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K EAST CANISTER SLUDGE SURVEY

A. L. Pitner

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Abstract: Sludge depths were measured in 60 selected canisters in the K East Basin. The projected K East basin total canister sludge inventory based on these measurements is 3 cubic meters. After sludge samples were extracted from 12 canisters, the sludge depth measurements were repeated to confirm adequate sample volumes had been obtained to perform prescribed analytical and testing activities.

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K EAST CANISTER SLUDGE SURVEY

A. L. Pitner

August 1996

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1.0 SUMMARY

To support a canister sludge sampling campaign in the K East basin, a survey was conducted using an ultrasonic probe to measure the sludge depth in 60 candidate canister barrels. A number of sludge samples from these candidate canisters are to be analyzed to determine the appropriate disposal pathway for canister sludge. Results of the survey were used to assure that proper canisters were selected to obtain adequate sludge sample volumes for analyses and characterization. The results were also used to estimate a total canister sludge inventory in the K East basin, which is projected to be about 3 cubic meters. Sludge depth measurements were repeated after sampling to confirm that adequate sample volumes had been obtained. Recent laboratory assessments have verified that suitable sludge sample quantities were in fact obtained for prescribed analytical and characterization activities.

2.0 INTRODUCTION

In the spring of 1996, sludge samples were taken from a number of canisters in the K East basin for laboratory analysis (Welsh 1996). The results of these analyses are expected to determine whether this canister sludge can be accepted for storage in the Tank Waste Remediation System (TWRS) or whether some other method of disposal will be required (Makenas 1996). In order to select appropriate candidate canisters for this sludge sampling, a survey was first conducted using an ultrasonic probe to measure the sludge depth in some 60 canister barrels to assure that an adequate sludge inventory was available for sampling. Canister selection for this campaign was based on observations made in the visual survey of the K East basin conducted in the summer of 1994 (Pitner 1995). A variety of canisters were measured for sludge depth, including "empty" canisters (i.e., canisters containing sludge but no spent fuel elements), canisters containing relatively clean fuel, and canisters containing highly degraded fuel.

This report gives the results of the sludge depth measurements made in the 60 candidate canisters. A projection of the total canister sludge inventory in the K East basin is also made based on these selected sludge depth measurements. In addition, sludge depth measurements in canisters actually sampled for sludge were repeated to provide an estimate of the sample volumes obtained.

3.0 TECHNIQUE

The measurements of sludge depth in the canisters were performed using an ultrasonic probe. Shown in Figure 1, this apparatus consisted of an ultrasonic transducer attached to the end of a probe suspended from crossbars that rested on the top of the canister barrel. The signal from the transducer measured the distance to the top of the sludge layer, or the bottom of the canister if no sludge were present. The system was developed and proof tested in a mockup test facility (Steele 1996) prior to the actual basin measurement campaign. The survey was conducted in accordance with a test plan developed for this endeavor (Pitner 1996). Basically, all the measurements possible in a canister barrel were made. For a barrel fully loaded with seven fuel assemblies, there are 12 possible measurement locations in the openings between the assemblies. In actuality, generally less than 12 measurements were obtained because of difficulty in inserting the probe and concern of potential damage to the probe if excessive force were applied. The openings around the outside edge (between the barrel and fuel elements) were generally more accessible than the inner spaces, but this zone accounts for about 2/3 of non-fuel area in the canister. The measurements obtained were averaged to define the sludge depth for each canister.

A total of 60 canister barrels were measured in this campaign. The canister locations selected were limited to those positions under the slots in the grating because the sludge sampling equipment is operable only in these locations. The canisters were selected to be representative of canister type (stainless steel or aluminum), fuel condition, and spatial distribution in the fuel storage basin.

4.0 SLUDGE DEPTH MEASUREMENTS

The results of the sludge depths measurements are presented in Table 1. The "E" or "W" designation in the location identifier indicates whether the east or west barrel was measured. Generally only one barrel of each canister was measured, but both barrels were measured on several select canisters. The canister type (stainless steel or aluminum) is also identified in the table, along with a general rating of the fuel condition in the canister barrel. A "Good" rating indicates that all the fuel elements are basically intact with no significant reacted fuel evident. A "Fair" rating indicates that one or more of the fuel elements are failed with definite fuel reaction products present. A "Bad" rating signifies that at least one fuel element is highly degraded with split and/or dilated cladding, and with some fuel voiding likely evident. This voided fuel would be presumed to contribute to the sludge inventory in the bottom of the canister. Finally the measured sludge depth (average of all measurements in the barrel) is given for each canister along with the standard deviation of the measurements. If no standard deviation value is given, it indicates that only a single measurement was possible in that canister barrel.

Although there is considerable scatter in the sludge measurement data, general trends are recognizable. Empty canister barrels typically have very little sludge in them, while the depth of sludge in canisters loaded with fuel is generally greater for those with the more degraded fuel. The standard deviations for these "Bad" fuel canisters are seen to generally be relatively high, reflecting the variation in sludge depth at various locations within the canister. When both barrels on a canister were measured, the depths were usually comparable if the fuel condition were the same in both barrels (canisters in Cubicles No. 2244, 4168, 4569, 5465, 5618, and 6413). In the double barrel measurement of the one canister that had different degrees of fuel condition in each barrel, the barrel with the more degraded fuel had more sludge (canister in Cubicle No. 5427).

