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

SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

FACILITY OPERATING LICENSE NO. NPF-38

LOUISIANA POWER AND LIGHT COMPANY

WATERFORD STEAM ELECTRIC STATION, UNIT 3

DOCKET NO. 50-382

INTRODUCTION

During the 1988 refueling outage the Louisiana Power and Light Company (the licensee) performed an inservice inspection of several welds in the reactor pressure vessel in the Waterford Unit 3 (Waterford). The examinations were performed in accordance with the 1980 Edition through Winter 1981 Addenda of ASME Section XI. As a result of conventional ultrasonic testing of the welds three recordable indications were observed. That examination indicated that two flaws were less than the allowable size criteria in Article IWB-3500 of ASME Section XI and one indication exceeded the criteria. The licensee again performed the examination of the flaws using equipment to enhance the characterization and as a result, all three flaws exceeded the criteria. Article IWB-3600 esta-blishes rules for evaluating flaw indications that exceed the acceptance criteria in Article IWB-3500. Paragraph 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. In a letter dated May 16, 1988 the licensee submitted for staff review the technical evaluation of the subject flaws.

STAFF EVALUATION

A. Nondestructive Examination

During the inservice ultrasonic examination of the hot leg nozzle-to-shell weld No. 01 - 021 three recordable indications were observed. Two (2) of the indications were detected with a 0 degree 2.25 mHz longitudinal wave examination from the nozzle bore, and the remaining indication was detected with a 20 degree, 2.25 mHz longitudinal wave examination from the nozzle bore. These indications are located within the weld at or near the weld/nozzle forging fusion line. The 0 degree longitudinal wave indications were determined to meet the acceptance standards in Table IWB-3512-1 of the ASME Code Section XI, 1980 Edition through the 1981 Addenda, while the 20 degree longitudinal wave indication exceeded the allowable limits of Table IWB-3512-1.

In an effort to further characterize these indications, particularly the 20 degree longitudinal wave indication, supplemental examinations were performed using the Dynacon Ultrasonic Data Recording and Processing System (UDRPS). Based on the UDRPS examination results all three reflectors exceeded the allowable limits of Table IWB-3512-1.

The upper shell thickness at the location of the indications is 10.75 inches. The ultrasonic examination indicates that the three flaws are located 2.73, 3.34 and 4.01 inches from the reactor vessels outside surface. Hence all the flaws may be considered embedded and are located closer to the outside surface.

The straight beam ultrasonic techniques produced relatively strong reflections. Satellite pulses were observed with the supplemental characterization technique suggesting that the flaw indications originate from volumetric type defects, such as slag or porosity. Even with small flaws the estimated size is more consistent with the beam size of the transducer rather than the size of the flaw (for beam sizes greater than the size of the flaw).

The staff has reviewed the examination results and concludes that the licensee's dimensions of the flaw indications are conservative. The conventional data indicates that the largest flaw has a depth of 1.19 inch. For the largest flaw, the UDRPS examination produced two separate reflectors which when sized according to Section XI proximity rules resulted in a depth of approximately 2.5 inches. The staff does not believe that hot leg nozzle-to-shell weld contains slag indications which have a depth of 2.5 inches. The examination data suggests that the reported dimensions are a function of the characteristics of the transducer rather than a measurement of the size of the flaw indication.

B. Fracture Mechanics Evaluation

The most conservative dimensions obtained during the ultrasonic examinations were used in the fracture mechanics evaluation of the hot leg nozzle-to-shell weld. The licensee has provided a flaw evaluation chart for the Waterford 3 hot leg nozzle-to-shell weld. The method and criteria used in the fracture mechanics analyses are documented in Reference 1. The portions of this document that were related to the Waterford flaw evaluation were documented in Enclosure 1 of licensee's May 16, 1988 submittal. The fracture mechanics analyses that were performed to develop the flaw evaluation chart were in accordance with the methodology and criteria specified in Article IWB-3600 and Appendix A of the ASME Section XI except that stresses were not linearized and stress intensity factors were not calculated in accordance with the recommendations in Appendix A. In lieu of linearizing the stress, the method used represented the actual stress profile by a third order polynomial. Stress intensity factors were calculated using the expressions of Reference 2. These stress intensity factor expressions have been shown to be applicable to vessels in Reference 3. These stress profiles and stress intensity factor expressions provide a more accurate determination of the critical flaw size, and are particularly important during the evaluation of emergency and faulted conditions where the stress profile is generally nonlinear and often very steep.

Important parameters in a fracture mechanics analyses are the materials' brittle fracture resistance and the projected flaw growth rate during operation of the component. The standard measurement of the brittle fracture resistance for the Waterford reactor vessel material are their crack initiation and arrest fracture toughness. These values of fracture toughness are used to determine a critical flaw size. Westinghouse indicates that the critical flaw size calculation used the crack initiation and arrest fracture toughness for vessel materials that are recommended in Appendix A of the ASME Section XI. The critical flaw size for the hot leg nozzle-to-shell weld location was determined using a reference temperature, RT_{NDT}, of 0°F and an upper shelf toughness of $200ksi(in)^{\frac{1}{2}}$. These values are acceptable for this location in the reactor vessel because the materials in this location are not subject to significant amounts of neutron irradiation and the RT_{NDT} value was the highest value for all material located in the hot leg nozzle-to-shell region. The reference temperature for all materials in the hot leg nozzle-to-shell region are reported on FSAR Table 5.2.-6. The staff reviewed this data in NUREG-0708 Supplement No. 1, "Safety Evaluation Report" October 1981. This staff evaluation indicates that a reference temperature of 0°F should be used for all welds outside the Waterford beltline region.

