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CREEP AND CRACKING ANALYSES OF
THE 241-BY-112 REINFORCED CONCRETE,
UNDERGROUND WASTE STORAGE TANK

F. R. Vollert

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CREEP AND CRACKING ANALYSES OF
THE 241-BY-112 REINFORCED CONCRETE,
UNDERGROUND WASTE STORAGE TANK

F. R. Vollert

General Plant and Utilities Engineering
Facilities Engineering Department
Chemical Processing Division

August 6, 1973

Operated for the Atomic Energy Commission by
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CREEP AND CRACKING ANALYSES OF
THE 241-BY-112 REINFORCED CONCRETE,
UNDERGROUND WASTE STORAGE TANK

INTRODUCTION

The 241-BY Tank Farm, located in 200 East Area of the Hanford Project, was designed and constructed in 1948-1949. The 241-BY Tank Farm has 12 reinforced concrete, underground waste tanks, numbered 241-BY-101 to 112. Each tank has an inside, $3/8$ inch thick carbon steel liner, for containment of liquid wastes. The capacity of each tank is 758,000 gallons. The reinforced concrete design drawings for the 241-BY Tank (H-2-1312, H-2-1314, and H-2-1315) are reproduced in this report.

The 241-BY Tank Farm was originally used to store liquid radioactive wastes with temperatures about 200° F. For approximately the last five years, the Waste Management Program has had the In-Tank Solidification Unit #2 (ITS-2) installed in the 241-BY-112 Tank. With ITS-2, this tank has operated with a liquid temperature of 250° F most of the time. Currently, Operations Support Engineering of Atlantic Richfield Hanford Company believes that ITS-2 could operate more effectively if the liquid in the 241-BY-112 Tank were heated to 280° F. Thus, the subject structural analyses were undertaken to predict how the tank structure responds to the 250° F and the proposed 280° F liquid temperatures. More specifically, the goals of these analyses were:

- Make a quantitative determination and evaluation of the time dependent creep, cracking, and stresses experienced to date by the 241-BY-112 reinforced concrete structure due to its surrounding soil load and the 250° F temperature history; and
- Predict and evaluate future time-dependent creep, cracking, and stresses in the 241-BY-112 concrete structure that would occur if ITS-2 operated with 280° F liquid in the tank.

CONCLUSIONS

Based on the analyses results presented herein, the 241-BY-112 reinforced concrete tank structure, with 7 feet of soil cover and operating with 250° F to 280° F liquid contents will experience thermal expansion, and time-dependent creep and cracking. However, the time-dependent cracking is shown to essentially stop progressing when the tank reaches a steady state temperature. The tank structure is stable and has sufficient structural capacity for safe, long-term operation under the temperature and load conditions assumed for these analyses. The conclusions here have the condition that the tank structure experiences no thermal shock, i.e., rapid changes in temperature.

METHOD OF ANALYSIS

Both elastic and time-dependent nonlinear analyses of the axisymmetric, composite (reinforced concrete) 241-BY-112 structure for sustained mechanical and thermal loadings are required to satisfy the goals listed in the introduction. A finite element structural analysis computer code called SAFECRACK has been developed to do such analyses (reference 1).

The development of SAFECRACK was supported by the U. S. Atomic Energy Commission in order to provide the means for comprehensive structural analyses of prestressed concrete reactor vessels. The code is applicable and was used for the subject analyses of the 241-BY-112 reinforced concrete (no prestressing) tank structure.

The SAFECRACK analyses allowed the 241-BY-112 Tank structure to be idealized as a composite system of kinematically dissimilar finite elements, i.e., of concrete and bonded reinforcement elements.* The finite element idealization of the waste tank used is described as follows.

