

**Attachment 2: Design Calculations for United States Geological Survey
1MW Mark I TRIGA Reactor – Tank Liner**

DESIGN CALCULATIONS
FOR
UNITED STATES GEOLOGICAL SURVEY
1MW MARK I TRIGA REACTOR - TANK LINER

BY

GILLAN'S ENGINEERING, INC.
5126 W 38TH AVE
DENVER, CO 80212
(303)480-0471

PREPARED BY
DENNIS R. MOSS

CHECKED BY
LELAND E. GILLAN

REVISED OCTOBER 5, 1987

USGS IMW TRIGA REACTOR
TANK LINER

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MISC
 MW gals/mol
 CO₂ 8.47
 H₂ 5.18
 N₂ 4.18
 H₂ 3.38

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MW	gas/mol
18	C ₂ 6.40
30	C ₃ 9.67
44	C ₄ 10.44
58	IC ₄ 12.40
72	C ₅ 13.88
86	IC ₅ 15.5
100	IC ₆ 17.2
114	C ₆ 17.49
128	C ₇ 19.47
142	C ₈ 21.64
156	C ₉ 24.07
170	C ₁₀ 26.71
184	C ₁₁ 29.57
198	C ₁₂ 32.64
212	C ₁₃ 35.93
226	C ₁₄ 39.44
240	C ₁₅ 43.17
254	C ₁₆ 47.12
268	C ₁₇ 51.29
282	C ₁₈ 55.68
296	C ₁₉ 60.29
310	C ₂₀ 65.12
324	C ₂₁ 70.17
338	C ₂₂ 75.44
352	C ₂₃ 80.93
366	C ₂₄ 86.64
380	C ₂₅ 92.57
394	C ₂₆ 98.72
408	C ₂₇ 105.09
422	C ₂₈ 111.68
436	C ₂₉ 118.49
450	C ₃₀ 125.52
464	C ₃₁ 132.77
478	C ₃₂ 140.24
492	C ₃₃ 147.93
506	C ₃₄ 155.84
520	C ₃₅ 163.97
534	C ₃₆ 172.32
548	C ₃₇ 180.89
562	C ₃₈ 189.68
576	C ₃₉ 198.69
590	C ₄₀ 207.92
604	C ₄₁ 217.37
618	C ₄₂ 227.04
632	C ₄₃ 236.93
646	C ₄₄ 247.04
660	C ₄₅ 257.37
674	C ₄₆ 267.92
688	C ₄₇ 278.69
702	C ₄₈ 289.68
716	C ₄₉ 300.89
730	C ₅₀ 312.32
744	C ₅₁ 323.97
758	C ₅₂ 335.84
772	C ₅₃ 347.93
786	C ₅₄ 360.24
800	C ₅₅ 372.77
814	C ₅₆ 385.52
828	C ₅₇ 398.49
842	C ₅₈ 411.68
856	C ₅₉ 425.09
870	C ₆₀ 438.72
884	C ₆₁ 452.57
898	C ₆₂ 466.64
912	C ₆₃ 480.93
926	C ₆₄ 495.44
940	C ₆₅ 510.17
954	C ₆₆ 525.12
968	C ₆₇ 540.29
982	C ₆₈ 555.68
996	C ₆₉ 571.29
1010	C ₇₀ 587.12
1024	C ₇₁ 603.17
1038	C ₇₂ 619.44
1052	C ₇₃ 635.93
1066	C ₇₄ 652.64
1080	C ₇₅ 669.57
1094	C ₇₆ 686.72
1108	C ₇₇ 704.09
1122	C ₇₈ 721.68
1136	C ₇₉ 739.49
1150	C ₈₀ 757.52
1164	C ₈₁ 775.77
1178	C ₈₂ 794.24
1192	C ₈₃ 812.93
1206	C ₈₄ 831.84
1220	C ₈₅ 850.97
1234	C ₈₆ 870.32
1248	C ₈₇ 889.89
1262	C ₈₈ 909.68
1276	C ₈₉ 929.69
1290	C ₉₀ 949.92
1304	C ₉₁ 970.37
1318	C ₉₂ 991.04
1332	C ₉₃ 1011.93
1346	C ₉₄ 1033.04
1360	C ₉₅ 1054.37
1374	C ₉₆ 1075.92
1388	C ₉₇ 1097.69
1402	C ₉₈ 1119.68
1416	C ₉₉ 1141.89
1430	C ₁₀₀ 1164.32

1.0 PURPOSE

THESE CALCULATIONS ARE PREPARED IN ACCORDANCE WITH ASME CODE, SECTION VIII, DIV 1, 1986 EDITION. ALTHOUGH BASICALLY THE TANK LINER IS A WATER FILLED ATMOSPHERIC TANK AND IS UNPRESSURIZED THE ASME PRESSURE VESSEL CODE PROVIDES A SOUND BASIS FOR A REASONABLE, SAFE AND ECONOMICAL DESIGN. THIS DESIGN SHALL INCLUDE SEISMIC, STRENGTH AND THERMAL CALCULATIONS FOR THE MECHANICAL AND STRUCTURAL INTEGRITY OF THE TANK LINER AND LIFTING LUGS.

2.0 REFERENCES

- 1) ASME BOILER AND PRESSURE VESSEL CODE, SECTION VIII, DIVISION 1, 1986 EDITION
- 2) ROARK, R.N. AND YOUNG, W.C., FORMULAS FOR STRESS AND STRAIN, 5th EDITION, MCGRAW HILL BOOK CO, 1975
- 3) API 650, WELDED STEEL TANKS FOR OIL STORAGE, 7th ED, NOV 1980
- 4) BEDNAR, H. PRESSURE VESSEL DESIGN HANDBOOK, 1st EDITION, VAN NOSTRAND REINHOLD CO, 1981, SECT 3.9
- 5) "ISAKOWER, R.I.", "RING REDUNDANTS", MACHINE DESIGN, MAR 1965

3.0 DESIGN DATA

DESIGN PRESSURE : INT: 10.83 PSI
 EXT: 1.184 PSI

DESIGN TEMP : MAX: 150°F
 MIN: 50°F

DESIGN LIQUID LEVEL: FULL OF WATER

CORROSION ALLOWANCE: NONE

JOINT EFFICIENCY : 1.0 (100% X-RAY)

SPECIFIC GRAVITY OF : 1.0 (WATER)
 CONTENTS

SEISMIC : PER API 650, APP'E', ZONE I

LOCATION : DENVER, COLORADO
 BLDG 15, DENVER FEDERAL CENTER

H	gals/mol
30	C ₁ 8.40
44	C ₂ 9.67
58	C ₃ 10.44
72	IC ₄ 12.40
86	C ₄ 11.95
100	IC ₅ 13.88
114	C ₅ 13.74
128	IC ₆ 15.5
142	C ₆ 15.59
156	IC ₇ 17.2
170	C ₇ 17.49
184	C ₈ 15.41
198	C ₉ 9.84
212	C ₁₀ 9.87

MW	gals/mol
	CO ₂ 8.47
	H ₂ 5.18
	N ₂ 4.18
	H ₂ 3.38

4.0 MATERIALS OF CONSTRUCTION

MW gals/mol

16	C ₁	6.40
30	C ₂	9.87
44	C ₃	10.44
58	IC ₄	12.40
72	C ₄	11.95
86	IC ₅	13.88
100	C ₅	13.74
114	IC ₆	15.5
128	C ₆	15.59
142	IC ₇	17.2
156	C ₇	17.48
170	IC ₈	19.41
184	C ₈	19.64
198	IC ₉	21.57
212	C ₉	21.87

SPEC	ALLOY	PRODUCT	PROPERTIES (KSI)			
			F _T	F _y	S _{amb}	S ₁₅₀
SB-209	6061-T4	SHT/PL	30	16	7.5	7.5
	5052-H32	"	31	23	7.8	7.8
	5154-H32	"	36	26	9.0	9.0
SB-241	6061-T4	PIPE				
	5052-O	"	25	10	6.3	6.3
SB-221	6061-T4	BAR/SHAPE	26	16	6.5	6.5
	5154-O	"	30	11	7.5	7.5
SB-211	6061-T6	BOLTS	42	35	8.4	8.4

NOTES :

(1) MATL SPECIFIED FOR TANK SHELL, BTM AND PL MAY BE TYPES 6061-T4, 5052-H32 OR 5154-H32. SINCE 6061-T4 HAS THE LOWEST DESIGN PROPERTIES THIS REPORT WILL UTILIZE 6061-T4 MATL. IF MATL OF GREATER STRENGTH ARE USED THEY WILL BE ACCEPTABLE.

