Wet/Dry/Sounding Reel Tape Final Report (U)

by

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KEYWORDS: reel tape, Tank Farm,
level

RETENTION: Permanent

WET / DRY / SOUNDING REEL TAPE FINAL REPORT (U)

D. L. Speed

November 30, 1994

Westinghouse Savannah River Company
Savannah River Site
Aiken, SC 29808

SAVANNAH RIVER SITE

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WET / DRY / SOUNDING REEL TAPE FINAL REPORT

by D. L. Speed

SUMMARY

The Interim Waste Technology (IWT) section of the Savannah River Technology Center evaluated a demonstration model of a modified reel tape for High Level Waste Engineering. The standard Robertshaw Model 185 reel tape is used in the Tank Farms as a conductivity probe to monitor liquid levels in waste tanks within ± 0.1 in. The demonstration model features a device that also stops the reel tape motor on loss of tension in the tape. Tests conducted at TNX showed that the modification enabled the reel tape to locate solid surfaces such as saltcake within approximately ± 0.5 in. The modified reel tape also located, within approximately ± 0.5 in., the sludge/supernate boundary exhibited by sludge from TNX Tank F, which closely approximates the sludge expected to exist after the Tank 42H sludge wash process.

IWT recommends that the tape tension modification, with the associated controls, be installed in all Robertshaw reel tapes used in the Tank Farms. The modified probe should also be considered for installation in those tanks that have a free or submerged semi-solid surface of interest.

INTRODUCTION

High Level Waste Engineering (HLWE) requested the Interim Waste Technology (IWT) section to evaluate a demonstration model of a modified reel tape. The reel tape currently used in the Tank Farms monitors the liquid level in waste tanks by lowering a conductivity probe into the tank, suspended by a steel tape (Figure 1). When the probe contacts a grounded conductor (the liquid waste), the Ground Sensing Circuit (GSC) cuts power to the spool motor. An encoder monitors how much tape is spooled out, and generates a readout of the liquid level.

However, some tanks have insufficient free liquid for this system to function properly: the GSC is not activated when the probe contacts a dry saltcake surface. Nor is the present design of use in locating a sludge/supernate boundary, as is needed for Tank 42 at the Extended Sludge Processing (ESP) facility. The method currently

employed is lowering a photocell assembly to measure opacity, a system expensive in both solid waste generation and personnel radiation exposure.

Figure 1. Current Reel Tape Configuration

The model evaluated consisted of a standard Model 185 Robertshaw reel tape and its associated control circuitry, with the addition of an electromechanical switch actuated by loss of tape tension (Figure 2). In the "Wet/Dry" mode of operation, the probe will halt upon contact with a liquid surface, as usual, through contact #3. If the probe encounters a solid surface first, however, the tape begins to go slack and the lever arm swings counterclockwise; the circuit to ground is completed through contact #1, and the tape drive stops. In the "Sounding" mode of operation, used for detecting a solid or semisolid surface, only the release of tape tension actuates the GSC (through contact #2).

Figure 2. Modified Reel Tape Configuration (shown in Wet/Dry mode)

DISCUSSION

Objectives

IWT was given the following directives:

- Verify the ability of the modified reel tape to locate a liquid surface.
- Verify the ability of the modified reel tape to locate a solid surface, both free and submerged.
- Evaluate the effectiveness of the modified reel tape in locating a sludge/supernate boundary.
- Install and verify any field modifications considered necessary or desirable to improve functionality and repeatability.

Assumptions

The following assumptions were made during this evaluation:

- The sludge used in the evaluation (from TNX Tank F) closely approximates the sludge expected to exist after the Tank 42H sludge wash process. Appendix A contains a chemical analysis of the sludge simulant.
- When locating the sludge/supernate boundary, the primary factor contributing to loss of tape tension is the increase in buoyant force as the probe moves into the sludge. The weight of the tape does not enter into the free-body calculations for the probe (refer to Appendix C), and the effect of drag is considered negligible due to the slow rate of descent of the probe, its geometry, and its smooth finish.

Test Setup

Figure 3 shows the general arrangement of the test equipment. The "tank" used in the test was a five foot length of 6 in. ID Plexiglas tube, epoxied to a square base plate. Approximately 6 gallons of sludge from TNX Tank F was poured into the tank; it settled to the dimensions shown. Figure 4 illustrates both the components and the operation of the lever arm assembly as delivered to IWT. The probe itself, supplied by Robertshaw, is 6 in. long and 1 in. diameter solid steel.

