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GPU NUCLEAR

B/A No. 128108

W/O No. 95-552A-52108

SEISMIC QUALIFICATION

No. SQ - T1-CO-T-0001A

REVISION 0

COMPONENT: CO-T-0001A

SUBCOMPONENT(S): ____________________

____________________

____________________

Sheet 1 of 27

FOR RICK AUGUSTINE TELECON 2/8/94

EVALUATED BY: [signature] DATE 2/8/94

EVALUATED BY: [signature] DATE 2-8-94

# SQUG DATA FILE INDEX



**COMPONENT TAG NUMBER** CO-T-0001A

DESCRIPTION CONDENSATE STORAGE TANK A

▸ **DOCUMENTS** — **NUMBERS/STATUS**

| | | |
|---|---|---|
| SEWS | | ✓ |
| GMS-2 (TECHNICAL FUNCTIONS DATA SURVEY) | | ✓ |
| PHYSICAL DRAWING/ASSEMBLY DRAWING | 1, 69-4476U (00485) | ✓ |
| VENDOR CATALOG/DATA/INSTRUCTION MANUAL | | — |
| INSTALLATION SPECIFICATION | | — |
| SEISMIC ANALYSIS/TEST REPORTS/CALCS | C 1101X-322C-A26 | ✓ |
| CONCRETE OR PAD DRAWINGS, SPECS, BLOCK WALLS | 435-201 | ✓ |
| EMBEDDED STEEL DRAWINGS | | — |
| ANCHORAGE DRAWING/DETAILS/AIDS | 423-039 | ✓ |
| FIELD CHANGE DOCS/MNCR'S | | |

OTHER 1a, 694476U (00485) shts 1,2,3,4,6,7,8,9 & 10
015-012

RL 5/11/93
signature

▸ **GENERIC ISSUES**

___ POTENTIAL OUTLIER

___ BASE PLATE PLUG WELDS

___ OTHERS

▸ **DISPOSITION**

___ NEED MORE DATA

___ KNOWN OUTLIER

___ SEISMIC DATA ACCEPTABLE, CONFIMATION WALKDOWN ONLY

ANCHORAGE CALCULATIONS: ___ EXIST ___ PERFORM IN FIELD

COMMENTS All info. available for tank evaluation.

✓ READY FOR SQUG WALKDOWN

[signature]
Seismic Capacity Engineer (SCE)



– Use reverse side for COMMENTS.

Status Y N U

SCREENING EVALUATION WORK SHEET (SEWS) Sheet 1 of 2

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

Equipment Description CONDENSATE STORAGE TANK 1A

Location: Bldg. YD Floor El. 305 Room, Row/Col S.E. OF TURB BLDG

Manufacturer, Model, Etc. (optional) CHICAGO BRIDGE AND IRON CO.

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

SEE ATTACHMENT A

ANCHOR BOLTS AND EMBEDMENT

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

SEE ATTACHMENT A & OUTLIER

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

SEE ATTACHMENT 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

SEE OUTLIER

SCREENING EVALUATION WORK SHEET (SEWS) Sheet 2 of 2

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

Equipment Description CONDENSATE STORAGE TANK 1A

COMMENTS

Evaluated by: R.D. Augustine Date: 1-24-94

[signature] 1-28-94

Revision 2
Corrected, 6/28/91

Sheet 1 of 2

Exhibit 5-1

OUTLIER SEISMIC VERIFICATION SHEET (OSVS)

1. OUTLIER IDENTIFICATION, DESCRIPTION, AND LOCATION

Equipment ID Number CO-T-0001A Equipment Class 21

Equipment Location: Building YD Floor Elevation 305

Room or Row/Column ___ Base Elevation 305

Equipment Description CONDENSATE STORAGE TANK 1A

2. OUTLIER ISSUE DEFINITION

a. Identify all the screening guidelines which are not met. (Check more than one if several guidelines could not be satisfied.)

| Mechanical and Electrical Equipment | | Tanks and Heat Exchangers | |
|---|---|---|---|
| Capacity vs. Demand | ___ | Shell Buckling[1] | |
| Caveats | ___ | Anchor Bolts and Embedment | X |
| Anchorage | ___ | Anchorage Connections | ___ |
| Seismic Interaction | ___ | Flexibility of Attached Piping[1] | ___ |
| Other | ___ | Other | ___ |

| Essential Relays | | Cable and Conduit Raceways | |
|---|---|---|---|
| | | Inclusion Rules | |
| Capacity vs. Demand | ___ | Other Seismic Performance Concerns | ___ |
| Mounting, Type, Location | ___ | Limited Analytical Review | ___ |
| Other | ___ | Other | ___ |

1 Shell buckling and flexibility of attached piping only apply to large, flat-bottom, vertical tanks.

b. Describe all the reasons for the outlier (i.e., if all the listed outlier issues were resolved, then the signatories would consider this item of equipment to be verified for seismic adequacy):

The tank does not meet the GIP guidelines.