CONCRETE ELEMENTS

The concrete body of the waste tank structure was subdivided into a mesh of triangular, axisymmetric finite elements. The mesh of concrete elements is shown in Figure 1. The haunch region of the tank is represented as a somewhat finer mesh because this region is most important to the structural behavior of the tank. Note in Figure 1

* The 3/8 inch carbon steel liner in the 241-BY-112 Tank, while critical to the containment integrity of the tank, is articulated from the concrete shell and does not contribute to the structural capacity of the tank. Thus, the liner was excluded from the finite element idealization of 241-BY-112.

that the base of the concrete cylinder (the cylinder to footing juncture) is assumed fixed; only vertical deflections are possible in the dome at the centerline (axis of symmetry) of the structure.

STEEL REINFORCEMENT

Uniaxial steel reinforcement elements are laid out on the boundaries of certain concrete elements. Thus, deformations of the steel elements are compatible with deformations of the concrete elements. Engineering judgment was exercised, and the effort was to make the idealized system of steel elements structurally approximate the tank reinforcing as closely as possible.

STRUCTURAL LOADS, 241-BY-112 WASTE TANK

The following items discuss the three types of structural loads (soil, hydrostatic, and thermal) that are superimposed on the 241-BY-112 structure.

SOIL COVER LOADS

The 241-BY-112 Tank is completely buried with compacted backfill, and the minimum depth of soil cover, at the dome crown, is seven feet. The density of the soil is assumed to be 120 pcf.

HYDROSTATIC LOADS

The cylinder walls of the 241-BY-112 Tank are subjected to hydrostatic pressure due to a 23 foot maximum depth of liquid contents. The specific gravity of the liquid was assumed for these analyses to be 1.25.*

THERMAL LOADS

Elevated temperature distributions in the 241-BY-112 Tank can be expected to produce thermal strains, stresses, creep, and cracking in the reinforced concrete structure. These temperature distributions, i.e., thermal loads, result from the 250° F (and 280° F, if used) liquid temperatures in the tank. Heat transfer analyses were required

* The 1.25 specific gravity value was obtained from: ARH-R-43 REV, November 1969, R. W. Harvey, "A Review of Tank Farm Management Practices." Upon completion of the 241-BY-112 analyses, the writer was informed that the specific gravity of 241-BY-112 liquid was 1.45-1.50. However, the tank is not operated with a full 23 foot liquid depth; thus, the hydrostatic pressures based on a 1.25 specific gravity are representative.

and performed to determine the thermal loads in the 241-BY-112 structure when operating with 250° F and 280° F liquid. The report describing the heat transfer analyses and giving the results is attached as the appendix to this document.

MATERIAL PROPERTIES

The material properties for the 241-BY-112 structure required for these analyses, and the respective values used for them are listed below:

Concrete Modulus of Elasticity	- 3.0×10^6 psi
Steel Modulus of Elasticity	- 30.0×10^6 psi
Concrete Coefficient Thermal Expansion	- 6.0×10^{-6} in/in°F
Steel Coefficient Thermal Expansion	- 6.0×10^{-6} in/in°F
Concrete Poisons Ratio	- 0.160
Steel Poisons Ratio	- 0.300
Concrete Uniaxial Tensile Strength	- 300 psi
Concrete Compressive Strength	- 3000 psi
Reinforcing Steel Yield Stress	- 33,000 psi

SCOPE OF THE ANALYSES

The objectives or goals of the creep and cracking analyses of the reinforced concrete 241-BY-112 Tank structure (using SAFECRACK) were given in the introduction. Based on these goals, the scope or plan for conducting these analyses was formulated as follows:

1. Perform an elastic analysis of the waste tank structure (assuming zero days time) for the soil backfill in place; the hydrostatic load, and the temperature at 65° F uniform (i.e., free from thermal stresses).
2. Perform nonlinear, time-dependent analyses of the backfilled, liquid filled tank structure, assuming that the tank is heated in 50 days at a uniform rate from 65° F to the 250° F liquid temperature condition (250° F is referred to as 90 percent of a 280° F maximum liquid temperature).

