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UNION ELECTRIC

Donald F. Schnell
Senior Vice President
Nuclear

December 18, 1990

U. S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Mail Station P1-137
Washington, D.C. 20555

Gentlemen: ULNRC- 2344

DOCKET NUMBER 50-483
CALLAWAY PLANT
SEISMIC DESIGN OF SAFETY-RELATED ABOVE-GROUND
VERTICAL LIQUID STORAGE TANKS

References:
1. NRC Request for Information letter, J. N. Hannon to D. F. Schnell, dated 5-23-89
2. ULNRC-2077 dated 9-21-89
3. NRC Request for Additional Information letter, S. V. Athavale to D. F. Schnell, dated 4-4-90
4. ULNRC-2237 dated 6-25-90
5. NRC Request for Additional Information letter, A. T. Gody, Jr. to D. F. Schnell, dated 10-5-90

The attachments to this letter provide the information requested in Reference 5 regarding the seismic design of the Refueling Water Storage Tank (RWST) at Callaway. The revised information further supports our determination that the RWST's seismic design is adequate.

If you have any questions regarding these attachments, please contact us.

Very truly yours,

Donald F. Schnell

Donald F. Schnell

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STATE OF MISSOURI)
)   S S
CITY OF ST. LOUIS)

Donald F. Schnell, of lawful age, being first duly sworn upon oath says that he is Senior Vice President-Nuclear and an officer of Union Electric Company; that he has read the foregoing document and knows the content thereof; that he has executed the same for and on behalf of said company with full power and authority to do so; and that the facts therein stated are true and correct to the best of his knowledge, information and belief.

By Donald F. Schnell
Donald F. Schnell
Senior Vice President
Nuclear

SUBSCRIBED and sworn to before me this 18th day of December, 1990.

Barbara J. Pfaff

BARBARA J. PFAFF
NOTARY PUBLIC, STATE OF MISSOURI
MY COMMISSION EXPIRES APRIL 22, 1993
ST. LOUIS COUNTY

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RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION REGARDING SEISMIC REANALYSIS OF VERTICAL STEEL TANKS FOR CALLAWAY PLANT

QUESTION 1:

During the audit performed by the staff on February 14, 1990, at Bechtel in Gaithersburg, Md., a handout for the presentation was provided. Provide the information contained in both Tables 2 and 3 including any other changes to the handout resulting from the reanalysis.

RESPONSE:

The handout presented to the NRC during the audit on February 14, 1990 has been updated to indicate the subsequent results of the reanalysis. Attachment 2 provides the revised handout. Pages 18, 19, 26, 28 (Table 2), 29, and 31 (Table 3) of 31 have been revised as indicated by revision bars on these pages. New pages 20 and 30 are due to text "carryover" from changes to previous pages.

Changes were made to Table 2, Flexible Analysis, Shell Course 6 OBE calculated and allowable stresses. The calculated stress was revised to reflect the use of the licensed OBE level of 0.12g rather than the previous use of 0.13g. The allowable stress was revised to reflect a more accurate interpolation of values from Figure VII-1102-4 of the ASME Code, 1974 Edition through Winter 1975 Addenda.

The Table 3 value for shear in a typical slab strip, calculated using flexible analysis, was revised per the response to Question 3 below.

QUESTION 2:

Provide the maximum stress values (due to sloshing) in the angle welds at the roof-cylinder junction with stresses combined from three components of earthquake (SSE). Also, provide a comparison of these stress values with the allowables.

QUESTION 2 (cont.)

RESPONSE:

The maximum force on the ¼ inch circumferential fillet weld of the steel angle connecting the tank roof to the tank cylinder was calculated with consideration given to the sloshing effects during an earthquake. A comparison f the calculated maximum force with the allowable force is known below:

CALCULATED MAXIMUM FORCE (KIPS/INCH)	ALLOWABLE FORCE (KIPS/INCH)
0.0253	3.00

QUESTION 3:

Provide a summary of the maximum stresses in the base slab (rebar and concrete) including those under the sump. Also, provide a comparison of the maximum stresses with the allowables.

RESPONSE:

The table below provides values of the allowable moments and shears at various sections of the base slab and the corresponding maximum design values. The maximum design values are based on factored loads and the allowable values are based on nominal strength multiplied by strength reduction factors in accordance with the American Concrete Institute code (ACI 318-1983).

