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IN-SITU DRYING PROCESS TEST PROPOSAL

D. R. Dixon

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July 15, 1977

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IN-SITU DRYING PROCESS TEST PROPOSAL

INTRODUCTION

After salt well pumping has been completed in an underground storage tank, interstitial liquid will remain in the salt cake or sludge. Due to the low permeability of the tank solids, this liquid will not drain into the salt well fast enough to make further pumping feasible. The potential mobility of this liquid presents a containment problem and removing it is the subject of this document. In-situ drying involves regulating the flow of air across the solid surface and evaporating the liquid remaining in the salt cake. In order to maximize the rate of moisture removal and better model the drying mechanism, a process test has been proposed.

SUMMARY

To determine if in-situ drying is a practical method of removing the non-recoverable interstitial liquid, a process test is needed. By reducing the tank ventilation rate, the salt cake or sludge will increase in temperature and more moisture can be evaporated. As long as the air flow rate is great enough to replace the moisture laden air with ambient air, the moisture removal rate (MRR) should increase. The maximum MRR will be determined by reducing the flow rate in a stepwise procedure.

A typical storage tank with ventilation equipment is shown in Figure 2. Tanks 105-BY, 107-BY, and 110-U have been chosen for use in these tests. Temperature increases resulting from the process tests will not exceed the maximum tank temperature limits (see Table A2)

DISCUSSION

A. Drying Theory

Since the original process test proposal for in-situ drying was issued (Reference 1), a quantitative theoretical basis for drying has been developed (Reference 2). This model can be used to predict the length of time needed to remove the interstitial liquor at different drying conditions. Laboratory work is presently being conducted to determine the empirical constants necessary to use this equation. In-situ drying times were estimated for Tank 105-BY in Reference 2.

As the air flow rate in a tank is decreased, the tank contents will heat up, raising the liquid vapor pressure and driving off more moisture. If the flow rate of air is great enough to accommodate the increased moisture load, the drying time would decrease. At some point, the air may become stagnant near the solid surface and the rate of moisture removal would

decrease, raising the drying time. Moisture will continue to be removed until the vapor pressure of water above the concentrated liquor is equal to that of the ambient air. The purpose of the process test is to determine the air flow rate at which the maximum amount of moisture can be removed from the tank.

B. Process Test Description

The process test will consist of regulating the air flow rate while measuring the moisture removal rate in the exhaust system (see Figure 1). To determine the moisture removal rate (MRR), psychrometric and air flow rate data will be needed on the inlet and outlet ducts of the tanks as shown in Figure 2. Tank thermocouple data will be needed to determine how much the tanks are increasing in temperature. The data will be used to decide how to adjust the flow rate in order to get the highest MRR. Each time the flow rate is adjusted, two to four weeks will be allowed for the tank to return to equilibrium.

Psychrometric data is presently taken using wet and dry bulb thermometers and a pitot tube for flow measurement. Due to the low air flow rates in some of the tanks, the accuracy of these measurements may not be sufficient. Better methods for taking this data are being explored, but initially will not be available. The psychrometric and air flowrate data will be taken twice weekly until a continuous monitoring system is developed. The tank thermocouple data will be taken at the same time as the psychrometric data. As long as the MRR is increasing, the air flow rate will be decreased.

C. Candidate Tanks

Several different tanks have been considered for use in the process tests. These tanks are shown in Table 1. In choosing a tank (or tanks) certain criteria needed to be met. This included:

- An exhauster system presently available
- No liquid on the surface of the solids
- Phase I salt well pumping complete.

In addition to these limitations, studying the drying properties of different types of solids with varying temperature gradients would be desirable.

Tanks 105-BY, 107-BY, and 110-U have been chosen for the initial tests. The two BY tanks contain salt cake from the atmospheric (ITS) evaporator and some sludge. 105-BY has a substantial temperature gradient but is the third tank in a three tank series on a single exhauster. Adjusting its air flow rate will necessitate changing the flow rate on the other two tanks in the series. 107-BY is on a single exhauster and can be easily adjusted.

This tank has a very small temperature gradient thus making it a good tank to contrast with 105-BY. 110-U is a low heat sludge tank which has been salt well pumped. Lowering the air flow rate to a low heat tank may not increase the MRR considerably.

