DRAFT SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

TOPICAL REPORT WCAP-17236-NP, REVISION 0, "RISK-INFORMED EXTENSION OF THE REACTOR VESSEL NOZZLE INSERVICE INSPECTION INTERVAL"

PRESSURIZED WATER REACTOR OWNERS GROUP

PROJECT NO. 694

1.0 INTRODUCTION AND BACKGROUND

By letter dated October 4, 2010, the Pressurized Water Reactor Owners Group (PWROG), submitted Topical Report (TR) WCAP-17236-NP, Revision 0, "Risk-Informed Extension of the Reactor Vessel Nozzle Inservice Inspection Interval" (Reference 1), for U.S. Nuclear Regulatory Commission (NRC) staff review. By letter dated August 26, 2011 (Reference 2), the PWROG submitted responses to the NRC staff's request for additional information (RAI) on WCAP-17236-NP, Revision 0 (hereafter referred to as the TR), but did not expand its scope as originally submitted for NRC staff review. Also attached to the August 26, 2011, letter is a revised WCAP-17236-NP, Revision 0, incorporating part of the PWROG's responses to the NRC's RAIs.

In the TR, the PWROG provided the technical and regulatory basis for decreasing the frequency of inspections by extending the American Society of Mechanical Engineers (ASME) *Boiler and Pressure Vessel Code* (ASME Code) Section XI inservice inspection (ISI) interval from the current 10 years to 20 years for ASME Code Section XI, Category B-F and B-J reactor vessel (RV) nozzle welds that do not contain Alloy 82/182.

The TR described a risk-informed methodology that relies on the probabilistic fracture mechanics (PFM) methodology which is similar to that used in the approved PWROG risk-informed ISI (RI-ISI) methodology for piping welds (Reference 3). The extension of the ISI interval from 10 to 20 years is also consistent with the methodology used in the approved application for extension of the ISI interval for RV welds (Reference 4) from 10 to 20 years.

The proposed changes may affect the RI-ISI program for each licensee who has implemented a RI-ISI program. In addition to the PWROG RI-ISI methodology, the NRC has endorsed plant-specific RI-ISI methodology based on the Electric Power Research Institute (EPRI) methodology (Reference 5), and has accepted relief requests based, in part, on the methodology in ASME Code Case N-716, "Alternative Piping Classification and Examination Requirements, Section XI, Division 1" (Reference 6). The effect of extending the ISI interval for nozzle welds for all three RI-ISI methodologies is addressed in the TR and this safety evaluation (SE).

2.0 REGULATORY EVALUATION

ISI of ASME Code Class 1, 2, and 3 components is performed in accordance with Section XI of the ASME Code and applicable Addenda as required by Title 10 of the *Code of Federal*

ENCLOSURE

Regulations (10 CFR) 50.55a(g), except where specific relief has been granted by the NRC pursuant to 10 CFR 50.55a(g)(6)(i). The regulation at 10 CFR 50.55a(a)(3) states that alternatives to the requirements of paragraph (g) may be used, when authorized by the NRC, if: (i) the proposed alternatives would provide an acceptable level of quality and safety or (ii) compliance with the specified requirements would result in hardship or unusual difficulty without a compensating increase in the level of quality and safety.

The regulations require that ISI of components and system pressure tests conducted during the first 10-year interval and subsequent intervals comply with the requirements in the latest edition and addenda of Section XI of the ASME Code incorporated by reference in 10 CFR 50.55a(b) 12 months prior to the start of the 120-month interval, subject to the limitations and modifications listed therein. The current requirements for the inspection of RV nozzle welds have been in effect since the 1989 Edition of ASME Code, Section XI. Article IWB-2000 of the ASME Code, Section XI establishes an ISI interval of 10 years. The TR proposed a methodology that can be used by individual licensees to demonstrate that extending the ISI interval on their Category B-F or B-J RV nozzle welds that do not contain Alloy 82/182 from 10 to 20 years would provide an acceptable level of quality and safety.

The NRC staff based its review of the risk information on NUREG-0800, “Standard Review Plan [(SRP)] for the Review of Safety Analysis Reports for Nuclear Power Plants,” Chapter 19.2, “Review of Risk Information Used to Support Permanent Plant-Specific Changes to the Licensing Basis: General Guidance” (Reference 7). SRP Chapter 19.2 directs the NRC staff to review each of the four elements suggested in Section 2 of Regulatory Guide (RG) 1.174, “An Approach for Using Probabilistic Risk Assessment in Risk-Informed Decisions on Plant-Specific Changes to the Licensing Basis" (Reference 8). These elements are: (1) define the proposed changes, (2) conduct engineering evaluations, (3) develop implementation and monitoring strategies, and (4) document the evaluations and submit the request. RG 1.174 also provides five key principles and numerical risk acceptance guidelines.

3.0 TECHNICAL EVALUATION

The objective of ISI is to identify conditions, such as flaw indications, that are precursors to leaks and ruptures and which violate pressure boundary integrity principles for plant safety.

The TR contains a methodology based on the risk-informed approach to assess the change in core damage frequency (ΔCDF) and the change in large early release frequency (ΔLERF) due to extension of the ISI interval from 10 years to 20 years for RV nozzle welds of four configurations. This part of the methodology follows the basic steps of RG 1.174. Many plants have implemented RI-ISI programs for piping, which considered RV nozzle welds as piping welds. Consequently, extension of the ISI interval for RV nozzle welds may affect the current RI-ISI assessment. Evaluation of this effect is the second part of the proposed methodology. This TR provides calculations for Beaver Valley Power Station, Unit 1 (BV-1), and Three Mile Island Nuclear Station, Unit 1 (TMI-1); illustrating the application of the proposed methodology to these two pilot plants.

