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

July 10, 1992

Docket Nos. 50-348
and 50-364

Mr. W. G. Hairston, III
Executive Vice President
Southern Nuclear Operating
Company, Inc.
Post Office Box 1295
Birmingham, Alabama 35201-1295

Dear Mr. Hairston:

SUBJECT: REQUEST FOR ADDITIONAL INFORMATION CONCERNING THE STEAM GENERATOR ALTERNATE PLUGGING CRITERIA AMENDMENT REQUESTS FOR JOSEPH M. FARLEY NUCLEAR PLANT, UNITS 1 AND 2 (TAC NOS. M79818 AND M79819)

By letter dated February 26, 1991, as supplemented by letters dated November 13, 1991, February 21, 1992, April 10, 1992, June 4, 1992, and June 16, 1992, you requested amendments to the Joseph M. Farley Nuclear Plant, Units 1 and 2, Technical Specifications to utilize alternate plugging criteria (APC) for steam generator tubes. In reviewing your submittals, we have identified the need for additional information.

Enclosure 1 contains the staff's request for additional information. As Enclosure 1 contains proprietary information withheld from public disclosure pursuant to the provisions of 10 CFR 2.790, a copy is not being placed in the Public Document Room (PDR). A non-proprietary version of the request for additional information is contained in Enclosure 2 and will be placed in the PDR. The places where the Proprietary Information would be contained in the enclosures are identified by enclosing them within brackets.

The enclosures include both questions and proposed changes to the APC submittals. Additional changes may be requested by the staff depending on the responses to the questions. Alternatives to the staff's requested changes may be proposed if appropriate justification is provided.

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A response to this request for additional information is required before we can complete our review of your requested amendments. Your responses to this request should be submitted as a revision to your amendment requests and should include an update of the supporting reports.

The reporting and/or recordkeeping requirements contained in this letter affect fewer than ten respondents; therefore, OMB clearance is not required under P.L. 96-511.

Sincerely,

Original signed by George F. Wunder for:

Stephen T. Hoffman, Project Manager
Project Directorate II-1
Division of Reactor Projects - I/II
Office of Nuclear Reactor Regulation

Enclosures:
As stated

cc/w Enclosure 2:
See next page

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Enclosure 2

REQUEST FOR ADDITIONAL INFORMATION

PROPOSED STEAM GENERATOR TUBE ALTERNATE PLUGGING CRITERIA

JOSEPH M. FARLEY NUCLEAR PLANT, UNITS 1 AND 2

1. The proposed steam generator tube alternate plugging criteria (APC) (see proposed Technical Specification 4.4.6.4.a.11 for Joseph M. Farley Nuclear Plant (Farley), Unit 1, and 4.4.6.4.a.14 for Farley, Unit 2) are applicable to tubes which are experiencing outer diameter, stress corrosion cracking (OD SCC) confined to the thickness of the tube support plates. Proposed Technical Specification 4.4.6.2.1 for Units 1 and 2 would require rotating pancake coil (RPC) inspections to establish if the principal indications can be characterized as OD SCC. Guidance for interpreting the RPC results is given in Appendix A, "NDE Data Acquisition and Analysis Guidelines", of WCAP-12871, "J.M. Farley Units 1 and 2 SG Tube Plugging Criteria for OD SCC at Tube Support Plates," (Revision 2). Section A.3.6 of Appendix A states that the purpose of the RPC inspections is to verify the applicability of the APC. This is to be based on establishing the presence of OD SCC with minor intergranular attack (IGA) as the cause of the bobbin indications. However, no guidance is given in these guidelines for distinguishing between minor versus major IGA involvement. The Nuclear Regulatory Commission (NRC) staff requests that Appendix A be revised to include such guidance. These revisions and their justifications should be submitted for staff review.

   The staff notes that pulled tube examinations from a number of plants have shown that OD SCC may be accompanied by varying amounts of IGA. The amount of IGA involvement observed to date has not been sufficient to degrade burst pressure to less than that associated with the observed cracks. In other words, OD SCC has been the dominant degradation mechanism affecting the structural integrity of the tubing. However, volumetric indications, as determined by the RPC, may indicate more IGA involvement than is reflected in the pulled tube data base. Thus, the guidelines need to define what constitutes an axial indication versus what constitutes a volumetric indication.

