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Evaluation of Heat Sources and Effect of Dry Out in Single-Shell Tanks 241-SX-108 and 241-SX-114

D. M. Ogden

Westinghouse Hanford Company, Richland, WA 99352

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Abstract: This report examines two tanks on the list of Single-Shell Tanks with High Heat Loads. This report assesses the maximum temperatures that might exist in the two tanks 241-SX-108 and 241-SX-114. In addition to assessing current conditions in the tanks, the effect of the drying out of the center of the tank on the maximum temperature in the waste and concrete was evaluated. A reassessment of the heat loads was also done using more recent temperature and psychrometric data obtained from these two tanks.

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EVALUATION OF HEAT SOURCES AND EFFECT OF DRY OUT
IN SINGLE-SHELL TANKS 241-SX-108 AND 241-SX-114

September 1996

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Process Engineering Analysis

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EVALUATION OF HEAT SOURCES AND EFFECT OF DRY OUT IN SINGLE-SHELL TANKS 241-SX-108 AND 241-SX-114

1.0 INTRODUCTION

This report examines two tanks on the list of Single-Shell Tanks (SST) with High Heat Loads ($>40,000$ Btu/h) (Hanlon 1996) with measured temperatures above 190°F . The heat loads listed in column 2 of Table 1 were evaluated as of 1988 (Hanlon 1996, Table A-5) and are based on several reports summarized by Gibby 1989. Column 3 of Table 1 gives the total heat source of each tank decayed to 1994 using the 28.6 yr half-life of strontium 90, which comprises the majority of the radioactive material in these waste tanks. Heat loads using recent analyses (Bander 1994) on these tanks are listed in column 4. The volumes are taken from Hanlon 1996.

Table 1. Current Tank Properties.

Tank	Total Heat Source (1000 Btu/h)			Waste depth ¹ (ft)	Solids Volume (Kgal ft ³)	
	Hanlon (1988)	(Decayed to 1994)	Bander (1994)			
SX-108	45	39	39	3.1	87	11,700
SX-114	58	50	50	5.9	181	24,200

1: Depth at center of tank

The ventilation system in the SX farm has been in service since 1954 and needs to be upgraded. If at all possible rather than upgrade the ventilation system it would be desirable to completely shut the system off. However there is a concern that temperatures in some of the SX tanks would exceed the Limiting Conditions for Operations (LCO) temperature limit, which is 300°F (Dougherty 1996). This report assesses the maximum temperatures that might exist in the two tanks 241-SX-108 and 241-SX-114. In addition to assessing current conditions in the tanks, the effect of the drying out of the center of the tank on the maximum temperature in the waste and concrete was evaluated. A reassessment of the heat loads was also done using more recent temperature and psychrometric data obtained from these two tanks.

2.0 THERMAL MODELS

The finite element model of the SST structure and the surrounding soil was constructed using PATRAN¹ (PATRAN 1990), a computer code for creating and analyzing finite element and finite difference models. The thermal analyses used P/THERMAL² (P/THERMAL 1991), a thermal analysis package for solving steady-state and transient problems. Results were post-processed using PATRAN. The thermal radiation view factors utilized in these analyses were calculated with P/VIEWFACTOR³ (P/VIEWFACTOR 1991), a computer code closely integrated with P/THERMAL. An emissivity of 0.9 (Kreith 1959) is used for all of the surfaces in the tank. The flow of air through the tank from the active ventilation is modeled with an advective heat transfer element from the tank air volume to the outside air.