D. Temperature Implications

Temperature increases resulting from the process tests must not violate the tank temperature criteria. A simplified method of determining the maximum solids temperature is shown in the appendix. The expected temperature changes and maximum allowable solids temperatures are listed in Table A2. No temperature problems are anticipated for the process tests.

E. Process Test Evaluation

As the air flow rate is lowered, the MRR will be determined and compared with the previous rate. Sufficient data must be taken to show a statistical change in the MRR. The data will be used to refine the existing model to allow for general process application. Future work on in-situ drying will be determined from the results of this process test.

REFERENCES

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

5. BNWL-2043, August 1976, S. C. Slate and P. J. Pelto, "Heat Transfer Analysis of an Underground Storage Tank Containing Solidified Heat Generating Wastes"

FIGURE I
PROCESS TEST FLOWSHEET

1. Take Data
(twice weekly)
 - Psychrometric Data
 - humidity
 - flow rate
 - Tank Thermocouple Data
2. Evaluate Data
 - Calculate moisture removal rate (MRR)
 - Compare with previous MRR
 - Determine new flow rate
3. Decrease (increase) flow rate
4. Allow two to four weeks for tank to reach equilibrium.
5. Repeat steps 1-4.

FIGURE 2

IN-SITU DRYING SCHEMATIC

TABLE I
CANDIDATE TANKS

Tank	Liquid Level	Sol. Level	Exhauster System	Temp. Range (°F)	Solids Type SC(Gal.) S(Gal.)	Air Flow Rate (CFM)	Comments
101-B		3' 9"	Yes	86-114	S(103)		
103-BY		14' 7"	Yes*	72-87	S(2) SC(43)	300	
104-BY		14' 10"	Yes*	82-177	S(43) SC(426)	350	Possible pocket of liquid below SC. Phase I pumping complete
105-BY	10'	19' 7"	Yes*	82-143	S(87) SC(539)	500	Cement in tank bottom Phase I pumping complete
107-BY	9'	11' 9"	Yes	77-78	S(150) SC(217)	2250	Phase II pumping
108-BY		11' 6"	Yes	75-100	S(178) SC(181)	300	Phase I pumping complete
112-BY		10' 0"	Yes	86-130	S(15) SC(295)		ITS 2
111-S	12' 6"	19' 6"	Yes	84-121	S(139) SC(484)	300	Phase II pumping
107-SX		3' 9"	Yes		S(109)	750	High Heat Sludge
108-SX		3' 1"	Yes		S(87)	600	High Heat Sludge
111-SX		4' 3"	Yes		S(125)	1000	High Heat Sludge
110-U		5' 6"	Yes	72-78	S(161)	150	Low Heat Sludge Phase I pumping complete

Gal in 1000's
S - Sludge
SC - Salt Cake

*Not individual exhausters

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APPENDIX

TEMPERATURE CALCULATIONS

CFM = Air flow
(ft³/min)
h = enthalpy
(Btu/lb_m)
v = specific
volume (ft³/lb_m)
k = thermal conductivity
(Btu/hr · ft · °F)
s = volumetric heat
generation rate
(Btu/hr · ft³)

ASSUMPTIONS

1. Tank is perfectly insulated on all sides except for the top.
2. $T_s = T_d$, good assumption at low air flow rates.
3. $T_s = T_o$, outlet air temperature is equal to the solid surface temperature.
4. $\Delta T_s = \Delta T_b$, linear temperature profile within solids.

$$Q_{\text{vent}} = Q_o - Q_i$$

$$Q_{\text{total}} = Q_{\text{dome}} + Q_{\text{vent}}$$

$$Q_d = Q_t - Q_v$$

$$Q_d = \frac{k_s A}{s} (T_d - T_a) = \frac{k_s A}{s} (T_s - T_a)$$

$$Q_v = (CFM)_o \frac{h_o}{v_o} - \left[(CFM)_i \frac{h_i}{v_i} + (CFM)_a \frac{h_a}{v_a} \right]$$

$$Q_{d1} \text{ @ time } t_1$$

Q_{d2} @ time t_2 after a change in the ventilation rate.