Exhibit 5-1 (Cont'd)

OUTLIER SEISMIC VERIFICATION SHEET (OSVS)

Equipment ID Number CO-T-0001A

3. PROPOSED METHOD OF OUTLIER RESOLUTION (OPTIONAL)

a. Define proposed method(s) for resolving outlier.

* CALCULATION SHOWS TANK IS SEISMICALY ADEQUATE. (Attached)

b. Provide information needed to implement proposed method(s) for resolving outlier (e.g., estimate of fundamental frequency).

4. CERTIFICATION:

The information on this OSVS is, to the best of our knowledge and belief, correct and accurate, and resolution of the outlier issues listed on the previous page will satisfy the requirements for this item of equipment to be verified for seismic adequacy:

Approved by: (For Equipment Classes #0 - #22, all the Seismic Capability Engineers on the Seismic Review Team (SRT) should sign; there should be at least two on the SRT. One signatory should be a licensed professional engineer. For Relays, the Lead Relay Reviewer should sign.)

| Print or Type Name | Signature | Date |
|---|---|---|
| R.D. AUGUSTINE | R.D. Augustine | 1-24-94 |
| ENRIQUE TANG | [signature] | 1-28-94 |
| | | |

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GPU Nuclear

**Calculation Sheet**

| Subject | Calc No. | Rev. No. | Sheet No. |
|---|---|---|---|
| CO-T-0001A & 1B | CO-T-0001A & 1B | 0 | 1 of 19 |
| Originator: R.O. Augustine | Date: 1-24-94 | Reviewed by: [signature] | Date: 1-28-94 |

**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 Implementation Procedure (GIP).

**References**


1. ES-022, Seismic Design Criteria
2. Gilbert Associates Drawing No. E-435-201 Rev.6
3. Gilbert Associates Drawing No. E-423-039 Rev. 2
4. Not Used
5. Chicago Bridge and Iron Company Drawing for Dome Roof for 48'-0" diameter tank (4692-17-058-0)
6. Chicago Bridge and Iron Company Drawing for Dome Roof for Anchor Bolt Chairs for tank 48'-0" x 20'-0" tall. (4692-17-055-0)
7. Generic Implementation Procedure (GIP) for the Seismic Verification of Nuclear Plant Equipment, Rev.2
8. EQE Report No. 42105-R-001
9. EPRI Report NP-6041, "A Methodology for Assessment of Nuclear Plant Seismic Margin: Final Report dated October 1988."
10. EPRI Report NP-5228-SL, "Seismic Verification of Nuclear Plant Equipment Anchorage", Volume 4
11. EPRI Report NP-5228-SL, "Seismic Verification of Nuclear Plant Equipment Anchorage", Volume 1
12. NUREG-CR-1161, "Recommended Revisions to Nuclear Regulatory Commission Seismic Design Criteria". Published May 1980
13. AISC Manual of Steel Construction 9th Edition
14. EQE Calculation 50097-C-010, Rev. 0, "TMI DBS Time Histories".
15. Haroun, M.A., and G.W. Housner, "Seismic Design of Liquid Storage Tanks," Journal of the Technical Councils, ASCE, April 1981.

GPU Nuclear

**Calculation Sheet**

| Subject | Calc No. | Rev. No. | Sheet No. |
|---|---|---|---|
| CO-T-0001A & 1B | CO-T-0001A & 1B | 0 | 2 of 19 |
| Originator: G.D. Augustine, Date: 1-24-94 | Reviewed by | | Date: 1-28-94 |

Determine allowable shear and tension loads for a 1-1/2" diameter cast-in-place anchor bolt in accordance with the guidelines of Reference 10. 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 1-1/2" 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 1.767 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 13, the nominal bolt area for a 1-1/2" diameter bolt = 1.767 $in^2$.

$Pt = 1.767 \cdot 34000 = 60078$ psi

$Pv = 1.767 \cdot 17000 = 30039$ psi

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:

| | | |
|---|---|---|
| a capacity reduction factor | $\phi$ := | 0.65 |
| concrete compressive strength in psi | fc := | 3500 |
| diameter of bolt or stud in inches | D := | 1.5 |
| embedment = 10D | L := | 15 |

where:

$$P := 4 \cdot \phi \cdot \sqrt{(fc)} \cdot \pi \cdot (L + D) \cdot L$$

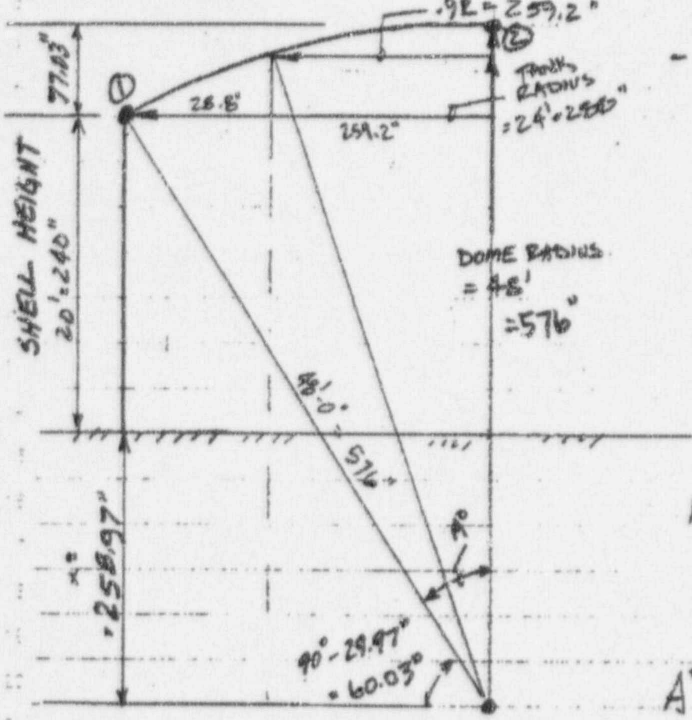
To determine the embedment lengths required by the GIP, the above equation was solved by setting P equal to twice the pullout capacity value given as $P_t$. Solving the equation for L in terms of bolt diameter for $f_c'$ = 3,500 psi yields a required embedment of 10D. Thus for a 1-1/2" diameter bolt, the embedment length must be a minimum of 15". Page 2-77 states that the minimum spacing and edge distance requirements are 12.5D and 8.75D respectively. This equates to 18-3/4" spacing and 13-1/8" edge distance requirements.

**GPU Nuclear** Calculation Sheet

| Subject | Calc No. | Rev. No. | Sheet No. |
|---|---|---|---|
| CO-T-0001A & 1B | CO-T-0001A & 1B | 0 | 3 of 19 |
| **Originator** R.D. Augustine | **Date** 1-26-94 | **Reviewed by** [signature] | **Date** 1-28-94 |

CALCULATIONS

- Determine height of freeboard above fluid surface:




- 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 0.9R from the tank ℄.

From Ref 5, the dome roof arc length from pt. ① to ② is 25'-1 5/16" =

$A° = 57.29578 \frac{\text{arc length}}{\text{radius}}$

$= 57.29578 \left( \frac{301.3125"}{48(12)} \right)$

$= 29.97°$

$x = (576 \sin 60.3) - 240$

$= 258.97'$

Freeboard $= (576^2 - 259.2^2)^{1/2} - 240 - 258.97$

$= 15.41"$

Freeboard above max. water level:

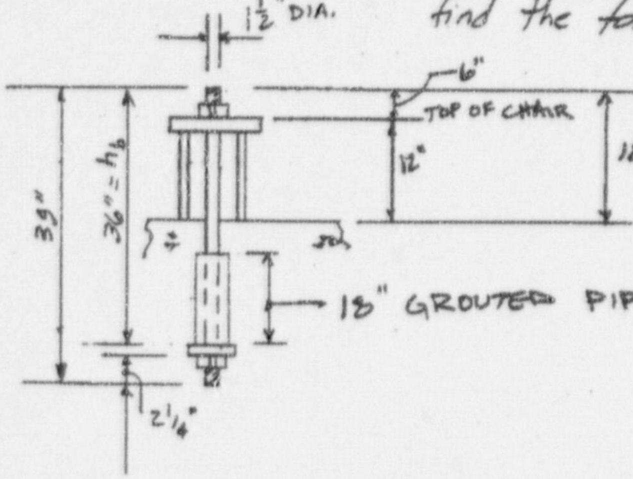
$15.41" + (20'\text{-}0" - 19'\text{-}7") = 15.82"$

**GPU Nuclear** **Calculation Sheet**

| Subject | Calc No. | Rev. No. | Sheet No. |
|---|---|---|---|
| CO-T-0001A & 1B | CO-T-0001A & 1B | 0 | 4 of 19 |

| Originator | Date | Reviewed by | Date |
|---|---|---|---|
| B.D. Augustine | 10-7-93 | [signature] | 1-28-94 |

- ANCHOR BOLTS - From Ref 2 find the anchor bolts are (16) Type TB2 bolts. From Ref 3 find the following:




The walkdown found the anchor bolts to have an edge distance = 9"

$$\text{Spacing} \Rightarrow \frac{2\pi r}{360} = \frac{x}{22.5^\circ} \Rightarrow X = \frac{2\pi(291.5)(22.5)}{360} = 114.5"$$

