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

South Texas Project
Units 1 and 2
Docket Nos. STN 50-498, STN 50-499
Amended Response to Request for Additional Information
Regarding Relief Request RR-ENG-10

References: 1) Correspondence from George F. Dick (NRC) to D. P. Hall (HL&P), dated June 29, 1992
2) Correspondence from S. L. Rosen (HL&P) to NRC Document Control Desk, dated January 17, 1992 (ST-HL-AE-3984)
3) Correspondence from S. L. Rosen (HL&P) to NRC Document Control Desk, dated August 24, 1992 (ST-HL-AE-4188)

Pursuant to NRC correspondence dated June 29, 1992, Houston Lighting & Power Company (HL&P) submits the attached amended response to the NRC request for additional information regarding Relief Request RR-ENG-10. The attached response is identical to that submitted as reference (3) except that a second page has been added to the response to NRC Question 6.

If there are any questions, please contact either Mr. P. L. Walker at (512) 972-8392 or me at (512) 972-7205.

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William J. Jump
General Manager,
Nuclear Licensing

PLW/ag

Attachment: Amended Response to Request for Additional Information

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1/1

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NRC QUESTION 1

Specify the equation number and page number in Tada's Handbook based on which the calculation on 30" welds is made.

RESPONSE

The solutions are reported on Pages 33.3, 33.4 and 33.6 of Tada's Handbook. The solutions on Pages 33.3 and 33.4 for applied uniform axial and bending stress, respectively, are based on the work of Sanders and are most accurate when crack lengths are relatively long (i.e., $a > 5(Rt)^{1/2}$). When the crack lengths are relatively short, the solution of Folias given on Page 33.6 of Tada's Handbook was used to conservatively approximate the behavior of K_1.

With reference to Table 1 in Attachment 4 of the Relief Request, Sander's solution was used in evaluating Weld EW1205-FW0032, and Folias solution was used for Welds EW1302-FW0032 and EW1102-FW0043. Subsequent to the submittal of the Relief Request, further review indicated that the solution reported by Zahoor on Page 1-1 through 1-5 of the "Ductile Fracture Handbook" (EPRI NP-6301-D, Volume 1, June 1989) provided a more complete and correct solution for the shorter cracks. The Sanders solution was still retained for long cracks. Therefore, in preparing the critical bending stress curves for the 30-inch pipe presented at the NRC presentation on March 13, 1992, the Sanders and Zahoor solutions were employed.

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NRC QUESTION 2

Supply an assessment of the reliability of K_{1c} values for Aluminum Bronze in the submittal. What would the impact be if the standard ASTM procedure is used instead of the crack tip opening displacement method described in Attachment 1?

RESPONSE

The fracture toughness was determined from twenty CTOD weld metal specimens all tested at 40°F. The conversion from CTOD to fracture toughness was accomplished by the following quasi-theoretical relationship:

$$K^2_c = m\ E\ \sigma_f\ \delta_c$$

(Ref: Barsom and Rolfe, Fracture and Fatigue Control in Structures, 2nd Edition, Prentice Hall, 1987, Page 162)

where.

- E is modulus of elasticity
- σ_f is the flow stress equal to $(\sigma_y + \sigma_u)/2$
- δ_c is the critical value of CTOD measured for each specimen
- m is the specimen constraint factor 1.2 to 1.6 (note: m was conservatively assumed as 1.2)
- K_c is the fracture toughness for the appropriate pipe thickness

The above correlation has been shown to provide reasonable estimates of K_c for ductile steels and, because of its theoretical basis, can be applied to other ductile materials, such as aluminum bronze.

At the time the Relief Request was prepared, a conservative analysis of fracture toughness was made using bounding parameters in the CTOD-K_c equation and a subset of the CTOD specimens. That conservative analysis yielded a lower bound estimate of K_{1c} = 112 ksi in $^{1/2}$. (It should be noted that K_{1c} was used generically to define the critical value of fracture toughness and was not intended to signify the ASTM E399 definition for plane strain fracture toughness). Subsequent to the release of the Relief

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Request, a more complete evaluation of fracture toughness was performed using all specimen data. From this later analysis, a conservative bound of 120 ksi $in^{1/2}$ was determined statistically based on the mean toughness value minus two standard deviations. This would correspond to 98% probability of occurrence.

