MAR 05 1998 Sta. 37 (20) **ENGINEERING DATA TRANSMITTAL**

1. EDT 608765

2. To: (Receiving Organization) Distribution	3. From: (Originating Organization) Process Analysis/8C453	4. Related EDT No.: 608765
5. Proj./Prog./Dept./Div.: High Heat Program	6. Design Authority/ Design Agent/Cog. Engr.: E. R. Cramer	7. Purchase Order No.: N/A
8. Originator Remarks: For approval and information		9. Equip./Component No.: N/A
		10. System/Bldg./Facility: 241-C-106/Tank Farms
11. Receiver Remarks: 11A. Design Baseline Document? [] Yes [X] No		12. Major Assm. Dwg. No.: N/A
		13. Permit/Permit Application No.: N/A
		14. Required Response Date: N/A

15. DATA TRANSMITTED

(A) Item No.	(B) Document/Drawing No.	(C) Sheet No.	(D) Rev. No.	(E) Title or Description of Data Transmitted	(F) Approval Designator	(G) Reason for Transmittal	(H) Originator Disposition	(I) Receiver Disposition
1	HNF-2152		0	HIGH HEAT PROGRAM, THERMAL HYDRAULIC COMPUTER MODELS	N/A	1,3	1	

16. KEY

Approval Designator (F)	Reason for Transmittal (G)	Disposition (H) & (I)
E, S, Q, D or N/A (see WHC-CM-3-5, Sec.12.7).	1. Approval 2. Release 3. Information 4. Review 5. Post-Review 6. Dist. (Receipt Acknow. Required)	1. Approved 2. Approved w/comment 3. Disapproved w/comment 4. Reviewed no/comment 5. Reviewed w/comment 6. Receipt acknowledged

17. SIGNATURE/DISTRIBUTION
(See Approval Designator for required signatures)

(G) Reason	(H) Disp.	(J) Name	(K) Signature	(L) Date	(M) MSIN	(G) Reason	(H) Disp.	(J) Name	(K) Signature	(L) Date	(M) MSIN
		Design Authority									
		Design Agent									
1	1	Cog.Eng. J. P. Sloughter	[signature]								
1	1	Cog. Mgr. J. P. Sloughter	[signature]								
		QA									
		Safety									
		Env.									

18.	19.	20.	21. DOE APPROVAL (if required)
E. R. Cramer [signature] 3/4/98 Signature of EDT Originator Date	DRB DR Bratzel 2/26/98 Authorized Representative for Receiving Organization Date	J. P. Sloughter [signature] 2/26/98 Design Authority/ Cognizant Manager Date	Ctrl. No. [] Approved [] Approved w/comments [] Disapproved w/comments

HIGH HEAT PROGRAM, THERMAL HYDRAULIC COMPUTER MODELS

D. M. Ogden
John Marvin, Inc., Richland, WA 99352

E. R. Cramer
Numatec Hanford Company, Richland, WA 99352
U.S. Department of Energy Contract DE-AC06-96RL13200

EDT/ECN: 608765 UC: 2070
Org Code: 8C453 Charge Code: N2FAA
B&R Code: EW3120072 Total Pages: 40

Key Words: 241-C-106, Sluicing, Thermal Computer Models

Abstract: The purpose of this report is to describe the thermal hydraulic computer models, the computer model benchmarking and methodology to be used in performing the analysis necessary for the resolution of the high heat safety issue for Tank 241-C-106.

GOTH is a trademark of JMI, which is derived from GOTHIC - a registered trademark of the EPRI Corp.

PTHERMAL is a trademark of the MacNeal-Schwendler Co.

HNF-2152, Rev 0

HIGH HEAT PROGRAM

THERMAL HYDRAULIC COMPUTER MODELS

D.M. Ogden

John Marvin, Inc.
Richland, Washington

E.R Cramer
Numatec Hanford Corporation
Richland, Washington

Issued by
Numatec Hanford Corporation
Richland, Washington
for the

U.S. DEPARTMENT OF ENERGY
RICHLAND OPERATIONS OFFICE
RICHLAND, WASHINGTON

CONTENTS

TABLES

FIGURES

1.0 INTRODUCTION

1.1 BACKGROUND

Tank 241-C-106 is a single shell tank with an estimated heat load for January 1997, of 123,000 Btu/hr (Ogden 1997). It is the only single shell waste tank which requires water additions to maintain active cooling. In January 1991, in accordance with Public Law 101-510, Section 3137 (the Wyden Amendment) (Bander 1996a), Tank 241-C-106 was identified as a Watch List tank because of the requirement for water additions, coupled with the leak potential of a single shell tank.

Project W320 is scheduled to begin removing waste from Tank 241-C-106 near September 1998 (Ferlan 1996). The goal of the first retrieval campaign (phase 1) is to remove a minimum of two feet of sludge from the tank. Previous thermal analysis (Bander 1996b) has shown that with two foot waste removal, water additions for Tank 241-C-106 can be discontinued, allowing the tank to dry out. The overall goal of Project W320 is to complete soft sludge removal. However, closure of the Tank 241-C-106 high heat safety issue, is possible after only partial retrieval.

1.2 PURPOSE

The Tank-C-106 high heat safety issue is scheduled to be closed by September 1999 (HNF-SP-1230). Complete retrieval of C-106 will certainly eliminate the high heat safety concern. However, after only partial retrieval, the resolution of the safety issue is possible through tank data monitoring and thermal hydraulic computer analysis. The analyses would evaluate the expected thermal response of the tank following the elimination of water additions and the subsequent dry out of the tank waste. Following the phase 1 sluicing for Project W320, the High Heat Safety Program will monitor Tank 241-C-106 tank data and perform thermal hydraulic analysis to show that water additions are no longer required for tank cooling, eliminating the high heat safety issue for Tank 241-C-106. These analyses will allow closure of the safety issue prior to completion of retrieval and consistent with the scheduled date for the safety issue closure.

The purpose of this report is to describe the thermal hydraulic computer models, the computer model benchmarking and methodology to be used in performing the analysis necessary for the resolution of the high heat safety issue for Tank 241-C-106.

1.3 SCOPE

This document contains a discussion of the overall methodology for using tank data from Tank 241-C-106, coupled with thermal hydraulic analysis. These will be used to demonstrate that water additions will not be required for active cooling following the Project W320 phase 1 retrieval as discussed in Section 2.0.

Resolution of the high heat safety issue will rely heavily on thermal hydraulic computer analysis. A description of the computer codes and the computer models used for the post sluicing analysis is provided in Section 3.0.

The computer models have been benchmarked against actual tank data to provide the validation necessary to assure the credibility of the post sluicing dry out analysis. This bench mark analysis includes the 1994 process test for Tank 241-C-106, Tank 241-S-111 breathing rates and seasonal temperature variations, and the Tank 241-C-105 1993 process test. Future bench marking will include the dry out behavior of tanks 241-SX-108 & 114 or other suitable SX farm tanks. These analyses are presented in section 4.0.

The maximum waste temperature which would occur following the elimination of water additions and subsequent tank dry out, depends upon a number of important parameters including

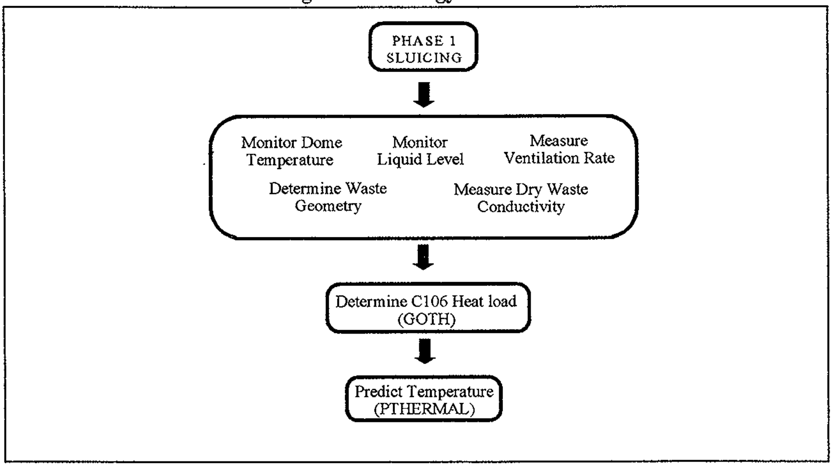
- dry waste conductivity
- waste geometry
- tank ventilation rates
- dry out time.

