UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

December 28, 2010

Mr. Robert J. Duncan II
Vice President – Robinson Nuclear Plant
Carolina Power & Light Company
H. B. Robinson Steam Electric Plant,
Unit No. 2
3581 West Entrance Road
Hartsville, South Carolina 29550

SUBJECT: H. B. ROBINSON STEAM ELECTRIC PLANT, UNIT NO. 2 – REVIEW OF REFUELING OUTAGE 25 INSPECTIONS OF THE REACTOR VESSEL NOZZLE DISSIMILAR METAL BUTT WELDS (TAC NO. ME0233)

Dear Mr. Duncan:

By letters dated December 8, 2008, as supplemented by letters dated January 22, 2009, January 18, 2010, and June 24, 2010, Carolina Power & Light Company (the licensee), now doing business as Progress Energy Carolinas, Inc., submitted to the U.S. Nuclear Regulatory Commission (NRC) the results of inspections conducted on dissimilar metal butt welds in the reactor vessel nozzles during the H. B. Robinson Steam Electric Plant, Unit No. 2, Refueling Outage 25 in 2008. The submittal includes the flaw evaluation of 10 indications in the hot and cold leg piping.

The NRC staff finds that the licensee evaluated the 10 flaws in the hot and cold leg nozzles in accordance with the American Society of Mechanical Engineers Boiler and Pressure Vessel Code, Section XI, IWB-3600. The licensee's flaw evaluation showed that the flaws are acceptable for continued operation after Refueling Outage 25 for at least an additional period of 36 months. The licensee will perform three successive examinations of the subject flaws in Refueling Outages 27, 29, and 32 to ensure that the structural integrity of the affected dissimilar metal welds and nozzles are maintained. The successive examinations will determine any potential flaw growth and verify the licensee's flaw evaluation predictions.

Please notify me when the results of the successive examinations are available during each of the above three refueling outages. If you have any questions about this matter, please contact me at (301) 415-2020.

Sincerely,

Tracy J Orf for

Brenda L. Mozafari, Senior Project Manager
Plant Licensing Branch LPLII-2
Division of Operating Reactor Licensing
Office of Nuclear Reactor Regulation

Docket No. 50-261

Enclosure: Evaluation Summary

cc: Distribution via Listserv

UNITED STATES
NUCLEAR REGULATORY COMMISSION
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SUMMARY BY THE OFFICE OF NUCLEAR REACTOR REGULATION OF THE EVALUATION OF FLAWS IN THE REACTOR VESSEL NOZZLE DISSIMILAR METAL BUTT WELDS

CAROLINA POWER & LIGHT COMPANY

H.B. ROBINSON STEAM ELECTRIC PLANT, UNIT NO. 2

DOCKET NO. 50-261

1.0 INTRODUCTION

By letters dated December 8, 2008, as supplemented by letters dated January 22, 2009, January 18, 2010, and June 24, 2010, Carolina Power & Light Company (the licensee), now doing business as Progress Energy Carolinas, Inc., submitted the results of inspections conducted on Alloy 82/182 dissimilar metal welds (DMW) in the reactor vessel nozzles at H.B. Robinson Steam Electric Plant (HBRSEP), Unit No. 2, during Refueling Outage (RO) 25 in 2008. In addition, the licensee submitted the evaluation of the flaws in the DMWs as shown in Westinghouse report WCAP-15621-NP, Revision 1, "Handbook on Flaw Evaluation for the H.B. Robinson Unit 2 Reactor Vessel," nonproprietary.

By letter dated January 22, 2009, the licensee submitted, based on the U.S. Nuclear Regulatory Commission (NRC) request, the Westinghouse proprietary report WCAP-15620-P, Revision 1, "Background and Technical basis: Handbook on Flaw Evaluation for the H.B. Robinson Unit 2 Reactor Vessel." By letter dated January 18 and June 24, 2010, the licensee responded to the staff's requests for additional information regarding the subject flaw evaluation.