If the ASTM standard for fracture toughness under plane strain conditions (K_{1c}) was used, it would be expected that the fracture toughness would be reduced. However, in order to achieve plane strain conditions, a specimen approximately 20 inches thick would be required to produce a valid test result. Since the pipe wall thicknesses are in the range of 0.250 to 0.375 inch, plane strain conditions will not prevail for the actual pipe geometries. Therefore, the use of K_c, as defined above, for defining fracture toughness is proper and the evaluation of the CTOD test results, as described, will give a conservative estimate of fracture toughness.

If plane strain conditions existed, the potential impact may be estimated by taking the square root of the ratio of yield strength to flow stress:

$$\frac{K_{1c}}{K_c} = (\sigma_y / \sigma_f)^{1/2} \approx 0.77$$

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NRC QUESTION 3

Explain in sufficient detail about the applied stresses, especially Pressure, Thermal and Transients.

RESPONSE

The stresses due to design pressure, deadweight, thermal stress due to temperature rise, and the stress due to the highest transient (seismic or water hammer) are combined to give the maximum stress for the evaluation of flaws in Table 1 of the Relief Request.

The response to Question 4 gives further details.

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NRC QUESTION 4

Explain the definitions of Equations 8, 9B, 9D, 10 and maximum stress that appeared on Page 13 of the Attachment 4.

RESPONSE

Equations 8, 9B, 9D and 10 referenced on page 13 of Attachment 4 of the presentation made to the NRC on March 13, 1992, refer to the standard equations for Class 3 piping design as given in ASME Code, Section III, Subsection ND, Paragraph ND-3652. Equation 8 refers to design stress conditions for sustained loads, Equation 9 to the stress requirements for occasional loads, and Equation 10 to the stress requirement for thermal stress. 9B and 9D refer to service levels in accordance with the ASME Code, Section III, Paragraph ND-3520 including consideration of transients.

Maximum stress for flaw evaluation purposes is defined as the maximum value of unconcentrated bending stress at a location by the summation:

(Equation 8, or 9B, or 9D, minus their respective pressure components, whichever is highest) + (Equation 10)

In the above equations, the geometric stress intensification factors are removed wherever they appear. The use of "unconcentrated" stress in the flaw evaluation procedures is stated in Paragraph C-3310 of Appendix C to the ASME Code, Section XI. The pressure components are deducted above because the membrane stress due to design pressure is pre-programmed into the flaw evaluation curves and is therefore already included in the flaw analysis.

This is the basis on which the margins for the then existing flaws were calculated in Table 1 of the Relief Request and on Page 20 of the Presentation.

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On page 13 of the Presentation, an effort was made to develop a "bounding case" for maximum stress for above ground welds based on Engineering judgments to select a sample stress calculation with high code stresses. The highest values for equations 8, 9B, 9D and 10 at different locations in this stress calculation were added. This provides an estimate of bounding stress for 30" above ground welds, for the purpose of illustration that even on such an unrealistically conservative basis, the critical crack size would be large enough to be readily detected by the monitoring methods at a much earlier stage and repaired. This data is not used for evaluations because the maximum stress used for evaluation of an individual flaw is the stress at the flaw location.

Page 13 is resubmitted incorporating these clarifications and some calculational corrections made after the Presentation. Page 19 is revised as a consequence. Page 14 is revised for editorial corrections. The revised Page 13 also contains, for comparison, the worst case bending stress (unintensified) at a single node in the same calculation. This is more representative of the likely bounding case for a single point in 30" above ground welds.

Pages 14 and 19 of the Presentation provided similar bounding estimates of maximum unconcentrated bending stress in below ground welds, and a "typical" stress, which represents the order of magnitude of stress likely to occur at most below ground welds.

ABOVE-GROUND STRESS ANALYSIS REVIEW RESULTS (Continued)

- Bounding Case for 30-Inch Pipe Summarized Below (stresses in psi):

Calc.	Pipe Size	Max. SLP Design	Maximum Unintensified Bending Stress From Equation 8	9B	9D	10	Max. Unintensified Bending Stress
RC967	30	3510	1574 (829)*	5504 (829)*	3484 (829)*	11241 (750)*	16745
RC967	30	3510	1010 (750)*	2647 (750)*	2028 (750)*	11241 (750)*	13888

*Denotes Node Number in Calc.