(2) F_T = MIN SPECIFIED TENSILE STRENGTH

F_y = MIN SPECIFIED YIELD

S = ALLOWABLE STRESS, TENSION AT AMBIENT OR 150°F

OTHER MATERIAL PROPERTIES (FOR 6061 ALLOY)

MOD OF ELAS : 9.8 x 10⁶
 COEF OF THERMAL EXPANSION : 12.76 x 10⁻⁶ in/in/°F
 POISSONS RATIO : .3
 WEIGHT : .098 lb/in³

MISC

44	CO ₂	6.47
4	H ₂	5.18
8	H ₂	4.16
2	H ₂	3.38

USSS 1 MW TRIGA MK I - TANK LINER

FIG 1 : SECTION VIEW OF OVERALL

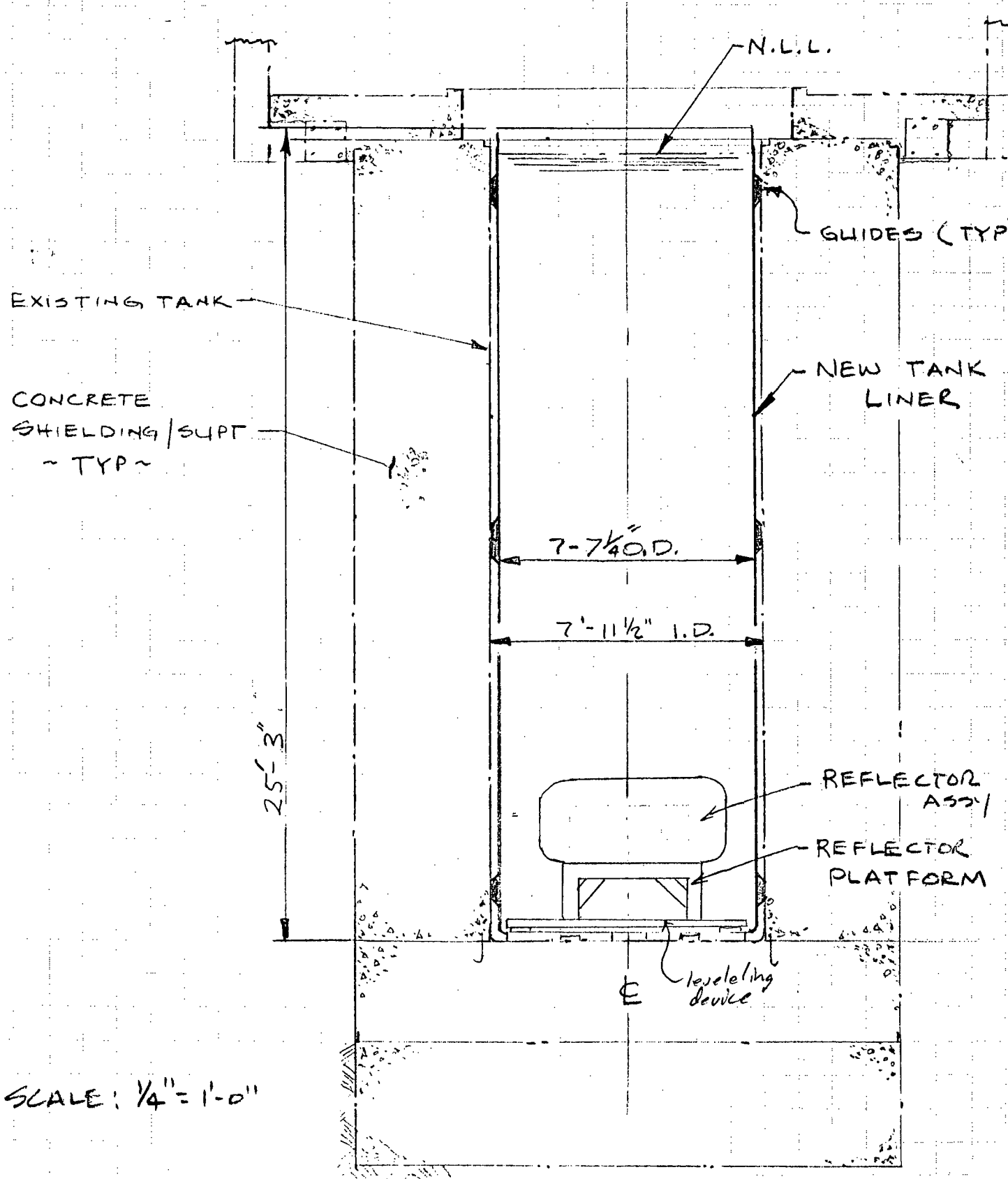
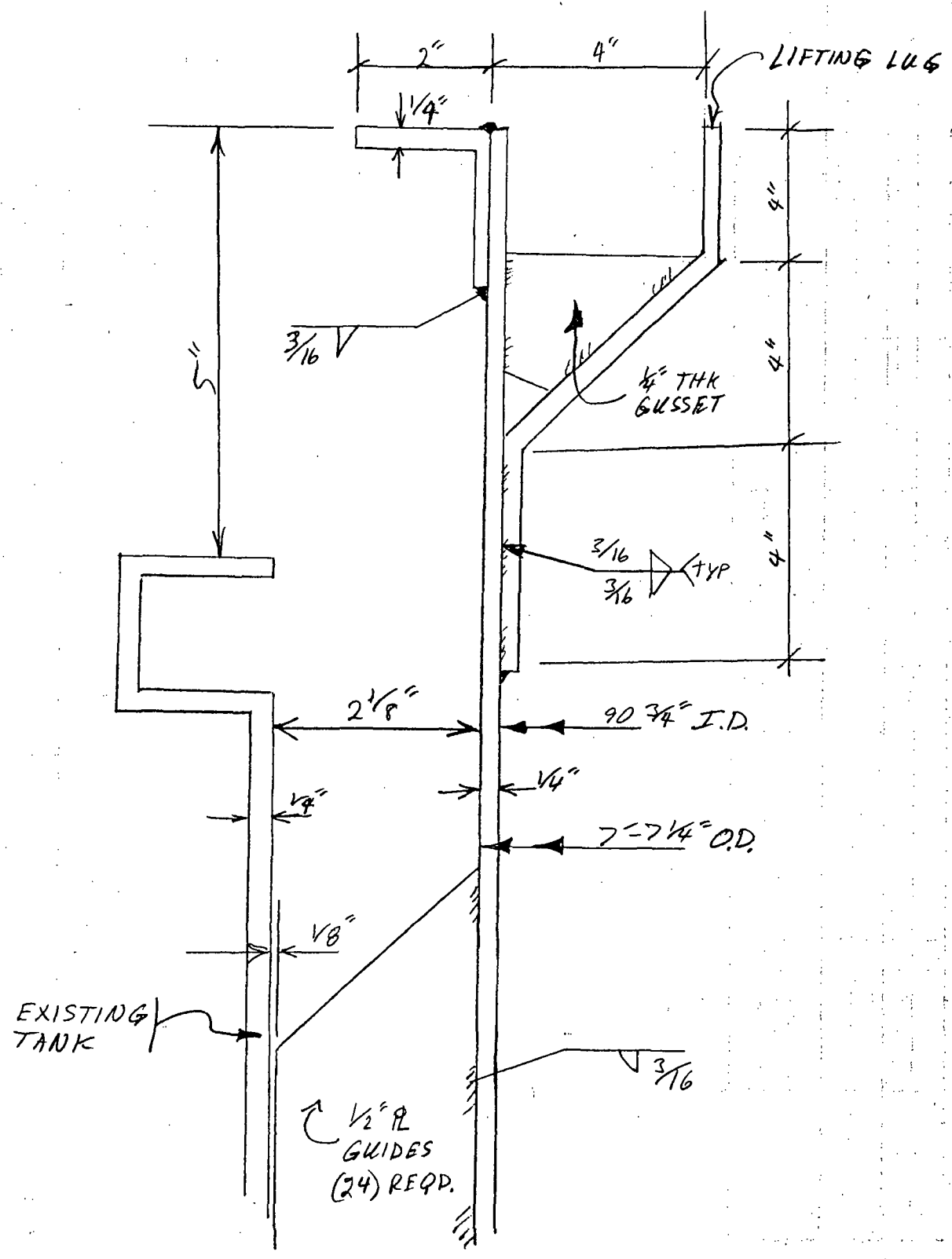


