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GPU NUCLEAR

B/A No. 128108

W/O No. 95-552A-52108

SEISMIC QUALIFICATION

No. SQ - T1 - DH-T-0001

REVISION 0

COMPONENT: DH-T-0001

SUBCOMPONENT(S): ______

______

______

Sheet 1 of 19

EVALUATED BY: R. D. Augustine DATE 10-6-93

EVALUATED BY: [signature] DATE 12-8-93

Status Y N U

SCREENING EVALUATION WORK SHEET (SEWS) Sheet 1 of 2

Equip. ID No. DH-T-0001 Equip. Class 21 - Tanks and Heat Exchangers

Equipment Description BWST

Location: Bldg. YD Floor El. 305 Room, Row/Col W RB HATCH

Manufacturer, Model, Etc. (optional)

SHELL CAPACITY VS DEMAND

Buckling capacity of shell of large, flat-bottom, vertical tank is equal to or greater than demand: (Y) N U N/A

Attach A

ANCHOR BOLTS AND EMBEDMENT

Capacity of anchor bolts and their embedments is equal to or greater than demand: Attach A (Y) N U N/A

CONNECTION BETWEEN ANCHOR BOLTS AND SHELL

Capacity of connections between the anchor bolts and the tank shell is equal to or greater than the demand: (Y) N U N/A

Attach A

FLEXIBILITY OF ATTACHED PIPING

Attached piping has adequate flexibility to accommodate motion of large, flat-bottom, vertical tank: (Y) N U N/A

TANK FOUNDATION

Ring-type foundation is not used to support large, flat-bottom, vertical tank: (Y) N U N/A

IS EQUIPMENT SEISMICALLY ADEQUATE? (Y) N U

SCREENING EVALUATION WORK SHEET (SEWS) Sheet 2 of 2

Equip. ID No. DH-T-0001 Equip. Class 21 - Tanks and Heat Exchangers

Equipment Description BWST

COMMENTS

NONE

Evaluated by: R. D. Augustine Date: 10-6-93

[signature] 12-8-93

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Originator	**Date**	**Reviewed by**		**Date**
R.D. Augustine	12-3-93	[signature]		12-8-93

Purpose The purpose of this calculation is to seismically verify the tank and its anchorage.

Methodology The methodology to be used in this calculation is that detailed in the Generic Implenentation Procedure (GIP).

References

1. ES-022, Seismic Design Criteria
2. Generic Implenentation Procedure (GIP) for the Seismic Verification of Nuclear Plant Equipment, Rev.2.
3. Gilbet Associates Drawing No. S-423-039 Rev. 2.
4. Gilbet Associates Drawing No. E-435-201 Rev. 6
5. Pittsburgh Des Moines Steel Company Drawing No. E2, Reference No. 4692-27-1032.
6. Pittsburgh Des Moines Steel Company Drawing No. E1, Babcock & Wilcox Drawing No. 620-0005, 6-44 028 01.
7. Pittsburgh Des Moines Steel Company Drawing No. E5, Babcock & Wilcox Drawing No. 620-0005, 36-44 023 01.
8. Gilbet Associates Bill of Material TMI-RA, Sheet No. 31-2.
9. EQE Report No. 42105-R-001.
10. "Handbook of Tables for Applied Engineering Science", 2nd Edition, Bolz & Tuve.
11. AISC Manual of Steel Construction, 8th Edition.
12. EPRI Report NP-5228-SL, "Seismic Verification of Nuclear Plant Equipment Anchorage", Volume 1, Rev. 1.
13. ACI 349.

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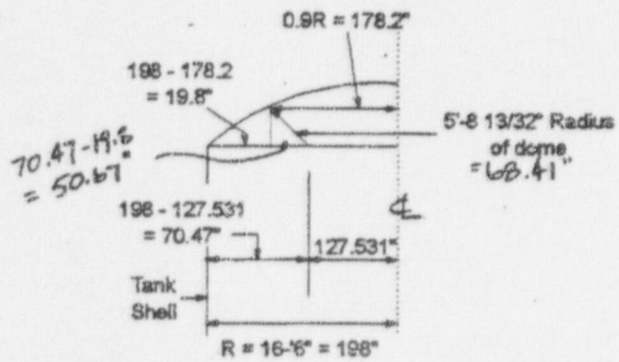
CALCULATIONS

- Per Reference 8 the tank is constructed of ASTM A240 Type 304 stainless steel. Per Reference 10, Table 1-57, page 104, the yield strength of Type 304 stainless steel is 35 ksi. Per Reference 10, page 117, the modulus of elasticity is 28×10^6 psi.

- Determine the height of freeboard clearance between the liquid surface and the tank roof in accordance with Section 7.3.5 of Reference 2. For tanks with domed roofs, measure the freeboard from the fluid surface to the point where the roof surface is at a distance of 0.9R from the tank centerline.

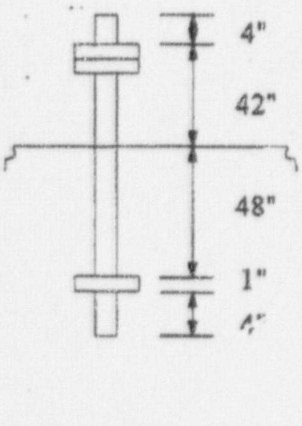


The diagram and dimensions are from Reference 7, Sketch A.

$$\text{freeboard} = \sqrt{68.41^2 - 50.67^2} = 45.96"$$

- Assume height of fluid at maximum fill level = 52'-0 1/4" = 624.25"

- From Reference 4 find the tank is anchored with (39) type TB-1 and (1) type TB-5 anchor bolts. Per Reference 3 find the following dimensions:



$$h_b = 42" + 48" = 90"$$

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- Determine allowable shear and tension loads for a 2" diameter cast-in-place anchor bolt in accordance with the guidelines of Reference 12. Note that this is the reference material for the derivation of the allowable loads for cast-in-place anchor bolts in the GIP. The values just were not derived for 2" diameter bolts.

The allowable tension and shear loads are based on the nominal bolt area times allowable shear and tension stresses. These allowable stresses (17,000 psi shear and 34,000 psi tension for A307 bolt material) are equal to 1.7 times the working stress design allowable given in Part 1 of the AISC specification for Design, Fabrication, and Erection of Structural Steel for Buildings, Reference 11.

Per Reference 11, the tensile stress area for a 2" diameter bolt = 2.50 in^2 and the minimum root area = 2.34 in^2.

P_t = 2.5 (34,000 psi) = 85,000 lbs. (conservative as tensile stress area < nominal bolt area).

P_v = 2.34 (17,000 psi) = 39,780 lbs. (conservative as minimum root area < nominal bolt area).

Determine Minimum Embedment, Spacing, and Edge Distance

The recommended minimum embedment lengths are developed by applying the concrete shear-cone theory put forth in Appendix B of the ACI Standard 349 (Reference 13), and assuring ductile failure mode in bolt material rather than brittle failure associated with pulling of concrete cone. The ACI concrete shear-cone theory gives the pullout strength of concrete P, as:

$$P = 4\phi\sqrt{f_c'}\,\pi(L + D)L$$

where:

ϕ = a capacity reduction factor = 0.65

f_c' = concrete compressive strength = 3,500 psi

D = diameter of bolt or stud (in.)

L = embedment length of bolt or stud (in.)

