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SOUTHERN COMPANY
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April 17, 1998

Docket Nos.: 50-348
50-364

10 CFR 50.90

U. S. Nuclear Regulatory Commission
ATTN.: Document Control Desk
Washington, DC 20555

Joseph M. Farley Nuclear Plant
Response to Request for Additional Information Related to Power Uprate
Facility Operating Licenses and Technical Specifications Change Request

Ladies and Gentlemen:

By letter dated February 14, 1997, Southern Nuclear Operating Company (SNC) proposed to amend the Facility Operating Licenses and Technical Specifications for Joseph M. Farley Nuclear Plant (FNP) Unit 1 and Unit 2 to allow operation at an increased reactor core power level of 2775 megawatts thermal (MWt). NRC letters dated July 1, 1997; August 21, 1997; and October 14, 1997 requested SNC provide additional information. SNC responded by letters dated August 5, 1997; September 22, 1997; and November 19, 1997 respectively. SNC letters dated December 17 and 31, 1997; January 23, 1998; February 12 and 26, 1998; March 3, 6 and 16, 1998; and April 13, 1998 responded to NRC questions resulting from conference calls. Attachment I of this letter provides a revised response to Question No. 3 of the Attachment to SNC letter dated April 13, 1998. As requested by the NRC Staff, Attachment II describes the methodology and input parameters used to estimate primary-to-secondary leak rate for a locked rotor event.

With regard to Question No. 3, the qualitative assessment of the RCP locked rotor and the control rod ejection events with respect to the Main Steam Line Break (MSLB) radiological analysis and steam generator Alternate Repair Criteria (ARC) has been revised. The assessment continues to consider the transient differential pressure between the primary and secondary side of the steam generators, estimate the primary leakage that potentially could occur, and then calculate offsite doses. The revised assessment results continue to support the validity of the conclusions of WCAP-12871, Revision 2, "J. M. Farley Units 1 and 2 SG Tube Plugging Criteria for ODSCC at Tube Support Plates," i.e., the MSLB is the most limiting event for ARC.

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As agreed to by the NRC Staff, the transient analysis, evaluations and calculations used to support the revised assessment have not been formalized. This qualitative assessment is based on power uprate conditions and conservative engineering judgment. The uprate radiological calculations previously submitted for Staff review will continue to remain the calculations of record. The revised assessment and methodology used to estimate leak rates are being provided to the Staff for information only.

If you have any questions, please advise.

Respectfully submitted,

SOUTHERN NUCLEAR OPERATING COMPANY

OH Morey

Dave Morey

Sworn to and subscribed before me this 17th *day of* April *1998*

Martha Gayle Dow
Notary Public

My Commission Expires: November 1, 2001

MGE/clt:pwrup40.doc

Attachment

cc: Mr. L. A. Reyes, Region II Administrator
Mr. J. I. Zimmerman, NRR Project Manager
Mr. T. M. Ross, Plant Sr. Resident Inspector

ATTACHMENT I

SNC Response to NRC Request For Additional Information Related to Power Uprate Submittal - Joseph M. Farley Nuclear Plant, Units 1 and 2

SNC REVISED RESPONSE TO NRC QUESTION NO. 3 RESULTING FROM NRC/SNC TELEPHONE CONFERENCE CALLS ON APRIL 9 & 13, 1998

(REFER TO ATTACHMENT OF SNC LETTER TO NRC DATED APRIL 13, 1998)

SNC Response to NRC Request For Additional Information Related to Power Uprate Submittal - Joseph M. Farley Nuclear Plant, Units 1 and 2

NRC Question No. 3 (Reference April 9 & 13, 1998 NRC/SNC Conference Call)

a) With respect to the 10 CFR Part 100 off-site and on-site dose limits, the Farley power uprate analyses, and the assumptions for steam generator tube ARC, are the RCP locked rotor and control rod ejection events (due to potentially large increases in source terms resulting from fuel cladding or pellet damage) more limiting than the main steam line break event?

b) Based on short-term transient parameters, provide a qualitative assessment for each of these events, which includes the potential for accident-induced steam generator tube leakage (similar to that estimated for application of ARC to the Farley steam generators) and the resultant impact on the off-site and on-site radiological doses.

