S O N G S - 1

EVALUATION OF THE REFUELING WATER STORAGE TANK (RWST) FOR BUCKLING

Purpose

The purpose of this calculation is to check the tank shell of the Refueling Water Storage Tank (RWST) with reduced thickness for buckling using the methodology given in the Seismic Qualification Utility Group (SQUG) "General Implementation Plan" for addressing Unresolved Safety Issues (USI) A-46 and A-40.

Conclusion

The RWST maximum compressive stress of 7.26 ksi in the tank shell is less than the allowable compressive stress of 9.14 ksi.

References

1. Seismic Qualification Utility Group (SQUG),"Generic Implementation Plan (GIP) for Seismic Verification of Nuclear Plant Equipment," Revision 2, February 1992, Section 7.

2. Calculation number DC-3679,"RWST Evaluation," March 29, 1992.

3. Impell report number 01-0310-1392,"San Onofre Nuclear Generating Station, Unit 1, Evaluation of the Refueling Water Storage Tank for Long Term Service," March 1986.

Calculation

All terms in the following calculations are defined according to Reference 1 nomenclature.

<u>Step 1:</u> Input Data

Tank Shell Material: A-283 Gr C

$R = 204$ in.

$H' = 445$ in.

$t_{min} = 0.25$ in.

$t_s = 0.299$ in.

t_b = 0.313 in.

σ_y = 30,000 psi

h_c = 12.75 in.

E_s = $29.5\text{x}10^6$ psi

V_s = 578 ft/sec. (Reference 3)

Fluid:

γ_f = 0.03611 lb_f/in^3 (=62.4 lb_f/ft^3)

H = 445 in.

h_f = 0. in.

Bolts:

N = 32 bolts

Size = 1 5/8 in.

h_b = 32.75 in.

E_b = $29.5\text{x}10^6$ psi

Loading:

0.67g Modified Housner Ground Spectrum at 4% damping.
Tank is located on a concrete foundation at grade.

<u>Step 2:</u> Calculate following ratios and values

H/R = 445/204 = 2.18

t_s/r = .299/204 = 0.00147

t_{av} = [88*0.299 + 357*0.250]/445 = 0.26 in.

t_{ef} = [0.26 + 0.25]/2 = 0.255 in.

t_{ef}/R = 0.255/204 = 0.00125

$W = \pi R^2 H \gamma_f = \pi (204)^2 (445) (0.03611)$

$= 2.1\text{x}10^6$ lb

The above parameters, values and ratios are within the applicable ranges of Table 7.1 in the GIP. Therefore, the procedure is applicable to the SONGS 1 RWST.

Step 3: Determine the fluid-structure modal frequency

Using Table 7-3 of the GIP with:

R= 204 in.

$t_{ef}/R = 0.00125$

$H/R = 2.18$

$F_f = 7.13$ Hz

Step 4: Determine the spectral acceleration

Using the .67g horizontal ground spectrum at 4% damping:
For 0.8 F_f = 0.8*7.13 = 5.70 Hz or 0.175 sec.
Sa_f = 1.031g

For 1.2 F_f = 1.2*7.13 = 8.56 Hz or 0.117 sec.
Sa_f = 0.886g

Since V_s is less than 3,500 ft/sec soil-structure interaction (SSI) effects on the frequency must be considered. From the SSI analysis performed in Impell Report No. 01-0310-1392, Reference 3, the spectral acceleration is 0.824g which is less than the above calculated acceleration. Therefore, Sa_f = 1.03g will be conservatively used for the seismic demand.

Step 5: (Not applicable to buckling check)

Step 6: The overturning moment has been rigorously calculated in Reference 2.

Steps 7 and 8: (Not applicable to buckling check)

Step 9: Tank shell stress

The tank shell stress (σ) is given by,

$$\sigma = \left(\frac{P_u\ e}{t_s^2}\right) \left[\frac{1.32\ Z}{\dfrac{1.43\ a\ h^2}{R\ t_s} + (4\ a\ h^2)^{0.333}} + \frac{0.031}{\sqrt{R\ t_s}} \right]$$

where,

$$Z = 1/\ [1 + 0.177\ a\ t_b\ (t_b/t_s)^2/\sqrt{R\ t_s}]$$

P_u (bolt load)= 27.7 kips (Reference 2)

a (width of the chair top plate parallel to the RWST shell) = 4.5 in.
The above value of a is very conservative since the chair top plate extends along the shell circumference without interruption.

h (height of chair) = 12.75 in.

e (eccentricity of anchor bolt with respect to shell outside surface) = 2.25 in.

It follows that $\sigma = 22.6$ ksi $< \sigma_y$ ($\sigma_y = 30$ ksi)

Steps 10 and 11: (Not applicable to buckling check)

Step 12: Fluid pressure for elephant-foot buckling

From Figure 7-7, in the GIP, the following value of P_e' is obtained by entering $Sa_f = 1.03g$, and $H/R = 2.18$:

$P_e' = 3.7$

Fluid pressure at the base (P_e) is given by,

$$P_e = P_e' \gamma_f R = (3.7)(0.03611)(204)$$

$$= 27.3 \text{ psi}$$

Step 13: Elephant-foot buckling stress capacity factor

From Figure 7-8, in the GIP, the following value of the elephant-foot buckling stress capacity factor (σ_{pe}) is obtained by entering P_e = 27.3, and t_s/R = 0.00147:

$$\sigma_{pe} = 12.7 \text{ ksi}$$

Step 14: Fluid pressure for diamond-shape buckling

From Figure 7-9, in the GIP, the following value of P_d' is obtained by entering Sa_f = 1.03g, and H/R = 2.18:

$$P_d' = 2.7$$

Fluid pressure at the base (P_d) is given by,

$$P_d = P_d' \gamma_f R = (2.7)(0.03611)(204)$$

$$= 19.9 \text{ psi}$$

Step 15: Diamond-shape buckling stress capacity factor

From Figure 7-10, in the GIP, the following value of the diamond-shape buckling stress capacity factor (σ_{pd}) is obtained by entering P_d = 19.9, and t_s/R = 0.00147:

$$\sigma_{pe} = 17.5 \text{ ksi}$$

Step 16: Allowable buckling stress (σ_c)

The allowable buckling stress (σ_c) is taken as 72% of the lower value of σ_{pe} or σ_{pd}. Therefore,

$$\sigma_c = (0.72)(12.7)$$

$$= 9.14 \text{ ksi}$$

Step 17: Overturning moment capacity

The overturning capacity of the RWST was checked by postulating a weak link ductile failure mode, with the weak link in the form of tank shell bending. The bending stress in the shell was calculated in Step 9:

$\sigma = 22.6 \text{ ksi} < \sigma_y$ $(\sigma_y = 30 \text{ ksi})$

Other checks in this step are to verify anchorage, which was evaluated per Reference 2.

Steps 18 through 22: (Not applicable to buckling check)