To determine the embedment lengths required by the GIP, the above equation was solved by setting P equal to twice the pullout capacity value given as P_t. Solving the equation for L in terms of bolt diameter for f_c' = 3,500 psi. yields a required embedment length of 10D. Thus for a 2" diameter bolt, the embedment length must be a minimum of 20". Page 2-77 states that the minimum spacing and edge distance requirements are 12.5D and 8.75D respectively. This equates to 25" spacing and 17.5" edge distance requirements.

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CAPACITY REDUCTION FACTORS FOR CAST-IN-PLACE BOLTS WITH NUTS OR HEADED STUDS

BORATED WATER STORAGE TANK

Bolt Dia. (D)inches:	2.000	Concrete Strength f'c (psi) =	3,000
Required Edge Dist. (Emin) inches:	17.5	Actual Edge Dist. (E) inches:	18
Required Embedment (Lmin) inches:	20	Actual Embedment (L) inches:	48
Required Spacing (Smin) inches:	25	Actual Spacing (S) inches:	29.8

Note: If actual embedment,spacing, or edge distance exceeds minimum required , use minimum values for calculation of reduction factors.

L = 20 inches S = 25 inches E = 17.5 inches

THETA (edge dist.) = 2 cos-1 (2E/(2L+D))
= 1.17 rad

r = (2L+D)/2
= 21

THETA (spacing) = 2 cos-1 (S/(2L+D))
= 1.87 rad

- **Edge Distance Check**

E = 18.0 >= Emin, no pullout reduction factor required.

E = 18.0 >= 8.75D, no shear reduction factor required.

- **Concrete Strength Check**

GIP Table C.3-1 allowables are based on a concrete strength = f'c = 3500 psi.

Concrete strength < 3,500 psi but >= 2,500 psi. Strength reduction factor required.

Reduction factor (RFp) = (RFs) = SQRT (f'c / 3500)
= 0.93

- **Embedment Check:** 10 * D = 20.00 4 * D = 8.00

L >= 10D, no reduction factor required.

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- **Spacing Check** 2 * D = 4.00

Actual spacing equals or exceeds required spacing, no pullout reduction factor required.

Shear capacity reduction factor for closely spaced cast-in-place anchor bolts = RSs:

RSs = 1.00 for actual spacing (S) >= 2 * D

- **Revised Allowable Loads**

From Table C.3-1 of the GIP, the subject bolt has the following full allowable loads:

For D = 2.000 inches, the allowable pullout capacity (Pu') = 85,000 lbs. and the allowable shear capacity (Vu') = 39,780 lbs.

The revised pullout load = Pu = Pu' * REp * RFp * RLp * RSp

= 78,695 lbs.

The revised shear load = Vu = Vu' * REs * RFs * RLs * RSs

= 36,829 lbs.

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VERTICAL TANKS -- BORATED WATER STORAGE TANK

STEP 1: Determine the following input data : Note tank is stainless steel.

TANK MATERIAL

diameter of tank (ft):	33
R (nominal tank radius) (inches):	198
(height of tank shell) (ft):	52
H' (height of tank shell) (inches):	624
t min (minimum shell thickness along height of tank) (inches):	0.25
t s (minimum thickness of tank in the lowest 10% of height) (inches):	0.421
F y (yield strength of tank shell mat'l) (psi):	35,000
h c (height of shell compression zone at base of tank, usually height of chair) (inches):	36.00
E s (elastic modulus of tank shell mat'l) (psi):	28,000,000
Vs (average shear wave velocity of soil for tanks located at grade) (ft/sec):	N/A

FLUID

GAMMA (weight density of fluid) (lb/in3):	0.036
H (height of fluid at maximum fill level) (inches):	624.25
h f (height of freeboard above fluid surface) (inches):	45.98

ANCHOR BOLTS

N (number of bolts):	40
d (diameter of bolt) (inches):	2
h b (eff. length of anchor bolt being stretched, usually from top of chair to embedded plate) (in.):	90
E b (elastic modulus of bolt material) (psi):	30,000,000
Anchor Bolt Allowable Tension Load (Pu) (lbs):	73,695
Anchor Bolt Allowable Shear Load (Vu) (lbs):	36,829

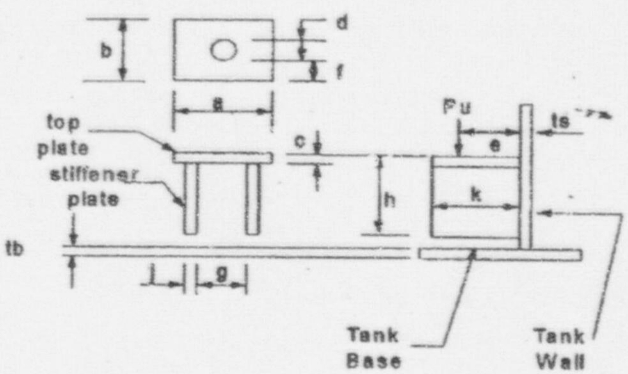
(Note: Allowables are with reduction factors applied)

Yield stress of anchor bolt material (f y) (psi):	36,000

From Figure 7-5 of the GIP, find the following dimensions (inches):

d =	2	j =	0.5	t b =	0.25
f =	1.25	g =	5.5	k =	5.6875
b =	6	c =	2	e =	2.75
a =	6.5	h =	24	t s =	0.421

Weld size between anchor chair and tank shell (t w) (inches): 0.1875



LOADING

Ground response spectrum at 4% damping for overturning moment and shear loadings on tanks and at 1/2% damping for fluid slosh height.

Ground response spectrum ZPA = 0.12 g

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STEP 2: Calculate the following ratios and values:

H/R = 3.153 t e/R = 0.002

t avg = thickness of tank shell averaged over the linear height of the tank shell
= (SUM t (* h)) / H'

= 0.309 inches

i	t	h	t x h
1	0.25	104	26
2	0.25	104	26
3	0.25	104	26
4	0.301	104	31.304
5	0.375	104	39
6	0.421	104	43.784
			192.088 = SUM t x h

t eff = (t avg + t min) / 2
= 0.28 in

(t eff)/R = 0.001

Ab = Cross-sectional area of embedded anchor bolt
= (PI x d^2) / 4
= 3.142 in^2

t' = equivalent shell thickness having the same cross-sectional area as the anchor bolts
= ((N * Ab) / (2 * PI * R)) * (Eb / Es)
= 0.1082

o' = coefficient of tank wall thicknesses and lengths under stress
= (t' / t e) * (h o / h b)
= 0.10

W = weight of fluid in tank
= PI * R^2 *H * GAMMA
= 2,767,842 lbs

CHECK TABLE 7-1 REQUIREMENTS

Tank Material = Carbon, Stainless Steel, Aluminum (circle one)
Tank Fluid Content = Water or similar YES or NO (circle yes or no), if no tank is an OUTLIER

Nominal Radius of Tank R=	198	inches	OK, Table 7-1 requirements met, 60 in >R <420 in
Height of Tank Shell (H') =	624	inches	OK, Table 7-1 requirements met, 120 in >H <960 in
Height of Fluid at the maximum Level to which the tank will be filled (H) =	624.25	inches	OK, Table 7-1 requirements met, 120 in >H <960 in
Minimum Thickness (t e) of the Tank Shell in the lowest 10% of the Shell Height =	0.421	inches	OK, Table 7-1 requirements met, 3/16 in >t e<1 in
Effective Thickness (t eff) of Tank Shell Based on the mean of the Average Thickness (t avg) =	0.279	inches	OK, Table 7-1 requirements met, 3/16 in >t e<1 in
Diameter of Anchor Bolt (d) =	2.000	inches	OK, Table 7-1 requirements met, 1/2 in > d <2 in
Number of Anchor Bolts (N) =	40		OK, Table 7-1 requirements met, N >= 8
Tank Wall Thickness (at Base)-to-Tank radius Ratio = (t e/R) =	0.002		OK, Table 7-1 requirements are met, .001 <= t e / R <= .01
Effective Tank Wall Thickness-to-Tank Radius ratio = (t eff/R) =	0.001		OK, Table 7-1 requirements met. .001 <= t eff < .01 inches.
H/R =	3.15		OK, Table 7.1 requirements met, 1 >H/R <5

STEP 3: Determine the fluid-structure modal frequency for vertical carbon steel tanks containing water:

R = 198 t eff / R = 0.001 , and H / R 3.153

From Table 7-3, find (F f) = 4.01 Hz.