2. WCAP-12871, Appendix A, Section A.3.7 provides guidance for establishing that bobbin indications are within the thickness of the tube support plate. The staff requests that Southern Nuclear Operating Company, Inc., (the licensee) provide a revision to Section A.3.6 which provides similar guidance for the RPC probe.

3. Consistent with the development of the APC in WCAP-12871, Revision 2, the staff requests that the licensee revise its proposed Technical Specification for APC to clarify that the APC bobbin coil voltage limit is not applicable in cases where the corresponding RPC indication is circumferential or volumetric or where the bobbin or RPC indication extends outside the support plate. The proposed Technical Specification

change should also be revised to require that any such findings (circumferential or volumetric indications or indications extending outside the support plate) be reported to the NRC prior to plant restart together with the licensee's assessment of any needed changes to the APC criteria and/or the need for additional RPC inspection samples.

4. The proposed voltage-based correlation for tube burst pressure is based on data for 7/8-inch tubing (which is the size of the tubing at Farley). These data exhibit considerable variability that introduce uncertainty into the burst pressure predictions. Additional burst data on 3/4-inch tubes were recently provided in WCAP-13237, "Preliminary Data on Voltage/Burst/Leakage of 3/4-Inch Diameter Tubing for ODSCC AT TSPs," which appear to exhibit even more variability than the 7/8-inch tube data. These data have been scaled on both a theoretical and an empirical basis by your consultant, Westinghouse Electric Corporation, to be directly comparable to the 7/8-inch tube data. Both sets of scaled 3/4-inch data (i.e., theoretical and empirical) were separately merged with the 7/8-inch data to provide combined burst pressure correlations. The combined correlation (using the theoretically scaled 3/4-inch data) indicates a critical voltage of [ ] volts for satisfying the limiting burst pressure criterion compared to a critical voltage of [ ] volts based on the 7/8-inch tube correlation. This indicates to the staff that the voltage-based correlation of burst pressure is quite sensitive to the inclusion of new data.

   In its letter dated April 10, 1992, the licensee stated that no firm conclusion can be drawn as to whether the 3/4-inch and 7/8-inch data should be evaluated separately or combined. The licensee also stated that further data collection and a more extensive review are required to establish the basis for 3/4-inch data evaluation. Thus the licensee concluded that the APC should be based solely on the 7/8-inch data. The staff finds that the licensee has not provided an adequate safety basis for not including the 3/4-inch data. The licensee is requested to provide such a basis or, alternatively, to propose a reduced voltage-based limit which reflects both the 3/4-inch and 7/8-inch tube data.

5. The licensee is requested to provide, in tabular form, the complete probability distribution functions of the following:

   a. The assumed probability function of burst pressure (which is sampled by the Monte Carlo analyses) for a 3.6 volt indication

   b. The calculated probability function of burst pressure at end of cycle (EOC) (as calculated by the Monte Carlo analyses) for an indication measuring 3.6 volts at the beginning of cycle (BOC)

   c. Similar probability distributions for a 2.5 volt indication

   The staff is particularly interested in the low probability tails of these distributions, so the tabulations should include and not obscure the detail in these regions. The staff also requests the mean, or best estimate, values.

6. The calculated probability of rupture during SLB may be strongly influenced by the lower tail of the burst pressure probability distribution as a function of voltage, the lower tail of the probability distribution of voltage measurement uncertainty, and the upper tail of the probability distribution of voltage growth. The tails of these distributions, particularly the burst pressure distribution, incorporate significant uncertainty; thus, the calculated probability of rupture during a postulated SLB may also incorporate significant uncertainty. The licensee is requested to quantify the uncertainties associated with this calculation of tube rupture probability. What is the sensitivity of this calculated probability as a function of being evaluated at the 90% and 95% confidence levels and on a best estimate basis?

7. In order to estimate the probability of multiple tube ruptures during an SLB, it may not be appropriate to consider the failure probability of each tube to be statistically independent of the failure probability for all other tubes. For example, systematic errors in the eddy current testing may result in under or over estimation of all crack sizes associated with eddy current indications observed during a particular steam generator inspection, or water chemistry conditions in the steam generators may result in unusually high or low growth rates for all of the cracks during a particular fuel cycle.