SNC Revised Response to Question No. 3

a) For the Farley power uprate with ARC, the Farley steam line break event radiological consequences are more limiting than the radiological consequences of postulated locked rotor and rod ejection events. The licensing basis for this statement is provided by the non-steam line break evaluations presented in WCAP-12871, Revision 2, "J. M. Farley Units 1 and 2 SG Tube Plugging Criteria for ODSCC at Tube Support Plates," February 1992. WCAP-12871, Section 11.3, concludes that the increased source terms associated with these events are offset by: reduced primary-to-secondary differential pressure; decreased flashing and increased mixing in the steam generator; and continued coverage of the steam generator tubes at the tubesheet and tube support plate interfaces. The assumption of no long-term tube uncovery is supported by WCAP-13247, "Report on the Methodology for Resolution of the Steam Generator Tube Uncovery Issue," March 1992. This licensing basis is supported by the qualitative assessment presented below.

b) An assessment of the primary and secondary system pressure transient data associated with the locked rotor and rod ejection analyses determined that the locked rotor pressure transients are more challenging than the control rod ejection pressure transients. Based on the pressure and temperature transient data from a locked rotor analysis performed especially to address this question, the primary pressure peaks in about 3 seconds, and it levels off after about 25 seconds.

To estimate primary-to-secondary leak rate in the Farley steam generators, scoping calculations were performed to determine the leak rate ratio for a steam line break versus a locked rotor transient. The calculation methodology is similar to that applied to adjust measured leak rates for pulled tube specimens. Based on the pressure and temperature transient results discussed above, the leak rate ratio was calculated separately for 0 to 25 seconds and >25 seconds time periods.

Ratio	0 to 25 seconds	>25 seconds
Leak Rate at SLB Condition / Leak Rate at Locked Rotor Condition	3.7	8.4

The above leak rate ratios are based on the equation for variation of crack opening area with primary-to-secondary differential pressure as described in EPRI Report NP-7480-L, Volume 1, Revision 1, "Steam Generator Tubing Outside Diameter Stress Corrosion Cracking at Tube Support Plates - Database for Alternate Repair Limits, Volume 1: 7/8 Inch Diameter Tubing," Appendix B, using leak rate test data for 5 pulled tube specimens from FNP Units 1 and 2 in the ARC database. It is also noted that since significant TSP movement is not expected during a locked rotor event, packed TSP crevices would preclude any significant leak through ODSCC indications as discussed in WCAP-14707, Revision 1, "Model 51 Steam Generator Limited Tube Support Plate Displacement Analysis for Dented or Packed Tube to Tube Support Plate Crevices," January 1997. This WCAP result is supported by the in situ leak test of FNP Unit 1 pulled tube R2C85 which had a throughwall crack of 0.42 inch, but did not leak at normal operating conditions.

As an illustration of applying the above ratios the following example is presented. The steam line break leak rate calculated for the limiting SG in Farley Unit 2 (including UOA indications with PIs and applying the latest ARC database) is 9.34 gpm (at room temperature). The corresponding leak rate estimates for a locked rotor condition obtained by applying the above leak rate ratios are 2.5 gpm (0 to 25 seconds) and 1.1 gpm (>25 seconds). It is noted the steam line break leak rate value used (9.34 gpm) was obtained assuming that leak rate is independent of bobbin voltage. With the recent NRC clarification on the requirements for a leak rate correlation, a leak rate vs. bobbin voltage correlation can now be applied for 7/8" tubes, which leads to a significant reduction in the estimated leak rate. It can be noted that the locked rotor primary-to-secondary pressure differential after 25 seconds is 944 psi, which is much less than the normal operating pressure differential of about 1450 psi. Since there is only a small amount of plastic crack opening from the 1866 psi differential during the first 25 seconds, the leak rate after 25 seconds would be less than the normal operation shutdown limit of 0.1 gpm. The very conservative leak rates in the current analysis are a consequence of extrapolating from SLB conditions to the low pressure differential rather than the closer extrapolation from normal operating conditions.