3.1 Define the Proposed Change

The TR proposed to extend the ISI interval for ASME Code, Section XI, Category B-F and B-J RV nozzle-to-safe-end and safe-end-to-pipe welds (excluding welds of Alloy 82/182 materials) from 10 years to a maximum of 20 years. The change will be accomplished through

plant-specific requests for an alternative pursuant to 10 CFR 50.55a(a)(3)(i) on the basis that the alternative ISI interval provides an acceptable level of quality and safety.

The PWROG provided in the TR a proposed RV nozzle weld inspection schedule for participating PWROG plants, with the intent to achieve a somewhat uniform number of inspections per year from 2011 to 2050. Thus, the NRC staff determined that in its request for an alternative, each licensee shall identify the years in which future inspections will be performed. The dates provided must be within plus or minus one refueling cycle of the dates identified in the implementation plan of Table 3-13 of the TR.

3.2 Risk-Informed Evaluations

According to the guidelines in RG 1.174 and SRP Chapter 19.2, a RI application is an analysis of the proposed change using a combination of traditional engineering analysis with supporting insights from a risk assessment. The RI analysis in this TR proposes to verify that a reduction in the frequency of volumetric examination of the RV nozzle welds can be accomplished with an acceptably small change in risk.

The engineering evaluations include the PFM analysis to estimate the change in weld failure frequency caused by extending the ISI interval, and the change in risk caused by the change in failure frequency. The PFM engineering evaluations in the TR were based on results from applying the Westinghouse Structural Reliability and Risk Assessment (SRRA) Code (Reference 9), which is also the tool supporting the approved PWROG RI-ISI methodology for piping (Reference 3). These evaluations utilized the PFM methodology to model changes in failure frequency caused by change to the ISI interval. The change-in-risk evaluations are similar to the change-in-risk evaluations supporting the approved RI-ISI methodologies. The proposed methodology includes modifications to the RI-ISI change-in-risk evaluations to incorporate the increased failure frequency expected from the extended ISI interval.

3.2.1 PFM Methodology Evaluation

The ISI interval extension methodology is based, in part, on a PFM analysis of the effect of different ISI intervals on the frequency of postulated RV nozzle weld failure modes (i.e., Small, Medium, and Large Loss of Coolant Accident, or SLOCA, MLOCA, and LLOCA with leakage rates of 100, 1500, and 5000 gallons per minute (GPMs)). The likelihood of RV nozzle weld failure was postulated to increase with increasing time of operation due to the growth of pre-existing fabrication flaws by fatigue. The PFM methodology allowed for the consideration of distributions and uncertainties in flaw density and depth, material properties, crack growth resulting from fatigue, failure modes, stresses, and the effectiveness of inspections. For each of the four RV nozzle weld configuration types, the PFM approach was used to estimate a bounding change in failure frequency for each failure mode, considering the change of ISI interval from 10 years to 20 years. The change-in-risk calculation can then be performed for a plant to determine the ΔCDF and ΔLERF associated with the increased ISI interval and changes to the RI-ISI program.

<u>Validation of the Flaw Characteristics</u>

The flaw characteristics used in the SRRA Code had already been accepted because this code was used in supporting the approved PWROG RI-ISI applications. The flaw characteristics were developed using the PRODIGAL Code, which relies on artificial intelligence rules that are based on experience to simulate each step in the weld fabrication, considering the various types

of inspections used in the process. It is stated in Section 2.2 of the TR, "[t]he limiting flaw depth specified above [a through-wall depth of greater than six percent of the wall thickness and a length equal to six times the depth] is based upon the upper 2-sigma bound on the log-normally distributed median value of the initial flaw depth used for the fracture mechanics (PFM) analyses." To validate this flaw depth distribution, DCI-RAI-1 requested the PWROG discuss the characteristics of the five recordable indications shown in Table 3-1 of the TR from the past RV nozzle ISI findings to justify the initial flaw depth distribution used in the PFM analyses in this application. The PWROG clarified in its August 26, 2011, response that all five indications identified in Table 3-1 of the TR are sub-surface flaws. Therefore, the NRC staff determined that using surface flaws of an aspect ratio of 6 to 1 in the PFM analyses is conservative and bounds operating experience for RV nozzle welds.

Regarding flaw density, the PFM analyses supporting the TR were based on the assumption of one surface flaw per weld. The TR directs a licensee (Section 2.2) to validate that at most one surface breaking flaw is present based on past ISI results. If multiple surface breaking flaws have been detected in past inspections, the TR directs that the frequency be multiplied by the number of surface flaws. If the total flaw size from this method exceeds the dimension assumed above, a weld-specific PFM analysis should be performed to develop a weld-specific change-in-frequency value. Validation of this flaw assumption must also be performed in the future through continued monitoring.

3.2.1.1 PFM and Leakage Analysis in the SRRA Code

Since the TR contains no details of the PFM methodology used in the application, DCI-RAI-2 requested the PWROG provide a summary of the PFM analysis methodology used in the TR, including the analysis methodology type (elastic plastic fracture mechanics or linear elastic fracture mechanics), failure criteria, and the growth law for a flaw with an initial flaw depth to a critical size or through-wall flaw, and eventually to a long flaw corresponding to SLOCA, MLOCA, or LLOCA. DCI-RAI-2 also requested information regarding the establishment of fracture toughness and other material properties critical to failure resistance for each of the two failure periods for the RV nozzle welds and the key parameters which affect through-wall flaw leakage, the leakage that is considered detectable, and how leak detection was credited.