   A discussion should be provided of the potential covariation of individual steam generator tube failure probabilities for tubes in the same generator during the same fuel cycle. For the failure probability distribution of tubes with 3.6 volt eddy current signals, please provide an estimate of the division of the uncertainty between purely random and potentially covariant contributions. Also, please describe the procedure used for making this estimate.

8. WCAP-12871, Section 8 included sensitivity studies of the effect of notch depth and notch length on voltage response and on burst strength. These studies considered both through-wall and part-through-wall notches. These studies provide useful, but only partial insight into why there is an apparent correlation between voltage response and burst strength. A sensitivity study of the effect of ligament size (between notches in an axial array) on voltage response and burst strength would provide further insight, and thus, lend additional credence to the empirical burst pressure versus voltage correlation. The licensee is requested to provide the results of such a study.

9. WCAP-12871, Section 8.2, described a study in which it was shown that five different bobbin coil probes supplied by Zetec gave essentially the same voltage responses for a wide variety of defects. The licensee is requested to provide similar information concerning the variability among probes supplied by Echoram. In addition, we request that the Appendix A guidelines in WCAP-12871 be revised to include a quality control requirement that any probe giving a voltage reading which is more than 5% different from the nominal voltage response for any ASME Section XI hole not be used for the APC.

10. The staff recommends that the licensee consider making the proposed probe wear standard an in-line standard to allow testing the probe each time a tube is inspected. If the probe begins to show signs of wear, it should be replaced before any significant number of tubes have been scanned. This would avoid the need to increase the voltage reading of the defects, pursuant to the current guidelines in WCAP-12871, Appendix A, in order to accommodate a probe that has a wear degraded voltage response greater than 15%. Furthermore, if the in-line wear standard included the ASME Section XI holes, then this standard could be used to achieve the 5% probe variation criterion discussed in Item 12 above.

11. The calibration and wear standards can become damaged due to rough handling in the generator and the support ring can corrode due to moisture. We request that the guidelines in WCAP-12871, Appendix A, be revised to require that these standards be compared periodically to an archive standard. An appropriate tolerance should be defined in the guidelines, and standards found to be out of tolerance should be discarded. Since the defect voltage is read from the 100/400 KHz differential mix, and the tube support is mixed out, any degradation of the tube support standard may change the results of this mix. The support standard should match the signal from the supports in the generator as closely as possible.

12. Variations in voltage from standard to standard will be minimized to about 5% (WCAP-12871, Appendix B) by calibrating the field standards against the reference standard used for APC laboratory work by the use of transfer standards. The staff concurs that this should minimize the variability of the field standards and serve as a check on the degradation of the field standards as long as the lab standard itself does not degrade. The licensee is requested to submit its assessment of the potential for degradation of the lab standard, and to incorporate any necessary checks or controls into the guidelines in Appendix A of WCAP-12871.

13. In WCAP-12871, it is estimated that a 1.5 volt indication can be identified in the presence of a dent signal ranging to 13 volts (peak to peak) using phase discrimination methods and that the measured flaw amplitude will exceed 1.5 volts. However, as noted in WCAP-13103, "Additional Information Supporting SG Tube Support Plate Plugging Criteria for J.M. Farley Units 1 and 2," detection of a flaw at the voltage limit with the bobbin probe becomes increasingly unreliable as the half-lobe dent signal increases above the voltage limit. The licensee is requested to revise the WCAP-12871, Appendix A guidelines to include the detailed procedures to be used by the analysts in identifying and quantifying the voltage of indications which are distorted by dents. The training and qualification of the analysts on the use of these procedures should be described to the staff. The probability of detection of an indication equal to the voltage limit as a function of dent voltage should be estimated and provided. In addition, there is a concern that crack volume, which directly affects the voltage amplitude of the crack indication, may be affected by the presence of a significant dent and/or by the growth of the dent over time such that the leakage and burst correlations with voltage may no longer be applicable. Based on the above, the licensee is requested to

propose and justify appropriate dent voltage threshold criteria, for inclusion into the guidelines of Appendix A of WCAP-12871, beyond which RPC inspection would be performed and beyond which the APC voltage limit would not apply.