NOTE: If the tank material is not carbon steel (Es not equal to 30,000 ksi) or fluid is not water (GAMMA not equal to 62.4 lbs/ft3) the frequency must be adjusted in accordance with the GIP STEP 3 as done below.

F f (e,f) = F f (SQRT (E s / 30,000,000) = 3.87 Hz

STEP 4: Determine the spectral acceleration (Saf) for the fluid-structure modal frequency.

Enter the 4% damped horizontal ground or floor response spectrum for the surface on which the tank is mounted, with the fluid-structure modal frequency determined in STEP 3, and determine the maximum spectral acceleration (Saf) over the following frequency range:

.8*Ff < F < 1.2 * Ff = 3.10 Hz < F < 4.81 Hz

Appropriate Spectral Acceleration (Saf) = 0.42 g 4% damping

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STEP 5: Determine the base shear load (Q).

Enter Figure 7-3 with (H/R) and (t eff/R) from above:

H/R = 3.153 and (t eff)/R = 0.001

And find base shear load coefficient (Q') = 0.735

Shear Load at Bottom of Tank = (Q) = Q' * W * Saf = 854,433 lbs

---

STEP 6: Determine the base overturning moment (M)

Enter Figure 7-4 with H/R = 3.153 and (t eff)/R = 0.001

And find M' = 0.405

Compute overturning moment = M = M' * W * H * Saf
= 293,903,102 lb-in

STEP 7: From the anchor bolt tensile load capacity, Pu, compute the allowable bolt stress (Fb):

Fb = Pu / Ab
= 25,046

Note: If the Section 4 and Appendix C criteria are not met for the anchorage, then the concrete is considered the weak link in the load path and the postulated failure mode is brittle. Determine an appropriate reduced allowable anchor bolt stress (Fr) per applicable code requirements.

STEP 8: Check the bending stress in the top plate of the chair. If each of the anchorage connection components meets the acceptance criteria defined below, then the bolt tensile capacity determined in STEP 7 is limiting. If, however, any of the components does not meet these guidelines, the reduced anchor bolt tension capacity represented by the equivalent value of anchor bolt allowable stress (Fr), as calculated here should be used. Note that if the top plate projects radially beyond the vertical plates, no more than 1/2 inch of this projecting plate can be included in the dimension f used in the following equation.

The maximum bending stress in the top plate is:

SIGMA = ((0.375 * g) - (0.22 * d)) * Pu / (f * c ^ 2)
= 25,537 < f y, Stress less than yield, top plate OK

Allowable anchor bolt stress (Fb) from Step 7 = 25,046 lbs

STEP 9: Check Tank Shell Stress

Shell Stress = 22,098 psi < F y. Shell Stress is OK

Z = 1 / (((0.177 * a * tb * (tb / ta) ^ 2) / (SQRT (R * ta))) + 1)
= 0.989

Allowable Anchor Bolt Stress = Fb = 25,046 lbs

STEP 10: The vertical stiffener plates are considered adequate if they satisfy the following guidelines:

1) (k / j) < (95 / ((f y / 1000) ^ 0.5))

k / j = 11.38 Guideline No. 1 Satisfied
95 / (((f y / 1000) ^ 0.5)) = 16.06

2) j >= 0.04 * (h - c) and j >= 0.5 in.

j = 0.50 Guideline No. 2 is an OUTLIER
0.04 * (h - c) = 0.88

3) (Pu / (2 * k * j)) < 21,000 psi

Pu/(2 * k * j) = 13,836 Guideline No. 3 is Satisfied

STEP 11: Check weld between the tank chair and the tank.

Load per linear inch of weld = Ww
= Pu * ((1 / (a + 2 * h)) ^ 2 + (e / (a * h + 0.667 * h ^ 2) ^ 2) ^ .5
= 1,498 lbs/inch

Allowable load per inch = (30,600 * t w) / SQRT(2) Weld is adequate
= 4,057 lbs/inch

STEP 12: Check tank wall for elephant's foot buckling:

Enter Figure 7-7 with the following parameters: Saf = 0.42 and H/R = 3.15

and find the fluid pressure coefficient (Pe') = 3.9

The fluid pressure at the base of the vertical tank from elephant-foot buckling type loading = (Pe) = Pe' * GAMMA * R (psi)
= 27.80 psi

STEP 13: Determine the elephant-foot buckling stress capacity factor: Figure 7-8 is for carbon steel, for stainless steel the elephant-foot buckling stress capacity factor is determined by using the following formula:

$$\text{Capacity factor} = \left(\frac{0.6 * E_s}{R/t_s}\right)\left[1-\left(\frac{P_s R}{\sigma_y t_s}\right)^2\right]\left[1-\frac{1}{1.12 + S_1^{1.5}}\right]\left[\frac{S_1 + \sigma_y/36{,}000\text{ psi}}{S_1+1}\right]$$

= 17,676 psi

$$S_1 = \frac{R}{400\ t_s} = 1.176$$

STEP 14: Determine the fluid pressure for diamond-shape buckling (Pd):

Enter Figure 7-8 with the following parameters:

Saf = 0.42 g and H/R = 3.153

and find the pressure coefficient for diamond-shape buckling (Pd') = 3.25

The fluid pressure at the base of the vertical tank from diamond-shape buckling type loading = (Pd) = Pd' * GAMMA * R
= 23.17 psi

STEP 15: Determine the diamond-shape buckling stress capacity factor: For stainless steel use the following formula.

$$\sigma_{pd} = (0.6\gamma + \Delta\gamma)\frac{E_s}{R/t_s} = 22{,}802\text{ psi}$$

where:

$$\gamma = 1 - 0.73\left(1 - e^{-\phi}\right) = 0.455$$

$$\phi = \frac{1}{16}\sqrt{\frac{R}{t_s}} = 1.355$$

$\Delta\gamma =$ increase factor for internal pressure (from Figure 7-11 of the GIP) = 0.11

$$\frac{P_d}{E_s}\left(\frac{R}{t_s}\right)^2 = 0.183$$

STEP 16: Select the allowable buckling stress, SIGMAc, as 72% of the lower value of the elephant-foot or diamond-shape buckling Capacity Factor:

Elephant-Foot Buckling Capacity Factor = 17,676 psi CONTROLS
Diamond-Shape Buckling Capacity Factor = 22,602 psi

Allowabe buckling stress = 12,727 psi

STEP 17: Determine the overturning moment capacity (Mcap).