The PWROG provided a summary in the August 26, 2011, response covering all aspects of the PFM analysis methodology that the NRC staff mentioned in DCI-RAI-2. This PFM analysis methodology was used in supporting the approved TR on PWROG RI-ISI for piping (Reference 3). The summary helped the NRC staff accept the inputs for the current application to the SRRA Code and identify additional conservatisms in the PFM analyses, such as the surface flaw assumption and the instant change from a semi-elliptic flaw to a circular through-wall flaw when leaking starts. Due to low neutron fluence and benign coolant condition, fatigue crack growth was identified as the only growth mechanism of concern in this application. The interface of leakage determination and PFM analysis is also consistent with the industry approach that has been used in other areas such as leak-before-break applications. In addition, the PWROG's response to DCI-RAI-3 confirmed that "there were no parts of the SRRA Code used in generating PFM results for this application that were not needed in generating PFM results for the prior risk-ranking application [approved by the NRC]." This statement further supported the NRC staff's decision of not repeating a full, detailed, rigorous review of the PFM and leakage methodology documented in Reference 9.

To gain additional confidence in applying the SRRA Code in this application, the NRC staff requested additional information. DCI-RAI-4 inquired about the adequacy of obtaining an

"average" change in failure frequency by dividing the difference in failure probability by 40 or 60 years. DCI-RAI-5 inquired about the use of engineering insights in certain places of the application. DCI-RAI-6 inquired about the RV nozzle diameter input. DCI-RAI-7 inquired about the difference between two flaw related inputs: "X-ray nondestructive examination (NDE)" and "One Flaw." DCI-RAI-8 inquired about the selection of the crack inspection accuracy parameter of 0.24 in adjusting the probability of detection (POD) curves used in the SRRA Code.

The response to DCI-RAI-4 included a histogram of the calculated failure frequencies corresponding to the first row of results in Table 3-7 of the TR. For the case of the 20-year ISI interval, the NRC staff estimated that the average failure frequency applicable between Year 50 and Year 60 would be 5.17E-7 based on the PWROG's failure frequency of 7.3E-8 at Year 50 and 1.47E-7 at Year 60. Similarly, for the case of the 10-year ISI interval, the NRC staff estimated that the average failure frequency applicable between Year 50 and Year 60 would be 7.52E-8 based on the PWROG's failure frequency of 2.0E-8 at Year 50 and 2.92E-8 at Year 60. Hence, the average change of failure frequency in the time between Year 50 and Year 60 due to the ISI interval change would be 4.42E-7/year, about three times the change in failure frequency based on averaging over 60 years as reported in the first row of Table 3-7. RG 1.174 directs that annual frequencies be estimated and used while the method of simulating lifetimes in PFM analysis results in failure probabilities which can vary over times that extend far beyond one year. Averaging the results over the full life of the facility is a reasonable approximation provided that the risk does not substantively increase toward the end of facility life. The factor of three differences in the annual frequency results is small compared to the generally large margin between the calculated changes in risk and the acceptable guideline values. Therefore, the NRC staff finds that the proposed conversion of the PFM results to annual frequency is acceptable because the evaluation in the TR indicates that other methods of conversion are not expected to substantively change the results.

The response to DCI-RAI-5 clarified that the fatigue stress range and design limiting stress, two of the SRRA Code inputs, were determined considering engineering (operating) experience. Also, when steam generator snubber lock-up is evaluated, the worst type of snubber was assumed in the analysis. The response stated that the heats-up and cool-down transients are the primary drivers for fatigue crack growth. This is appropriate because it is consistent with operating experience. Also, considering the current industry practice of having a refueling cycle of 1.5 years and the rare scenario of experiencing several heat-ups and cool-downs before a defective component is successfully repaired during a scheduled or forced outage, the NRC staff considers the assumed 5 cycles per year for heat-up and cool-down transients (specified in the accompanying table) conservative. Therefore, DCI-RAI-5 is resolved.

The response to DCI-RAI-6 clarified that the input of RV nozzle diameter may not reflect the real nozzle geometry. Instead, "all grouping of thickness and diameter inputs were evaluated….the grouping that provided the highest change in failure (MLOCA) frequency between 10-year and 20-year inspection intervals was selected as being limiting for that nozzle type." Therefore, DCI-RAI-6 is resolved because the PWROG's approach of using the nozzle geometry that gave limiting results is conservative. Response to DCI-RAI-7 clarified that regardless what the SRRA input on flaw was called, "the SRRA Code simulate a maximum of one flaw at the worst stress location that could result in the first failure of the nozzle weld." Therefore, DCI-RAI-7 is resolved because the PWROG's approach of selecting the worst stress location for evaluation is conservative.

The response to DCI-RAI-8 provided PWROG's viewpoint regarding use of the crack inspection accuracy parameter of 0.24 versus 0.1. Since the NRC staff's conclusion does not depend on the results based on one particular performance factor, DCI-RAI-8 is resolved.

Based on the above evaluation and aided by the resolution of the eight DCI-RAIs, the NRC staff determined that the PWROG's use of SRRA Code in this application is appropriate and the PWROG's inputs for the SRRA Code are acceptable.

3.2.1.2 Change in Failure Frequencies Due to Extending the ISI Interval from 10 to 20 Years

The likelihood of RV nozzle weld failure was postulated to increase with increasing time of operation between inspections due to the growth of pre-existing fabrication flaws by fatigue. The likelihood of failure after an inspection decreased reflecting the possibility of identifying and repairing a flaw. The PFM approach in the TR simulated the growth of flaws over time between inspections and the repair of flaws that are detected during each ISI. The largest cracks were expected to exist at the end of the plant's operating life because, even with periodic inspection, flaws may be missed during an inspection. These flaws would remain in service and grow until eventually detected by ISI, failed in SLOCA, MLOCA, and LLOCA, or the end of plant life is reached. Therefore, the change in the likelihood of the event of concern is evaluated individually in the TR for SLOCA, MLOCA, and LLOCA.

