December 12, 2012

Mr. Frederick P. Schiffley, II
BWROG Chairman
c/o GE Hitachi Nuclear Energy
P.O. Box 780
3901 Castle Hayne Road, M/C F-12
Wilmington, NC 28402

SUBJECT: DRAFT SAFETY EVALUATION FOR THE BOILING WATER REACTOR OWNERS' GROUP LICENSING TOPICAL REPORT BWROG-TP-11-022, "PRESSURE-TEMPERATURE LIMITS REPORT METHODOLOGY FOR BOILING WATER REACTORS," REVISION 1, NOVEMBER 2011 (TAC NO. ME7649)

Dear Mr. Schiffley:

By letter dated November 17, 2011 (Agencywide Documents Access and Management System Accession No. ML113260534), the Boiling Water Reactor Owner's Group (BWROG) submitted BWROG-TP-11-022, Revision 1 dated November 2011, "Pressure-Temperature Limits Report Methodology for Boiling Water Reactors," to the U.S. Nuclear Regulatory Commission (NRC) staff for review. Enclosed for BWROG review and comment is a copy of the NRC staff's draft safety evaluation (SE) for the Licensing Topical Report.

Twenty working days are provided for you to comment on any factual errors or clarity concerns contained in the draft SE. The final SE will be issued after making any necessary changes and will be made publicly available. The NRC staff's disposition of your comments on the draft SE will be discussed in the final SE.

To facilitate the NRC staff's review of your comments, please provide a marked-up copy of the draft SE showing proposed changes and provide a summary table of the proposed changes.

If you have any questions, please contact Joseph Golla at 301-415-1002.

Sincerely,

/RA/

Sheldon D. Stuchell, Acting Chief
Licensing Processes Branch
Division of Policy and Rulemaking
Office of Nuclear Reactor Regulation

Project No. 691

cc w/ encl: See next page

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DRAFT SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

LICENSING TOPICAL REPORT BWROG-TP-11-022, REVISION 1

"PRESSURE-TEMPERATURE LIMITS REPORT METHODOLOGY

FOR BOILING WATER REACTORS"

PROJECT NO. 691

1.0 INTRODUCTION AND BACKGROUND

In a letter dated November 17, 2011, the Boiling Water Reactor (BWR) Owners' Group (BWROG) submitted Licensing Topical Report (LTR) BWROG-TP-11-022 (SIR-05-044), Revision 1, "Pressure Temperature Limits Report Methodology for Boiling Water Reactors," dated June 2011 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML113260534), to the U.S. Nuclear Regulatory Commission (NRC) for review and acceptance for referencing in subsequent licensing actions. LTR BWROG-TP-11-022, Revision 1 (hereafter referred to as the LTR), is a revision of LTR SIR-05-044-A with the same title and contains minor modifications of the pressure-temperature (P-T) limit methodology. As was the case for LTR SIR-05-044-A, the BWROG provided this LTR to support the BWR licensees to relocate their P-T curves and associated numerical values (such as heatup/ cooldown rates) from facility Technical Specifications (TS) to a Pressure Temperature Limits Report (PTLR), a licensee-controlled document, using the guidelines provided in Generic Letter (GL) 96-03, "Relocation of the Pressure Temperature Limit Curves and Low Temperature Overpressure Protection System Limits."

This review also includes evaluation of the BWROG's responses to NRC staff requests for additional information (RAIs), which were provided to the NRC in a letter from the BWROG dated June 7, 2012 (ADAMS Accession No. ML12160A355).

2.0 REGULATORY EVALUATION

The NRC has established requirements in Appendix G, "Fracture Toughness Requirements," of Part 50 to Title 10 of the *Code of Federal Regulations* (10 CFR), in order to protect the integrity of the reactor coolant pressure boundary (RCPB) in nuclear power plants. The regulation at 10 CFR Part 50, Appendix G requires that the P-T limits for an operating light-water nuclear reactor be at least as conservative as those that would be generated if the methods of Appendix G, "Fracture Toughness Criteria for Protection Against Failure," to Section XI of the American Society of Mechanical Engineers *Boiler and Pressure Vessel Code* (ASME Code) were used to generate the P-T limits. The regulation at 10 CFR Part 50, Appendix G also requires that applicable surveillance data from reactor pressure vessel (RPV) material surveillance programs be incorporated into the calculations of plant-specific P-T limits, and that the P-T limits for operating reactors be generated using a method that accounts for the effects of neutron irradiation on the material properties of the RPV beltline materials.

