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B. Document Number RPP-7495-FP

C. Title
Results of Sludge Mobilization Testing at Hanford High-Level Waste Tank

D. Internet Address none

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F. Complete for a Journal Article

1. Title of Journal

G. Complete for a Presentation

1. Title for Conference or Meeting Waste Management '01 Conference
2. Group Sponsoring WM Symposia Inc. and University of Arizona
3. Date of Conference 2/25/01-3/1/01
4. City/State Tucson, Arizona
5. Will Information be Published in Proceedings? [ ] No [x] Yes
6. Will Material be Handed Out? [x] No [ ] Yes

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A-6001-401 (12/00)

RPP-7495-FP

Results of Sludge Mobilization Testing at Hanford High-Level Waste Tank

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

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Contractor for the U.S. Department of Energy
Office of River Protection under Contract DE-AC06-99RL14047

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RPP-7495-FP

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To Be Published
February 2001

To Be Presented at
Waste Management 2001 Symposium
Tucson, Arizona
February 25 - March 1, 2001

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

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Office of River Protection under Contract DE-AC06-99RL14047

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RESULTS OF SLUDGE MOBILIZATION TESTING AT HANFORD HIGH-LEVEL WASTE TANK

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ABSTRACT

Waste stored in Tank 241-AZ-101 at the United States Department of Energy Hanford Site is scheduled as the initial feed for high-level waste vitrification. Tank 241-AZ-101 currently holds over 3,000,000 liters of waste made up of a settled sludge layer covered by a layer of liquid supernatant. To retrieve the waste from the tank, it is necessary to mobilize and suspend the settled sludge so that the resulting slurry can be pumped from the tank for treatment and vitrification.

Two 223.8-kilowatt mixer pumps have been installed in Tank 241-AZ-101 to mobilize the settled sludge layer of waste for retrieval. In May of 2000, the mixer pumps were subjected to a series of tests to determine (1) the extent to which the mixer pumps could mobilize the settled sludge layer of waste, (2) if the mixer pumps could function within operating parameters, and (3) if state-of-the-art monitoring equipment could effectively monitor and quantify the degree of sludge mobilization and suspension.

This paper presents the major findings and results of the Tank 241-AZ-101 mixer pump tests, based on analysis of data and waste samples that were collected during the testing. Discussion of the results focuses on the effective cleaning radius achieved and the volume and concentration of sludge mobilized, with both one and two pumps operating in various configurations and speeds.

The Tank 241-AZ-101 mixer pump tests were unique in that sludge mobilization parameters were measured using actual waste in an underground storage tank at the Hanford Site. The methods and instruments that were used to measure waste mobilization parameters in Tank 241-AZ-101 can be used in other tanks. It can be concluded from the testing that the use of mixer pumps is an effective retrieval method for the mobilization of settled solids in Tank 241-AZ-101.

INTRODUCTION

Radioactive chemical waste generated from decades of nuclear weapons production at the United States Department of Energy Hanford Site is stored in 177 underground storage tanks. As part of the mission to clean up the Hanford Site, tank wastes will be retrieved, pretreated, and immobilized for final disposal. High-level waste staged in underground double-shell tanks will be retrieved and transferred via piping to a new Waste Treatment Plant. The high-level waste staged in double-shell tanks is made up of settled solids in a sludge layer covered by a layer of supernatant. The sludge will be mixed with the supernatant to form a slurry that can be pumped from the tanks.

Mixer pump systems were chosen as the planned retrieval method for double-shell tanks based on engineering technology studies, past experience with hydraulic sluicing at the Hanford Site, and experience with mixer pumps at other United States Department of Energy sites. Retrieval work at the Savannah River Site and the West Valley Nuclear Services Site has shown that more than one mixer pump must be used in a tank to achieve waste mobilization of a large fraction of the settled solids (Ref. 1). Hanford double-shell tank waste is thought to be similar to the Savannah River Site waste; therefore, it is probable that multiple mixer pumps will be required.

Limited testing has been performed in waste tanks at the Hanford Site on the use of a single mixer pump for mitigation of safety issues such as hydrogen generation; however, multiple mixer pump systems for waste retrieval have not been tested. This paper documents the results of sludge mobilization testing in May of 2000 using mixer pumps in Tank 241-AZ-101 (Ref. 2). The sludge mobilization effectiveness of mixer pumps can be determined by measuring the effective cleaning radius. The effective cleaning radius is defined as the radial distance from the pump centerline that the mixer pump jet can effectively mobilize the sludge located at the bottom of the tank. Testing was performed to determine if the effective cleaning radius could be measured reliably in a full-scale tank with the available instruments and if the mixer pumps could mobilize the sludge to a predicted effective cleaning radius. Sludge mobilization measurement is used to predict the amount of settled solid material that can be retrieved from a tank. Predicting the amount of sludge that can be mobilized is important for planning delivery of waste feed batches to the Waste Treatment Plant.

