UNITED STATES
NUCLEAR REGULATORY COMMISSION
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SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

RECIRCULATION SUCTION NOZZLE TO SAFE-END WELD INDICATION EVALUATION

ENERGY NORTHWEST

WNP-2

DOCKET NO. 50-397

1.0 INTRODUCTION

By letter dated December 15, 1998, and supplemented by letters dated April 29 and July 2, 1999, Energy Northwest (the licensee) submitted for NRC review, its examination results of the reactor recirculation system suction nozzle N1A to safe-end weld, 24RRC(2)A-1, and the associated flaw evaluation for the detected flaw for WNP-2. The weld connects a steel nozzle to a stainless steel safe-end with Inconel weld material. The diameter of the safe end is 24 inches, and the nominal wall thickness is 2 inches. The ultrasonic (UT) examination of weld 24RRC(2)A-1 was conducted during the 1998 refueling outage (the 13th outage). The examination results reveal a circumferential indication of 3.52 inches in length and 0.29 inch in depth at the root of the weld, through the heat affected zone, and into the base material. This indication was not found in the 1994 UT examination (the 9th outage). However, reprocessing the 1994 UT data using the more advanced 1998 equipment confirmed that this indication existed in 1994. This indication exceeded the specifications of Table IWB-3514-2 of Section XI of the American Society of Mechanical Engineers (ASME) Code for allowable planar flaws in austenitic steels. Consequently, the licensee intended to demonstrate through an analytical flaw evaluation that WNP-2 could be operated without repair until the 15th outage (projected to commence in April 2001 with approximately 970 days of operation).

2.0 INDICATION CHARACTERIZATION

2.1 Licensee

The indication was detected and sized using a 45° shear wave (45S) and verified with a 45° refracted longitudinal (45RL) wave. The data generated by the sound waves were manipulated and analyzed with computer and were pictorially displayed. The analyses identified the indication as a circumferential flaw measuring 3.52 inches long on the C-scan and 0.29 inch deep (2.00 inches - 1.71 inches) on the A-scan.

The licensee is contending that the reflection is from a repair weld at the root of the production weld on the safe-end side of the weld. This is based on the observation that the sound scattering occurs prior to impingement at the inside diameter surface, and the indication does not exhibit responses characteristic of a crack or stress corrosion cracking.

2.2 NRC Staff

A review of the pictorial displays showed that the 45S produced high energy reflections without distinct corner traps. The 45RL did produce a clear corner trap but no tip reflection, hence, the A-scan was used for sizing. The absence of a clear pictorial display of flaw depth suggests that the flaw may be something other than a crack.

The licensee's evaluation of the same weld area using data taken during the 9th outage showed the same indication with similar dimension. The slight difference in dimensions can be explained by the measuring error for the UT technique. The absence of any growth would imply that the indication may be something other than a crack. However, the staff does not agree with the licensee's conclusion that the indication is a fabrication repair. Sound waves reflecting off from grains in stainless steel and Inconel can cause extraneous reflections which can interfere with analyses. Further, the licensee's repair records cannot precisely connect the repair location to the indication location. Consequently, a flaw evaluation is needed.

3.0 FLAW EVALUATION

3.1 Licensee

The flaw indication was evaluated by the licensee using a linear elastic fracture mechanics (LEFM) code, NASCRAC, by Failure Analysis Associates. The licensee reported that the flaw is located on the inside surface of the safe-end made of SA 336 Class F8 forged type 304 stainless steel with stress intensity S_m of 16.65 ksi (at 575°F). The initial flaw size was characterized to be 3.52 inches in length and 0.29 inch in depth. Based on the initial flaw size, the licensee employed three models to estimate the final crack shape due to intergranular stress corrosion cracking (IGSCC) and fatigue crack growth. The bounding model considered IGSCC for 970 days and one year of fatigue growth after the IGSCC growth. The fatigue growth includes 1 cycle of thermal discontinuity, 300 cycles of OBE, and 10 cycles of SSE. The IGSCC growth equation was from NUREG-0313, Rev. 2, "Technical Report on Material Selection and Process Guidelines for BWR Coolant Pressure Boundary Piping," and the fatigue growth rate was for the BWR water environment. The fracture toughness used for the stainless steel material was 150 ksi(in)^{½}. The bounding model gives a final crack depth of 1.055 inches.

