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2015-150 BWR Vessel & Internals Project (BWRVIP)

November 19, 2015

Document Control Desk
U.S. Nuclear Regulatory Commission
11555 Rockville Pike
Rockville, MD 20852

Attention: Joseph Holonich

Subject: Project No. 704 – BWRVIP Response Regarding Proposed Words in BWRVIP-234 Draft Safety Evaluation

References:
1. Joseph Holonich, NRC, October 1, 2015, 1:28 pm EDT, email to Charles Wirtz, EPRI, Proposed Words in BWRVIP-234 Draft Safety Evaluation
2. Charles Wirtz, EPRI, October 1, 2015, 2:30 pm EDT, email reply to Joe Holonich, NRC, RE: Proposed Words in BWRVIP-234 Draft Safety Evaluation

The NRC provided some proposed language that outlined a possible condition to be included in the draft Safety Evaluation for BWRVIP-234, "Boiling Water Reactor Vessel and Internals Project, Thermal Aging and Neutron Embrittlement Evaluation of Cast Austenitic Stainless Steels for BWR Internals" (Reference 1). The BWRVIP notified the NRC that the proposed language did not contain any EPRI proprietary information (Reference 2). Copies of the emails and the content of the Word document are included in Attachment 1.

A teleconference was held on October 29, 2015 to discuss the possible conditions that may be associated with BWRVIP-234 Safety Evaluation. An open discussion ensued where the NRC explained their concerns leading to possible conditions on the use of BWRVIP-234. The BWRVIP representatives provided feedback to the staff. At the conclusion of the call, the BWRVIP committed to provide their feedback via a formal written response. Attachment 1 provides that response.

If the response contained in Attachment 1 does not resolve the staff's concerns, the BWRVIP requests that the staff notify the BWRVIP before proceeding with issuance of the BWRVIP-234 Safety Evaluation.

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If you have any comments or questions please contact Bob Carter at 704.595.2519 or by email at bcarter@epri.com.

Sincerely,

A. O. McGehee A. D. Odell

Andrew McGehee, EPRI, BWRVIP Program Manager
Drew Odell, Exelon, BWRVIP Integration Committee Chairman

c: BWRVIP Technical Chairs
BWRVIP EPRI Task Managers

Attachment 1

NRC Comments on BWRVIP-234

Based on the staff's review of the responses to RAIs 7a and 11 and the existing BWRVIP reports, the staff notes that the existing BWRVIP inspections do not consistently consider the potential for IGSCC on those components with a significant consequence of failure fabricated from CF-8 materials. In the NRC-approved inspections of BWRVIP-41 and 42, some components fabricated from CF-8 have a high consequence of failure. The approved inspection methodologies assume inspections on the cast side are not needed because the cast product form has a high resistance to IGSCC in BWR core environments. In several locations with a medium consequence of failure, no inspections are recommended because the material is cast. However, the approvals were based on the assumed resistance to IGSCC due to the duplex microstructure.

Based on the information in Section 4.1 of BWRVIP-234, there is a minimum level of carbon and ferrite needed to ensure there is adequate protection from IGSCC. NUREG-0313, Rev. 2 suggests limits of $\leq 0.035\%$ C and $\geq 7.5\%$ ferrite to reduce susceptibility to IGSCC; the GALL report references the NUREG-0313, Rev. 2 limits for the aging management of CASS in PWR reactor coolant systems. Appendix A of BWRVIP-234 shows that a significant fraction of the heats fail to meet the limits for carbon and ferrite contents.

In consideration of the existing BWRVIP augmented inspections, the staff has determined that when publishing the approved version of BWRVIP-234-A, the text should be revised to identify (1) all welds with a significant consequence of failure in the existing BWRVIP reports that could include CASS materials as one of the base materials and (2) an acceptable carbon and ferrite level at which there is reasonable assurance of resistance to IGSCC. This is Topical Report Condition 2.

