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

REGARDING FLAW INDICATION IN REACTOR COOLANT SYSTEM COLD LEG PIPE WELD

OHIO EDISON COMPANY

PENNSYLVANIA POWER COMPANY

DUQUESNE LIGHT COMPANY

BEAVER VALLEY POWER STATION, UNIT NO. 1

DOCKET NO. 50-334

1.0 SUMMARY

In a letter dated April 23, 1996, Duquesne Light Company, the licensee for Beaver Valley Power Station, Unit No. 1 (BVPS-1) submitted a flaw evaluation concerning ultrasonic test (UT) indications found in a weld in the primary system cold leg piping. The weld in question (DLW-LOOP3-7-S-02) joins a statically cast stainless steel elbow to a centrifugally cast section of the cold leg piping for loop "C." Both the elbow and pipe are A351, Grade CF8M austenitic stainless steel. The indications were found on the ID of the submerged arc (SA) weld which joins the pipe and elbow. The weldment also contained a tungsten-inert gas (TIG) root pass. The indications exceeded the ASME Boiler and Pressure Vessel Code Section XI acceptance criteria in Table IWB-3514-2.

Previous non-destructive examinations had not revealed indications at this location. In addition, an ID eddy current test (ET) of the region performed during the current outage revealed no surface breaking indications. The licensee performed an evaluation of the indications per the flaw evaluation procedures of ASME Section XI IWB-3640 and Appendix C and found the assumed flaw to be acceptable for continued service until the end of the service lifetime. The flaw evaluation used an assumed single composite surface breaking flaw which bounded the indications found.

The NRC staff has reviewed the flaw evaluation and has found that the postulated flaw meets the IWB-3640 requirements with significant margins of safety to the end of the service lifetime. In accordance with IWB-2420, successive examinations of the weld will be required during the next three inspection periods.

2.0 APPLICABLE REGULATORY REQUIREMENTS

The 1989 Edition of ASME Section XI is the most recent edition approved by the NRC and referenced for use in 10 CFR 50.55a(b)(2). For flaws exceeding the size of the allowable flaws in IWB-3500, an analytical evaluation of flaws may be performed under IWB-3600. IWB-3640 and Appendix C to Section XI cover evaluation of flaws in austenitic piping. Note (e) to IWB-3610 states that "The evaluation procedures shall be the responsibility of the owner and shall be subject to approval by the regulatory authority having jurisdiction at the plant site."

3.0 EVALUATION

Materials and Geometry

Weld DLW-LOOP3-7-S-02 is an SA weld containing a TIG root pass and joins a cold leg elbow and straight pipe of cast A351 CF8M austenitic stainless steel. The combination of the castings and composite weld create difficult conditions for accurate interpretation of the indications from UT. Therefore the possibility of consideration of the signals as ultrasonic reflectors of geometric or metallurgical origin has to be considered. The consideration for the signals as reflectors is reinforced by the results of the licensee's ET of the weld which showed no surface breaking indications. However, an independent evaluation of the weld by NRC staff personnel concluded that the indication was crack like in the fusion zone on the pipe side with a length of 2-1/2 inches circumferentially. No explicit measurement for depth was made, but the maximum depth was judged to be no greater than 1 inch based on the absence of a signal from a transducer focused at a depth of 1-1/2 inches.

Results of the Licensee's Non-Destructive Examination

The licensee's examination revealed the presence of four ID indications grouped in a band ranging from 4 inches to 14 inches below top dead center in the 9 o'clock to 12 o'clock quadrant looking toward the vessel. Individual depths were not reported. However, the four indications were considered to be conservatively bounded by a single composite flaw with the following dimensions:

Crack Depth (a) =	0.68 inches
Crack Length (l) =	10 inches
Wall Thickness (t) =	2.66 inches
a/t =	25.6%
a/l =	0.07

The NRC staff considers this approach to provide a conservative application of the flaw shape requirements of Appendix C to Section XI of the ASME Code.