Parametric analyses were performed to assess the degree to which these parameters affect the maximum waste temperature. An understanding of the sensitivities of these parameters will guide future decisions concerning tank monitoring and data requirements. The parametric analyses are provided in Section 5.0. Conclusions and recommendations are given in Section 6.0.

2.0 STRATEGY AND MODEL OVERVIEW

Closure of the high heat safety issue for Tank 241-C-106 depends upon complete or partial retrieval of the waste with credible thermal hydraulic analysis. This would then demonstrate that without water additions, the subsequent waste dry out will not result in waste temperatures which exceed any operational and safety limits. While Project W320 is expected to remove all the soft sludge, the project schedule is not compatible with the safety resolution schedule. Furthermore, there could be an unexpected delay between Project W320 phase 1 and phase 2 sluicing as a result of high heat or flammable gas issues in the receiver tank. Therefore, the High Heat Program will conduct an evaluation of Tank 241-C-106 following the phase 1

Figure 2.1 Strategy overview.



sluicing to determine if continued water additions would be required if complete waste retrieval is delayed. This could potentially allow the earliest closure of the high heat safety issue. If phase 2 sluicing is then delayed, the evaluation of Tank 241-C-106 may allow for the elimination of water additions.

The overall strategy is shown in Figure 2.1. Following the phase 1 sluicing, there will be a period of tank data monitoring and data collection. The information required to determine the remaining tank heat load will be the first priority. There are currently two thermocouple trees in Tank 241-C-106, located in riser 8 and 14. The waste around these thermocouple trees will be significantly disturbed during sluicing. This will make any direct measurements of the waste temperature difficult. Each tree however has several thermocouples in the head space of the tank. These should be operable after sluicing and provide a good record of the dome space temperature. This will be important data for estimating the tank heat load.

The auto ENRAF gauge which monitors the liquid level in the tank will not be operable during sluicing but should be available during the post monitoring period to measure the tank liquid level. This data will be used to determine the tank evaporation rate. This data together with the dome temperature and ventilation rate will be used to perform an energy balance and determine the tank heat load.

Additional information will be needed to support the tank dry out analysis. Photographic records of the waste surface will be required to determine the geometry of the remaining waste. Of particular importance is the waste depth, and any significant non-uniformities in the radial or azimuthal directions. The maximum waste temperature during dry out is a function of the waste thermal conductivity. A waste sample may be required to measure the dry waste conductivity. The waste sample will not be needed if the phase 1 sluicing removes significantly more than two feet of waste, since conservative values may be used in the dry out analysis without exceeding any tank temperature limits. A sensitive parameter in determining the dry out time and therefore the maximum waste temperature is the evaporation rate. This is primarily a function of tank heat load. The salt content of the tank causes some vapor pressure suppression which may effect the evaporation rate and the dry out time. A sample of the supernatant will be required to determine the vapor suppression of the post sluicing supernatant.

Thermal analysis will be performed following the tank monitoring and data collection to predict the maximum temperature after tank dry out. First, the GOTH computer code (Section 3.1) will be used to determine the remaining heat load in Tank 241-C-106. The dome temperature, rate of change in tank liquid level and the tank ventilation rate will provide the necessary input for this analysis. The tank heat load, waste geometry and dry waste conductivity will provide input into a PTHERMAL model (Section 3.2). The PTHERMAL model will be used to predict the maximum waste temperature following waste dry out. If this temperature does not exceed the operational and safety temperature limits, water additions may be discontinued if needed and the high heat safety issue for Tank 241-C-106 can be closed. This strategy relies heavily on thermal hydraulic computer analysis to predict the maximum waste temperature following waste dry out. These models must be credible and benchmarked against actual tank data to the extent possible. A description of the computer codes and models is described in the following section. The model bench marking is provided in Section 4.0.

3.0 COMPUTER MODELS

3.1 GOTH MODEL

The GOTH computer code will be used to determine the remaining heat load in Tank 241-C-106 following the phase 1 sluicing. A description of the computer code and Tank 241-C-106 model is provided in the following sections.

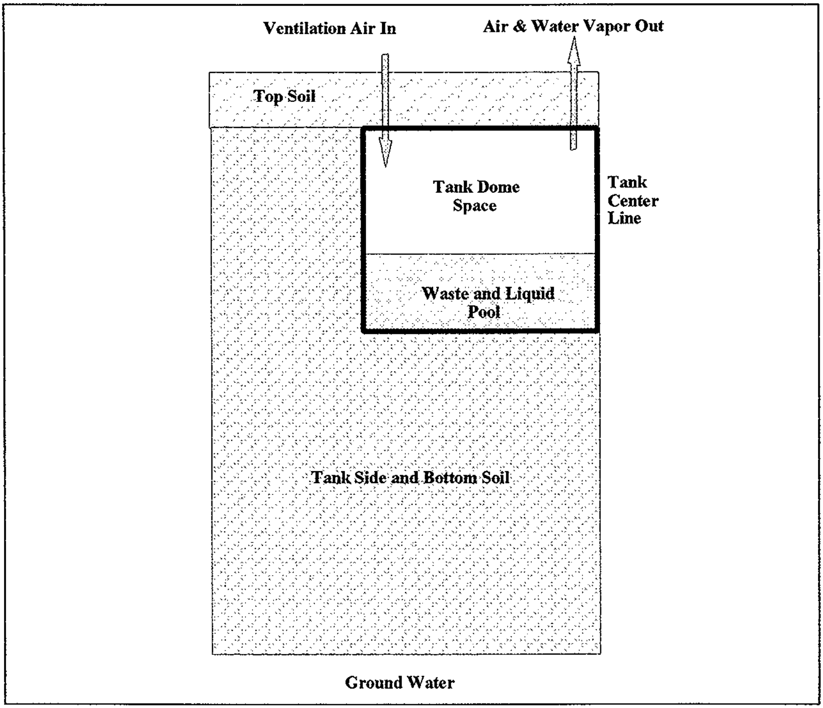
3.1.1 GOTH Code Description

The GOTH code is a proprietary computer code of John Marvin, Inc. It is a multi-dimensional, multi-phase, finite difference, thermal hydraulic computer code which has been applied extensively to the analysis of waste tanks. This code is particularly suited for determining the heat load in Tank 241-C-106 because of it's mechanistic treatment of the pool evaporation and capability to include actual meteorological data boundary conditions (temperature, pressure and humidity). The GOTH code includes standard one dimensional heat conduction models used to model the soil and waste conduction.

3.1.1 GOTH Model Description

The GOTH model of Tank 241-C-106 is shown in Figure 3.1. For details of this model see Thurgood 1996. The main features of the model include axi-symmetric modeling of the tank top side and bottom soil and the tank waste. The tank liquid pool is modeled one dimensional in the axial direction. The tank head space is modeled as a single lumped parameter volume. There is no need for distributed parameter modeling in the head space since heat and mass transfer from the liquid surface can be modeled with a single volume. Ventilation flow and meteorological conditions are provided as boundary conditions. The waste heat load following the phase 1 sluicing will be determined by parametrically varying the heat load to match the tank dome temperature and evaporation rates. Best estimate values of waste properties are included in the model. However, these parameters do not effect the dome temperature and thus the heat load estimate.

Figure 3.1 Tank 241-C-106 GOTH model.



3.2 PTHERMAL MODEL

The PTHERMAL model will be used to evaluate the thermal behavior of the 241-C-106 waste during the waste dry out which will occur when water additions are eliminated. A description of the code and model is provided in the following sections.

