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

SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

RELATED TO REVISED FEEDWATER NOZZLE ANALYSIS

TO FACILITY OPERATING LICENSE NO. NPF-43

DETROIT EDISON COMPANY

ENRICO FERMI NUCLEAR POWER PLANT, UNIT 2

DOCKET NO. 50-341

1.0 INTRODUCTION

By letter dated December 1, 1997, as supplemented by letter dated June 24, 1998, Detroit Edison Company (DECo or the licensee) submitted confirmation of a revised feedwater nozzle crack growth analysis for Fermi Unit 2 (Fermi 2). The information was in response to an NRC letter dated December 8, 1992, which requested that the licensee confirm the revised analysis with new operating data on thermal cycles. The NRC also requested that the licensee submit the analysis for review 6 months prior to the end of 12 operating years.

The original analysis submitted by letter dated November 22, 1989, demonstrated that the postulated crack would grow to 1.0 inch in 8.9 operating years. For the analysis the licensee used estimated or assumed thermal cycles based on the limited actual data available at that time. The crack growth analysis did not satisfy the Generic Letter (GL) 81-11 criterion of limiting growth of a postulated 0.25-inch deep crack to a depth no greater than 1.0 inch in 40 years.

The revised analysis submitted by letter dated July 29, 1992, demonstrated that the postulated crack would grow to a 1.0-inch depth in 38.3 years. Since the analysis results were close to, but did not satisfy the criterion in GL 81-11, the staff determined that the overall methodology was acceptable; but confirmation of the analysis was required. The licensee also committed to follow the feedwater nozzle inspection schedule and examination specified in NUREG-0619, "BWR [Boiling-Water Reactor] Feedwater Nozzle and Control Rod Drive Return Line Nozzle Cracking," in order to monitor the structural integrity of the feedwater nozzles in the interim.

Feedwater is distributed through spargers that deliver the flow evenly to assure proper jet pump subcooling and help maintain proper core power distribution. The thermal sleeve, which projects into the nozzle bore, is intended to prevent the impingement of cold feedwater on the hot nozzle surface. The incoming feedwater is colder than the reactor vessel during normal operation. The feedwater is much colder during startup and shutdown when feedwater heaters are not in service. Turbulent mixing of the hot water returning from the steam separators and dryers and the incoming cold feedwater causes thermal stress on the nozzle bore if it is not protected by a thermal sleeve.

ENCLOSURE

In the late 1970's, inspections at BWR plants disclosed cracks in feedwater nozzles for those plants that have a loose-fit sparger/thermal sleeve design. The loose-fit design allows leakage past the area where the thermal sleeve and the nozzle safe-end meet. This bypass leakage is the primary source of cold water impingement on the nozzle bore. Bypass leakage past a loose thermal sleeve causes fluctuations in the metal temperature of the feedwater nozzle and can result in metal fatigue and crack initiation. The flow of cold feedwater into the vessel during startup, shutdown, and hot standby conditions can induce crack growth if feedwater additions are not modulated smoothly.

General Electric (GE) performed an extensive feedwater nozzle/sparger testing and analysis program, and the results of this program were reported to the staff in several documents. The final document, which incorporates the information from all earlier submittals, is topical report NEDE-21821-A, "BWR Feedwater Nozzle/Sparger Final Report, February 1980."

In November 1980, the NRC issued NUREG-0619, "BWR Feedwater Nozzle and Control Rod Drive Return Line Nozzle Cracking," recommending that BWR owners (1) remove feedwater nozzle cladding, (2) install modified sparger/thermal sleeves, (3) change operating procedures, (4) modify the feedwater control system with a low-flow controller, and (5) follow the NRC's inspection program.

Comments received from GE and BWR owners after the publication of NUREG-0619 noted the difficulties in meeting the requirements for a low-flow controller having the six characteristics described in GE report NEDE-21821-A. The comments also stated that an existing controller may not meet the six characteristics, but the system may still meet the criterion of the crack growth analysis from which the characteristics were derived. The staff recommended the use of the low-flow controller, as opposed to an on-off flow control system, in order to modulate feedwater additions.