The overturning moment capacity of the tank, (Mcap), is dependent upon whether the postulated weak link failure mode is ductile or brittle. A ductile failure mode is defined as one in which the weak link is one of the following:

- Anchor bolt stretching (Step 7)
- Chair top plate bending (Step 8)
- Tank shell bending (Step 9)

A brittle mode of failure is defined as one in which the weak link is one of the following:

- Concrete cone failure (Step 7)
- Chair stiffener plate shear or buckling failure (Step 10)
- Chair-to-tank wall weld shear failure (Step 11)

For DUCTILE failure, enter Figure 7-12 with the following parameters and find the base overturning moment coefficient (Mcap') = 0.19

F (b or r) = 25,046 psi h b = 90.00 h c = 36.00 inches

Allowable Buckling Stress = 12,727 psi

c' = 0.10 ((Allowable Buckling Stress)/(Fb))* (h c / h b) = 0.203

For BRITTLE failure, enter Table 7-4 with the following parameter and find the base overturning moment coefficient (Mcap') = N/A

c' = 0.10 and ((Allowable Buckling Stress)/(Fb))* (h c / h b) = 0.203

Per Steps 7 to 10, the expected failure mode is DUCTILE

Use (Mcap) value = 0.19 for DUCTILE failure.

Compute (Mcap) based on the following formula:

Mcap = (Mcap') * (2 * Fb) * (R^2 * te) * (h b / h c)
= 392,712,258 lb-inches

STEP 18: Compare the overturning moment capacity of the tank (Mcap) from Step 17 with the overturnig moment (M) from Step 6.

Mcap = 392,712,258 lb-in > M = 263,903,102 lb-in

The tank is seismically adequate for this loading.
0

STEP 19: Compute the base shear load capacity (Qcap) of the tank

Qcap = .55 * (1 - 0.21 * Saf) * W
= 1,388,045 lbs

STEP 20: Compare the base shear load capacity of the tank (Qcap) from Step 19 with the shear load (Q) from Step 5.

Qcap = 1,388,045 lbs > Q = 854,433 lbs

Shear capacity exceeds demand. The tank is adequate for this loading.

STEP 21: Compare the freeboard clearance to the slosh height to ensure that the roof is not subjected to significant forces from the sloshing liquid.

In calculating the slosh height, (h s), the spectral acceleration, (Saf), must be obtained from the input demand spectrum at the sloshing mode frequency, (Fs), and a damping value of 1/2%. Care should be exercised in assuring that the spectrum values are accurately defined in the sloshing mode frequency range, typically for 0.5 Hz to 0.2 Hz.

Fs = (1 / (2 * PI)) * (SQRT ((1.84 * g) / R) * tanh ((1.84 * H) / R))
= 0.30 Hz

Spectral acceleration, (Saf), from 1/2% damped input responce spectrum at the sloshing mode frequency (Fs): NOT CLEARLY DEFINED

Slosh height = h s = 0.837 * R * Sas
= N/A inches

Alternatively, if the spectrum values (Saf) are not well defined in the range of the sloshing mode frequency (Fs) determine the slosh height by entering Table 7-5 with the following parameters to find the slosh height, (h's), of the fluid in the tank for a ZPA of 1g at the base of the tank:

H / R = 3.15 and R = 198 inches

to find (h's) = 85.13

Compute the slosh height (h s), : h s = h's * ZPA = 10.22 inches

where ZPA is from horizontal response spectrum = 0.12 g

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STEP 22: Determine the available freeboard above the fluid surface at the maximum level to which the tank will be filled:

For conical roofs, measure the freeboard from the fluid surface to the intersection of the wall and the roof (a distance R from the tank centerline).

For tanks with a domed roof, measure the freeboard from the fluid surface to the point where the roof surface is at a distance of 0.8R from the tank centerline.

h f = 45.96 inches

Compare the available freeboard (h f) to the slosh height of the fluid (h s), from Step 21.

h f = 45.96 inches > h s = 10.22 inches

Available freeboard exceeds expected slosh height. This tank is adequate for this condition.

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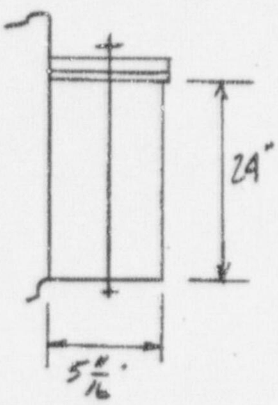
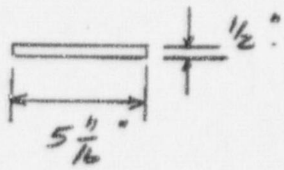
- Per Step 10 the vertical stiffener plates for the anchor bolt chairs are classified as outliers. Check actual compressive stress:





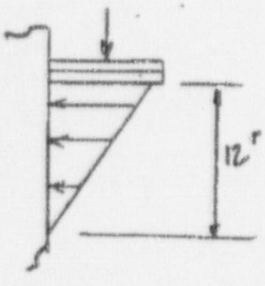
$$I_x = \frac{(5\frac{11}{16})(\frac{1}{2})^3}{12} = 0.059\,in^4$$

$$I_y = \frac{\frac{1}{2}(5\frac{11}{16})^3}{12} = 7.66\,in^4$$

$$A = \tfrac{1}{2}(5\tfrac{11}{16}") = 2.84\,in^2$$

$$r = \sqrt{\frac{I}{A}} = \sqrt{\frac{.059}{2.84}} = 0.144\,in$$

- The load is applied to the stiffener plates by the anchor bolt. The load distribution is not linear along the length of the plate but is distributed along the upper 1/2 of the plate. The lower 1/2 of the plate will see little to no loading as the top cap plate is not wide enough to distribute the load down to it.



Use a value of 1.0 = K to determine the allowable compressive stress: (Edge to tank and to plate are welded)

$$\frac{Kl}{r} = \frac{1.0(12)}{.144} = 83$$

GPU Nuclear

Calculation Sheet

Subject	Calc No.	Rev. No.	Sheet No.
DH-T-0001	DH-T-0001	0	A16 of 16

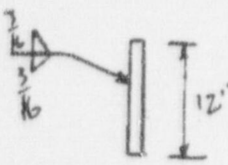
Originator	Date	Reviewed by	Date
S.D. Augustine	12-3-93	[illegible]	12-8-93

From Table 3-36, Ref 11, find $F_a = 14.9^{ksi}$

From Step 10 find actual compressive stress = 13.8^{ksi}

$13.8^{ksi} \le 14.9^{ksi}$ } PL OK, Outlier Resolved

Check weld of stiffener plate to tank:



Allowable load = $(\frac{3}{16}")(.707)(2\text{ welds})(30.6^{ksi})(12"\text{ long})$

$= 97^{k}$ (per plate)

Weld OK by judgement

NOTE: The anchor bolts are not exactly equally spread around the tank base. They vary by 1 to 2 degrees. This spacing is judged to be adequate.

CONCLUSION: The tank and its anchorage are seismically adequate.