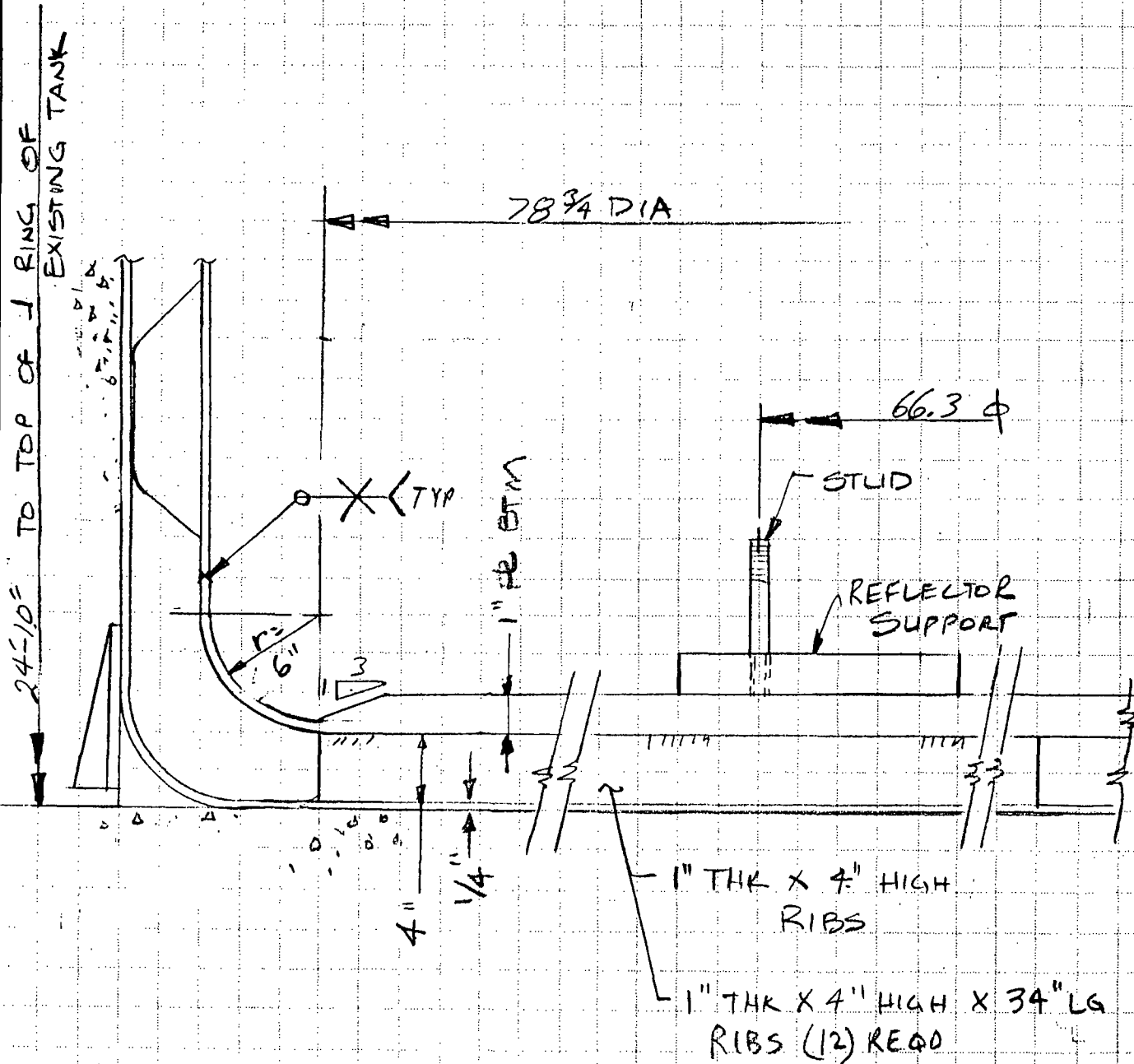
FIG 2 : SECTIONAL VIEW OF
TANK TOP CONFIGURATION
USGS 17N TRIGA MK I - TANK LINER

22-141 50 SHEETS
22-142 100 SHEETS
22-144 200 SHEETS
AMPAD



MW	gals/mol
16	C ₁ 8.40
30	C ₂ 9.67
44	C ₃ 10.44
58	IC ₄ 12.40
72	C ₄ 11.98
86	IC ₅ 13.88
100	C ₅ 13.74
114	IC ₆ 15.8
128	C ₆ 15.89
142	IC ₇ 17.2
156	C ₇ 17.49
170	C ₈ 19.41
184	C ₉ 19.84
198	C ₁₀ 19.87

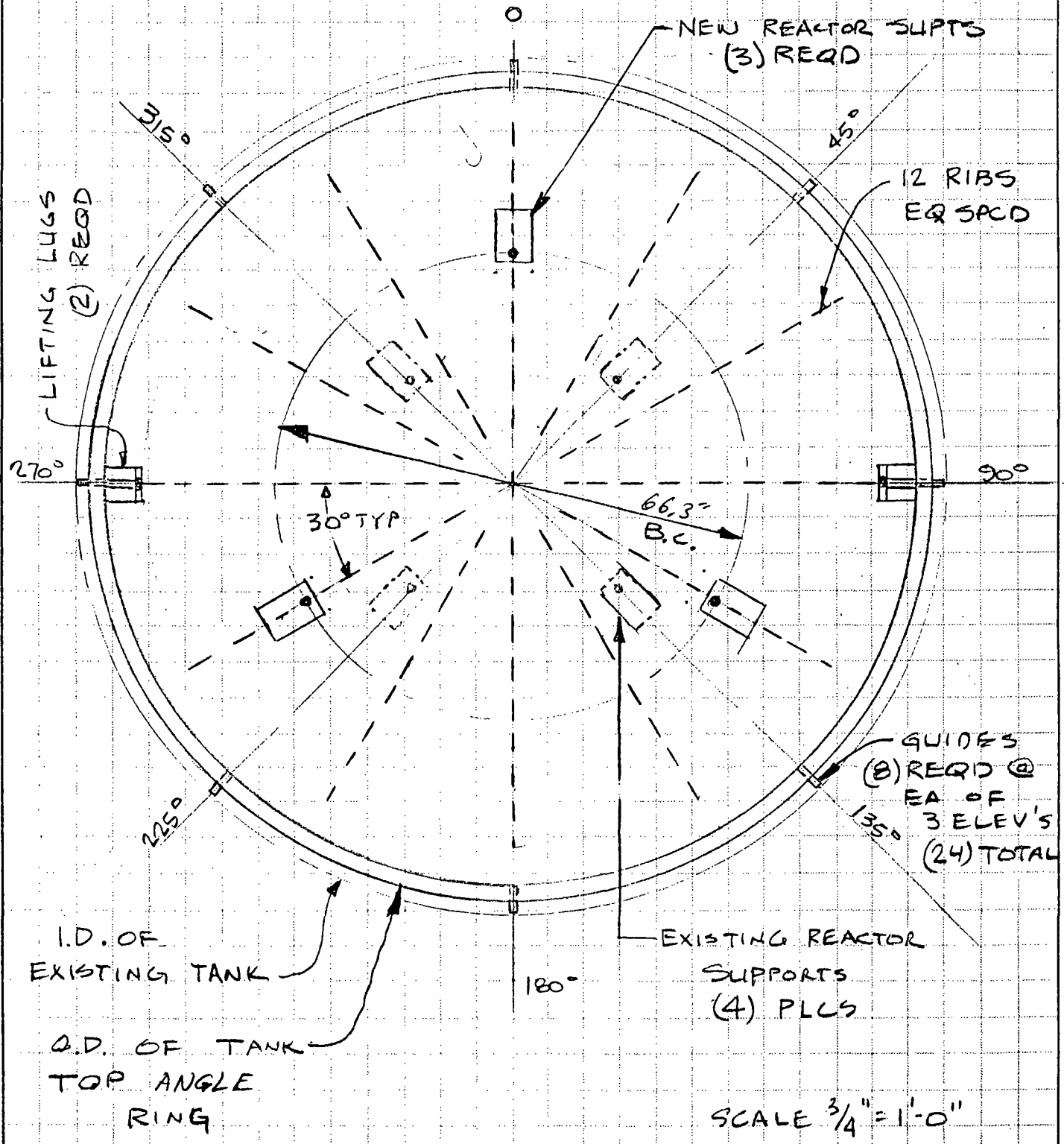
FIG 3: SECTIONAL VIEW OF TANK BTM CONFIGURATION



MISC

MW	gals/mol
44	CO ₂ 8.47
	H ₂ S 8.18
	N ₂ 4.18
	H ₂ 3.38

FIG 4: PLAN VIEW OF TANK LINER



MW	gals/mol
16	C ₂ 8.40
30	C ₃ 9.87
44	C ₄ 10.44
58	IC ₂ 12.40
72	C ₅ 11.95
86	IC ₃ 13.86
100	C ₆ 13.74
114	IC ₄ 15.8
128	C ₇ 15.59
142	IC ₅ 17.2
156	C ₈ 17.49
170	IC ₆ 19.41
184	C ₉ 19.84
198	IC ₇ 21.8
212	C ₁₀ 21.87

MW	gals/mol
44	CO ₂ 8.47
34	H ₂ O 5.18
28	N ₂ 4.16
22	H ₂ 3.38

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DATE 8-23-87

CALCULATIONS and SKETCHES

CONT. NO.

BY DRM

CHK'D

SHEET NO. 8/

6.0 TANK VOLUME (FULL)

$90\frac{3}{4}'' \text{ I.D.} \times 25\text{'-}1\frac{1}{4}'' \text{ LG} = 1127 \text{ ft}^3$

$1127 \text{ ft}^3 = 8435 \text{ GALLONS} = 70,324 \text{ lb WATER}$

7.0 TANK WEIGHTS (EST @ .098 #/in³)

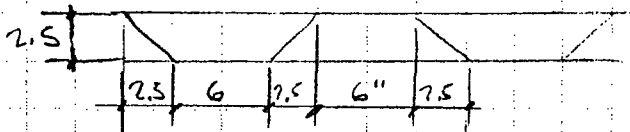
SHELL : $\frac{1}{4}'' \text{ PL} \times 90\frac{3}{4}'' \text{ I.D.} \times 205'' = 1432$ } 2438
 $\frac{3}{8}'' \text{ PL} \times 90\frac{3}{4}'' \text{ I.D.} \times 96'' = 1006$ }

BTM HEAD : $1'' \text{ PL} \times 78\frac{3}{4}'' \phi = 460 \#$
 $\frac{1}{4}'' \text{ PL} \times 91\frac{1}{4}'' \text{ O.D.} \times 78\frac{3}{4}'' = 55 \#$

TOP J RING:

(1) $\frac{1}{4}'' \text{ PL} \ 91\frac{1}{4}'' \text{ I.D.} \times 95\frac{1}{4}'' \text{ O.D.} = 10 \#$
 (1) $\frac{1}{4}'' \text{ PL} \ 91\frac{1}{4}'' \text{ I.D.} \times 2'' \text{ LG} = 11 \#$

GUIDE PLATES:



= 30 #

RIBS : (12) $1'' \times 2'' \times 34'' \text{ LG} = 80 \#$

MISC: LIFT LUGS
 SUPT PDS

= 15 #

3099 #

MW	gals/mol
16	C ₂ 8.40
30	C ₃ 9.87
44	C ₄ 10.44
58	IC ₄ 12.40
84	C ₆ 11.95
72	IC ₆ 13.88
98	C ₈ 13.74
84	IC ₈ 15.5
98	C ₁₀ 13.59
100	IC ₁₀ 17.2
70	C ₁₂ 17.49
14	C ₁₄ 19.81
78	C ₁₆ 18.44
42	C ₁₈ 9.87

MW	gals/mol
44	CO ₂ 8.47
	H ₂ 5.18
	N ₂ 4.18
	H ₂ 3.28

MW	gals/mol
16	C ₁ 6.40
30	C ₂ 9.67
44	C ₃ 10.44
58	IC ₄ 12.40
72	C ₄ 11.95
86	IC ₅ 13.88
100	C ₅ 13.74
114	IC ₆ 15.5
128	C ₆ 15.59
142	IC ₇ 17.2
156	C ₇ 17.48
170	C ₈ 19.41
184	C ₉ 19.64
198	C ₁₀ 19.67

WEIGHTS (CONT.)

FAB WT: 3099 X 1.06 = 3285 #
 (ADD 6% FOR FE OVERAGES
 WELDING, ETC.)

TEST WT:

FAB WT : 3285 #
 + WATER : 70,324 = 73,609 #

OPER WT:

FAB WT: 3285 #
 + REACTOR : 3500 #
 + WATER 67524 # = 74,309 #

ASSUME REACTOR DISPLACES
 ABOUT 45 ft³ OF WATER

45 X 62.4 = 2800 #
 70324 - 2800 = 67524

MW	gals/mol
44	CO ₂ 6.47
	H ₂ 5.38
	N ₂ 4.16
	H ₂ 5.38

MW	gas/mol
18	C ₁ 8.40
30	C ₂ 9.87
44	C ₃ 10.44
58	IC ₄ 12.40
72	C ₄ 11.98
86	IC ₅ 13.88
100	C ₅ 13.74
114	IC ₆ 15.5
128	C ₆ 15.59
142	IC ₇ 17.2
156	C ₇ 17.49
170	IC ₈ 19.41
184	C ₈ 19.64
198	IC ₉ 21.47

8.0 SHELL THICKNESS REQD FOR INT. PRESSURE

$$t = \frac{PR}{SE - 0.6P} = \frac{10.83(45.375)}{7500(1.0) - 6.5} = .065'' \text{ USE } \frac{1}{4}'' \text{ MIN THK}$$

S_{150°} = 7500 PSI FOR 6061-T4 ALUM

P = 10.83 PSI

R = 45.375

E = 1.0

MAXIMUM ALLOWABLE EXTERNAL PRESSURE

L = 300''
 D_o = 9 1/4''
 t = .25

L/D_o = 3.29

D_o/t = 365

FROM ASME SECT VIII, DIV 1 FIG UG-28.0

FACTOR A = .00006

FOR VALUES TO THE LEFT OF THE APPLICABLE
 MATL/TEMP LINE

ALLOWABLE EXTERNAL PRESSURE, P_a, PSI

$$P_a = \frac{2AE}{3(P_o/t)} = \frac{2(.00006) 9.8 \times 10^4}{3(365)} = 1.07 \text{ PSI}$$

MISC	MW	gas/mol
	44	CO ₂ 8.67
		H ₂ 2.18
		N ₂ 4.18
		H ₂ 2.38

9.0 SEISMIC DESIGN

THE SEISMIC DESIGN WILL BE COMPUTED IN TWO WAYS;

1) FOR THE TANK SHELL THE TANK WILL BE DESIGNED AS AN OPEN TOPPED TANK IN ACCORDANCE WITH APP 'E' OF API-650. THE SEISMIC ZONE FACTORS OF API-650 WILL BE CONVERTED TO ACCOMMODATE UBC SEISMIC ZONES, THIS WILL INSURE THAT BOTH CODES ARE MET.

THE TANK SHELL WILL BE ASSUMED TO BE UNANCHORED BUT GUIDED, THE TANK GUIDES WILL TRANSMIT THE HORIZONTAL FORCES (BASE SHEAR) TO THE OUTER SHELL WALL.

SINCE THIS PROCEDURE IS BASED ON FREE STANDING STRUCTURES IT WILL BE CONSERVATIVE FOR THIS APPLICATION.

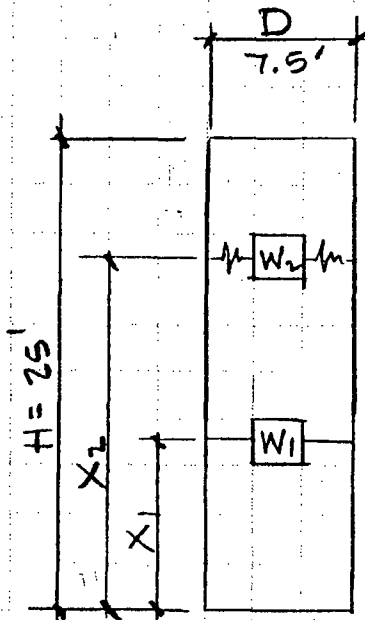
2) THE TANK BOTTOM WILL BE DESIGNED TO TAKE THE DEAD WT LOAD OF THE REACTOR PLUS CONTENTS AND 'A' SEISMIC REACTION LOAD FROM THE REACTOR SUPPORT STRUCTURE.

	gas/mol
C ₁	8.40
C ₂	9.67
C ₃	10.44
IC ₁	12.50
C ₄	11.99
IC ₂	13.88
C ₅	13.74
IC ₃	15.3
C ₆	15.59
IC ₄	17.2
C ₇	17.69
C ₈	19.41
C ₉	9.67

MISC	gas/mol
CO ₂	8.47
H ₂	4.18
H ₂	4.18
H ₂	3.38

MW	gals/mol
16	C ₂ 8.40
30	C ₂ 9.87
44	C ₂ 10.44
58	IC ₂ 12.60
72	C ₂ 11.95
86	IC ₂ 13.88
100	C ₂ 13.74
114	IC ₂ 15.5
128	C ₂ 15.58
142	IC ₂ 17.2
156	C ₂ 17.49
170	IC ₂ 19.41
184	C ₂ 19.64
198	IC ₂ 21.87

SEISMIC DESIGN (CONT)



TO CONVERT API SEISMIC FACTOR Z TO UBC SEISMIC FACTOR;

$$Z' = \frac{K(C_s)Z}{C_1}$$

WHERE;

- K = 2.0
- C_s = .14 MAX
- C₁ = .24
- Z = .1875, ZONE 1

FOR ZONE 1

$$Z' = \frac{2.0(.14).1875}{.24} = .2187$$

I = OCCUPANCY importance factor = 1.0
 C₁ = lateral E.Q. coefficient = .24

RATIOS

$$D/H = 7.5/25 = .3$$

$$W_1/W_T = .925 \text{ FIG E-2}$$

$$W_2/W_T = .075 \text{ FIG E-2}$$

$$X_1/H = .475 \text{ FIG E-3}$$

$$X_2/H = .9 \text{ FIG E-3}$$

SEISMIC DESIGN (CONT)

S = SITE AMPLIFICATION FACTOR = 1.0

$K = .56$

$T = K \sqrt{D} = .56 \sqrt{7.5} = 1.53 \text{ SECS}$

$C_2 = \frac{.13 S}{T} = \frac{.13}{1.53} = .196$

$W_3 = 2438 \#$

$W_T = 73,609 \#$

$W_1 = .925 (73,609) = 68,088 \#$

$W_2 = .075 (73,609) = 5,521 \#$

$X_1 = .475 (25) = 11.875'$

$X_2 = .9 (25) = 22.5'$

$X_3 = 12.5'$ (DISTANCE TO C.G. OF SHEAR)

OVERTURNING MOMENT, M, FT-LBS

$M = ZI (C_1 W_3 X_3 + C_1 W_1 X_1 + C_2 W_2 X_2)$
 $= .2187 (1.0) [225,712] = 49,363 \text{ FT-LBS}$

$.24 (2438) 12.5 = 7314$

$.24 (68,088) 11.875 = 194050$

$.196 (5,521) 22.5 = 24348$

225,712

BASE SHEAR, V = 2104 + 67760 + 5494 = 75,358 #

W	gals/mol
8	C ₁ 8.90
9	C ₂ 9.67
44	C ₃ 10.44
58	IC ₁ 12.40
8	C ₄ 11.94
7	IC ₂ 13.88
7	C ₅ 13.74
46	IC ₃ 15.5
64	C ₆ 16.59
100	IC ₄ 17.2
0	C ₇ 17.49
1	C ₈ 19.41
8	C ₉ 19.64
42	C ₁₀ 19.67

MISC	
MW	gals/mol
44	CO ₂ 8.47
	H ₂ S 5.18
	H ₂ 4.16
	H ₂ 3.38

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SEISMIC DESIGN (CONT)

SEISMIC UPLIFT, W_U , lb/FT-CIRC

$$W_U = \frac{4M}{\pi D^2} = \frac{4(49,363)}{\pi (7.6^2)} = 1088 \text{ #/FT-CIRC}$$

WEIGHTS RESISTING UPLIFT

FROM SHELL, $W_T = \frac{W_s}{\pi D} = \frac{2438}{\pi (7.6)} = 102 \text{ #/FT}$

FROM LIQUID, $W_L = 1.25 G H D = 1.25 (1.0) 25 (7.6) = 238 \text{ #/FT}$

Where G = SP Grav of contents

FROM REACTOR, $W_R = \frac{3500}{\pi D} = 148 \text{ #/FT}$

$\Sigma W = 102 + 238 + 150 = 490 \text{ #/FT}$

SHELL COMPRESSION, f_a (BOTTOM COURSE ONLY!)