TEST EQUIPMENT AND INSTRUMENTATION

Tank 241-AZ-101

Tank 241-AZ-101 is located in the AZ Tank Farm in the Hanford Site 200 East Area. The 23-meter inside-diameter underground double-shell storage tank has a 3,785,400-liter storage capacity. The tank currently contains over 3,000,000 liters of neutralized current acid waste, including approximately 40 centimeters of sludge (settled solids) covered by 7 meters of supernatant. Heat is generated within the waste primarily from radioactive decay. Before the start of the test, the estimated heat generation rate was 46.1 kilowatts per hour in the sludge and 33.3 kilowatts per hour in the supernatant (Ref. 3). The initial waste temperatures averaged approximately 63 °C in the sludge and 54 °C in the supernatant.

Tank 241-AZ-101 has primary and secondary steel liners, both contained inside a reinforced concrete shell. It has a flat bottom and a domed top with a height of approximately 10.7 meters at the walls and a height of 13.9 meters at the center. The tank is below grade and has approximately 2.1 meters of soil overburden for shielding. Access into the tank for instrumentation and equipment is available through pipe penetrations or risers of various sizes at various locations on the tank dome. A primary ventilation system maintains the tank at a negative pressure so that all air leakage is into the tank air space. An additional ventilation system is available for the annulus area between the two liners.

Numerous in-tank components include 22 air-lift circulators and 12 drywells for instrumentation. The air-lift circulators were used to evenly distribute solids while the tank was being filled and to mitigate hot spots in the tank caused by sludge pile-up. The air-lift circulators had not operated for about 7 years before the test, during which time the solids had settled and consolidated.

Mixer Pumps

The diameter of the tank bottom is 22.9 meters. Two 223.8-kilowatt mixer pumps have been installed in tank penetrations located 6.7 meters north (mixer pump no. 2) and south (mixer pump no. 1) of the tank center. Each mixer pump takes in fluid through a screened intake located 18 centimeters from the tank bottom and discharges the fluid horizontally through two 15-centimeter-diameter opposing nozzles, with the nozzle centerline located 43 centimeters above the tank bottom. A variable-frequency drive unit controls the motor speed of each pump and thus varies the rate of fluid velocity from the nozzles. Each pump is mounted on a turntable, enabling a drive mechanism to oscillate the pumps between –90 degrees and +90 degrees from the north direction. This allows each nozzle to make a 180-degree arc, providing 360-degree coverage around each pump. Each mixer pump assembly is supported on a reinforced concrete pad at the top of the riser flange. The pump shaft is approximately 17 meters long, and the support column has an outside diameter of 40 centimeters. Each pump penetrates the tank through a 107-centimeter-diameter riser. Pump characteristics are provided in Table I.

Table I. Mixer Pump Characteristics

Item	Description
Pump type	Vertical line-shaft-drive mixer pump
Motor type	225 kW, 1,200 rpm, 480 volt / 3-phase / 60 Hz weather-protected enclosure
Total pump weight	12,250 kg (water column filled)
Number of jet nozzles	(2) 180-degree opposed
Diameter of each nozzle	15 centimeters
Flow rate of each nozzle	19,700 L/min @ 1,000 rpm
Fluid velocity @ each nozzle	2.7 m^2/s @ 1,000 rpm
Jet flow direction	Horizontal
Nozzle centerline distribution above floor	43 centimeters
Pump platform rotation speed	180 degrees oscillating at 0.05 to 0.2 rpm

Instrumentation

The primary method for determining the mixer pump effective cleaning radius was by monitoring thermocouples located in and around the sludge layer. Temperatures in the sludge were, on average, approximately 9 °C higher than in the supernatant before the start of the test. The effective cleaning radius of the mixer pumps was determined by inferring movement of sludge away from thermocouples based on decreases to the localized waste temperatures. Thermocouples also were used to determine the change to the bulk waste temperature caused by operation of the mixer pumps.

Thermocouples used to monitor changes in waste temperature include (1) tank bottom thermocouples located just under the primary liner, (2) air-lift circulator thermocouples that protrude from the air-lift circulator assemblies to approximately 10 centimeters off the tank bottom, (3) thermocouples at the bottom of tank drywells located approximately 10 centimeters off the tank bottom, and (4) profile thermocouples located at approximately 10, 35, and 355 centimeters off the tank floor. Thermocouple data were read and recorded at specific intervals before, during, and after pump operation. With the exception of seven locally read thermocouples, all thermocouple data were read and recorded through a data acquisition system located in the 241-AZ-156 Building outside of the AZ Tank Farm. The seven locally read thermocouples included four sludge thermocouples and three profile thermocouples that were manually read by operators by connecting a meter to the thermocouple leads at the top of the tank.