Section 3.2.3 of the TR provides the bounding change-in-failure-frequency analysis results for all four types (Types A, B, C, and D) inlet and outlet nozzles for the failure modes of SLOCA, MLOCA, and LLOCA with 40 and 60 years' plant operation when the crack inspection accuracy parameter was assumed to be 0.24 (Tables 3-3 to 3-6). Detailed information supporting the MLOCA case in Tables 3-5 and 3-6 is provided in Tables 3-7 and 3-8, along with additional results for a crack inspection accuracy parameter of 0.1. The PWROG established the bounding nature of the results by first performing simulations at the highest and lowest weld temperatures and at different nozzle dimensions to determine the limiting case for the MLOCA. Subsequently, additional results using the identified limiting case were generated for the SLOCA and LLOCA for the normal and off-normal conditions.

During the implementation of a related TR, WCAP-16168-NP-A (Reference 4), which extended the ISI interval for RV welds, the NRC staff has concluded that relief from ASME Code 10 year inspection requirements should be requested every 20 years. Consistent with the requirement that relief be requested every 20 years, licensees need to determine whether the 40 or 60 year change in failure frequencies are most representative of the end of the requested 20 year extension.

In response to DRA-RAI-9, Westinghouse clarified that selecting whether the 40 or the 60 year failure frequencies should also include consideration of the plant life that has been used in the RI-ISI program. RI-ISI programs may have been based on the failure frequency after a 40 year plant life. If necessary, the plant life used in the RI-ISI program should be adjusted to match that required by the extension request. The examples in the TR sometimes use the 40 year values and sometimes the 60 year values but the NRC staff does not endorse the examples - only the estimated change in failure frequencies and the general methodology. Each licensee should identify in its relief request which failure frequencies were selected and why.

Based on the NRC staff's evaluation of the PFM methodology in the SRRA Code, the associated key SRRA Code input parameters for this application, and the reasonable approach for determining the limiting case, as described above, the NRC staff accepts the PWROG's

change-in-failure-frequency analysis results when used as described in the NRC staff endorsed version of this TR to evaluate the risk increase from extending the ISI interval for RV nozzle welds from 10 to 20 years.

3.2.2 Risk Assessment

In its response to DRA-RAI-1 and modifications to the TR, Westinghouse confirmed that at least one, and normally two, plant-specific changes in risk will be required to extend the RV nozzle welds ISI interval from 10 to 20 years: 1) the change in risk from the ASME Code, Section XI ISI program, and 2) the modified change in risk from the RI-ISI program if one is implemented.

The current ASME Code, Section XI requirements call for inspection of 100 percent of the RV nozzle welds every 10 years. The change in risk from the ASME Code, Section XI ISI program is required to identify the change in risk associated with relief from the 10 year inspection requirements in the ASME Code. Most licensees have, however, implemented a PWROG RI-ISI or an EPRI/ASME RI-ISI program to replace their ASME Code, Section XI ISI program. In this case, the change in risk from the RI-ISI program is required to be modified to include any additional change in risk associated with extending the interval.

The TR provides a methodology and part of the risk assessment inputs (the change in weld failure frequencies in Tables 3-3, 3-4, 3-5, and 3-6) for both risk assessments. The plant-specific risk assessment inputs to the change-in-risk calculations are the conditional core damage probabilities (CCDPs) and the conditional large early release probabilities (CLERPs) for SLOCA, MLOCA, and LLOCAs.

3.2.2.1 Change in Risk Associated with Relief from ASME Code, Section XI Inspection Interval Requirements

The change in risk is estimated by combining the appropriate change in weld failure frequencies from the TR with the plant-specific CCDPs and CLERPs. All change in failure frequency values are found in Tables 3-3 through 3-6. The TR proposes that failure frequency values without leak detection should be used for comparison to the ASME Section XI ISI interval. As discussed above, the licensee will need to select, and justify, either the 40 or the 60 year life. The estimated change in risk for each LOCA size is estimated by multiplying the change in failure frequency, the number of welds in the nozzle, and the CCDP and CLERP for each size. The total change in risk from the increased interval is obtained by summing the risk from all LOCA sizes. The NRC staff concurs with the TR’s direction that each licensee estimate the change in risk associated with extending the interval on the inspection of 100 percent of the welds from 10 to 20 years in each relief request that includes a request to extend the ISI intervals.

The NRC staff finds that the use of change in failure frequency without leak detection is conservative and therefore acceptable. The proposed calculations include the risk contribution for each possible weld failure and therefore yield estimates of the ΔCDF and ΔLERF that reflect the change in risk from the increased intervals. The NRC staff concurs that an estimated change that is less than the guidelines from RG 1.174 indicates that any increase in risk caused by changing the ASME Code, Section XI ISI program to extend the ISI interval for nozzle welds from 10 to 20 years is small and satisfies Principle 4 in RG 1.174.

