Safety Evaluation Report

Related to the License Renewal of Vermont Yankee Nuclear Power Station

Supplement 1

Docket No. 50-271

Entergy Nuclear Operations, Inc.

U.S. Nuclear Regulatory Commission

Office of Nuclear Reactor Regulation

May 2009

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ABSTRACT

This document is a supplemental safety evaluation report (SSER) for the license renewal application for Vermont Yankee Nuclear Power Station (VYNPS) as filed by Entergy Nuclear Operations, Inc. and Entergy Nuclear Vermont Yankee, LLC. (Entergy or the applicant). By letter dated January 25, 2006, Entergy submitted its application to the United States Nuclear Regulatory Commission (NRC) for renewal of the VYNPS operating license for an additional 20 years. The NRC staff published a final safety evaluation report (SER) in two volumes, dated May 2008, which summarizes the results of its safety review of the renewal application for compliance with the requirements of Title 10, Part 54, of the *Code of Federal Regulations*, (10 CFR Part 54), "Requirements for Renewal of Operating Licenses for Nuclear Power Plants." This document only lists the changes to the May 2008 SER.

This SSER documents the safety review results of confirmatory environmentally adjusted fatigue cumulative usage factors analyses for the reactor core spray nozzle and the reactor pressure vessel recirculation outlet nozzle at VYNPS. The applicant provided these analyses in response to the staff's proposed license condition that would require Entergy to perform these fatigue analyses no later than two years prior to entering the period of extended operation.

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TABLE OF CONTENTS

Appendices

ABBREVIATIONS

ACRS	Advisory Committee on Reactor Safeguards
ASLBP	Atomic Safety and Licensing Board Panel
ASME	American Society of Mechanical Engineers
CS	core spray
CFR	Code of Federal Regulations
CUF	cumulative usage factor
CUF_{en}	environmentally assisted fatigue cumulative usage factor
DO	dissolved oxygen
HWC	hydrogen water chemistry
F_{en}	environmental fatigue life correction factor
FW	feedwater
LAS	low-alloy steel
LRA	license renewal application
NRC	Nuclear Regulatory Commission
NWC	normal water chemistry
RO	recirculation outlet
SER	safety evaluation report
SSER	supplemental safety evaluation report
US	United States
UFSAR	updated final safety analysis report
VYNPS	Vermont Yankee Nuclear Power Station

SECTION 1

INTRODUCTION AND GENERAL DISCUSSION

1.1 Introduction

This document is a supplemental safety evaluation report (SSER) for the license renewal application (LRA) for Vermont Yankee Nuclear Power Station (VYNPS) as filed by Entergy Nuclear Operations, Inc. and Entergy Nuclear Vermont Yankee, LLC. (Entergy or the applicant). By letter dated January 25, 2006, Entergy submitted its application to the United States Nuclear Regulatory Commission (NRC) for renewal of the VYNPS operating license for an additional 20 years. The NRC staff (the staff) issued a final safety evaluation report (SER) in two volumes, dated May 2008, which summarizes the results of its safety review of the renewal application for compliance with the requirements of Title 10, Part 54, of the *Code of Federal Regulations*, (10 CFR Part 54), "Requirements for Renewal of Operating Licenses for Nuclear Power Plants." This SSER supplements portions of Sections 1.1, 4.3.3, and Appendix B of the May 2008 SER.

In letters dated January 15, 2009, and March 12, 2009, Entergy provided the results of its confirmatory environmentally adjusted fatigue cumulative usage factors analyses for the VYNPS reactor pressure vessel recirculation outlet nozzle and the reactor core spray nozzle. The letters provide Entergy's response to the fourth proposed license condition stated in Section 1.7 of the final SER, which would require performing fatigue analysis on these nozzles in accordance with the American Society of Mechanical Engineers Boiler and Pressure Vessel Code at least two years prior to entering the period of extended operation.

1.7 SUMMARY OF PROPOSED LICENSE CONDITIONS

The staff does not have any changes or updates to this section of the final SER.

SECTION 2

STRUCTURES SYSTEMS AND COMPONENTS

The staff does not have any changes or updates to this section of the final safety evaluation report.

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SECTION 3

AGING MANAGEMENT REVIEW RESULTS

The staff does not have any changes or updates to this section of the final safety evaluation report.

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SECTION 4

TIME LIMITED AGING ANALYSIS

4.3.3 Effects of Reactor Water Environment on Fatigue Life

4.3.3.1 Summary of Technical Information in the Application

The staff does not have any changes or updates to this section of the final safety evaluation report (SER).