Other instruments used to help determine sludge depth and/or movement included the following:

- Sludge weights, consisting of flat metal plates connected to graduated cables that are manually lowered down a riser until they stop at the sludge surface. A distance reading is taken at the tank surface, and a sludge depth can be calculated by subtracting the obtained reading from the known distance to the bottom of the tank

- Three ultrasonic interface level analyzers, which use an ultrasonic ranging technique to measure the depth of the sludge interfaces in the tanks. The ultrasonic interface level analyzers were mounted at three separate riser locations during the test

- A suspended-solids profiler, which uses a light-scatter technique to measure the suspended solids concentration as a function of height from the bottom of the tank. The suspended solids profiler was located on a riser between the two mixer pumps during the test

- Two portable gamma activity detection systems, which were used to monitor total gamma activity within the waste. The gamma detectors could be lowered down a number of different drywells to obtain gamma activity profiles.

TEST PROCEDURE

Sludge mobilization effectiveness was determined by measuring the effective cleaning radius with one pump operating in a fixed mode, and with one and two pumps operating in an oscillating mode. The primary method for determining the effective cleaning radius was by monitoring thermocouples at known locations for a decrease in temperature as the sludge was being removed and replaced with the cooler supernatant. Before operation of the pumps, the average temperature measured in the sludge layer was approximately 9 °C higher than the supernatant temperature. The average temperature of the insulating concrete thermocouples, located just under the tank floor liner, was approximately 7.8 °C higher than the supernatant temperature. If the thermocouple temperature at a specific location was observed to decrease by 2.8 °C or more for approximately 30 minutes, it was assumed that the mixer pump(s) "cleaned" the sludge off of the thermocouple and mobilized the waste to that point.

The term "fixed mode" is used to describe operation of the pump when the discharge nozzles are oriented at a particular angle and fixed at that angle during testing. Testing to determine the effective cleaning radius in the fixed mode was performed with mixer pump no. 1 oriented to four different fixed positions (see Table II). The positions were chosen so that initial testing also could be performed to determine the force of the mixer pump jet against specific in-tank components. At each position, the pump was oriented toward a specific in-tank air-lift circulator or instrumentation drywell. Fine-tuning of the pump orientation was performed at each position to determine the angle resulting in the maximum deflection of the component as viewed by closed-circuit television. After the angle was determined, the pump was adjusted to the angle of maximum deflection, or if no deflection was observed, the pump was positioned at the calculated angle of the component relative to the pump position. At each fixed position, the pump was operated for approximately 9 hours - three hours each at 700 rpm, 1,000 rpm, and maximum speed (nominally 1,200 rpm).

Table II. Mixer Pump No. 1 Fixed Positions for Effective Cleaning Radius Testing

Position	Component/Pump Orientation	Approximate Pump Nozzle Angle From Console (degrees)
1	Profile thermocouple assembly with strain gauges – Riser 15F	-29
2	Profile thermocouple assembly with strain gauges – Riser 15E	-70
3	Air-Lift Circulator No. 8	41
4	Air-Lift Circulator No. 2	0

The distance to the farthest location where a sustained temperature drop was observed was determined to be the estimated effective cleaning radius for that fixed position. The accuracy of this effective cleaning radius value is limited by the location of and distances between thermocouples in the path of the pump flow and should, therefore, be treated as a minimum distance in each case. For each fixed position, "target" thermocouples were specified that represent the maximum effective cleaning radius that could be achieved. If a sustained temperature decrease was reached at the target thermocouple, effective cleaning radius testing was considered complete at that position. In addition to tank thermocouples, gamma probes, ultrasonic interface level analyzers, suspended-solids profiler, and sludge weights also were used to monitor test parameters and record data during this phase of testing.

The term "oscillating mode" is used to describe operation of the pump when the discharge nozzles are rotated back and forth approximately 180 degrees, allowing for 360 degree coverage around the pump. Effective cleaning radius testing for one mixer pump in the oscillating mode was performed with mixer pump no. 1 oscillating at 0.05 rpm and operating at pump motor speeds of 700 rpm, 1,000 rpm, and maximum speed. Target thermocouples were specified that represented the maximum effective cleaning radius that could be achieved. The mixer pump was operated for a maximum of 24 hours at each of the three pump motor speeds or until there was a sustained decrease of 2.8 °C at the target thermocouples.

Effective cleaning radius testing for two mixer pumps in the oscillating mode was essentially the same procedure as for one pump except that both mixer pumps were operated simultaneously at the same three operating speeds. However, operation of mixer pump no. 2 was limited to a speed of 700 rpm when oriented between pump nozzle positions –30 degrees and +30 degrees because of excessive deflection of a drywell, located approximately 3 meters south of mixer pump no. 2. The first test sequence was operated normally, with both mixer pumps operating at a nominal speed of 700 rpm and oscillating at a speed of 0.05 rpm. At higher pump speeds (1,000 rpm and maximum), mixer pump no. 2 was operated manually rather than continuously oscillated. Mixer pump no. 2 was operated at a fixed location for a period of time (nominally 1 to 2 hours) and then manually rotated to a fixed position, typically 10 degrees from the previous position. When the pump nozzle position was moved between –30 degrees and +30 degrees or vice versa, the pump motor speed was reduced to 700 rpm and the pump was rotated through this zone. The pump motor speed was then increased back to its normal operating speed for the test. This test sequence consisted of approximately 72 hours of operating time (24 hours each at 700 rpm, 1,000 rpm, and maximum speed).