LOCATION	ALLOWABLE MOMENT (KIP-FT/ft)	MAXIMUM DESIGN MOMENT (KIP-FT/ft)	ALLOWABLE SHEAR (KIPS/ft)	MAXIMUM DESIGN SHEAR (KIPS/ft)
1 Typical base slab strip	216.57	174.2	79.35	63.5
2 Slab strip around the sump pit	568.3	494.0	79.35	74.5
3 Sump pit slab (2'6" thick)	88.5	13.2	32.9	11.9

QUESTION 4:

In response to question 2(a) of the staff's RAI dated April 4, 1990, you indicated that, because of the static friction between the tank bottom and the concrete slab, the bolts will not experience any shear load. This cannot be justified unless slotted or oversized bolt holes are used to allow for tank bending and flexibility. Provide maximum calculated stresses in bolts under the three components of earthquake (SSE), in pure tension as well as when tension and shear are combined (if applicable). Provide a comparison of these stresses with allowables.

RESPONSE:

As requested in Reference 3 and reported in Reference 4, the anchor bolt analysis was revised using classical methods to be consistent with the foundation analysis. The analysis for transmitting shear loads from the tank to the foundation was also revised to consider the static friction between the tank bottom and the concrete footing. With consideration given to this static friction, it was demonstrated that tank sliding will not occur and, therefore, the anchor bolts will not experience any shear loads.

The tank base is anchored to the foundation by 2 inch diameter anchor bolts and the base plate is provided with 3 ½ inch diameter holes for the bolts. Since oversized bolt holes are used, the static friction utilized in the analysis for transferring shear loads is justified. Based upon the above, the anchor bolts have been adequately evaluated for pure tension resulting from uplift loads. The maximum tension load calculated in any anchor bolt under the three components of the earthquake (SSE) is 9.864 kips; the corresponding allowable tension per anchor bolt is 50.625 kips.