**GPU Nuclear** **Calculation Sheet**

| Subject | | Calc. No. | Rev. No. | Sheet No. |
|---|---|---|---|---|
| CO-T-0001A & 1B | | CO-T-0001A & 1B | 0 | 5 of 19 |
| Originator: W.D. Augustin | Date: 1-9-94 | Reviewed by: [signature] | Date: 1-28-94 | |

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

**CONDENSATE WATER STORAGE TANK**

| | | | |
|---|---|---|---|
| Bolt Dia. (D) inches: | 1.5 | Concrete Strength f'c (psi) = | 3,000 |
| Required Edge Dist. (Emin) inches: | 13.125 | Actual Edge Dist. (E) inches: | 9.00 |
| Required Embedment (Lmin) inches: | 15 | Actual Embedment (L) inches: | 18.00 |
| Required Spacing (Smin) inches: | 18.75 | Actual Spacing (S) inches: | 114.50 |

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

L = 15 inches S = 18.75 inches E = 9 inches

THETA (edge Dist.) = 2 cos-1 (2E/(2L+D))
= 1.93 radians

r = (2L+D)/2
= 15.75

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

Edge Distance Check

E = 9.0 >=4D, but not > Emin, pullout reduction factor must be applied

REp = Pullout Capacity Reduction Factor
= A(reduced)/A(nominal)

A(reduced) = (PI)( r^2)-.5((r^2)(THETA edge)-2rE sin (THETA edge /2))
= 657 in^2

A(nominal) = .96(PI/4)((2L+D)^2))
= 748 in^2

REp = 0.88

E = 9.0 >=4D, but not > 8.75D, shear reduction factor must be applied

REs = Shear Capacity Reduction Factor = 0.0131*(E/D)^2
= 0.47

GPU Nuclear

**Calculation Sheet**

| Subject | Calc. No. | Rev. No. | Sheet No. |
|---|---|---|---|
| CO-T-0001A & 1B | CO-T-0001A & 1B | 0 | 6 of 19 |
| Originator: R.D. Augustin | Date: 1-9-94 | Reviewed by: [signature] | Date: 1-28-94 |

- **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 >= ?,500 psi. Strength reduction factor required.

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

- **Embedment Check:** 10 * D = 15.00 4 * D = 6.00

L >= 10D, no reduction factor required.

- **Spacing Check** 2 * D = 3.00

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 = 1.500 inches, the allowable pullout capacity (Pu') = 60,078 lbs. and the allowable shear capacity (Vu') = 10,039 lbs

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

= 49,168 lbs.

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

= 13,130 lbs.

**GPU Nuclear** Calculation Sheet

| Subject | Calc. No | Rev. No. | Sheet No. |
|---|---|---|---|
| CO-T-0001A & 1B | CO-T-0001A & 1B | 0 | 7 of 9 |

| Originator | Date | Reviewed by | Date |
|---|---|---|---|
| G.D. Augustini | 1-9-94 | [illegible] | 1-28-94 |

## VERTICAL TANKS -- CONDENSATE WATER STORAGE TANK

**STEP 1:** Determine the following input data :

### TANK MATERIAL

diameter of tank (ft): 48

R (nominal tank radius) (inches): 288

(height of tank shell ) (ft): 20
H' (height of tank shell ) (inches): 240

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): 0.25

F y (yield strength of tank shell mat'l) (psi): 36,000

h c (height of shell compression zone at base of tank, usually height of chair) (inches): 12

E s (elastic modulus of tank shell mat'l) (psi): 29,000,000

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): 235

h f (height of freeboard above fluid surface) (inches): 15.82

### ANCHOR BOLTS

N (number of bolts): 16

d (diameter of bolt) (inches): 1.50

h b (eff. length of anchor bolt being stretched, usually from top of chair to embedded plate) (in.): 36

E b (elastic modulus of bolt material) (psi): 29,000,000

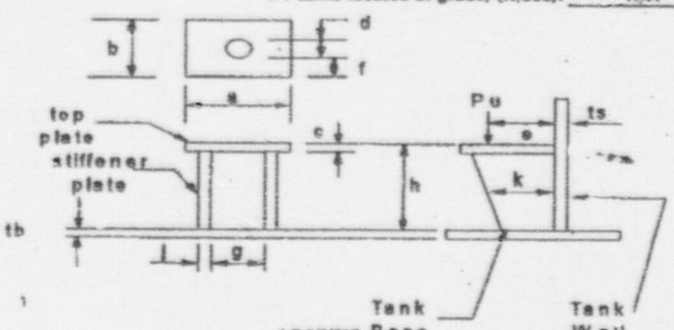
Anchor Bolt Allowable Tension Load (Pu) (lbs): 49,168
Anchor Bolt Allowable Shear Load (Vu) (lbs): 13,130
(Note: Allowables are with reduction factors applied)