The results of the canister sludge measurements are presented graphically in Figure 2. The measurements are segregated by canister type (stainless steel or aluminum), but not by fuel condition. As indicated in the box in the figure, the sludge depth in aluminum canisters averages about twice that in stainless steel canisters. This is consistent with the observation that the most degraded fuel was generally loaded in aluminum canisters (Pitner 1995).

The relationship between sludge depth and fuel condition becomes more apparent in the graphic representation shown in Figure 3, where average sludge depths for each category are plotted. While the qualitative ratings along the abscissa have no real quantitative meaning, the general trend of increasing sludge depth with increasing fuel degradation is quite evident. Also, the depth of sludge in aluminum canisters with degraded fuel is greater than that in stainless steel canisters with degraded fuel, consistent with the observation made above. The error bars shown in the figure represent one standard deviation for all the measurements in a particular category. The large scatter on "Bad" aluminum canisters reflects the varying number of failed fuel elements in this broad fuel rating category; i.e., the number of elements with dilated and split cladding ranged from one to all of the

elements in a barrel. The average sludge depths ranged from very little (1/2 inch or less) in empty canisters and canisters containing good fuel, to over 5 inches for aluminum canisters with bad fuel.

5.0 CANISTER SLUDGE INVENTORY ESTIMATE

Using the average sludge depth values for each category of fuel condition and based on the distribution of canister fuel conditions in the basin (Pitner 1995), an estimate can be made of the total sludge inventory in the canisters containing fuel. For this purpose, the sludge in empty (no fuel elements) canisters (which was measured to be low) is not considered. Empty canister sludge would be expected to be similar in composition to floor sludge, and likely will be treated as such. Depending on characterization results, canister sludge may turn out to be different enough that special treatment and/or disposal methods might be required.

The basis for estimating the total canister sludge inventory in the K East basin is presented in Table 2. The number of each type of canisters in the various fuel condition categories is given along with the average sludge depth in that category based on the average ultrasonic probe measurements. To calculate the volume of sludge in the canisters, it is assumed that canisters in the "Good" and "Fair" categories have 7 fuel assemblies loaded in each barrel, and canisters in the "Bad" category have 6 fuel assemblies loaded in each barrel. Although there are exceptions to this situation, the visual survey of the fuel generally supports this assumption. Even though most of the fuel is contained in stainless steel canisters, most of the sludge volume resides in aluminum canisters based on these estimates. The total canister sludge volume shown in Table 2 is about 2.6 cubic meters. Allowing for the 3% of the canisters that were not included in the visual survey due to viewing obstructions and for measurement uncertainties, the total K East basin canister sludge volume is estimated to be about 3 m³.

An earlier estimate of the canister sludge volume in the K East basin projected a volume of 7.8 m³ (Baker 1995). That estimate, however, was based on limited data for empty canisters, with no information on canisters loaded with fuel elements. Consequently, considerable conjecture was involved in the previous estimate. Interestingly enough, though, with two-sigma uncertainties applied to the current survey results the estimated total canister sludge volume would be 7.4 m³, very close to the previous estimate.

6.0 SLUDGE SAMPLE VOLUMES

Attempts at obtaining sludge samples for laboratory analysis were made on twelve canister barrels. After the sampling campaign, ultrasonic measurements were repeated on the sampled canister barrels to obtain some indication of the quantity of the sludge sample recovered. Results of these measurements are given in Table 3. The pre- and post- sampling sludge depths are reported, along with the change in sludge depth, the specific volume of sludge per inch of depth based on the number of elements loaded, and the corresponding estimate of sludge sample volume based on the ultrasonic measurements. A nominal objective was to obtain sludge samples volumes on the order of 500 cm³.

The ultrasonic measurements indicate that for one of the empty canisters sampled (No. 4638E), no sludge sample was obtained. The same small depth measured before and after sampling probably indicates no sludge was present in this canister barrel; i.e., the measured values are on the order of uncertainty in canister height which must be factored in when interpreting the ultrasonic signals. On two other canister barrels (Nos 5043W and 6070W) the 16 inch long ultrasonic probe was buried in the sludge before and after sampling, so no signals were obtained in these measurement attempts. Thus the volume of sludge for these two samplings is inconclusive. For the remaining nine samplings, the ultrasonic measurements indicate definite decreases in sludge depth levels following the samplings. The accuracy of the indicated sample volumes in Table 3 must be kept in perspective considering the large standard deviations involved in the individual canister measurements, especially for "Bad" fuel canisters. However, the general indications are that substantial sludge sample volumes were usually obtained. This includes obtaining a suitable sample from an empty canister (No. 6073W).