05-14-97 15:39:04

166435

GPU NUCLEAR

B/A No. 128108

W/O No. 95-552A-52108

SEISMIC QUALIFICATION

No. SQ - T1 - DH-T-0001

REVISION 0

COMPONENT: DH-T-0001

SUBCOMPONENT(S): ______

Sheet 1 of 19

EVALUATED BY: R. D. Augustine DATE 10-6-93

EVALUATED BY: [signature] DATE 12-8-93

9706040078 19pp

Status Y N U

SCREENING EVALUATION WORK SHEET (SEWS) Sheet 1 of 2

Equip. ID No. DH-T-0001 Equip. Class 21 - Tanks and Heat Exchangers

Equipment Description BWST

Location: Bldg. YD Floor El. 305 Room, Row/Col W RB HATCH

Manufacturer, Model, Etc. (optional)

SHELL CAPACITY VS DEMAND

Buckling capacity of shell of large, flat-bottom, vertical tank is equal to or greater than demand: Attach A — (Y) N U N/A

ANCHOR BOLTS AND EMBEDMENT

Capacity of anchor bolts and their embedments is equal to or greater than demand: Attach A — (Y) N U N/A

CONNECTION BETWEEN ANCHOR BOLTS AND SHELL

Capacity of connections between the anchor bolts and the tank shell is equal to or greater than the demand: Attach A — (Y) N U N/A

FLEXIBILITY OF ATTACHED PIPING

Attached piping has adequate flexibility to accommodate motion of large, flat-bottom, vertical tank: (Y) N U N/A

TANK FOUNDATION

Ring-type foundation is not used to support large, flat-bottom, vertical tank: (Y) N U N/A

IS EQUIPMENT SEISMICALLY ADEQUATE? (Y) N U

SCREENING EVALUATION WORK SHEET (SEWS) Sheet 2 of 2

Equip. ID No. DH-T-0001 Equip. Class 21 - Tanks and Heat Exchangers

Equipment Description BWST

COMMENTS

NONE

Evaluated by: R. D. Augustine Date: 10-6-93

[signature] 12-8-93

GPU Nuclear

Calculation Sheet

Subject		Calc No.	Rev. No.	Sheet No.
DH-T-001		DH-T-001	0	A1 of 16
Originator: G. D. Augustine	Date: 12-3-93	Reviewed by:		Date: 12-8-93

Purpose The purpose of this calculation is to seismically verify the tank and its anchorage.

Methodology The methodology to be used in this calculation is that detailed in the Generic Implenentation Procedure (GIP).

References

1. ES-022, Seismic Design Criteria
2. Generic Implenentation Procedure (GIP) for the Seismic Verification of Nuclear Plant Equipment, Rev.2.
3. Gilbet Associates Drawing No. S-423-039 Rev. 2.
4. Gilbet Associates Drawing No. E-435-201 Rev. 6
5. Pittsburgh Des Moines Steel Company Drawing No. E2, Reference No. 4692-27-1032.
6. Pittsburgh Des Moines Steel Company Drawing No. E1, Babcock & Wilcox Drawing No. 620-0005, 6-44 028 01.
7. Pittsburgh Des Moines Steel Company Drawing No. E5, Babcock & Wilcox Drawing No. 620-0005, 36-44 023 01.
8. Gilbet Associates Bill of Material TMI-RA, Sheet No. 31-2.
9. EQE Report No. 42105-R-001.
10. "Handbook of Tables for Applied Engineering Science", 2nd Edition, Bolz & Tuve.
11. AISC Manual of Steel Construction, 8th Edition.
12. EPRI Report NP-5228-SL, "Seismic Verification of Nuclear Plant Equipment Anchorage", Volume 1, Rev. 1.
13. ACI 349.

GPU Nuclear

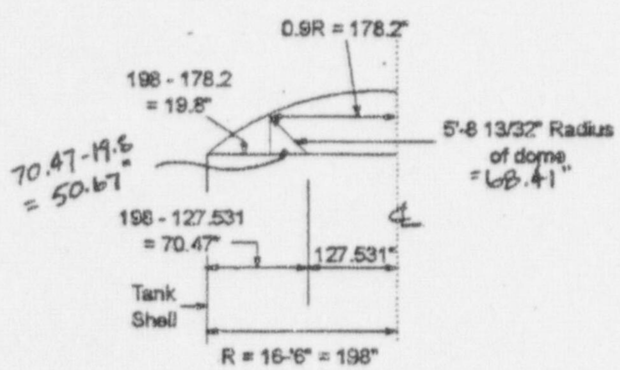
Calculation Sheet

Subject	Calc No.	Rev. No.	Sheet No.
DH-T-001	DH-T-001	0	A2 of 16
Originator / **Date**	**Reviewed by**		**Date**
G.D. Augustine / 12-3-93	[signature]		12-8-93

CALCULATIONS

- Per Reference 8 the tank is constructed of ASTM A240 Type 304 stainless steel. Per Reference 10, Table 1-57, page 104, the yield strength of Type 304 stainless steel is 35 ksi. Per Reference 10, page 117, the modulus of elasticity is 28×10^6 psi.

- Determine the height of freeboard clearance between the liquid surface and the tank roof in accordance with Section 7.3.5 of Reference 2. For tanks with domed roofs, measure the freeboard from the fluid surface to the point where the roof surface is at a distance of 0.9R from the tank centerline.

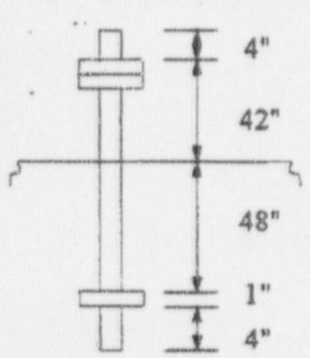


The diagram and dimensions are from Reference 7, Sketch A.

$$\text{freeboard} = \sqrt{68.41^2 - 50.67^2} = 45.96"$$

- Assume height of fluid at maximum fill level = 52'-0 1/4" = 624.25"

- From Reference 4 find the tank is anchored with (39) type TB-1 and (1) type TB-5 anchor bolts. Per Reference 3 find the following dimensions:



$h_b = 42" + 48" = 90"$

GPU Nuclear

Calculation Sheet

Subject		Calc No.	Rev. No.	Sheet No.
DH-7-0001		DH-7-0001	0	A3 of 16
Originator	Date	Reviewed by		Date
R.D. Augustino	12-3-93	[signature]		12-8-93

- Determine allowable shear and tension loads for a 2" diameter cast-in-place anchor bolt in accordance with the guidelines of Reference 12. Note that this is the reference material for the derivation of the allowable loads for cast-in-place anchor bolts in the GIP. The values just were not derived for 2" diameter bolts.

The allowable tension and shear loads are based on the nominal bolt area times allowable shear and tension stresses. These allowable stresses (17,000 psi shear and 34,000 psi tension for A307 bolt material) are equal to 1.7 times the working stress design allowable given in Part 1 of the AISC specification for Design, Fabrication, and Erection of Structural Steel for Buildings, Reference 11.

Per Reference 11, the tensile stress area for a 2" diameter bolt = 2.50 in^2 and the minimum root area = 2.34 in^2.

P_t = 2.5 (34,000 psi) = 85,000 lbs. (conservative as tensile stress area < nominal bolt area).

P_v = 2.34 (17,000 psi) = 39,780 lbs. (conservative as minimum root area < nominal bolt area).

<u>Determine Minimum Embedment, Spacing, and Edge Distance</u>

The recommended minimum embedment lengths are developed by applying the concrete shear-cone theory put forth in Appendix B of the ACI Standard 349 (Reference 13), and assuring ductile failure mode in bolt material rather than brittle failure associated with pulling of concrete cone. The ACI concrete shear-cone theory gives the pullout strength of concrete P, as:

$$P = 4\phi\sqrt{f_c'}\,\pi(L + D)L$$

where:

ϕ = a capacity reduction factor = 0.65

f_c' = concrete compressive strength = 3,500 psi

D = diameter of bolt or stud (in.)

L = embedment length of bolt or stud (in.)

To determine the embedment lengths required by the GIP, the above equation was solved by setting P equal to twice the pullout capacity value given as P_t. Solving the equation for L in terms of bolt diameter for f_c' = 3,500 psi. yields a required embedment length of 10D. Thus for a 2" diameter bolt, the embedment length must be a minimum of 20". Page 2-77 states that the minimum spacing and edge distance requirements are 12.5D and 8.75D respectively. This equates to 25" spacing and 17.5" edge distance requirements.