14. WCAP-12871, Appendix A, states that the APC will not apply at intersections exhibiting copper interference, but that this is not expected to be a concern at Farley. The licensee is requested to propose and justify, for inclusion into the guidelines in Appendix A of WCAP-12871, the threshold at which copper interference is considered to exist, and what inspections should be performed for OD SCC in cases of copper interference above this threshold.

15. Interference (artifact) signals can also arise from magnetite, material property variations, and how well the support plate signal can be eliminated from the 400/100 kHz mix. These artifact signals are expected typically to be very small, but if large, these artifact signals could affect flaw detection and voltage measurement. For completeness, therefore, the licensee is requested to propose and justify, for inclusion into the guidelines in Appendix A of WCAP-12871, an appropriate artifact signal threshold beyond which RPC inspections would be performed and the APC voltage plugging limit would not apply.

16. The proposed Technical Specification amendments for APC call for an RPC inspection at all support plate intersections exhibiting bobbin coil indications in excess of 1.5 volt signal amplitude. As noted in Item 1 above, these inspections are intended to confirm that the indications are consistent with OD SCC occurring within the thickness of the support plate. The staff requests that the proposed Technical Specification amendments be revised to include an additional RPC sample of 200 intersections (i.e., intersections exhibiting bobbin indications less than or equal to 1.5 volts, including intersections with no indications). This 200 intersection sample should include a random sample, but should also include intersections with relatively large amplitude dents and artifact indications ranging to the threshold values referred to in Items 16 and 18 above. (Intersections with dents and artifact indications exceeding the threshold values would already be subject to RPC inspections per Items 16 and 18 above.)

17. The staff notes that the 3-coil RPC probe design (including a coil oriented to detect axial cracks, a coil oriented to detect circumferential cracks, and a normal pancake coil) appears to do the best job of distinguishing between axial, circumferential, and volumetric flaws. The licensee is requested to describe the kind of RPC probe it plans to utilize and to discuss its suitability for this application.

18. The RPC standard specified in the WCAP-12871, Appendix A, guidelines will permit the RPC probe to be set up to mix out the support plate signal. Use of the mixed RPC signals can be helpful in performing flaw characterizations, and thus, the staff requests that Section A.3.6 of the guidelines be revised to require the analysts to look at the mixed RPC signals.

19. The licensee is requested to describe its program for qualifying the eddy current test personnel on the use of the inspection and data analysis guidelines in Appendix A of WCAP-12871, including the training and testing of the personnel. The WCAP-12871, Appendix A guidelines should be revised to include a description of this program. The description of this program should address, but not be limited to the following:

   a. Analyst training and qualification tests that include several different OD SCC indications whose voltage amplitudes are difficult to quantify. These should also include defect indications affected by dents and other artifact indications to the extent they are representative of field conditions. The qualification tests should consist of a statistically significant number of signals representing the range of conditions that are encountered in the field.

   b. The variability of the analyst for a passing grade on the test that is consistent with the assumed probability distribution of measurement uncertainty due to analyst variability assumed in the development of the APC (i.e., 10% variability at 90% cumulative probability, 20% variability at 100% confidence interval as discussed in the top paragraph on page 8-16 of WCAP-12871, Revision 2). The licensee is requested to fully explain the strategy for accomplishing this objective.

20. The licensee is requested to describe the procedures for resolving discrepancies in voltage measurements between the primary and secondary analysts. The staff recommends that these procedures also be described in WCAP-12871, Appendix A.

21. Independent, but preliminary staff sponsored analyses, provided in Attachment A, indicate that the proposed SLB leakage model may not provide a sufficiently conservative basis for predicting SLB leakage. These independent analyses suggest that the actual SLB leakage may be an order of magnitude higher than is predicted by the proposed model. Notwithstanding these difficulties with the proposed model, the staff sponsored analyses in Attachment A also indicate that the proposed Monte Carlo analyses may be substantially under-predicting the leakage they should be calculating with the proposed model. Preliminary findings from the staff's review indicate that this problem with the Monte Carlo analyses may stem from the use of too few iterations. The staff is reviewing these preliminary findings, which are described in additional detail in Attachment A, and requests that the licensee address these findings as well.

22. The Monte Carlo analysis estimates of SLB rupture probability are based on 100,000 iterations for each indication. The licensee is requested to provide information demonstrating that this is a sufficient number of iterations to permit an accurate calculation.

