examination of the affected locations at inspection intervals determined by a method acceptable to the NRC);

(3) repair or replacement of the affected locations.

The staff finds that the original fatigue evaluations were analyzed based on the design transients. The applicant has plant-specific operating transient data that could be used to refine the fatigue analyses to remove the conservatism which was assumed during the design stage. The applicant also could use later developments in the ASME Code fatigue assessment to lower the CUF. On the above mentioned basis, the staff finds that option (1) is acceptable.

ASME Code, Section XI, IWB-3740(a) states that "Appendix L provides procedures that may be used to assess the effects of thermal and mechanical fatigue concerns on component acceptability for continued service." IWB-3740(b) states that "Appendix L provides procedures that may also be used when the calculated fatigue usage exceeds the fatigue usage limit defined in the original Construction Code." On the basis that option (2) meets the recommendation of the ASME Code, the staff finds option (2) acceptable.

The repair and replacement of the affected locations to ensure the structural integrity is a corrective action. On this basis, the staff finds option (3) acceptable.

In its letter dated July 6, 2006, the applicant stated that if it selects the option to manage environmental-assisted fatigue during the period of extended operation, details of the aging management program such as scope, qualification, method, and frequency will be provided to the NRC prior to the period of extended operation. The staff reviewed the applicant's letter and noted that the applicant must provide adequate time for the staff to review and approve the aging management program. The staff asked the applicant to address this issue. In a letter dated August 22, 2006, the applicant revised its LRA to address this issue. In this letter, the applicant stated that detail of the aging management program such as scope, qualification, method, and frequency will be provided to the NRC for review and approval, two-years prior to the period of extended operation. The staff finds that two-years will provide adequate time for the NRC to review and approve the aging management program.

In its letter date July 3, 2007, the applicant revised Commitment #27 to specify refinement of the fatigue analyses to lower the predicted CUFs to less then 1.0, with additional options if conditions outside the analysis bounds are indicated, at least two years prior to the period of extended operation.

In order to make a determination on the acceptability of the applicant's TLAA on EAF under the requirements of 10 CFR 54.21(c)(1), in RAI 4.3.3-1, the staff requested that the applicant provide additional information on the option (or options) that will be used for LRA Commitment #27. The applicant is requested to describe the methodology that will be used for the chosen option(s) in sufficient detail for staff review. Specifically, the staff requested that:

A. If Option (1) is chosen, describe the methodology and the process that will be used to ensure that assumptions, transients, cycles, external loadings, F_{en} values, and analysis methods are valid for the refined or new fatigue analyses.

   In the event the refined analyses performed under Option (1) result in CUFs greater than 1.0, describe the option(s) that may be used in addition to Option (1).

B. If Option (2) is chosen, describe the AMP in sufficient detail with regard to inspection scope, inspection methods, inspection frequency, and inspection qualification techniques.

C. If Option (3) is chosen, describe how the repair or replacement activity will be implemented in accordance with applicable repair or replacement requirements of the ASME Code Section XI.

In a letter dated July 30, 2007, the applicant provided its response and stated that:

> Vermont Yankee (VY) intends to comply with Commitment #27 by demonstrating, through the implementation of Option 1, that the cumulative usage factors (CUF) of the most fatigue sensitive locations are less than 1.0 throughout the license renewal period, considering both mechanical and environmental effects. The processes that will be used to develop the calculations for Option 1 are established design and configuration management processes. These processes are governed by Entergy's 10 CFR 50 Appendix B Quality Assurance (QA) program and include design input verification and independent reviews ensuring that valid assumptions, transients, cycles, external loadings, analysis methods, and environmental fatigue life correction factors will be used in the refined or new fatigue analyses.
>
> The analysis methods for determination of stresses and fatigue usage will be in accordance with an NRC endorsed Edition of the ASME Boiler and Pressure Vessel Code, Section III Rules for Construction of Nuclear Power Plant Components Division 1 Subsection NB, Class 1 Components, Subarticles NB-3200 or NB-3600 as applicable to the specific component.
>
> VY will utilize design transients from VY Design Specifications as well as design transient information from typical BWR-4 references to bound all operational transients. The numbers of cycles used for evaluation will be based on the design number of cycles and actual VY cycle counts projected out to the end of the license renewal period (60 years).
>
> Environmental effects on fatigue usage will be assessed using methodology consistent with the Generic Aging Lessons Learned Report, NUREG-1801, Revision 1, (GALL) that states; "The sample of critical components can be evaluated by applying environmental life correction factors (F_{en} Methodology) to