When placed in automatic service, as is customary for waste tanks with a free liquid surface, the reel tape is set to seek level every 30 seconds by procedure.¹ This cycle consists of the motor energizing to lift the probe high enough to clear the grounded

condition, then immediately lowering the probe again until the GSC is actuated. The spool motor can also be operated manually to raise or lower the probe.

Figure 3. Plexiglas Sludge Tank

Figure 4. Lever Arm Details (not to scale)

Operation in Wet/Dry Mode

When the ground wire was inserted into the tank as shown in Figure 3, and the selector switch was in the "Wet/Dry" position, the probe located the liquid surface exactly as it would in a waste tank with a liquid surface.

When the probe was over a solid surface, however, such as a Plexiglas cover placed over the top of the tank, the probe located the surface and stopped with the probe leaning slightly (approximately 15 to 20° from vertical). This angle, which was a result of the tape slack that allowed the lever arm to rotate properly, was exaggerated with each subsequent seek until the probe was nearly lying down and the motor controller would display an error.

To correct this behavior, the motor controller's timing circuit was modified to lift the probe approximately two inches each time before lowering it. This modification prevented the accumulation of slack in the tape, and the probe came to rest at approximately the same angle each time.

A second problem was noticed after several hours of total operating time: the lever arm tended to chatter as it rode on the tape, and no amount of adjustment of the nut (refer to Figure 4) would eliminate the chatter. However, the lever arm had been quickly constructed from available spare parts, and the chatter was readily stopped by fabricating a new lever arm of oil-impregnated bronze (a detail sketch is attached as Appendix B), which eliminated the steel-on-steel friction. The new arm, though threaded for an adjusting nut, worked well without one, so the nut was left off for the remainder of the evaluation.

Operation in Sounding Mode

When in Sounding mode, the standard 6 in. stainless steel probe passed completely through the sludge/supernate boundary (the "interface") and lodged out of sight in the sludge. This result was repeatable within approximately 0.5 in. However, the objective was to locate the interface itself. The approach taken consisted of two parts: Determining the specific gravity (SG) characteristics of the sludge, and using the data to modify a standard probe so it would stop at the interface.

Sludge characteristics

Samples were taken of the sludge in 64 ml bottles at various depths, and the results are plotted as Figure 5 below:

Figure 5 Sludge SG vs. Depth

The data is interesting in that it shows a regular increase in SG from the interface down to the bottom of the four-inch "fluff" layer, so named because it was lighter both in color and in density than the sludge below. At 7.5 in. below the interface (3 inches below the fluff), however, the sludge has already reached its maximum SG of 1.76, and this value is constant down to the bottom of the tank.

Probe modification

A 250 ml plastic bottle, 5 in. high, was hung from the steel tape in place of the steel probe. The bottle was weighted with a sand and water mixture, then metallic weights were added until the bottle halted about 3 inches deep in the fluff. Calculations (Appendix C) show that the tape tension at which the lever arm operated was approximately 0.6 lb.

The simplest way to modify the standard probe to meet the tape tension requirement at the interface was to make it hollow. The probe was sawed in half, and a length of thin-walled stainless steel tubing was welded in with a threaded fitting to

allow adding lead shot. This modified probe was 10 inches long, with a mass of approximately one lb (refer to Appendix C). This probe would immerse itself in the sludge to approximately 8 in.

RESULTS

The results of this evaluation can be summarized against the objectives as follows:

- In "Wet/Dry" mode, the modified reel tape will locate a liquid surface with the same accuracy as an unmodified tape (± 0.1 in.²).
- The modified reel tape will locate a solid surface, both free (in any mode) and submerged (in "Sounding" mode only), with an accuracy estimated at ± 0.5 in.²
- When in "Sounding" mode, the modified reel tape will locate a sludge/supernate boundary in sludge similar to that found in TNX Tank F, repeatedly locating the boundary within approximately ± 0.5 in.² after several readings. Since the unit is calibrated by procedure to locate the probe tip, and the probe was immersed in the sludge approximately 8 in., the actual interface location was approximately 8 in. higher than the reading on the reel tape display. The unit cannot distinguish between cloudy and clear supernate (both have SG's of 1.0).
- Several field modifications were installed during this evaluation that improved functionality and repeatability of the demonstration model. The lever arm was redesigned to be cut from a single piece of oil-impregnated bronze stock, thus eliminating chatter. The timing circuit was modified to raise the probe approximately two inches before seeking a level; this prevented tape slack from increasing on consecutive seeks when locating a hard surface. Finally, the probe itself was modified to more closely locate the interface.