GPU Nuclear

Calculation Sheet

Subject		Calc No.	Rev. No.	Sheet No.
DH-T-0001		DH-T-0001		A4 of 16
Originator	Date	Reviewed by		Date
R.D. Augustino	12-3-93	[signature]		12-8-93

CAPACITY REDUCTION FACTORS FOR CAST-IN-PLACE BOLTS WITH NUTS OR HEADED STUDS

BORATED WATER STORAGE TANK

Bolt Dia. (D)inches:	2.000	Concrete Strength f'c (psi) =	3,000
Required Edge Dist. (Emin) inches:	17.5	Actual Edge Dist. (E) inches:	18
Required Embedment (Lmin) inches:	20	Actual Embedment (L) inches:	48
Required Spacing (Smin) inches:	25	Actual Spacing (S) inches:	29.8

Note: If actual embedment,spacing, or edge distance exceeds minimum required, use minimum values for calculation of reduction factors.

L = 20 inches S = 25 inches E = 17.5 inches

THETA (edge dist.) = 2 cos-1 (2E/(2L+D)) = 1.17 rad

r = (2L+D)/2 = 21

THETA (spacing) = 2 cos-1 (S/(2L+D)) = 1.87 rad

- **Edge Distance Check**

E = 18.0 >= Emin, no pullout reduction factor required.

E = 18.0 >= 8.75D, no shear reduction factor required.

- **Concrete Strength Check**

GIP Table C.3-1 allowables are based on a concrete strength = f'c = 3500 psi.

Concrete strength < 3,500 psi but >= 2,500 psi. Strength reduction factor required.

Reduction factor (RFp) = (RFs) = SQRT (f'c / 3500) = 0.93

- **Embedment Check:** 10 * D = 20.00 4 * D = 8.00

L >= 10D, no reduction factor required.

Subject		Calc No.	Rev. No.	Sheet No.
DH-T-001		DH-T-0001	0	A5 of 16
Originator	Date	Reviewed by		Date
R.D. Augustine	12-3-93	[signature]		12-8-93

- **Spacing Check** 2 * D = 4.00

Actual spacing equals or exceeds required spacing, no pullout reduction factor required.

Shear capacity reduction factor for closely spaced cast-in-place anchor bolts = RSs:

RSs = 1.00 for actual spacing (S) >= 2 * D

- **Revised Allowable Loads**

From Table C.3-1 of the GIP, the subject bolt has the following full allowable loads:

For D = 2.000 inches, the allowable pullout capacity (Pu') = 85,000 lbs. and the allowable shear capacity (Vu') = 39,780 lbs.

The revised pullout load = Pu = Pu' * REp * RFp * RLp * RSp

= 78,695 lbs.

The revised shear load = Vu = Vu' * REs * RFs * RLs * RSs

= 36,829 lbs.

GPU Nuclear

Calculation Sheet

Subject	Calc No.	Rev. No.	Sheet No.
DH-T-001	DH-T-001	0	A6 of 16

Originator	Date	Reviewed by	Date
R. D. Augustine	12-3-93	[illegible]	12-8-93

VERTICAL TANKS -- BORATED WATER STORAGE TANK

STEP 1: Determine the following input data :

Note tank is stainless steel.

TANK MATERIAL

diameter of tank (ft): 33

R (nominal tank radius) (inches): 198

(height of tank shell) (ft): 52

H' (height of tank shell) (inches): 624

t min (minimum shell thickness along height of tank) (inches): 0.25

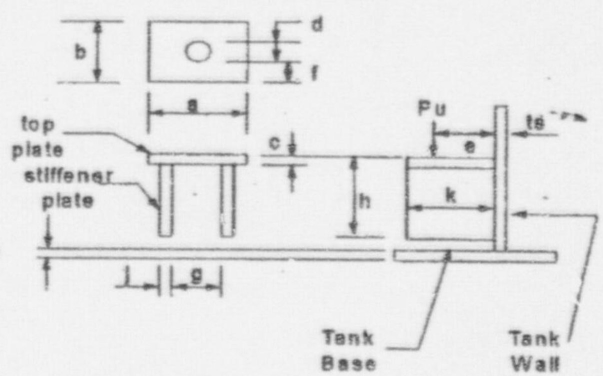
t s (minimum thickness of tank in the lowest 10% of height) (inches): 0.421

F y (yield strength of tank shell mat'l) (psi): 35,000

h c (height of shell compression zone at base of tank, usually height of chair) (inches): 36.00

E s (elastic modulus of tank shell mat'l) (psi): 28,000,000

Vs (average shear wave velocity of soil for tanks located at grade) (ft/sec): N/A



FLUID

GAMMA (weight density of fluid) (lb/in3): 0.036

H (height of fluid at maximum fill level) (inches): 524.25

h f (height of freeboard above fluid surface) (inches): 45.96

ANCHOR BOLTS

N (number of bolts): 40

d (diameter of bolt) (inches): 2

h b (eff. length of anchor bolt being stretched, usually from top of chair to embedded plate) (in.): 90

E b (elastic modulus of bolt material) (psi): 30,000,000

Anchor Bolt Allowable Tension Load (Pu) (lbs): 78,695

Anchor Bolt Allowable Shear Load (Vu) (lbs): 38,829

(Note: Allowables are with reduction factors applied)

Yield stress of anchor bolt material (f y) (psi): 36,000

From Figure 7-6 of the GIP, find the following dimensions (inches):

d =	2	j =	0.5	t b =	0.25
f =	1.25	g =	5.5	k =	5.0875
b =	8	c =	2	e =	2.75
a =	6.5	h =	24	t s =	0.421

Weld size between anchor chair and tank shell (t w) (inches): 0.1875

LOADING

Ground response spectrum at 4% damping for overturning moment and shear loadings on tanks and at 1/2% damping for fluid slosh height.

Ground response spectrum ZPA = 0.12 g

GPU Nuclear — Calculation Sheet

Subject	Calc No.	Rev. No.	Sheet No.
DH-T-001	DH-T-0001	0	47 of 16
Originator: J.D. Augustini	Date: 12-3-93	Reviewed by: [illegible]	Date: 12-8-93

STEP 2: Calculate the following ratios and values:

H/R = 3.153   ts/R = 0.002

t avg = thickness of tank shell averaged over the linear height of the tank shell
= (SUM t i * h i) / H'
= 0.308 inches

i	t	h	t x h
1	0.25	104	26
2	0.25	104	26
3	0.25	104	26
4	0.301	104	31.304
5	0.375	[illegible]	39
6	0.421	104	43.784
			192.088 = SUM t x h

t eff = (t avg + t min) / 2
= 0.28 in

(t eff)/R = 0.001

Ab = Cross-sectional area of embedded anchor bolt
= (PI x d^2) / 4
= 3.142 in^2

t' = equivalent shell thickness having the same cross-sectional area as the anchor bolts
= ((N * Ab) / (2 * PI * R)) * (Eb / Es)
= 0.1082

c' = coefficient of tank wall thicknesses and lengths under stress
= (t' / ts) * (hc / hb)
= 0.10

W = weight of fluid in tank
= PI * R^2 *H * GAMMA
= 2,767,842 lbs

CHECK TABLE 7-1 REQUIREMENTS

Tank Material = Carbon, Stainless Steel, Aluminum (circle one)

Tank Fluid Content = Water or similar YES or NO (circle yes or no), If no tank is an OUTLIER