the existing ASME Code fatigue analyses. Formulae for calculating the environmental life correction factors are contained in NUREG/CR-6583 for carbon and low-alloy steels and in NUREG/CR-5704 for austenitic stainless steels."

The Fatigue Monitoring Program currently tracks actual plant transients and evaluates these against the design transients. Current cycle counts show no limits are approached or are expected to be approached for the current license term. VY has committed to modify the current fatigue monitoring program to require periodic updates of the cumulative usage factors and to include corrective actions if the numbers of analyzed transients are approached (LRA Commitments #5 and #7). The Fatigue Monitoring Program will ensure that the numbers of transient cycles experienced by the plant remain within the analyzed numbers of cycles and hence, the component CUFs remain below the values calculated in the design basis fatigue evaluations. If ongoing monitoring indicates the potential for a condition outside that analyzed above, Vermont Yankee may perform further reanalysis of the identified configuration using established configuration management processes as described above.

If Option 2 of Commitment #27 becomes necessary, the inspection program submitted for approval by the NRC will be described in terms of the ten elements specified in Branch Technical Position RLSB-1 (NUREG-1800, Appendix A-1). Parameters monitored will be the presence and sizing of cracks. Frequency of inspection and acceptance criteria will be established such that detection of aging effects will occur before there is a loss of the component intended function(s). The method of inspection will be a qualified volumetric technique based on plant-specific and industry-wide operating experience.

If Option 3 becomes necessary, repair or replacement of the effected component(s) will be in accordance with established plant procedures governing repair and replacement activities. These established procedures are governed by Entergy's 10 CFR 50 Appendix B QA program and meet the applicable repair or replacement requirements of the ASME Code Section XI.

The staff reviewed the applicant's implementation plan for using Option (1) of Commitment #27 against the staff's recommendation in SRP-LR Section 4.3.3.2, "Generic Safety Issues." The staff determined that the refined environmentally-assisted fatigue calculations would be based on the recommendations for performing environmentally-assisted fatigue calculations in NUREG/CR-6583 for steel components and in NUREG/CR-5704 for stainless steel components and that the methods for determination of stresses and fatigue usage factors would be in accordance with an NRC-endorsed edition of the ASME Code Section III, Division 1 Subsection NB, Subarticles NB-3200 or NB-3600, as applicable to the specific component. The staff determined that the option is in conformance with the "corrective actions" recommendations in the both the Standard Review Plan for License Renewal SRP-LR and in GALL AMP X.M1, "Metal Fatigue of the Reactor Coolant Pressure Boundary." Based on this assessment, that staff concludes that Option (1) of Commitment #27 is an acceptable "corrective actions" option for this TLAA.

The staff determined that the implementation plan for using Option (2) of the commitment conforms to the examination provisions stated in paragraph L-3400 of the ASME Code Section XI, Non-mandatory Appendix L and with "corrective actions" recommended in GALL

AMP X.M1. Based on this assessment, that staff concludes that Option (2) of Commitment #27 is an acceptable "corrective actions" option for this TLAA.

The staff determined that, since the implementation of repair and replacement activities will be based on applicable ASME Code Section XI requirements, Option (3) of Commitment #27 is consistent the "corrective actions" recommended in GALL AMP X.M1. On this basis, the staff concludes that Option (3) of Commitment #27 is also an acceptable "corrective actions" option for this TLAA. Therefore, the staff's concern described in RAI 4.3.3-1 is resolved.