3. Continue nonlinear, time-dependent analyses of the tank structure holding the 250° F liquid temperature condition until creep, cracking, and stress changes with time become small or stop.
4. Perform additional nonlinear, time-dependent analyses of the tank structure assuming that the tank is heated in 20 days at a uniform rate from 250° F liquid to 280° F liquid temperature condition.
5. Continue nonlinear, time-dependent analyses of the tank structure holding the 280° F liquid temperature condition; predicting the safe operating life of the structure at this temperature or until creep, cracking, and stress changes with time become small or stop.

RESULTS

This discussion and Figures 2 through 10 present the results of the creep and cracking analyses of the 241-BY-112 Tank structure, performed per the scope outlined above.

The initial elastic analysis of the 241-BY-112 reinforced concrete structure showed the tank to be in compression due to the soil back-fill, except for some tension in and on the outside surface of the haunch, and in the cylinder. In Figure 2, the zero days deflected shape was constructed from the results of the elastic analysis. The stresses in the concrete and steel reinforcement of the unheated, buried tank were calculated to be nominal.

The results of the nonlinear, time-dependent analyses, per items 2 and 3 of the scope, are: heating the liquid to 250° F causes the tank structure to expand; some cracking of the concrete in the haunch and cylinder results from the heating; operating with 250° F causes the concrete to creep (reducing the expansion) and some additional cracking; by 900 days total time (50 days of which are heatup), the time dependent creep and cracking at 250° F have nearly ceased. In Figure 2, the 25, 50, and 900 days deflected shapes show the structures expansion with heatup, and the subsequent creep. Figures 4, 5, 6, 7, and 8 show the progressive cracking predicted for the 250° F liquid temperature history. These figures show that most of the concrete cracking occurs in the lower cylinder portion of the tank. The Figure 2 deflected shapes are indications that the predicted lower cylinder cracking is influenced by the assumption of a fixed cylinder base. The tank cylinder was constructed fixed to the base, but the base would also expand radially with temperature. Thus, it is believed that a conservative estimate of the cracking in the lower cylinder is given here.

Analyses per items 4 and 5 of the scope were then continued. The tank structure was analytically heated from the 250° F to the 280° F liquid temperature condition in the period 900 to 920 days. Then the tank was assumed to operate at the 280° F liquid condition until 1,900 days total time. The results are: heating the liquid from 250° F to 280° F will cause a small amount of additional expansion and concrete cracking; limited creep and cracking in the concrete continue as the tanks operate with 280° F liquid; time dependent creep and cracking will nearly cease before 1,900 days total time. In Figure 3, the 900, 920, and 1,900 days deflected shapes show a minor perturbation caused by raising the liquid temperature from 250° F to 280° F. A comparison of Figures 9 and 10, the concrete cracking diagrams for 920 and 1,900 days, with Figure 8 shows that very little additional cracking is predicted for the 280° F liquid temperature.

DISCUSSION

There are several other factors related to the 241-BY-112 structural capacity which should be weighed by personnel responsible for any engineering judgments and operating decisions based on the above presented analyses, results, and conclusions. These are discussed in the following.

CONCRETE COMPRESSIVE STRENGTH

The compressive strength of concrete is known to decrease at elevated temperatures (reference 2). The modulus of elasticity for concrete should also decrease at elevated temperature (reference 3). Data in reference 2 indicate that the compressive strength of 3,900 psi concrete made with siliceous aggregate would be reduced to about 90 percent original strength at 300° F. Data in reference 3 indicate that the modulus of elasticity of 4,000 psi concrete would be reduced to about 85 percent original value at 300° F.