$b = W_T + W_U = 102 + 1078 = 1180 \text{ #/FT CIRC}$

$f_a = \frac{b}{12t} = \frac{1180}{12(1.25)} = 393 \text{ PSI}$

ALLOWABLE SHELL COMPRESSION, F_a

PER API

$$F_a = \frac{10^6 t}{2.5 D} + 600 \sqrt{GH} = \frac{10^6 (1.25)}{2.5 (7.6)} + 600 \sqrt{1.0 (25)}$$

$= 16,158$ but not greater than $.5 F_y$

$.5 F_y = .5 (16,000) = 8000 \text{ PSI}$

W	gas/mol
C ₁	8.60
C ₂	9.87
C ₃	10.44
IC ₁	12.40
C ₄	11.95
IC ₂	13.88
C ₅	13.74
IC ₃	15.3
C ₆	15.59
IC ₄	17.2
C ₇	17.49
C ₈	19.41
C ₉	9.84
C ₁₀	9.87

MISC	gas/mol
CO ₂	6.47
H ₂ S	5.18
N ₂	4.18
H ₂	3.38

ALLOWABLE LONG COMPRESSION PER ASME

REF: UG-23

$$B = \frac{AE}{2} = \frac{.00006 (9.8 \times 10^6)}{2} = 294 \text{ PSI}$$

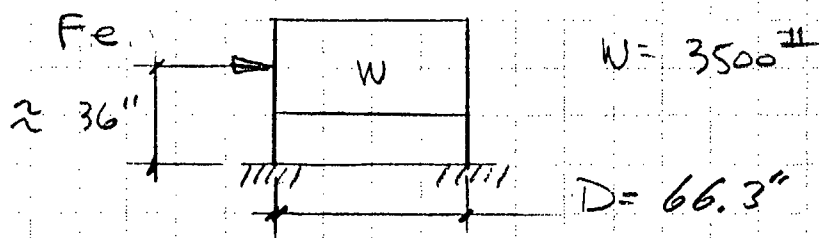
IF THE BOTTOM COURSE WERE INCREASED TO $\frac{3}{8}$ " THK THAN THE LONG COMPRESSION BECOMES

$$f_a = \frac{D}{12t} = \frac{1166}{12(.375)} = 259 < 294 \text{ OK}$$

∴ INCREASE BTM 8' OF SHELL TO $\frac{3}{8}$ " THK

10.0 TANK BOTTOM DESIGN

ASSUME A .2G FORCE APPLIED TO REACTOR FOR SEISMIC OCCURANCE



$$F_e = .2(3500) = 700 \#$$

$$M_t = 36 (700) = 25200 \text{ in-lbs}$$

MW	gals/mol
16	C ₂ 8.40
30	C ₃ 9.67
44	C ₄ 10.44
58	IC ₄ 12.40
72	C ₅ 13.88
86	C ₆ 15.5
100	IC ₆ 17.2
114	C ₇ 17.99
128	C ₈ 19.41
142	C ₉ 20.64
156	C ₁₀ 22.67

MISC	MW	gals/mol
	CO ₂	8.47
	H ₂ S	5.18
	H ₂	4.16
	N ₂	3.58

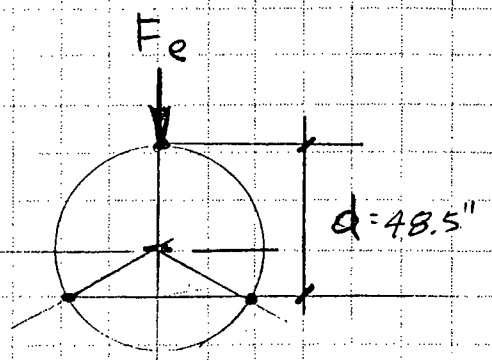
TANK BTM DESIGN (CONT)

MAX COMP. FORCE, f

$$f = \frac{W}{N} - \frac{4 M t}{N d}$$

$$= \frac{3500}{3} - \frac{4(25,200)}{3(48.5)}$$

= 1859 # CONCENTRATED LOAD (MAX)

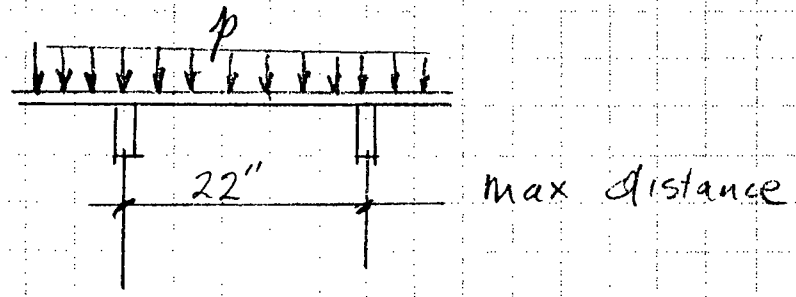


UNIFORM LOAD, p , PSI

$$p = \frac{F}{\pi R^2} = \frac{70,324}{\pi (44.75^2)} = 11.18 \text{ PSI}$$

Where F = TOTAL WT OF WATER = 70324 #

Since the tank bottom rests on the ribs and the ribs in turn on the bottom assume a 1" wide section of the tank bottom acting as a beam, uniformly loaded and both edges simply supported.



MW	gas/mol
18	C ₁ 8.40
30	C ₂ 9.87
44	C ₃ 10.44
58	IC ₄ 12.40
86	C ₄ 11.99
72	IC ₅ 13.88
86	C ₅ 13.74
86	IC ₆ 15.5
86	C ₆ 15.59
100	IC ₇ 17.2
100	C ₇ 17.49
14	C ₈ 19.41
28	C ₉ 9.64
42	C ₉ 9.87

MISC	MW	gas/mol
44	CO ₂	8.47
	H ₂	5.18
	N ₂	4.18
	H ₂	3.38

TANK BTM DESIGN (CONT)

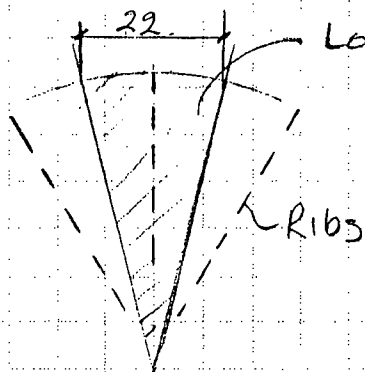
MAX MOMENT ; $M = \frac{w l^2}{8} = \frac{10(22^2)}{8} = 605 \text{ in-lbs}$

STRESS, $f_b = \frac{M}{Z} = \frac{6(605)}{1} = 3630 \text{ PSI OK}$

where $Z = \frac{bh^2}{6} = \frac{1.0(1^2)}{6} = \frac{1}{6}$

Allow STRESS bending = $.6 F_y = .6(16) = 9600 \text{ PSI}$

Assuming a uniformly loaded square section



LOAD AREA = 30° SECTION
 $= 398 \text{ in}^2$
 $= 20 \times 20$

UTILIZING ROARK, TABLE 26; CASE 1

$a/b = 1 \therefore \beta = .2874$
 $\alpha = .0444$
 $\gamma = .420$

Max Stress $\sigma = \frac{\beta q b^2}{t^2} = \frac{.2874(10) 20^2}{1^2} = 1150 \text{ PSI}$

MAX Deflection $y = \frac{-\alpha q b^4}{E t^3} = \frac{-.0444(10) 20^4}{9.8 \times 10^6 (13)} = .0072$

MW	gals/mol
16	C ₁ 8.40
30	C ₂ 9.87
44	C ₃ 10.44
58	IC ₄ 12.40
72	C ₅ 11.95
86	IC ₆ 13.88
100	C ₇ 13.74
114	IC ₈ 15.5
128	C ₉ 15.59
142	IC ₁₀ 17.2
156	C ₁₁ 17.49
170	C ₁₂ 18.21
184	C ₁₃ 18.84
198	C ₁₄ 19.67

MISC	MW	gals/mol
**	CO ₂	6.47
	H ₂ S	5.18
	N ₂	4.18
	H ₂	3.38

1	gal/mi
2	C ₁ 6.90
3	C ₂ 9.67
4	C ₃ 10.44
5	IC ₁ 12.40
6	C ₄ 11.99
7	IC ₂ 13.88
8	C ₅ 13.74
9	IC ₃ 15.3
10	C ₆ 15.59
11	IC ₄ 17.2
12	C ₇ 17.49
13	C ₈ 19.41
14	C ₉ 9.64
15	C ₁₀ 9.87