In a letter dated September 17, 2007, the applicant amended the LRA with respect to its basis for its environmentally-assisted fatigue analysis. The applicant submitted the refined fatigue analyses results for all the locations identified in NUREG/CR-6260. The staff noted that this fatigue analyses results submission is in accordance with Option (1) under Commitment #27, which indicates that for NUREG/CR-6260 locations, the applicant will refine the fatigue analysis to demonstrate that the predicted CUF is less than 1.0 prior to the period of extended operation. The applicant provided additional information on Fatigue Monitoring Program (FMP) to reflect the refined fatigue analyses. The staff reviewed the additional information on the FMP and determines that the FMP now includes the assessment of the impact of reactor water environment on critical components, as identified in NUREG/CR-6260. The FMP will be consistent with GALL AMP X.M1. The transients assumed in the assessment will be added to the FMP, which will track and periodically review the transient cycles to ensure that they are less than the cycles analyzed during the period of extended operation. On this basis, the staff finds the additional information submitted by the applicant on the FMP acceptable from a cycle counting point of view in an attempt to demonstrate compliance with 10 CFR 54.21(c)(1)(iii). However, the "corrective actions" element of the FMP allows for refinement of the fatigue analyses.

The staff needed to verify the validity of the applicant's EAF analyses at NUREG/CR-6260 locations. Therefore, the staff performed an additional audit (on October 9-10, 2007) at VYNPS. During the audit, the staff asked six questions relating to the stress analysis using Green's function or the ANSYS software. Specifically, the applicant was asked to explain how stress intensity for thermal transients was calculated for the locations that were identified in NUREG/CR-6260.

In a letter dated November 14, 2007, the applicant explained that for each controlling location, the component stress differences which most closely matched the total stress intensity calculated by ANSYS was used as input for the calculation. In addition, the applicant stated 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."

The staff reviewed the applicant's response and determined that shear stress can not be neglected in the calculation for stress intensities which were used to determine CUFs of all NUREG/CR-6260 locations. The applicant's implementation of the Green's function input to the software assumes that shear stresses are negligible. This implementation is a simplified NB-3200 analysis for regular piping as stated in NB-3653.2 of ASME Section III. It is numerically adequate at the safe-end when non-symmetric loadings are not applicable. This implementation may not be valid for those locations with geometric discontinuity or non-symmetric load cases (e.g., thermal stratifications), which may cause significant shear stresses. However, it is difficult to determine the threshold for the when shear stresses are negligible. Therefore, the applicant's implementation for calculating the stress intensity cannot be validated. The staff concluded that the way the software calculates the stress intensity is inconsistent with the ASME Code. Therefore, the staff could not conclude the validity of refined fatigue analysis calculation and RAI 4.3.3-2 was issued, in which the applicant was asked to provide the following:

> "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 quantities 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."

In a letter dated December 11, 2007, the applicant provided its response to RAI 4.3.3-2. In the response, the applicant stated that "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." The applicant extended the fatigue analysis from 40 years to 60 years by multiplying the design transient cycles by a factor of 1.5 and the resulting CUF was further multiplied by F_{en} to obtain the EAF CUF. The values were under the Code limit of 1.0. This is consistent with the ASME Code and the SRP-LR. The staff's concerns at the RPV vessel shell/bottom head, RPV shell at shroud support, RR Class 1 piping, RR inlet nozzle forging, and RR outlet nozzle forging locations (locations 1, 2, 4, 5, and 6 of the September 17, 2007 supplement) are resolved. New stress analyses were performed for the FW, RR outlet, and CS nozzles (locations 3, 7, 8, and 9 of the September 17, 2007 supplement) per ASME III, NB-3200. At these locations, the applicant provided additional EAF analysis data where maximum component stress differs from the stress intensity calculated by ANSYS. The applicant also provided plots with comparison between the component stress differences, (SZ-SX, SY-SX, SZ-SY), and stress intensity calculated from ANSYS.

