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U. S. Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, DC 20555-0001

South Texas Project
Unit 2
Docket No. STN 50-499
Supplemental Response to Request for Additional Information Regarding the
2RE08 Steam Generator Tube Voltage-Based Repair Criteria 90-Day Report

Reference: Letter, M. E. Kanavos to NRC, "2RE08 Steam Generator Tube Voltage-Based Repair Criteria 90-Day Report," dated June 28, 2001 (NOC-AE-01001108)

Supplemental information in response to an NRC request for additional information regarding the referenced report is attached to this letter. If there are any questions regarding this response, please contact Mr. Chet McIntyre at (361) 972-8597 or me at (361) 972-7902.

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jtc

Attachment

A001

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ATTACHMENT

South Texas Project Unit 2 EOC-8 In situ Leak Test Data
Procedure for Adjusting Measured Leak Rate to Steam Line Break Conditions

The leak rates measured during the South Texas Project Unit 2 EOC-8 in situ leak tests were adjusted to steam line break (SLB) conditions using the adjustment methodology presented in Appendix B of Reference 1. The attached EXCEL spreadsheet contains calculations for adjusting the data from one of the tests (SG-D, R24C47-3H). The following is a step-by-step description of the leak rate adjustment process.

Input Data

The in situ test for tube R24C47-3H in SG-D contains five data points as shown in rows 6 through 10 of the spreadsheet. The various input data are:

Col. A, B	Tube identification
Col. C	Test identifier
Col. D, E	Primary and secondary side pressures during the test (psig)
Col. F	Primary to secondary differential pressure (psi)
Col. G, H	Primary and secondary side temperatures during the test (^{o}F)
Col. I	Measured leak rate (gpm at room temperature)
Col. J, K	Test condition – Room temperature test and no prior tube expansion
Col. L	Saturation vapor pressure at primary side temperature

Data Adjustment

Brief Description of Methodology

From Equation B-11 in Reference 1, the ratio of leak rates at two conditions is obtained as:

$$R = \frac{LR_2}{LR_1} = \alpha\beta\gamma \qquad \text{(B-11)}$$

Subscript 1 represents the test condition and subscript 2 represents the desired condition to which the test data is to be adjusted.

The α factor accounts for the variation in the crack opening area with pressure differential across the tube wall and is given by Equation B-15 in Reference 1:

$$\alpha = 10^{\frac{(\Delta p_2 - \Delta p_1)}{b}} \qquad \text{(B-15)}$$

where ($\Delta p = p_p - p_s$) represents primary-to-secondary pressure differential and b is a constant.

The β term accounts for the leak rate dependency on temperature due to the variation in crack opening area because of variation in tube material properties with temperature as well as due to fluid density variation with temperature. It is given by Equation B-21 in Reference 1 (for a room temperature test with $T_{primary} = T_{ambient}$):

$$\beta = \frac{E_1 \sigma_1}{E_2 \sigma_2} \sqrt{\frac{\rho_2}{\rho_1}} \qquad \text{(B-21)}$$

where ρ is the fluid density, and E and σ, respectively, represent flow stress and Young's modulus of the tube material.

The γ term accounts for the variation in fluid flow with pressure differential and is given by Equation B-22 in Reference 1. With $C_p = 1.0$ and possibility of flashing at both conditions, this factor is given by:

$$\gamma = \sqrt{\frac{\dfrac{(p_{p2} - p_{f2})}{\Delta p_2}}{\dfrac{(p_{p1} - p_{f1})}{\Delta p_1}}} \qquad \text{(B-22)}$$

where p_f represents fluid saturation pressure at the primary side temperature.

Step-by-Step Description of the Adjustment Process

The following is a description of the steps involved in adjusting a leak rate at a given condition to SLB condition.

Step 1: **Adjust measured leak rate to the standard SLB primary side temperature ($T = 616^{\circ}F$) and secondary side pressure ($p_s = 15$ psi) while maintaining the same total pressure differential (Δp).**

Since the total pressure differential is maintained the same $\Delta p_1 = \Delta p_2 = \Delta p$, $\alpha = 1$. Therefore,

$$R_{std} = \frac{LR_2}{LR_1} = \beta \gamma_{std}$$

where, β is given by Equation B-21, and

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

Columns M through AE contain calculations involved in this step.