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BURIED ECW PIPING

For 30-Inch Pipe*
(stresses in psi)

		Code Equation			Unconcentrated Stress	
Equation	Location	Stress	Allowable	SIF	Axial	Bending
9D	D	40756	43200	8.81	1590	5927
10	OPQRS	12970	27000	11.31	0	1147

For 10-Inch Pipe*
(stresses in psi)

		Code Equation			Unconcentrated Stress	
Equation	Location	Stress	Allowable	SIF	Axial	Bending
9D	D	17088	43200	8.81	317	2538
10	HIJ	5833	27000	2.605	0	2239

*Worst Case Condition at Piping Tee Weld

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RESULTS – GENERIC ANALYSIS

Pipe Size (in)	Location	Wall Thickness (in)	Peak Applied Bending Stress (psi)	Critical Flaw Size (% Circ.)	Critical Flaw Size (in)
30	Above Ground	0.25	16745	10.9	10.1
30	Below Ground(1)	0.25	7,074	20.0	18.8
30	Below Ground(2)	0.25	2,167	32.2	30.3
10	Below Ground(1)	0.365	4,777	56.0	18.9
10	Below Ground(2)	0.365	2,189	67.5	22.8

Notes: (1) Worst Case Condition at Piping Tee Weld
(2) Typical Case for Welds in Straight Pipe

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NRC QUESTION 5

Supply the "Code equation" described on Page 14 of Attachment 4 and explain the "unconcentrated stress" described on the same page.

RESPONSE

The code equations listed on Page 14 (of the March 13 presentation to the NRC) are explained in the response to Question 4 above. "Unconcentrated" stress means the appropriate equational stress (8, 9B, 9D, 10) without the stress intensification factors. The use of unconcentrated stress in flaw evaluation procedures is defined by Paragraph C-3310 of Appendix C to the ASME Code, Section XI.

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NRC QUESTION 6

Supply one example of obtaining the critical bending stress shown on Page 20 by using Sanders' method.

RESPONSE

The following example calculations for fracture are provided for Weld EW1205-FW0043:

$$K_I = \left[\sigma_m F_m + \sigma_b F_b \right] (\pi a)^{1/2}$$

where,

a = Half crack length
σ_m = Uniform axial stress
σ_b = Global bending stress
F_m = Free surface correction factor for uniform stress
F_b = Free surface correction factor for global bending stress

The critical bending stress (σ_b^c) for fracture is:

$$\sigma_b^c = \frac{K_c}{F_b (\pi a)^{1/2}} - \sigma_m \ (F_m / F_b)$$

where,

K_c = 120 ksi in$^{1/2}$
a = 5.1875 inches
σ_m = 3.6 ksi

From Tada Solutions 33.3 and 33.4, after some algebraic manipulations:

$$F_m = C \left[\theta + \frac{1 - \theta \cot \theta}{2 \cot \theta + \sqrt{2} \cot [(\pi - \theta)\sqrt{2}]} \right]$$

$$F_b = C \sin \theta \left[1 + \frac{\theta - \cot\theta \ (1 - \theta \cot \theta)}{4 \cot \theta + 2\sqrt{2} \cot [(\pi - \theta)/\sqrt{2}]} \right]$$

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NRC QUESTION 6 (Con't)

where,

$C_2 = (R\sqrt{2}/\epsilon\pi a)^{1/2}$
$\epsilon^2 = (t/R)/[12(1-\nu^2)]^{1/2}$
ν = Poisson's ratio = 0.3
t = Wall thickness = 0.250 inch
R = Mean radius = 14.875 inches
θ = Crack half angle = a/R = 0.34874 rads

After substitution of appropriate input parameters, the following values are obtained:

ϵ = 0.071316
C = 4.2544
F_m = 1.5192
F_b = 1.4889

$\therefore\ \sigma_b^c$ = 16,290 psi

If the very conservative value of 112 ksi in$^{1/2}$ is used for K_c in the above evaluation as was done in preparing Attachment 4 of the Relief Request (reference 2), then σ_b^c = 14,960 psi. This is the same value of critical stress that appears in Table 1 of Attachment 4 for the subject weld.

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NRC QUESTION 7

Discuss the safety/shutdown implications of a guillotine rupture of a 30" diameter service water pipe. Include in this discussion an identification of the worst case flaw location.

RESPONSE

Each Unit at STPEGS has three Essential Cooling Water (ECW) trains. A rupture in one train does not affect operation of the other trains. Loss of a single ECW train will not affect the safe shutdown capability.

The ECW system is operated with the three trains maintained as independent trains. The "cross-tie" mode of operation described in section 9.2.1 of the UFSAR, which appears to contradict the foregoing statement, is effectively prohibited by operating procedures. Section 9.2.1 of the Safety Evaluation Report contains the correct description of the normal operating lineup.