3.2.2.2 Change in Risk Associated with Relief from RI-ISI Inspection Interval Requirements

Most plants have implemented RI-ISI and no longer inspect 100 percent of the RV nozzle welds. The RI-ISI program development selects welds to inspect based on the risk significance of piping segments. One or more welds within high-safety-significant (HSS) piping segments are generally selected for inspection. Since failure in the primary reactor coolant loops can lead to un-isolable LLOCAs, these segments are often HSS. Some plants select welds other than the RV nozzle welds in the primary coolant loops to fulfill RI-ISI inspection requirements. Some plants select RV nozzle welds. If a plant has selected no RV nozzle welds for inspection, the risk of discontinuing inspections in those locations is already included in the RI-ISI change in risk estimates. Plants which have included inspection of one or more RV nozzle welds in their RI-ISI program should include the increased risk from extending the ISI interval in the RI-ISI program's change in risk estimate. The TR provides the change in failure frequencies and the methodology to include the increased risk from extending the ISI interval in the RI-ISI program change-in-risk estimate.

The TR proposes that the "with leak detection" failure frequencies be used in the RI-ISI change-in-risk calculations. Primary coolant leak detection capability in containment is mandated by regulation and the NRC staff finds that crediting this capability is acceptable and consistent with the RI-ISI methodologies.

The TR proposes a total of seven different methods to include the increased interval in the RI-ISI change-in-risk estimates; three of which could be used with the PWROG RI-ISI methodology, four of which could be used with the EPRI methodology.

<u>PWROG RI-ISI</u>

The PWROG RI-ISI methodology is based on weld failure frequencies developed using the same methods and computer programs used in this TR. The PWROG RI-ISI methodology uses a single, worst case, weld frequency to represent a segment failure frequency for each LOCA size regardless of the number of welds in the segment. A change in risk is only estimated when all inspections in a segment are discontinued, when one or more inspection is introduced in a previously uninspected segment, or when augmented inspections are improved. Changing the number of welds inspected within a segment does not result in an estimated change in risk. As described in the NRC SE on the PWROG RI-ISI methodology (Reference 3), the change-in-risk calculations were not intended to "precisely estimate the magnitude of the change, [but] the calculation can illustrate whether resulting change will be a risk increase or a risk decrease." The lack of precision in the risk increase estimate was found acceptable, in part, because the PWROG RI-ISI method included acceptance guidelines that called for a neutral change in risk or a risk decrease instead of the risk increases permitted according to the RG 1.174 guidelines.

The TR proposes three alternative methods to estimate the change in risk between the ASME program and a PWROG RI-ISI program that includes an extended ISI interval for selected RV nozzle welds. In response to DRA-RAI-7, Westinghouse provided detailed equations describing the variables and the manipulations required to implement each of the alternatives. All three methods modify the PWROG RI-ISI change-in-risk methodology by assigning the segment failure frequency to each weld in the segment, and accounting for changing the number of inspections within each segment. The three methods differ by increasing the resolution of the CCDPs and CLERPs assigned to each segment from a worst case plant-wide estimate to a worst case system estimate and finally to a segment-specific estimate. Increasing the resolution will result in lower change in risk estimates.

The NRC staff finds that all three methods may be used. However, in response to DRA-RAI-2 and DRA-RAI-4, Westinghouse states that nozzles should be treated as segments and therefore nozzles with two welds should only use a single weld frequency (i.e., segment basis). This is inconsistent with the modified PWROG methodology and risk increase acceptance guidelines in the TR where segment failure frequency is multiplied by the number of welds in the segment (i.e., weld basis). Notwithstanding the RAI responses, the equations provided in the revised TR, step 4 under each of the three methods clearly states that the risk increase for the nozzles is calculated on a weld basis. Section 4.0 of this SE, Limitations and Conditions, states that licensees should use the equations in the TR, or identify any differences as deviations. Therefore, licensees that do not follow step 4 and use, instead, a single frequency for a nozzle with two welds must report this deviation from the equations.

The TR then proposes to modify the acceptance guidelines in the PWROG RI-ISI method from risk neutral to reactor coolant system and total risk increases that would meet the very small risk increase guidelines in RG 1.174. This modification of acceptance guidelines is consistent with the alternative methods which now account for the changes in the number of welds inspected instead of the number of segments inspected. If the risk increase guidelines cannot be met with the current RI-ISI program, the TR directs the licensee to add inspections until the guidelines are met. The NRC staff finds that the methodology and the associate acceptance guidelines acceptable because they incorporate any risk increase from extending the interval into the RI-ISI program. The resolution and thereby the precision of the change-in-risk estimates are increased by accounting for the changes in the number of welds inspected and therefore changing the acceptance guidelines to larger acceptable risk increases continue to provide confidence that the increase in risk is acceptable.

<u>EPRI/ASME RI-ISI</u>

The EPRI/ASME RI-ISI methodology is based on weld failure likelihood “bins” determined only by the presence or absence of potential degradation mechanisms. Identification of segment safety significance and determination of the number of inspections is based on which degradation mechanism may be present and the CCDP and CLERP in each segment. The final change-in-risk estimates in the EPRI/ASME methods use a single break size frequency and single values for CCDP and CLERP. The change-in-risk estimate is the product of the failure frequency of an uninspected weld associated with the potential degradation mechanism, the estimated CCDP and CLERP, and, optionally, an inspection effectiveness (IE) factor between 0 and 1 that characterizes the likelihood that inspections will identify flaws before weld failure. This IE factor is similar to the crack inspection accuracy parameter discussed in Section 3.2.1.1 of this SE and included in the frequency estimates in Tables 3-3 through 3-6 of the TR. Therefore, any calculation that combines frequencies from Tables 3-3 through 3-6 together with an IE factor would incorrectly account twice for inspections.

The risk increase from each discontinued inspection and decrease from each new inspection are included. The TR proposes four alternative methods to estimate the change in risk between the ASME program and an EPRI/ASME RI-ISI program that includes an extended ISI interval for RV nozzle welds that are included in the RI-ISI program.