To justify its use of maximum component stress difference and that shearing stresses can be neglected, the applicant provided evaluations of FW, RR outlet, and CS nozzles at the safe end and the blend radius locations. In these evaluations, the staff noted that for thermal transients, maximum stress differences and intensities were calculated with a software using Green's functions and the computer code ANSYS. In addition, the staff noted these stress intensities for thermal transient were combined directly with the stress intensities from pressure and attached piping loads. The pressure stresses were simulated by increasing the radius to 1.5 times that of the header radius along with using a stress multiplier of 1.33. The CUFs calculated using the above mentioned method was compared to the CUFs submitted by the applicant on September 17, 2007. As indicated in the letter, both the safe end and the blend radius locations showed the difference in calculated CUFs from the two analyses for 60 years, including environmental effects, is 0.003.

To address the staff's concern regarding locations with geometrical discontinuities as well as stress differences at the 0-180 degree axis and the 90-270 degree axis, the applicant stated in the letter that:

"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 staff reviewed the applicant's response as well as the additional calculations and determined that the applicant did not resolve the staff's concerns. Specifically, the staff noted that it was reported in the applicant's response that component stress differences could be 10% to 50% lower than the maximum stress intensity calculated by ANSYS. In addition, the staff noted that the applicant utilized the Green's function as part of the computer software input to calculate stresses due to temperature transient. The staff noted for new evaluations performed, new Green's functions must be developed using maximum stress intensity calculated by ANSYS. The staff finds there is not enough information to assure the validity of the Green's function input. The concerns identified above were related to the applicant via a telephone conference call on December 18, 2007. The applicant and the staff were unable to resolve the issues raised, and the applicant requested to have a public meeting to further discuss the EAF analysis performed for the plant.

On January 8, 2008, the Office of Nuclear Reactor Regulation staff and Entergy (Vermont Yankee) met in a public meeting to discuss the response to the RAI. Following the applicant's presentation and discussion, the applicant agreed to perform a updated EAF analysis on the reactor pressure vessel FW nozzle. The FW nozzle was selected for analysis because it is the limiting case among the three nozzles being reviewed. It is subjected to more transients and cycles, and the transients are more severe.

This analysis would use the same axisymmetric finite element model, thermal transients, transients cycles, and water chemistry input as the analysis submitted on December 11, 2007. The updated analysis would use ASME Code, Section III, Subsection NB-3200 methodology to calculate the stress intensities. In addition, the updated analysis will use ANSYS computer code without referencing Green's functions or any special purpose computer software, apply ASME code rules such as elastic-plastic correction factor, Ke, and stress intensities correction factor for modulus of elasticity. The use of environmental fatigue life correction factor (F_{en}) must be justified for each transient pair. The staff noted the thermal transients and axisymmetric finite element model from the previous fatigue analysis to be used in this updated analysis have been reviewed and accepted and the issues related to them were resolved during the audit (October 9-10, 2007). In addition, the staff finds that by following the described process, this analysis would have the technical merit to demonstrate the FW nozzle fatigue analysis meets the requirements of ASME Code, Section III, Subsection NB-3200..

In a letter dated January 30, 2008, the applicant submitted the results of the updated FW analysis to the NRC. The staff noted that for both the safe end and the blend radius of the FW nozzle, the reported CUF values are lower in this analysis than the previous EAF analysis submitted on December 11, 2007. The applicant stated in this letter that the parameters, data, and methodology (described in the previous paragraph) used for the updated analysis are the same as those agreed upon following the January 8, 2008 public meeting.