ATTACHMENT A

Discussion of Proposed Leak Rate Correlation

The data correlation of Figure 9-3 (WCAP-12871) relates leak rates to bobbin coil voltages. The mean curve of this correlation is used in calculations to determine if the proposed plugging criteria are an acceptable means to limit the amount of leakage that will occur from degraded tubes given a SLB accident.

A total of 34 data points from tube leak tests were used to develop Figure 9-3. Only about 20% of the tests (6) were for pulled tube specimens taken from various operating plants. Three of these specimens were for Farley tubes. The remainder of the leak tests (28) were on model boiler specimens with laboratory induced OD SCC.

As a general observation, the leak correlation was based on a more limited data set compared to the burst pressure correlation. The data also exhibit a much greater level of scatter. As a result it was much more difficult to develop an acceptable equation to predict the leak rate behavior.

Much of the difficulty in correlating leak rates comes from the fact that many specimens had several deep cracks, none of which penetrated the wall of the tube. Such specimens can give substantial voltages, but will not leak. In Figure 9-3 seven tests showing no leakage were arbitrary plotted in the Farley submittal at a leak rate of 0.0001 l/hr, and these seven points were the determining factor that governed the slope of the line for predicting leak rates versus bobbin voltages.

Leak rates from steam generator tubes are well known to be difficult to predict, and the correlation of Figure 9-3 is no exception to this trend. The data show a scatter of some two orders of magnitude about the mean curve, and the mean curve is to a large extent governed by how zero leakage tests are treated in developing the correlation. It should also be noted that one of the three Farley specimens leaked at a rate of about 100 times greater than predicted by the mean equation.

Alternate Leak Rate Model

An alterative leak rate model that avoids some of the difficulties of the proposed Farley correlation has been examined. This model is believed to better describe the leakage behavior of tubes with OD SCC. The alternative model addresses the fact that degraded tubes will not leak unless the degradation actually penetrates the wall of the tube. The model recognizes that two tubes with the same bobbin voltage can leak at much different rates - depending on the extent of through wall crack penetration.

Figures 1 and 2 were developed on the basis of the same data used in Figure 9-3 to develop the Farley correlation. In this approach the prediction of leak rates is a two step process. The first step addresses the probability that a tube with a given voltage does or does not leak. The second step then predicts the leak rate for the voltage of interest, given the occurrence of a leak.

In this model, the probability of obtaining a leak is modeled by a logistic function:

$$Pr(Leak|V) = logit(-5.3 + 7.37 \cdot \log(V)) \qquad (1)$$

where $\mathrm{logit}(z) = (1 + \exp(-z))^{-1}$. The data given in the submittal were used to determine the equation shown in Figure 1. As indicated by the correlation shown in Figure 1, there is a relatively well defined voltage-based curve that predicts the probability that a given tube will have any leakage. At voltages below about 2 volts very few tubes will leak, whereas at greater than 10 volts essentially all tubes will exhibit leakage. These results are consistent with the pulled tube data described in the submittal.

The second portion of the model quantifies the leak rate, given that the tube leaks. The alternate model [
]

$$\log(LR_i) = -0.21 + 0.70 \cdot \log(V_i) + E_i \tag{2}$$

with a standard deviation of 0.803.

The coefficients were obtained by regressing the non-zero leak rates against voltage. This should be compared to the model presented in the report;

[ ] (3)

with a standard deviation of 1.465.

It should be noted that the data set used to obtain equation 3 does not include the two model boiler data points at 133.5 volts and 137.9 volts, but does include the tube with a 7.2 volt signal for which no leak rate test was performed. If the data set is altered to add the two large voltage tubes and delete the tube with no experimental measurements, then the following equation is obtained;

[ ] (4)

Figure 2 shows the voltage-based correlation of leak rates for those tubes that do leak. The correlation is weak - with the leak rates being rather independent of the voltage level. The poor quality of the correlation is further confirmation that leak rates are relatively unpredictable.