TANK BTM DESIGN (CONT)

FOR THE CONCENTRATED LOAD THERE IS A RIB DIRECTLY UNDER EACH ANCHOR PT OF THE REACTOR. THIS LOAD WOULD BE TRANSMITTED DIRECTLY TO THE FOUNDATION. THE RIB/TANK BTM COMPOSITE WOULD BE IN DIRECT COMPRESSION THERE...

$$\sigma_c = \frac{F}{A} = \frac{1859 \#}{3.1 \text{ in}^2} = 620 \text{ PSI OK}$$

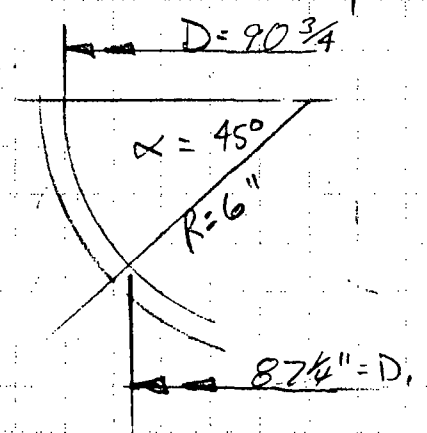
THICKNESS REQD FOR THE FLANGED ONLY PORTION OF HEAD;

MAX Long. Load, $f_1 = 1180 \#/\text{FT}$ (from p.14)

$$f = \frac{1180}{12} = 98 \text{ lb/in Compression}$$

Equivalent pressure (@ 45°, $D_1 = 86"$)

$$P_1 = P + \frac{4f}{D_1} = 10.83 + \frac{4(98)}{87\frac{1}{4}} = 15.32 \text{ PSI}$$



$$L_1 = \frac{D_1}{2 \cos \alpha} = \frac{87\frac{1}{4}}{2 \cos 45^\circ} = 61.7$$

$$m = .25 \left(3 + \sqrt{\frac{L_1}{R}} \right) = .25 \left(3 + \sqrt{\frac{61.7}{90\frac{3}{4}}} \right) = .96$$

MISC
gal/mi
CO ₂ 6.47
H ₂ 5.18
N ₂ 4.18
H ₂ 3.34

MW	gals/mol
16	C ₁ 8.40
20	C ₂ 9.87
44	C ₃ 10.44
68	IC ₄ 12.40
16	C ₅ 11.98
7	IC ₆ 13.88
7	C ₇ 13.74
66	IC ₈ 15.5
66	C ₉ 15.59
100	IC ₁₀ 17.2
20	C ₁₁ 17.49
1	C ₁₂ 19.41
8	C ₁₃ 9.84
42	C ₁₄ 9.87

TANK PJTM (CONT.)

Req'd thickness of knuckle

$$t_{rk} = \frac{P_1 L_1 M}{2SE - 2P} = \frac{1546(61.7) \cdot 96}{2(7500)1.0 - 2(1546)} = .061" \quad \text{USE } 3/8" \text{ THK}$$

CIRCUMFERENTIAL STRESS IN KNUCKLE @ D₁

REF (A) pp 68,69

Compression w/ LOADS ...

$$\sigma_c = \frac{P L_1}{t} - \frac{P_1 L_1}{t} \left[\frac{L_1}{2R} \right] = \frac{10.83(61.7)}{.375} - \frac{1546(61.7)}{.375} \left[\frac{61.7}{2(6)} \right] = (-) 11,297 \text{ PSI}$$

Compression w/o LOADS ...

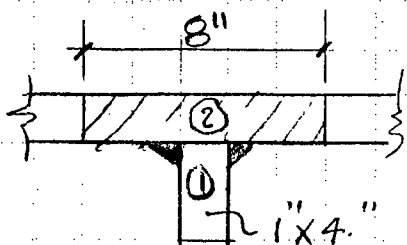
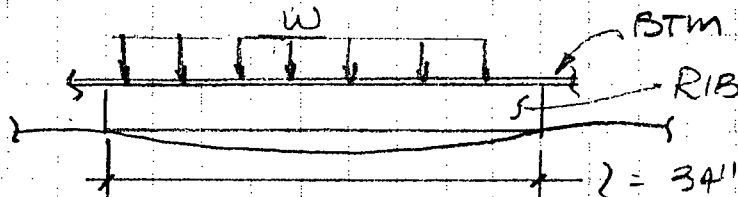
$$\sigma_c = \frac{P L_1}{t} \left(1 - \frac{L_1}{2R} \right) = \frac{10.83(61.7)}{.375} \left(1 - \frac{61.7}{12} \right) = (-) 7380 \text{ PSI}$$

FAILURE WOULD OCCUR BY LOCAL YIELDING RATHER THAN BUCKLING ∴ A HIGHER ALLOWABLE STRESS IS WARRANTED. BEDNAR RECOMMENDS THE LESSER OF 2SE OR F_y.

$$\sigma_c < 2SE < F_y \quad \therefore \text{STRESS IS ACCEPTABLE}$$

TANK BTM (CONT)

IN THE EVENT THE FOUNDATION OF THE TANK BOTTOM IS NOT LEVEL THERE IS A CHANCE THAT THE RIBS WILL NOT REST UNIFORMLY ON THE FOUNDATION OR PREVIOUS TANK LINER. THIS COULD RESULT IN SOME BENDING IN THE RIBS WELDED TO THE UNDER SIDE OF THE TANK. AS AN APPROXIMATION OF BENDING A UNIFORM LOAD IS ASSUMED ACROSS THE RIB AS A BEAM



	A	Y	AY	AY ²	I
①	4	1	4	4	.666
②	8	2.5	20	50	.666
Σ	12		24	54	1.33

$$C = \frac{\sum AY}{\sum A} = \frac{24}{12} = 2.0"$$

$$I = \sum AY^2 + \sum I - C \sum AY$$

$$= 54 + 1.33 - 2.0(24) = 7.33 \text{ in}^4$$

$$W = \frac{Ap}{L} = \frac{298 \text{ in}^2 (10.16 \text{ lb/in}^2)}{34"} = 88 \text{ \#/in}$$

$$M = \frac{W L^2}{8} = \frac{88 (34^2)}{8} = 12,716 \text{ in-lb}$$

$$\sigma_b = \frac{M c}{I} = \frac{12,716 (2.4)}{7.33} = 4163 \text{ PSI OK}$$

gas/mol

C ₁	8.40
30 C ₂	9.67
44 C ₃	10.44
58 IC ₄	12.40
C ₅	11.95
IC ₆	13.88
C ₇	13.74
64 IC ₈	15.3
64 C ₉	15.59
70 IC ₁₀	17.2
C ₁₁	17.48
C ₁₂	19.41
C ₁₃	9.84
42 C ₁₄	9.67

MISC

CO ₂	6.47
H ₂ S	5.18
N ₂	4.18
H ₂	3.24

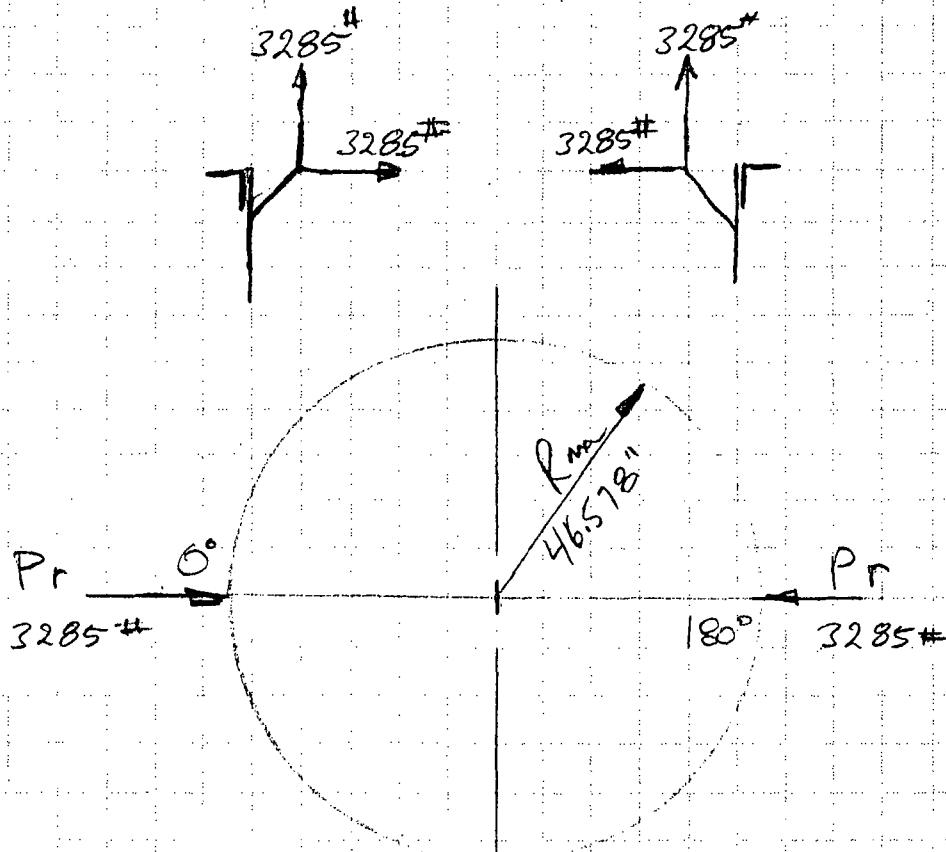
11.0 TOP J RING

SINCE THERE IS NO ROOF CONNECTED TO THE TOP OF THE TANK AND NO WIND LOAD THE ONLY LOADING ON THE TOP RING IS INDUCED DURING ERECTION BY THE LIFTING LUGS.

