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SCHWENCER,A. OPERATING REACTORS BRANCH 1

SUBJECT: RESPONSE TO NRC 790117 TELCON REQUEST FOR ADDL INFO RE QUESTIONS ON ANALYSIS IN SUPPORT OF 50% TUBE WASTAGE PLUGGING LIMIT FOR STEAM GENERATOR TUBES.

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April 9, 1979

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Office of Nuclear Reactor Regulation
ATTENTION: Mr. Albert Schwencer, Chief
Operating Reactors Branch No. 1
United States Nuclear Regulatory Commission
Washington, D. C. 20555

H. B. ROBINSON STEAM ELECTRIC PLANT, UNIT NO. 2
DOCKET NO. 50-261
LICENSE NO. DPR-23
STEAM GENERATOR TUBE PLUGGING CRITERIA QUESTIONS

Dear Mr. Schwencer:

In a telephone conversation with your staff on January 17, 1979, Carolina Power & Light Company was requested to provide additional information in response to questions on our previously submitted analysis in support of a 50 percent tube wastage plugging limit for steam generator tubes. The questions and the response provided to us by the NSSS vendor are given below:

Question 1: On Page 2-12, it is stated that a limit analysis in accordance with rules of the ASME Code, Section III, Appendix F, has been performed. Indicate whether all the other requirements of F-1323.2 have been satisfied. Provide details of how the collapse loads, the LOCA loads (1568), and the SSE loads (407) were determined. Define M_p*.

Answer: In this analysis: a) specified loads are less than 90 percent of the collapse load determined by lower bound limit analysis, b) the yield strength used equals 230 percent of the tabulated s_m value at 600°F. There was not any deformation limit specified in the E-Spec. Therefore, it is considered that all requirements of F-1323.2 are fully satisfied.

The collapse load is determined by the collapse moment. M_p is the collapse moment at a section without wall degradation. M_p* is the collapse moment at a section with uniform tube wall degradation to .015". The collapse moments were calculated by considering combined bending and membrane action as follows: From Figure 1, it is clear that the tube area under tension (area 1) is different from the tube area under compression (area 2). The equilibrium condition dictates that σ_1 x area 1 = σ_2 x area 2.

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Since area 1 and area 2 are functions of σ_1 and σ_2, σ_1 and σ_2 were computed by first calculating the axial tensile membrane stress and then calculating σ_1 and σ_2, i.e.,

$$\sigma_1 = S_y - \text{tensile membrane stress}$$
$$\sigma_2 = S_y + \text{tensile membrane stress}$$

After σ_1 and σ_2 were determined, x_1, x_2, y_1, and y_2 were calculated.

The collapse moment M_p or M_p* was finally calculated by using the relation,

$$M_p \text{ or } M_p^* = (\sigma_1)(\text{area 1})(y_1) + (\sigma_2)(\text{area 2})(y_2)$$

The LOCA loads were calculated by employing a dynamic finite element computer code, SAP4. A finite element model of the U-tube was constructed and the LOCA rarefaction wave pressure history was input. The U-tube was modelled as a continuously supported tube (Figure 2) and a simply supported tube (Figure 3). With the simply supported tube, the maximum bending moment during the transient occurs at location 3 (see Figure 3). This maximum moment was labelled as M_{LOCA}.

The SSE load was determined from SSE tube stress derived from a dynamic seismic analysis. The maximum bending stress σ in the plane of the U-bend is 9 ksi as reported in Table 2-1 of the report, WTD-SM-77-058. The corresponding moment is

$$M = \frac{\sigma r}{I} .$$

where σ = 9 ksi
r = outer radius of the tube
I = area moment of inertia of the tube
M_{SSE} = k M, where k = 1.8

Since the seismic model employed a U-tube continuously supported at tube support plate locations, M_{SSE} was computed by multiplying M by the ratio of the moment at location 3 (see Figures 2 and 3) from the simply supported semi-circular tube LOCA run and the continuously supported U-tube LOCA run.