An assessment of the potential impact on the off-site doses based on the leak rate ratios presented above follows. Since the accident induced leakage estimated for the locked rotor accident bounds that for the control rod ejection, this leak rate will be used for both assessments. For similar steam generator tube conditions (i.e., those which result in the limiting leakage of 24 gpm for a main steam line break), the locked rotor leakage is 1/3.7 of the limiting leak rate (i.e., 6.5 gpm) for the 0 to 25 seconds period and 1/8.4 of the limiting leak rate (i.e., 2.9 gpm) for the >25 seconds period. These leakage rates are assumed to exist in all three steam generators, and the long-term leakage is assumed to last until the RCS and steam generator pressures equalize. For the control rod ejection event, the duration, as described in the Farley Power Uprate NSSS Licensing Report (WCAP-14723), is 2500 seconds. For the locked rotor event, it is assumed that the RCS pressure remains constant to the RHR cut-in at 8 hours. In addition, for the locked rotor, the estimated fuel failure has been reduced from the power uprate radiological assumption of 20% of the gas gap to the Farley-specific value of 6.3%. (This is a conservatively large number for the "rods in DNB" calculated for the Farley uprate locked rotor analysis; e.g., the Farley Unit 2 Cycle 13 value is <0.135%.) The rod ejection event source term assumption is the same as used in the power uprate radiological analysis. Comparison of the control room X/Q with iodine protection factor and the off-site X/Q indicates the control room thyroid doses for these accidents with accident-induced leakage is not limiting. The limiting off-site thyroid doses compare to the acceptance limits as follows.

Event	Partition Factor	Total Leakage	Duration	Acceptance Limit (REM)	Percent of Limit
MSLB (ARC)	1	24 gpm	8 hr	30	100
Locked Rotor	0.01	19.5 gpm (τ <25 sec) 8.6 gpm (τ >25 sec)	8 hr	30	73
Rod Ejection	0.01	19.5 gpm (τ <25 sec) 8.6 gpm (τ >25 sec)	2500 sec	75	61[(1)]

These qualitative results demonstrate that the accident-induced leakage limit determined for the main steam line break remains limiting.

(1) SNC letter dated April 13, 1998, listed a value of 63; the correct value should have been 59 for the rod ejection event "Percent of Limit."

W/dh & wjs & vs - 4/15/98 & SCS/jaw - 4/16/98

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ATTACHMENT II

SNC Response to NRC Request For Additional Information Related to Power Uprate Submittal - Joseph M. Farley Nuclear Plant, Units 1 and 2

LEAK RATE ESTIMATES FOR A LOCKED ROTOR EVENT

SNC Response to NRC Request For Additional Information Related to Power Uprate Submittal - Joseph M. Farley Nuclear Plant, Units 1 and 2

LEAK RATE ESTIMATES FOR A LOCKED ROTOR EVENT

Summary

This write-up describes the methodology and input parameters used to estimate leak rate for a locked rotor event and summarizes the results. Leak rate estimate is presented as a ratio of leak rate at SLB condition to locked rotor condition. Separate values are shown for two time periods in the transient.