2.0 REGULATORY EVALUATION

Pursuant to Title 10 of the *Code of Federal Regulations* (10 CFR) Section 50.55a, "Codes and standards," Paragraph (g)(4), American Society of Mechanical Engineers (ASME) Boiler & Pressure Vessel Code Class 1, 2, and 3 components (including supports) must meet the requirements set forth in the ASME Code, Section XI, "Rules for Inservice Inspection (ISI) of Nuclear Power Plant Components," to the extent practical within the limitations of design, geometry, and materials of construction of the components. The regulations require that inservice examination 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 1995 edition of the ASME Code, Section XI, is the code of record for the current ISI interval.

Enclosure

Paragraph (e) of the ASME Code, Section XI, IWB-3610, "Acceptance Criteria for Ferritic Steel Components 4 in. and Greater in Thickness," requires that the analytical evaluation of flaws be subject to approval by the regulatory authority having jurisdiction at the plant site. IWB-3640, "Evaluation Procedures and Acceptance Criteria for Flaws in Austenitic and Ferritic Piping," requires that the flaw evaluation procedures be provided to the regulatory authority having jurisdiction at the plant site.

3.0 LICENSEE'S FLAW EVALUATION

The licensee performed the examinations of the reactor pressure vessel (RPV) nozzle-to-safe end DMWs during the RO-25 in accordance with the industry guidance as described in the Materials Reliability Program (MRP), MRP-139, "Primary System Piping Butt Weld Inspection and Evaluation Guidelines," and ASME Code, Section XI, Appendix VIII using Performance Demonstration Initiative (PDI) qualified ultrasonic test (UT) techniques. The UT was performed on the hot and cold leg nozzles from the inside surface of the pipe.

The licensee detected axially oriented (longitudinal) flaws in, and adjacent to, the Alloy 82/182 welds. The flaws are not connected to the inside or outside surface of the pipe. Therefore, the flaws are most likely to be fabrication, rather than service-induced, defects. These axial flaws were detected in the austenitic stainless steel cladding side, and into the DMW, in the B inlet (cold leg) nozzle, and in the three outlet (hot leg) nozzle-to-safe end welds. The results of the licensee's ISI are listed below.

Nozzle	UT for Axial Flaws	UT for Circ Flaws	Eddy Current Results	ASME Sec XI IWB-3500	ASME Sec XI IWB-3600
"A" Hot Leg Outlet @ 130 degree location	Flaws sized	Not required. Subject flaws are axially oriented	Flaws not ID connected	3 axial flaws in SS clad 1 axial flaw in weld	1 axial flaw in weld
"B" Hot Leg Outlet @ 10 degree location	Flaws sized	Flaws sized	Flaws not ID connected	7 axial flaws in SS clad 4 axial flaws in weld/safe end 3 circ flaws in clad	2 axial flaws in safe end 2 axial flaws in weld
"C" Hot Leg outlet @ 250 degree location	Flaws sized	Not required. Subject flaws are axially oriented	Flaws not ID Connected	4 axial flaws in SS clad 3 axial flaws in weld 1 axial flaw in SS safe end	3 axial flaws in weld 1 axial flaw in safe end
"A" Cold Leg Inlet @ 80 degree location	Flaws not detected	Flaws not detected	Not required	Flaws not detected	Not required

"B" Cold Leg inlet @ 320 degree location	Flaws sized	Flaws sized	Flaws not ID Connected	2 axial flaws in weld* 2 circ flaws in clad	1 axial flaw in weld
"C" Cold Leg inlet @ 200 degree location	Flaws sized	Not required. Subject flaws are axially oriented	Not required	3 axial flaws in clad	Not required

Note: SS = stainless steel.
ID = inside diameter
*Two axial flaws evaluated as one flaw per proximity rules of IWA-3000

By letter dated June 24, 2010, the licensee stated that the axial flaws are located in safe-end base material and the interface between the safe end and DMW. Only the vessel nozzles are clad. The DMW and safe end are not clad. The five circumferential flaws are fully contained in the cladding and did not require the ASME Code Section XI, IWB-3600 evaluation per IWB-3514.1(d)(1). The indications that were detected are not connected to the inside surface of the pipe.

According to the licensee, construction records confirm that the inlet nozzles were originally manufactured for the Malibu vessel in 1964 and the outlet nozzles were forged in 1966 to refit the vessel for HBRSEP. The nozzle material is ASME SA-336, the inside diameter (ID) is clad with 304 stainless steel, and the weld joint is buttered with NiCrFe weld metal on the cold leg nozzles prior to fit-up and welding of the safe end. The hot leg nozzles were not buttered with NiCrFe weld metal before welding to the safe ends. The safe ends are stainless steel SA-182, F316 metal welded to the nozzle using the NiCrFe weld metal.