Question 2: Provide the justification for selecting and value of θ_3 used in the moment calculations. Provide details of the analyses done that result in the moment curves shown in Figure 2-6, e.g., where the LOCA and SSE analyses performed assuming pinned connections at the top support plate?

Answer: The angle θ_3 was selected because the moment calculated by SAP4 is a maximum at $\theta_3 = 15^\circ$ as shown in Figure 3. The moment curves shown in Figure 2-6 for LOCA and SSE conform to the fundamental mode (an antisymmetrical mode) of the tube and are verified by the output from

the SAP4 calculation with a semi-circular tube simply supported at the top tube support plate. Since plastic moments, M_p, are counteracting at both plastic hinges, the sign of M_p is opposite to that of the LOCA + SSE moments.

Question 3: Provide the reference for the equation on Page 2-14 used to calculate the lower bound collapse pressure. Why does D = .817 inches? Why does P = 900 psi? Why does e_o = 2%?

Answer: The equation on page 2-14 was derived in the following paper. N. C. Small, "Plastic Collapse of Oval Straight Tubes Under External Pressure," American Society of Mechanical Engineers, Transactions, Journal of Pressure Vessel Technology, Volume 100, February 19/8, pp. 46 to 51.

Since the tube is assumed to be degradated to 0.021", the outside diameter is,

$$D = .875 - 2 \times (0.050 - 0.021) = 0.817''.$$

The steam temperature at 100 percent full load operation is 516°F. Following the LOCA, the largest steam temperature increase is less than 15°F. Consequently, 15°F was added to the full load steam temperature and the corresponding saturation pressure was found to be 893 psi. The maximum secondary to primary external pressure is, therefore, less than the 900 psi used in the collapse calculation.

The maximum ovality which is consistent with tubing fabrication tolerances prior to bending is 1.5 percent. As a result of mill bending operations, the tube ovality could exceed 1.5 percent locally in the bend region. The ovality e_o = 2%, is an assumed maximum uniform tube ovality for use with the above collapse pressure equation.

Question 4: The effects due to the LOCA rarefaction wave, LOCA shaking, and SSE should be combined with the effects from the external pressure. Provide criteria for combining results of separate analyses and the two loading conditions. The minimum acceptable tube wall thickness should be recalculated to account for all effects combined.

Answer: The LOCA rarefaction wave has passed through the steam generator in 0.07 seconds after the rupture. The maximum tube bending moment occurs at 0.1 to 0.2 seconds after the rupture. Furthermore, it takes at least one second for the primary pressure to drop to the same level as the secondary pressure, and more than five seconds for the primary pressure to drop to a significant level (see Figure 4). The tube response to the LOCA rarefaction wave will be damped out long before the external pressure is applied. Therefore, the effects due to the LOCA rarefaction wave and LOCA shaking need not be combined with the effect from the external pressure. The added effect from SSE to external pressure is considered negligible for the following reasons. During SSE loading, bending stress in the axial direction of the tube exists. The maximum value of 9 ksi is less than 30 percent of the expected minimum yeild strength at 550°F. At the same time, the tube collapse unber external pressure is predominantly due to hoop compression. Therefore, the contribution of SSE loading to the tube collapse is believed to be insignificant and can be neglected.

Question 5: The seismic response spectra, shown in Figure 2-2, is the same curve used in WCAP-7832-A. Is this spectra conservative for the Robinson 2 facility?

Answer: Yes. The highest earthquake load specified in the plant dependent E-Spec is 0.37g in the horizontal direction and 0.25g in the vertical direction.

If you have any questions concerning this matter, please contact our staff.

