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Progress Energy

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United States Nuclear Regulatory Commission
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H. B. ROBINSON STEAM ELECTRIC PLANT, UNIT NO. 2
DOCKET NO. 50-261/LICENSE NO. DPR-23

RESPONSE TO NRC REQUEST FOR ADDITIONAL INFORMATION REGARDING REVIEW OF REFUELING OUTAGE 25 INSPECTIONS OF THE REACTOR VESSEL NOZZLE DISSIMILAR METAL BUTT WELDS

Ladies and Gentlemen:

By letter dated December 24, 2009, the NRC requested that Carolina Power and Light Company, also known as Progress Energy Carolinas, Inc. (PEC), respond by January 18, 2010 to a request for additional information (RAI) regarding review of Refueling Outage 25 inspections of the reactor vessel nozzle dissimilar metal butt welds. The attachment to this letter provides the RAI response for the H. B. Robinson Steam Electric Plant, Unit No. 2.

If you have any questions concerning this matter, please contact Mr. C. A. Castell at (843) 857-1626.

Sincerely,

Curtis A. Castell

Curtis A. Castell
Supervisor – Licensing/Regulatory Programs

CAC/ahv

Attachment

c: Mr. L. A. Reyes, NRC, Region II
Mr. T. J. Orf, NRC, NRR
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H. B. ROBINSON STEAM ELECTRIC PLANT, UNIT NO. 2

RESPONSE TO NRC REQUEST FOR ADDITIONAL INFORMATION REGARDING REVIEW OF REFUELING OUTAGE 25 INSPECTIONS OF THE REACTOR VESSEL NOZZLE DISSIMILAR METAL BUTT WELDS

NRC Question A

The licensee accepted one flaw in the cold leg and 9 flaws in the hot leg by analysis. Discuss whether these 10 flaws will be subject to successive examinations. If so, discuss the schedules for the successive examinations of these 10 flaws.

Response:

H. B. Robinson Steam Electric Plant, Unit No. 2, is currently planning to inspect the above mentioned flaws in Refueling Outage 27 (RO27) currently scheduled to begin on September 17, 2011. During RO27, mitigation measures will be taken on an as-needed basis. If mitigation measures are taken, a return to the normal 10-year frequency will occur. If mitigation measures are not taken then HBRSEP, Unit No.2, plans to inspect the 'A' and 'C' Cold Legs every 6 years (RO29) and 'B' Cold Leg and all three Hot Legs in the next 3 inspection periods in accordance with ASME Code requirements.

NRC Question B.1

Page 2-1. Combining Moments. The licensee used the square root of the sum of the square of the moment components to estimate the equivalent moment for bending stress. NUREG/CR-6299 recommends the following for good comparisons to finite element results:

$$M_{eff} = \sqrt{M_x^2 + M_y^2 + \left(\frac{\sqrt{3}}{2}T\right)^2}$$

In light of moment combination in NUREG/CR-6299, discuss the validity of the square root of the sum of square of the moment components.

Response:

The use of the square root of the sum of square of the moment components is in accordance with Section 2.3.1 in Journal of Pressure Vessel Technology, Pressure Vessel and Pipe (PVP) Codes, Volume 108, August 1986, "Evaluation of Flaws in Austenitic Steel Piping," which is the technical basis for the ASME Section XI flaw evaluation procedure. The relevant statement from Section 2.3.1 is shown below:

"*...The primary membrane and primary bending stresses used in ASME Section XI, Subsection IWB-3640 correspond to the unconcentrated primary stress intensity values defined in equation (9) of ASME III Section NB-3650...*"