CONCRETE CREEP PROPERTIES

The creep data formulated currently in the SAFE CRACK code for concrete is experimental, but no data for temperatures over 200° F is included. In other words, for any concrete 200° F and higher, the code uses 200° F creep properties for analysis. Since creep rates in concrete increase with temperature and much of the 241-BY-112 concrete is over 200° F, the creep deformations calculated by the analyses would be some less than actual. However, this should not invalidate the results and conclusions given because increasing the compressive creep would bring the deflected shape of the structure closer to the original, before thermal expansion; concrete creep, after the time length associated with these analyses, will nearly halt; and the amount of and nature of reinforcement steel in the 241-BY-112 structure will limit creep.

LONG-TERM DURABILITY

Long-term durability of concrete, i.e., no significant loss of structural properties with age, was assumed for these analyses of the 241-BY-112 Tank structure. This assumption was made because generally concrete compressive strength increases (beyond 28 day strength) with age. Concrete occasionally will have relatively short durability. In practice, some of the causes of this that have been noted are: chemical reaction between the aggregate and the alkali in cement, exposure to severe freeze-thaw conditions; and extensive cracking due to heat of hydration. The latter problem is usually only a concern for massive concrete pours. No reasons for suspecting concrete durability problems with the 241-BY-112 structure are known.

LIQUID CONTAINMENT

The results and conclusions of the structural analyses reported here indicate that the 241-BY-112 reinforced concrete shell structure (for the operating conditions considered) will support and encase the inner 3/8-inch carbon steel liner. However, the cracking predicted for the reinforced concrete structure means that the concrete structure could not be counted on to maintain containment of liquid waste if the steel liner were breached by some mechanism such as corrosion.

TEMPERATURE LOAD DATA

The heat transfer analysis (see appendix) which supplied the temperature load data used for these structural analyses of 241-BY-112 is dependent on a number of assumptions about soil thermal conductivity, vapor space temperature, etc. The instrumentation in the 241-BY Tank Farm does not include thermocouples in the locations necessary to verify the results of the heat transfer analysis.

REFERENCES

1. GA-9994, March 23, 1970, Y. R. Rashid, Gulf General Atomic Inc., "Nonlinear Quasi - Static Analyses of Two-Dimensional Concrete Structures"
2. Paper SP 25-2, M. S. Abrams, Portland Cement Association, "Compressive Strength of Concrete at Temperatures to 1600° F"
3. Research Department Bulletin 191, C. R. Cruz, Portland Cement Association, "Elastic Properties of Concrete at High Temperatures"

QUARTER PLAN OF TANK FLOOR
SCALE 3" = 1'-0"

SPECIFICATIONS
REINFORCEMENT OBTAINED FROM
BILLET STEEL, IMMEDIATE
GRADE ASTM SPEC A15-37
CONCRETE CONCRETE FOR BASE FOOTING
AND WALL SHALL HAVE MINIMUM
ADJUSTABLE COMPRESSIVE STRENGTH
OF 4,000 PSI AT 28 DAYS
MAXIMUM SIZE AGGREGATE 1/2"
WHERE THE AGGREGATE AND CEMENT PASTE SHALL BE
PLACED IN THE FORM AND THE FORMS
SHALL BE REINFORCED

TYPICAL WALL & FOOTING
SECTION

NOTE:
PROVIDE 3 ANCHORS PER FILASTER @ 24" C-C.
TOTAL REQ'D: 182 FOR 21 FILASTERS.

REQD	RENT	SIZE	LENGTH	FT IN	MARK	SPACE
12TAUXS	TANA					
1464	122	3 9	47	0	440	
120	10		33	3	433-3	
96	8		33	4	433-4	
96	8		33	0	433	
48	4		32	3	432-3	
48	4		32	3	432-3	
48	4		31	10	431-10	
48	4		31	4	431-4	
48	4		30	9	430-9	
48	4		30	3	430-3	
48	4		29	7	429-7	
48	4		29	10	429-10	
48	4		28	5	428	
48	4		27	1	427-1	
48	4		26	6	426-6	
48	4		25	2	425-2	
48	4		24	0	424	
48	4		22	10	422-10	
48	4		21	3	421-3	
48	4		20	2	420-2	
48	4		18	8	418-8	
48	4		17	1	417-1	
48	4		15	4	415-4	
48	4		13	6	413-6	
48	4		11	6	411-6	
48	4		9	3	409-3	
48	4		7	0	407	
48	4		4	6	404-6	
48	4		3	6	403-6	
48	4		23	2	423-2	
48	4		23	3	423-3	
48	4		10	9	410-9	
1440	120		5	0	405	