REVISED FEBRUARY 14, 1990 HANDOUT

CALLAWAY & WOLF CREEK

RWST SEISMIC ANALYSIS

1. TANK MODEL - MASS

   1 MASS FOR CONVECTIVE (SLOSHING) EFFECTS

   1 MASS FOR BASE SLAB

   9 MASS POINTS FOR SHELL AND IMPULSIVE COMPONENTS OF FLUID

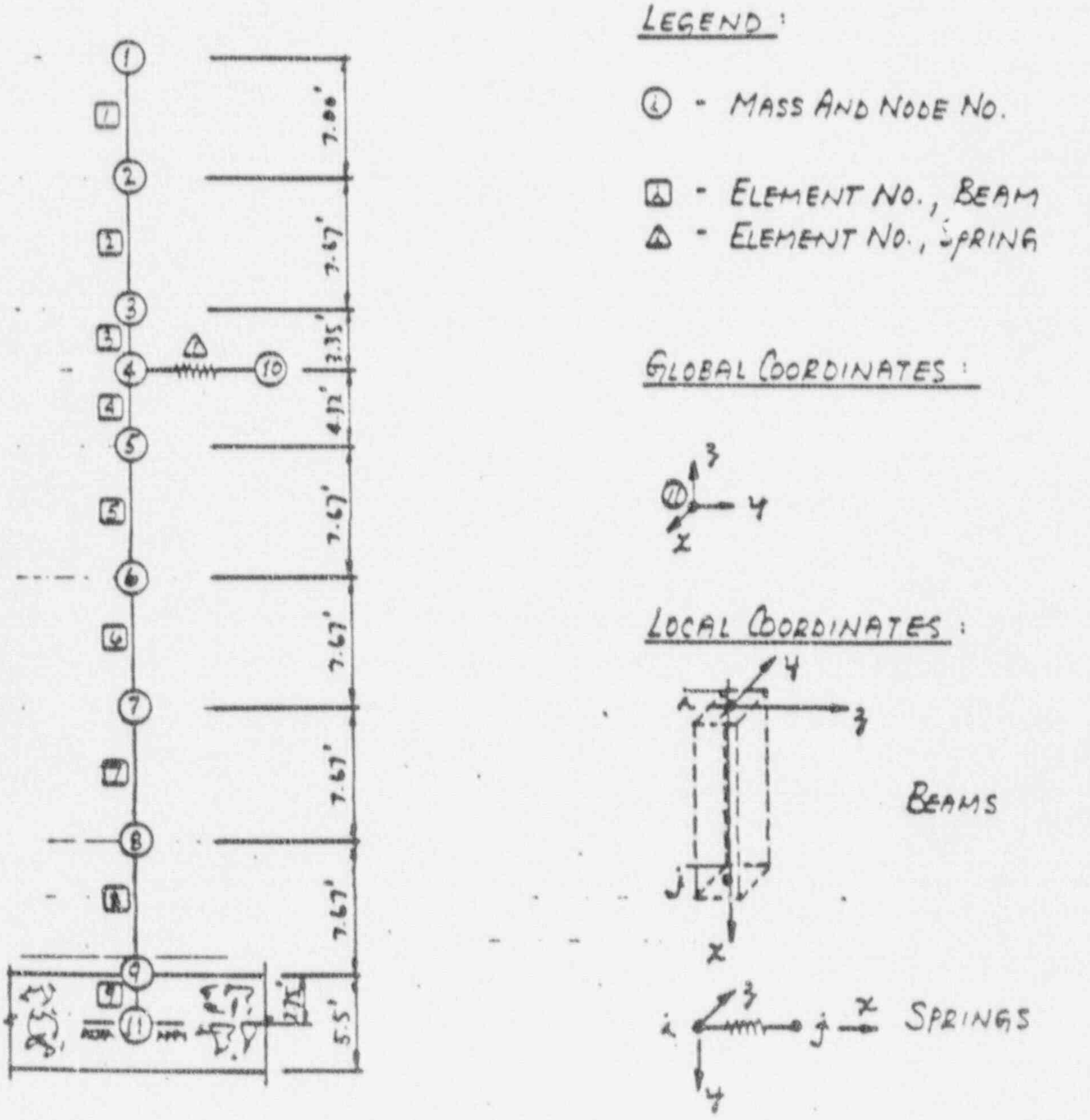
CALCULATION SHEET

JOB NO.	CALC. NO.	REV. NO.	SHEET NO.
14894	C-1989-130	0	7

ORIGINATOR	DATE	CHECKED	DATE
[signature]	6-29-89	J.C. Oleinik	7-11-89

B. ANALYTICAL / COMPUTER MODELS:

1. FIXED-BASE LUMPED MASS MODEL:



SUMMARY OF MASS POINT WEIGHTS:

POINT	WEIGHTS (K) HORIZONTAL	VERTICAL
1	8	8
2	12	12
3	6	6
4	4	725 *
5	9	9
6	2859	2859
7	18	18
8	20	20
9	36	36
10	721	0 *
11	1210	1210
Σ =	4903^K	4903^K

* THE CONVECTIVE WATER WILL BE LUMPED AT NODE 4 FOR THE VERTICAL ANALYSIS. THIS IS ACCEPTABLE FOR THE VERTICAL DIRECTION SINCE SLOSHING DOES NOT OCCUR.

NOTE:

THE PREVIOUS ANALYSES, BY THE VENDOR (REFERENCES 12-14), CONSERVATIVELY INCLUDED AN ADDITIONAL ROOF LOAD (SNOW LL AT 73 PSF, 91.734^K) AT MASS POINT ①. CONSISTENT WITH THE SNUPPS CRITERIA AND BUILDING ANALYSES (REFERENCES 27-29), THIS LOAD NEED NOT BE INCLUDED IN THE SEISMIC ANALYSIS.

CALCULATION SHEET

JOB NO.	CALC. NO.	REV. NO.	SHEET NO.
14894	C-1989-130	0	31

ORIGINATOR	DATE	CHECKED	DATE
George DeStefano	7-13-89	J.C. Olinik	7-14-89

SUMMARY OF LUMPED MASS PARAMETERS:

MASS No.	WEIGHT $(W_i)^K$	HEIGHT ABOVE BASE (l_i) ft	$(W_i)(l_i)^2$ k-ft²	I_i k-ft²	IW_i k-ft²
①	8	55.77	24882	863	25745
②	12	48.77	28542	1617	30159
③	6	41.10	10135	1084	11219
④	4	37.75	5700	754	6454
⑤	9	33.43	10058	1686	11744
⑥	2859	25.76	1897169	2768	1899937
⑦	18	18.09	5891	3514	9405
⑧	20	10.42	2172	4015	6187
⑨	36	2.75	272	2008	2280
⑩	721	37.75	1027470	0	1027470
⑪	1210	0	0	151797	151797
Σ =	4903		3012291	170106	3182397

TOTAL $IW_i = I_o^H = 3,182,397$ k·ft² (BOTH HORIZONTAL DIRECTIONS)

$\therefore I_o^H = \frac{3182397}{32.2} = 98832$ k·ft·sec²

RWST SEISMIC ANALYSIS

1. TANK MODEL - STIFFNESS

   STRUCTURE - 3D BEAMS
   (TANK SHELL ONLY)