The first method is a qualitative method. As stated in the TR, “[t]his method implicitly assumes that all inspections are performed on the same interval.” The discussion in the TR does not provide any alternative to this assumption which is no longer valid if the ISI interval is extended and therefore the NRC staff does not approve the use of the qualitative method.

The second method estimates the increased risk from extending the ISI interval and adds that increase in risk to the EPRI/ASME RI-ISI change in risk. The RI-ISI change in risk is illustrated in equation 3-1 of the TR. The increased risk is the product of the increased frequency (from Tables 3-3 through 3-6) and the CCDP and CLERP for reactor coolant loop LOCAs as described in the TR. Simply adding this risk increase to the increase in risk from implementing an EPRI/ASME RI-ISI program is consistent with adding the increased risk from the extended interval with the increased risk from implementation of the RI-IS program and therefore acceptable.

The third and fourth methods modify the IE factor that would be applied to the welds with the extended ISI interval. The IE factor is directly characterized by assigning a POD or calculated using a Markov model. Equations 3-2 and 3-3 of the TR illustrate these methods. Both equations 3-2 and 3-3 of the TR include parameters characterizing the failure frequency of an uninspected weld. Changes to the ISI interval are reflected in changes in the IE factor. In the discussion following these equations, the TR states that changes in failure frequency from Tables 3-3 through 3-6 should somehow be used in the equations. This discussion is inconsistent with the definitions of the parameters in the equations and would yield incorrect results when combined with changes in the IE factors. Therefore, licensees that use the frequencies from Tables 3-3 through 3-6 cannot use these equations and parameter definitions and must report this deviation and identify and justify their proposed method and input values.

The third method would change the POD based on the increased ISI interval. The TR did not address changes to the POD, so each licensee would need to describe and justify any changes to the POD. The fourth method changes the ISI interval which is an input parameter to the Markov model and calculates the change in IE. The Markov method has been found acceptable for use in developing an EPRI/ASME RI-ISI program, and the NRC staff concurs that the model can appropriately incorporate changes to the ISI interval. The use of equations 3-2 and 3-3 requires the use of an uninspected weld failure frequency. Section 4.0 of this SE, Limitations and Conditions, states that licensee must identify and justify the frequency used.

The NRC staff finds that the proposed qualitative method is not acceptable because it does not provide an alternative for the assumption that all inspections are performed on the same interval. The NRC staff concurs that the three proposed quantitative methods to incorporate the extension of the ISI interval into the EPRI/ASME RI-ISI program change-in-risk estimates are consistent with the EPRI methodology and acceptable. The failure frequencies in Tables 3-3 through 3-6 of the TR may only be used in the first quantitative method. Uninspected weld failure frequencies must be identified and justified for the second and third quantitative methods. Unlike the PWROG RI-ISI methodology, the change-in-risk acceptance guidelines are not changed. The NRC staff finds this is appropriate and acceptable because the EPRI/ASME RI-ISI methodology uses changes in the number of welds inspected and these additional risk calculations also use changes in the number of welds inspected together with the new change in failure frequency estimates.

3.2.2.3 Evaluation of PRA Technical Adequacy

Technically adequate is defined, at the highest level, as an analysis that is performed correctly, in a manner consistent with accepted practices, commensurate with the scope and level of detail required to support the proposed change. The TR does not address the technical adequacy of the PRA.
The TR requires CCDPs and CLERPs for SLOCA, MLOCA, and LLOCA. The acceptance guidelines are comparable to the acceptance guidelines for a RI-ISI program. The NRC staff

finds that a PRA that is adequate to support the development of a RI-ISI program is adequate to support the change-in-risk evaluations described in the TR because the PRA calculations required by the TR are fewer than, or equivalent to, those required to develop a RI-ISI program. Any licensee that has no RI-ISI program that requests relief to extend the ISI interval would need to justify that its PRA is technically adequate to support the request.

3.3 Submit Proposed Change

The fourth and final element in the RG 1.174 approach is the development and submittal of the proposed change to the NRC. Since the 10-year ISI interval is required by Section XI, IWB-2412, as codified in 10 CFR 50.55a, a relief for an alternative, in accordance with 10 CFR 50.55a(a)(3)(i), must be submitted and approved by the NRC to extend the ISI interval. Licensees that submit a request for an alternative based on the TR need to submit plant-specific information summarizing which methods from the TR were used and addressing each of the limitations and conditions in Section 4.0 of this SE.

3.4 Conformance to RG 1.174

In addition to the four element approach discussed above, RG 1.174 states that RI plant changes are expected to meet a set of five key principles. This section summarizes these principles and the NRC staff findings related to the conformance of the TR methodology with changes to ISI programs in general and with the extension of the ISI interval proposed in the TR.

Principle 1 states that the proposed change must meet the current regulations unless it is explicitly related to a requested exemption or rule change. ISI of ASME Code Class 1, 2, and 3 components is performed in accordance with Section XI of the ASME Code and applicable addenda as required by 10 CFR 50.55a(g), except where specific relief has been granted by the NRC pursuant to 10 CFR 50.55a(g)(6)(i). This RI application requires a request for an alternative under CFR 50.55a(a)(3)(i) which meets the current regulations and, therefore, satisfies Principle 1.

Principle 2 states that the proposed change shall be consistent with the defense-in-depth philosophy[1]. The NRC staff believes that ISI is an integral part of defense-in-depth and extending the interval may change the robustness of the reactor coolant pressure boundary, albeit very slightly. However, the NRC staff concludes that increasing the failure frequency by extending the ISI interval is similar to increasing the failure frequency by discontinuing inspections in RI-ISI. Unlike RI-ISI, these increases are not offset by inspecting new locations but, also unlike RI-ISI, the scope of the change is limited to the small, well defined, population of nozzle welds. Therefore, consistent with the NRC staff conclusions endorsing RI-ISI, the NRC staff concludes that there is a reasonable assurance that the resulting ISI program will provide a substantive ongoing assessment of piping condition and therefore the Principle 2 is met.