Col. M, N, O	Desired standard conditions: $p_{secondary} = 0$ psig, $T_{primary} = 616^{\circ}F$, Δp same as in the test.
Col. P	Does water flash to steam during the test because the secondary side pressure is below the saturation pressure at the primary side temperature?
Col. Q, R	Young's modulus at test and desired conditions
Col. S, T	Flow stress at test and desired conditions
Col. U, V	Fluid density at test and desired conditions
Col. W	Saturation pressure at the desired condition
Col. X	Calculated β factor
Col. Y, Z	Self explanatory
Col. AA	Calculated γ factor. Note that this term cannot be calculated for a test condition where the primary side pressure for the desired condition $p_p = (\Delta p + 15)$ falls below the saturation pressure at the desired primary temperature ($616^{\circ}F$).
Col. AD	Product β times γ
Col. AE	Measured leak rate adjusted to the standard SLB primary side temperature ($T = 616^{\circ}F$) and secondary side pressure ($p_s = 15$ psi) while maintaining the same Δp as in the test

Step 2: Calculate b factor in alpha term (Equation B-15)

Step 1 adjusts the measured leak rate to a condition where the secondary pressure is 15 psi and primary side temperature is $616^{\circ}F$ while maintaining the same total pressure differential. This leak rate is adjusted to the SLB pressure differential with the following equation:

$$R = \alpha\gamma = \gamma 10^{\frac{(\Delta p_{SLB} - \Delta p_m)}{b}}$$

where, R is the ratio of the leak rates at the SLB and test measurement total pressure differentials. (The β factor is not affected by total pressure differential.)

Three different methods were used to calculate the b factor and the value that yielded the largest leak rate at the desired SLB pressure differential was picked for use in a leak rate correlation.

Method 1

When more than two data points are available, a value for b can be obtained by fitting a linear regression line to the natural log of leak rate versus Δp data. The b value is given by the inverse of the slope value.

Cell G15 in the spreadsheet contains the b value calculated with this method.

Methods 2A and 2B

Alternately, a value for b can obtained using only the two data points with Δp values that bound the SLB Δp ($\Delta p_2 < \Delta p_{SLB} < \Delta p_1$):

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

Two slightly different methods were used to pick the leak rate values used to calculate the "R" term in the above equation. In one method (Method 2A), measured leak rates adjusted to standard conditions (in Step 1) were used. In the second method (Method 2B), leak rate values at Δp_2 and Δp_1 were calculated using the correlation between log (leak rate) vs. Δp developed in Method 1, and their ratio yielded R. The values for b obtained with Methods 2A and 2B are shown in Cells G27 and G34, respectively.

Step 3: Convert leak rate at test pressure differential to SLB pressure differential

The measured leak rates adjusted to standard conditions in Step 1 are adjusted to the SLB pressure differential with the following equation:

$$R = \alpha\gamma = \gamma 10^{\frac{(\Delta p_{SLB} - \Delta p_m)}{b}}$$

Columns AE to AG show the leak rates adjusted to SLB Δp =2560 psi using the three values for factor b obtained in Step 2. Columns AH to AJ show the corresponding adjusted leak rates at SLB Δp =2405 psi. Note that each test measurement is adjusted to the SLB condition with the exception of measurements that cannot be adjusted to the standard conditions in Step 1 (tests with $\Delta p < p_{sat}$ at 616°F). The adjusted SLB leak rate value for the test measurement with Δp closest to and higher than the SLB Δp is chosen for use in a leak rate correlation (Test # 3 in Row 8). There are three choices corresponding to the three values for the b factor (values in Cells AE8, AF8 and AG8 for SLB Δp=2560 psi) and the largest of the three values is chosen (Cell AE8).

Reference

1. EPRI Report NP-7480-L, "Steam Generator Tubing Outside Diameter Stress Corrosion Cracking at Tube Support Plates – Database for Alternate Repair Criteria, Volume 2: ¾ Inch Diameter Tubing," October 1993

South Texas Unit-2 InSitu Leak Test Results
SG-D R24 C47 TSP 3H
Adjustment to Steamline Break Conditions

Test Data Entry									Describe the Test			Enter the Desired Conditions for Each Test			
Test Spec	Test ID/ Setup	Test Seq. #	Pp (psig)	Ps (psig)	Δp_{test}	T_p	T_s	Measured Leak Rate (@Tp) (gpm - RT)	Is leak rate a room temperature msmt. of a hot test? (yes/no)	Was the Specimen Previously Expanded with a Bladder? (yes/no)	P_{sat} at T_p (psia)	Desired Conditions			Water Flash to Steam At Test Conditions?
												Ps) gauge	Δp	Tp	
South Texas 2 2001	R24C47-3H	1	1440	0	1440	75	75	0.0002	no	no	0.44	0	1440	616	no
		2	2046	0	2046	75	75	0.08466	no	no	0.44	0	2046	616	no
		3	2530	0	2530	75	75	0.24024	no	no	0.44	0	2530	616	no
		4	2700	0	2700	75	75	0.40074	no	no	0.44	0	2700	616	no
		5	2849	0	2849	75	75	0.53798	no	no	0.44	0	2849	616	no

	Col F	Col AE	
Leak Rate	Total Δp (psi)	Log of Adjusted Leak Rate	Label
#VALUE!	1440	#VALUE!	a1
0.032854602	2046	-1.4834	b1
0.132505802	2530	-0.8778	c1
0.235415259	2700	-0.6282	d1
0.330287014	2849	-0.4811	e1