The amount of projected flaw growth was determined to be negligible. The calculation was performed for the reactor vessel design transients that are listed in Table 2-1 in Enclosure 1 of the April 28, 1988 submittal. The rate of fatigue growth was calculated using the ASME reference curve for air environment. Since the flaws under evaluation are embedded, this method of calculating the flaw growth rate is acceptable.

The flaw evaluation chart was constructed from fracture mechanics analyses of reactor vessel design and operating transients, that are listed in Table 2-1. These transients included events during upset, test and emergency and faulted conditions.

The evaluation of emergency and faulted conditions included pressurized thermal shock (PTS) events which were categorized in Reference 4. Reference 4 was a PTS evaluation of Calvert Cliffs. The Calvert Cliffs plant was chosen as the representative generic Combustion Engineering designed plant for the pressurized thermal shock issue. Since Waterford is a Combustion Engineering designed plant, the transients in Reference 4 were assumed to be representative of events for the Waterford plant. The PTS transients included moderate to severe cooldowns with sever repressurizations up to the relief valve setting of 2500 psi. Since severe cooldowns will produce compressive thermal stresses on flaws located near the outside surface, the flaws in the Waterford nozzle-to-shell weld which are located near the outside surface may be conservatively evaluated by neglecting the compressive thermal stress and considering the maximum pressure during the event. Hence, the limiting PTS transients for this evaluation were events involving repressurization to the relief valve set point, which included large steam line and small steam line breaks.

After considering all events during upset, test, emergency and faulted conditions, the limiting event for the hot leg nozzle-to-shell location was determined to be the Primary Side Hydrotest with pressurization to 3105 psi. The flaw evaluation chart resulting from the fracture mechanics analysis of this event indications that the reported flaw sizes meet the criteria in Article IWB-3600 for the 40 year service life of the plant.

In addition to the reactor vessel design transients, which are listed in Tables 2-1 and 4-1, the licensee evaluated a postulated low temperature overpressure (LTOP) event, which was not mitigated by the LTOP protection system. To determine whether this event was either an upset or an emergency/faulted condition the licensee performed a probabilistic risk assessment. The assessment included failure probabilities for the valves in the Waterford LTOP system. The valve failure probabilities form the basis for the risk assessment. The failure probabilities used in the licensees assessment compare favorably with the valve failure rates identified in NUREG/CR 2728 "Interim Reliability Evaluation Procedure Guide," January 1983. The licensee's detailed probabilistic risk assessment indicated that this event should be classified as a faulted condition. The licensee's analysis of the postulated LTOP event indicates that the LTOP event is not a governing transient because it is much less severe than the other faulted conditions.

The NRC required licensees to install LTOP protection systems in 1979. Since the industry installed LTOP protection systems, there has been only one event in which the LTOP system did not mitigate the event. This event occurred on November 28, 1981 at Turkey Point Unit 4 (Reference 5). In this event, the pressure rose to 1100 psi, at a temperature of 110°F. Pressurized water reactors (PWRs) have accumulated approximately 400 years of plant operation since installation of LTOP protection systems. Since only one event has occurred in 400 be expected to occur during the 40 year life of a PWR nuclear power plant. Hence, according to Appendix A, 10 CFR 50, the event is not an anticipated operational occurrence and may be considered an emergency/faulted condition.

To conservatively bound LTOP events for the Waterford reactor vessel, the staff has performed a fracture mechanics analysis for the Waterford reactor vessel in which the postulated event occurred at 110°F and pressurized the vessel at 1500 psi. The analysis was performed using the methodology described in Appendix A of ASME Section XI. The staff's evaluation indicates that for the postulated event, the flaws in the nozzle-to-shell weld will meet the acceptance criteria in Article IWB-3600 for emergency/faulted conditions.

CONCLUSIONS

1) Based on the licensee's and the staff's independent evaluation of a postulated LTOP event, the flaws in the hot leg nozzle-to-shell weld No. 01 - 021 satisfy the analytical evaluation criteria in Article IWB-3600. Based on these analyses, the flaws in the weld will not grow during the life of the plant to a size that will affect the integrity of the reactor vessel. The reactor vessel is acceptable for the 40 years of service life of the plant.

2) However, the flaws in the hot leg nozzle-to-shell weld are conditionally acceptable. Pursuant to ASME Section XI paragraphs IWB-3122.4(b) and IWB-2420(b), weld No. 21 will be reexamined during the next three inspection periods. The staff concludes that the licensee should evaluate the use of an additional transducer with a narrower beam spread for the reexamination. A comparison of the results with the transducer used during the 1988 examination and another with optimum characteristics at the location of the flaw should provide a better definition of the dimensions of the reflector.

References

1. Bamford, W.H., et. al., Handbook on Flaw Evaluation Waterford Unit 3 Reactor Vessel Outlet Nozzle-To-Shell Welds," May 1988.

2. Shah, R.C. and Kobayashi, A.S., "Stress Intensity Factor for an Elliptical Crack Under Arbitrary Loading", Engineering Fracture Mechanics, Vol. 3, 1981, pp. 71-96.

3. Lee, Y.S. and Bamford, W.H., "Stress Intensity Factor Solutions for a Longitudinal Buried Elliptical Flaw in a Cylinder Under Arbitrary Loads", presented at ASME Pressure Vessel and Piping Conference, Portland Oregon, June 1983. Paper 83-PVP-92.

4. Shelby, D.L. et al., Pressurized Thermal Shock Evaluation of the Calvert Cliffs Unit 1 Nuclear Power Plant," Oak Ridge National Labs Report ORNL/TM 9408, NUREG-CR 4022, September 1985.

5. W.D. Lanning, "Low Temperature Overpressure Event at Turkey Point Unit 4," Case Study Report by Office for Analysis and Evaluation of Operational Data, NRC, March 1984.