Fracture Toughness

Since an elastic-plastic fracture analysis was performed in accordance with ASME Section XI, Appendix C, the parameters J_{IC} and T are required to determine the flaw tolerance. Values of J_{IC} and T from the literature were reported for the pipe and weld metal. The bounding values used for the flaw evaluation were those for the piping in the thermally aged condition (J_{IC} = 410 in-lbs/in^2 and T_{Mat} = 13). These values are considered by the NRC staff to be conservative. Cast stainless steels in the original fabricated condition typically exhibit J_{IC} values in excess of 2000 in-lbs/in^2. Based on the work of Nakajima, et al. (Reference 1), some potential exists for a further reduction in J_{IC} in a water environment under slow strain rate loading. However, this work was for a BWR environment. In addition, the effect of strain rate has not been quantified through a technical consensus process and would only be applicable for extremely slow rates which are not consistent with the limiting transients considered for this evaluation.

Loads

Appendix C to ASME Section XI requires use of the design loads defined in the ASME Code Piping Stress Reports for the flaw evaluation. The licensee provided these loads in Table 1 of the submittal and the fracture mechanics analysis indicates that the emergency/faulted service (Levels C and D) loads are controlling.

Potential for Stress Corrosion Cracking (SCC)

The licensee's submittal states that "the potential for stress corrosion is minimized by proper material selection immune to SCC as well as preventing the occurrence of a corrosive environment." The NRC staff considers that material immunity to SCC is likely to be an un-achievable goal and that unplanned excursions in the primary system chemistry can sometimes result in a locally corrosive environment. For the reasons cited in the submittal (operating experience, water chemistry controls, etc.), the NRC staff does not consider that a high probability exists for SCC in a PWR primary circuit. However, there is currently insufficient evidence to completely rule out this possibility for the future.

Crack Growth Analysis

The crack growth analysis considered only the potential for fatigue crack growth and not SCC for the reasons described previously. The approach to quantifying the potential amount of crack growth due to fatigue involved using the air environment curve of ASME Section XI, Appendix C, adjusted for the presence of the PWR environment by multiplying by a factor of 2. As stated in the licensee's submittal, there is presently no reference fatigue crack growth rate curve in the ASME Code for austenitic stainless steels in a water environment. However, significant research work has been performed in this area. NUREG/CR-6176 (Reference 2) suggested a factor of 2.5X over the air curve to account for the effects of a PWR environment and recent work by Chopra, et al., (Reference 3) showed peak multiplying factors of as high as 5X. Although these significant differences exist and a consensus has not yet been developed, the impact on the present analysis is negligible since the overall amount of crack growth predicted to the end of the service life is very small (maximum of 0.050 inches). The NRC staff encourages the licensee to seek approval of environmentally assisted fatigue crack growth rate curves through a consensus process such as the ASME Code. Until consensus guidance is available, the NRC staff will evaluate such submittals on a case-by-case basis.

4.0 SUMMARY AND CONCLUSIONS

Due to the difficulties encountered with characterizing the indications from the UT examinations, the NRC staff concludes that the licensee made the appropriate call in dispositioning the indications as a flaw and performing a flaw evaluation in accordance with ASME Code procedures. In this regard, it is important to emphasize that such an evaluation requires NRC review and approval.

The high toughness of the stainless steel materials involved, even in a degraded condition, allows for a significant degree of flaw tolerance. As an example, the ASME Code Section XI, Appendix C methodology has an applicability range for SA welds to 60% through-wall with a continuous circumferential crack when limit load conditions prevail. The licensee has applied conservative estimates of the flaw shape and fracture toughness and used an ASME Code approved procedure for performing the flaw evaluation. The predictions for fatigue crack growth in the PWR environment were found to be less conservative than others found in the literature. However, the overall impact on the present analysis is negligible. In conclusion, the NRC staff finds that the postulated flaw meets the IWB-3640 requirements with significant margins of safety to the end of the service lifetime. However, per the requirements of the ASME Code, Section XI, Article IWB-2420, the weld in question shall be subject to reexamination during the next three inspection periods.

Principal Contributor: E. Hackett

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5.0 REFERENCES

1.) N. Nakajima, et al., "The Fracture Toughness Measured on Sensitized 304 Stainless Steel in Simulated Reactor Water," Nuclear Engineering and Design 93 (1986) 95-106.

2.) NUREG/CR-6176, "Review of Environmental Effects on Fatigue Crack Growth of Austenitic Stainless Steels," May 1994.

3.) O. K. Chopra, H. M. Chung, T. F. Kassner, and W. J. Shack, "Environmentally Assisted Cracking of LWR Materials, NUREG/CP-0149, Twenty Third Water Reactor Safety Information Meeting, Vol. 3, pp. 17-31, March 1996.