Estimation of "b" Constant

Method 1
Linear Regression
Log(adjusted leak rate-col AG) versus ΔP

789.8 <-- "b" constant

m	0.0012662	-4.073	b
se_m	3.684E-05	0.0939	se_b
r2	0.9983101	0.0223	se_y
F	1181.4888	2	df
ssreg	0.5850319	0.001	ssresid

Method 2a
Based on Two Neighboring Datapoints Using As-Measured Leak Rate

"b" constant

b = 1068.51 b1 and c1

Method 2b
Based on Two Neighboring Datapoints Leak Rate Estimated from Regression Fit

"b" constant

b = 1051.81 b2 and c2

Regression Line - Log (leak rate) vs. Δp
(Used for Plotting)

Total Δp (psi)	Calculated Leak Rate using m & b Log (leakra	Calculated Leak Rate using m & b Leakrate	Label
1440	-2.2493	0.0056	a2
2046	-1.4820	0.0330	b2
2530	-0.8692	0.1351	c2
2700	-0.6539	0.2218	d2
2849	-0.4653	0.3425	e2

	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC
1													
2													
3	Young's Modulus for Temp. Correction		Flow Stress for Temp Correction		Density for Temp Correction		Psat	β For the Desired Temperature	Primary Pressure Greater Than Psat At the Desired Condition?	Does the Test Flash at the desired conditions?	γ factor for desired temperature and pressure	βγ	Corrected for Temp and Pressure (βγ) at the desired conditions
4	**Test**	**Desired**	**Test**	**Desired**	**Test**	**Desired**	**Desired**						**(gpm - RT)**
5	**Temp.**	**Temp.**	**Temp.**	**Temp.**	**Temp.**	**Temp.**	**Temp.**						
6	31.23	28.52	78.92	71.70	62.23	40.85	1738	0.977	no	yes	undefined	undefined	-
7	31.23	28.52	78.92	71.70	62.23	40.85	1738	0.977	yes	yes	0.397	0.388	0.0329
8	31.23	28.52	78.92	71.70	62.23	40.85	1738	0.977	yes	yes	0.565	0.552	0.1325
9	31.23	28.52	78.92	71.70	62.23	40.85	1738	0.977	yes	yes	0.602	0.587	0.2354
10	31.23	28.52	78.92	71.70	62.23	40.85	1738	0.977	yes	yes	0.629	0.614	0.3303
11													
12													
13													
14													
15											SLB Leak	Rate - Plot Data	
16											1600	0.146415	**33.3**
17											2560	0.146415	
18											2560	0.0001	
19													
20													
21													
22													
23											SLB Leak	Rate - Plot Data	
24											1600	0.095437	**21.7**
25											2405	0.095437	
26											2405	0.0001	
27													
28													
29													
30													
31													
32													
33													
34													
35													
36													
37													
38													

	AD	AE	AF	AG	AH	AI	AJ
1		**Steamline Break Δp = 2560 psi**			**Steamline Break Δp = 2405 psi**		
2		**Method 1**	**Method 2a**	**Method 2b**	**Method 1**	**Method 2a**	**Method 2b**
3	Leak Rate 2560 psi Steamline Break Ref. Condn.	Leak Rate 2560 psi Based on "b" from L.S. Fit Slope (Cell G15)	Leak Rate 2560 psi Based on 'b' Factor from Cell G27	Leak Rate 2560 psi Based on 'b' Factor from Cell G34	Leak Rate 2405 psi Based on "b" from L.S. Fit Slope (Cell G15)	Leak Rate 2405 psi Based on 'b' Factor from Cell G27	Leak Rate 2405 psi Based on 'b' Factor from Cell G34
4	**(gpm)**	**(gpm - RT)**	**(gpm - RT)**	**(gpm - RT)**	**(gpm - RT)**	**(gpm - RT)**	**(gpm - RT)**
5							
6	-	-	-	-	-		
7	1.47E-01	2.12E-01	1.43E-01	1.46E-01	1.26E-01	9.54E-02	9.66E-02
8	1.45E-01	1.46E-01	1.43E-01	1.43E-01	8.74E-02	9.54E-02	9.50E-02
9	1.57E-01	1.49E-01	1.65E-01	1.65E-01	8.88E-02	1.10E-01	1.09E-01
10	1.42E-01	1.29E-01	1.61E-01	1.60E-01	7.72E-02	1.07E-01	1.06E-01
11							
12							
13		**Pick these values for inclusion in the leak rate correlation as the total Δp for this case is closest to the desired SLB pressure differential**					
14							
15							
16							
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38							

South Texas -2 SG-D R24C47-3H In Situ Leak Test Data

(Normalized to Tp= 616°F and ps = 15 psia Reference SLB Conditions)