$$\frac{Q_{d1}}{Q_{d2}} = \frac{Q_t - Q_{v1}}{Q_t - Q_{v2}} = \frac{\frac{K_s A}{s_X} (T_{s1} - T_{a1})}{\frac{K_s A}{s_X} (T_{s2} - T_{a2})}$$

$$\frac{Q_{d1}}{Q_{d2}} = \frac{(T_{s1} - T_{a1})}{(T_{s2} - T_{a2})}$$

$$Q_{d1} (T_{s2} - T_{a2}) = Q_{d2} (T_{s1} - T_{a1})$$

$$Q_{d1} T_{s2} = Q_{d2} (T_{s1} - T_{a1}) + Q_{d1} T_{a2}$$

$$T_{s2} = \frac{Q_{d2}}{Q_{d1}} (T_{s1} - T_{a1}) + T_{a2} \quad (1)$$

Tank 105-BY

$$Q_t = S_s V_s + S_c V_c$$

s = sludge
c = salt cake

$$Q_t = \frac{(3.2 \text{ Btu/hr ft}^3) (87,000 \text{ gal.}) + (.3 \text{ Btu/hr ft}^3) (539,000 \text{ gal.})}{7.48 \text{ gal/ft}^3}$$

$$Q_t = 58,837 \text{ Btu/hr}$$

From psychrometric data (see Table A1)

$$3/8/77 \quad T_{s_1} = 64^\circ\text{F} \quad T_{a_1} = 52^\circ\text{F}$$

$$Q_{v_1} = 12,285 \text{ Btu/hr}$$

$$Q_{d_1} = Q_t - Q_{v_1} = 46,552$$

If the ventilation system were turned off

$$Q_{v_2} = 0$$

$$Q_{d_2} = 58,837$$

Plugging into Eq. 1

$$T_{s_2} = \frac{58,837}{46,552} (64 - 52) + T_{a_2}$$

$$T_{s_2} = 15.2 + T_{a_2}$$

Assuming $T_{a_2} = 75^\circ\text{F}$ during the summer

$$T_{s_2} = 90.2^\circ\text{F}$$

$$T_{b_2} = 151^\circ\text{F}$$

TABLE A1
PSYCHROMETRIC DATA 105-BY

Date	T _a	Flow rate (CFM)		Enthalpy (Btu/lb _m)			Specific Volume (ft ³ /lb _m)			Q _v (Btu/hr)	T _s
		105-BY	106-BY*	h _o	h _a	h _i	v _o	v _a	v _i		
9/13/76											75
10/12/76	62	2809	1272	25.5	20.75	26.3	13.6	13.25	13.7	25,080	
11/7/76											70
11/1/76	57	2135	1016	22.7	19.75	23.7	13.5	13.15	13.6	8,328	
12/4/76											82
12/10/76	36	1166	539	18.74	12.0	19.73	13.2	12.55	13.3	15,376	
1/3/77											74
2/8/77	42	530	268	20.23	13.4	21.36	13.1	12.7	13.2	6,501	
2/26/77											64
3/8/77	52	781	309	22.55	17.17	21.35	13.3	13.0	13.3	12,285	
3/28/77											70
4/20/77	51	608	201	23.1	17.77	30.6	13.5	13.0	13.6	1,906	
4/27/77											72
5/10/77	62	488	310	25.65	23.16	25.64	13.4	13.3	13.4	1,860	

*106-BY exhausts into 105-BY

TABLE A2
TANK TEMPERATURES

Tank	Current Temp. Range (F°)	Current Airflow (CFM)	Minimum Airflow	Maximum ⁺ Solids Temp. (F°) Expected	Allowable* Solids Temp. (F°) from the Standard	Comments
103-BY	72-87	300	50	93	200	103-BY, 105-BY, and 106-BY on single exhauster
105-BY	82-143	500	50	151	200	
106-BY	83-153	300	50	157	200	
107-BY	77-78	2250	50	80	200	
111-S	84-121	300	50	130	230	
110-U	72-78	150	50	100	330	

*Average of bottom four thermocouples

+Average summer ambient temperature assumed 75°F