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

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

| | | | | | |
|---|---|---|---|---|---|
| d = | 1.75 | j = | 0.5 | t b = | 0.25 |
| f = | 0.875 | g = | 2.5 | k = | 3.72 |
| b = | 5 | c = | 0.75 | e = | 3.25 |
| a = | 4.5 | h = | 12 | t s = | 0.25 |

Weld size between anchor chair and tank shell (t w) (inches): 0.25




### LOADING

Ground or floor 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



N 0016 (06-86)

**STEP 2:** Calculate the following ratios and values:

H/R = 0.816 t s/R = 0.001

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

= 0.250 inches

| i | t | h | t x h |
|---|---|---|---|
| 1 | 0.25 | 80 | 20 |
| 2 | 0.25 | 80 | 20 |
| 3 | 0.25 | 80 | 20 |
| 4 | | | |
| 5 | | | |
| | | | 60 = SUM t x h |

t eff = ( t avg. + t min ) / 2
= 0.25 in

(t eff)/R = 0.001

Ab = Cross-sectional area of embedded anchor bolt
= ( PI x d^2 ) / 4
= 1.767 in^2

t' = equivalent shell thickness having the same cross-sectional area as the anchor bolts
= ( ( N * Ab ) / ( 2 * PI * R ) ) * ( Eb / Es )
= 0.0158

c' = coefficient of tank wall thickness and lengths under stress
= ( t' / t s ) * ( h c / h b )
= 0.02

W = weight of fluid in tank
= PI * R^2 *H * GAMMA
= 2,204,475 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= | 288 | inches | OK, Table 7-1 requirements met, 60 in >R <420 in |
| Height of Tank Shell (H') = | 240 | 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) = | 235 | 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 = | 0.25 | 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.) = | 0.250 | inches | OK, Table 7-1 requirements met, 3/16 in >t s<1 in |
| Diameter of Anchor Bolt (d) = | 1.500 | inches | OK, Table 7-1 requirements met, 1/2 in > d <2 in |
| Number of Anchor Bolts (N) = | 16 | | OK, Table 7-1 requirements met, N > = 8 |
| Tank Wall Thickness (at Base)-to-Tank radius Ratio = (t s/R) = | 0.001 | | 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 = | 0.816 | | Table 7-1 requirements not met. Classify as an OUTLIER and proceed wit H / R not 1.0 to 5.0 |

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

R = 288 t eff / R = 0.001 , and H / R 0.816

From Table 7-3, find (F f) = 9.78 Hz.

NOTE: If the tank material is not carbon steel (Es not equal to 29,000 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.

**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 = 7.82 Hz < F < 11.74 Hz

Appropriate Spectral Acceleration (Saf) = 0.46 g 5% damping

g 4% damping = g5% (SQRT(5/4)) = 0.51 g

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

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

H/R = 0.816 and (t eff)/R = 0.001

And find base shear load coefficient (Q') = 0.64

Shear Load at Bottom of Tank = (Q) = Q' * W * Saf = 719,541 lbs

**STEP 6:** Determine the base overturning moment (M)

Enter Figure 7-4 with H/R = 0.816 and (t eff)/R = 0.001

And find M' = 0.306

Compute overturning moment = M = M' * W * H * Saf
= 80,582,830 lb-in

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

Fb = Pu / Ab
= 27,826

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)
= 96,588 > f y. Capacity reduction factor must be used.

Reduction Factor = f y / SIGMA = 0.37

Reduced Anchor Bolt Stress = Fr = Fb * (f y/SIGMA) = 10,296 psi



N 0016 (06-86)

**STEP 9: Check Tank Shell Stress**

Shell Stress = 133,435 psi > Fy, Reduction factor must be applied

Z = 1 / (((0.177 * a * tb * (tb / tc) ^ 2) / (SQRT (R * ts))) + 1)
0.977

Reduction Factor = F y / SHELL STRESS = 0.27

Reduced Anchor Bolt Allowable Stress = Fr = 7,513 psi

**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 = 7.44 Guideline No. 1 Satisfied
95 / ( ( ( f y / 1000 ) ^ 0.5 ) ) = 15.83

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

j = 0.50 Guideline No. 2 Satisfied
0.04 * (h - c) = 0.46

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

Pu/(2 * k * j) = 13,217 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
= 2,027 lbs/inch

Allowable load per inch = (30,600 * t w ) / SQRT(2) Weld is adequate
= 5,409 lbs/inch

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

Enter Figure 7-7 with the following parameters: Sef = 0.51 and H/R = 0.816

and find the fluid pressure coefficient (Pe') = 1.4

The fluid pressure at the base of the vertical tank from elephant-foot buckling type loading = (Pa) = Pe' * GAMMA * R (psi)
= 14.5152 psi

**STEP 13:** Determine the elephant-foot buckling stress capacity factor:

Enter Figure 7-8 with the following parameters:

Pe = 14.5152 psi and te / R = 0.001

And find the Capacity Factor = 12,000 psi

Note: The above Capacity Factor is for carbon steel. If the tank being evaluated is of some other material, see STEP 13 in the GIP for the conversion factor.