Yours very truly,

M. A. McDuffie

for E. E. Utley
Senior Vice President
Power Supply

JJS/mf
Attachment

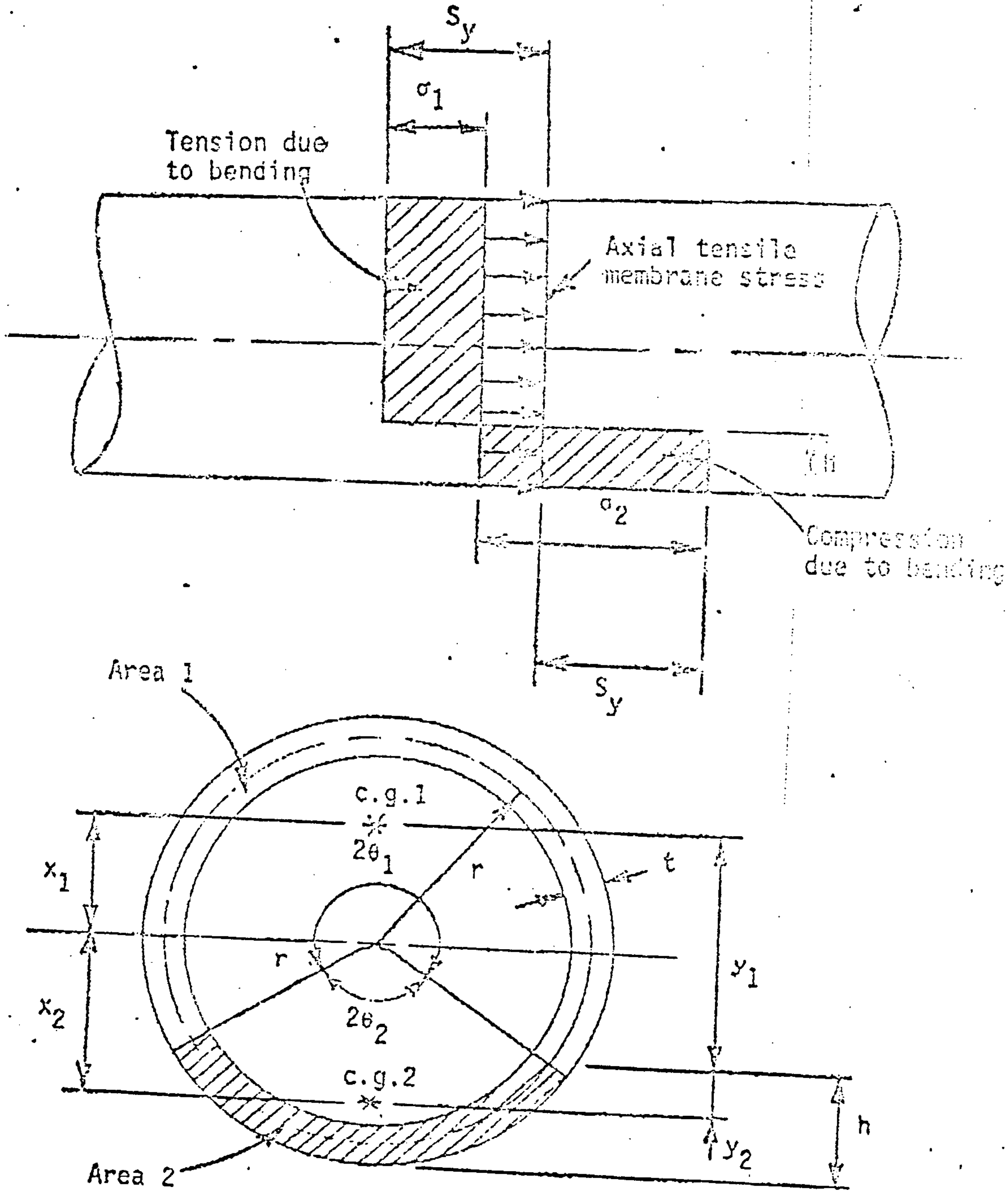

Figure 1.