DEAD WT OF TANK = 2900#

IMPACT FACTOR = 1.5

LOAD PER LIFT LUG = $1.5 (3285) \div 2 = 2464 \#$



RING LOADING

	gas/mol
C ₁	8.90
C ₂	9.87
C ₃	10.44
IC ₁	12.40
C ₄	13.33
IC ₂	13.88
C ₅	13.74
IC ₃	13.53
C ₆	13.59
IC ₄	17.2
C ₇	17.49
C ₈	18.41
E ₁	24.4
C ₉	24.7

MISC

gas/mol	
CO ₂	0.47
H ₂ S	5.18
N ₂	4.18
H ₂	3.38

MW	gals/mol
6	C ₁ 6.40
20	C ₂ 9.87
44	C ₃ 10.44
58	IC ₄ 12.40
6	C ₄ 11.98
2	IC ₅ 13.88
7	C ₆ 13.74
58	IC ₆ 15.3
58	C ₇ 15.59
100	IC ₇ 17.2
0	C ₈ 17.49
4	C ₉ 18.41
8	C ₁₀ 9.84
42	C ₁₁ 9.67

TOP RING (CONT)

PER REF (5) THE INTERNAL BENDING MOMENT DUE TO RADIAL LOADS IS . . .

$$M = \sum (k_r P_r) R_m =$$

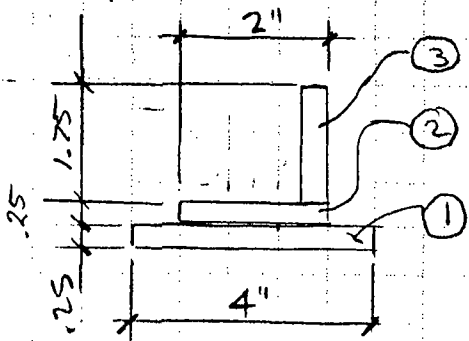
$$k_r @ 0^\circ = -.2387 (2464) = -588$$

$$k_r @ 180^\circ = +.0796 (2464) = +196$$

$$-392$$

$$M = \sum (k_r P_r) R_m = -392 (47.2) = (-) 18,500 \text{ in-lbs}$$

PROPERTIES OF TOP RING . . .



EQUIVALENT SECTION

	A	Y	AY	AY ²	I
①	.125	.125	.015	.005	
②	.5	.375	.1875	.0703	.0026
③	.4375	1.375	.6016	.8271	.1117
Σ	1.9375	1.1642	.9124	.1195	

$$C = \frac{\Sigma AY}{\Sigma A} = \frac{1.1642}{1.9375} = .6009$$

$$I = \Sigma AY^2 + \Sigma I - C \Sigma AY$$

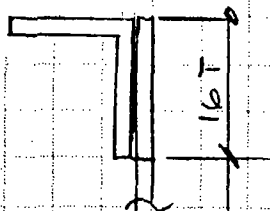
$$= .8271 + .1195 - .6009 (.6016)$$

$$= .5851 \text{ in}^4$$

$$D_b = \frac{MC}{I} = \frac{18500 (.6009)}{.5851} = 18,999 \text{ PSI}$$

$$F_b = .6 F_y = .6 (16) = 9600 \text{ PSI}$$

MUST USE SPREADER TO LIFT

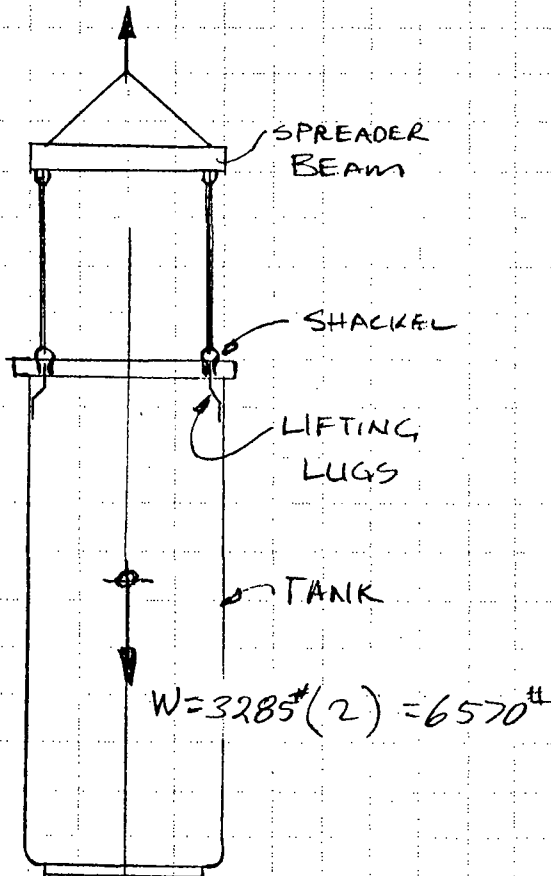


ACTUAL TOP SECT

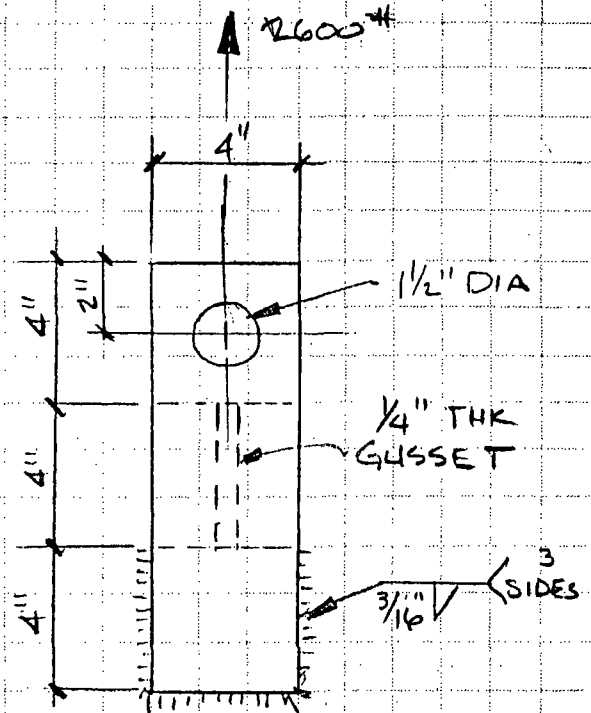
MW	gals/mol
CO ₂	8.47
H ₂ S	5.19
N ₂	4.18
H ₂	3.58

W	gas/mol
1	C ₂ 8.40
30	C ₂ 9.87
44	C ₂ 10.44
58	IC ₂ 12.40
	C ₂ 11.95
	IC ₂ 13.88
	C ₂ 13.74
86	IC ₂ 15.5
96	C ₂ 15.59
100	IC ₂ 17.2
	C ₂ 17.49
	C ₂ 19.41
	C ₂ 9.84
42	C ₂ 9.87

12.0 LIFTING LUGS



LIFTING PLAN



NOTE: THE DESIGN OF THE TOP J RING MAKES IT MANDATORLY THAT A SPREADER BEAM BE USED IN LIFTING. TO NOT DO SO COULD DAMAGE THE TANK RIM!

WELDS

ALLOW STRESS FOR FILLET WELDS IN SHEAR

Assume 1/3 OF TENSILE strength = .2(30KSI) = 6KSI

∴ 3/16" FILLET HAS SHEAR AREA/INCH = .1875 in²

MISC	gas/mol
CO ₂	8.47
H ₂	5.18
N ₂	4.18
H ₂	3.38

LIFTING LUGS (CONT)

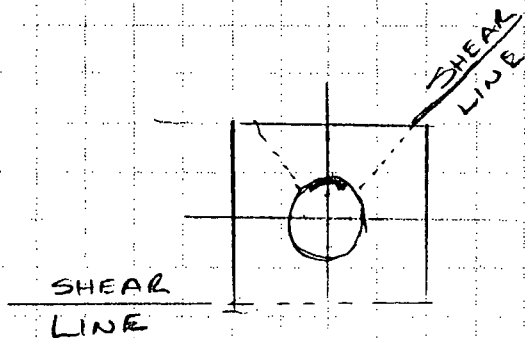
∴ THE ALLOWABLE LOAD / INCH OF WELD

$$6 \text{ KSI} \times .1875 \text{ in}^2 = 1.125 \text{ KIPS}$$

EACH LUG HAS 12" OF 3/16" WELD

$$\therefore 12 (1.125) = 13.5 \text{ KIPS} > 2.6 \text{ OK}$$

SHEAR AREA



SHEAR AREA:

Length of
 $.25 \times 4 = 1 \text{ in}^2$

$$2(.25) 1.25 = .625 \text{ in}^2$$

$$\tau = \frac{F}{A} = \frac{3285}{.625} = 5256 \text{ PSI}$$

$$\text{ALLOW SHEAR} = .4 F_y = .4 (16000) = 6400$$

∴ THE DESIGN IS ACCEPTABLE PROVIDING THE SHACKLE PIN IS AT LEAST 1" DIA.