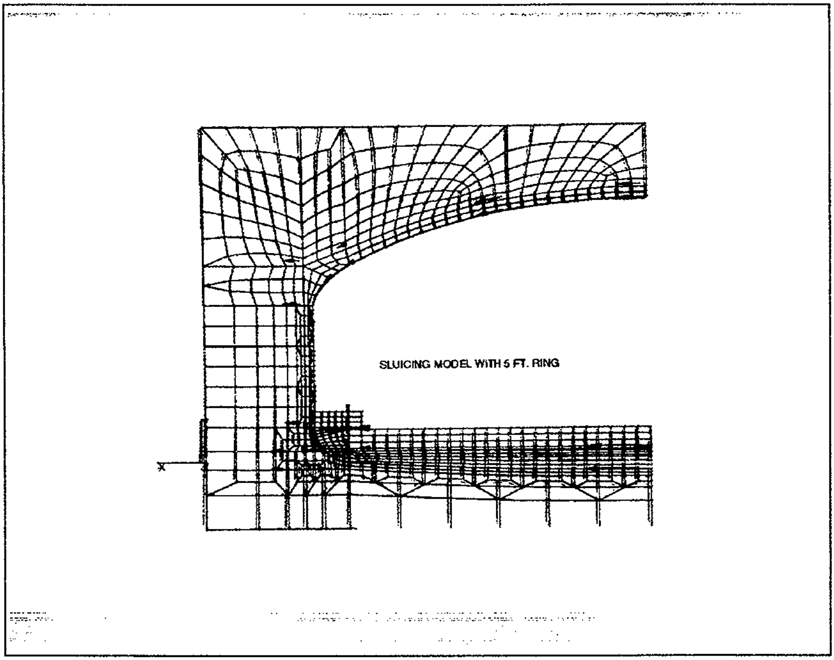
3.2.1 PTHERMAL Code Description

The PTHERMAL code is a finite element thermal analysis computer code. It is multi-dimensional and models radiation, conduction and convection heat transfer (PTHERMAL is a proprietary product of the MacNeal-Schwendler Co). The PTHERMAL code has been validated for use at Hanford (Valdiviez 1991). Unlike GOTH, it is a single phase computer code. Because it is a finite element code, it can model the temperature distribution through the waste and soil in considerable detail. This will be particularly important if the geometry of the waste following phase 1 sluicing is highly non-uniform. The PTHERMAL code includes flow boundary conditions. Unlike GOTH, PTHERMAL does not model the mass transport due to evaporation mechanistically. However, an evaporation boundary condition developed through GOTH analysis can be used to provide a boundary condition.

3.2.2 PTHERMAL Model Description

The Tank 241-C-106 PTHERMAL model is shown in Figure 3.2. This is an axi-symmetric model of the tank and surrounding soil. Although not shown in Figure 3.2, the model also includes a cylindrical column of soil extending below the tank to the ground water at 200 feet below the soil surface. The ground water is presumed to be at a constant temperature of 55 °F. The model shows a possible configuration of the waste following phase 1 sluicing where an annulus of waste is left to protect the tank walls during sluicing. The actual waste geometry following sluicing will be included in the model used after the Phase 1 sluicing of 241-C-106. The ventilation flow rates, ambient temperature and evaporation rates will be provided as boundary conditions. The expected evaporation rate and tank heat load will be based upon GOTH analysis. Waste dry out is modeled by changing the waste conductivity and evaporation rates as a function of time. These models are discussed in Section 4.2.

Figure 3.2 PTHERMAL 241-C-106 model.



4.0 MODEL BENCHMARKS

The PTHERMAL and GOTH codes are both third party software. As such, they have received considerable validation and verification on the basic code models. The following section provides benchmark analysis for the GOTH and PTHERMAL codes using waste tank data. These are representative of analysis performed on waste tanks using the two codes. The section is not however intended to be a comprehensive summary of all the benchmark analysis performed with GOTH and PTHERMAL.

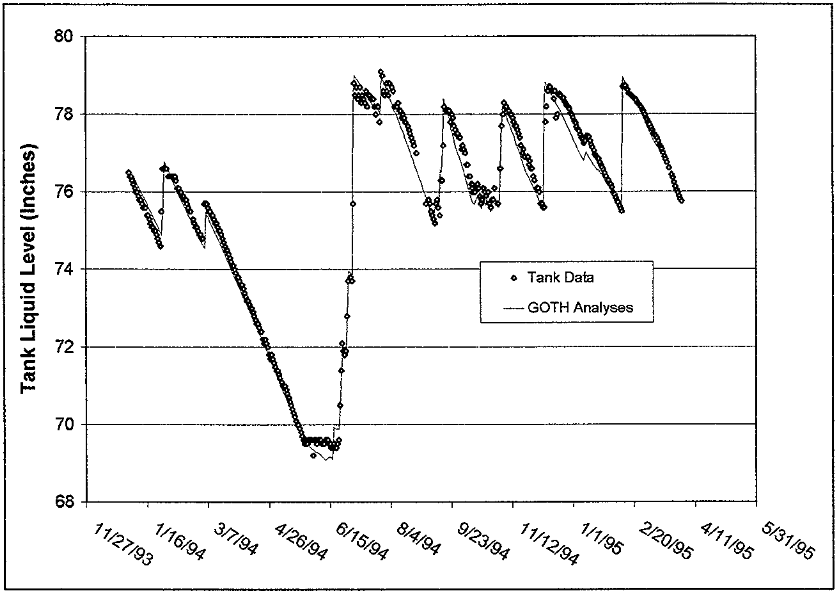
4.1 GOTH MODEL BENCHMARK

The GOTH computer code formulation includes conservation equations for continuum liquid and vapor phases and a particle field. This has allowed the modeling of waste movement, which can occur in tanks such as 241-S-102 during a gas release event or even Tank 241-C-106 during the 1994 process test when steam trapped in the waste resulted in a vertically expanding waste level. The GOTH code has been used extensively at Hanford for waste tank design, operation and safety applications. The following two section presents the results of two such applications which help demonstrate the GOTH code capability for modeling basic dome space heat and mass transfer. A transfer is necessary for it's application in the High Heat Program.

4.1.1 Tank 241-C-106 1994 Process Test

In March of 1994 a process test was conducted for tank 241-C-106. The purpose of the test was to allow for a draw down of the tank liquid level through evaporation to demonstrate that the tank could be operated at a lower level if necessary. During the course of the test, the waste was inadvertently uncovered causing a diminished evaporative heat transfer. This resulted in a waste temperature violation of the Operational Safety Document (OSD) limit of 20 °F increase per day. The process test and numerous water addition cycles following the test, were thoroughly analyzed using the GOTH computer code (Thurgood 1995). The evaporative loss during the process test is of particular interest for the High Heat Program. Figure 4.1 shows the tank liquid level compared to the GOTH predicted level. The water addition prior to the process test and after the test can be seen as the rapid increase in level. During the process test (starting near March 1, 1994), the water additions were eliminated. The predicted and actual levels agree very well. There was close agreement with other tank data parameters such as dome space temperature and waste temperatures. This demonstrated the code's capabilities of modeling the tank heat transfer including soil conduction, evaporation and ventilation sensible heat loss. Thus, GOTH is suited for determining the remaining heat load in Tank 241-C-106 following the Project W320 phase 1 sluicing.

Figure 4.1 GOTH analysis of Tank 241-C-106 1994 process test.



4.1.2 Tank 241-S-111 Breathing Rates

GOTHIC (George 1995) (GOTHIC is copyrighted by the Electric Power Research Institute (EPRI)) modeling was performed in support of the Flammable Gas Program. The purpose of the modeling was to determine the breathing rate of non-ventilated (passive breathing) single shell tanks. The GOTH code was developed from the GOTHIC code by the addition of the particle field modeling. All other models in GOTH are essentially unchanged from GOTHIC. Thus the following analysis provides a benchmark for the GOTH. Tank 241-S-111 was analyzed using a simple single lumped parameter model with a heat structure representing the waste. This problem involves natural convection (buoyancy) flows with sensible heat removal and soil conduction. There is dynamic interaction between the seasonal temperature variation and the waste temperature. The model includes detailed (hourly) meteorological data to accurately model the natural convection flows.

The predicted dome space temperature and actual dome temperatures are shown in Figure 4.2. As seen in the figure, there is excellent agreement. This demonstrates the codes capability of correctly predicting the tank breathing rates and soil conduction. The ambient temperature is shown in Figure 4.2. Notice the lag time between the ambient and dome temperatures. This is the result of the interaction of the tank waste, which heats and cools more slowly than the dome and soil.

The tank waste temperatures are compared to the predicted temperatures in Figure 4.3. The conductivity of the tank waste was not known and was selected to give the correct maximum waste temperature. However, GOTH correctly predicted the dynamics of the waste temperature. The dynamics are the seasonal minimum and maximum temperatures predicted to occur during April and October, consistent with the tank data.

