UNITED STATES
NUCLEAR REGULATORY COMMISSION
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ENCLOSURE 2

SAFETY EVALUATION OF GEORGIA POWER COMPANY'S FRACTURE MECHANICS ANALYSIS

EDWIN I. HATCH NUCLEAR PLANT, UNIT 2

Introduction

In a letter from J. T. Beckham, Jr. to J. F. Stolz dated September 19, 1984, the Georgia Power Company (the licensee) submitted for staff review a fracture mechanics analysis. The licensee indicates that the analysis demonstrates that the low flow feedwater controller is in compliance with NUREG-0619 as amended by NRC Generic Letter 81-11 and is acceptable for continued use. The analysis predicts for the forty year life of the Edwin I. Hatch Nuclear Plant, Unit 2 (EIHNP-2), the amount of fatigue growth that would occur for postulated cracks in the plant's reactor vessel feedwater nozzles. The analysis was performed by General Electric (GE) and is contained in GE Report NEDC-30256, "Edwin I. Hatch Nuclear Power Station, Unit 2, Feedwater Nozzle Fracture Mechanics Analysis to Show Compliance with NUREG-0619."

In the period 1974 thru 1980 inspection of the feedwater nozzle/sparger systems disclosed some degree of cracking in the bore and inner radii of reactor vessel feedwater nozzles in 18 of the 23 commercially operated boiling water reactor (BWR) plants in the United States. The staff reviewed this issue as part of Generic Technical Activity A-10. The staff's review and recommendations are contained in NUREG-0619, "BWR Feedwater Nozzle and Control Rod Drive Return Line Nozzle Cracking," November 1980.

In NUREG-0619 the staff concluded that crack initiation in feedwater nozzles was caused by high-cycle thermal fatigue. From analyses and experience in repairing feedwater nozzles, it is known that high-cycle thermal fatigue cracks

propagate to a depth of about 0.25 inch before the cyclic thermal stress amplitude attenuates to an insignificant level. Analyses also indicate that stainless steel cladding contributes to high-cycle thermal fatigue crack initiation.

The staff concluded that significant, crack propagation of the small high-cycle thermal fatigue cracks would result from low frequency but high amplitude stresses, which are caused by the intermittent flow of cold feedwater into the vessel during startup and shutdown and during hot standby conditions when feedwater is added to maintain reactor water level. The frequency and magnitude of the stresses depend to a large degree on whether such additions are modulated or are made by an on-off flow control system.

The staff's position in NUREG-0619 was that improvements should include nozzle clad removal, installation of improved-design spargers and system changes. The system changes include a low-flow controller having the six characteristics described in Section 3.4.4.3 of the GE Report NEDE-21821-A, "Boiling Water Reactor Feedwater Nozzle/Sparger Final Report" and rerouting of the reactor water cleanup system (RWCS) to all feedwater nozzles. As a result of comments received from GE and others, the staff in Generic Letter 81-11 dated February 20, 1981 clarified its position relative to installation of low-flow controllers. The staff indicates in this letter that continued use of existing controllers is acceptable, provided a plant-specific fracture mechanics analysis or application of the analysis already existing in Section 4 of NEDE-21821-A do not result in the growth of a crack to greater than one inch during the forty year life of the plant.

The licensee has removed the nozzle clad, installed welded-in type spargers, rerouted the RWCS to all feedwater nozzles in the reactor vessel at EIHNP-2

and provided the staff with a fracture mechanics analysis (NEDC-30256). The staff in this safety evaluation reviewed the fracture mechanics analysis contained in NEDC-30256.

Discussion

According to NUREG-0619 the amount of crack growth in a feedwater nozzle is dependent upon the amount of crack growth resulting from high cycle thermal stresses and low frequency high amplitude stresses. The low frequency high amplitude stresses are caused by intermittent flow of cold feedwater into the vessel during startup, shutdown and hot standby conditions.

The GE fracture mechanics fatigue analysis in NEDC-30256 assumes the existence of a .25 inch deep flaw at both the feedwater nozzle bore and inner radii. Since stresses from high-cycle thermal fatigue attenuate to an insignificant level at 0.25 inches, a .25 inch deep flaw would conservatively estimate the amount of crack growth from high-cyle thermal fatigue stresses.

The amount of crack growth from low cycle thermal fatigue stresses was evaluated for a 40 year period. This is the period of the time remaining for the plant's license after removal of the clad, which was completed prior to putting EIHNP-2 into commercial operation. To project the cyclic and thermal transient conditions for the remainder of the plant's life, the licensee recorded the number of thermal cycles, feedwater flow and temperature for startups, shutdowns and scrams to the hot standby condition during the period from 1979 thru 1982 (4 years). The total number of events and cycles were extrapolated to a period of 40.0 years.