Principle 3 states that the proposed change shall maintain sufficient safety margins. The TR states that no safety analyses are changed. The NRC staff concurs that there are no changes to the evaluations of design-basis accidents in the Final Safety Analysis Report (FSAR). This proposal is only to extend the ISI interval and no other portions of the current inspection

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1 The NRC staff finds the defense-in-depth discussion in, and following, Table 3-12 of the TR, while supportive of defense-in-depth, is more descriptive of the strategies that will be used to monitor the impact of the proposed change and addresses the TR discussion under Principle 5.

requirements are eliminated. The NRC staff finds that extending the ISI interval may permit some flaws to remain undetected and thereby reduce the margin to failure of these welds. However, the proposal does not, for example, change the acceptance criteria used to determine whether any identified flaws are acceptable and therefore the NRC staff finds that sufficient safety margins are maintained and Principle 3 is met.

Principle 4 states that when proposed changes result in an increase in CDF or risk, the increases should be small and consistent with the intent of the Commission's Safety Goals. The TR provides methods to estimate the change in risk associated with changing the ASME Code, Section XI inspection program for RV nozzle welds from 10 to 20 years, and from changing the ISI interval for RV nozzles in an existing RI-ISI program from 10 to 20 years. Provisions to increase the number of welds for inspection if the acceptance guidelines are not met are provided. Therefore, Principle 4 is met.

Principle 5 states that the impact of the proposed change should be monitored using performance measurement strategies. The TR states that nondestructive examinations will still be conducted, but on a less frequent basis not to exceed 20 years and that indications of potential generic degradation mechanisms of RV nozzle welds will still be available during this extended ISI interval (e.g., foreign experience, inspection of other similar locations, and periodic testing with visual examinations). To demonstrate that there will be a sampling of inspections performed over the 20-year interval that will provide an indication of emerging issues, a somewhat optimized implementation schedule was developed. This schedule is for the period from 2009 to 2048 and applies to plants with non-alloy 82/182 Category B-F and B-J welds. Since the RV nozzle weld inspections are performed at the same time as the RV shell weld inspections, the schedule is based on the schedule developed for the RV shell weld ISI interval extension provided in PWROG Letter OG-09-454 (Reference 10). The schedule is based upon every plant identified in Table 4-1 implementing the 10-to-20-year interval extension for the inspection of RV nozzle welds. Any indications that are found during the inspections will be treated as flaw indications and evaluated under ASME Code, Section XI, and so there is no change to this monitoring aspect. Therefore, Principle 5 is met.

4.0 CONDITIONS AND LIMITATIONS

This section summarizes the conditions and limitations that should be addressed by all applicants in their relief requests to increase the ISI interval for RV nozzle welds from 10 years to 20 years:

- The PFM analyses supporting the TR were based on a key assumption - one surface flaw per weld. Therefore, consistent with the TR guidance in Section 2.2, the NRC staff requires applicants to validate that at most one surface breaking flaw is present based on past ISI results. If multiple surface breaking flaws have been detected in past inspections, then the resulting change in failure frequency shall be multiplied by the number of surface flaws. If the total flaw size from this method exceeds the dimension assumed in the TR, i.e., a through-wall depth of greater than six percent of the wall thickness and a length equal to six times the depth, a weld-specific PFM analysis should be performed to develop a weld-specific change-in-frequency value. Validation of this flaw assumption must also be performed in the future through continued monitoring.

- The NRC staff accepts the PWROG's change-in-failure-frequency analysis results when used as described in the NRC staff endorsed version of this TR to evaluate the risk

increase from extending the ISI interval for RV nozzle welds from 10 to 20 years. Licensees must select the 40 or 60 year change-in-failure-frequency results, clarify the relationship between the selected life time and the values used in the RI-ISI, and justify the selected values. Generally, selecting the most conservative values will be acceptable without additional justification.

- Licensees must submit plant-specific change-in-risk results using the appropriate change in failure frequency from Tables 3-3 to 3-6 in the relief requests as described in the TR. A change in risk between the ASME requirements and the extended ISI interval must always be provided. If the licensee has a RI-ISI program, the change in RI-ISI risk results including the extended intervals should be provided. If any change in risk exceeds the applicable risk guidelines in the TR, the licensee should identify and justify the deviation.

- The NRC staff does not endorse the qualitative change in risk evaluation described in the TR because it provides no alternative for the assumption that all inspections are performed on the same interval.

- Licensees must identify specifically which of the six change-in-risk equations in the TR was used. Any deviations from the selected equations must be identified and justified.

- The use of the third and fourth methods for the EPRI methodology (equations 3-2 and 3-3) requires the use of an uninspected weld failure frequency. Each licensee must identify and justify the frequency used.

- Licensees should address PRA quality in their relief request. Licensees relying on a NRC staff approved RI-ISI program to demonstrate PRA quality should provide this statement in their submittal. Licensees without a NRC staff approved RI-ISI program must describe the technical adequacy of their PRA in the relief request.

- Licensees that use the EPRI/ASME method that reflects changes in failure frequency by changing the POD must describe and justify the proposed change to the POD.

- The NRC staff does not endorse the BV-1 and TMI-1 examples or the use of any quantative results from any tables besides Tables 3-3 through 3-6 of the TR. Licensees (including BV-1 and TMI-1) may not refer to the examples to justify any evaluation or calculation.