Time Period	SLB Leak Rate/Locked Rotor Leak Rate
0 to 25 seconds	3.7
> 25 seconds	8.4

1.0 Application of EPRI NP-7480-L, Volume 1, Revision 2, Appendix B

From equation B-11, the ratio of leak rates between two conditions is obtained as:

$$R = \frac{LR_2}{LR_1} = \alpha\beta\gamma$$

From equation B-15, the factor accounting for crack opening area and difference in pressure differential is (equivalent to ratio of leak rates for room temperature leak rates):

$$\alpha = 10^{\frac{(\Delta p_2 - \Delta p_1)}{b}}$$

From equation B-21 with no adjustment for volumetric leak rate from hot to room temperature conditions, the temperature correction is:

$$\beta = \frac{E_1 \sigma_1}{E_2 \sigma_2}\sqrt{\frac{\rho_2}{\rho_1}}$$

From equation B-22 with $C_p = 1.0$ and flashing at both leak rate conditions, the factor for the difference in flashing conditions (difference in primary pressure and saturation pressure) is:

$$\gamma = \sqrt{\frac{\frac{(p_{p2} - p_{f2})}{\Delta p_2}}{\frac{(p_{p1} - p_{f1})}{\Delta p_1}}}$$

where

$\Delta p_2 = p_{p2} - p_{s2}$ equals primary to secondary pressure differential for condition 2

p_{f2} equals saturation pressure at condition 2.

Step 1: Adjustment of Measured Leak Rate to Standard Conditions (p_s = 15 psi and T = 620 °F) at Same Δp

$$R_{std} = \beta \gamma_{std}$$

$$\gamma_{std} = \sqrt{\frac{p_{p2} - p_{f2}}{p_{p1} - p_{f1}}}, \qquad p_{p1} = \Delta p_1 + 15$$

Step 2: Determination of b in alpha term (example based on two test points)

Step 1 previously applied to each of the test points to obtain leak rates at 15 psi secondary pressure and 620 °F. R is the ratio of the leak rates for the two test points.

$$R = \alpha\gamma = \gamma\, 10^{\frac{(\Delta p_2 - \Delta p_1)}{b}}$$

$$b = \frac{\Delta p_2 - \Delta p_1}{\log(R/\gamma)}$$

This equation for b is equivalent to the last equation in Section B.6.1 with the generality that gamma can include flashing at both conditions.

When more than two data points are available over the range of interest, a mean value of b can be obtained by fitting a regression curve to the leak rate versus Δp data and obtaining b from the slope of the regression fit. For simplicity, b values in this study were obtained using the leak rates at the highest two pressure differentials included in the tests for Farley pulled tubes. This is equivalent to extrapolating leak rates from SLB conditions down to lower pressure differentials.

Step 3: Calculation of Leak Rate Ratio Between the Measured Point 1 and the Desired Point 2

Apply above equations B-11, B-15 and B21 to obtain the ratio R between the leak rates at the locked rotor conditions (point 2) and SLB leak rates (point 1).

2.0 Evaluation of Locked Rotor for > 25 Seconds Into the Transient

The primary to secondary pressure differential peaks at about 1866 psi at about 3 seconds into the event and then reaches a quasi-steady value of about 944 psi beyond 25 seconds. For tube leakage, the crack opening at the higher pressure consists of elastic and plastic opening area contributions. The plastic opening would not significantly decrease as the pressure differential decreases, but the elastic opening would decrease. This condition can be evaluated in two ways. Conservatively, one can assume that the crack opening area does not change between the 1866 and 944 psi conditions. More realistically, the plastic opening can be estimated at 1866 psi using the CRACKFLO code and included in the leak rate estimate for 944 psi. Both of these methods are described below.

From equation B-12,

$$\alpha = \frac{A_2}{A_1}\sqrt{\frac{\Delta p_2}{\Delta p_1}}$$

Conservatively assuming the crack area is totally plastic between 1866 and 944 psi conditions, the areas are equal and:

$$\alpha = \sqrt{\frac{\Delta p_2}{\Delta p_1}} = 1.41$$

The gamma factor between the 1866 and 944 psi conditions can be obtained from the expression given above from equation B-22. The product of alpha and gamma yields the leakage ratio between the 1866 and 944 conditions. Gamma is calculated to be 0.935 so that the ratio of leak rates between 1866 psi and 944 psi pressure differentials becomes 1.32.