The licensee dispositioned a total of 32 indications in accordance with the ASME Code, Section XI, IWB-3500. Of these, 22 were located wholly in the cladding weld metal and are judged to be acceptable per IWB-3510.1. The remaining 10 flaws were rejected by IWB-3510.1 and are shown in the table below. The licensee evaluated the following 10 flaws using the IWB-3600 methodology. These 10 flaws are all axially oriented. The licensee determined that the flaws were embedded in the weld thickness based on eddy current testing. However, based on the proximity rule of the ASME Code, Section XI, IWA-3300, the licensee considered these flaws as ID-surface connected. The licensee stated that the depth sizing results for these 10 flaws includes 0.087 inch measurement uncertainty as part of an NRC-approved relief request regarding root-mean-square error in UT measurements dated October 22, 2008.

Nozzle	Flaw ID	Flaw Sizing Results			a/l	a/t
		a (inch) depth	l (inch) length	t (inch) thickness		
B inlet (cold leg) 320 deg	21A-1&2	1.254	1.50	2.53	0.836	0.4957
A outlet (hot leg) 130 deg	9A-4	0.356	0.250	2.59	1.424	0.1372
B Outlet (hot leg) 10 deg	1A-8	0.459	0.350	2.59	1.310	0.1769
	1B-1	0.514	0.400	2.59	1.285	0.1981
	1B-2	0.409	0.450	2.59	0.909	0.1577
	1B-3	0.424	0.450	2.59	0.942	0.1635
C Outlet (hot leg) 250 deg	17A-1	0.386	0.600	2.59	1.554	0.1488
	17A-2	0.453	0.550	2.59	0.824	0.1746
	17B-1	0.512	0.400	2.59	1.280	0.1974
	17B-8	0.444	0.300	2.59	1.480	0.1712

The licensee stated that the IWB-3600 analysis requires a margin consistent with original component design, which is nominally a factor of three on stress for normal and upset operation and a factor of one and a half on stress for emergency and faulted loading conditions. The licensee also stated further that additional margin is provided in the flaw tolerance calculation by the use of conservative factors such as the use of a crack growth value that is higher than the mean value.

In addition to the ASME code margins on allowable flaw size, the Section XI, IWB-3640 flaw evaluations show a factor of about 2 and 1.3, for the outlet and inlet nozzle welds, respectively, between the as-found indications and the maximum allowable flaw size.

Based on its flaw evaluation, the licensee concluded that the three outlet (hot leg) and the B inlet (cold leg) RPV nozzle-to-safe end welds with axial flaws are shown to be acceptable for safe continued operation after RO-25 for at least an additional period of 36 months.

4.0 STAFF EVALUATION

4.1 Issues Related to Licensee's Flaw Evaluation Methodology

The staff had the following questions regarding the methodology and analysis input used in the licensee's flaw evaluation.

Bending Moment Calculation

Page 2-1 of the Westinghouse report WCAP-15620-P shows that the square root of the sum of the square of the moment components were used to estimate the equivalent moment for bending stress. The staff noted that NUREG/CR-6299, "Effects of Toughness Anisotropy and Combined Tension, Torsion, and Bending Loads on Fracture Behavior of Ferritic Nuclear Pipe," recommends a different approach in deriving moments that resulted in good comparisons to finite element results. By letter dated January 18, 2010, the licensee clarified that the use of the square root of the sum of squares of the moment components is in accordance with Section 2.3.1 in Reference 1, which is the technical basis for the flaw evaluation procedure in ASME Code, Section XI. Section 2.3.1 states that "... 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 Code, Section III, NB-3650 is determined based on resultant moment Mi (i.e., square root of the sum of square of the moment components).

The licensee noted that there is no known change, 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 in determining primary bending stress. In addition, the use of the square root of the sum of squares of the moment components is conservative compared to that recommended in NUREG/CR-6299. The staff concludes that the licensee has followed the ASME Code requirement. However, the staff notes that NUREG/CR-6299 recommends an improved methodology of deriving the equivalent moment based on finite element analyses. Use of the improved methodology in future flaw evaluations could provide a more accurate estimate of the equivalent moment for bending stress.