Table 1 to 10 CFR Part 50, Appendix G provides the NRC staff's criteria for meeting the P-T limit requirements of ASME Code, Section XI, Appendix G, as well as the minimum temperature requirements of the rule for bolting up the vessel during normal and pressure testing operations.

In addition, the NRC staff regulatory guidance related to P-T limit curves is found in Regulatory Guide (RG) 1.99, Revision 2, "Radiation Embrittlement of Reactor Vessel Materials" and Standard Review Plan Chapter 5.3.2, "Pressure-Temperature Limits, Upper-Shelf Energy, and Pressurized Thermal Shock."

The regulation at 10 CFR Part 50, Appendix H, "Reactor Vessel Material Surveillance Program Requirements," provides the NRC staff's criteria for the design and implementation of RPV material surveillance programs for operating light-water reactors.

In March 2001, the NRC staff issued RG 1.190, "Calculational and Dosimetry Methods for Determining Pressure Vessel Neutron Fluence." Fluence calculations are acceptable if they are performed with approved methodologies or with methods which are shown to conform to the guidance in RG 1.190.

On January 31, 1996, the NRC staff issued GL 96-03 to inform licensees that they may request a license amendment to relocate the P-T limit curves from the TS into a PTLR or other licensee-controlled document that would be controlled through the TS. GL 96-03 specified requirements for an acceptable PTLR: the P-T limits for light-water reactors would need to be generated in accordance with an NRC-approved methodology and that the methodology to generate the P-T limits would need to comply with the requirements of 10 CFR Part 50, Appendices G and H; be documented in an NRC-approved topical report or plant-specific submittal; and be incorporated by reference in the Administrative Controls Section of the TS. The GL also mandated that the TS Administrative Controls Section would need to reference the NRC staff's safety evaluation (SE) issued on the PTLR request and that the PTLR be defined in Section 1.0 of the TS. Attachment 1 to GL 96-03 provided a list of the criteria that the approved methodology and PTLR would be required to meet.

TS Task Force (TSTF) Traveler No. TSTF-419, Revision 2, "Pressure Temperature Limits Report," dated September 16, 2001 (ADAMS Accession No. ML012690234) amended the Standard TS (STS) (NUREGs-1430, -1431, -1432, -1433, and -1434) to: (1) delete references to the TS limiting condition for operation specifications for the P-T limits in the TS definition of the PTLR, and (2) revise STS 5.6.6 to identify, by number and title, NRC-approved topical reports that document PTLR methodologies, or the NRC SE for a plant-specific methodology by NRC letter and date. A requirement was added to the reviewers note to specify the complete citation of the PTLR methodology in the plant-specific PTLR, including the report number, title, revision, date, and any supplements. Only the figures, values, and parameters associated with the P-T limits are relocated to the PTLR. The methodology for their development must be reviewed and approved by the NRC. TSTF-419, Revision 2 did not change the requirements associated with the review and approval of the methodology or the requirement to operate within the limits specified in the PTLR. Any changes to a methodology that had not been approved by the NRC staff would continue to require NRC staff review and approval pursuant to the license amendment request provisions and requirements of 10 CFR 50.90, "Application for amendment of license or construction permit."

3.0 TECHNICAL EVALUATION

As discussed in Section 2.0 of this SE, 10 CFR Part 50, Appendix G requires licensees to establish limits on the pressure and temperature of the RCPB in order to protect the RCPB against brittle failure.

These limits are defined by P-T limit curves for normal operations (including heatup and cooldown operations of the reactor coolant system (RCS), normal operation of the RCS with the reactor being in a critical condition, and transient operating conditions) and during pressure testing conditions (i.e., either inservice leak rate testing and/or hydrostatic testing conditions).

The LTR was prepared by Structural Integrity Associates, Inc., for the BWROG and has sections and appendices identical to its previous edition, LTR SIR-05-044-A. Since the LTR contains only limited modifications when compared with LTR SIR-05-044-A, this SE focuses on these modifications (excluding editorial changes) and will not repeat the evaluation of the LTR contents which have already been discussed and accepted in the NRC SE included in LTR SIR-05-044-A.