172	6	1° 8	20	0	351°	FAL	35° 10'
12	1	1° 0	7	0	352°	FAL	35° 10'
172	6	1° 9	40	0	353°	FAL	36° 4'
12	1	1° 0	12	0	354°	FAL	36° 4'
144	12	1° 9	40	0	355°	FAL	37° 0'
36	3	1° 0	16	0	356°	FAL	37° 0'
144	12	1° 9	40	0	357°	FAL	37° 0'
24	2	1° 0	31	0	358°	FAL	37° 0'
144	12	1° 9	40	0	359°	FAL	38° 8'
24	2	1° 0	47	0	361°	FAL	38° 8'
144	12	1° 9	40	0	361°	FAL	38° 8'
24	2	1° 0	31	0	362°	FAL	38° 8'
144	12	1° 9	40	0	363°	FAL	39° 16'
24	2	1° 0	36	0	364°	FAL	39° 16'
168	12	1° 9	44	0	365°	FAL	39° 16'
168	12	1° 9	40	0	367°	FAL	40° 0'
24	2	1° 0	30	0	368°	FAL	40° 0'

-960	82	1	8	60	0	560	12	55	2	55	2	55	2
120	10	1	1	13	4	317-4	22	44	1	4	1	4	1
120	10	1	8	60	0	315-3	22	44	1	4	1	4	1
2496	203	30	60	0	760	24	55	2	55	2	55	2	55
312	26	3	1	17	3	717-3	22	44	1	4	1	4	1
512	26	2	1	12	7	712-7	22	44	1	4	1	4	1

5760	130	33	25	1	625-2	5-11-37
4320	360	44	11	2	6A1	2-3-
2880	240	34	11	2	6A2	

WILKINSON	139	VARIED	3	PT
ADAMS	138			
	137			

2-1/2" x 1/4" STEEL PLATE

WEIGHT OF REINFORCING STEEL
1 TANK 24.91 TONS
12 TANKS 298.2 TONS
WEIGHT OF STRUCTURAL STEEL
1 TANK
12 TANKS

ELEV. 601.92 TANK 101, 104, 107, 110, 111
 ELEV. 600.92 TANK 102, 105, 108, 111
 ELEV. 599.92 TANK 103, 106, 109, 112

NOTE:
PROVIDE 3 ANCHORS PER FILASTER @ 24" C-C.
TOTAL REQ'D: 182 FOR 21 FILASTERS.

[illegible]

200	2	345	6	0	628	STRAIGHT
200	2		6	0	627.6	
200	2		2	0	628	
200	2		3	6	627.6	
200	2		5	0	625.2	
200	2		7	2	617	
200	2		9	6	619.6	
1300	112		20	0	620	
1300	114		31	5	621.5	
200	2		26	0	620	
624	57		32	0	630	
624	57		31	5	631.5	
200	2		32	6	633.6	
624	57		35	0	635	
624	57		36	5	636.5	
200	2		38	6	638.6	
200	2		44	6	644.6	
200	2		51	6	651.6	
200	2		57	6	657.6	
625	54		60	0	662	
200	2		60	3	661	R.5
200	4		21	6	662	R.6
200	4		22	6	663	R.7
200	4		27	3	664	R.8
200	4		31	0	665	R.9
200	4		34	0	666	R.10
200	4		37	0	667	R.11
200	4		40	6	668	R.12
200	4		43	6	669	R.13
200	4		46	6	670	R.14
200	4		50	0	671	R.15
200	4		53	0	672	R.16
200	4		56	0	673	R.17
200	4		59	0	674	R.18
2706	228		12	7	671