This analysis further demonstrates the capability of GOTH to model the tank heat transfer which is necessary to predict the heat load of 241-C-106 following the phase 1 sluicing.

Figure 4.2 GOTH analysis of Tank 241-S-111 dome temperature.

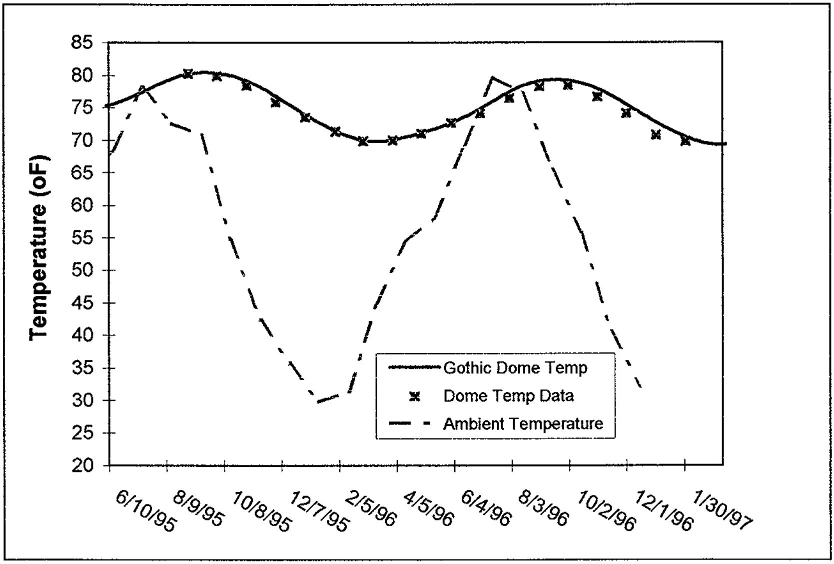
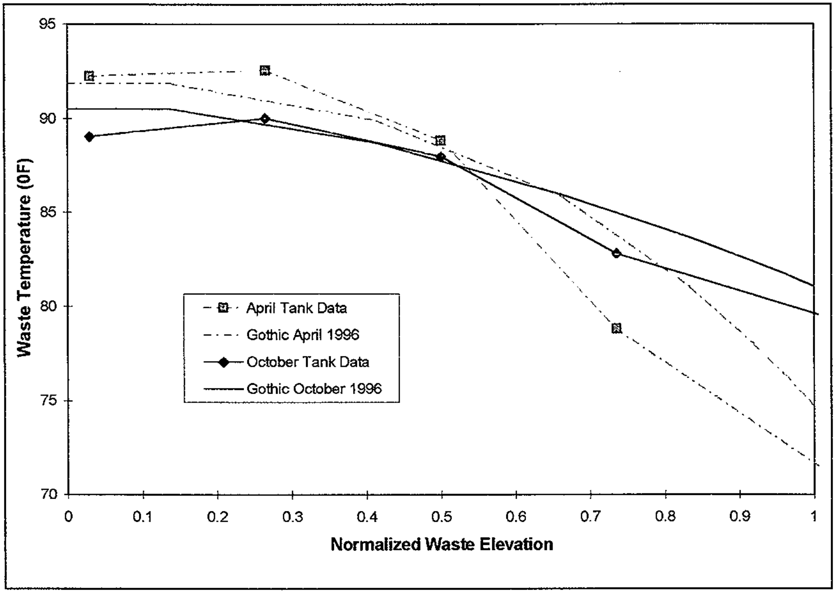


Figure 4.3 GOTH analysis of Tank 241-S-111 waste temperature.



4.2 PTHERMAL MODEL BENCHMARK

The PTHERMAL and GOTH codes are both third party software. As such, the basic code models have received considerable validation and verification. Additional verification is performed using tank data where it is available. The basic heat conduction model of PTHERMAL is well verified. The current bench marking focuses on the dry out model used for the analysis. Several tanks which are in a different stages of waste dry out were considered. A process test was conducted for Tank 241-C-105 in 1993 in which water additions were discontinued. The waste was quickly uncovered and has been drying for over four years. There is extensive data for this tank, although the dry out time is not long. Water additions in most of the SX farm tanks were discontinued prior to 1970. These tanks have completely dried out (this has been verified through waste samples). There is little data for these tanks prior to 1980. However, there may be a sufficient amount to provide a meaningful bench mark. Tanks in other single shell tank farms will also be considered.

The 241-C-105 benchmark is presented in the following section. This benchmark activity is in progress. Benchmark analysis for other tanks will be initiated later this year. This report will be updated to include all the benchmark analysis of the PTHERMAL dry out model.

4.2.1 Tank 241-C-105 Process Test

A simple dry out model has been used in the PTHERMAL model. It assumes that the waste dry out occurs linearly with time and that evaporation and waste properties such as conductivity decrease linearly from an initial value to the final dry waste value. The initial evaporation rate has been determined from the change in pool level during the process test. The dry out time has been determined from the linearly decreasing evaporation rate and the initial inventory of water in the tank. For Tank 241-C-105, the dry out time for the base case is just over 12 years.

Figure 4.4 shows the dome space and bottom waste temperatures along with the tank liquid pool level for Tank 241-C-105. The process test began in mid 1993 as seen by the decrease in liquid level. The level reaches a near constant value near 45 inches. This represents the tank waste level. Waste dry out began at that time.

Approximately 12,000 gallons of water were evaporated in an 18 month period leading to the loss of the liquid pool over the waste. This established the initial evaporation rate of about 0.2 inches per month. The analysis used this constant average value for the period prior to the time the waste surface was exposed. When the waste is initially uncovered, water can only evaporate from the porous region of the waste. This represents about 50% of the waste area.

Consequently, the initial evaporation rate may be reduced by up to 50%. This was addressed in a parametric analysis.

The initial wet waste conductivity was based upon modeling of Tank 241-C-106 and was assumed to be 1.0 Btu/hr-ft-°F. The dry out waste conductivity is based upon data measured for the SX farm waste (Bouse 1975). A value of 0.270 btu/hr-ft-°F was used.

The model was initialized using the tank data prior to complete evaporation of the liquid. Figure 4.5 shows a comparison of the calculated dome space and waste temperatures at the location of the bottom thermal couple. A tank heat load of 33,000 Btu/hr resulted in good agreement with the data. Actual meteorological data and tank measured ventilation flow were used in the calculation. Table 4.1 shows the tank ventilation rate for Tank 241-C-105. Notice the period with no ventilation flow. This analysis provides a good baseline for the dry out analysis.

Table 4.1 Tank 241-C-105 ventilation flows.

Date	Ventilation flow (cfm)
01/01/91	800
01/01/92	650
01/31/92	0
06/01/92	0
07/01/92	800
06/23/93	500
07/09/93	1320
04/01/94	1320
12/31/94	860
10/30/96	460

The PTHERMAL analysis of the Tank 241-C-105 waste dry out following the 1993 process test is shown in Figure 4.6 and 4.7. Four cases were analyzed. The first used the meteorological data and the tank ventilation rates but assumed that no dry out occurred. This is the waste temperature response that would be predicted if the pool liquid level had not been decreased to the waste level. This case is seen in Figure 4.6. An increase in waste temperature should be noticed. This is due to the meteorological data and the decrease in ventilation flow rate shown in table 4.1, and not due to waste dry out. However, this effect does not account for all the temperature increase seen in the data.

The purpose of this benchmark analysis is to demonstrate that the dry out model discussed above, adequately describes the waste dry out behavior of Tank 241-C-105. This benchmark analysis can be applied to Tank 241-C-106 after phase 1 sluicing. Three dry out cases were considered. All the cases assume that the waste was fully uncovered April 1994. As seen in Figure 4.4, the liquid level reaches waste level about 1 year earlier. An earlier time for the initiation of dry out may be justified and will be considered in future analysis. The base case dry out analysis is shown in Figure 4.7 as the 12.5 year dry out time. This is the time required for the water contained in the waste to evaporate assuming a linearly decreasing evaporation rate. This calculation under predicts the waste temperature (at the location of the bottom thermocouple). This analysis assumed that dry out began in April of 1994. The under prediction in the first several years would be improved if the dry out was initiated early, which is justified by the level data. The temperature increase is clearly lower than in the actual data, in the later years.