W	gas/mol
1	C ₁ 8.40
30	C ₂ 9.87
44	C ₃ 10.44
58	IC ₁ 12.40
72	C ₄ 11.93
86	IC ₂ 13.88
100	C ₅ 13.74
114	IC ₃ 15.5
128	C ₆ 15.59
142	IC ₄ 17.2
156	C ₇ 17.49
170	C ₈ 19.41
184	C ₉ 19.84
198	C ₁₀ 21.87

MW	gas/mol
44	CO ₂ 8.47
32	H ₂ O 5.18
2	H ₂ 4.18
28	N ₂ 3.38

13.0

THERMAL EXPANSION

$$\text{ALUMINUM 6061} = 13.5 \times 10^{-6} \text{ in/in/}^{\circ}\text{F}$$

$$\text{TANK DIA.} = 90"$$

$$\text{TANK PERIMETER} = 282.74"$$

It is assumed the size of the existing tank will not vary in size do to thermal expansion because of the concrete backing. The new tank liner will expand from room temperature, $\approx 70^{\circ}\text{F}$ to a maximum of 150°F .

$$(282.74) \text{ in } (150 - 70)^{\circ}\text{F} \cdot 13.5 \times 10^{-6} \frac{\text{in}}{\text{in}^{\circ}\text{F}} = .31 \text{ in}$$

Causing a diameter change of:

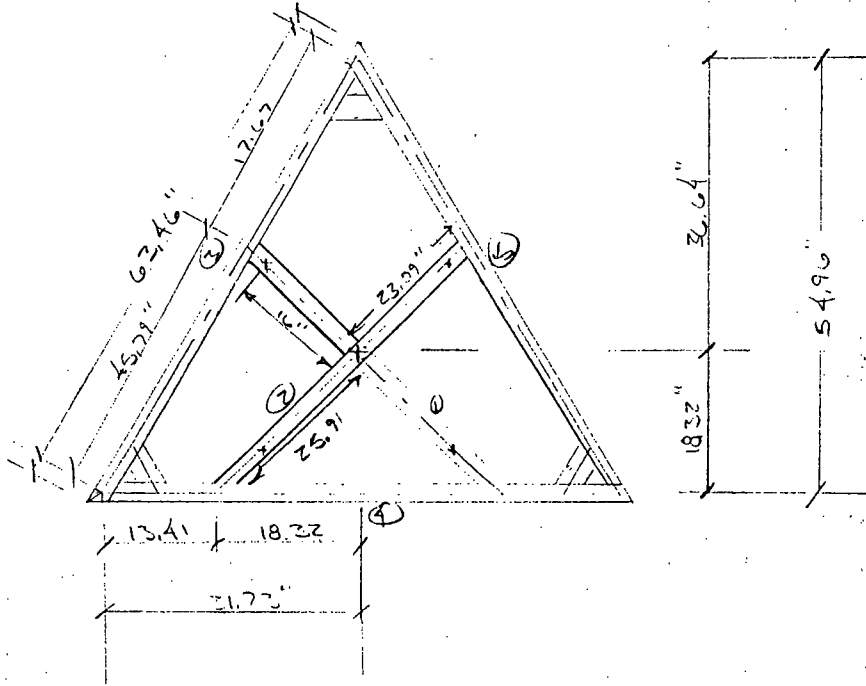
$$((282.74 + .31) / \pi) - (90) = .10 \text{ in}$$

Use a gap of $\frac{1}{8}"$ between the guides of the tank liner and the existing tank.

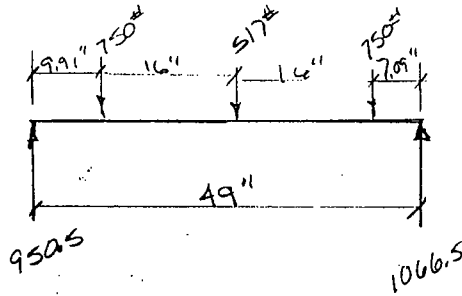
REACTOR LEVELING STAND

14.0

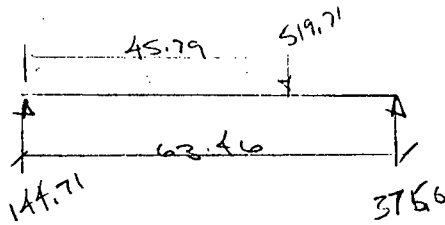
22-141 50 SHEETS
22-142 100 SHEETS
22-144 200 SHEETS



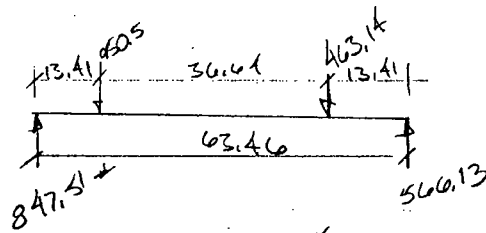
BEAM #2



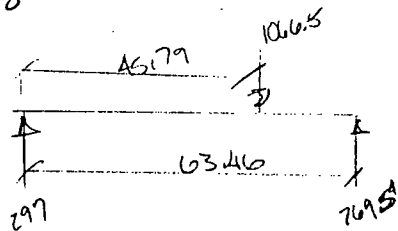
BEAM #3



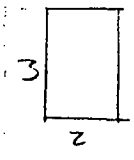
BEAM #4



BEAM #5



14.0 CONT.

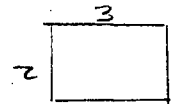


2x3 BAR

$$S = \frac{2 \cdot 3^2}{6} = 3.0 \text{ in}^3$$

$$f_b = \frac{13,598}{3} = 4533 \text{ psi}$$

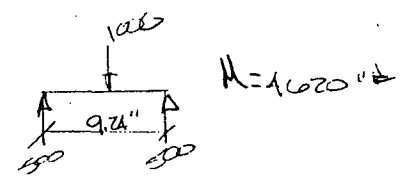
$$F_b = 7500 \text{ psi}$$



$$S = \frac{3 \cdot 2^2}{6} = 2.0 \text{ in}^3$$

$$f_b = \frac{13,598}{2} = 6799 \text{ psi} < F_b$$

CROSS MEMBER



WELDS

ALLOW STRESS FOR FILLET WELDS IN SHEAR

ASSUME 1/2 OF TENSILE STRENGTH = 2 (30KSI) = 6KSI

3/16" Fillet has shear area/inch = 1.1875 in²

∴ Allow Load per inch of WELDS

$$6 \text{ KSI} \times 1.1875 \text{ in}^2 = 11.25 \text{ K}$$

EACH CORNER HAS 10" OF 3/16" WELD

$$\therefore 10 \times (1.125) = 11.25 \text{ K} > 1 \text{ K}$$

ADJUSTING BOLTS

FROM MARK'S STANDARD HANDBOOK FOR MECH. ENG.

SECTION 8, TABLE 31 FOR THREAD LOAD

USE 1" ALUMINUM BOLT.

14.0 CONT.

FROM 10.0 OF THESE CALCULATIONS:

$F_e = 700\#$ SIDE LOAD DUE TO SEISMIC
ASSUME A MAXIMUM EXTENSION OF ADJUSTING
BOLT OF $3\frac{1}{2}"$ INCLUDING $1\frac{1}{2}"$ OF NON ADJUSTABLE
SPACE.

ALLOW STRESS BENDING $= .6 F_y = 21,000 \text{ psi}$

USE $1"$ BOLT $(F_y = 35,000)$

$$D = 0.8444" \text{ - (MIN. BOLT DIA.)}$$

$$S = .098175 D^3 = 0.0591$$

$$M = 3.5 \times \left(\frac{700}{3}\right) = 817 \text{ in-lb}$$

(3 EXTENSION BOLTS TO BE USED)

$$T = \frac{M}{S} = 13,822 \text{ psi}$$

USE $1"$ ALUMINUM BOLTS

15.0 PUMP TUBES

6" PUMP TUBE UNDER EXTERNAL PRESSURE

$$L = 240"$$

$$D_o = 6"$$

$$t = .125$$

$$\frac{L}{D_o} = 40$$

$$\frac{P_o}{t} = 48$$

FROM ASME SECT VIII, DIV. I FIG UG-28.0

$$A = .0005$$

$$B = 2500$$

$$P = \frac{4B}{3\left(\frac{P_o}{t}\right)} = 69 \text{ psi}$$

OK

3" PUMP TUBE UNDER EXTERNAL PRESSURE

$$L = 60"$$

$$D_o = 3"$$

$$t = .125$$

$$\frac{L}{D_o} = 20$$

$$\frac{P_o}{t} = 24$$

$$A = .002$$

$$B = 8500$$

$$P = 472 \text{ psi}$$

PER ASME UG-36 (c) - NOZZELS 3" OR LESS
 IN HEADS 3/8" THICK OR LESS DO NOT
 REQUIRE REINFORCEMENT.

22-141 50 SHEETS
 22-142 100 SHEETS
 22-144 200 SHEETS