The boundary conditions on the soil surfaces are shown in Figure 1. An average annual air temperature of 53 °F (Stone et al. 1983) is used for the outside ambient air. The energy loss to the atmosphere through the soil surface is modeled using a forced convective heat transfer coefficient of 2 Btu/(h ft² °F) (Bander 1992) at the ground surface, which is based on an average wind speed of 7.7 mi/h across the surface (Stone et al. 1983). An isothermal boundary of 55 °F (Bander 1992) is employed at the water table 200 ft below the ground surface. The axisymmetric model assumes an adiabatic boundary condition at the outer cylinder of the soil at a radius of 60 ft. The 75 ft diameter tanks were built with a distance of 102 ft between centers of tanks. The 60 ft radius provides more soil for heat absorption than a typical tank would have, thus a higher total heat source would be required to attain the temperatures inside the tank. This gives some conservatism to the thermal models used in estimating the total heat source.

A separate model was developed for each tank. The heat source is assumed to be linearly distributed in the waste with the bottom a factor of 2 higher than the top. The main method for evaluating the heat source was a comparison of measured temperatures from thermocouples (TC) in the waste with calculated temperatures from the thermal models. The linearly varying heat source was needed in order to obtain the nearly linear temperature profile as measured by the TC trees. The thermal properties of the various materials in the models are shown in Table 2. The dry waste thermal conductivity of 0.083 Btu/h-ft-°F is based on the minimum thermal conductivity measured on waste from 12 tanks (Bouse 1975). Average waste thermal conductivities of 0.25 to 0.32 Btu/h-ft-°F were obtained by matching the slopes of the temperature profiles in the waste tanks. Since steady-state thermal solutions were obtained, only thermal conductivity is relevant.

¹PATRAN is a registered trademark of the MacNeal-Schwendler Corporation.

²P/THERMAL is a registered trademark of the MacNeal-Schwendler Corporation.

³P/VIEWFACTOR is a registered trademark of the MacNeal-Schwendler Corporation.

Table 2. Thermal Properties.

Material	Thermal conductivity Btu/(h ft °F)
Air	0.016
Concrete	0.435
Soil (dry)	0.152
Soil (average)	0.484
Waste (very Dry)	0.083
Waste (average)	0.25-0.32

SSTs in the SX-Tank Farm have one million gallon capacities and a dished bottom. Figure 2 shows the thermal model in the region of a SX tank. There are eight TC trees in each of the SX tanks. However, only trees #2 and #8 are currently being recorded on a regular basis. Tree #2 is about 30 ft from the center of the tank and tree #8 is about 20 ft from the center of the tank. The tank bottom at the location of trees #2 and #8 are 0.8 ft and 0.3 ft, respectively, higher than the bottom center of the tank.

Figure 3 shows the thermal model with a 10 ft radius dried out section in the center of the tank. This model was used to analyze the effect of a dry zone in the center of the tank, which has a reduced thermal conductivity.

Five years of temperature data (1990 through 1994) were averaged to obtain the temperature distributions for TC trees #2 and #8 of each tank. The TCs from all of the trees have been manually read occasionally. Figure 4 shows the 5 year averaged data and the data for all the trees taken on March 25, 1994 for tank 241-SX-108. The data from the TC tree in riser #15 is considered bad and has not been included. There is about a 30 F° spread in the data at the two lower TCs which are in the waste. The data does not correlate with distance from the center of the tank. A recent core sample from this tank shows that the sludge is very dry.

Figure 5 shows the 5 year averaged data and the data for all the trees taken on April 8, 1996 for tank 241-SX-114. All of the data is fairly compact, except for the TCs in riser #18 which are much lower, with about a 15 to 20 F° spread.

3.0 CASES ANALYZED

Because the SX tanks on the High-Heat list have been interim stabilized for more than 10 years, steady-state solutions of the thermal equations are sufficient to characterize the temperature conditions in each tank. In all of the figures showing tank temperatures versus depth, the depth is measured from

the bottom of the tank at the location of the TC trees. The depth of the waste reported (Hanlon 1994 and Tran 1993) is at the center of the tank. Three cases were analyzed, a bench mark case and two dry out cases.