The second dry out case assumed that waste dry out occurred in 5 years. This requires the evaporation rate to decrease more slowly in the early years. This is consistent with a dry out front moving down in the waste and becoming increasingly diffusion limited as the liquid level recedes into the waste. As seen in the figure, the initial temperature is still under predicted, suggesting that waste dry out was initiated earlier. In the later years, the rate of temperature increase is clearly higher than the actual data.

The third case assumes that when the waste surface is exposed, the surface area for evaporation is reduced by up to 50% because of the porosity of the waste. The evaporation rate would then also be decrease, although probably less than 50%. However, for the purpose of the parametric analysis, the initial evaporation rate was decrease by 50%. This results in a doubling of the waste dry out time, since the water inventory is fixed. This parametric analysis is shown as the 25 year, reduced evaporation rate curve. The waste temperature in March of 1993, is still under predicted. Again, earlier initiation of dry out is indicated. The predicted waste temperatures in 1994 and 1995 however are closer to the tank data. The predicted temperatures in the later years are under predicted, indicating that the dry out time is too long. The third analysis however is a much better match with the data. The PTHERMAL Code predicted dome temperatures are compared with the tank dome temperature in Figure 4.8. Again, the early year prediction is reasonable good, but increasingly under predicts the dome temperature in later years. Future analysis will initiate the waste dry out about one year earlier, include the initial decrease in evaporation due to the exposure of the waste surface, and explore non linear dry out assumptions more consistent with a mass diffusion model for a porous media.

It is evident from the 241-C-105 benchmark analysis that a significant portion of the waste temperature increase is due to surface effects. The benchmark analysis will be improved by using an addition 1.5 years of data which will be available by summer of 1998. It is also important to investigate other tanks which are in later stages of dry out so that the PTHERMAL dry out model can be adequately benchmarked.

Figure 4.4 Tank 241-C-105 process test data.

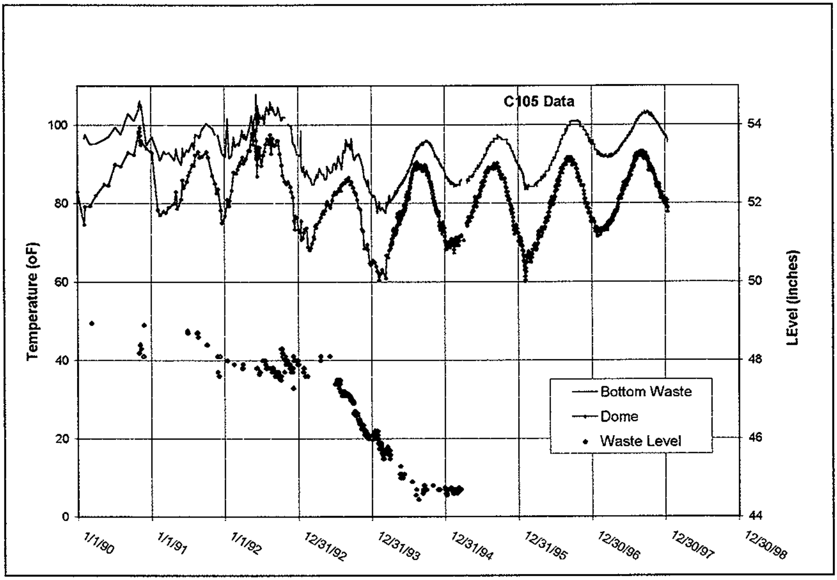


Figure 4.5 PTHERMAL heat load evaluation of Tank 241-C-105.

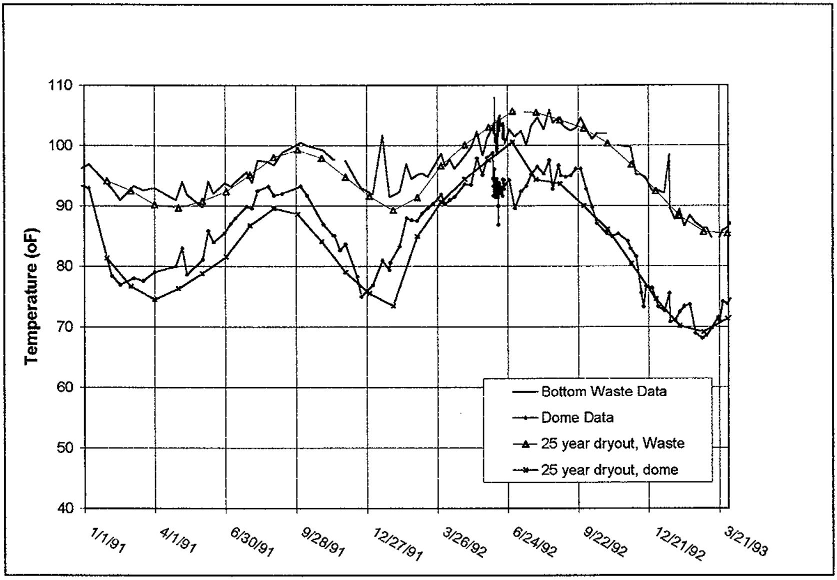


Figure 4.6 PTHERMAL evaluation of Tank 241-C-105 process test, no dry out.

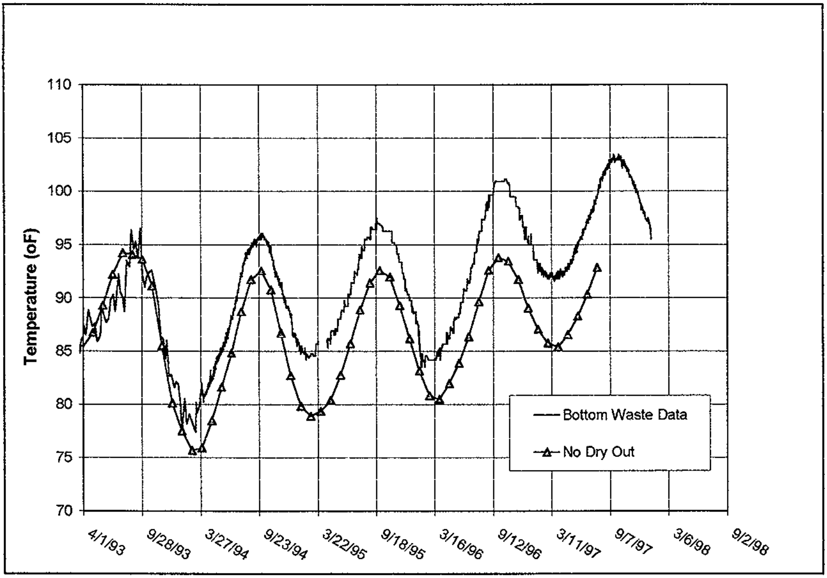


Figure 4.7 PTHERMAL evaluation of Tank 241-C-105 process test, dry out parametric.