3.1 Evaluation of Modification 1 - A New Alternative Thermal Stress Intensity Factor Equation

Section 2.5.3 provides a new equation (Equation (2.5.3-3a)), along with the existing equation (Equation (2.5.3-3b)), to calculate the thermal stress intensity factor (K_{It}) at the one-quarter thickness (1/4T) location of a postulated axial flaw in a nozzle corner. The LTR states that, "either Equation 2.5.3-3a or 2.5.3-3b may be used for any nozzle configuration in a BWR." The NRC staff issued RAI-1 requesting the BWROG provide a basis for this recommendation.

The BWROG's June 7, 2012, response to the RAI-1 indicated that Equation (2.5.3-3a) for the sharp-corner nozzle does not have a rigorous theoretical basis. Actually, this equation represents an average of the solution from a model of a quarter-crack in an infinite quarter-space and the model of a half-crack in an infinite half-space. The NRC staff found that there is no theoretical basis in Fracture Mechanics and Elasticity for averaging solutions from two entirely different crack shapes in two entirely different component geometries to arrive at a solution for a component with a crack. Therefore, the NRC staff believes that Equation (2.5.3-3a) is best considered as an empirical solution and its usefulness should be judged by past experience of using it. The BWROG's June 7, 2012, response to RAI-1 further indicated that the basic formulation for Equation (2.5.3-3a) and Equation (2.5.3-3b) was originally developed in EPRI NP-339, "Improved Evaluation of Nozzle Corner Cracking," which evaluates feedwater nozzles in a BWR, and the two models give stress intensity factor values that differ by less than 5 percent.

The NRC staff confirmed that Equation (2.5.3-3a) was already approved in 1980 (e.g., NEDE-21821-A, "Boiling Water Reactor Feedwater Nozzle/Sparger Final Report,") for the BWR feedwater nozzle application. In addition, Equation (2.5.3-3a) was considered acceptable for the sharp-corner nozzles in the ORNL/TM-2010/246 report, "Stress and Fracture Mechanics Analyses of Boiling Water Reactor and Pressurized Water Reactor Pressure Vessel Nozzles." Based on these two considerations and the rather small difference of 5 percent between results using this empirical equation or Equation (2.5.3-3b), the NRC staff accepts the use of Equation (2.5.3-3a) in the LTR as an alternative for all RPV nozzle geometries. RAI-1 is resolved.

3.2 Evaluation of Modification 2 - A New Alternative Pressure Stress Intensity Factor Equation

Regarding the nozzle corner flaw stress intensity factor due to pressure (K_{Ip}), in addition to Equations (2.5.3-5a) and (2.5.3-5b), Section 2.5.3 of the LTR adds a new equation (Equation (2.5.3-5c)) based on Appendix 5 of Welding Research Council (WRC) Bulletin No. 175, "PVRC Recommendations on Toughness Requirements for Ferritic Materials," as an alternative to calculate this value. Although the proposed alternative is based on a three dimensional finite element method (FEM) modeling of a nozzle, considerable progress has been made in fracture mechanics and FEM techniques since the publication of WRC-175. As a result, the WRC-175 approach on nozzles, which is the best available methodology at that time, may not be as accurate as those provided in Equations (2.5.3-5a) and (2.5.3-5b). RAI-2 basically requests the BWROG reconsider the addition of Equation (2.5.3-5c) to the LTR.

The BWROG's June 7, 2012, response to RAI-2 indicated that using Equation (2.5.3-5c) for RPV nozzles is permitted by ASME Code, Section XI, Appendix G, and, therefore, is considered already accepted by the NRC. The NRC staff considers that adding Equation (2.5.3-5c) to the LTR provides licensees a choice to select Equation (2.5.3-5c) based on the ASME Code, Section XI, Appendix G methodology or Equations (2.5.3-5a) and (2.5.3-5b) based on the more advanced methodology in calculating K_{Ip}, which was approved in LTR SIR-05-044-A. RAI-2 is resolved.