3.1 BENCH MARKED AGAINST DATA

The total heat load and waste thermal conductivity were adjusted to match measured temperature profiles at the TC locations. Dry soil properties were assumed for the soil surrounding the tank. This case represents what the conditions most likely are currently in and surrounding the tank.

3.2 DRY OUT CASES

Two cases were analyzed for dry conditions in the tanks. The first one represents what conditions might exist as the tank dries from the center out. Dry soil properties were assumed for the soil surrounding the tank. The total heat load assumed was the same as in the bench mark case. A cylinder of waste of 10 ft radius at the center of tank was assumed to have dry waste thermal conductivity, with the remainder of the waste having the same thermal conductivity as for the bench mark case.

The second case represents what temperatures might exist as the tank dries out with average soil properties surrounding the tank. A cylinder of waste of 10 ft radius at the center of tank was assumed to have dry waste thermal conductivity. The total heat load and waste thermal conductivity outside the dry cylinder in the center was adjusted to match measured temperature profiles at the TC locations.

4.0 THERMAL ANALYSIS RESULTS

Table 3 gives the total heat source and thermal conductivities used in the cases, and the calculated maximum temperatures in the waste and concrete. The maximum concrete temperature occurs in the center at the bottom of the waste. Note that for all cases the maximum concrete temperature is below 350 °F, which is the OSR Safety Limit for concrete in SSTs.

Table 3. Total Heat Source, Soil and Waste Conductivity, and Maximum Waste and Concrete Temperature.

Tank /case	Total Heat Source (Btu/h)	Soil Thermal Conductivity Btu/(h ft °F)	Waste Thermal Conductivity outer/center Btu/(h ft °F)	Maximum Temperature (°F)	
				Waste	Concrete
SX-108					
B M ¹	53,800	0.152	0.25/0.25	243	243
Dry 1 ²	53,800	0.152	0.25/0.083	327	312
Dry 2 ³	75,400	0.484	0.35/0.083	343	304
SX-114					
B M ¹	35,900	0.152	0.32/0.32	214	214
Dry 1 ²	35,900	0.152	0.32/0.083	290	266
Dry 2 ³	54,400	0.484	0.45/0.083	321	260

- 1: Bench Marked Case
2: Dry Soil Thermal Conductivity
3: Average Soil Thermal Conductivity

4.1 TANK 241-SX-108

There are eight TC trees in tank 241-SX-108. However, only tree #2 (riser 10) and tree #8 (riser 19) are currently being recorded on a regular basis. There are four TCs on each tree. The distances of the TCs from the bottom of the tank at the tree location are: 0.50 ft, 1.92 ft, 3.33 ft, and 4.67 ft (TRAN 1993). The waste level in tank 241-SX-108 was about 3.1 ft at the center of the tank during the time period over which the temperatures were averaged, therefore the two TCs at the top of the trees are in the tank air-space. An average airflow of 462 scfm obtained from psychrometric data from July 1994 through June 1995 was used in the model.

Figure 6 shows the calculated waste temperatures at the TC tree locations and the center of the tank for the bench marked case. The calculated dome air-space temperature, which represents an average for the entire dome air-space, is about 140 °F which is close to the measured dome temperatures. A comparison with the measured data at tree #2 (30 ft from the center of the tank) is close. The model predicts higher temperatures at TC tree #8 (20 ft from the center of the tank) than the measured data. This may be due to nonuniform heat load distribution or nonhomogeneous thermal conductivities in the waste.

Figure 7 shows the calculated waste temperatures at the TC tree locations and the center of the tank for the two dry center waste cases. For the two dry center cases the maximum temperatures which occur at the center of

the tank increase 85 to 100 F° above the bench marked maximum temperature. The maximum temperature in the concrete increases about 60 to 70 F°. Also note that the maximum temperature in the waste occurs about 0.8 ft above the bottom of the tank. The main point to be noted from these plots is that the temperatures at the TC tree locations do not vary much for the three cases. Thus as the tank dries from the center out the increase in temperatures at the center of the tank are not reflected at the TC tree locations.