The staff reviewed the results of final analysis, and requested that the applicant provide responses to two additional questions. The applicant was asked to demonstrate why the final analysis for the FW nozzle bounds the geometry of the recirculation outlet nozzle. In addition, the applicant was asked to describe how water chemistry effects were accounted for in the CUF calculation for EAF. In a letter dated February 5, 2008, the applicant submitted its response. In response to the question on the applicability of FW geometry to bound the geometry of the recirculation outlet nozzle, the applicant indicated that BWRVIP-108 included evaluation of a recirculation outlet nozzle and other nozzle configuration. BWRVIP-108 shows the recirculation outlet nozzle configuration does not have stress results that are significantly different from the other nozzle configurations. The staff reviewed the applicant's response as well as part of BWRVIP-108 to confirm that the recirculation outlet nozzle does not provide significantly different stress results from other locations evaluated in the report. In addition, the staff noted that the axisymmetric model does provide accurate geometry for the different stresses between the skewed inside surface for thermal transient and the pressure loadings for the branch pipe at the nozzle. On these bases, the staff finds the applicant's response acceptable.

In response to the water chemistry effects question, the applicant stated that

> "Per Section X.M1 of NUREG 1801 (GALL Report) the environmentally assisted fatigue (EAF) evaluations used appropriate Fatigue Life Correction Factors (F_{en}) calculated using the methodology in NUREG/CR-6583 for carbon and low alloy steels and NUREG/CR-5704 for stainless steels."

In addition, the applicant provided an explanation on how input values of these variables were selected to maximize most of the calculated F_{en} factors. The staff reviewed the applicant's response and finds that the applicant did not fully describe the water chemistry inputs for the F_{en} value. Therefore, the staff could not reach the conclusion that F_{en} was conservatively calculated using the methodology in NUREG/CR-6583 for carbon and low alloy steels and NUREG/CR-5704 for stainless steels, and requested an audit of the final analysis.

During the audit on February 14, 2008, the staff reviewed the four inputs used to develop the F_{en} factors in NUREG/CR-6583: dissolved oxygen, strain rate, temperature and sulfur content. In addition, the staff noted that NUREG/CR-5704 uses three of these four inputs (dissolved oxygen (DO), strain rate, and temperature) to develop the F_{en} value. During the audit, the staff asked the applicant to provide additional information on the monitoring of DO by the plant, and confirm that DO level was used as part of the input to develop the F_{en} factor. In its response, the applicant confirmed that DO was used as an input and the value was obtained by averaging the DO data over 13 years with one standard deviation added for conservatism. The applicant stated that DO data was obtained by daily oxygen sampling at the plant, and submitted these DO data to the NRC in a letter dated February 21, 2008 . The staff noted that the DO input to the F_{en} might not be accurate because during transients, DO values might be higher than those calculated using the method stated. The staff therefore asked the applicant to describe when DO excursions may occur. The applicant responded that excursion occurred at startup and provided the data it accrued thus far for confirmation. The staff noted that for a BWR, there are no significant thermal transients for the FW nozzle during the startup period. Therefore, the staff finds that the excursion of DO has no impact on the CUF and the DO value for F_{en} calculation to be conservative for the purpose of calculating CUF.

The staff also reviewed the strain rate and sulfur content inputs to the F_{en} factor, and noted that the input values for these two variables were the bounding values for F_{en} calculations, as defined by NUREG/CR-6583. In addition, the strain rate input also maximizes the F_{en} value for austenitic stainless steel, as defined by NUREG/CR-5704. The staff reviewed the temperature used in the F_{en} calculation, and noted that the applicant uses the normal operating temperature of 550°F to maximize the effects on F_{en} factor and therefore finds it to be conservative.

To ensure the validity of these four inputs for the period of extended operation (PEO), the staff asked the applicant if these inputs will remain bounding in the PEO. The applicant responded that all inputs except DO will remain valid for the PEO. The applicant further explained that Water Chemistry and Fatigue Monitoring Programs will ensure that DO value remains below the DO value used as the input to the F_{en} factor. On this basis, the staff finds the applicant adequately accounted the water chemistry effects in the evaluation of environmentally assisted fatigue.