TEST RESULTS

Temperature data were collected from thermocouples located within the sludge below the tank bottom to estimate the effective cleaning radius for various test sequences performed in the fixed mode and oscillating mode (Ref. 4).

Operation of One Pump in the Fixed Mode

The test plan and procedure specify that during fixed-mode testing, mixer pump no. 1 operate for a minimum of 3 hours at each speed of 700 rpm, 1,000 rpm, and maximum speed (nominally 1,200 rpm) at each position. The actual time and duration of pump operation at each speed and at each position is shown in Table III. At position 1, pump operation was interrupted by a high-current alarm while operating at maximum speed. The pump speed was reduced to 700 rpm per the alarm response procedure and then gradually increased while monitoring the pump voltage, current, and bearing temperatures. The pump speed was raised to 1,190 rpm, which was the maximum allowable to maintain current below the alarm point. Total operating time at position 1 was approximately 11 hours and 40 minutes rather than the normal 9 hours. At position 3, the pump speed was lowered from 1,194 rpm to 1,185 rpm and then to 1,178 rpm, to keep a high current setpoint from alarming.

Table IV shows each thermocouple that indicated a sustained temperature decrease near the average solution temperature for each fixed position tested. The starting and ending temperatures of each thermocouple are shown, as well as the ending average solution temperature at the completion of the test sequence. The distance to each affected thermocouple from the centerline of mixer pump no. 1 (Riser 1C) also is presented in the table (effective cleaning radius). Figure 1 is a diagram of the tank bottom, identifying thermocouples in the sludge or underneath the tank bottom (labeled as insulating concrete thermocouples). The diagram shows the sludge areas that were cleaned in each pump position, as determined from the drop in thermocouple temperatures.

Thermocouple response was not dependent on thermocouple type (i.e., insulating concrete, air-lift circulator, profile thermocouple tree, or sludge). Some of the thermocouples showed relatively rapid decreases from sludge temperature to solution temperature, while other thermocouple responses were more gradual. Generally, once a thermocouple temperature was near the solution temperature it would sustain this lower temperature reading. Thermocouple temperatures would slowly rise over time when the mixer pump was turned off or turned to a different position, indicating that the solids were again settling.

The areas of sludge removed by the mixer pump in the fixed mode are pie-shaped, as shown in Figure 1. The angle produced by the jet at each of the four fixed positions, based on thermocouple measurements, ranged from 23 degrees to 29 degrees. These values are conservative because of the spacing of the thermocouples. The amount of sludge mobilized is time dependent and was limited during the fixed-mode test because of the short (9 hours) run time.

Table III. Test Duration in the Fixed Mode with One Pump Operating

Position 1					
Speed (rpm)	**Actual Speed**	**Date**	**Start**	**Stop**	**Duration**
700	700	04/27/00	17:31	21:00	3:29
1,000	700-1,000		21:00	21:31	0:31
1,000	1,000		21:31	1:10	3:39
Maximum	1,000-1,210	04/28/00	1:10	2:38	1:28
Maximum	1,210		2:38	3:45	1:07
Maximum	1,190		5:25	6:51	1:26
TOTAL					**11:40**
Position 2					
Speed (rpm)	**Actual Speed**	**Date**	**Start**	**Stop**	**Duration**
700	730	04/29/00	4:44	7:47	3:03
1,000	995		7:47	10:47	3:00
Maximum	1,199		10:47	13:43	2:56
TOTAL					**8:59**
Position 3					
Speed (rpm)	**Actual Speed**	**Date**	**Start**	**Stop**	**Duration**
700	725	04/29/00	17:25	20:44	3:19
1,000	980		20:44	23:48	3:04
Maximum	1,194		23:48	23:55	0:07
Maximum	1,185		23:55	0:57	1:02
Maximum	1,178	04/30/00	0:57	2:48	1:51
TOTAL					**9:23**
Position 4					
Speed (rpm)	**Actual Speed**	**Date**	**Start**	**Stop**	**Duration**
700	725	04/30/00	7:10	10:09	2:59
1,000	1,000		10:09	13:10	3:01
Maximum	1,178		13:10	16:19	3:09
TOTAL					**9:09**

Table IV. Mixer Pump No. 1 (Riser 1C) Fixed-Position Effective Cleaning Radius Testing Results