Plastic Moment

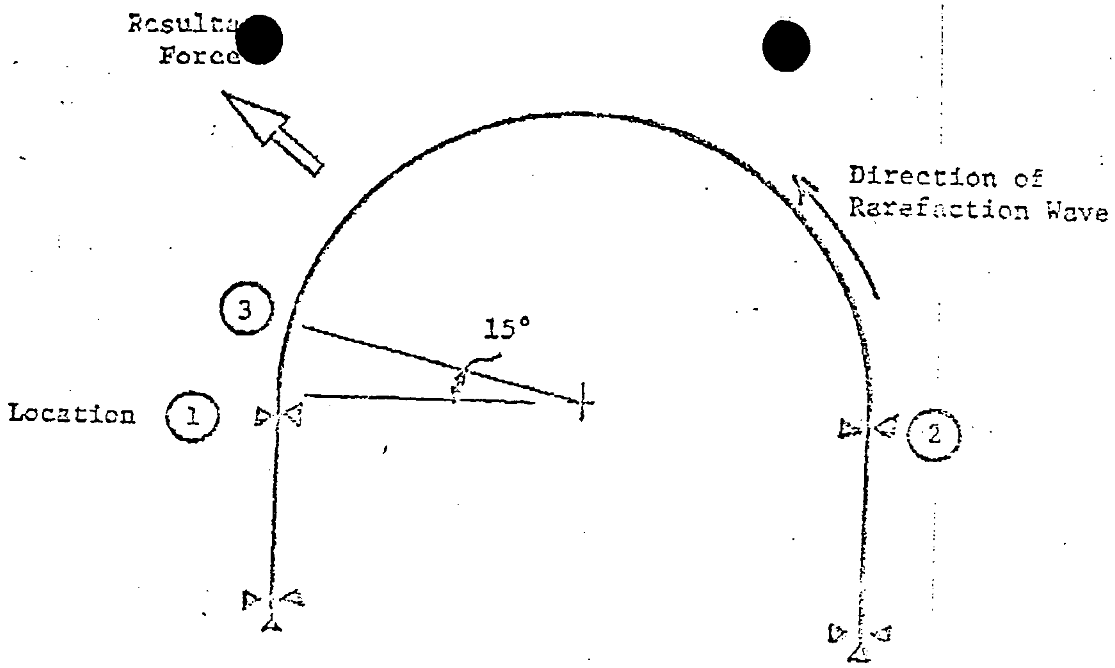

Figure 2. Continuous LOCA Tube Model

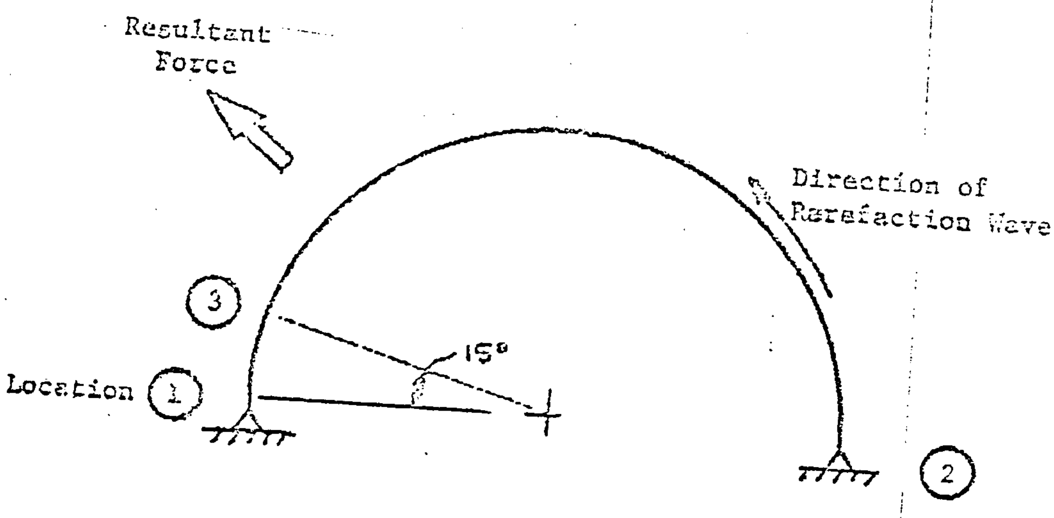