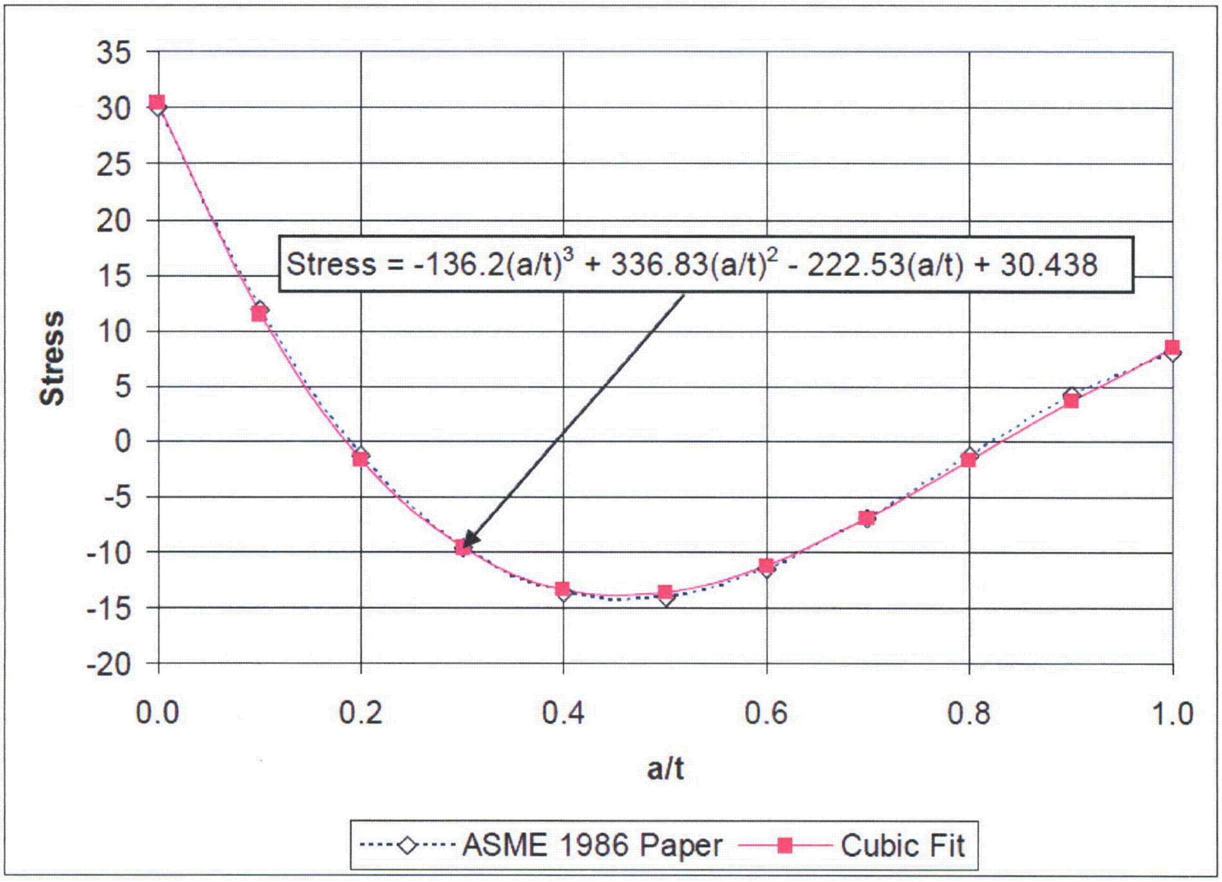
The primary bending stress defined in Equation (9) of ASME III Section NB-3650 is determined based on resultant moment Mi, i.e., square root of the sum of square of the moment components. There is no known change as of to-date pertaining to the technical basis of the ASME Section XI, IWB-3640 flaw evaluation approach with regard to the use of the resultant moment (as stated in Section 2.3.1 of the 1986 PVP paper) in determining primary bending stress. In addition, the use of the square root of the sum of square of the moment components is conservative compared to that recommended in NUREG-6299.

NRC Question B.2

Page 2-3. A third order approximation is used for the through wall thickness stress profile. In many cases, this representation may not be adequate, especially for welding residual stress. This approximation can underpredict the stresses on the crack face and provide non-conservative approximations of time to leakage. Discuss the validity of using the third order approximation for the through wall thickness stress.

Response:

The through-wall residual stress profiles used in the evaluation are shown in Figure 3-5 on page 3-12 of WCAP-15620-P. This residual stress profile was obtained from the "Journal of Pressure Vessel Technology," Pressure Vessel and Pipe Codes, Volume 108, August 1986, "Evaluation of Flaws in Austenitic Steel Piping." A third order approximation is adequate to represent such through-wall residual stress profile as shown below even though the actual axial residual stress distribution is a fourth order polynomial.