Thermo couple Number	Location	Effective Cleaning Radius (m)	Starting Thermocouple Temperature (°C)	Ending Thermocouple Temperature (°C)	Ending Average Solution Temperature (°C)
Position 1					
38	Air-Lift Circulator #2	2.29	58.5	54.7	54.5
64	Riser 15F	4.24	59.9	55.6	
21	Insulating Concrete	4.75	59.8	54.9	
4	Insulating Concrete	5.79	70.6	54.8	
72	Riser 14C	5.82	59.0	50.9	
37	Air-Lift Circulator #1	6.71	67.3	57.3	
1	Insulating Concrete	**8.56**	69.7	54.9	
Position 2					
11	Insulating Concrete	1.95	63.4	56.3	54.8
46	Air-Lift Circulator #10	2.26	61.3	54.3	
61	Riser 15E	6.25	63.4	56.6	
12	Insulating Concrete	6.68	67.5	55.0	
49	Air-Lift Circulator #13	7.92	61.7	54.7	
20	Insulating Concrete	**8.17**	61.5	56.3	
Position 3					
10	Insulating Concrete	3.26	70.0	56.8	54.8
44	Air-Lift Circulator #8	5.03	67.3	55.2	
100	Riser 14F	7.10	58.2	53.4	
23	Insulating Concrete	7.50	60.4	57.1	
9	Insulating Concrete	7.80	69.7	56.3	
58	Air-Lift Circulator #22	**8.05**	61.5	54.9	
Position 4					
22	Insulating Concrete	4.75	59.9	54.8	54.8
3	Insulating Concrete	5.06	69.4	55.6	
37	Air-Lift Circulator #1	6.71	58.5	55.9	
2	Insulating Concrete	8.08	72.3	56.0	
43	Air-Lift Circulator #7	**8.96**	59.7	55.7	

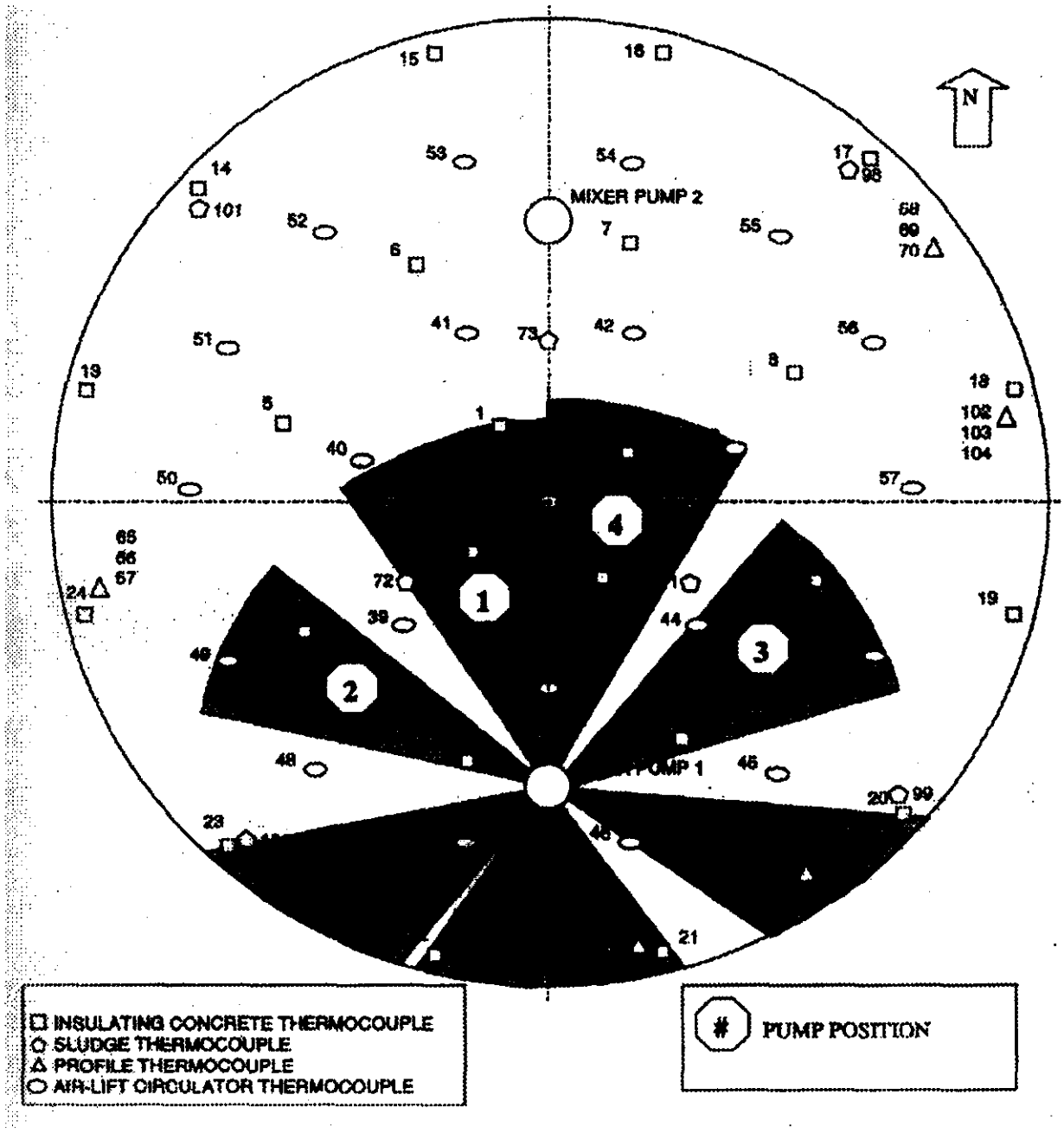

Figure 1. Estimate of Sludge Cleared By Mixer Pump No. 1 Operation in the Fixed Mode at 700 rpm, 1,000 rpm, and Maximum Speed