4.3.3.2 Staff Evaluation

The staff discussed Entergy's Nuclear Operations, Inc. (Entergy's) confirmatory analysis of the feedwater (FW) nozzle in the final SER. Entergy performed the confirmatory analysis of the FW nozzle to address concerns raised by the staff regarding the Green's function methodology used to calculate the fatigue cumulative usage factor (CUF) for three reactor vessel nozzles at the Vermont Yankee Nuclear Power Station (VYNPS).

The Green's function methodology involves performing a detailed stress analysis of a component to calculate its response to a step change in temperature. This detailed analysis is used to establish an influence function, which is subsequently used to calculate the stresses caused by actual plant temperature transients. In implementing this approach, Entergy used a simplified input for applying the Green's function in which only one component of stress tensor was used for the evaluation of the actual plant transients. The detailed stress analysis, however, requires consideration of six stress components, as discussed in the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (ASME Code), Section III, Subarticle NB-3200. Thus, the concern is whether the simplified input for the Green's function methodology provided acceptable and conservative results. Entergy used the simplified input for applying the Green's function to perform fatigue calculations at the reactor vessel FW nozzle, recirculation outlet (RO) nozzle and core spray (CS) nozzle. The analyses that utilized the Green's function methodology are referred to as the refined analyses in this supplemental safety evaluation report.

Entergy performed a confirmatory analysis of the reactor vessel FW nozzle to demonstrate the validity of using the simplified input in conjunction with the Green's function methodology. The FW nozzle was selected because it had the largest CUF of the three nozzles where the Green's function methodology was used. The confirmatory analysis resulted in an acceptable CUF for the FW nozzle. However, the confirmatory analysis did not demonstrate the conservatism of the Green's function methodology used by the applicant. As a consequence, the staff proposed a license condition which would require that Entergy perform confirmatory ASME Code analyses for the CS and RO nozzles.

The staff's proposed license condition would require Entergy to perform the fatigue analysis of the CS and RO nozzles in accordance with the methodology of the ASME Code and submit the analyses to the staff for review and approval no later than two years prior to entering the period of extended operation. Entergy submitted the analyses by letter dated January 15, 2009. Entergy indicated that the methodology applied to the CS and RO nozzle confirmatory analyses was in accordance with the approach used for the FW confirmatory analysis and contained no significantly different scientific or technical judgments from those used in the FW nozzle calculations. Entergy reported confirmatory environmentally adjusted fatigue cumulative usage factor (CUF_{en}) analyses for each of the nozzles that were well within the allowable limit of 1.0. Entergy reported the CUF_{en} at two locations for each nozzle. These locations were the low-alloy steel (LAS) nozzle blend radius and the nozzle safe end. The highest CUF_{en} reported was in the LAS nozzle blend radius for both nozzles. The confirmatory analysis CUF_{en} for the CS nozzle blend radius was lower than the refined analysis, and the confirmatory analysis CUF_{en} for the RO nozzle blend radius was higher than the refined analysis. The staff considered the differences between the reported CUFs in the refined and confirmatory analyses to be illustrative of the concern regarding potential nonconservatisms of the applicant's simplified input for the Green's function methodology.

The staff reviewed the analysis methodology identified in the calculations. The finite element analyses were based on the previous ANSYS axisymmetric models that were used to develop the Green's functions (ANSYS is finite element analysis software). However, the Green's function methodology was not used in the confirmatory analyses. All six components of stress were extracted from finite element analyses of all transients and then used in calculating the fatigue usage factor in accordance with subarticle NB-3200 in Section III of the ASME Code. This methodology is the same approach used in the FW confirmatory analysis and is acceptable to the staff.

The RO and CS nozzles are constructed from LAS, clad with stainless steel. For the fatigue analysis, stresses at the nozzles were extracted from the LAS material. ASME Code Section III, Subparagraph NB-3122.3, states that for stresses and fatigue evaluation purposes the presence of the cladding should be considered in the analyses and both materials, cladding and base metal, shall meet the code stresses and fatigue requirements. However, if the integrally bonded cladding is 10 percent or less of the total thickness of the component, subparagraph NB-3122.3 states that the cladding does not need to be added to the component's structural integrity, and the analyst is allowed to exclude the cladding and evaluate only the stresses and fatigue on the base metal.

Entergy included the cladding in the ANSYS finite element model for the RO and CS nozzles, but since the cladding is less than 10 percent, the cladding was excluded from the fatigue analysis. The stresses were extracted on the LAS base metal surface adjacent to the cladding (base metal stresses), which were then used to evaluate the base metal for fatigue usage. The staff finds that this approach satisfies the ASME Code requirements and is, therefore, acceptable.