The only physical interface between trains which can be utilized by procedure is the chemical analysis skid. This skid pumps a very small quantity of water from the return header of one train to the return header of another train, but the quantity is much too small to affect the operation of either train.

Complete circumferential separation is highly unlikely in the 30-inch ECW buried piping. However, for the purposes of safe shutdown implications, the guillotine break is assumed to occur in a single train. The worst location for an underground break is only of consequence from the standpoint of access for repairs. As discussed below, an underground break would not result in erosion of foundation soils leading to a common mode failure of all the ECW pipes or damage to other safety-related structures.

Thirty-inch diameter aluminum-bronze pipes connect the Essential Cooling Pond intake and discharge structures with the Mechanical Auxiliary Buildings of each unit. At various locations, three to

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six pipes are buried in trenches excavated in natural clay soils or category 1 backfill. The trenches have a minimum 4 inch thick lean concrete seal mats covering the bottom. Category 1 structural backfill was used to fill the trenches. The centerline of the pipes range from 10 to 18 feet below the ground surface. Each pipe is continuously supported on a concrete cradle with a concrete embedment of 8.5 inches.

A complete circumferential crack in the ECW pipe (without displacement) is postulated as the worst case scenario for the buried portion of the pipe line. This type of break would not result in a significant separation of the pipe due to the continuous confinement of the concrete cradle and the surrounding soil backfill. Without separation of the two pipe ends, a massive leak and erosion of foundation soil that could lead to a common mode failure of all the ECW pipes is not considered a credible event.

Scour of backfill soil is possible and expected even with flow rates resulting from the postulated underground break. Erosion of backfill material would, by necessity, start at the surface and propagate downward toward the source of the leak. This would mean surface run-off that would at least be apparent to an inspector. There is a program in place to inspect the route of the buried ECW pipe lines for anomalous wet conditions. Scour of adjacent pipe foundations is unlikely because of the relatively low flow rate, associated slow erosion process and the highest seepage gradient would be from the source of the leak to the surface.

A guillotine break in the 30-inch ECW piping inside a building is not considered a credible event because current monitoring methods will detect cracks at a much earlier stage. The only area where flooding from an ECW pipe leak could potentially affect other trains is in the Mechanical Auxiliary Building. Analysis of credible pipe ruptures in the 30-inch ECW pipe is included in the original design basis of the plant, including the effect of loss of one train and system interaction effects such as flooding and spray. The design is based on Branch Technical Position ASB 3-1. The rate of flooding from a "critical crack" in ECW piping, as defined in the design basis, is less than 10% of the rate of flooding due to the worst case event postulated in the design basis.

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Two rooms in the MAB through which the 30-inch pipe is routed contain components associated with all three safety trains; however, the components are either qualified for a spray environment or immune to damage from spray by the nature of the component (i.e. heat exchangers, etc.).

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NRC QUESTION 8

Provide more details of the new leaks identified in the Supplement to the Relief Request ST-HL-AE-4120 dated June 22, 1992.

(This question was given verbally in a telephone conversation on 8/6/92.)

RESPONSE

The following is additional information on the leaks identified in the referenced supplement:

- 6" casting adjacent to Weld EW2309-FS-3453 in Unit 2, Train C. The leak consisted of a small indication of seepage due to dealloying of the cast material detected by the monitoring. The leak was detected in February, 1992, and repaired by removal of the casting and replacement with wrought material in May, 1992.

- 6" casting adjacent to Weld EW2106-FW-3489, in Unit 2, Train A. The leak consisted of a small indication of seepage due to dealloying of the cast material detected by monitoring. The leak was detected in April, 1992, and repaired by removal of the casting and replacement with wrought material in June, 1992.

- EW1202-AQ, Tee in Unit 1, Train B:
The leak is localized in the base metal in the form of seepage. The defect has no dimensions measurable by ultrasonic testing. Localized repair is scheduled during the outage beginning September, 1992.

- Thermowell N1 EWTE-6853, Unit 1, Train A:
The leakage is localized and in the form of seepage at the stainless steel to aluminum bronze weld. It was discovered in February, 1992, and the thermowell was removed and replaced by an aluminum bronze thermowell in May, 1992.

- Thermowell N1 EWTE-6877, Unit 1, Train C:
The leakage is localized and in the form of seepage at the stainless steel to aluminum bronze weld. It was discovered in February, 1992, and is scheduled to be replaced by an aluminum bronze thermowell in the outage beginning September, 1992.