---

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

Enter Figure 7-9 with the following parameters:

Saf = 0.51 g and H/R = 0.816

and find the pressure coefficient for diamond-shape buckling (Pd') = 1.25

The fluid pressure at the base of the vertical tank from diamond-shape buckling type loading = (Pd) = Pd' * GAMMA * R
= 12.86 psi

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**STEP 15:** Determine the diamond-shape buckling stress capacity factor

Enter Figure 7-10 with the following parameters:

Pd = 12.86 psi and te / R = 0.001

And find the capacity factor = 12,000 psi

Note: The above Capacity Factor is for carbon steel. If the tank being evaluated is of some other material, see STEP 15 in the GIP for the conversion factor.

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**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 Bucking Capacity Factor = 12,000 psi CONTROLS
Diamond-Shape Buckling Capacity Factor = 12,000 psi CONTROLS

Allowable buckling stress = 8,640 psi

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**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') = 0.06

F (b or r) = 7,513 psi    h b = 36.00    h c = 12.00 inches

Allowable Buckling Stress = 8,940 psi

σ' = 0.02    ((Allowable Buckling Stress)/(Fb))* (h c / h b) = 0.383

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

σ' = 0.02 and ((Allowable Buckling Stress)/(Fb))* (h c / h b) = 0.383

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

Use (Mcap) value = 0.06 for DUCTILE failure.

Compute (Mcap) based on the following formula:

Note: Fb is the smallest of Fb from Step 7, Fr from Step 8, or Fr from Step 9 = 7,513

Mcap = ( Mcap' ) * ( 2 * Fb ) * ( R^2 * ts ) * ( h b / h c )
= 56,084,244 lb-inches

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

Mcap = 56,084,244 lb-in < M = 80,582,930 lb-in

The tank is not seismically adequate for this loading and must be classified as an OUTLIER. proceed to Section 5 OUTLIER RESOLUTION after completing the remainder of the evaluations.

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

Cap = .55 * ( 1 - 0.21 * Saf ) * W
= 1,082,607 lbs

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

Cap = 1,082,607 lbs > Q = 719,541 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 ) )
= 0.24 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 = 0.82 and R = 288 inches

to find (h's) = 108

Compute the slosh height (h s), : h s = h's * ZPA = 12.96 inches

where ZPA is from horizontal response spectrum = 0.12 g

**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 = 15.82 inches

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

h f = 15.82 inches > h s = 12.83 inches

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

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**Calculation Sheet**

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| H.D. Augustino / 1-24-94 | [signature] | | 1-28-94 |

# STEP 2 OUTLIER RESOLUTION

Per Step 2 of the GIP evaluation the tank is classified as an OUTLIER as the Height / Radius does not meet the class inclusion guidelines. The Height / Radius of this tank = 20' / 24' = 0.816. The minimum ratio per the guidelines is 1.0. Page 2-3 (Reference 10) states that the range of parameters for the database tank are Diameter from 10' to 70' and a Height from 10' to 80'. The Condensate Water Storage does not meet the ratio guidelines but does meet the parameter range (diameter = 48' and the fluid height = 20'). As such, an explicit tank evaluation is required.

The input parameters used in the GIP evaluation were taken from a H /R value equal to 1.0. This is conservative as the overturning moment calculations with a H /R value equal to 1.0 will be larger than a H /R value equal to 0.816.

To verify this assumption, each step in the GIP evaluation will be checked to ensure values of H/R = 1.0 are conservative.

**STEP 3:** For constant values of tef / R, as H /R decreases the corresponding impulsive mode frequency increases. Therefore, using the frequency for H / R =1.0 will yield a lower impulsive mode frequency than the value of H /R = 0.816 would.

**STEP 5:** The curves shown in GIP Figure 7-3 show a decreasing Base Shear Load Coefficient as the value of H /R decreases. As this value decreases the corresponding actual base shear load also decreases. Therefore, using the Base Shear Load Coefficient for H / R =1.0 will yield a higher actual base shear load than the value of H /R = 0.816 would.

**STEP 6:** The curves shown in GIP Figure 7-4 show a decreasing Base Overturning Moment Load Coefficient as the value of H /R decreases. As this value decreases the corresponding actual base overturning moment also decreases. Therefore, using the Base Overturning Moment Load Coefficient for H / R =1.0 will yield a higher actual base overturning moment than the value of H /R = 0.816 would.