The calculation of the environmental fatigue life correction factors (F_{en}) for the LAS RO and CS nozzles was in accordance with NUREG/CR-6583, "Effects of LWR Coolant Environments on Fatigue Design Curves of Carbon and Low-Alloy Steels," issued March 1998. The staff reviewed the four inputs (sulfur content, temperature, strain rate and dissolved oxygen (DO))

used to develop the F_{en} multipliers as specified in NUREG/CR-6583. Both LAS nozzle confirmatory analyses used the NUREG/CR-6583 bounding sulfur content of 0.015 weight percent. The confirmatory analyses also assumed NUREG/CR-6583 bounding strain rate of 0.001 percent per second for the F_{en} multipliers in all load pairs. These same assumptions were also used in the refined analyses. The staff finds the strain rate and sulfur values used to calculate the F_{en} multipliers in confirmatory analyses of the RO, as well as those of the CS nozzles, acceptable because they were calculated consistent with NUREG/CR-6583.

The staff found that both nozzle confirmatory analyses accounted for the DO water chemistry effect for hydrogen water chemistry (HWC) as well as the normal water chemistry (NWC) employed by the applicant prior to the implementation of HWC. The staff confirmed that the DO values used in the calculation of the F_{en} values for the RO and CS confirmatory analyses are the same as those used in the refined analyses. Therefore, the staff finds the DO values used in the refined analyses acceptable for the confirmatory analyses.

The only input in the calculation of the F_{en} values for the confirmatory analyses that differed from the refined analysis was temperature. The refined analyses used the maximum reactor vessel temperature to calculate a single F_{en} value that was applied to all transients. Using the maximum temperature for all transients is a conservative assumption. The confirmatory analyses calculated a separate F_{en} value for each transient pair based on the maximum temperature during the individual transients. This is the same procedure that was used for the FW nozzle confirmatory analysis. The staff finds the use of the maximum temperature for each individual transient pair to calculate the F_{en} values acceptable for the RO and CS confirmatory analyses because this is also a conservative approach in evaluating the F_{en} values.

The staff conducted a three-day audit of the confirmatory RO and CS nozzle calculations on February 18-20, 2009. The staff audit identified concerns with the input assumptions and output stresses as reported in the confirmatory analyses. By letter dated February 26, 2009, Entergy identified revisions to the calculations that would be made to address the staff concerns. Entergy submitted the revised calculations by letter dated March 12, 2009. The reported CUF_{en} values for each nozzle were still well within the allowable limit of 1.0. The results of the staff audit are documented in an audit summary dated May 8, 2009.

Entergy identified the following revisions to the RO outlet nozzle confirmatory calculations:

- Incorrect material properties (those for Alloy 600 instead of those for stainless steel) were used to calculate the CUF_{en} at the safe end location. Use of the correct material properties increased the CUF_{en} at the safe end location. However, the safe end CUF_{en} was still well within the allowable limit of 1.0. In addition, the nozzle blend radius remained the limiting location for the RO outlet nozzle.
- A stress concentration factor was applied to the nozzle blend radius for the stresses resulting for the attached piping loads. This had no significant impact on the CUF_{en} calculation.
- One thermal transient was different from the one used in the refined analysis. Revision of this transient had no significant impact on the CUF_{en} calculation.

The staff reviewed the revised calculations and agrees with Entergy's assessment that the revisions did not significantly impact the limiting CUF_{en} previously reported for the RO nozzle confirmatory analysis. While the revision of the material properties increased the CUF_{en} at the safe end location, it did not result in a change to the location of the limiting CUF_{en} for the nozzle, and the value was still well within the allowable limit of 1.0.

The confirmatory analysis RO nozzle blend radius CUF_{en} of 0.111 is larger than the CUF_{en} of 0.0836 reported in the refined analysis, even though the confirmatory analysis removed some conservatism from the calculation of the F_{en} value. The staff reviewed the RO nozzle stress calculations and determined that the increase in CUF_{en} was due to a significant increase in the confirmatory analysis calculated stresses for certain transient load combinations.

On the basis of discussions with Entergy's contractor during the audit, the staff determined that the confirmatory finite element analyses used a different element type from that used in the refined analyses. According to Entergy's contractor, it had encountered problems obtaining accurate results using the original element type in the finite element model and, therefore, switched to the different element to provide assurance that it obtained accurate stresses from the finite element model. This change in element type accounted for the difference in stresses between the confirmatory and refined analyses. Entergy confirmed that the confirmatory analyses for the CS and RO nozzels used the same appropriate element type as the confirmatory analysis for the FW nozzles.