BWRVIP Response:

Purpose of BWRVIP-234:

Discussion of IGSCC in BWRVIP-234 was included simply to support the concluding paragraph of Section 4.1, which states:

> *Since the threshold for crack initiation by IGSCC is <12% ferrite based on the study in Reference [16] and the threshold for thermal aging embrittlement is 14% or higher, one can argue that concurrent crack initiation and loss of toughness due to thermal aging is unlikely and additional evaluation is not needed. However, many CASS reactor internals components are subject to neutron irradiation and therefore, the ferrite levels by themselves are not adequate to exempt CASS components from augmented inspections. Therefore, additional screening criteria must be considered as discussed in the following sections.*

welds, and included in IGSCC Category A. If extensive weld repairs were performed the residual stress may be unfavorable, in which case such welds should be included in Category D.

Based the GL88-01 information it appears that the staff position on carbon and ferrite percentages were focused on sensitization and its impact on susceptibility to IGSCC. Even when the CASS material was beyond the carbon and ferrite limits it was allowed to be examined at the same frequency as non-susceptible or resistant material. And if sensitization was the issue, its impact would be limited to weld HAZ. Thus the inspection of welds joining wrought and cast materials in jet pump assemblies and low pressure coolant injection coupling lines that are required by BWRVIP-41 and BWRVIP-42 are consistent with the intent of GL88-01, which is for piping which is more highly stressed than the reactor internals. In the case of BWRVIP-41, it is acknowledged that the requirements do not specifically require inspection of the CASS side heat affected zones of the welds, but in performing the required EVT-1 examinations of the welds, the heat affected zones of the CASS sides of the welds are captured in the field of view and any significant cracking would be identified.

As stated in BWRVIP Letter 2012-148 (ML12265A078), measured values of ferrite were not available from the certified material test reports (CMTRs). Consequently, Hull's equivalent factors were used to determine ferrite. Per Reference 5 of BWRVIP-234, this was recommended by the NRC when actual values were not available. As shown in Table A-1 of BWRVIP-234, the Mo content was not measured for all heats compiled. Thus, there was some uncertainty regarding the calculated ferrite for the total population of heats compiled. As a result, a study was undertaken to investigate the variation in Mo content as a function of the calculated ferrite content. Using the data in Table A-1 of BWRVIP-234, the Mo content was varied for each heat of material, ranging from 0.1 wt.% to 0.5 wt.% in increments of 0.1 wt.%. A limit of 0.5 wt.% was used because this was the upper bound value specified for CF-3 and CF-8.

When reviewing the staff's comments, the BWRVIP believes that the average ferrite and carbon contents as documented in BWRVIP-234 and as amended by BWRVIP Letter 2012-148 are well within an acceptable IGSCC susceptibility level per Figure 4-1 (Reference 16 in BWRVIP-234).

The basis for this conclusion is that using the assumption of Mo at a maximum of 0.5 wt.% and a reported C having an average of 0.05 wt.%, the calculated average ferrite level is approximately 12%. Applying the upper curve (labeled "CF-3/CF-8 WELDED") in Figure 4-1 of BWRVIP-234 shows that a carbon content of 0.05 wt.% and a ferrite content of 12% is sufficient to suppress IGSCC, i.e., the average C and ferrite level are positioned to the right of the curve.

Additionally, it is the BWRVIP's opinion that IGSCC is an early life cracking mechanism, versus a late life aging management mechanism. To support this position, there have been no operating experiences in BWRs (even with plants exceeding 40+ years of operation) associated with cracking of vessel internal cast stainless steel components. This supports the BWRVIP position that cast materials are resistant to IGSCC in a BWR environment (in particular when operating under hydrogen water chemistry) and the conclusions stated in BWRVIP-234 are technically justified.

Conclusion:

The discussion above establishes that the average ferrite and carbon contents for CASS materials in BWR internals are well within the upper IGSCC susceptibility curve as shown in Figure 4-1. Additionally, it is important to note that there has been no operating experience of IGSCC in BWR CASS components. Consequently, there is reasonable assurance of resistance to IGSCC for BWR CASS internals.