On February 20, 1981, the NRC issued GL 81-11 to amend NUREG-0619 and to allow for a plant-specific fracture mechanics analysis in lieu of replacing the existing controller. The analysis must show that the growth of a postulated 0.25-inch crack does not exceed 1.0 inch in 40 years. GL 81-11 stated that the analysis should be submitted as part of the reporting requirements specified in NUREG-0619.

2.0 EVALUATION

In accordance with the proposed solutions in NUREG-0619, Fermi 2 uses a triple-sleeve sparger design which provides an acceptable improvement over previous designs. In addition, the Fermi 2 vessel was manufactured with unclad feedwater nozzles. The presence of stainless steel cladding on nozzle surfaces contributes to fatigue cracking because thermal stresses from the cycling are higher in the stainless steel than they would be in the unclad base metal. In addition, the thermal expansion coefficients of the base metal and the clad are different. Fermi 2 uses a plant-specific low-flow controller that is different from the one recommended in the GE analysis described in GE report NEDE-21821-A. The licensee opted to perform a plant-specific fracture mechanics analysis in lieu of replacing the existing controller. This option is recommended in GL 81-11.

GE performed both the original and the revised feedwater nozzle analyses which consisted of thermal cycle definition, plant operating history, finite element analysis, and crack growth analysis. Thermal cycles were estimated or assumed in the original analysis based on the limited actual data available at that time. The revised analysis submitted in 1992 used thermal cycles that were based on plant operating data with actual cycle counts from 1986-1990. By letter dated December 8, 1992, the staff determined that the fracture mechanics analysis method was acceptable. The current confirmation of the revised analysis adds thermal cycles that are based on operating data from 1991-1996, excluding 1994 since very little plant operation occurred in 1994.

Thermal cycles for feedwater nozzles can occur as a result of several different normal and upset events. GE assessed these events as either startup, shutdown, or SCRAM to low and high pressure hot standby followed by a return to full power. The startup, shutdown, and SCRAM cycles for 1991-1996 (excluding 1994) were 17, 17, and 16, respectively. The licensee also counted power reductions to less than 50% as SCRAMS which resulted in 10 additional SCRAM cycles. Adding the data from 1986-1990 resulted in 46 startups and shutdowns, and 78 SCRAMs for the confirmation analysis. These cycles were projected to 40 years for a total of 496 thermal cycles of startups, shutdowns, and SCRAMs. The licensee stated that the confirmation of the revised analysis is conservative because the number of thermal cycles for the first 10 years is assumed to repeat 4 times for the projection to 40 years of operation.

In the revised analysis, GE used the fatigue crack growth rate for low alloy steel from the 1989 Edition of Appendix A to Section XI of the American Society of Mechanical Engineers (ASME) Code to calculate crack growth. For each thermal cycle, the maximum and minimum stress intensity factor and the number of occurrences were calculated. The stress intensity factor range and the corresponding R-ratio[1] were calculated for each cycle. Using the calculated information described above and the crack growth data in the ASME Code, the incremental crack growth was calculated for each cycle. This process was repeated for all cycles until all events had been analyzed.

The confirmation of the revised analysis result shows that a postulated 0.25-inch crack is estimated to grow to approximately 0.8 inch depth in 40 years. This result satisfies the crack growth criterion in GL 81-11.

The staff confirmed that the methodology used in the revised crack growth analysis remains valid when considering the new thermal cycle count data from 1991-1996 (excluding 1994). In addition, the staff determined that the confirmation of the revised analysis is acceptable, and satisfies the criterion in GL 81-11.

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1 The R-ratio (K_{min}/K_{max}) is defined as the algebraic ratio of two specified stress intensities in a stress cycle, used for prediction of fatigue crack growth.

3.0 CONCLUSION

The staff has determined that the confirmation of the revised feedwater nozzle crack growth analysis for Fermi 2 is acceptable and satisfies the Generic Letter (GL) 81-11 criterion of limiting growth of a postulated 0.25-inch deep crack to a depth no greater than 1.0 inch in 40 years.

Principal Contributor: A.D. Lee

Date: August 5, 1998