The exact volume of sludge that was mobilized in the fixed mode, corresponding to the effective cleaning radius at each position, is difficult to determine from thermocouple data for several reasons. First and foremost, the accuracy of the effective cleaning radius is limited to the spacing of the operational thermocouples, which in some cases are several meters apart. This gives a conservative estimate of the effective cleaning radius. Secondly, because the air-lift circulator, sludge, and bottom-profile thermocouples used for measuring the effective cleaning radius are located 10.2 centimeters off the tank bottom, it is not known for certain, from the change in thermocouple temperatures, if the mixer pumps cleaned the sludge completely to the bottom of the tank floor. It is possible that sludge residue less than 10.2 centimeters deep could remain on the tank bottom, even if the sludge thermocouples reach supernatant temperatures. Finally, because the mixer pump jet becomes less effective as it travels farther away from the pump, the sludge likely will be cleaned to a greater depth near the pump than it will farther away.

Operation of One Pump in the Oscillating Mode

Table V lists the thermocouples farthest from the mixer pump that showed a sustained temperature drop close to the average solution temperature for each speed tested in the oscillating mode. The starting and ending temperature of each thermocouple is shown, as well as the ending average solution temperature at the completion of the test sequence. The effective cleaning radius also is presented in the table.

Table V. Mixer Pump No. 1 Oscillating Effective Cleaning Radius Results

Thermo couple Number	Type	ECR (m)	Starting Thermocouple Temperature (°C)	Ending Thermocouple Temperature (°C)	Ending Average Solution Temperature (°C)
Mixer Pump No. 1 – Oscillating at 700 rpm					
40	Air-lift Circulator	8.8	66.6	54.9	54.8
Mixer Pump No. 1 – Oscillating at 1,000 rpm					
5	Insulating Concrete	10.5	69.7	57.1	55.4
Mixer Pump No. 1 – Oscillating at Maximum Speed					
8	Insulating Concrete	11.3	63.6	56.8	56.2

ECR = Effective cleaning radius.

Figure 2 is a diagram of the tank bottom, identifying thermocouples in the sludge or underneath the tank bottom and showing each thermocouple's general location. The diagram contains a set of arcs representing the estimated cleaned area at different operating speeds, based on thermocouple temperature change from the start to the completion of the test sequences. Figure 2 corresponds to testing performed with only mixer pump no. 1 operating in the oscillating mode. Temperatures at thermocouples that dropped to within a few degrees of the solution temperature at the completion of the test sequence are included inside or on the arc for the particular operating speed.

Operation of Two Pumps in the Oscillating Mode

Table VI lists the thermocouples farthest from the mixer pumps of interest that indicated a sustained temperature drop at or near the average solution temperature for each speed tested with both pumps oscillating. The starting and ending temperature of each thermocouple is shown as well as the ending average solution temperature at the completion of the test sequence. The distance of the particular thermocouple from the centerline of the mixer pump(s), or effective cleaning radius, also is presented in the table.

Table VI. Mixer Pumps No. 1 and No. 2 Oscillating Effective Cleaning Radius Testing Results

Thermo couple Number	Type	Effective Cleaning Radius (m)	Starting Thermocouple Temperature (°C)	Ending Thermocouple Temperature (°C)	Ending Average Solution Temperature (°C)
Mixer Pumps No 1 and No. 2 – Oscillating at 700 rpm					
5	Insulating Concrete	10.5 [Pump 1]	67.0	54.9	54.5
8	Insulating Concrete	6.7 [Pump 2]	66.8	54.9	54.5
Mixer Pumps No. 1 and No. 2 – Oscillating at 1,000 rpm					
19	Insulating Concrete	11.4 [Pump 1]	61.2	56.0	55.2
51	Air-Lift Circulator	8.0 [Pump 2]	78.2	56.0	55.2
Mixer Pumps No. 1 and No. 2 – Oscillating at Maximum Speed					
19	Insulating Concrete	11.4 [Pump 1]	-[1]	-[1]	-[1]
18[2]	Insulating Concrete	11.4 [Pump 2]	63.1	61.6	61.2

[1] This thermocouple was previously cleared when mixer pumps No. 1 and No. 2 were oscillating at 1,000 rpm.

[2] This thermocouple did not clear during the section of the test being performed for effective cleaning radius testing. This thermocouple did clear while performing the settling testing section of the test. Temperatures reflected are during settling testing.