   BASE SLAB - 3D BEAM

   CONVECTIVE (SLOSHING)
   EFFECTS - SPRING

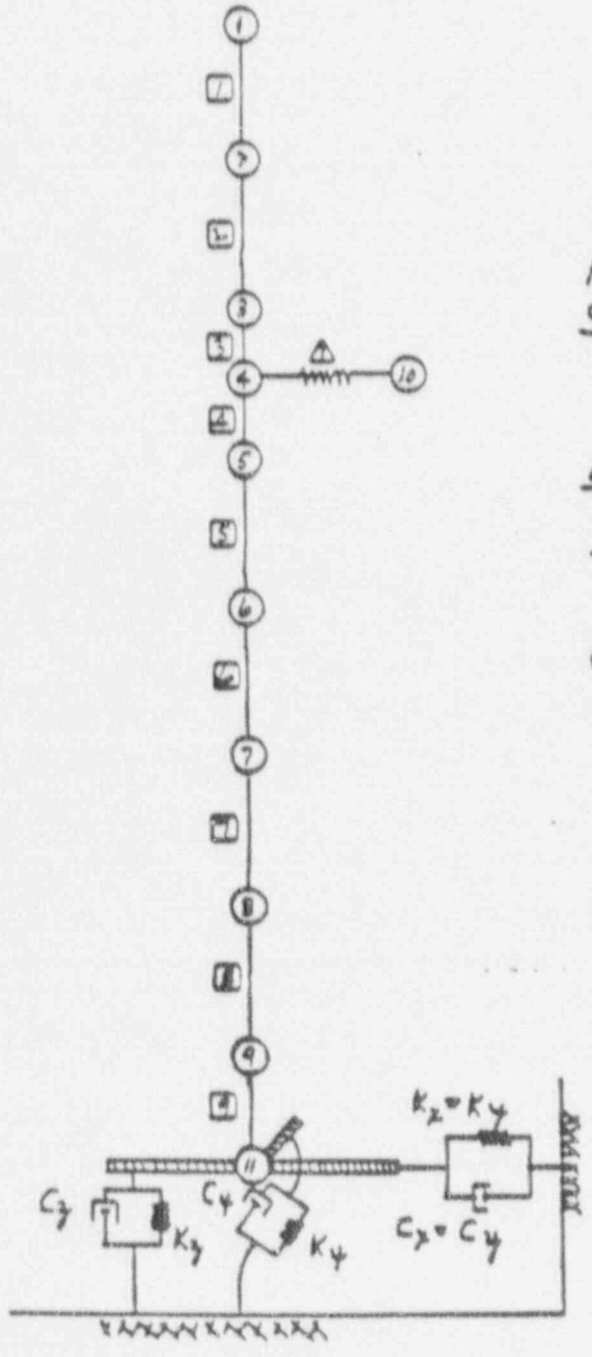
   SOIL - SPRINGS

CALCULATION SHEET

JOB NO.	CALC. NO.	REV. NO.	SHEET NO.
14894	C-1989-130	0	8

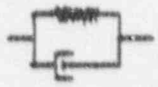
ORIGINATOR	DATE	CHECKED	DATE
[signature]	6-29-89	[signature]	7-11-89

2. <u>LUMPED MASS MODEL OF STRUCTURE-FOUNDATION SYSTEM</u>:



FOR INFORMATION NOT SHOWN, SEE SHEET NO. 7

<u>LEGEND</u>:

 SOIL SPRINGS AND DAMPERS

(MODEL USING BOUNDARY ELEMENTS)

SUMMARY OF MEMBER PROPERTIES :

MEMBER NUMBER	AREA (ft^2)	(1) SHEAR AREAS (ft^2) NS	EW	AREA MOMENTS OF INERTIA (ft^4) NS	EW
1	4.202	2.101	2.101	488	488
2	1.9627	0.982	0.982	392	392
3	1.9627	0.982	0.982	392	392
4	1.9627	0.982	0.982	392	392
5	3.27	1.635	1.635	653	653
6	3.924	1.962	1.962	784	784
7	5.231	2.6155	2.6155	1044	1044
8	5.231	2.6155	2.6155	1044	1044
9	1500	1350	1350	184397	184397

(1) SHEAR AREAS ARE TAKEN AS ½ AREA FOR TANK SHELL PER REFERENCE 31. FOR SLAB, SHEARS ARE TAKEN AS 0.9 AREA PER REFERENCE 31 ASSUMING A CIRCULAR SOLID SECTION.

DUE TO SYMMETRY, TORSION WILL NOT OCCUR. THE COMPUTER RUNS, HOWEVER, REQUIRE AN INPUT FOR J (TORSIONAL MOMENT OF INERTIA) TO EXECUTE. AS SUCH, EITHER THE CALCULATED VALUES OF C OR A FICTIOUS VALUE (OF 1.0 ft^4) WILL BE INPUT.

H. MATERIAL PROPERTIES:

DENSITY, OF CONCRETE $\gamma_c = W = 145$ pcf
OF STEEL $\gamma_s = 490$ pcf

YOUNG'S MODULUS, OF CONCRETE(1) $E_c = 524757$ Ksf
OF STEEL $E_s = 4176000$ Ksf

WHERE $E_c = (W)^{1.5}(33)\sqrt{f'_c} = (145)^{1.5}(33)\sqrt{4000}$ psi (2)

SHEAR MODULUS, OF CONCRETE(3) $G_c = 209903$ Ksf
OF STEEL $G_s = 1612800$ Ksf

WHERE $G_c = 0.4\,E_c$

POISSON'S RATIO, FOR CONCRETE $\nu_c = 0.25$
FOR STEEL $\nu_s = 0.30$

WHERE ν_c IS BASED ON THE RELATIONSHIP BETWEEN E_c AND G_c

DAMPING,(4) STRUCTURE $\xi = 2\%$ (OBE)
$= 4\%$ (SSE)
. CONVECTIVE FLUID (REFERENCE 3) $= 1/2\%$

(1) SEE SECTION 8.5.1 OF REFERENCE 24.
(2) SEE REFERENCE 22.
(3) SEE PAGE 137 OF REFERENCE 26.
(4) PERCENT OF CRITICAL DAMPING FOR A WELDED STEEL STRUCTURE FROM REFERENCE 25.

