October 17, 2001

Carl Terry, BWRVIP Chairman
Niagara Mohawk Power Company
Post Office Box 63
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SUBJECT: SAFETY EVALUATION OF THE "BWRVIP VESSEL AND INTERNALS PROJECT, CRD INTERNAL ACCESS WELD REPAIR (BWRVIP-58)," EPRI REPORT TR-108703, DECEMBER 1998 (TAC NO. MA4465)

Dear Mr. Terry,

The NRC staff has completed its review of the Electric Power Research Institute (EPRI) proprietary report TR-108703, "BWR Vessel and Internals Project, CRD Internal Access Weld Repair (BWRVIP-58)," dated December 1998. The proprietary and non-proprietary versions of the BWRVIP-58 report were submitted to the U. S. Nuclear Regulatory Commission (NRC) for staff review by letter dated December 22, 1998. The BWRVIP-58 report provides the technical basis and application of an internal access weld repair for leaking control rod drive (CRD) housing penetrations in BWR/2 through BWR/5 reactors. The repair weld was designed to replace the load carrying capability of the CRD housing to stub tube J-weld in addition to providing a seal to prevent leakage from the reactor pressure vessel (RPV). The BWRVIP provided the BWRVIP-58 report to support generic regulatory efforts related to the weld repair of BWR CRD housing penetrations.

The NRC staff has reviewed the BWRVIP-58 report and found, in the enclosed safety evaluation (SE), that, while its guidance is generally acceptable, several issues have been identified that need to be addressed. With the exception of the noted items, the staff has concluded that licensee implementation of the BWRVIP-58 report is acceptable for providing an adequate repair design criteria of the safety-related components, except where the staff's conclusion differs from the BWRVIP's, as discussed in the enclosed SE. This finding, based upon the information submitted, is consistent with NRC approved methodology.

The BWRVIP-58 report is considered by the staff to be applicable for licensee usage, as modified and approved by the staff, at any time during either the current operating term or during the extended license period.

The staff requests that the BWRVIP review and resolve the issues raised in the enclosed SE, and incorporate the staff's conclusions into a revised BWRVIP-58 report. Please inform the staff within 90 days of the date of this letter as to your proposed actions and schedule for such a revision.

Please contact C. E. (Gene) Carpenter, Jr., of my staff at (301) 415-2169 if you have any further questions regarding this subject.

Sincerely

/ra/

William H. Bateman, Chief
Materials and Chemical Engineering Branch
Division of Engineering
Office of Nuclear Reactor Regulation

Enclosure: As stated

cc: BWRVIP Service List

Please contact C. E. (Gene) Carpenter, Jr., of my staff at (301) 415-2169 if you have any further questions regarding this subject.

Sincerely

William H. Bateman, Chief
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Enclosure: As stated

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U.S. NUCLEAR REGULATORY COMMISSION

OFFICE OF NUCLEAR REACTOR REGULATION

SAFETY EVALUATION OF THE "BWRVIP VESSEL AND INTERNALS PROJECT, CRD INTERNAL ACCESS WELD REPAIR (BWRVIP-58)," EPRI REPORT TR-108703

1.0 INTRODUCTION

1.1 Background

By letter dated December 22, 1998, the Boiling Water Reactor Vessel and Internals Project (BWRVIP) submitted the Electric Power Research Institute (EPRI) proprietary Report TR-108703, "BWR Vessel and Internals Project, CRD Internal Access Weld Repair (BWRVIP-58)," dated December 1998, for U. S. Nuclear Regulatory Commission (NRC) staff review. The BWRVIP-58 report provides the technical basis and application of an internal access weld repair for leaking control rod drive (CRD) housing penetrations in BWR/2 through BWR/5 reactors. The repair weld was designed to replace the load carrying capability of the CRD housing to stub tube J-weld in addition to providing a seal to prevent leakage from the reactor pressure vessel (RPV). The BWRVIP provided the BWRVIP-58 report to support generic regulatory efforts related to the weld repair of BWR CRD housing penetrations.