The CRACKFLO calculations for the 1866 and 944 psi conditions show that the crack opening areas are dominantly elastic for both conditions. The plastic area at 1866 psi is only 16% of the elastic area, and at 944 psi, the plastic area is only 3% of the elastic area. The CRACKFLO data can be used to calculate the area ratio in alpha based on the sum of the elastic + plastic areas at 1866 psi relative to the sum of the elastic area at 944 psi + plastic area at 1866 psi. This ratio is calculated to be 1.73 which compares to 2.19 calculated with both crack openings at their respective pressures. Then, the more accurate estimate for alpha between 1866 and 944 psi is:

$$\alpha = 1.73\sqrt{\frac{\Delta p_2}{\Delta p_1}} = 2.44$$

The product of alpha and gamma then becomes 2.28. That is, the leak rate after 25 seconds is 1/2.28 = 0.438 of the leak rate during the peak pressure differential at about 25 seconds.

When CRACKFLO calculated leak rates for 1866 psi and 944 psi are adjusted for the higher differential plastic opening described above, CRACKFLO yields a leak rate ratio of about 4 compared to the 2.28 obtained above. This indicates the conservatism in the Appendix B procedure.

3.0 'b' Factor Calculated from Farley Pulled Tube Specimens

The following are the values for the 'b' factor calculated applying the following equations to the leak rate data for Farley pulled tube specimens shown in the tables attached (Table 1 to 4).

$$b = \frac{\Delta p_2 - \Delta p_1}{\log(R/\gamma)}$$

Specimen	b
R4C73	405
R21C22	909
R34C53	424
R2C85	674 – 706
R28C35	868 – 953*

(* Measurement at Δp = 1906 psi excluded)

The largest value for 'b' based on the above data is 953.

4.0 Thermal Hydraulic Conditions for a Locked Rotor Event

The primary and secondary pressure transients predicted for a locked rotor event show that the primary system pressure and primary-to-secondary pressure differential peak at about 3 seconds and become nearly constant after 25 seconds. The transient is divided into 2 periods.

<u>0 to 25 seconds</u>

The conditions at the 3 seconds peak were applied for this time period.

Primary pressure = 2702 psia
Secondary pressure = 838 psia
Primary temp. = 584 °F
Sat. pressure at primary temp. = 1368 psia
Primary-to-secondary diff. pr. = 1866 psid

<u>≥ 25 seconds</u>

Quasi-steady conditions predicted after 25 seconds.
Primary pressure = 2132 psia
Secondary pressure = 1188 psia
Primary temp. = 583 °F
Sat. pressure at primary temp. = 1360 psia
Primary-to-secondary diff. pr. = 944 psid

Steam Line Break Conditions

Primary pressure = 2575 psia
Secondary pressure = 15 psia
Primary temp. = 607 ° F
Sat. pressure at primary temp. = 1625 psia
Primary-to-secondary diff. pr. = 2560 psid

5.0 Ratio of Leak Rate at SLB condition to Locked Rotor Condition

0 to 25 seconds

α factor is given by,

$$\alpha = 10^{\frac{(2560 - 1866)}{953}}$$

$$\alpha = 5.3$$

Neglecting the effect of temperature on material properties, β factor is given by

$$\beta = \sqrt{\frac{\rho_2}{\rho_1}}$$

$$\beta = \frac{42.1}{44.4}$$

$$\beta = 0.97$$

γ factor is given by,

$$\gamma = \sqrt{\frac{\frac{(2575 - 1625)}{2560}}{\frac{(2702 - 1368)}{1866}}}$$

$$\gamma = 0.72$$

The above calculation utilizes Farley plant specific T_{hot} value of 607 °F for a SLB event.