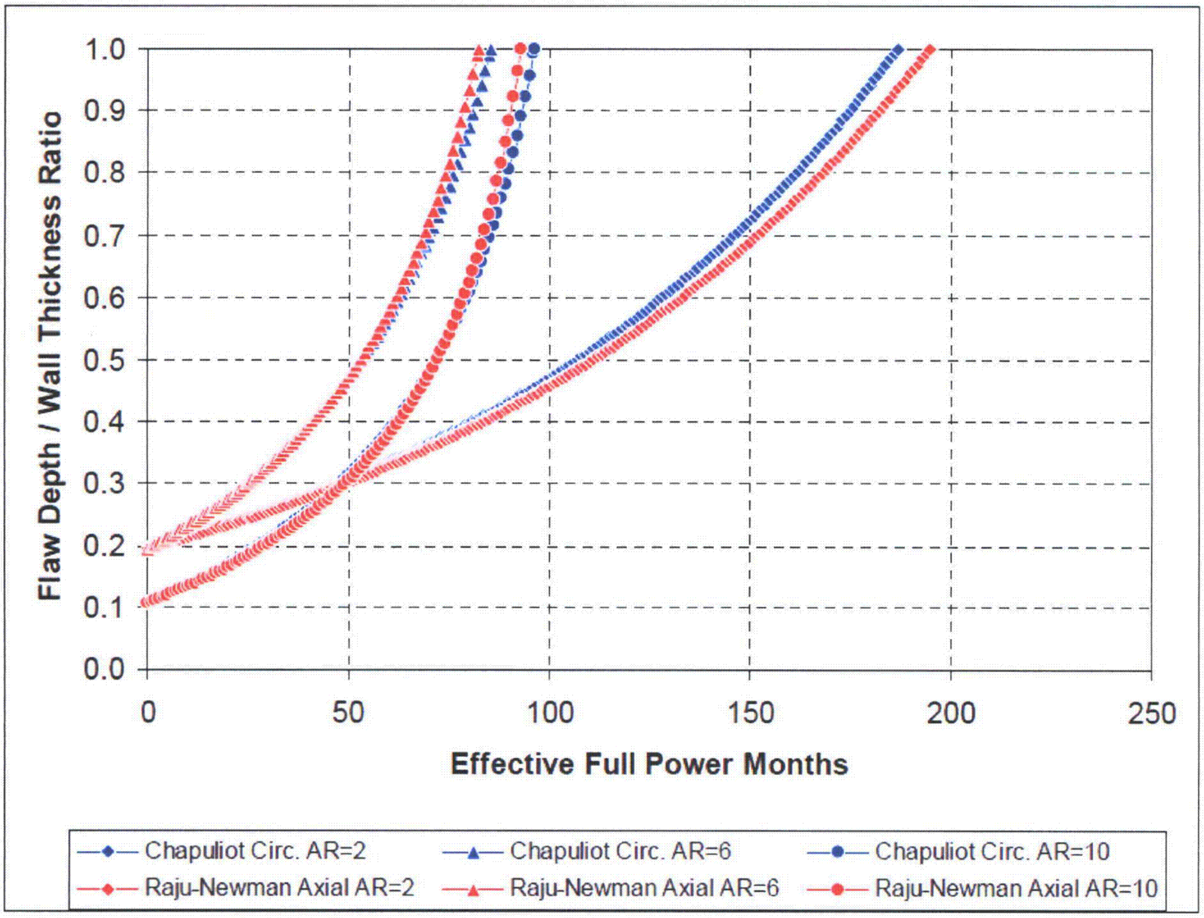
NRC Question B.3

Page 2-3. The licensee stated that the same influence functions for stress intensity are used for longitudinal and circumferential flaws because there is no difference until the crack is deep. Both American Petroleum Institute (API) and American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Section XI, have published influence functions that are different for circumferential and longitudinal cracks and illustrate they are a function of Rlt, location (internal/external), etc. Please provide references or examples to show why the same influence functions for stress intensity can be used for longitudinal and circumferential flaws.

Response:

Figures 197 and 199 in "Compendium of Stress Intensity Factors, D. P. Rooke and D. J. Cartwright, London, Her Majesty's Stationery Office," provides the crack tip stress intensity factors respectively for a longitudinal and circumferential flaw in a cylindrical shell. A comparison of the magnification factors for the same uniform membrane stress field indicated that the stress intensity factor calculated based on a longitudinal flaw would be conservative for a circumferential flaw.

Primary Water Stress Corrosion Crack (PWSCC) growth curves with various aspect ratios (flaw length/flaw depth ratio) were generated using the stress intensity factor expression for circumferential flaw (S. Chapuliot, M. H. Lacire, and P. Le. Delliou, "Stress intensity factors for internal circumferential cracks in tubes over a wide range of radius over thickness ratios," ASME PVP Vol. 365, 1998) and the Raju-Newman stress intensity factor expression for longitudinal flaw (Raju, I. S., and Newman, J. C., "Stress Intensity Factors for Internal and External Surface Cracks in Cylindrical Vessels," Journal of Pressure Vessel Technology, Vol. 104, 1982, pp. 293-298). The input to the PWSCC growth analysis is the same as those used in WCAP-15620-P for circumferential flaws at the outlet nozzle dissimilar metal weld. The crack growth results shown below indicated that the results are in good agreement with only minor differences.



NRC Question B.4

Page 2-7. The licensee stated that Z factors for Alloy 182 are used, and referenced the ASME Code, Section XI. However, to date the 1995 edition of the ASME Code, Section XI, does not have Z factors for Alloy 182. Provide the Z factors that were used in the analysis and discussion from which edition or addenda of the ASME code were the Z factors taken.