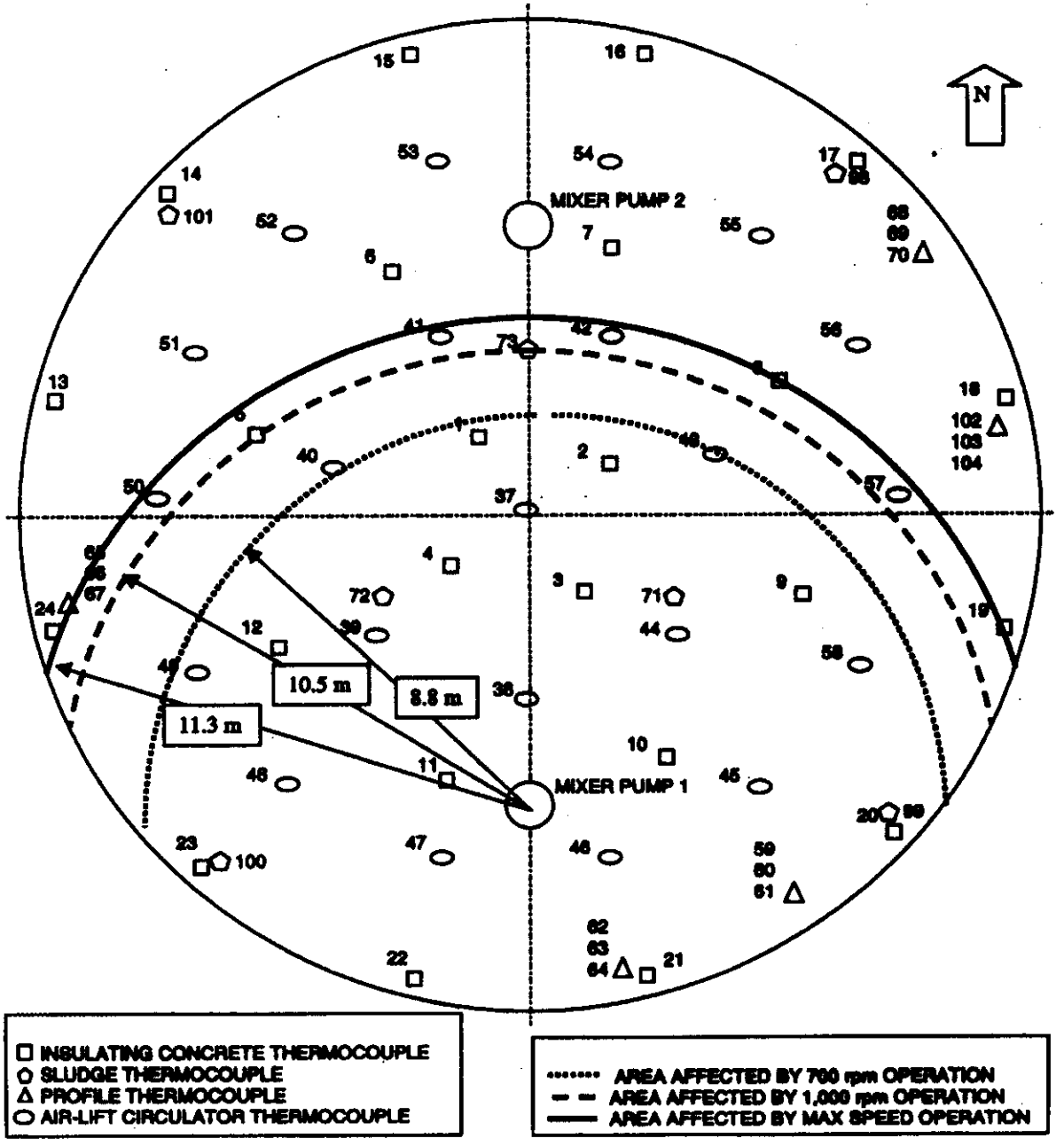

Figure 2. Estimate of Sludge Cleared from Mixer Pump No. 1 Operation in the Oscillating Mode at 700 rpm, 1,000 rpm, and Maximum Speed

Figure 3 is a diagram of the tank bottom, identifying thermocouples in the sludge or underneath the tank bottom (labeled as insulating concrete thermocouples) and showing each thermocouple's general location. The diagram contains a set of arcs representing the estimated cleaned area at different operating speeds, based on thermocouple temperature change from the start to the completion of the test sequences.

Figure 3 corresponds to testing performed with both pumps operating in the oscillating mode. Temperatures at thermocouples that dropped to within a few degrees of the solution temperature at the completion of the test sequence are included inside or on the arc for the particular operating speed. Figure 3 shows a much larger arc (radius of 10.5 meters) for mixer pump no. 1, operated at 700 rpm, than for mixer pump no. 2. This is because the sludge in the half of the tank nearest mixer pump no. 1 had previously been mobilized by pump operation and had resettled. Thus the arc around mixer pump no. 1, when operated at 700 rpm, represents mobilization of recently disturbed material. Figure 3 also shows that all thermocouples present in the sludge and underneath the tank bottom are cleared by the operation of both mixer pumps.

Thermocouples 13 and 18, tank bottom thermocouples (shown as insulating concrete), were the last two thermocouples to clear to solution temperature. These thermocouple temperatures showed a more gradual decline over time, appearing to support the idea of material slowly being eroded away, unlike the response of most of the thermocouples, which took sharper temperature drops to within a few degrees of the ending average solution temperature.