Stress Approximation

Page 2-3 of the Westinghouse report WCAP-15620-P shows that a third order approximation was used to generate through-wall thickness stress profiles. The staff finds that this representation may not be as accurate as compared to a fourth order approximation, especially for calculating welding residual stress. The third order approximation can underpredict the stresses on the crack face and provide nonconservative approximations of time to leakage. By letter dated January 18, 2010, the licensee explained that the through-wall residual stress profiles were obtained from the accepted and recognized technical paper (Reference 1). The licensee believes that a third order approximation is adequate to represent such through-wall residual stress profile. Although the third order approximation of residual stresses has been used in flaw evaluations, the staff notes that the fourth order polynomial provides and improved approximation of the residual stresses.

Influence Functions

Page 2-3 of the Westinghouse report WCAP-15620-P states 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 and ASME Code, Section XI, have published influence functions that are different for circumferential and longitudinal cracks and illustrate that they are a function of R/t (R is the outside radius, t is the wall thickness) and crack location (internal/external). The staff asked the licensee to provide references or examples to show why the same influence functions for stress intensity can be used for longitudinal and circumferential flaws.

By letter dated January 18, 2010, the licensee responded that Figures 197 and 199 in Reference 2 provide 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. The licensee stated further that primary water stress corrosion cracking (PWSCC) growth curves with various aspect ratios (flaw length/flaw depth ratio) were generated using the stress intensity factor expression for circumferential flaw (Reference 3) and the Raju-Newman stress intensity factor expression for longitudinal flaw (Reference 4). The input to the PWSCC growth analysis is the same as those used in WCAP-15620-P for circumferential flaws at the outlet nozzle DMW. The licensee stated that the crack growth analysis indicated that the results are in agreement with only minor differences.

The staff finds that the licensee's use of influence functions for the circumferential and longitudinal cracks at HBRSEP does not appear to affect the outcome significantly. Therefore, the influence functions used for this particular crack geometry at HBRSEP are reasonable.

Z-Factors (Elastic-Plastic Fracture Mechanics)

The licensee used Z-factors for Alloy 182 based on the ASME Code, Section XI. (Z-factor, 1.30 [1 + 0.010 (D-4)], where D is pipe outside diameter, provided in the 1995 edition of the ASME Code, Section XI. 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, (Reference 5), where Z = 0.0000022(NPS)3 - 0.0002(NPS)2 + 0.0064(NPS) + 1.1355, where NPS is nominal pipe size. The staff finds the Z-factor used in the flaw evaluation is acceptable.

Stress Intensity

Page 2-8 of the Westinghouse report WCAP-15620-P shows that in dealing with net section collapse of DMWs, the lower strength of the base metal controls the failure. If the higher strength of Alloy 182 was used in the flaw evaluation, it will over-estimate the maximum load carrying capacity of the weld. The staff asked the licensee to clarify the value of Sm for the DMWs. By letter dated January 18, 2010, the licensee responded that 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 DMWs is 19.8 ksi and that for the inlet nozzle DMWs 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. The staff does not object that the Sm value of the DMW was used because PWSCC growth will most likely occur in the DMW.

Aspect Ratios

Page 3-1 of the Westinghouse report WCAP-15620-P shows that the flaw was assumed to maintain a constant shape as it grew. The staff asked the licensee to clarify the constant shape and constant aspect ratio in the analysis. By letter dated January 18, 2010, the licensee responded that various aspect ratios were considered in the development of the flaw evaluation charts to facilitate flaw disposition. The aspect ratio was plotted as flaw shape (flaw depth/flaw length) in the flaw evaluation charts. If the aspect ratio of 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. The staff finds that the licensee has used appropriate aspect ratios based on the ASME Code, Section XI, IWA-3000.

Weld Residual Stresses

Page 3-7 of the Westinghouse report WCAP-15620-P provides welding residual stresses based on a 1986 paper (Reference 1) on similar metal welds. A third order approximation for a yield stress of 30 ksi is assumed. The staff notes that recent work on DMWs has shown that this approximation can significantly underestimate the welding residual stresses. The 2008 ASME Pressure Vessel & Piping Conference (PVP) paper written by Westinghouse (Reference 6) suggests the inside diameter welding residual stress for ASME Code, Section XI, analyses should be about 54 ksi. The staff noted that using the data from the 1986 paper may under-predict the times to failure.