1.2 Purpose

The staff reviewed the BWRVIP-58 report to determine whether its proposed guidance will provide an acceptable repair design criteria of the subject safety-related RPV internal components. The review assessed the design objectives, structural evaluation, analysis of weld repair stresses, materials, intergranular stress corrosion cracking (IGSCC) susceptibility and welding qualifications, as well as whether the required inspection and testing requirements meet Code and BWRVIP established criteria.

1.3 Organization of this Report

Because the BWRVIP report is proprietary, this SE was written not to repeat information contained in the report. The staff does not discuss in any detail the provisions of the guidelines nor the parts of the guidelines it finds acceptable. A brief summary of the contents of the BWRVIP-58 report is given in Section 2 of this SE, with the evaluation presented in Section 3. The conclusions are summarized in Section 4. The presentation of the evaluation is structured according to the organization of the BWRVIP-58 report.

ENCLOSURE

2.0 SUMMARY OF BWRVIP-58 REPORT

The BWRVIP-58 report addresses the following topics in the following order:

- Background and Component Description - A general physical description of the CRD housing and stub tube geometry is provided along with a summary of its operational and safety functions. Due to leakage in past service experience, the potential locations of cracking in these furnace-sensitized stainless steel components is discussed in addition to an overview of the repair process based on earlier work performed by EPRI. The BWRVIP-58 report concluded that "cracking is not a significant safety issue since the leakage would be detected and the plant could be safely shutdown."

- Repair Design - The repair process to the CRD housing is both qualitatively and quantitatively described. Topics of discussion include: Code design compliance, analysis of weld repair stresses, loading conditions, stress analysis results from the finite element evaluations, weld anomaly analysis and susceptibility of CRD repair to intergranular stress corrosion cracking (IGSCC). The stress levels for the mechanical and thermal loading cases were presented in tabular form which indicated an allowable stress ratio (calculated stress/allowable stress) for the penetrations.

- Repair Design Equipment - An overview of the implementation of the weld repair procedure is given. The function of the CRD nozzle bore plug, used to prevent water from leaking into the CRD housing during repair, is briefly explained as well. Other equipment, designed and fabricated to employ internal access weld repair, described are the: weld prep machining tool, remote machine welding system, distortion monitoring system, CRD housing dye penetrant (PT) and ultrasonic testing (UT) tool.

- Repair Process Qualifications - The BWRVIP CRD Repair Project included development, qualification and mockup demonstrations including water jet machining, machine gas tungsten arc welding, and NDE methods including visual testing (VT), PT, and UT. The results of these testing models and NDE demonstrations are discussed in detail by a series of illustrations depicting the details and physical characteristics of the mockup.

3.0 STAFF EVALUATION

The penetrations for CRDs are located in the reactor vessel lower head of boiling water reactors (BWRs). These components are designed to provide a portion of the reactor coolant pressure boundary, location and support for the bottom end of the CRD guide tube, housing and support for the CRD mechanisms, and a thermal barrier to limit heat flow from the reactor vessel lower head to the CRD housing interior.

In some domestic and non-domestic BWRs, CRD penetrations have leaked due to cracking in the region of the J-groove weld joining the CRD housing to the stub tube. The cracking is not considered a significant safety issue since the leakage would be detected and the plant could be safely shutdown. However, any leakage is considered an operational issue that could cause or extend an outage. The subject weld repair procedure, which does not require defueling and vessel drain-down, was developed in accordance with ASME Code Case N-606, "Similar and Dissimilar Material Welding Using the Ambient Temperature Machine GTAW Temperbead

Technique," as well as requirements specified in ASME Boiler and Pressure Vessel Code, Section XI, Rules for Inservice Inspection, 1995 edition.

