April 24, 2013

Dennis Madison
Southern Nuclear
Chairman, BWR Vessel and Internals Project
3420 Hillview Avenue
Palo Alto, CA 94304-1395

SUBJECT: REQUEST FOR ADDITIONAL INFORMATION FOR THE BOILING WATER REACTOR (BWR) VESSEL INTERNALS PROJECT (BWRVIP)-234, "THERMAL AGING AND NEUTRON EMBRITTLEMENT EVALUATION OF CAST AUSTENITIC STAINLESS STEEL FOR BWR INTERNALS" (TAC NO. ME5060)

Dear Mr. Madison:

By letter dated September 29, 2011, the U.S. Nuclear Regulatory Commission staff transmitted Request for Additional Information (RAI) questions (Agencywide Document Access and Management System (ADAMS) Accession No. ML112630638) for the BWRVIP-234, "Thermal Aging And Neutron Embrittlement Evaluation Of Cast Austenitic Stainless Steel For BWR Internals." On September 18, 2012, the BWRVIP provided its responses to the RAIs (ADAMS Accession No. ML12265A078).

The NRC staff completed its review of the responses to the RAI questions, and has identified additional areas for which information is needed to complete the review. The additional RAI questions are enclosed.

On March 21, 2013, Mr. Larry Steinert, representing BWRVIP, and I agreed that the NRC staff will receive your response to the enclosed RAI questions by May 31, 2013. If you have any questions regarding the enclosed RAI questions, please contact me at 301-415-7297.

Sincerely,

/RA/

Joseph J. Holonich, Senior Project Manager
Licensing Processes Branch
Division of Policy and Rulemaking
Office of Nuclear Reactor Regulation

Project No. 704

Enclosure:
RAI Questions

Dennis Madison
Southern Nuclear
Chairman, BWR Vessel and Internals Project
3420 Hillview Avenue
Palo Alto, CA 94304-1395

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ADAMS Accession No.: ML13079A210 **NRR-106**

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SECOND REQUEST FOR ADDITIONAL INFORMATION ON BWRVIP-234,

"THERMAL AGING AND NEUTRON EMBRITTLEMENT EVALUATION OF CAST AUSTENITIC

STAINLESS STEEL FOR BWR INTERNALS" (TAC NO. ME5060)

The U.S. Nuclear Regulatory Commission (NRC) staff is in the process of reviewing the September 18, 2012 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML12265A078) responses to the first set of Request for Additional Information (RAI) questions. Based on the review conducted to date, the NRC staff has developed a second set of RAI questions that includes two new RAI questions (RAI 10 and RAI 11), a revised RAI 7-a, and a follow-up RAI 9-a.

RAI 7-a
Typically, the measured delta ferrite values are not reported on the certified material test record. In Section 3.4, "Ferrite Content," the Ni and Cr equivalent equation from Hull are used to calculate the delta ferrite content. In the May 19, 2000, letter from Christopher Grimes, NRC, to Mr. Douglas Walters, Nuclear Energy Institute (NEI), the calculated ferrite content from Hull's equations represents the mean value with a significant uncertainty (± 6%).

Justify why 6 percent should not be added to the calculated ferrite values based on chemistry to represent an upper-bound to the ferrite content, which is based on chemistry. Provide additional discussion in Section 4.1 as to how the uncertainty in the calculations affects the screening process.

RAI 9-a
In the September 18, 2012, RAI response, the BWRVIP stated the following:

> As stated in the responses to RAI 6 and RAI 7, the uncertainty in delta ferrite and potential for an increase in delta ferrite due to welding and weld repairs is not expected to be significant. In RAI 6 it was shown that even when assuming the maximum Mo content of 0.5 wt.% the average increase in ferrite was relatively small. This marginal increase in ferrite would have a slight effect on reducing the toughness of the material (since an increase in ferrite results in a decrease in toughness). However, for the range of exposure conditions that would be experienced for cast austenitic stainless steel (CASS) components in a BWR, the toughness values are expected to be well above recommended lower bound toughness of 255 kJ/m^2. Therefore, the BWRVIP believes that use of the lower bound toughness is sufficiently conservative and consequently, would not affect the methodology to estimate the toughness for irradiated conditions.

The NRC staff has reviewed the technical bases for the RAI responses and compared the methodology used in BWRVIP-234 to predict fracture toughness as a function of neutron exposure to a previously reported prediction from NUREG/CR-6960. The comparison is shown in Figure 1 along with the range of predicted J values at 2.5 mm crack extension for unirradiated CF-8 with no thermal embrittlement (TE) and maximum TE (no irradiation) for CF-8 with > 15 percent delta ferrite (Section 3.1.1 of NUREG/CR-4513, Rev. 1).