As Built Substitutions For S/D1 to 7 & Double Hook Bars

<u>NO.</u>	<u>Substitution</u>	<u>C-O</u>
S/D1	2'-4"	1'-0"
S/D2	2'-10"	1'-6"
S/D3	3'-5"	2'-1"
S/D4	4'-1"	2'-9"
S/D5	3'-9"	2'-5"
S/D6	3'-4"	2'-0"
S/D7	3'-0"	1'-6"

The diagram shows a cross-section of a double hook bar. It consists of two horizontal bars, each with a 180-degree hook. The top bar has a horizontal segment of length 11d, followed by a hook with a vertical leg of length 0.2d and a horizontal leg of length 11d. The bottom bar has a horizontal segment of length 11d, followed by a hook with a vertical leg of length 0.0 and a horizontal leg of length 11d. The total width of the assembly is 11d + 11d = 22d.

SPECIFICATIONS:
REINFORCING: DEFORMED BARS, BULLET STEEL
INTERMEDIATE GRADE, ASTM SPEC. A108-39
CONCRETE: CONCRETE FOR DATE FOOTING AND WALL
DALL HAVE MINIMUM 4000 PSI COMPRESSIVE
STRENGTH. CONCRETE FOR CURB AND DRIVE
WALLS MIN 3000 PSI COMPRESSIVE STRENGTH
WALLS TO BE 12" THICK. COATED BARS SHALL BE
BARS FOR THE STITCHED CURB WALLS MUST
BE SUBSTITUTED

THIS DRAWING ONLY
WEIGHT OF REINFORCING STEEL

1 TANK	63 TONS
12 TANKS	816 TONS

NOTED

HANFORD ENGINE WORKS

75-FOOT TANK
DOME REINFORCING

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FIGURE 1
FINITE ELEMENT IDEALIZATION OF
24I-BY-112 CONCRETE STRUCTURE

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RAY VOLLETT 222-T

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ARC400

FIGURE 2
241-BY-112 WASTE TANK STRUCTURE,
EXAGGERATED DISPLACEMENTS
VERSUS TIME

FIGURE 3
241-BY-112 WASTE TANK STRUCTURE,
EXAGGERATED DISPLACEMENTS
VERSUS TIME

TIME = 5 DAYS
TEMPERATURE = 9% OF MAXIMUM

FIGURE 4
24I-BY-112 CONCRETE CRACKING

TIME = 50 DAYS
TEMPERATURE = 90% OF MAXIMUM
LIQUID = 250°F

FIGURE 7
24I-BY-112 CONCRETE CRACKING

TIME = 900 DAYS
TEMPERATURE = 90% OF MAXIMUM
LIQUID = 250°F

FIGURE 8
241-BY-112 CONCRETE CRACKING

FIGURE 9
241-BY-112 CONCRETE CRACKING

FIGURE 10
241-BY-112 CONCRETE CRACKING

Date: APR 13 1973

To: T. D. Anderson

From: D. A. Cavanagh

*Douglas A. Cavanagh*Subject: USE OF AMGAB TO MODEL HEAT TRANSFER IN THE
112-BY TANK

High temperatures, or large temperature gradients, in the concrete and steel underground waste storage tanks of the 200 Area tank farms present a problem with respect to tank structural integrity. The Technical Systems Section was asked to model some of the tanks in question in order to calculate temperature distributions for the tank structures and surrounding soil. The temperature distribution data could then be used in stress analysis of the structures. This memorandum is a report on results obtained from the study of one such tank, 112-BY, using the computer code AMGAB.

AMGAB is a finite element heat conduction program, written in the FORTRAN language, for solving steady state or time dependent heat transfer problems involving structures with complex geometries. To analyze a given situation, a grid is established which characterizes an appropriate cross section of the plane or axisymmetric structure in question.