**STEP 12:** The curves shown in GIP Figure 7-7 show a decreasing Pressure Coefficient for Elephant-Foot Buckling as the value of H /R decreases. As this value decreases the corresponding actual fluid pressure at the base of the tank from elephant-foot buckling type loading also decreases. Therefore, using the Pressure Coefficient for Elephant-Foot Buckling for H / R =1.0 will yield a higher actual fluid pressure than the value of H /R = 0.816 would.

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**STEP 14:** The curves shown in GIP Figure 7-9 show a decreasing Pressure Coefficient for Diamond-Shape Buckling as the value of H /R decreases. As this value decreases the corresponding actual fluid pressure at the base of the tank from diamond-shape buckling type loading also decreases. Therefore, using the Pressure Coefficient for Diamond-Shape Buckling for H / R =1.0 will yield a higher actual fluid pressure than the value of H /R = 0.816 would.

**STEP 21:** The values shown in GIP Table 7-5 show a Slosh Height of Water as the value of H /R decreases. As this value decreases the corresponding slosh height also decreases. Therefore, using the Slosh Height of Water value for H / R =1.0 will yield a higher actual slosh height than the value of H /R = 0.816 would.

The use of H / R values equal to 1.0 are judged to be acceptable and the OUTLIER is considered to be resolved.

## STEP 18 OUTLIER RESOLUTION

Per Step 18 this tank is classified as an OUTLIER as the computed overturning moment is greater than the computed overturning capacity. Per page 2-5 (Reference 10), Reference 9 was used to determine the overturning demand of vertical steel tanks. Page H-3 (Reference 9) states that the overturning moment demand is only summarized and that Reference 12 can be used for a more detailed overturning moment demand calculation.

Per page 115 (Reference 12) the minimum acceptable analysis must incorporate at least two contributors to the horizontal mode. These are the IMPULSIVE mode where the response of the tank roof and shell are coupled together with the portion of the fluid contents which moves in unison with the shell and the SLOSHING mode where a portion of the tank contents moves independent of the tank shell.

**HORIZONTAL IMPULSIVE MODE**

It is necessary to estimate the fundamental frequency of the vibration of the tank including the impulsive contained fluid weight. From Steps 2 and 3 of the GIP analysis it is found that the SSE free field acceleration at 4% damping for the fluid-structure modal frequency is 0.51g.

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**SLOSHING MODE**

The fundamental convective (sloshing) mode frequency can be estimated by from the following equation from page H-11, Reference 9:

$H_{ft} := 19.58$ feet $\quad R := 24$ feet

$$fs := \sqrt{\frac{1.5}{R} \cdot \tanh\left(1.835 \cdot \frac{H_{ft}}{R}\right)} \qquad fs = 0.24 \text{ Hz}$$

From Reference 14 for a frequency of 0.24 Hz, find a OBE acceleration with 5% damping =

$$acc\_OBE\_5\% := -.123 \cdot fs^3 + 0.207 \cdot fs^2 \qquad acc\_OBE\_5\% = 0.010 \text{ g}$$

$$acc\_SSE\_5\% := 2 \cdot acc\_OBE\_5\% \qquad acc\_SSE\_5\% = 0.020 \text{ g}$$

Using the guidelines of Section 4.4.3 of the GIP and assuming the free-field response spectrum is the input spectrum, convert the 5% damped acceleration to 1/2% damped:

$$acc\_SSE\_0_5 := acc\_SSE\_5\% \cdot \sqrt{\frac{5}{.5}} \qquad acc\_SSE\_0_5 = 0.064 \text{ g}$$

Reference 10 states that the overturning moment demand (M) of vertical storage tanks is a combination of the mass of the contents (m), the sloshing mode mass of the contents ($m_s$), the impulsive flexible mass ($m_f$), and the rigid motion mass of the contents ($m_r$) being applied at the the respective heights, (H) height of the fluid level, ($h_s$) height of sloshing mode, ($h_f$) height of the impulsive flexible mass, ad ($h_r$) height of the rigid mass.

From Figures 3 to 9 of Reference 15, find the following ratios:

SLOSHING: $m_s / m = Ms := 0.50$ $\qquad h_s / H = Hs := 0.57$

IMPULSIVE FLEXIBLE: $m_f / m = Mf := 0.48$ $\qquad h_f / H = Hf := 0.41$

IMPULSIVE RIGID: $m_r / m = Mr := 0.48$ $\qquad h_r / H = Hr := 0.40$

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**Calculation Sheet**

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The following values have already been defined in the GIP part of the analysis:

Weight =W := 2204475 lbs $\qquad H_{in}$ := 240

4% damped acceleration =acc4% := 0.51g $\qquad$ ZPA := 0.1g

From page 2-7 of Reference 10 the overturning moment is defined as follows:

$$M := \sqrt{(Ms \cdot Hs \cdot acc\_SSE\_0_5)^2 + (Mf \cdot Hf \cdot acc4\%)^2 + (Mr \cdot Hr - Mf \cdot Hf)^2 \cdot ZPA^2 \cdot W \cdot H}$$

M = 53960924 lb·in

Per Step 17 of the GIP evaluation, the tank has an overturning moment capacity of 56,084,244 lb-in. As the capacity exceeds the demand, the tank is seismically adequate and the OUTLIER is adequately resolved.

