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

Enclosure

SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

RELATED TO FRACTURE MECHANICS ANALYSIS OF FLAW INDICATION IN HPCS WELD KC-32

NIAGARA MOHAWK POWER CORPORATION

NINE MILE POINT UNIT 2

DOCKET NO. 50-410

1.0 INTRODUCTION

In a letter dated December 28, 1990 the Niagara Mohawk Power Corporation (the licensee) submitted for staff review and approval a fracture mechanics evaluation of a flaw found in the Nine Mile Point Unit 2 (NMP-2) reactor pressure vessel 10-inch core spray nozzle safe end to safe end extension weld KC-32. In a subsequent letter dated January 7, 1991, the licensee committed to perform a mid-cycle inspection of the flaw in weld KC-32.

2.0 DISCUSSION

During the October 1990 inservice inspection of NMP-2, ultrasonic examination (UT) of weld KC-32 revealed a flaw that was 0.15 inch (17.6% of the wall thickness - 0.176t) in depth, 1.9 inches (6.3% of the circumference - 0.063C) in length and was circumferentially oriented. The weld consists of an Alloy 82 root pass, with the remainder being Alloy 182. The indication exhibited the characteristics of intergranular cracking, which could be attributed either to stress corrosion or to hot cracking during fabrication of the weld.

After discovering the flaw, the licensee utilized a Mechanical Stress Improvement Process (MSIP) to improve the residual stress distribution around the tip of the flaw. The rate of stress corrosion crack growth in Alloy 182 is dependent upon the amount of tensile residual stress at the tip of the flaw. In a BWR reactor coolant environment, a tensile residual stress can cause stress corrosion crack growth of Alloy 182 weld metal while a compressive residual stress can inhibit stress corrosion crack growth. Experimental tests at Argonne National Laboratory indicated that MSIP produces a compressive residual stress from the inside surface of the weld to approximately mid-thickness (0.5t) and a tensile residual stress on the outer half of the weld. The peak residual stress is at the inner and outer surface, the stress distribution is generally linear through the weld and is approximately zero at 0.5t. Hence, MSIP will inhibit stress corrosion crack growth for cracks extending from the inside surface to approximately 0.5t and will increase crack growth for flaws extending beyond 0.5t.

The licensee performed a nonlinear computer analysis on a finite element model of the core spray assembly to demonstrate that MSIP converts tensile residual stresses along the inside surface of the piping into compressive residual stresses. The finite element analysis indicates that MSIP induces significant axial compressive residual stresses well beyond the depth of the detected indication and that the compressive state of stress is maintained at the indication location even after loads are included.

After MSIP, the weld was reinspected. The reinspection indicated that the flaw depth was 0.41t and its length was 0.113C. The increased size of the flaw was attributed to an increase in ultrasonic reflectivity of the flaw which resulted from MSIP. Since MSIP produces a compressive residual stress between the inside surface and 0.5t, it should not have caused the increase in the size of the flaw.

According to the criteria in IWB-3600 of ASME Code Section XI, the reactor pressure vessel is acceptable for service without excavation and repair of the flaw if the fracture mechanics analysis indicates the flaw will not exceed 0.6t. The licensee performed a fracture mechanics growth analysis of the flaw in weld KC-32. The analysis did not include the compressive residual stresses from MSIP and indicates that the flaw will grow from a depth of 0.41t to a depth of 0.59t during one fuel cycle of operation. The axial stress was calculated using normal operating piping loads and moments and included a through-wall residual weld stress distribution for large diameter pipe, which is reported in NUREG-0313, Revision 2, January 1988. The through-wall residual weld stress distribution for large diameter pipe is typically axisymmetric and would produce large compressive stresses at the tip of the flaw being analyzed. For small diameter pipe, such as in the 10-inch core spray system, the through-wall residual weld stress distribution may not be axisymmetric and could produce tensile stresses at the tip of the flaw. Since the tensile stresses would increase the rate of growth of the flaw, the licensee's assumed residual weld stress distribution is non-conservative and would produce non-conservative flaw growth calculation results.

The stress intensity factors were calculated using the Buchalet and Bamford method which is documented in ASTM STP 590, Mechanics of Crack Growth, 1976. This method involves fitting a third order polynomial to the axial stress distribution through the piping wall at the location of the flaw. These stress profiles and stress intensity factor expressions are believed to provide accurate values for this application because the stress profile is nonlinear. The rate of crack growth was determined using the crack growth relationship for intergranular stress corrosion cracking, in NUREG 0313, Revision 2 with an upper "plateau" of 5×10^{-5} in/hr.

3.0 CONCLUSIONS

1) Although the licensee's fracture mechanics analysis indicates that the flaw in weld KC-32 will meet the acceptance criteria in IWB-3600 of ASME Code Section XI for one additional fuel cycle, the analysis did not conservatively assess residual weld stresses for the 10-inch core spray piping and it did not evaluate the uncertainty in the size of the flaw resulting from ultrasonic examination.

2) To account for these uncertainties and provide an acceptable level of quality and safety for the component, the flaw in weld KC-32 should be ultrasonically reexamined at a mid-cycle inspection.

3) Based on the licensee's commitment to perform a mid-cycle inspection, the NMP-2 reactor pressure vessel is currently acceptable for service without excavation and weld repair of the flaw in weld KC-32.

4.0 RECOMMENDATION

The licensee must provide the staff with a revised fracture mechanics evaluation which assesses: (1) the residual weld stresses in 10-inch diameter pipe, (2) the uncertainty in the size of the flaw resulting from ultrasonic examination, and (3) the results from the mid-cycle inspection. The analysis must be submitted for staff review and approval prior to resuming operation from the mid-cycle inspection.

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