RWST SEISMIC ANALYSIS

1. TANK MODEL - DAMPING

BASED ON SNUPPS FSAR
(REG.GUIDE 1.61)

STEEL TANK
OBE - 2%
SSE - 4%

CONVECTIVE FLUID
1/2 %

SOIL
(BASED ON SNUPPS
EHS/FEA STUDY APPROACH)

RWST SEISMIC ANALYSIS

2. FOUNDATION MEDIUM

- NRC SUGGESTION TO USE SIMPLIFIED APPROACH

- CONSISTENT WITH EHS/FEA STUDY

- RICHERT EQUATIONS

- LAYERING BASED ON WEIGHTED AVERAGE (DEPTH = BASE DIM.)

- USED DYNAM (BSAP FAMILY OF COMPUTER PROGRAMS

( ))

CALCULATION SHEET

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ONE BASE DIMENSION = (2)(21'-4") = 42'-8" ; USE 43'

SITE SPECIFIC SOIL PROFILES ARE:

CALLAWAY (Grade; 43'; 15')

- ACCRETION GLEY — $\gamma = 127$ pcf, $\nu = 0.47$, G (@ $\varepsilon = 0.0001\%$) = 1670 ksf — 15'
- GLACIAL TILL — $\gamma = 134$ pcf, $\nu = 0.47$, G (@ $\varepsilon = 0.0001\%$) = 2900 ksf — 13'
- GRAYDON CHERT CONGLOMERATE — $\gamma = 158$ pcf, $\nu = 0.39$, G (@ $\varepsilon = 0.0001\%$) = 18900 ksf — 32'
- BURLINGTON, BUSHBERG AND SYNDER CREEK FORMATIONS — $\gamma = 160$ pcf, $\nu = 0.42$, G = 67109 ksf — 41'
- BEDROCK

WOLF CREEK (7.5')

- JACKSON PARK SANDSTONE — $\gamma = 125$ pcf, $\nu = 0.3$, G = 29000 ksf — 9'
- UPPER HEUMADER SHALE — $\gamma = 135$ pcf, $\nu = 0.4$, G (@ $\varepsilon = 0.0001\%$) = 5000 ksf — 18.5'
- LOWER HEUMADER SHALE — $\gamma = 150$ pcf, $\nu = 0.35$, G (@ $\varepsilon = 0.0001\%$) = 15000 ksf — 12'
- PLATTSMOUTH LIMESTONE — $\gamma = 165$ pcf, $\nu = 0.30$, G = 270000 ksf — 12.5'
- HEEBNER, LEAVENWORTH AND SYNDERVILLE FORMATIONS — $\gamma = 140$ pcf, $\nu = 0.3$, G = 58000 ksf — 16'
- TORONTO LIMESTONE — $\gamma = 160$ pcf, $\nu = 0.30$, G = 270000 ksf — 15.5'
- BEDROCK

FOR CALLAWAY:

$$\gamma_a = \frac{\Sigma \gamma_i H_i}{\Sigma H_i} = \frac{(127)(15)+(134)(13)+(158)(15)}{43} = 133 \text{ pcf}$$

$$\nu_a = \frac{\Sigma \nu_i H_i}{\Sigma H_i} = \frac{(0.47)(15)+(0.47)(13)+(0.39)(15)}{43} = 0.442$$

$$G_a = \frac{\Sigma G_i H_i}{\Sigma H_i} = \frac{(1670)(15)+(2900)(13)+(18900)(15)}{43} = 8052 \text{ Ksf}$$

INCORPORATE THE +/- 50% ON THE VALUE OF G_a.