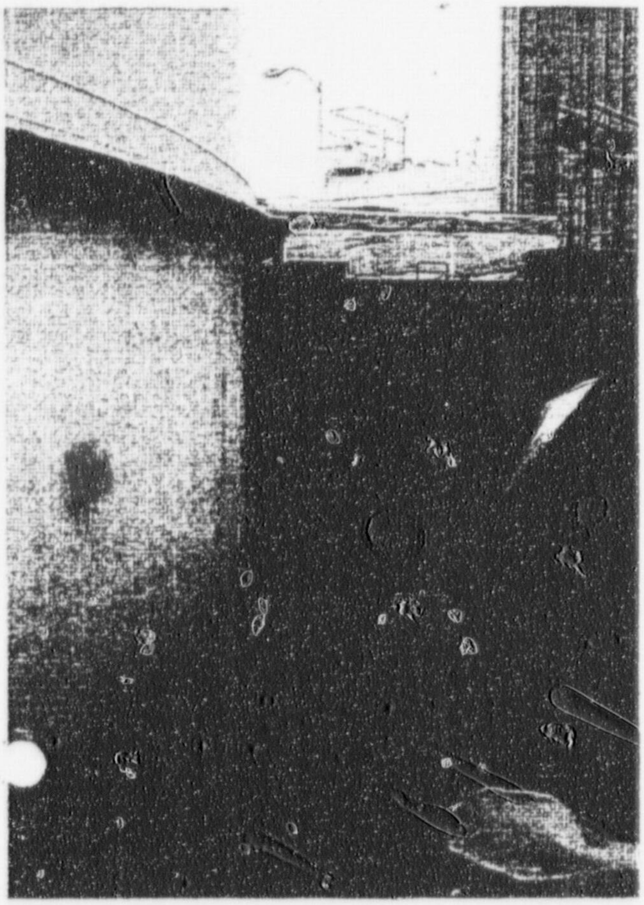
CONLCUSION: The Condensate Water Storage Tank is seismically verified.

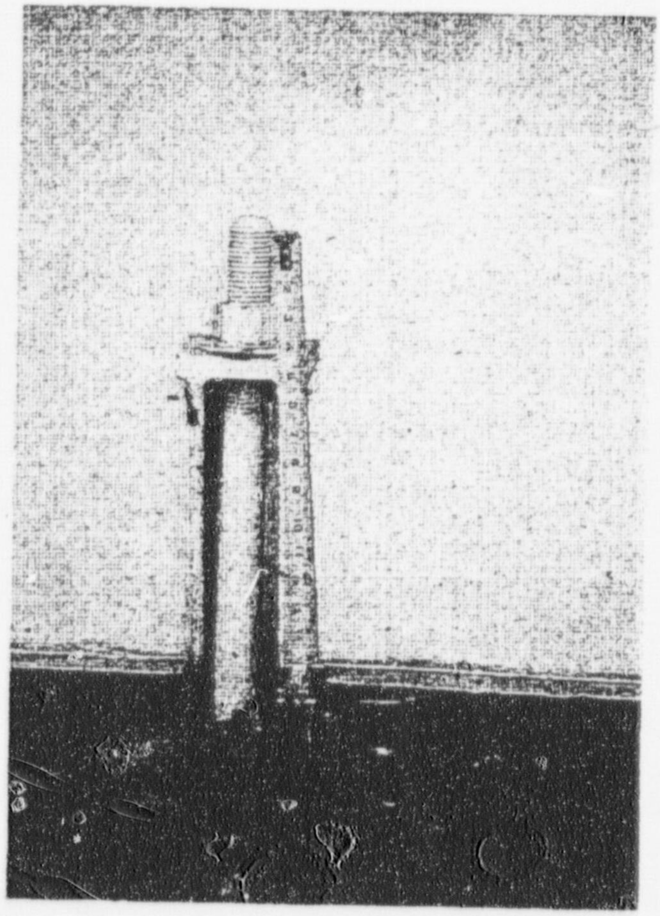
January 21, 1994

To: Rick Augustine

From: Phil Hashimoto

I have reviewed your A-46 evaluation of the Three Mile Island condensate storage tank. I concur with the technical approach adopted, including that used for outlier resolution, and have verified that the results obtained are correct.





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