Given the poor correlation of leak rates to voltages, use of the mean curve of Figure 2 cannot be considered to be an acceptable or sufficiently conservative basis for predicting leak rates for SLB accidents. There are few data on measured leak rates and the scatter in the data is large. In addition, most of the data are for model boiler specimens rather than from service degraded intersections from pulled tubes. To address the large uncertainties in the mean leak rate correlation for pulled tubes, the upper 95% confidence limit on the mean curve as shown in Figure 2 as opposed to the best estimate mean curve is used to describe leakage. The 95% confidence limits plotted in Figure 2 show the uncertainty associated with the position of the mean curve. Over the voltage range of interest (1 to 10 volts), a leak rate of about 10 l/hr provides a reasonable approximation of the upper 95% confidence limit. Thus, the leak rate expression (equation 2) becomes:

$$\log(LR_i) = 1.0 + E_i \tag{5}$$

To compare the two models, we can compute the expected (i.e., average) leak rate associated with a voltage V, which is denoted by E(LR|V), and turns out to be for the alternate model;

$$E(LR|V) = logit(-5.3 + 7.37 \cdot \log(V)) \cdot 10^{(1.0 + 1.151 \cdot 0.803^2)} \tag{6}$$

versus the Westinghouse model;

$$[\qquad\qquad\qquad\qquad] \tag{7}$$

The above formulas use the fact that the mean and standard deviation of a log-normal variable, $Y = 10^x$, where $E(X) = \mu$ and $sd(X) = \sigma_x$ are given by the formula;

$$E(Y) = 10^{\left(\mu_x + 1.151\, \sigma_x^2\right)} \tag{8}$$

and

$$sd(Y) = E(Y)\left(10^{2.303\sigma_x^2} - 1\right)^{1/2} \tag{9}$$

Figure 3 compares the predicted leak rates of the alternate model with the leak rates from the Westinghouse model. The alternate model is seen to predict higher leak rates than the Westinghouse model over the range of voltages of interest by about an order of magnitude.

The leak rate models plotted in Figure 3 were compared to Monte Carlo simulation results presented in Reference 7. From page 12.7 of this report, we know that 4000 tubes that test out at exactly 2 volts will produce a leak rate somewhat less than 1 gpm (227 l/h). (Monte Carlo simulations on the 4000 tubes actually produce a 90% quantile of 1 gpm.) These results can be compared to the value obtained using equation 7. From this equation one obtains;

$$\begin{aligned} E(LR|2\ Volts) &= [\qquad\qquad\qquad\qquad] \\ &= 0.155\ l/h \end{aligned} \tag{10}$$

and this value should be comparable to the average leak rate from the Monte Carlo simulations, which is about 227/4000 = 0.057 l/h. In other words, the Monte Carlo simulations seem to be producing a value that is about one-third of the theoretical mean. If one considers that:

1) This value is supposed to be an upper 90% bound and not the average, and

2) The Monte Carlo simulations are adding in the effects of crack growth and variability for measurement error into the results, and

3) Includes variability to account for regression uncertainty (inflated sigma values),

we should find that the Monte Carlo simulations are producing values substantially larger than 0.155 l/h.

To investigate the cause for this difference, several leak rate simulations involving different numbers of iterations were performed. No attempt was made to include ET uncertainty or voltage growth in these simulations. Histograms of the Log(LR) and the unlogged LR were obtained for 100 indications of 2 volts amplitude. The number of iterations varied from 100 to 10,000. The mean for the simulated distribution was obtained from equation 3:

$$[\qquad\qquad] \tag{11}$$

The standard deviation for the simulations was 1.465. From these calculations it was observed that the simulated mean leak rate was very sensitive to the number of iterations. The simulated mean displayed a great deal of variability about the theoretical mean. The simulated mean was usually less than the theoretical mean; however, in a few cases, the simulated mean was quite large. We observed the simulated mean leak rate was heavily influenced by a few large leakers from the extreme tail of the log-normal leak rate distribution. Based on this work, we conclude that the number of iterations used in the Monte Carlo simulations of SLB leak rate is quite important. Therefore, an inadequate number of iterations may be the cause of this difference and justification should be provided for the number of iterations used in the submittal.

Figure 1 Logistic Fit to Proportion of Leakers

Figure 2 Alternate and Westinghouse Leak Rate Models

Figure 3 Comparison of Expected Leak Rates as a Function of Voltage for the Alternate and Westinghouse Leak Rate Models