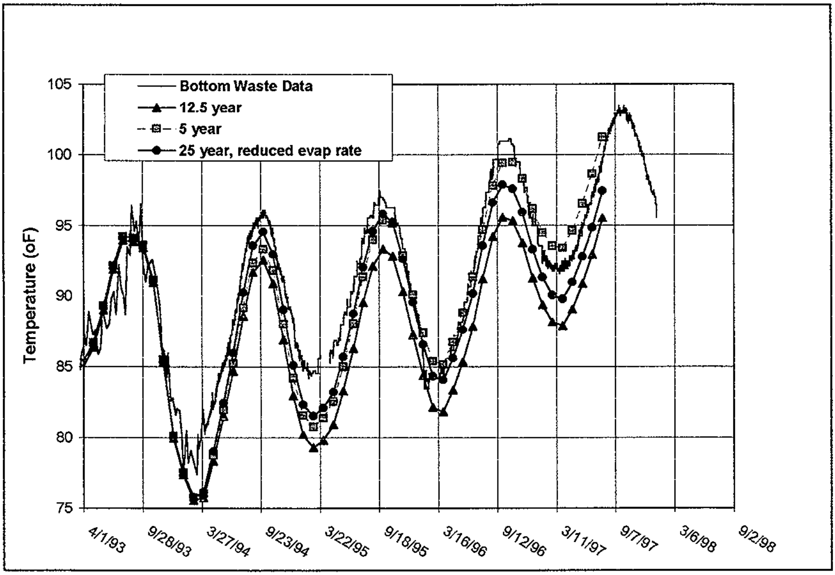
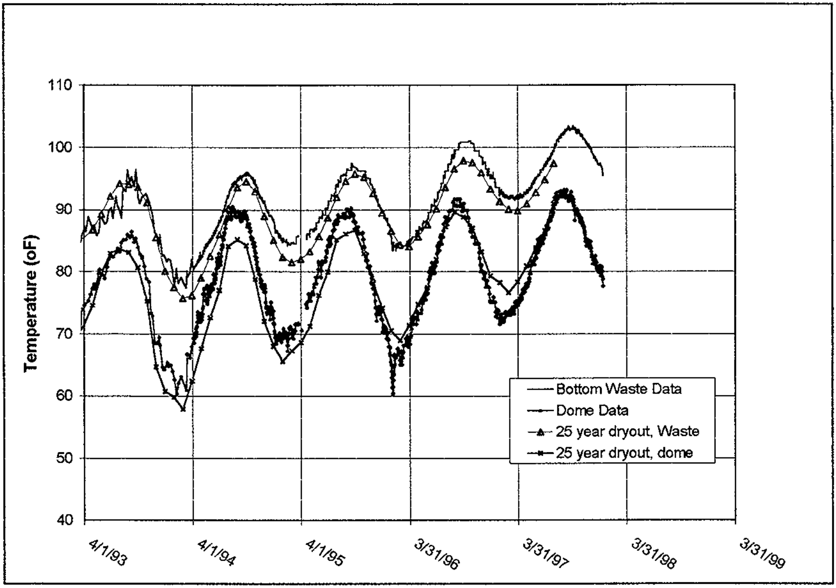


Figure 4.8 Tank 241-C-105 process test, 25 year dry out time.



4.2.2 Additional Benchmark Analysis

Work is in progress to complete the Tank 241-C-105 benchmark analysis and to perform additional analysis for other waste tanks which have dried for longer periods of time. Candidate tanks include 241-SX-108 and 241-SX-114. Both are considered high heat tanks with heat load estimates in 1994 of 45,000 and 58,000 Btu/hr. The waste of both tanks have been sampled and shown to be completely dry. These are excellent candidates for benchmarking if sufficient temperature data can be obtained. Other SX farm tanks under consideration include Tank 241-SX-104. This tank was partially pumped in 1983, which exposed the waste surface. It has been declared a leaking tank, however, recent analysis of tank data indicate that the leaker status may not be justified. The liquid level in this tank is slowly receding into the waste which makes it a good candidate for benchmark analysis. Tanks from other single shell tank farms will also be considered.

5.0 TANK 241-C-106 DRY OUT PARAMETRIC ANALYSIS

The maximum waste temperature in 241-C-106, following tank dry out is dependent upon several important parameters. These include; the waste thermal conductivity, the geometry of the waste, tank ventilation flow rates, and the time required for the waste to dry. Parametric analysis were performed with the PTHERMAL model to assess the sensitivity of the maximum waste temperatures to these parameters. An understanding of the sensitivity of these parameters will provide valuable information about monitoring and data collection requirements following the phase 1 sluicing.

For simplicity in comparing results, the following parametric analyses were performed with average meteorological conditions (i.e. average ambient temperature). The 241-C-105 benchmark analysis exhibited the seasonal variation in dome space and waste temperatures. The following analysis represent the seasonal average tank temperatures.

All cases assume a 2 foot uniform retrieval of waste during the phase 1 sluicing of Project W320.

5.1 WASTE CONDUCTIVITY PARAMETRIC ANALYSIS

The thermal conductivity during the dry out of a porous media varies non-linearly with the waste moisture fraction (Hillel 1982). Figure 5.1 shows the conductivity as a function of available moisture. This suggests that the waste conductivity may actually increase for a period as the waste drys. Parametric analyses were performed for a linearly decreasing conductivity and the porous media conductivity shown in figure 5.1. In addition, analyses were performed for a reduced dry out conductivity.

Figure 5.2 compares the maximum waste temperatures for the three waste conductivity parametric analyses. All three cases were performed for an assumed dry out time of 5.7 years. The PTHERMAL dry out model currently assumes a linear decrease in conductivity from an initial wet value to a dry value (Section 3.2.2). That is the base case shown in Figure 5.2. The temperature initially drops because the phase 1 sluicing has reduced the tank heat load and more importantly has reduced the conduction length of the waste. For a uniform distribution of heat, the maximum waste temperature decreases by the square of the conduction length. After the new steady state temperature is reached the waste temperature begins to increase as the waste conductivity decreases. The analyses model the radio nuclide decay which is a second order effect compared to the waste dry out. The maximum temperature is reached when the waste completely drys at 5.7 years. At that point the maximum waste temperature decrease linearly with the radio nuclide decay.

The second case uses the porous media conductivity. Similar to the base case, the initial temperature decreases as the waste establishes a new steady state temperature, for the reduced waste height and tank power. The temperature continues to drop as the conductivity increases as is shown in Figure 5.1. At approximately three years the temperature begins to increase as the waste conductivity decreases. Because the dry out times are the same, the peak waste temperature is the same as the base case (there is a small difference because of the different plot frequencies of the two curves). Thus, the temperature history leading to the peak temperatures are affected by the porous media conductivity. It should be noted that the maximum temperature is not effected.

The third curve shows the maximum waste temperature for a reduced dry waste conductivity. The dry conductivity was reduced from 0.27 Btu/hr-ft-°F to 0.20 Btu/hr-ft-°F. This value represents the minimum measured waste conductivity of the Bouse data discussed in Section 4.2.1. The maximum waste temperature has increased with the smaller waste conductivity. The maximum temperature is nearly 80 °F higher. For this reason, there is a significant sensitivity to the dry waste conductivity.

Figure 5.1 Porous media conductivity during drying.

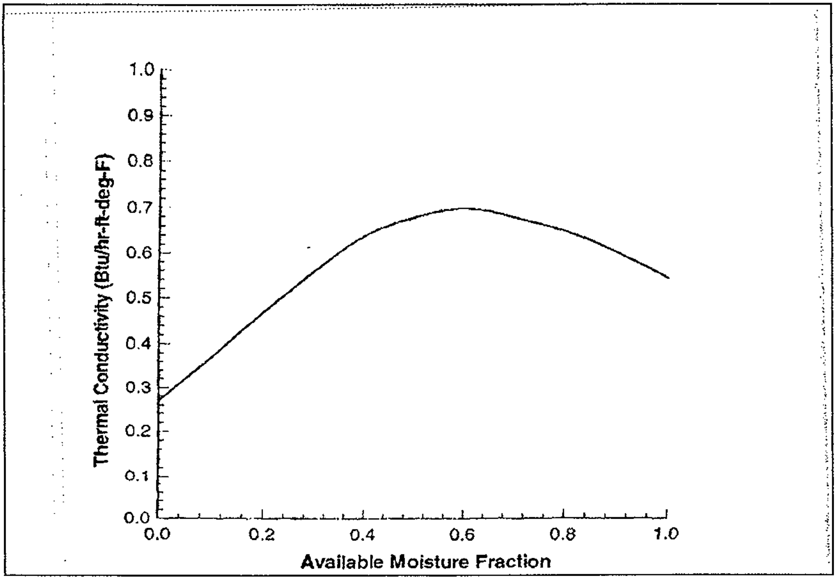
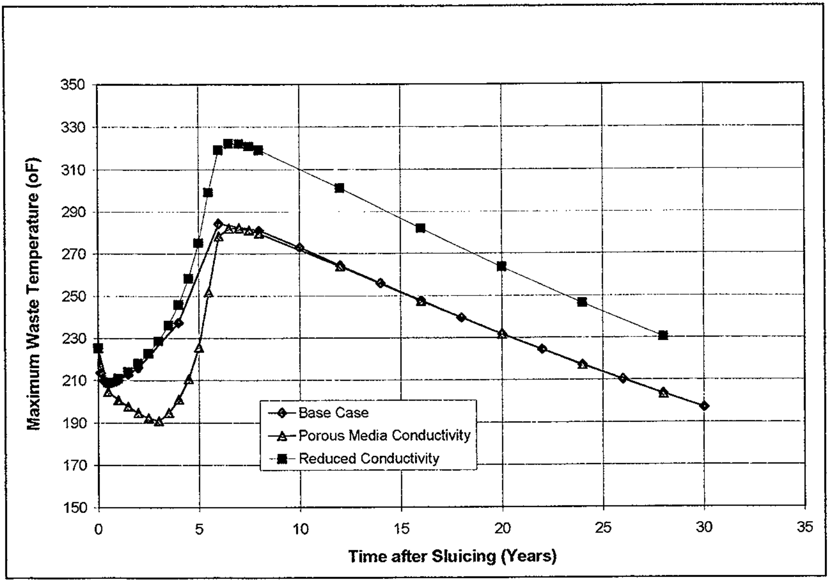


Figure 5.2 Tank 241-C-106 waste conductivity parametric analysis.