Figure 3. Simply Supported LOCA Tube Model

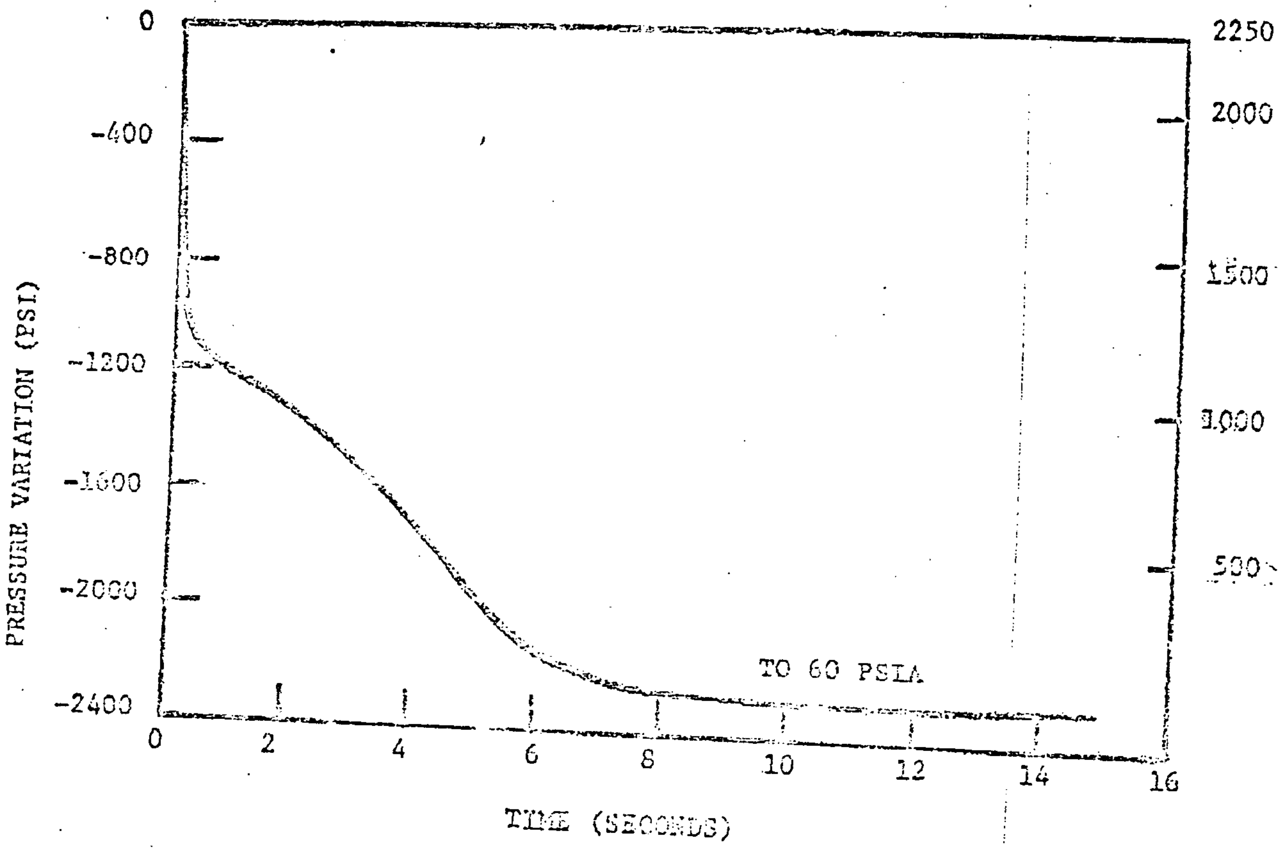

Figure 4

Reactor Coolant Pipe Break - Pressure Variation