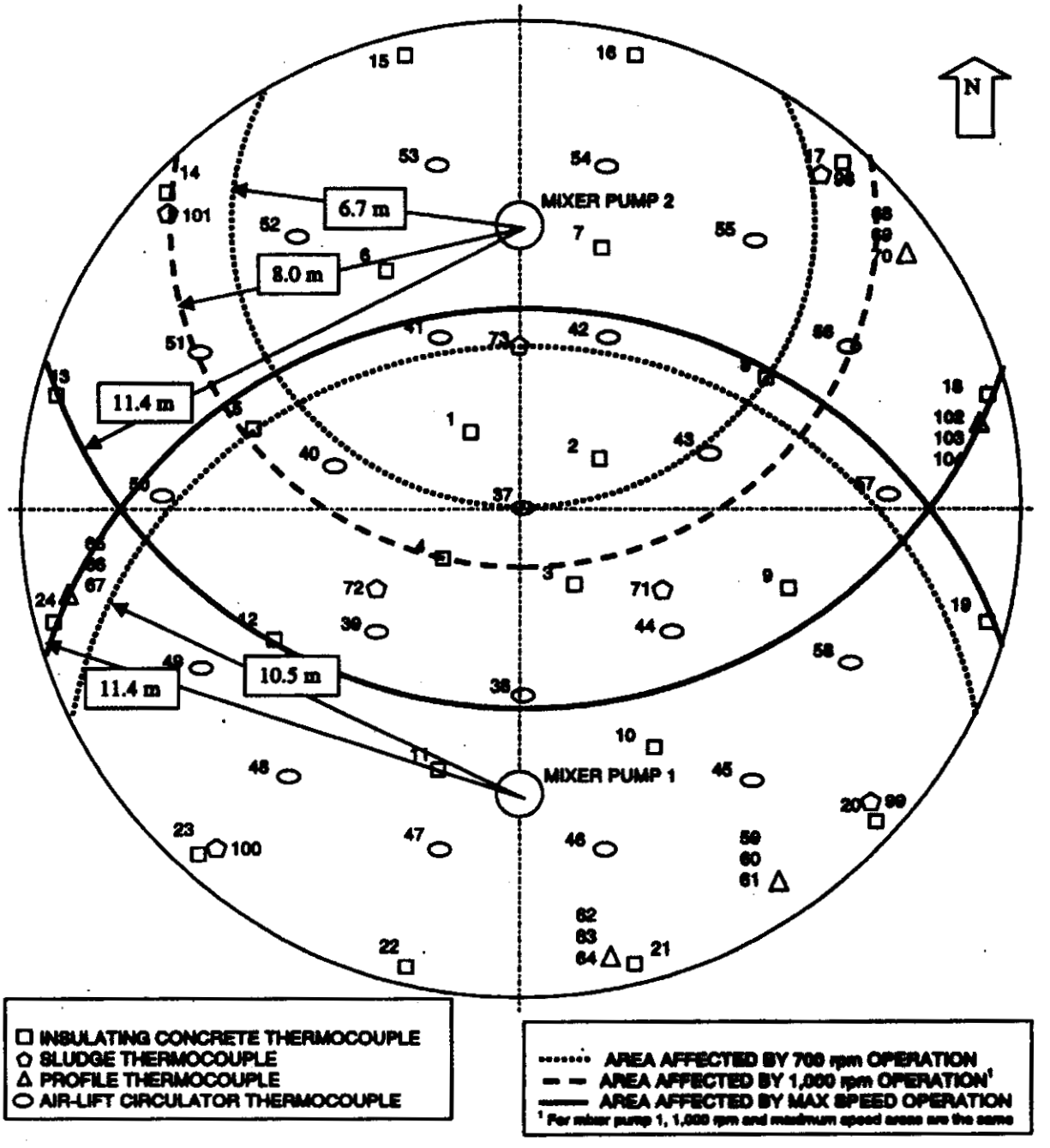

Figure 3. Estimate of Sludge Cleared from Mixer Pump No. 1 Operation in the Oscillating Mode at 700 rpm, 1,000 rpm, and Maximum Speed

SUMMARY

As a result of mixer pump operation during the test, thermocouple temperature decreases indicated that all thermocouples near the tank bottom previously covered by sludge were cleared. This represents an area of approximately 95% of the tank bottom. Because thermocouples are not present at the tank wall, it is not possible to state unequivocally that the area between the last thermocouple and the tank wall was cleared, however, it can be inferred from the thermocouple data that sludge was mobilized from 100% of the tank bottom. The predicted effective cleaning radius at rated speed (1000 rpm) for the mixer pumps was expected to be 9.8 meters (32.2 feet). The actual effective cleaning radius at rated speed, as demonstrated by mixer pump no. 1, was at least 11.4 meters (37.4 feet).

The results of the mixer pump test shows that the use of mixer pumps is an effective method for mobilizing settled sludge for waste retrieval. These test results, and continued preparations for the treating of Hanford's tank waste, provide additional confidence that settled sludge can be mobilized and transferred as slurry feed suitable for Waste Treatment Plant vitrification.

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