In actuality, nine sludge samples were obtained and transferred to the laboratory for characterization. To date, four of these samples have been transferred to graduated cylinders where the actual sample volumes can be observed. These results are also included in Table 3. In general, the laboratory observations agree reasonably well with the estimates made from the ultrasonic measurements of sludge depth. The sample volumes indicated are considered adequate to perform prescribed analyses and characterization.

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Table 1. Sludge Depth Measurements.

Location	Canister Type	Fuel Condition	Sludge Depth (in)	Std Dev (in)
418W	SS	Fair	0.66	0.32
627W	SS	Bad	1.00	0.59
660E	SS	Bad	3.23	1.37
1236W	Al	Bad	4.61	4.36
1243W	Al	Bad	2.27	0.39
1267E	Al	Bad	4.77	2.41
1743W	Al	Empty	0.00	0.21
1845E	SS	Good	2.33	0.35
1858E	Al	Fair	0.81	1.03
2210E	Al	Fair	1.06	0.51
2211W	Al	Bad	4.02	1.92
2214E	Al	Bad	2.26	1.11
2229E	Al	Bad	3.31	1.75
2244E	SS	Good	0.00	0.26
2244W	SS	Good	0.00	0.16
2248W	SS	Good	0.00	0.08
2350E	Al	Bad	3.44	1.23
2353E	Al	Fair	1.79	0.97
2355W	Al	Bad	1.68	0.59
2540E	SS	Bad	1.16	0.59
2575W	Al	Empty	0.48	0.42
2711E	SS	Fair	1.71	1.44
2722E	SS	Bad	1.80	0.59
2756E	SS	Bad	1.36	0.71
3128W	SS	Bad	3.34	2.26
3727W	Al	Fair	3.02	2.03
3971W	SS	Bad	1.24	0.36
4138W	Al	Fair	3.32	0.78
4143W	Al	Bad	2.29	1.70
4168E	Al	Fair	0.39	0.15
4168W	Al	Fair	0.44	0.12
4359W	SS	Fair	0.28	0.17
4569E	Al	Bad	3.42	----
4569W	Al	Bad	10.59	----
4620W	Al	Fair	2.67	0.90
4627W	Al	Fair	1.31	0.66
4638E	SS	Empty	0.38	0.14
4661E	SS	Good	0.00	0.20
4767E	SS	Empty	0.41	0.11
4865W	Al	Fair	2.05	0.76
5043W	Al	Bad	12.5	----
5055W	Al	Bad	5.66	2.01
5069E	Al	Fair	2.74	1.50
5238W	SS	Fair	1.24	1.10
5254E	Al	Fair	1.32	0.50
5427E	Al	Fair	1.58	0.48
5427W	Al	Bad	3.24	3.05
5445E	Al	Bad	7.52	3.40
5465E	Al	Bad	6.84	----
5465W	Al	Bad	8.55	1.87
5608E	SS	Fair	0.00	0.15
5618E	SS	Fair	0.85	0.15
5618W	SS	Fair	1.53	0.33
5655W	SS	Empty	0.13	0.08
6057E	SS	Fair	1.91	1.40
6069W	Al	Fair	0.07	----
6071W	Al	Bad	8.74	2.12
6073W	SS	Empty	0.53	0.13
6413E	SS	Fair	1.46	0.31
6413W	SS	Fair	1.83	0.27

Table 2. Total Canister Sludge Volumes.

Category	Canister Type	No.	Avg Sludge Depth (in.)	Volume of Sludge (cm ³)
Good	SS	1433	0.47	416,000
	A1	391	0.47	114,000
Fair	SS	690	1.15	490,000
	A1	855	1.63	861,000
Bad	SS	49	1.88	71,000
	A1	155	5.32	633,000
Totals	SS	2172		977,000
	A1	1401		1,608,000
Grand Total		3573		2,585,000

Table 3. K East Canister Sludge Sample Volumes.

Location	No. of Elements	Pre-Sampling Depth (in)	Post-Sampling Depth (in)	Change in Depth (in)	Void Vol/in (cm ³ /in)	UT Measured Sample Vol. (cm ³)	Observed Lab. Sample Vol. (cm ³)
1845E	5	2.33	1.64	0.69	460	317	310
2350E	7	3.44	1.36	2.08	309	643	430
2711E	7	1.70	0.44	1.26	309	389	
3128W	6	3.34	2.39	0.96	384	369	350
4638E	0	0.38	0.39	0.00	837	0	
5043W	6	>12*	>12*	----	384	---	
5055W	6	5.66	4.71	0.95	384	365	
5465E	6	6.84	5.92	0.93	384	357	
5465W	6	8.55	7.52	1.03	384	396	320
6070W	7	>12*	>12*	----	309	---	
6071W	7	8.74	4.73	4.02	309	1242	
6073W	0	0.53	0.00	0.53	837	444	

* UT probe buried in sludge

Figure 1. Ultrasonic Sludge Depth Measurement Probe.

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Figure 2. Canister Sludge Depth Measurements in K East Basin.

Figure 3. Sludge Depth vs. Fuel Condition.

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