Finite element computer codes were used to develop thermal and pressure stresses acting on the feedwater nozzle during startup, shutdown and scram conditions. Heat transfer coefficients and annulus boundary temperatures were developed from the "Moss Landing Feedwater Nozzle" simulation tests, which were documented in NEDE-21659-1. This document has not been provided for staff review by either the licensee or its vendor (GE). In section 4.3.4.1.8 (6) of GE Report NEDE 21821-A, GE indicates that with no steam carryunder, the heat transfer coefficient would be in the range of 3000-4000 BTU/hr.-ft^2 -°F. The licensee has used a heat transfer coefficient of 700 BTU/hr-ft^2 -°F. A lower heat transfer coefficient would result in reduced thermal stresses and would be non-conservative. In Section 4 of NEDE 21821-A, GE performed a finite element analysis with nozzle and sparger similar to that in EIHNP-2. The peak thermal stresses predicted by the analysis in NEDC-30256 are significantly less than that predicted in Table 4-32, NEDE-21821-A.

The thermal and pressure stresses were converted to stress intensity factors using the methods reported in Section 4 of NEDE-21821-A. The stress intensity factors were then used to predict the amount of crack growth. The amount of crack growth per cycle was calculated using the fatigue crack growth data for low alloy steels from Section XI of the ASME Code and "best fit" curves developed by GE in Section 4 of NEDE-21821-A. The amount of fatigue crack growth is dependent upon the changes in stress intensity factor resulting from the change in pressure and thermal stresses. The analysis performed for the licensee has considered the effect of pressure and thermal stresses on the amount of crack growth at the nozzle location with the highest combined (Node Element 281) stress. They have not evaluated the location with the highest thermal stress (Node Element 421) and the location with the highest pressure stress (Node Element 193). Since Node elements 421 and 193 have significantly larger thermal and pressure stresses than Node element 421, the fatigue growth analysis at Node element 281 may not be limiting.

Based upon the amount of events, cycles and thermal conditions projected to occur in the remaining life (40 years) of EIHNP-2, and using Section XI of the ASME Code and "best fit" crack growth relationships, the amount of fatigue crack growth in the feedwater nozzles at the end of the plant's life were predicted by the licensee to be greater than one inch. Hence, the licensee concluded that the existing feedwater low flow controller at EIHNP-2 is not in compliance with NUREG-0619 as amended by Generic letter 81-11 and requires corrective action by GPC.

The licensee using Section XI of the ASME Code crack growth relationship predicts one inch of crack growth would occur in 12 years of operation. The "best fit" crack growth relationship predicts one inch of crack growth would occur in 33 years of operation. The licensee indicates that comparison between field data and those calculated using the "best-fit" curve resulted in good agreement. However, the licensee has not provided a justification for this conclusion. Until the licensee provides this justification, we will consider the 12 year prediction to be applicable for EIHNP-2. EIHNP-2 will reach 12 years of operation in 1991.

Evaluation of NEDC-30256

We cannot complete our evaluation of NEDC-30256 until the licensee has provided:

(a) General Electric Report NEDE-21659-1 or explained why the boundary temperature conditions and heat transfer coefficients in Appendix A of NEDC-30256 are more appropriate for EIHNP-2 than those recommended in NEDE-21821A;

(b) an explanation as to why the peak thermal stresses in the NEDC-30256 analysis are significantly less than the peak thermal stresses in NEDE-21821A (Figure 4-134 and Table 4-33) when the nozzles/spargers in both analyses have equivalent geometries and heat transfer co-efficients;

(c) additional analyses that indicate crack growth at Node elements 421 and 193 will be less than at Node element 281; and

(d) an analysis, which indicates whether the Section XI of ASME Code crack growth relationship or "best fit" crack growth relationship is more approrpriate for EIHNP-2. In evaluating field data consider initiation and growth separately.

Conclusion

Based on the amplitude and number of thermal transients (startup, shutdown and scram) events predicted to occur in the remaining life of EIHNP-2, the amount of crack growth in the reactor vessel feedwater nozzles should be greater than one inch. Hence, the existing low flow controller is not in compliance with the requirements of NUREG-0619 as amended by Generic Letter 81-11. We request that licensee provide within the next six months a schedule for modification of the existing low flow feedwater controller system or for submitting additional fracture mechanics analyses and/or inservice inspection results of the nozzles I.D. radii and bores, which indicates that crack growth will be less than one inch during the forty year life of the plant.

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