Response:

The Z-factor, 1.30 [1 + 0.010 (D-4)], where D is Pipe Outside Diameter (in.), provided in the 1995 edition of the ASME Code, Section XI, were used in the evaluation. This Z-factor is conservative when compared to the following Z-factor developed for Alloy 182 material per the Materials Reliability Program (MRP) guidelines, MRP-216, "Advanced FEA Evaluation of Growth of Postulated Circumferential PWSCC Flaws in Pressurizer Nozzle Dissimilar Metal Welds," Revision 1.

$$Z = 0.0000022(NPS)^3 - 0.0002(NPS)^2 + 0.0064(NPS) + 1.1355$$

Where NPS is Nominal Pipe Size (in.)

NRC Question B.5

Page 2-8. In dealing with net section collapse of dissimilar metal welds, the lower strength base metal controls the failure. It is unclear what value of Sm was used in the analyses for the dissimilar metal welds. Using the higher strength Alloy 182 is the predictions will over estimate the maximum load carrying capacity. Clarify the value of Sm for the dissimilar metal welds.

Response:

Based on weakness of the material data from the Certified Material Test Report of the base metal and high strength Alloy 182 weld, Sm for the outlet nozzle dissimilar metal (DM) welds is 19.8 ksi and that for the inlet nozzle DM welds is 23.3 ksi. For axial flaw, the Sm value for the Alloy 182 weld can be used since PWSCC growth occurs within the susceptible weld material.

NRC Question B.6

Page 3-1. The licensee stated that the flaw was assumed to maintain a constant shape as it grew. Does constant shape mean constant aspect ratio? And if so, what aspect ratio was assumed?

Response:

The flaw was assumed to maintain a constant aspect ratio or crack shape as it grew. Various aspect ratios were considered in the development of the flaw evaluation charts in WCAP-15621-NP, Revision 1, to facilitate flaw disposition. The aspect ratio was plotted as flaw shape (flaw depth/flaw length) in the flaw evaluation charts. If the as-found flaw shape is higher than 0.5, the flaw shape is assumed to be 0.5 in accordance with the requirement in ASME Code, Section XI, Subsection IWA-3000. The flaw depth/flaw length ratio for all the as-found flaws are larger than 0.5 and therefore 0.5 was used.

NRC Question B.7

Page 3-7. The licensee estimated welding residual stresses based on a 1986 paper on similar metal welds. A third order approximation for a yield stress of 30 ksi is assumed. Recent work on dissimilar metal welds (Alloy 81/182 metal) has shown that this approximation can significantly underestimate the welding residual stress. In fact, a 2008 ASME PVP paper written by Westinghouse staff (Bamford, et al, "Technical Basis For Revisions To Section XI Appendix C For Alloy 600/82/182/132 Flaw Evaluation In Both PWR And BWR Environments," PVP2008-61840, Proceedings of PVP2008, 2008 ASME Pressure Vessel and Piping Division Conference, July 28 -31, 2008, Chicago, IL USA) suggests the inside diameter welding residual stress for Section XI analyses should be about 54 ksi. Using the data from the 1986 paper can underpredict the calculated times to failure. Justify the use of welding residual stresses from the 1986 paper.

Response:

A comparison of the welding residual stress from the 1986 ASME paper with those generated using finite element analysis for dissimilar metal welds without any prior weld repairs is shown in Figures 8-2 and 8-3 of MRP-106 (Material Reliability Program: Welding Residual and Operating Stresses in PWR Plant Alloy 182 Butt Welds). Based on the comparison and the conclusion in Section 8.0 of MRP-106, as quoted below, the use of the estimated welding residual stress from the 1986 paper for dissimilar metal welds without any prior weld repairs is a reasonable approximation.

"...the stresses predicted by the empirical model tend to be higher than the finite element analysis results over the inside half of the nozzle wall. This will lead to the empirical model predicting higher stress intensities over the inside half of the pipe wall. This will dominate the crack growth and lead to conservative crack growth predictions of time to a leak."

Similar conclusion can be drawn from Figure 8 of PVP2008-61840 paper (Technical Basis For Revisions To Section XI Appendix C For Alloy 600/82/182/132 Flaw Evaluation In Both PWR And BWR Environments) by reviewing the axial residual stress for the hot leg without repair.

Studies (PVP2009-77269, "Residual Stress Evaluation of Dissimilar Weld Joint Using Reactor Vessel Outlet Nozzle Mock-up Model – Report 2") have been made pertaining to the effect on the as-welded residual stress profile in the dissimilar metal weld after the completion of the safe end to pipe stainless steel weld. The results of the studies indicated that the resulting residual stress profile at the dissimilar metal weld is compressive at the inner surface of the weld. The flaw evaluation charts generated for Robinson did not take credit for the stainless steel safe end effect. Therefore, use of the residual stress from the 1986 ASME paper for the dissimilar metal welds without prior repair is a reasonable approximation based on the latest literature and publications available at the time the analyses were performed.