RWST SEISMIC ANALYSIS

3. SUMMARY OF RESPONSE

MODES:

FREQ. RANGE (Hz)	*MODE*	*EFFECTIVE MASS*
.22	*(CONVECTIVE)*	*15%*
4.6/6.2	*(1ST HORIZ)*	*70%*
8.4/13.1	*(1ST VERT)*	*93%*

RWST SEISMIC ANALYSIS

4. TREATMENT OF MODES

HORIZONTAL DIRECTIONS

- HYDRODYNAMIC COMPUTED PER NUREG CR-1161 (SRSS OF IMPULSE, SLOSHING AND VERTICAL MODES

- HYDROSTATIC & HYDRODYNAMIC SUMMED ABS

RWST SEISMIC ANALYSIS

4. TREATMENT OF MODES

HORIZONTAL DIRECTIONS:
(CONTINUED)

- ONE HORIZ. ANALYSIS (DUE TO SYMMETRY)
- 2ND HORIZ. DIRECTION IS 40% OF FIRST
- ADDED NOZZLE LOADS FROM SEPARATE ANALYSIS FOR EACH DIRECTION

RWST SEISMIC ANALYSIS

4. TREATMENT OF MODES (CONTINUED)

- COMBINED TWO HORIZ. DIRECTIONS AS VECTOR SUM

- VERTICAL DIRECTION CONSERVATIVELY ADDED ABS TO HORIZ

- USED MULTIMODE APROACH TO COMBINE ALL MODES IN A SPECIFIC DIRECTION

RWST SEISMIC ANALYSIS

5. SLOSHING HEIGHT

- BASED ON NUREG CR-1161
- CONSIDERED ROOF STRESSES
  - SNOW LOAD CONTROLLED

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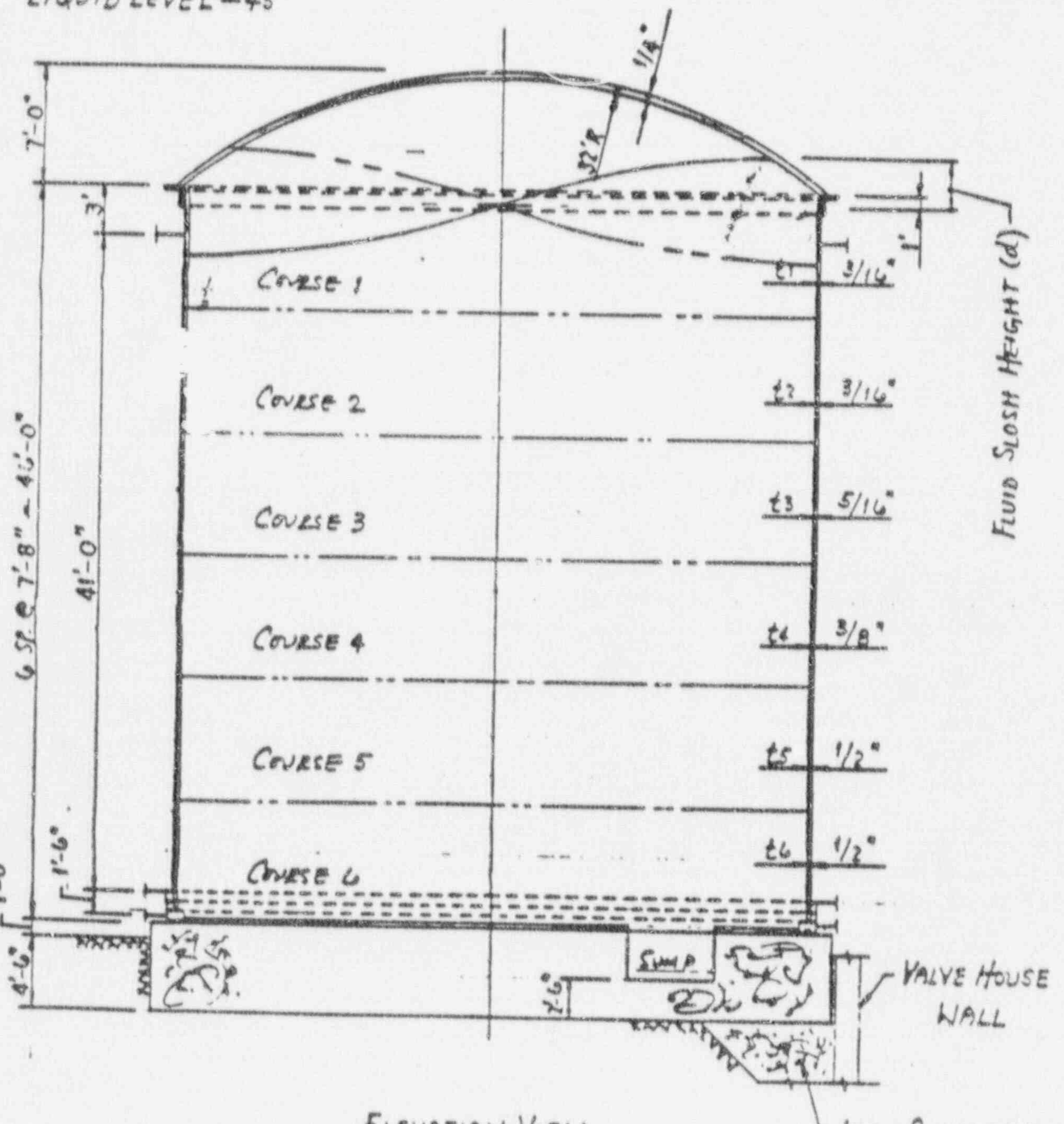
A. SKETCHES (CONTINUED):