Nominal Radius of Tank R =	198	inches	OK, Table 7-1 requirements met, 60 in >R <420 in
Height of Tank Shell (H') =	624	inches	OK, Table 7-1 requirements met, 120 in >H <960 in
Height of Fluid at the maximum Level to which the tank will be filled (H) =	624.25	inches	OK, Table 7-1 requirements met, 120 in >H <960 in
Minimum Thickness (t s) of the Tank Shell in the lowest 10% of the Shell Height =	0.421	inches	OK, Table 7-1 requirements met, 3/16 in >t s<1 in
Effective Thickness (t eff) of Tank Shell Based on the mean of the Average Thickness (t avg) =	0.279	inches	OK, Table 7-1 requirements met, 3/16 in >t s<1 in
Diameter of Anchor Bolt (d) =	2.000	inches	OK, Table 7-1 requirements met, 1/2 in > d <2 in
Number of Anchor Bolts (N) =	40		OK, Table 7-1 requirements met, N > = 8
Tank Wall Thickness (at Base)-to-Tank radius Ratio = (t s/R) =	0.002		OK, Table 7-1 requirements are met, .001 <= t s / R <=.01
Effective Tank Wall Thickness-to-Tank Radius ratio = (t eff/R) =	0.001		OK, Table 7-1 requirements met. .001 <= t eff < .01 inches.
H/R =	3.15		OK, Table 7.1 requirements met, 1 >H/R <5

STEP 3: Determine the fluid-structure modal frequency for vertical carbon steel tanks containing water:

R = 198 t eff / R = 0.001 , and H / R 3.163

From Table 7-3, find (F f) = 4.01 Hz.

NOTE: If the tank material is not carbon steel (Es not equal to 30,000 ksi) or fluid is not water (GAMMA not equal to 62.4 lbs/ft3) the frequency must be adjusted in accordance with the GIP STEP 3 as done below.

F f (s,f) = F f (SQRT (E s / 30,000,000) = 3.87 Hz

STEP 4: Determine the spectral acceleration (Saf) for the fluid-structure modal frequency.

Enter the 4% damped horizontal ground or floor response spectrum for the surface on which the tank is mounted, with the fluid-structure modal frequency determined in STEP 3. and determine the maximum spectral acceleration (Saf) over the following frequency range:

.8*Ff < F < 1.2 * Ff = 3.10 Hz < F < 4.81 Hz

Appropriate Spectral Acceleration (Saf) = 0.42 g 4% damping

STEP 5: Determine the base shear load (Q).

Enter Figure 7-3 with (H/R) and (t eff/R) from above:

H/R = 3.153 and (t eff)/R = 0.001

And find base shear load coefficient (Q') = 0.735

Shear Load at Bottom of Tank = (Q) = Q' * W * Saf = 854,433 lbs

STEP 6: Determine the base overturning moment (M)

Enter Figure 7-4 with H/R = 3.153 and (t eff)/R = 0.001

And find M' = 0.405

Compute overturning moment = M = M' * W * H * Saf
= 283,903,102 lb-in

STEP 7: From the anchor bolt tensile load capacity, Pu, compute the allowable bolt stress (Fb):

Fb = Pu / Ab
= 25,046

Note: If the Section 4 and Appendix C criteria are not met for the anchorage, then the concrete is considered the weak link in the load path and the postulated failure mode is brittle. Determine an appropriate reduced allowable anchor bolt stress (Fr) per applicable code requirements.

STEP 8: Check the bending stress in the top plate of the chair. If each of the anchorage connection components meets the acceptance criteria defined below, then the bolt tensile capacity determined in STEP 7 is limiting. If, however, any of the components does not meet these guidelines, the reduced anchor bolt tension capacity represented by the equivalent value of anchor bolt allowable stress (Fr), as calculated here should be used. Note that if the top plate projects radially beyond the vertical plates, no more than 1/2 inch of this projecting plate can be included in the dimension f used in the following equation.

The maximum bending stress in the top plate is:

SIGMA = ((0.375 * g) - (0.22 * d)) * Pu / (f * c ^ 2)
= 25,537 < f y, Stress less than yield, top plate OK

Allowable anchor bolt stress (Fb) from Step 7 = 25,046 lbs

STEP 9: Check Tank Shell Stress

Shell Stress = 22,086 psi < F y. Shell Stress is OK

Z = 1 / (((0.177 * a * tb * (tb / ts) ^ 2) / (SQRT (R * ts))) + 1)
= 0.869

Allowable Anchor Bolt Stress = Fb = 25,046 lbs

STEP 10: The vertical stiffener plates are considered adequate if they satisfy the following guidelines:

1) (k / j) < (95 / ((f y / 1000) ^ 0.5))

k / j =	11.38	Guideline No. 1 Satisfied
95 / (((f y / 1000) ^ 0.5)) =	16.06	

2) j >= 0.04 * (h - c) and j >= 0.5 in.

j =	0.50	Guideline No. 2 is an OUTLIER
0.04 * (h - c) =	0.86	

3) (Pu / (2 * k * j)) < 21,000 psi

Pu/(2 * k * j) =	13,836	Guideline No. 3 is Satisfied

STEP 11: Check weld between the tank chair and the tank.

Load per linear inch of weld = Ww
= Pu *((1 / (a + 2 * h))^2 + (a / (a * h + 0.667 * h ^ 2)^2)^.5
= 1,498 lbs/inch

Allowable load per inch = (30,600 * t w) / SQRT(2)
= 4,057 lbs/inch

Weld is adequate

STEP 12: Check tank wall for elephant's foot buckling:

Enter Figure 7-7 with the following parameters: Sef = 0.42 and H/R = 3.15

and find the fluid pressure coefficient (Pe') = 3.9

The fluid pressure at the base of the vertical tank from elephant-foot buckling type loading = (Pe) = Pe' * GAMMA * R (psi)
= 27.80 psi

STEP 13: Determine the elephant-foot buckling stress capacity factor: Figure 7-8 is for carbon steel, for stainless steel the elephant-foot buckling stress capacity factor is determined by using the following formula:

$$\text{Capacity factor} = \left(\frac{0.6 * E_s}{R/t_s}\right)\left[1-\left(\frac{P_e R}{\sigma_y t_s}\right)^2\right]\left[1-\frac{1}{1.12 + S_1^{1.5}}\right]\left[\frac{S_1 + \sigma_y/36{,}000 \text{ psi}}{S_1 + 1}\right]$$

= 17,676 psi

$$S_1 = \frac{R}{400\ t_s} = 1.176$$

STEP 14: Determine the fluid pressure for diamond-shape buckling (Pd):

Enter Figure 7-9 with the following parameters:

Saf = 0.42 g and H/R = 3.153

and find the pressure coefficient for diamond-shape buckling (Pd') = 3.25

The fluid pressure at the base of the vertical tank from diamond-shape buckling type loading = (Pd) = Pd' * GAMMA * R = 23.17 psi

STEP 15: Determine the diamond-shape buckling stress capacity factor: For stainless steel use the following formula.

$$\sigma_{pl} = (0.6\gamma + \Delta\gamma)\frac{E_s}{R/t_s} = 22{,}802 \text{ psi}$$

where:

$$\gamma = 1 - 0.73\left(1 - e^{-\phi}\right) = 0.455$$

$$\phi = \frac{1}{16}\sqrt{\frac{R}{t_s}} = 1.355$$

$\Delta\gamma$ = Increase factor for internal pressure (from Figure 7-11 of the GIP) = 0.11

$$\frac{P_d}{E_s}\left(\frac{R}{t_s}\right)^2 = 0.183$$

STEP 16: Select the allowable buckling stress, SIGMAc, as 72% of the lower value of the elephant-foot or diamond-shape buckling Capacity Factor:

Elephant-Foot Buckling Capacity Factor = 17,676 psi CONTROLS
Diamond-Shape Buckling Capacity Factor = 22,802 psi

Allowabe buckling stress = 12,727 psi

STEP 17: Determine the overturning moment capacity (Mcap).