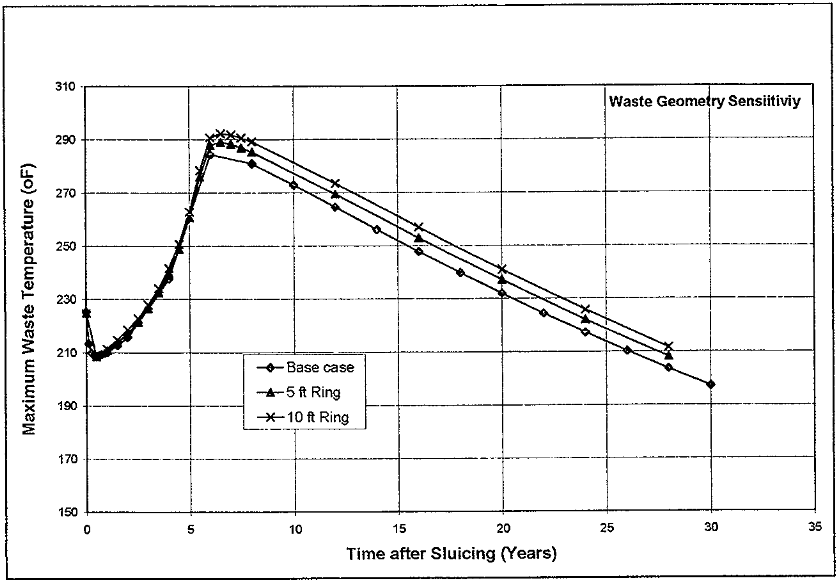
5.2 WASTE GEOMETRY PARAMETRIC ANALYSIS

During the sluicing of Tank 241-C-106, an annular ring of waste will be left near the wall to protect the wall. While the ring is expected to be about 5 feet in width, it may be larger. Near the end of the phase 2 sluicing this ring will be removed. However, the dry out analysis performed after phase 1 sluicing must account for any waste left near the wall.

Three cases were analyzed to assess this waste geometry. The base case assumed that no waste was left at the wall and two feet of waste was removed uniformly. The second case assumed a 5 foot wide ring at the wall and the third case assumed a 10 foot wide ring of waste at the wall. Other waste geometries are also possible. Perhaps the most likely is more waste removed at the center of the tank. This case was not considered for this sensitivity analysis because it results in lower maximum waste temperatures. It is bounded by the cases considered.

Figure 5.3 shows the maximum waste temperature for the waste geometry sensitivity analysis. All cases assume a 5.7 year dry out time. There is little difference among the three cases during the dry out period. The temperature drops initially to a new steady state value based on the reduced waste level and tank heat load. The temperature increases as the waste dries, reaching a maximum at 5.7 years. The waste at the tank wall makes little difference in the maximum waste temperature. The temperature difference is less than 10 °F for the 10 foot ring. Consequently, there is only a small sensitivity to this waste geometry. It is still however important to model the actual waste geometry for the 241-C-106 dry out analysis.

Figure 5.3 Tank 241-C-106 waste geometry parametric analysis.



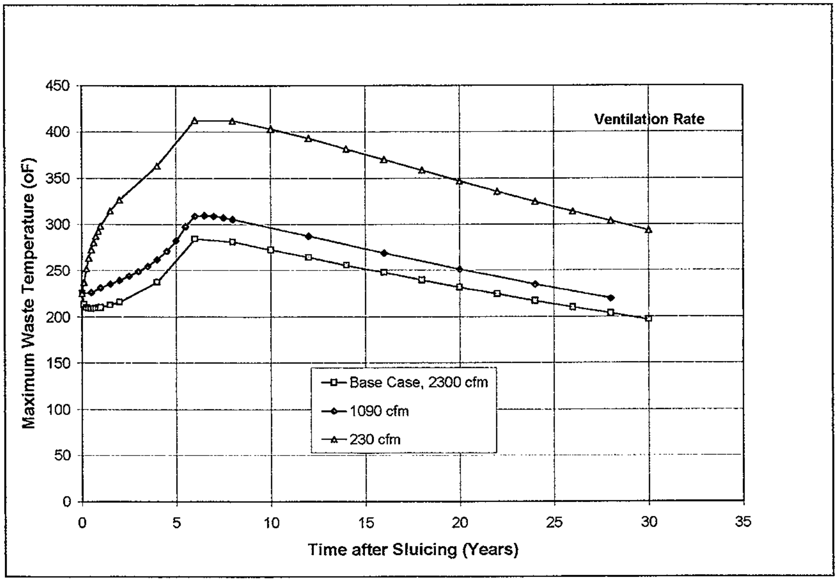
5.3 VENTILATION RATE PARAMETRIC ANALYSIS

In the event of a partial retrieval of Tank 241-C-106, water additions may be discontinued if a minimum of two feet of waste has been removed. However, active ventilation will be required for this minium level of waste removal. Parametric analyses were performed based on a uniform two foot waste removal with a 5.7 year dry out time. Ventilation flow rates of 2300 cfm, 1090 cfm and 230 cfm were evaluated. The value of 230 cfm represents an expected upper end flow for passive ventilation.

Figure 5.4 shows the maximum waste temperatures for the ventilation rate parametric analysis. The base case temperature initially decreases as the waste establishes a new steady state with two feet of waste removed. The base case ventilation flow is 2300 cfm which is the current operating level in the tank. For the 1090 cfm sensitivity case the temperature does not initially decrease. The decreased waste conduction length from the two foot waste removal is compensated by the lower ventilation rate. The waste temperature increases to the peak waste temperature which is about 25 °F higher than the base case.

The 230 cfm case is shown in Figure 5.4. The temperatures initially increase rapidly as the waste establishes a new steady state temperature with this significantly reduced ventilation flow. The peak waste temperature exceeds 400 °F. Passive ventilation is obviously not practicable for a minimum waste removal. However, the peak waste temperature is only modestly sensitive to the ventilation rate for reasonable active ventilation rates.

Figure 5.4 Tank 241-C-106 ventilation rate parametric analysis.

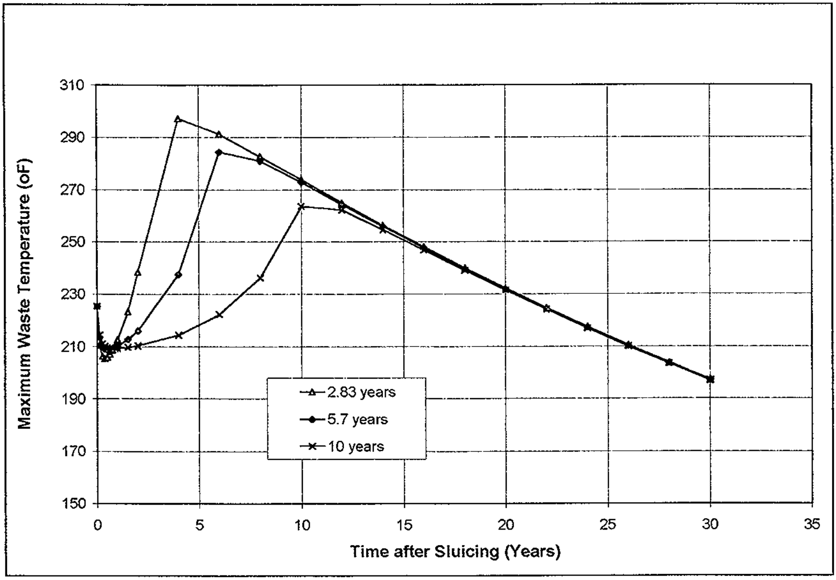


5.4 DRY OUT TIME PARAMETRIC ANALYSIS

The dry out time for the PTHERMAL dry out model will be determined through the benchmark analysis of Tank 241-C-105 and at least one additional SX farm tank. This bench marking is still in progress. A parametric study was performed to assess the sensitivity of the maximum waste temperature to this important parameter. Three cases were considered. The base case assumed a 5.7 year dry out time. A shorter dry out time of 2.83 years and a longer time of 10 years was considered.