4.2 TANK SX-114

There are eight TC trees in tank 241-SX-114. However, only tree #2 (riser 10) and tree #8 (riser 19) are currently being recorded on a regular basis. There are eight TCs on each tree and, since the TC elevations have not been verified (Tran 1993), the spacing from the bottom of the tank is assumed the same as for tank 241-SX-112. The distances of the TCs from the bottom of the tank at the tree location are: 0.50 ft, 1.17 ft, 1.92 ft, 2.58 ft, 3.33 ft, 4.00 ft, 4.67 ft, and 5.33 ft (TRAN 1993). The waste level in tank 241-SX-114 has been at about 5.5 ft at the center of the tank for the last six years, therefore the top TC of the trees may be in the tank air-space. An average airflow of 312 scfm obtained from psychrometric data from July 1994 through June 1995 was used in the model.

Figure 8 shows the calculated waste temperatures at the TC tree locations and the center of the tank for the bench marked case. The calculated dome air-space temperature, which represents an average for the entire dome air-space, is about 140 °F which is about 5 to 10 F° above the measured dome temperatures. A comparison with the measured data at tree #2 (30 ft from the center of the tank) is close. The model predicts higher temperatures at TC tree #8 (20 ft from the center of the tank) than the measured data. This may be due to nonuniform heat load distribution or nonhomogeneous thermal conductivities in the waste.

Figure 9 shows the calculated waste temperatures at the TC tree locations and the center of the tank for the two dry center waste cases. For the two dry center cases the maximum temperatures which occur at the center of the tank increase 80 to 100 F° above the bench marked maximum temperature. The maximum temperature in the concrete increases only about 50 F°. Also note that the maximum temperature in the waste occurs about 1.5 ft above the bottom of the tank. The main point to be noted from these plots is that the temperatures at the TC tree locations do not vary much for the three cases. Thus as the tank dries from the center out the increase in temperatures at the center of the tank are not reflected at the TC tree locations.

5.0 CONCLUSIONS

If tanks 241-SX-108 and 241-SX-114 become dry from the center outward and the thermal conductivity decreases to the very dry condition of 0.083 Btu/(h ft °F) the temperature in the center of the tank can increase around 100 F° while the TC temperatures at the tree in riser 19 (20 ft from

center of tank) increase only around 5 F°. This increase of 5 F° is less than the seasonal variation that occurs in these tanks.

The maximum waste temperature for both tanks for all cases is less than 350 °F. The maximum concrete temperature for tank 241-SX-108 exceeds 300 °F for the dry waste center cases. The concrete exceeds 300 °F in the bottom center of the tank for a radius of about 5 ft. The maximum concrete temperature for tank 241-SX-114 does not exceed 300 °F for all cases.

6.0 RECOMMENDATIONS

Tanks 241-SX-108 and 241-SX-114 should continue to have their temperatures measured in risers 10 and 19 on a regular basis. The current temperatures should be compared with previous measurements during the same time of the year, taking into account the seasonal variation of the ambient temperature. This will give some indication if the temperatures in the tank are increasing due to the thermal conductivity decreasing in the waste.

Figure 1. Entire Thermal Model for 1 Million gal Single-Shell Tank.

Figure 2. SX-Tank Thermal Model.

Figure 3. SX-Tank Thermal Model with 10 ft radius dry waste
in Center of Tank.

Figure 4. Tank SX-108 Measured Temperatures.

Figure 5. Tank SX-114 Measured Temperatures.