LIQUID LEVEL ≈ 45'



ELEVATION VIEW
(SEE REFERENCES 12, 14 AND 22)

RWST SEISMIC ANALYSIS

6. UPLIFT POTENTIAL

- ANALYSIS BY CLASSICAL METHOD INDICATES UPLIFT (I.E. TENSION IN BOLTS)

- TANK DISPLACEMENTS CONSIDERED IN PIPE ANALYSIS

RWST SEISMIC ANALYSIS

7. OVERTURNING MOMENTS

- CONTROLLING CASES
  - FULL TANK W/SEISMIC
  - EMPTY TANK W/WIND
- BOLTS DESIGN PER CLASSICAL METHOD, BOLTS TAKE TENSION LOAD ONLY
- SHEAR LOAD TRANSFERRED TO CONCRETE FOOTING BY STATIC FRICTION BETWEEN TANK BOTTOM AND CONCRETE (OVERSIZED HOLES PROVIDED

RWST SEISMIC ANALYSIS

IN TANK BASE TO JUSTIFY THE ABOVE)

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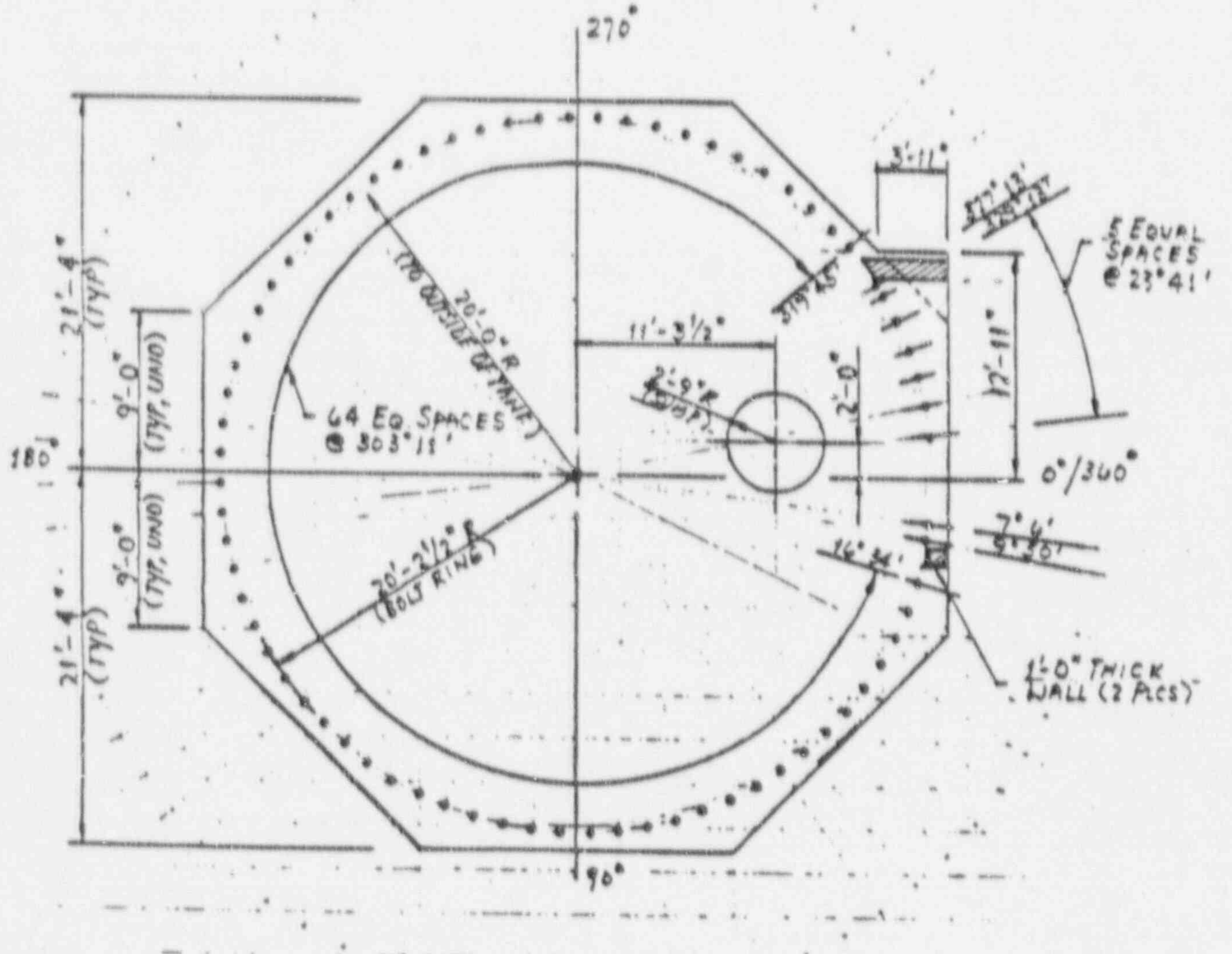
[signature]	6-29-89	J.C. [signature]	7-11-89