With the exception of the items discussed below, the NRC staff finds that the results of the internal access weld repair presented in the subject report to be acceptable for repair of leaking CRD housing penetrations in BWRs.

3.1 Structural and Design Evaluation

A structural evaluation was performed to determine the acceptability of the components that are affected by the repair method. These include CRD housing stub tube, stub tube-to-vessel weld, CRD housing-to-stub-tube weld, CRD housing repair weld, and the vessel wall. The loadings considered in the evaluation included the dead weight, seismic, scram loading on the housing (stuck rod scram and scram end of stroke, no buffer), internal pressure and the thermal loads during a steady state temperature distribution.

The repair weld geometry is not explicitly recognized in the ASME Section III, Subsection NB-3300 weld categories, but is similar to a partial penetration weld Category D. The penetration meets the ASME Code reinforcement requirements without taking credit from the housing. The housing has been rolled into the penetration with an interference fit to limit external housing bending reactions on the repair weld. In lieu of satisfying the normal partial penetration weld sizing requirements by establishing weld size based on the housing wall thickness, the weld has been sized by meeting the basic stress limits of ASME Section III, Subsection NB-3300 for the specified service loadings. The attachment weld has been sized to meet the primary and special stress ASME Code allowables for the identified mechanical loadings. A detailed stress analysis has been performed on the attachment weld considering secondary thermal stresses in addition to the mechanical stresses. The primary plus secondary stresses and the fatigue usage factor satisfy the ASME Code allowables.

The weld geometry has been shown to meet the detailed stress requirements of ASME Code Section III, Subsection NB-3200 and, therefore, meets the design by analysis requirements. The vessel head integrity has not been altered since this was previously an unreinforced opening and the repair has not altered the material available for reinforcement. On the basis of its review, the staff finds that this configuration satisfies the ASME Section III, Subsection NB-3300 requirements.

The loading conditions represent the steady-state plant operating condition with coolant flow through the CRD housing and with applied dead weight, seismic, and scram loads. The seismic excitation of the section of the CRD housing, which extends below the reactor vessel bottom head, results in a lateral load and moment on the housing. However, because of the interference (due to the roll repair) fit between the CRD housing and the vessel bore, which prevents the lateral deflection of the nozzle, the lateral load and moment are not affected by the repair weld. Accordingly, these loads were not considered in this evaluation. The staff finds this reasonable and acceptable.

Stress results for the finite element evaluations were determined for the mechanical and thermal loading cases on the basis of three-dimensional and two-dimensional analytical models. Although the stress distributions were determined to be different between these models, the locations and magnitude of maximum stresses were similar. For all load cases

analyzed, stress levels were determined to be acceptable. Based on its review of the results, the staff finds that there is adequate margin between the calculated and allowable stresses for various cases analyzed and are therefore acceptable.

The possible affects of weld anomalies on the integrity of the repair were evaluated. It was determined by testing that anomalies larger than 0.05-inch could be reliably detected during post-weld UT inspections. However, anomalies smaller than 0.05-inch may not be observed. Therefore, the effect of leaving an undetected 0.05-inch anomaly in place was analyzed and evaluated. For the evaluation, the indications were assumed to be 0.05-inch extending from the root of the weld at the stainless steel CRD housing outside diameter. The extension was assumed to be arbitrary in direction and could lie in the weld metal, heat affected zone of the CRD housing or low alloy steel base metal. Because the possibility of a crack growing through the CRD housing wall on the vessel side cannot be precluded, the analysis for the case of the CRD housing segment severed on the vessel side of the repair weld demonstrates that this condition is structurally acceptable. The repair weld is the new pressure boundary weld for the CRD housing and the stub tube maintains its fuel assembly support function.

The possibility that the weld anomalies will initiate cracks that will propagate by fatigue was also evaluated. The change in stress intensity factor was calculated per Appendix A of ASME Section XI. The calculated crack growth from cyclic fatigue was determined to be negligible for the remainder of the service life. Therefore, it was also concluded that the assumed weld anomaly will remain stable for fatigue and loading.