3.3 Evaluation of Modification 3 - Nozzles in the Beltline Region

Unlike LTR SIR-05-044-A, Section 2.5.3 of the LTR addresses nozzles in the beltline region, providing general guidelines for special cases such as when adequate material chemistry data is not available; when nozzle inserts are made of Alloy 600, stainless steel, or carbon or low alloy steel; and when the thickness of nozzle section is 2.5 inches or less. For those nozzle inserts which are ferritic, ASME Code, Section XI, Appendix G, Paragraph G-2223(c) provides a conditional exemption: "Fracture toughness analysis to demonstrate protection against nonductile failure is not required for portions of nozzles and appurtenances having a thickness of 2.5 in. (63 mm) or less, provided the lowest service temperature is not lower than RT_{NDT} plus 60 °F (33 °C)." Based on the NRC staff's experience of reviewing license renewal applications (LRAs), the NRC staff found that some applicants missed the second half of Paragraph G-2223(c) regarding the lowest service temperature. Hence, RAI-3 was issued to request the BWROG modify the statement in the LTR to add clarification on applying the ASME Code specified conditional exemption for small RPV nozzles.

The BWROG's June 7, 2012, response to RAI-3 adds the following sentence in the LTR to clarify the use of ASME Code, Section XI, Appendix G, Paragraph G-2223(c):

> The ART plus 60 °F, for ferritic nozzles in the beltline, is the appropriate limit for comparison with the lowest service temperature, rather than RT_{NDT} plus 60 °F as currently stated in ASME XI, Appendix G, Subparagraph G-2223(c).

The NRC staff determined that revising Section 2.5.3 of the LTR by adding the above sentence after a direct quote of ASME Code, Section XI, Appendix G, Paragraph G-2223(c) has the effect of highlighting and clarifying the condition of the exemption provided by Paragraph G-2223(c). RAI-3 is resolved.

3.4 Issues Raised in a Generic RAI Regarding P-T Limits

In LRAs, some RPV non-beltline materials which were not considered in the P-T limit evaluation before are considered as "extended beltline materials" and require evaluation because of their higher neutron fluence value. Further, in determining the P-T limits, plants do not always perform P-T limit calculations for non-beltlines materials. Therefore, to ensure that the much higher stresses associated with RPV discontinuities and the lowest operating temperature requirement of RCPB are considered in the P-T limits, the staff issued a generic RAI for all relevant license amendment requests, power uprates, and LRAs which contain P-T limit evaluation to address the following two concerns:

1. RPV nozzles, penetrations, and other discontinuities have complex geometries that may exhibit significantly higher stresses than those for the RPV beltline shell region. These higher stresses can potentially result in more restrictive P-T limits, even if the reference temperature (RT_{NDT}) for these components is not as high as that of RPV beltline shell materials that have simpler geometries.

2. Ferritic RCPB components that are not part of the RPV may have initial RT_{NDT} values, which may define a more restrictive lowest operating temperature in the P-T limits than those for the RPV beltline shell materials.

For BWRs, P-T limit calculations for non-beltline discontinuities were always performed in determining the P-T limits for the RPV. This is further supplemented by LTR BWROG-TP-11-023, Revision 0, "Linear Elastic Fracture Mechanics Evaluation of General Electric Boiling Water Reactor Water Level Instrument Nozzles for Pressure-Temperature Curve Evaluations," November 2011. Therefore, the NRC staff determined that only Concern 2 applies to BWRs. However, since each plant has initial RT_{NDT} values for all ferritic RCPB components, Concern 2 is listed in Section 4.0 as a plant-specific issue to be addressed by each future applicant referencing this LTR.

4.0 CONDITIONS AND LIMITATIONS

Based on the evaluation in Section 3.0, the staff determined that there is one condition on this LTR for future potential applicants to address in their application of this LTR to their plant-specific P-T limit or PTLR submittals:

> Each applicant referencing this LTR shall provide the lowest service temperatures for all ferritic RCPB components that are not part of the RPV based on their initial RT_{NDT} values and demonstrate that this requested information will not be in conflict with the lowest operating temperature established in the P-T limits.

5.0 CONCLUSION

The limited modifications in the LTR (as compared with LTR SIR-05-044-A) have been identified and evaluated by the NRC staff and are determined to be acceptable. The rest of the LTR contains only editorial changes and remains acceptable based on the February 6, 2007, SE attached to LTR SIR-05-044-A. Therefore, the NRC staff concludes that LTR BWROG-TP-11-022, Revision 1 satisfies the criteria in Attachment 1 to GL 96-03 and provides adequate methodology for BWR licensees to calculate P-T limit curves.

By using this methodology and following the PTLR guidance in GL 96-03, as amended by NRC TSTF-419, BWR licensees will be able to relocate the P-T limit curves and the associated heatup/cooldown rates from TS to a PTLR, a licensee-controlled document.

Principal Contributor: S. Sheng

Date: December 12, 2012