Figure 6. Tank SX-108 Calculated Temperature.
(Benchmark Case)

Figure 7. Tank SX-108 Calculated Temperatures.
(Dry Center Cases)

Figure 8. Tank SX-114 Calculated Temperature.
(Benchmark Case)

Figure 9. Tank SX-114 Calculated Temperatures.
(Dry Center Cases)

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APPENDIX A. SX Tank Farms Exhauster Process Test

**Westinghouse
Hanford Company****Internal
Memo**

From: Plant Systems Technical Basis
Phone: 376-0205 HO-34
Date: October 25, 1995
Subject: SX TANK FARMS EXHAUSTER PROCESS TEST

74D10-95-BAC-042

To: S. H. Rifaey T4-07

cc: T. J. Bander HO-34
T. D. Kaiser T4-07
J. R. Kriskovich S2-24
D. M. Ogden HO-34
J. G. Propson S2-02
E. A. Smith H5-56
BAC File/LB

- References:
- (1) WHC, 1995, *Tank Farms Interim Operational Safety Requirements, Rev. 0*, WHC-SD-WM-OSR-018, Rev. 0, Westinghouse Hanford Company, Richland, Washington.
 - (2) Bander, T. J., and C. A. Hinman, 1994, *Evaluation of Heat Sources in High-Heat Single-Shell Tanks*, WHC-SD-WM-ER-333, Rev. 0, Westinghouse Hanford Company, Richland, Washington.
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The exhauster/sludge cooler for the SX tank farms no longer meets current regulations for discharge to the environment. In addition, it requires frequent maintenance, and has poor reliability. If it must be operated for years into the future then resources must be committed to upgrade the system to meet current environmental discharge regulations and to improve the maintainability and reliability of the system. Work is in progress to plan a process test to investigate the possibility of placing the SX tank farm in a passive ventilation mode. This memo is an interim report on the analyses that are underway to resolve the thermal and flammable gas issues associated with conducting this test.

The basic concept of the test is to turn the exhauster off for some predefined period of time and carefully monitor the transducers that are installed in the tank (both thermocouples and hydrogen monitoring system). If the test is properly designed and executed then enough empirical data may be gathered from this type of process test to evaluate the effect of permanent shutdown of the exhauster. At the very least enough data may be acquired to justify conducting another test of longer duration.

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Current models for both temperatures and hydrogen concentrations predict that if the exhauster for the SX tank farms is turned off both the temperatures in the waste and probably hydrogen concentrations in the dome space will exceed current limits. The peak waste and structural temperatures aren't measured, but are inferred from the measured temperatures based on a thermal model of the tank. The hydrogen concentrations in the tank dome space are directly measured.

This process test will provide data that can be used to upgrade (reduce conservatism) the thermal models for the tanks in the SX farm (particularly the hotter tanks SX-114 and SX-108). The direct data from the hydrogen monitoring system can also be used to upgrade the hydrogen generation/distribution model for the hydrogen generating tanks in the SX tank farms.

One of the tasks that was undertaken was a recalculation of the heat load in tanks SX-114 and SX-108 based on a larger data set than was used in the initial screening calculations reported in Reference 2. The methodology and models used were the same. The result of this is a revised estimate for total heat generation in SX-114 of 65,000 Btu/hr. Based on this heat load shutting off the ventilation system will result in an initial rate of rise of the peak waste temperature of 8 °F/month.

While the composition of the interstitial liquid in tank SX-114 isn't known some of the information from Reference 3 would indicate that the principal solute is sodium nitrate. This doesn't have nearly as much of a depressant effect on the vapor pressure as sodium hydroxide, and so vapor pressure as a function of temperature for the liquid in the tank has been taken to be 85% of the value for pure water. This value is needed to predict when saturated conditions occur in the tank.

One of the requirements of this test is that none of the limits that govern the operation of the tanks being tested will be violated. The waste temperature limit is 300 °F, but there is also the requirement that a tank that is projected to boil be placed on active ventilation. Preliminary thermal analysis predicts that a point within tank SX-114 will reach the local saturation temperature about 60 days after the ventilation system is shut down, and the volume that is at the local saturation temperature is projected to exceed 8000 gallons within 90 days of shutting down the ventilation system. The exact meaning of the word "boil" in the existing single shell tank operating specification is not defined, and the original intent may have been to describe continuous active evolution of steam. But technically, when a fluid reaches the saturation temperature it is "boiling."