By letter dated January 18, 2010, the licensee responded that a comparison of the welding residual stress from the 1986 ASME paper with those generated using finite element analysis for DMWs without any prior weld repairs is shown in Figures 8-2 and 8-3 of MRP-106 (Reference 7). 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 DMWs 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."

The licensee stated that a similar conclusion can be drawn from Figure 8 of PVP2008-61840 paper (Reference 6) by reviewing the axial residual stress for the hot leg without repair. Studies (Reference 8) have been made pertaining to the effect on the as-welded residual stress profile in the DMW 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 DMW is compressive at the inner surface of the weld. The licensee has shown that welding of the safe end to the pipe provides favorable compressive stress in the DMW.

The licensee stated further that the flaw evaluation charts generated for HBRSEP did not take credit for the stainless steel safe end effect. Therefore, use of the residual stress from the 1986 ASME paper for the DMWs without prior repair is a reasonable approximation based on the latest literature and publications available at the time the analyses were performed. The staff finds that welding of stainless steel safe end to the pipe may reduce residual stresses in the DMW, depending on the distances between the safe-end-to-the-pipe weld and the DMW.

Therefore, the staff concludes that the licensee's model of welding residual stresses is acceptable.

The staff finds that the licensee followed the requirements of IWB-3600 of the ASME Code, Section XI to perform its flaw evaluation. Some of the staff's questions regarding licensee's methodology and analysis input may not be considered in the ASME Code, Section XI, IWB-3600 in analyzing PWSCC in DMWs. However, the staff finds these issues are relevant in the flaw evaluation for DMWs and should be addressed.

The staff notes that the NRC and the industry are working cooperatively on industry-wide guidance regarding the flaw evaluation of PWSCC in Alloy 82/182 DMWs. The guidance would provide acceptance criteria for the analysis input and methodology regarding the issues the staff raised above. As for the Robinson's flaw evaluation, the licensee has committed to perform three successive examinations that will validate the accuracy of the licensee's flaw evaluation.

4.2 NRC Staff Independent Analysis

The staff performed an independent analysis to verify the licensee's flaw evaluation results. The focus of the staff's independent analysis is to estimate the time period for the detected flaw to reach the allowable flaw size.

In its independent analysis, the staff assumed that the Alloy 82/182 DMW was repaired during the original construction because operating experience of other nuclear plants has shown that some welds were repaired during construction. The weld repairs increase the weld residual stresses. The staff's analysis showed that the worst case flaw, of the 10 flaws that the licensee analyzed, would grow to the unacceptable flaw size (i.e., 75 percent through wall) ranging from 8.4 months to 34.5 months. The staff notes that the predicted 8.4 month period may be conservative because the staff used conservative assumptions.

The staff's flaw analysis requires information regarding the details of reactor vessel nozzle fabrication. Per the staff request, by letter dated June 24, 2010, the licensee provided the information regarding the width (axial length) of the safe ends and Alloy 82/182 DMW in the hot and cold leg nozzles, and the distance between the center line of the safe-end-to-pipe weld and the center line of the DMW for the hot and cold legs. The licensee stated that the pipe-to-safe-end weld was a field weld made by Ebasco Services using a 5/32 inch EB Type A consumable weld insert. This configuration would make the center line of the weld 5/64 inch beyond the dimension shown for the safe end.

The licensee described the fabrication process for the inlet (cold leg) nozzles as follows:

- The nozzle forgings were machined and weld clad on the inside diameter (ID) surface using 309 and 308 filler metal.
- The 22½ degree weld bevel was machined, weld clad with 182 filler metal (Inconel), and remachined.
- The safe ends were then welded to the nozzles using Inconel weld.
- Intermediate postweld stress reliefs were applied following the cladding and safe end welds.

