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

ENCLOSURE

SAFETY EVALUATION FOR THE OFFICE OF NUCLEAR REACTOR REGULATION

RELATED TO REACTOR VESSEL MATERIAL SURVEILLANCE PROGRAM

ANALYSIS OF CAPSULE V

FLORIDA POWER AND LIGHT COMPANY

TURKEY POINT PLANT UNITS NOS. 3 AND 4

I. BACKGROUND

By letter dated August 29, 1986 and supplemented on February 26, 1987, Florida Power and Light Company (the licensee) submitted for staff review a report entitled, "Reactor Vessel Material Surveillance Program for Turkey Point Unit 3, Analysis of Capsule V." The request for review is based on the licensee's need to use the surveillance report results for future Technical Specification changes related to 10 CFR 50, Appendix G and 10 CFR 50.61. The surveillance capsule measurements, tests and analyses were performed by the Southwest Research Institute (report dated August 1986).

The report discusses the testing and the results from the irradiated material specimens and the measurement and analyses of the neutron dosimeters. The report also contains reactor vessel material surveillance data, which are used to evaluate the effect of neutron irradiation on the Turkey Point (TP) reactor vessel beltline materials. The licensee had previously withdrawn other reactor vessel material surveillance capsules from TP-3 and TP-4 and reported the test results of those capsules.

In a letter dated April 22, 1985, the staff approved an Integrated Surveillance Program for TP-3 and TP-4. The integrated program was requested by the licensee and approved by the staff in accordance with the criteria in Section II.C of 10 CFR 50, Appendix H.

II. DISCUSSION

The evaluation portion of this Safety Evaluation is divided into two parts. The first part includes an assessment of the dosimetry, including the methods of analysis, the results and the staff findings. The second part is an assessment of the Charpy V-notch specimens to determine the effects of irradiation on the limiting beltline weld materials, the Capsule V results, and the staff findings.

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III. EVALUATION

A. Dosimetry

The original dosimeter materials included copper, nickel, aluminum-cobalt wire, (cadmium shielded and bare), neptunium-237 and uranium-238. This choice of dosimeters is adequate for flux and spectral measurements at the location of the capsule. Due to faulty experimental procedures, all of the above dosimeters were rejected. However, flux determination was based on the reaction Fe^{54} (n,p) M_n^{54} where the iron was obtained from the activated Charpy V-notch specimens in the capsule. The specific location of the shaving from the specimen, its orientation and whether it was shielded or not have not been discussed. The experimental procedures for weighting and counting the specimens (dosimeters) were carried out with good accuracy. For example, the balance accuracy was ±.10 microgram, the activity was determined by an IT-5400 Ge(Li) multichannel analyzer and the calibration used M_n^{54}, C_o^{60} and Cs^{137} radioactivity standards provided by the National Bureau of Standards. The measurement procedures were those specified in the applicable ASTME standards.

For this measurement the uncertainty is estimated to ±10%. However, this measurement refers to one point in the neutron spectrum, therefore the uncertainty of the measured flux is large. No specific experimental uncertainty analysis has been performed. The neutron spectrum used for the determination of the reaction cross-sections and the energy integral of the flux were calculated. The original calculations were performed using the P_1 cross-sections scattering approximation. This part of the analysis was repeated using P_3 and S_8 approximations, the DOT-4 code and an ENDF/B-IV-based cross-section set, and a calculational uncertainty of ±27.50% has been provided. Thus, the total uncertainty (combined analytical and experimental, as used in the licensee's submittal) is about ±30%, which is in the neighborhood of the expected uncertainty range.

We have determined that the method of analysis and results are acceptable based on the above evaluation. However, we require that future applications of these results be supported by a systematic error analysis.

B. Charpy V-Notch Specimen

The Charpy V-notch specimens in Capsule V were tested to determine the effect of neutron irradiation on reactor vessel and correlation monitor materials. The effect of neutron irradiation on these materials can be predicted using Regulatory Guide (R.G.) 1.99, Rev. 1 and proposed R.G. 1.99, Rev. 2. Proposed R.G. 1.99, Rev. 2 was issued for public comment and is being reviewed by NRC management prior to being issued as a final guide. These guides predict neutron irradiation will increase the Charpy transition temperature (30 ft-lb Charpy V-notch temperature) and decrease the Charpy Upper-Shelf Energy (USE). The amount of change is dependent upon the amounts of residual elements and neutron fluence.