Figure 5.5 shows the maximum waste temperatures for the dry out time parametric analysis. After the initial temperature decreases the temperature increased as the conductivity is linearly reduced, reaching the dry waste value at the dry out time indicated. The maximum temperature in all cases, lies on the near linear temperature line which represents the radio nuclide decay. The peak temperature is linearly related to the dry out time. For Tank 241-C-105 (Section 4.2.1), the dry out time is between 12 and 25 years. It will be important to reduce the uncertainty in dry out time as much as practicable. As seen in the figure, there is a 60 °F temperature difference between 12 and 25 years.

Figure 5.5 Tank 241-C-106 dry out time parametric analysis.



6.0 POST SLUICING MONITORING AND DATA COLLECTION

After the completion of the phase 1 sluicing for Project W320, Tank 241-C-106 data will be monitored and additional data collected to provide the necessary input to the GOTH and PTHERMAL analysis of the tank heat load and waste dry out behavior. The GOTH analysis will require dome space temperature and liquid pool level data at a frequency of at least once per day. In addition, the tank ventilation rate must also be measured. This need only be measured once if the tank flow rates are expected to remain nearly constant. Any changes to the tank ventilation flow rates will require addition flow measurements. Meteorological data will also be required. These data can be obtained from the Hanford weather station. From these data, the GOTH 241-C-106 model can be used to determine the remaining tank heat load. The tank will be undergoing a thermal transient as the waste establishes a new quasi-steady state with the reduced tank heat load and waste depth. As a result, a minimum of several months of data will be required to establish a good heat load estimate.

The PTHERMAL dry out analysis will use the GOTH estimated heat load for the waste dry out analysis. The parametric analysis of Section 5.0 showed the sensitivity of the maximum waste temperature during dry out for four parameters. Reasonable value of these parameters must be obtained to provide input into the PTHERMAL model. These include

- waste surface geometry
- waste dry out thermal conductivity
- waste dry out time

The tank ventilation rate will be measured to provide input to the GOTH analysis. However, the dry out analysis will be performed will parametrically vary the ventilation rate to determine the minimum required flow to maintain waste temperatures below applicable temperature limits.

The waste surface geometry can be obtained from photographic data of the waste surface. The modeling will only need to include significant non-uniformity in the waste surface.

The last two parameters will require the collection of Tank 241-C-106 waste samples. These samples (several at different axial locations) can be dried to measure the dry waste thermal conductivity. The parametric analysis discussed in Section 5.1 showed that the maximum temperature is very sensitive to this parameter.

The relative water fraction can also be determined from a Tank 241-C-106 waste sample. The water fraction data, together with the tank heat load estimate will provide the necessary input to the PTHERMAL model to determine the expected waste dry out time.

A sensitive parameter in determining the dry out time and therefore the maximum waste temperature is the evaporation rate. This is primarily a function of tank heat load. The salt content of the tank causes some vapor pressure suppression which may effect the evaporation rate and the dry out time. A sample of the supernatant will be required to determine the vapor suppression of the post sluicing supernatant.

The radio-nuclide content of the waste is not needed. The heat load of the tank can be better estimated by performing the tank energy balance through the use of the GOTH model.

7.0 CONCLUSIONS AND RECOMMENDATIONS

The following is a summary of conclusions and recommendations based upon the GOTH and PTHERMAL model development and benchmark activities.

- The GOTH and PTHERMAL models are adequate to determine the post sluicing heat load in Tank 241-C-106 and to predict the long term waste dry out.
- The Tank 241-C-106 high heat safety issue can be closed if the maximum waste temperatures during waste dry out are shown to be less than the applicable tank temperature limits.
- The GOTH model has been shown to be adequate for predicting the Tank 241-C-106 heat load following the Project W320 phase 1 sluicing.
- The Tank 241-C-105 benchmark analysis and benchmark analysis of at least one additional tank are required to satisfactorily benchmark the PTHERMAL dry out model.
- The tank data monitoring and collection identified in Section 6.0 are essential to provide the minimum input to the GOTH and PTHERMAL models to perform the heat load and waste dry out analyses.
- It is recommended that this report be reissued when the PTHERMAL bench marking is complete near the end of the fiscal year.

8.0 REFERENCES

Bander, T.J., *High Heat Generation Safety Issue in Tank 241-C-106*, WHC-SD-WM-ER-586, Rev 0, July 1996.

Bander, T.J., B.A. Crea, D.M. Ogden, *Tank 241-C-106 Sluicing Evaluation*, WHC,SD,ER,588, Rev 0, June 1996.

Bouse, D.G., *Thermal Conductivity of Hanford Waste Tank Solids and SX Farm Soil Samples,* ARH-CD-378, Atlantic rihcfield Hanford Company, July 1975.

Ferlan, *K.B., Project W320 Project Management Plan,* HNF-SD-W320-PMP-001, Rev 4, February 1996.

Hillel, D., *Introduction to Soil Physics, Academic Press, 1982*

Ogden, D.M., B.C. Fryer, K. Sathyanarayana, *Project W-320 SAR and Process Control Thermal Analysis,* HNF-SD-W320-ER-004, Rev 1, June 1997.

Thurgood, M.J., B.C. Fryer, *Revised Tank Heat Laad Estimate for the Process Test,* JMI-WT-002, John Marvin, Inc., Richland, Wa., June 1996

Tank Waste Remediation System Fiscal Year 1998 Multi-Year Work Plan WBS 1.1, HNF-SP-1230, Rev. 0,

Valdiviez, R. 1991, *Verification Report for the P/THERMAL Computer Code, HWC-SD-GN-CSWD-319*, Rev 0, Westinghouse Hanford Co., Richland, Wa.

DISTRIBUTION SHEET

To	From	Page 1 of 1
Distribution	Process Analysis/8C453	Date 02/04/98
Project Title/Work Order		EDT No. 608765
High Heat Program Thermal Hydraulic Computer Models		ECN No.

Name	MSIN	Text With All Attach.	Text Only	Attach./ Appendix Only	EDT/ECN Only
<u>Duke Engineering and Services Hanford Inc.</u>					
M. C. Brady	A6-80	X			
D. R. Bratzel	S7-14	X			
R. J. Cash	S7-14	X			
T. C. Geer	R1-43	X			
G. D. Johnson	S7-14	X			
C. E. Leach	R1-49	X			
R. G. Stickney	R1-49	X			
Central Files	B1-07	X			
<u>Fluor Daniel Hanford, Inc.</u>					
B. K. Hampton	S7-40	X			
<u>John Marvin, Inc.</u>					
D. M. Ogden	H0-34	X			
<u>Lockheed Martin Hanford Company</u>					
W. B. Barton	R2-12	X			
N. W. Kirch	R2-11	X			
J. G. Kristofzski	R2-12	X			
D. A. Reynolds	R2-11	X			
<u>Numatec Hanford Company</u>					
J. W. Bailey	S2-48	X			
A. F. Choho	H6-35	X			
E. R. Cramer	H0-34	X			
J. W. Lentsch	S2-48	X			
J. P. Sloughter	H5-49	X			
<u>U.S. Department of Energy, Richland Operations Office</u>					
W. Abduhl	S7-53	X			
D. H. Irby	S7-54	X			
G. M. Neath	S7-54	X			
C. L. Sohn	S7-54	X			
HTI Proj. File (2)	H6-08	X			