IV. DESIGN CALCULATIONS:

A. TANK/FOUNDATION ARRANGEMENT SKETCHES: (REFS. 12-18 AND 22)



PLAN VIEW.
(FROM REFERENCE 22)

RWST SEISMIC ANALYSIS

8. STRESSES IN SHELL

- BASED ON ORIGINAL SPEC. FOR TANKS

- ASME SECTION III SUBSECTION NC

RWST SEISMIC ANALYSIS

9. SUMMARY - HOOP STRESS RIGID ANALYSIS:

   -ONLY HYDROSTATIC PRESSURES CONSIDERED

   -PRESSURES COMPUTED AT BASE OF EACH COURSE

RWST SEISMIC ANALYSIS

FLEXIBLE ANALYSIS:

-HYDRODYNAMIC AND HYDROSTATIC PRESSURES WERE CONSIDERED

-PRESSURES COMPUTED ONE FOOT ABOVE BASE OF EACH COURSE

THICKNESS REQUIREMENTS COMPARED IN TABLE 1

TABLE 1

Comparison Of Required Shell Course Thicknesses (inches)

Shell Courses	Computed Required Thickness Rigid Analysis	Computed Required Thickness Flexible Analysis	Actual Thickness
1	0.0520	0.1875 *	0.1875
2	0.1041	0.1875 *	0.1875
3	0.1563	0.2179	0.3125
4	0.2083	0.2789	0.3750
5	0.2605	0.3418	0.5000
6	0.3126	0.4061	0.5000

* Minimum Requirements Govern

RWST SEISMIC ANALYSIS

9. SUMMARY - ROOF DESIGN

- SLOSH HEIGHT OF 3.36 FT (CALCULATED PER NUREG CR-1161)

- PREVIOUS DESIGN LOADS (ROOF SNOW LOADS) CONTROL

- CONNECTION WELD BETWEEN TANK ROOF AND CYLINDER JUNCTION CHECKED

RWST SEISMIC ANALYSIS

9. SUMMARY - COMPRESSION

-SEISMIC GOVERNED OVER WIND

-SSE CONTROLLED RIGID ANALYSIS

-FLEXIBLE ANALYSIS CONSIDERED OBE AND SSE

COMPRESSION STRESSES COMPARED IN TABLE 2

TABLE 2

Comparison Of Longitudinal Compression Stresses (PSI)

Shell Courses	Rigid Analysis		Flexible Analysis	
	Stress	Allowable	Stress	Allowable
1	*	---	124 (----)	2698 (1484)
2	*	---	165 (----)	2698 (1484)
3	1912	3307	140 (----)	4200 (2310)
4	2925	3933	2670 (----)	5400 (2970)
5	**	---	4273 (2749)	7000 (3850)
6	4235	4964	6584 (3927)	7000 (3960)

* Signifies Negligible
** Course 5 was enveloped by Course 6

In flexible analysis, OBE values are given in parenthesis. Values shown as (----) were not computed since SSE stress was less than the OBE allowable.

RWST SEISMIC ANALYSIS

9. SUMMARY - FOUNDATION

- SOIL PRESSURES

- SHEAR AND MOMENT IN BASE SLAB EVALUATED

- SHEAR AND MOMENT IN BASE SLAB ADJACENT TO SUMP PIT EVALUATED

- SHEAR AND MOMENT IN SUMP PIT SLAB (2'-6"THICK) EVALUATED

RWST SEISMIC ANALYSIS

-COMPARISONS PROVIDED IN TABLE 3

TABLE 3

Foundation Comparisons

Item of Comparison	Rigid Analysis	Flexible Analysis	Allowable
Static Soil Pressure (ksf)	3.36	3.27	20.00
Dynamic Soil Pressure (ksf)	7.81	15.14	30.00
Shear in Typ. Slab Strip (Vu in Kips/FT)	49.90	63.5	79.35
Moment in Typ. Slab Strip (Mu in Kip-Ft/Ft)	107.90	174.20	216.57
Shear in Slab Strip around the Sump Pit (Vu in Kips/ft)	-	74.5	79.35
Moment in Slab Strip around the Sump Pit (Mu in Kip-FT/ft)	-	494.0	568.3
Shear in 2'-6" thick Sump Pit Slab (Vu in Kips/ft)	-	11.9	32.9
Moment in 2'-6" thick Sump Pit Slab (Mu in kip-FT/ft)	-	13.2	88.5