Current models predict that if the ventilation system for SX-114 is permanently shut down and the contents of SX-114 are allowed to heat up temperatures will be reached that will drive off the interstitial liquid that is currently trapped in the sludge in some reasonably short period of time (less than a decade). If this occurs then the effective thermal conductivity of the waste in the tank is expected to decline significantly. Preliminary assessment of this condition indicates that the temperature of

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both the waste and the concrete can be expected to exceed 400 °F. This of course violates both the waste temperature limit and the Tank Structural Temperature Limit which is 350 °F.

There is also a set of proposed operating limits that are contained in Reference 1. I believe that there is a commitment to implement these limits in the near term although I don't believe that final approval has been obtained at this time. One of the provisions in Reference 1 that will affect this test if the limits are implemented as currently presented is the provision that sludge temperatures be maintained at or below established baseline temperatures. Established baseline temperatures in this context are taken to mean "recent" operating values. When and if this provision is implemented it will effectively prohibit any action that would tend to increase the sludge temperatures. This would of course include the process test itself.

There may be a preferred time of year to conduct this test. The preferred time depends on whether it is deemed most desirable to have as long a test as possible, or to maximize the sensitivity of the instruments used to monitor the test. There is a yearly cycle to the waste temperatures based on the winter-summer temperature variation of the inlet air used for cooling the tanks. Peak temperatures in the waste occur in the last quarter of the calendar year. Minimum temperatures occur in the spring, typically around March or April. The capability to discriminate temperature rise trends from normal variation will be enhanced if the expected/normal behavior of the tank would be a decreasing trend in temperature. From this viewpoint the best time of the year to start the test is probably during the month of November.

It is expected that the length of time that the test can be conducted will be governed by the time required to reach temperature limits (saturation) this would argue that the test is best started in the March-April time frame, since the waste will be at the yearly low temperature (presuming reliable continuous exhaust operation during the winter months) during this time frame.

Based on preliminary thermal evaluation tank SX-114 can be expected to reach the saturation temperature for the liquid in the tank within 60 days after the exhaust system is turned off if the tank is at "average" conditions. Since the yearly temperature swings in the tank are on the order of 12-16 °F and the initial rate of rise for the temperatures is around 8 °F/month it is possible that the length of the test could be extended to around 90 days if it was conducted around the time that the temperatures reach their yearly low.

Initial calculation of the hydrogen concentrations, using an existing analytical model, show that the equilibrium hydrogen concentration depends on the boundary condition chosen. One reasonable but limiting boundary condition shows that the limit (1% by volume) is exceeded. A different limiting case boundary condition shows that it's not. It is expected that the data from the installed hydrogen monitoring system will be closely monitored during the test, and the ventilation system will be restarted if

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October 25, 1995

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it is seen to approach the limit specified in the test plan. The limit for the test is expected to be set at some level below the normal operating limit to allow adequate time to restart the system.

This exhauster system services 13 of the 15 tanks in the SX tank farms. The high heat status of tank SX-114 and possibly tank SX-108 make it unlikely that the results of the proposed process test will support the complete shutdown of the exhauster in this tank farm. A process test should resolve the issue of whether or not the hydrogen watch list tanks require active ventilation. There are also several other tanks in the farm that are on active ventilation and probably don't need it. The current flow for the whole farm is around 3000 cfm. This flow could possibly be reduced to around 1000 cfm by isolating some of the tanks and still meet the cooling needs of the hot tanks. A process test can give valuable information about the tanks in the SX farm that would allow informed decisions to be made concerning changes/upgrades to the farm ventilation systems. It is unlikely that the information obtained will support passive ventilation of all the tanks in the SX farm.

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CONCURRENCE:

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Date: 10/26/95

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