5.0 CONCLUSION

The NRC staff has reviewed WCAP-17236-NP and concludes that the TR, as modified by the conditions and limitations summarized in Section 4.0 of the SE, provides an acceptable methodology that can be used to support a request to extend the ISI interval for Category B-F or B-J RV nozzle welds that do not contain Alloy 82/182 from 10 to 20 years.

Section 3.2.1.1 of this SE mentioned that due to low neutron fluence and benign coolant condition, fatigue crack growth was identified as the only growth mechanism of concern in this application. Also discussed in this section are the postulated surface crack, the fatigue stress range, number of fatigue cycles, and design limiting stresses. Since extending the RV ISI interval could increase the risk of RV failure from such cracks, the SRRA Code was used to

perform the fatigue crack growth analysis to produce PFM results for the subsequent risk-informed calculations. Based on the NRC staff evaluation of Section 3.2.1.1, the NRC staff has concluded that the TR has appropriately postulated and modeled the potential change in failure frequency risk that could be caused by fatigue crack growth over the life of operating facilities. Therefore the NRC staff accepts the PWROG's change-in-failure-frequency analysis results (in Tables 3-3 through 3-6) when used as described in the NRC staff endorsed version of this TR to evaluate the risk increase from extending the ISI interval for RV nozzle welds from 10 to 20 years.

The evaluation in the TR illustrates the variability in the estimated annual failure frequencies. This variability is incorporated into all the methodologies approved for the development of RI-ISI programs. The analysis that was performed to support this TR does not reduce this variability and therefore the NRC staff does not endorse any changes to PWROG or the EPRI/ASME RI-ISI program methodology development.

Based on the above conclusions, the ASME Code Section XI ISI interval for examination categories B-F and B-J welds in PWR RVs can be extended from 10 years to a maximum of 20 years. Since the 10 year ISI interval is required by Section XI, IWB-2412, as codified in 10 CFR 50.55a, a request for an alternative, in accordance with 10 CFR 50.55a(g)(6)(i), must be submitted and approved by the NRC to extend any facility's ISI interval. During the implementation of a related TR WCAP-16168-NP-A (Reference 4) which extended the ISI interval for RV welds, the NRC staff has concluded that relief from ASME Code 10 year inspection requirements should be requested every 20 years. Similarly, relief from the ASME Code 10 year inspection requirement should be requested every 20 years when applying TR WCAP-17236-NP, Revision 0, in coordination with the TR WCAP-16168-NP-A application. Each licensee shall identify the years in which future inspections will be performed. The dates provided must be within plus or minus one refueling cycle of the dates identified in the implementation plan of Table 3-13 of the TR.

The NRC staff does not endorse the BV-1 and TMI-1 examples. Licensees (including BV-1 and TMI-1) may not refer to the examples to justify any evaluation or calculation. The NRC staff will not repeat its review of the matters described in the WCAP-17236-NP, as modified by the attachment to the supplement dated August 18, 2011, when the report appears as a reference in a request for an alternative, except to ensure that the material presented applies to the specific plant involved and the licensee has submitted all the information requested in Section 4.0 of this SE.

6.0 REFERENCES

1. WCAP-17236-NP, Revision 0, "Risk-Informed Extension of the Reactor Vessel Nozzle Inservice Inspection Interval," September 2010 (ADAMS Accession No. ML102790088).

2. Letter from Melvin L. Arey Jr., PWR Owners Group, "Responses to the NRC Supplemental Request for Additional Information (RAI) on PWR Owners Group (PWROG) WCAP-17236-NP, Revision 0, 'Risk Informed Extension of the Reactor Vessel Nozzle Inservice Inspection Interval,' (TAC NO. ME4878) PA-MSC-0440," August 26, 2011 (ADAMS Accession No. ML11280A084).

3. WCAP-14572, Revision 1-NP-A, "Westinghouse Owners Group Application of Risk-Informed Methods to Piping Inservice Inspection Topical Report," February 1999 (ADAMS Accession Nos. ML042610469).

4. WCAP-16168-NP-A, Revision 2, "Risk-Informed Extension of the Reactor Vessel In-Service Inspection Interval," June 2008 (ADAMS Accession No. ML082820046).

5. EPRI Topical Report TR-112657, Revision B-A, "Revised Risk-Informed Inservice Inspection Evaluation Procedure," December 1999 (ADAMS Accession No. ML013470102).

6. ASME Code Case N-716, "Alternative Piping Classification and Examination Requirements, Section XI, Division 1."

7. U.S. NRC, NUREG-0800, Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants," Section 19.2, "Review of Risk Information Used to Support Permanent Plant-Specific Changes to the Licensing Basis: General Guidance," June 2007 (ADAMS Accession No. ML071700658).

8. U.S. NRC, Regulatory Guide 1.174, Revision 1, "An Approach for Using Probabilistic Risk Assessment in Risk-Informed Decisions on Plant-Specific Changes to the Licensing Basis," November 2002 (Adams Accession No. ML023240437).

9. WCAP-14572, Revision 1-NP-A, Supplement 1, "Westinghouse Structural Reliability and Risk Assessment (SRRA) Model for Piping Risk-Informed Inservice Inspection," February 1999 (ADAMS Accession No. ML042610375).

10. PWR Owners Group letter OG-09-454, "Revised Plan for Plant Specific Implementation of Extended Inservice Inspection Interval per WCAP-16168-NP, Revision 1, 'Risk Informed Extension of the Reactor Vessel In-Service Inspection Interval,' PA-MSC-0120," dated December 1, 2009 (ADAMS Accession No. ML093370133).

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