ENCLOSURE

The NRC staff is concerned that the BWRVIP-100 model for CASS may be inadequate for the following reasons:

- The data base for development of the BWRVIP-100 model to predict toughness does not include any CASS materials, just welds, heat affected zone material, and base metal. Further, the number of welds in the database is limited, and the delta ferrite content for these welds is unknown. Welds typically contain 7 to 10 percent ferrite while CASS materials can have between 5 and 25 percent ferrite. Therefore, the toughness predicted by the BWRVIP-100 model may not be appropriate or conservative for CASS materials.

- The NUREG/CR-6960 model is based on data from CASS materials, welds, and wrought materials; therefore, the NRC staff believes it more conservatively represents the fracture toughness of irradiated CASS materials. At fluence values > 0.3 dpa, the toughness predicted by the NUREG/CR-6960 curve is below the value of 255 kJ/m^2 used as the basis for the screening based on toughness in BWRVIP-234.

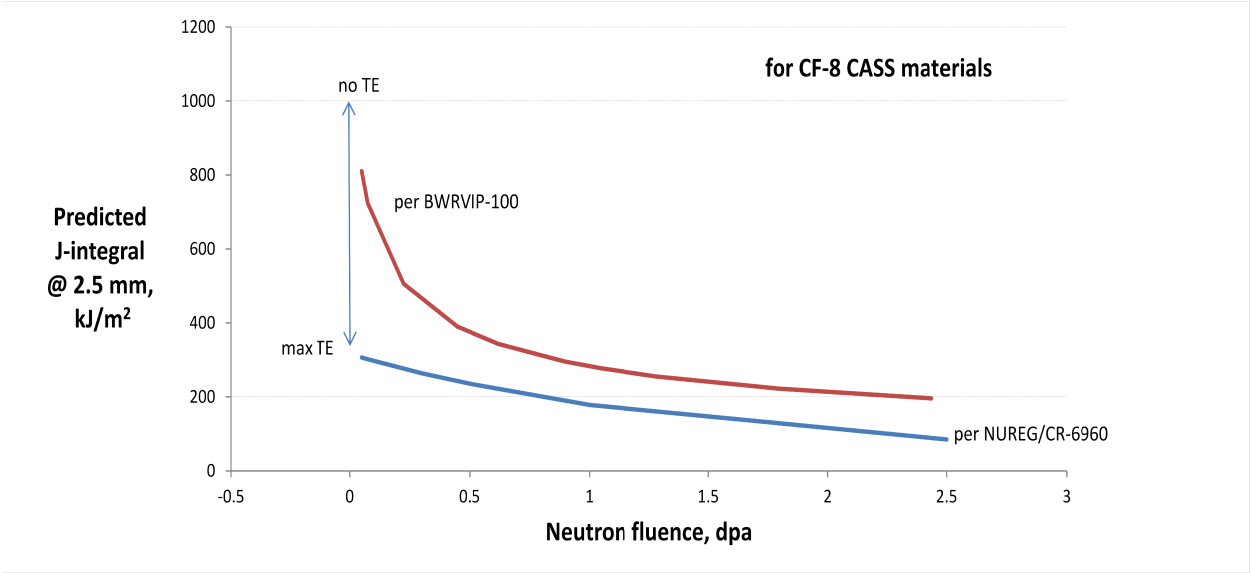

Figure 1. Plot of predicted toughness (J-integral value at 2.5 mm crack extension) from BWRVIP-100 and NUREG/CR-6960 as a function of neutron fluence. The predicted lower-bound toughness of CF-8 due to TE alone is shown for reference.

The NRC staff requests that the BWRVIP review all available data on fracture toughness of irradiated CASS materials, and the associated uncertainties, and to either revise its methodology to predict the lower-bound toughness of CASS materials at reactor operating temperatures after approximately 60 years of operation, or provide further justification that BWRVIP-100 is sufficiently conservative.

New, RAI 10
The BWRVIP-234 report has considered only the properties of CASS materials at operating temperatures. The NRC staff requests that the BWRVIP assess the structural integrity of CASS materials at typical leak test temperatures.

New, RAI 11
The nondestructive examination methods of the existing examinations discussed in Section 6, "Assessment of CASS Components," were justified because they were capable of detecting degradation other than loss of fracture toughness due to the combined effects of thermal and neutron embrittlement. Given the lower-bound toughness for a CASS component, which could have significantly higher delta ferrite than core shroud welds and is subject to both thermal and neutron embrittlement, justify the adequacy of the existing BWRVIP inspections to detect subcritical flaws as discussed in the GALL report, Rev. 2, XI.M9 paragraph 4 -- *Detection of Aging Effects.*