The overturning moment capacity of the tank, (Mcap), is dependent upon whether the postulated weak link failure mode is ductile or brittle. A ductile failure mode is defined as one in which the weak link is one of the following:

- Anchor bolt stretching (Step 7)
- Chair top plate bending (Step 8)
- Tank shell bending (Step 9)

A brittle mode of failure is defined as one in which the weak link is one of the following:

- Concrete cone failure (Step 7)
- Chair stiffener plate shear or buckling failure (Step 10)
- Chair-to-tank wall weld shear failure (Step 11)

For DUCTILE failure, enter Figure 7-12 with the following parameters and find the base overturning moment coefficient (Mcap') = 0.19

F (b or r) = 25,04 psi   h b = 90.00   h c = 36.00 inches

Allowable Buckling Stress = 12,727 psi

c' = 0,10   ((Allowable Buckling Stress)/(Fb))* (h c / h b) = 0.203

For BRITTLE failure, enter Table 7-4 with the following parameter and find the base overturning moment coefficient (Mcap') = N/A

c' = 0.10 and ((Allowable Buckling Stress)/(Fb))* (h c / h b) = 0.203

Per Steps 7 to 10, the expected failure mode is DUCTILE

Use (Mcap) value = 0.19 for DUCTILE failure.

Compute (Mcap) based on the following formula:

Mcap = (Mcap') * (2 * Fb) * (R^2 * te) * (hb / hc)
= 392,712,258 lb-inches

STEP 18: Compare the overturning moment capacity of the tank (Mcap) from Step 17 with the overturnig moment (M) from Step 6.

Mcap = 392,712,258 lb-in > M = 283,903,102 lb-in

The tank is seismically adequate for this loading.
0

STEP 19: Compute the base shear load capacity (Qcap) of the tank

Qcap = .55 * (1 - 0.21 * Saf) * W
= 1,388,045 lbs

STEP 20: Compare the base shear load capacity of the tank (Qcap) from Step 19 with the shear load (Q) from Step 5.

Qcap = 1,388,045 lbs > Q = 864,433 lbs

Shear capacity exceeds demand. The tank is adequate for this loading.

STEP 21: Compare the freeboard clearance to the slosh height to ensure that the roof is not subjected to significant forces from the sloshing liquid.

In calculating the slosh height, (h s), the spectral acceleration, (Saf), must be obtained from the input demand spectrum at the sloshing mode frequency, (Fs), and a damping value of 1/2%. Care should be exercised in assuring that the spectrum values are accurately defined in the sloshing mode frequency range, typically for 0.5 Hz to 0.2 Hz.

Fs = (1 / (2 * PI)) * (SQRT ((1.84 * g) / R) * tanh ((1.84 * H) / R))
= 0.30 Hz

Spectral acceleration, (Saf), from 1/2% damped input response spectrum at the sloshing mode frequency (Fs): NOT CLEARLY DEFINED

Slosh height = h s = 0.837 * R * Sas
= N/A inches

Alternatively, if the spectrum values (Saf) are not well defined in the range of the sloshing mode frequency (Fs) determine the slosh height by entering Table 7-5 with the following parameters to find the slosh height, (h's), of the fluid in the tank for a ZPA of 1g at the base of the tank:

H / R = 3.15 and R = 198 inches

to find (h's) = 85.13

Compute the slosh height (h s), : h s = h's * ZPA = 10.22 inches

where ZPA is from horizontal response spectrum = 0.12 g

GPU Nuclear — Calculation Sheet

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E.D. Augustine	12-3-93	[illegible]	12-8-93

STEP 22: Determine the available freeboard above the fluid surface at the maximum level to which the tank will be filled:

For conical roofs, measure the freeboard from the fluid surfaces to the intersection of the wall and the roof (a distance R from the tank centerline).

For tanks with a domed roof, measure the freeboard from the fluid surface to the point where the roof surface is at a distance of 0.8R from the tank centerline.

h f = 45.86 inches

Compare the available freeboard (h f) to the slosh height of the fluid (h s), from Step 21.

h f = 45.86 inches > h s = 10.22 inches

Available freeboard exceeds expected slosh height. This tank is adequate for this condition.

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Calculation Sheet

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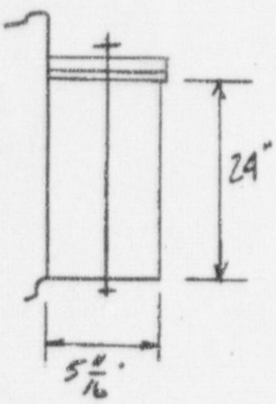
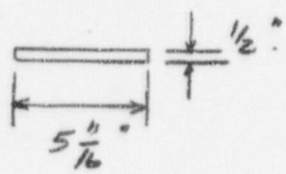
Originator	Date	Reviewed by	Date
R.D. Augustine	12-3-93	[signature]	12-8-93

- Per Step 10 the vertical stiffener plates for the anchor bolt chairs are classified as outliers. Check actual compressive stress:





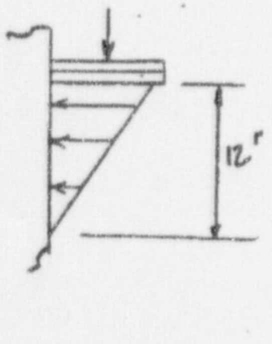
$$I_x = \frac{(5\frac{11}{16})(\frac{1}{2})^3}{12} = 0.059\,in^4$$

$$I_y = \frac{\frac{1}{2}(5\frac{11}{16})^3}{12} = 7.66\,in^4$$

$$A = \tfrac{1}{2}(5\tfrac{11}{16}") = 2.84\,in^2$$

$$r = \sqrt{\frac{I}{A}} = \sqrt{\frac{.059}{2.84}} = 0.144\,in$$

- The load is applied to the stiffener plates by the anchor bolt. The load distribution is not linear along the length of the plate but is distributed along the upper 1/2 of the plate. The lower 1/2 of the plate will see little to no loading as the top cap plate is not wide enough to distribute the load down to it.



Use a value of 1.0 = K to determine the allowable compressive stress: (Edge to tank and to plate are welded)

$$\frac{K\ell}{r} = \frac{1.0(12)}{.144} = 83$$

GPU Nuclear

Calculation Sheet

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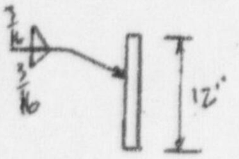
Originator S.D. Augustin	**Date** 12-3-93	**Reviewed by** [illegible]	**Date** 12-8-93

From Table 3-36, Ref 11, find $F_a = 14.9^{ksi}$

From Step 10 find actual compressive stress = 13.8^{ksi}

$13.8^{ksi} \leq 14.9^{ksi}$ } PL OK, Outlier Resolved

Check weld of stiffener plate to tank:



Allowable load = $(\frac{3}{16}")(.707)(2\text{ welds})(30.6^{ksi})(12"\text{ long})$

$= 97^k$ (per plate)

Weld OK by judgement

NOTE: The anchor bolts are not exactly equally spread around the tank base. They vary by 1 to 2 degrees. This spacing is judged to be adequate.

CONCLUSION: The tank and its anchorage are seismically adequate.