To determine the allowable flaw size, the licensee used Tables IWB-3641-5 for normal and upset conditions and IWB-3641-6 for emergency and faulted conditions from Section XI of the ASME Code. These tables, which are derived from limit load analysis, give an allowable depth of 1.2 inches for the normal and upset conditions and 1.076 inches for the emergency and faulted conditions.

Since the predicted final crack depth at the 15th outage is less than the allowable flaw depth for the limiting emergency and faulted conditions, the licensee concluded that the flaw meets the requirements of the ASME code, and the N1A nozzle is acceptable for continued operation without repair of the weld until April 2001.

3.2 NRC Staff

Although the staff expressed concerns regarding the flaw evaluation using NASCRAC in previous submittals by the licensee, the staff has not issued a definitive position on this issue. The NASCRAC code employs influence functions to calculate the stress intensity factors for flaws under specified loading conditions. As opposed to the influence functions based on results from numerous finite element method (FEM) simulations, the influence functions of NASCRAC are based on results from the boundary integral equations (BIE) as documented in NUREG/CR-2198, Vol. 5. Applying these influence functions to estimate stress intensity factors for circumferential semi-elliptical cracks in pipes have been validated extensively in Appendix B of the NUREG. Hence, the staff determined that it is acceptable to use NASCRAC in the current application. Further, in 1994 the licensee performed crack growth calculations using different approaches for the crack detected on the recirculation pipe. The results were reported in a submittal dated June 9, 1994, entitled, "Report on Flaw in Reactor Recirculation Piping." That study indicated that using NASCRAC is more conservative than using the approach of NUREG-0313, Rev. 2.

In conducting the flaw evaluation, the licensee used NASCRAC to calculate the crack growth due to IGSCC and fatigue. The IGSCC growth rate was from NUREG-0313, Rev. 2, and, therefore, is acceptable. The fatigue growth rate for austenitic stainless steel underwater environment was not specified in the ASME Code. Hence, using the rate based on actual data for the BWR water environment is appropriate. The licensee's bounding model considered IGSCC for 970 days and one year of fatigue growth after the IGSCC growth. Since it is not obvious that applying one year of fatigue growth to the crack which has accumulated three years of IGSCC growth is more conservative than applying three years of IGSCC and fatigue growth progressively, the staff requested the licensee to demonstrate this assumption quantitatively. The licensee provided this demonstration in the letter dated July 2, 1999, and revised the predicted crack depth at the 15th outage to 1.055 inches. The staff is satisfied with the detailed information provided there. For the allowable crack depth, the licensee calculated it to be 1.076 inches for the limiting emergency and faulted conditions in accordance with the ASME Code. Since the predicted crack depth at the 15th outage is less than the allowable flaw depth, the staff determined that the licensee's flaw evaluation meets the rules of the ASME Code, and continued operation for WNP-2 with the flaw indication in the recirculation system suction nozzle N1A to safe-end weld is acceptable.

4.0 REINSPECTION REQUIREMENTS

For BWR piping weldments, the reinspection requirements are more stringent than those specified in the ASME Code. NUREG-0313, Rev. 2 requires a detected flaw that has not been repaired (Category F) be reinspected every refueling outage. The flaw may be upgraded to Category E with less frequent reinspection after four successive examinations indicate no adverse change in cracking condition. The staff has examined the 1994 UT scan data and agrees with the licensee's conclusion that there is no adverse change in cracking condition during the past four outages. Hence, the proposed reinspection in 2001 meets the intent of the reinspection requirements of NUREG-0313, Rev. 2 and the flaw can be upgraded from Category F to Category E.

5.0 CONCLUSION

The staff determined that the flaw evaluation meets the rules of the ASME Code and the requirements in NUREG-0313, Rev. 2. Further, the staff determined that the proposed reinspection in 2001 meets the intent of the requirements specified in NUREG-0313, Rev. 2. Since the predicted crack depth at the 15th outage (1.055 inches) is less than the allowable flaw depth (1.076 inches), the staff determined that continued operation for WNP-2 with the flaw indication in the recirculation system suction nozzle N1A to safe-end weld is acceptable until April 2001.

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