Therefore, the ratio of leak rates at SLB to locked rotor condition for 0 to 25 seconds is:

$$R = \frac{LR_{SLB}}{LR_{LR}} = \alpha\beta\gamma = 5.3 \times 0.97 \times 0.72 = 3.7$$

$\geq$ 25 seconds

Based on the evaluation presented here in Section 2.0, leak rate at > 25 seconds is estimated to be 1/2.28 of the estimate for 0 to 25 seconds. Accordingly, the ratio of leak rate at SLB conditions to leak rate at locked rotor conditions for 25 seconds is ($3.7 \times 2.28 = 8.4$).

Table - 1 Farley Unit 1 Leak Test Data

Specimen	Test Type: Differential Pressure (psi)	Leak Rate (liters/hour)	Test Conditions			
			P_p(psig)	P_s(psig)	T_p(°F)	T_s(°F)
R2C85 TSP 1 (13.7V field bobbin Ind.)	NOC: 1560	0.130	1566	6	RT	RT
	ITC1: 2255	89.4	2290	35		
	ITC2: 2453	166	2550	97		
	SLB: 2563	249	2729	167		

NOC = normal operating conditions; ITC = intermediate test conditions; SLB = steam line break; RT = room temperature.

Table - 2 Farley Unit 2 Leak Test Data

Specimen	Test Type ΔP (psi)	Leak Rate (liters/hour)	Test Conditions			
			P_p(psig)	P_s(psig)	T_p(°F)	T_s(°F)
R34C53 TSP1	ET NOC: 1520	0.095	2082	762	610	613
	ET ITC: 2238	0.436	2544	306	598	586
	ET SLB1: 2533	2.30	2753	220	591	587
	ET SLB2: 2557	≥ 1.80*	2744	187	584	592

NOC=normal operating conditions; ITC=intermediate test conditions; SLB=steam line break.

* Since the differential pressure for the SLB1 test was slightly lower than the target differential pressure, the test was repeated. The leak rate for the SLB2 test of Tube R34C53 TSP1 was observed to decrease during the second half of the test. As a consequence, the leak rate was 22% lower than for the SLB1 test, even though the differential pressure was slightly higher. Differing leak rates for the same test conditions occur relatively infrequently and usually for low to moderate leak rates (tighter cracks); but when differing rates happen, they occur such that lower leak rates are experienced with increasing time. This observation is probably related to ID crud particles becoming trapped in the crack and partially sealing the leak.

Table 3

Leak Test Data for the TSP1 Region of Tube R28C35

Differential Pressure, psi	Leak Rate, liters/hr	Primary Pressure, psig	Secondary Pressure, psig	Primary Temperature, °F	Secondary Temperature, °F
1302	0.172	2058	756	579	597
1558	0.290	2074	517	574	590
1906	0.625	2430	524	560	572
2165	1.04	2536	370	550	524
2341	1.35	2706	365	534	490
2544	3.26	2774	230	454	402*

* Secondary side was at T_{sat} conditions. The larger cooling coil collection system was used for the 2544 psi differential pressure test. The larger cooling coil intake line reaches to the bottom of the secondary side autoclave.

Table 4

Leak and Burst Data for Tubes Removed from Farley Unit 2

	Farley - 2		
Test	Tube R4-C73	Tube R21-C22	Tube R38-C46
Leak Test			
Operating Leak Rate (delta P = 1500 psi)	0 - 0.3 ml/hr	0- <<7 ml/hr*	No Leak
Steam Line Break Rate (delta P = 2650 psi)	174 ml/hr	108 ml/hr	No Leak
Burst Test			
Burst Pressure (psig)	5925	6525	9975
Burst Ductility (% delta D)	5.6	5.6	7.6
Burst Opening Length (inches)	0.459	0.784	0.881
Burst Opening Width (inches)	0.135 (OD), 0.100 ID)	0.210 (OD), 0.148 (ID)	0.167

*Problems with back pressure regulator increased the measured leak rate.