The crack growth into the head was not explicitly calculated. However, a comparison of the crack growth rates in Appendix A Section XI for low alloy steel versus that which was assumed for the weld indicates that the growth will be on the same order as for the weld and therefore very small.

Based on its review as discussed above, the staff finds the structural evaluation to leave undetected anomalies of 0.05 or less in place reasonable and acceptable.

3.2 Items That Need to be Revised

Item 1. Section 4.2.4, “Non-Destructive Examinations (NDE),” of the BWRVIP-58 report discusses procedures and tooling to perform remote NDE (PT and UT) of the weld prep in accordance with ASME Section XI inspection requirements. However, BWRVIP-03, “BWR Vessel and Internals Project, Reactor Pressure Vessel and Internals Examination Guidelines,” Revision 1, dated March 1999, Section 13, “Lower Plenum,” addresses the inspection guidance for the control rod drive housing and stub tube. In addition, generic inspection methodology and flaw evaluation procedures are specified in BWRVIP-47, “BWR Vessel and Internals Project, BWR Lower Plenum Inspection and Flaw Evaluation Guidelines,” dated December 1997. The recommendations specified in the BWRVIP-03, Rev. 1 and BWRVIP-47 reports should be implemented and cited, wherever appropriate, within the BWRVIP-58 report to ensure consistency with prior NRC approved inspection guidelines pertaining to CRD internal components.

Item 2. Section 2.1.1, "Code Design Compliance," states that "the repair weld geometry is not explicitly recognized in the ASME Section III NB-3300 weld categories but is similar to a partial penetration weld Category D." Any weld geometry that does not explicitly meet either Code requirements or those of the staff-approved BWRVIP-58 report should be discussed with and approved by the NRC staff prior to initiation of the weld repair procedure.

4.0 CONCLUSION

The BWRVIP-58 report is considered by the staff to be applicable for licensee usage, as modified and approved by the staff, at any time during either the current operating term or during the extended license period. The staff requests that, if, during the course of implementing these repair guidelines, it is determined that implementation cannot be achieved as described in the guideline, or that meaningful results are not obtained, the user notify BWRVIP with sufficient details to support development of alternative actions. These notifications, as well as planned actions by BWRVIP, should be summarized and reported to the NRC. It should be noted that an Owner is responsible for reviewing regulatory requirements for the system. If the repair is an alternative repair to that specified in the regulations, i.e., 10 CFR 50.55a, the Owner may need to pursue the appropriate regulatory action.

The NRC staff has reviewed the BWRVIP-58 report and found it to be acceptable for providing guidance for the repair of CRD housing penetrations welds inside the reactor vessel except where the staff's conclusions differ from the proposed guidance, as discussed above. This finding, based upon the information submitted in the subject report, is consistent with NRC approved methodology. Therefore, the staff has concluded that licensee implementation of the guidelines in BWRVIP-58, with modifications to address the staff's conclusions above, will provide an acceptable repair design criteria of the safety-related components addressed in the BWRVIP-58 document. The staff requests that the BWRVIP review and resolve the issues raised in the enclosed SE, and incorporate the staff's conclusions into a revised BWRVIP-58 report. Please inform the staff in writing as to this resolution.

5.0 REFERENCES

1. Carl Terry, BWRVIP, to USNRC, "BWR Vessel and Internals Project, CRD Internal Access Weld Repair (BWRVIP-58)," EPRI Report TR-108703, dated November 13, 1998.

2. BWRVIP-03, "BWR Vessel and Internals Project, Reactor Pressure Vessel and Internals Examination Guidelines," Revision 1, dated March 1999

3. BWRVIP-47, "BWR Vessel and Internals Project, BWR Lower Plenum Inspection and Flaw Evaluation Guidelines," dated December 1997.