In the January 30, 2008 letter, the applicant included an update to supplement the EAF analysis of the CS nozzle included in the September 17, 2007 submittal. During the February 14, 2008 audit, the staff asked the applicant to provide an explanation for the change in CS nozzle forging blend radius environmentally-assisted CUF value, documented in the January 30, 2008 letter. In its response, the applicant stated that the change was to correct a computer code input error that was now corrected in accordance to the design specification. In a letter dated February 21, 2008, the applicant submitted its condition report on this correction. The staff reviewed the report and finds it acceptable because design transients are correctly applied to the CS.

During the audit, the staff reviewed the axisymmetric finite element model, analyzed transient definitions and cycles, and water chemistry input into the final analysis for the FW nozzle to ensure that these parameters are the same as previously analyzed. The staff reviewed the updated analysis for the FW nozzle and finds that the applicant correctly applied elastic-plastic correction factor, adjusted the modulus of elasticity ratios for stress intensities, and selected the bounding environmental fatigue life correction factor for each transient pair. During the audit, the staff noted that the September 17, 2007 and December 11, 2007 EAF analyses used the maximum F_{en} for all transients pairs while the final analysis uses a different, but appropriate value for each transient pair. The staff asked the applicant to provide the CUF value at the FW nozzle blend radius using the maximum F_{en} value used in the previous analyses. With the maximum F_{en} value used, the new EAF CUF is 0.893 (this value was verbally provided during the audit), which is greater than the previous value of 0.639 reported by using the Vermont Yankee Green's function application. This indicates that the results of the Green's function application using the specific software could underestimate the CUF, and therefore, can not be the analysis of record. However, the final analysis, whether using the maximum F_{en} or appropriate F_{en}'s, yields CUFs lower than the Code allowable. The staff concludes that these final analysis should be considered as the analysis of record for the FW nozzle. Based on the above discussion, the staff concludes that similar analysis should be performed for the CS and the RR outlet nozzles and that these analyses should be documented as the "analysis of record" for these two nozzles.

On this basis, the staff finds that although the applicant has used a 2-dimensional axisymmetric model to handle thermal transient and pressure, it did consider the six stress components and use them to develop three principle stresses and the stress intensities. Therefore, the staff finds that for the updated analysis of the FW nozzle, the stress intensities and the CUFs are calculated in accordance with ASME code requirements. The staff concluded that the updated

FW analysis consistent with the rules of the ASME Section III Code yields lower EAF CUF values for the FW nozzle. In the letter dated February 21, 2008, the applicant stated that it considers the updated EAF analysis, submitted in the January 30, 2008 letter, as the analysis of record for the FW nozzle. The staff's concern expressed in RAI 4.3.3-2 is resolved. However, a license condition for performing the ASME Code analysis for the CS and the RR outlet nozzles will remain in effect until the applicant has completed and submitted those final analysis for NRC review and approval no later than two years prior to entering the PEO.

4.3.3.3 UFSAR Supplement

The applicant provided a UFSAR Supplement summary description of its TLAA evaluation of effects of reactor water environment on fatigue life in LRA Section A.2.2.2.3.

The staff reviewed the applicant's Commitment #27 and concludes that implementation of this commitment prior to period of extended operation will address environmentally assisted fatigue for the seven components which have not been addressed.

On the basis of its review of the UFSAR Supplement, the staff concludes that the summary description of the applicant's actions to address effects of reactor water environment on fatigue life is adequate.

4.3.3.4 Conclusion

On the basis of its review, and Commitment #27 as discussed above, the staff finds that the applicant has demonstrated that, as required by 10 CFR 54.21(c)(1)(iii), the effects of aging on the intended function(s) will be adequately managed for the period of extended operation. The staff also concludes that the UFSAR Supplement contains an appropriate summary description of the TLAA evaluation, as required by 10 CFR 54.21(d).