The confirmatory CUF_{en} at the CS nozzle blend radius was 0.140 compared to the value of 0.1668 reported in the refined analysis. Since the confirmatory analysis CUF is comparable to the value reported in the refined analysis, the reduction of CUF_{en} at the CS nozzle blend radius in the confirmatory analysis is due to the use of specific F_{en} values based on maximum temperature for each transient pair as opposed to the use of a bounding F_{en} value in the refined analysis. Therefore, the staff finds Entergy's F_{en} calculation acceptable.

The staff's review of the calculations found the CS nozzle blend radius primary membrane plus bending stress intensity reported in the confirmatory analysis was more than ten percent lower than the value reported in the refined analysis. This result was attributed to change in element type between the refined analysis and the confirmatory analysis. Although the change in element type impacted the maximum primary membrane plus bending stress intensity, the change in element type did not have a significant impact on the CS nozzle blend radius CUF.

The staff's review of the confirmatory analyses for the RO and CS nozzles confirmed that the calculations were performed in accordance with ASME Code requirements, the F_{en} values were calculated in accordance with staff guidance documents, and the resulting CUF_{en} values were within the acceptance limit of 1.0.

4.3.3.3 UFSAR Supplement

The applicant provided a UFSAR Supplement summary description of its time-limited aging analysis (TLAA) evaluation of the effects of reactor water environment on fatigue life in LRA Section A.2.2.2.3.

As noted by the staff in the original SER, implementation of the applicant's Commitment No. 27, prior to the period of extended operation, would address the environmentally assisted fatigue issue. Also as noted by the staff in the original SER, the applicant had revised its Commitment No. 27 to specify refinement of the fatigue analyses in order to lower the predicted CUFs to less than 1.0, at least two years prior to the period of extended operation. With the completion of the confirmatory analyses for the RO and CS nozzles, the applicant has satisfied VYNPS license renewal Commitment No.27.

4.3.3.4 Conclusion

Based on its review of the confirmatory analyses, the staff finds that the applicant's determination of F_{en} values is in accordance with NUREG/CR-6583 and that the applicant has adequately accounted for reactor water chemistry effects in calculating the CUFs for the CS and RO nozzle blend radius locations. In addition, the staff determined that the confirmatory analyses are in accordance with the rules and requirements of ASME Code, Section III, Subarticle NB-3200, and are, therefore, acceptable.

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SECTION 5

REVIEW BY THE ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

The staff has provided the Advisory Committee on Reactor Safeguards with a copy of this supplemental safety evaluation report.

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SECTION 6

CONCLUSION

On the basis of its review of the confirmatory calculations, the staff concludes that Entergy Nuclear Operations, Inc., has satisfied the concern indentified in the proposed license condition regarding the CS and RO nozzles. The staff concludes that the confirmatory analyses of the core spray and recirculation outlet nozzles performed by the applicant, to address concerns with the use of Green's function in calculating fatigue cumulative usage factors for Vermont Yankee Nuclear Power Station components, are acceptable.

APPENDIX B

CHRONOLOGY

This appendix contains a chronological listing of the licensing correspondence between the staff of the U.S. Nuclear Regulatory Commission and Entergy Nuclear Operations, Inc. This appendix updates the correspondence regarding the staff's review of the Vermont Yankee Nuclear Power Station license renewal application (under Docket No. 50-271) since the publication of NUREG-1907 in May 2008.

CHRONOLOGY	
Date	**Subject**
May 2008	NUREG-1907, Vol. 1, Safety Evaluation Report Related to the License Renewal of Vermont Yankee Nuclear Power Plant (Accession No. ML081430057)
May 2008	NUREG-1907, Vol. 2, Safety Evaluation Report Related to the License Renewal of Vermont Yankee Nuclear Power Plant (Accession No. ML081430109)
November 24, 2008	Atomic Safety and Licensing Board Panel, Partial Initial Decision (Ruling on Contentions 2A, 2B, 3, and 4) (LBP-08-25) (Accession No. ML083290331)
January 15, 2009	Vermont Yankee Nuclear Power Station License No. DPR-28 (Docket No. 50-271) License Renewal Application, Amendment No. 37 (BVY 09-006) (Accession No. ML090230678)
February 26, 2009	Letter to Board Advising of Some Inconsequential Changes in the Confirmatory Environmentally Assisted Fatigue Analyses (Accession No. ML090690302)
March 12, 2009	Vermont Yankee Nuclear Power Station License No. DPR-28 (Docket No. 50-271) License Renewal Application, Amendment No. 38 (BVY 09 019) (Accession No. ML090760976)
May 8, 2009	Audit Summary Regarding the Vermont Yankee Nuclear Power Station License Renewal Application (Accession No. ML090860380)