Table I (attached) compares the measured and predicted increase in transition temperature for reactor vessel and correlation monitor materials, which were irradiated within Capsule V in the TP-3 reactor vessel. The predicted values reported in Table I were calculated using the adjusted reference temperature formula in R.G. 1.99, Rev. 1, the mean value formula for the adjustment in reference temperature in proposed R.G. 1.99, Rev. 2, and the RT_{PTS} formula in 10 CFR 50.61, "Fracture Toughness Requirements for Protection Against Pressurized Thermal Shock Events."

Table II (attached) compares the measured and predicted Charpy USE for reactor vessel and correlation monitor materials, which were irradiated within Capsule V in the TP-3 reactor vessel. The predicted values reported in Table II were calculated using trend lines in R.G. 1.99, Rev. 1 and Rev. 2. The trend curves for predicting the decrease in Charpy USE with neutron irradiation are the same for Rev. 1 and Rev. 2 of R.G. 1.99.

For TP-3 and TP-4, the controlling (most embrittled) material is the center girth weld that is positioned at about midheight of the core. Fabrication records show that the two welds were made with the same materials, that is, the same weld wire heat and the same flux lot. The surveillance weld for TP-4 was made with the same weld wire heat. The weld flux lot was different, but that is considered to be of secondary importance in determining sensitivity to radiation. Capsule V Charpy-notch data indicates that the weld metal is the controlling material because it has the lowest USE and the largest increase in transition temperature. For the limiting weld metal, the measured increase in transition temperature (Table I) is less than the values predicted by the regulatory guides and PTS equation, and the measured Charpy USE (Table II) is greater than the value predicted by the guides. Hence, the Capsule V surveillance data indicates that the formulas in the regulatory guides and 10 CFR 50.61 conservatively predict the effect of neutron irradiation on the limiting weld metal in the TP-3 and TP-4 reactor vessels.

Through linear interpolation of data from Capsule V and Capsule T (which was previously withdrawn), the licensee determined that the Charpy USE for the limiting weld metal would reach 50 ft-lb at a neutron fluence of 1.05×10^{19} n/cm^2. R.G. 1.99, Rev. 1 permits linear interpolation between credible data points. However, proposed R.G. 1.99, Rev. 2 recommends that the Charpy USE be predicted by fitting the data with a line drawn parallel to the existing trend lines and bounding the data. This method, although conservative, is necessary when plant-specific data is sparse and scattered. Based on the TP surveillance data, the staff believes that the bounding method in R.G. 1.99, Rev. 2 is applicable for predicting Charpy USE for the limiting TP-3 and TP-4 reactor vessel weld metals. This method indicates that the limiting TP-3 and TP-4 weld metals will reach 50 ft-lb at a neutron fluence of 6×10^{18} n/cm^2. Based on the neutron fluence estimated by the licensee for TP-3 and TP-4 in their pressurized thermal shock submittal, which is contained in their letter to H.L. Thompson dated January 23, 1986, the TP-3 and TP-4 reactor vessels have exceeded 6×10^{18} n/cm^2. Hence, the prediction methods in R.G. 1.99, Rev. 2 indicate that the Charpy USE for the limiting weld metals in TP-3 and TP-4 are less than 50 ft-lb.

Section V.C. of Appendix G requires that when the Charpy USE is predicted to be less than 50 ft-lb, the reactor vessels may continue to operate provided the following requirements are satisfied:

1. A volumetric examination of 100 percent of the beltline materials that are predicted to be less than 50 ft-lb.

2. Additional evidence of the fracture toughness of the beltline materials after exposure to neutron irradiation is to be obtained from results of supplemental fracture toughness tests.

3. An analysis is performed that conservatively demonstrates, making appropriate allowances for all uncertainties, the existence of equivalent margins of safety for continued operation.

Section III.B of Appendix G requires that the test methods for supplemental fracture toughness tests, described in item 2 above, be submitted to and approved by the Director, Office of Nuclear Reactor Regulation, prior to testing. These tests should be on materials irradiated in the TP-3 or TP-4 reactor vessels or commercial reactor vessels similar to TP-3 and TP-4. If test reactor data is used, the licensee must demonstrate that the neutron flux and thermal environment in the test reactor is equivalent to the environments in the TP-3 and TP-4 reactor vessels.