Parameters to be specified include material properties, heat generation and flux rates, constant temperature points, and convective coefficients. Each grid space, or element, is assigned a material type and is assumed to be completely homogeneous. Material properties (conductivity, heat capacity, density) as well as heat generation rate, if any, are included for each material type. Element sides may be assigned flux rates; however in this application of the program, only the adiabatic condition (flux across boundary = zero) was used. Nodal points can be kept at constant temperature or allowed to vary. Convective heat transfer is specified by assigning a convective coefficient and bulk fluid temperature to appropriate element sides. No provision is made for possible thermal resistance between materials (contact resistance).

Figure I shows the upper portion of the 30 by 50 nodal point grid which was set up to model the 112-BY tank. In contrast to past tank farm modeling studies, a constant

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liquid temperature, rather than heat generation rate, was specified. This is the situation existent when liquid of very low activity is being boiled off with heat supplied by immersible heaters. It was assumed that the resistance to heat transfer at the liquid-solid interface was negligible; therefore, the wall (steel liner) temperature was taken to be that of the liquid.

Liquid temperatures for the study were 250° F and 280° F. Of the many variables, it was expected that the choice of soil conductivity involved the greatest uncertainty and would have the greatest effect on the results. Therefore cases were run at two soil conductivities, 0.15 and 0.33 Btu/hr. ft. ° F, for each of the two temperatures. Steam was assumed to condense on the inside surface of the dome at 212° F.

For boundary conditions, the tank model was surrounded by a cylindrical adiabatic barrier of radius 60 ft. (this, in essence, assumes that similar heat sources are in the near vicinity). A 60° F constant temperature plateau was assumed at 150 ft. below the tank bottom to simulate ground water. Air temperature above ground level was assumed constant at 65° F.

Figures II through V consist of isotherms, drawn about an outline of the tank, for each of the four cases. These isotherms were drawn from computer generated plots of nodal point temperatures. Note the large temperature gradient in evidence along the tank wall between liquid surface and tank dome - this gradient is obviously very sensitive to the choice of vapor temperature in the dome. Changing the soil conductivity does not appear to have made a large difference in temperature profiles, except near the foot of the tank, but the difference in flux rates is quite large. It is expected that variation of the soil conductivity for tanks having constant heat generation rates would greatly affect temperature profiles.

Other assumptions which appear to be significant are those involving choices for convective film coefficients, adiabatic boundaries, and temperature values where specified as constant. There is no direct way of verifying the

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accuracy of the data used, and the results should be considered with this in mind. However, values were carefully chosen and large variations from the assumed values would be necessary to cause any significant changes in the solution isotherms.

Detailed computer output for the four cases has been forwarded to F. R. Vollert for use in stress analyses.

DAC:jm

Att.

cc: DA Cavanagh (2)
RD Jensen
DJ Larkin
CK Rosnick
RD Shimer
FR Vollert

MATERIAL PROPERTIES

With the exception of soil conductivities and liquid temperatures, which varied as indicated for the four runs, the following constants were used in all cases:

Concrete thermal conductivity	= 0.48 Btu/hr. ft. ° F
Steel thermal conductivity	= 25. Btu/hr. ft. ° F
Sludge thermal conductivity	= 0.45 Btu/hr. ft. ° F
Convective film coefficient (inside of dome)	= 750 Btu/hr. sq. ft. ° F
Convective film coefficient (ground level)	= 2.5 Btu/hr. sq. ft. ° F

FIGURE I
112-BY Tank Model Grid

AXISYMMETRIC ISOTHERMS
241-BY, TANK 112 (ITS-2)

FIGURE II

AXISYMMETRIC ISOTHERMS
241-BY TANK 112 (ITS-2)

AXISYMMETRIC ISOTHERMS
241-BY, TANK 112 (ITS-2)

FIGURE IV

AXISYMMETRIC ISOTHERMS
241-BY, TANK 112 (ITS-2)