The licensee clarified that these intermediate treatments are not detailed in the records since they were applied under another contract and there was no recording required by Code. Furnace data shows the "interstage" stress reliefs for the nozzles were ½ hour holding times. The fabrication process for the outlet (hot leg) nozzles is as follows:

- The outlet nozzle forgings were procured, machined, and weld clad on the ID surface using 309 and 308 weld filler metal.
- The 22½ degree weld bevel was machined, and the extensions (safe ends) were welded to the nozzles using 182 (Inconel) filler metal. The outlet nozzle 22½ degree bevels were not clad prior to the DMW to the nozzle.
- Intermediate post weld stress reliefs were applied similar to the inlet nozzles.
- The inlet and outlet nozzles were welded into the vessel shell and the vessel ID cladding was back-welded.
- The heat treatment of the completed vessel, nozzle extensions (safe ends) included, was a final stress relief for 13 hours at 1150 degrees Fahrenheit +/- 25 degrees Fahrenheit, for which the time-temperature recordings are available.

The licensee stated further that the safe ends were produced from forgings to SA182, Type 316, stainless steel. The Westinghouse design drawing E232-267 shows that the inlet nozzle forging was clad on the 22 degree 30 minute bevel before the DMW was joined to the safe end. This is confirmed by the Weld Inspection Record. The heat treatment of the inlet (cold leg) nozzles, after buttering and before the DMW, was done on the Malibu Vessel contract and is not evident in the "Furnace Logs." Intermediate post-weld heat treatment was allowed by code without the time-temperature recordings. The "Furnace Data" records show that the "interstage stress reliefs" performed following the DMW of the extension (i.e., the safe end) to the nozzle consisted of holding times of 1/2 hour. The piece specific time and temperature of these intermediate stress reliefs are not reported in the records.

For its stress analysis, the staff assumed that: (1) the nozzle is machined and beveled, (2) the nozzle is buttered, (3) the nozzle is attached to reactor pressure vessel and heat treated, (3) the safe end is welded to the nozzle with Alloy 82/182 weld, and (4) the safe end is welded to piping with stainless steel 308 filler metal.

The staff finds that the licensee's RPV fabrication record implies that the Alloy 82/182 DMWs have been heat treated twice. The first time probably did not relieve all the stresses, but the second time at 13 hours the residual stresses probably were relieved by some percentage. However, the stainless steel safe ends had experienced the heat treat process, which may have sensitized the base metal, resulting from precipitation of chromium carbides at grain boundaries. The licensee indicated that the safe end is made of Type 316 and not 316L, which has lower carbon content. Based on operating experience and studies, the staff believes that the subject Type 316 safe end may be more susceptible to sensitization than Type 316L. The staff suggests that the licensee monitor the stainless steel safe ends for potential cracking due to sensitization.

Based on the above fabrication information provided by the licensee, the weld residual stresses may be minimal, which would lead to a slower flaw growth. This would extend the above time period.

4.3 Successive Examinations

By letter dated January 18, 2010, the licensee stated that it plans to inspect the welds containing 10 analyzed flaws in RO-27, currently scheduled to begin on September 17, 2011. The licensee stated that it will consider mitigation measures during RO-27, if needed. If mitigation measures are not taken, the licensee plans to inspect the 'A' and 'C' cold leg nozzles every 6 years and 'B' cold leg nozzles and all three hot leg nozzles in the next three inspection periods in accordance with ASME Code requirements. If mitigation measures are taken, the inspection frequency for the mitigated welds will return to the normal 10-year frequency.

In the June 24, 2010, letter, the licensee clarified further that in accordance with the ASME Code, Section XI, IWB-2420, reexamination of four of the six reactor vessel nozzles is currently scheduled for RO-27 in October 2011, RO-29 in October 2014, and RO-32 in April 2019. The licensee performed visual examination in RO-26 in 2010 as required by 10 CFR 50.55a for implementation of ASME Code Cases N-722 and N-729-1. For RO-27, the licensee has scheduled to perform visual examinations on the hot leg DMW. In addition, volumetric examinations are scheduled to be performed on the indications on the four nozzles.

The staff finds that the licensee will follow the ASME Code, Section XI, IWB-2420 to perform successive examinations of the flaws that have been accepted by IWB-3600. The licensee's three successive examinations will provide assurance that the flaws will be monitored properly, allowing the structural integrity of the affected nozzles to be maintained.

5.0 CONCLUSION

The staff finds that the licensee evaluated the 10 flaws in the hot and cold leg nozzles in accordance with the ASME Code, Section XI, IWB-3600. The licensee's flaw evaluation showed that the affected hot and cold leg nozzles are acceptable for continued operation after RO-25 for at least an additional period of 36 months.