In letters to the Office of Nuclear Reactor Regulation, USNRC, dated May 3, 1984 and March 25, 1986, the licensee provided analyses which are intended to demonstrate that at a neutron fluence of 2.88×10^{18} n/cm^2, the fracture toughness of the reactor vessel is assured with substantial margins of safety. These analyses are being reviewed by the staff. These analyses were submitted to satisfy item 3 above. The licensee has not provided the staff with a plan for complying with the other regulatory requirements in Appendix G, 10 CFR 50, when the Charpy USE is predicted to be less than 50 ft-lb.

In addition to the dosimetry and Charpy V-notch test analyses, the Capsule V surveillance report recommends that Capsule X in TP-3 be removed from the current location to some other high flux location to increase the capsule lead factor. We concur with this recommendation.

As the result of the above evaluation, the staff has determined:

1. Based on the Charpy V-notch test data from Capsule V, the formula in R.G. 1.99, Rev. 1, proposed R.G. 1.99, Rev. 2, and 10 CFR 50.61 conservatively predict the effect of neutron irradiation on the limiting weld metal in the TP-3 and TP-4 reactor vessels.

2. Based on the neutron fluence estimated by the licensee and the method of predicting Charpy USE in proposed R.G. 1.99, Rev. 2, Charpy USE for the limiting weld metals in TP-3 and TP-4 are less than 50 ft-lb.

In addition to the above findings, the staff recommends:

1. Since the licensee has an approved integrated surveillance program for TP-3 and TP-4, the surveillance test data from all capsules withdrawn from TP-3 and TP-4 should be integrated to evaluate the effect of neutron irradiation on the TP-3 and TP-4 reactor vessel beltline materials. The integrated analysis must include an evaluation of the TP-3 and TP-4 pressure-temperature limits.

2. The licensee should revise the integrated surveillance program by moving Capsule X to a higher flux location.

IV. CONCLUSIONS AND RECOMMENDATIONS

Based on the our evaluation, we have concluded that (1) the method of analysis and the results are acceptable; (2) the test data indicates the formula in Regulatory Guide 1.99 (Rev. 1 and proposed Rev. 2) and 10 CFR 50.61 conservatively predict the effects of neutron irradiation on the limiting beltline weld materials in both units; and (3) the measured Charpy USE for the limiting beltline weld materials may be less than the required fracture toughness of 10 CFR 50, Appendix G.

We further conclude that future use of the information and data in the report requires a systematic error evaluation to support the method of analysis and results. The systematic error evaluation is needed because neutron surveillances, such as those detailed in the report, are subject to significant error (combined analytical and experimental) due to expected uncertainties. We also require that you submit a plan for complying with all of the Appendix G, Section V.C. requirements within six months of the date of the enclosed SE in that the measured Charpy value may be less than the required fracture toughness of 10 CFR 50, Appendix G.

We recommend that an integrated analysis of all capsule surveillance data withdrawn from both units be provided and that the integrated surveillance program be revised by moving Capsule X to a higher flux location.

Dated: October 30, 1987

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Table I

Comparison of Measured and Predicted Increase in Transition Temperature (ΔRT_{NDT}) for Capsule V Samples

Material	Increase in ΔRT_{NDT} Measured from Test Samples	Increase in ΔRT_{NDT} Predicted by R.G. 1.99, Rev. 1	*Increase in ΔRT_{NDT} Predicted by Proposed R.G. 1.99, Rev. 2	**Increase in ΔRT_{NDT} Predicted by PTS Equation
Reactor Vessel Forging	55	55	54	48
Reactor Vessel Weld Metal	180	316	206	209
Reactor Vessel Heat Affected Zone	55	55	54	48
Correlation Monitor	125	194	106	102

* Transition temperature increase based on mean value formula in Proposed R.G. 1.99 Rev. 2.

** Transition temperature increase from Equation 1 in 10 CFR 50.61 = $[-10 + 470\ Cu + 350\ Cu\ Ni]\ f^{0.27}$.

TABLE II

Comparison of Measured and Predicted Charpy USE for Capsule V Samples

Material	Charpy USE Measured from Test Samples (ft-lb)	Charpy USE Predicted by Trend Curves in R.G. 1.99 Rev. 1 and Rev. 2 (ft-lb)
Reactor Vessel Forging	154	123
Reactor Vessel Weld Metal	48	36
Reactor Vessel Heat Affected Zone	162	141
Correlation Monitor	60	53