The staff does not have immediate safety concerns regarding the fabrication defects because of the favorable results of the licensee's flaw evaluation and the staff's independent calculations. In addition, the licensee will perform three successive examinations using UT of the subject flaws in refueling outages 27, 29, and 32 to ensure that the structural integrity of the affected DMWs and nozzles is maintained. The successive examinations are intended to detect any potential flaw growth, and verify the licensee's flaw evaluation prediction. The licensee has performed and will perform visual examinations of the subject nozzles per 10 CFR 50.55a(g)(6)(ii)(E) based on ASME Code Case N-722.

The staff and the industry are cooperatively developing guidance on the flaw evaluation of PWSCC in Alloy 82/182 DMWs. The guidance will provide a methodology that staff and industry will find acceptable.

The NRC staff finds that in submitting its flaw evaluation to the NRC, the licensee has satisfied the requirements of the ASME Code, Section XI, IWB-3610 and IWB-3640.

6.0 References

1. "Evaluation of Flaws in Austenitic Steel Piping," Journal of Pressure Vessel Technology, American Society of Mechanical Engineers, Pressure Vessel and Piping Division Codes, Volume 108, August 1986.
2. Rooke, D. P. and Cartwright, D. J., "Compendium of Stress Intensity Factors," Her Majesty's Stationery Office, London.
3. Chapuliot, S., Lacire, M. H., and Le Delliou, P., "Stress intensity factors for internal circumferential cracks in tubes over a wide range of radius over thickness ratios," ASME PVP Volume 365, 1998.
4. 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.
5. Materials Reliability Program, MRP-216, "Advanced FEA [Finite Element Analysis] Evaluation of Growth of Postulated Circumferential PWSCC Flaws in Pressurizer Nozzle Dissimilar Metal Welds," Revision 1.
6. Bamford, W., et al, "Technical Basis for Revisions to Section XI Appendix C for Alloy 600/82/182/132 Flaw Evaluation in Both PWR [Pressurized-Water Reactor] and BWR [Boiling-Water Reactor] Environments," PVP2008-61840, Proceedings of PVP2008, 2008 ASME PVP Conference, July 28 -31, 2008, Chicago, IL USA.
7. Material Reliability Program: Welding Residual and Operating Stresses in PWR Plant Alloy 182 Butt Welds.
8. ASME, PVP2009-77269, "Residual Stress Evaluation of Dissimilar Weld Joint Using Reactor Vessel Outlet Nozzle Mock-up Model – Report 2."

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December 28, 2010

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Dear Mr. Duncan:

By letters dated December 8, 2008, as supplemented by letters dated January 22, 2009, January 18, 2010, and June 24, 2010, Carolina Power & Light Company (the licensee), now doing business as Progress Energy Carolinas, Inc., submitted to the U.S. Nuclear Regulatory Commission (NRC) the results of inspections conducted on dissimilar metal butt welds in the reactor vessel nozzles during the H. B. Robinson Steam Electric Plant, Unit No. 2, Refueling Outage 25 in 2008. The submittal includes the flaw evaluation of 10 indications in the hot and cold leg piping.

The NRC staff finds that the licensee evaluated the 10 flaws in the hot and cold leg nozzles in accordance with the American Society of Mechanical Engineers Boiler and Pressure Vessel Code, Section XI, IWB-3600. The licensee's flaw evaluation showed that the flaws are acceptable for continued operation after Refueling Outage 25 for at least an additional period of 36 months. The licensee will perform three successive examinations of the subject flaws in Refueling Outages 27, 29, and 32 to ensure that the structural integrity of the affected dissimilar metal welds and nozzles are maintained. The successive examinations will determine any potential flaw growth and verify the licensee's flaw evaluation predictions.

Please notify me when the results of the successive examinations are available during each of the above three refueling outages. If you have any questions about this matter, please contact me at (301) 415-2020.

Sincerely,
/RA by TOrf for/
Brenda L. Mozafari, Senior Project Manager
Plant Licensing Branch LPLII-2
Division of Operating Reactor Licensing
Office of Nuclear Reactor Regulation

Docket No. 50-261

Enclosure: Evaluation Summary

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