CONCLUSIONS

Installing the modifications noted to the Robertshaw level detectors currently used in the Tank Farms will enhance their functionality by adding the capability to locate a hard surface, conducting or non-conducting. This is true even when using the standard Model 185 probe. The further addition of a probe modified as in the previous section will add the ability to locate the sludge/supernate interface during settling, for sludge similar to that found in TNX Tank F. Using the same probe in sludge with a different SG would yield a different offset value; however, even if the exact depth of penetration into the sludge is unknown, the ability to measure the settling rate of the sludge is unimpaired.

PATH FORWARD

IWT recommends that all Model 185 reel tapes in the Tank Farms receive the tape tension modification, with the associated controls. The modified probe should be considered for installation in those tanks that have a free or submerged semi-solid surface of interest.

A test to evaluate the interface-finding capability of the modified reel tape with a caustic salt solution ($SG \approx 1.3-1.5$) as a supernate is currently in progress. This situation is more common in the Tank Farms than a water supernate. The primary deliverable will be a probe weight that will allow the probe to pass down through the dense caustic but still allow it to locate the interface.

During this evaluation, it was noted that water spray easily removed any simulated sludge adhering to the probe. Since use of the interface feature places the probe in contact with sludge or salt it would be prudent to assure that sufficient means exist to remove the sludge prior to lifting the probe and contaminated tape into the reel tape housing. Use of a spray ring is suggested.

Some wear on the bronze lever arm where it rides on the tape is inevitable. Good maintenance practice dictates monitoring the modified units with an eye toward possible buildup of material or other wear-related problems.

QUALITY ASSURANCE

This evaluation was performed in accordance with Test QA Plan WSRC-RP-93-1408.³

REFERENCES

1. Y6.2 Manual, WMM-14452, "Standardization/Configuration/Alarm Verification of the Robertshaw Model 185 Reel Tape", Revision 5, February 9, 1992.
2. Inter-Office Memorandum, T. D. Phillips to S. S. Cathey, "Waste Tank Level Wet/Dry/Sounding Reel Tape", WSRC-HLE-93-1271, August 13, 1993.

3. D. L. Speed. *Demonstration Of The Waste Tank Level Wet/Dry/Sounding Reel Tape Task QA Plan.* USDOE Report WSRC-RP-93-1408, Savannah River Site, Aiken, SC 29808 (1993)

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APPENDIX A.
TNX F-TANK ANALYSIS

12/14/93

INTER-OFFICE MEMORANDUM

Savannah River Site

01-Dec-1993 11:44am EST

To: GILL-GL-A9163@A1

From: JOHNSON_LC

(JOHNSON_LC@SLTLIM@MRGATE@SLSRP1)

SL-671T- RESULTS (U)

SAMPLE ANALYSES RESULTS

CHEMICAL HAZARDS: BENZENE,CR

THESE RESULTS WERE OBTAINED VIA EITHER A 'TECHNIQUE DEVELOPMENT', A 'METHOD DEVELOPMENT', OR AN 'APPROVED PROCEDURE'. PLEASE REFER TO THE TESTING SCHEME.

December 01, 1993

11:44 AM

Sample ID: 200035753

Report ID: 100146616

Submis ID: 100030255

User Sample ID: SL-671T-A-SL-WASTE

Sample Type CODE: SL-WASTE-675-T-SFT

Task ID: 300138945

Method: TNX-AA(AQ REG) [K] {WT%}

POTASSIUM (K) 1.780 WT %

Task ID: 300138941

Method: TNX-AA(HNO3/HCL) [HG] {PPM}

MERCURY (HG) <.0006 (VGA) PPM

Task ID: 300138946

Method: TNX-AE(AQ REG) [CS] {WT%}

CESIUM (CS) 0.045 WT %

Task ID: 300138944

Method: TNX-CBN(AS RECD) [TIC/TOC/TC]

TOTAL INORGANIC CARBON 580 PPM
TOTAL ORGANIC CARBON 12942 PPM
TOTAL CARBON 13522 PPM

Task ID: 300138929

Method: TNX-GC/PURGE&TRAP(AS RECD) [BENZENE]

BENZENE (PPB) 648 PPB
COMMENTS NOT REQUESTED NONE

Task ID: 300138931

P. 15/27

Method: TNX-IC(FILTER) [ANI] {MG/L}

FLUORIDE (F[1-])	<100	MG/L
FORMATE (COOH[1-])	35116	MG/L
CHLORIDE (CL[1-])	445	MG/L
NITRITE (NO2[1-])	<100	MG/L
NITRATE (NO3[1-])	18384	MG/L
SULFATE (SO4[2-])	252	MG/L
OXALATE (C2O4[2-])	<100	MG/L
PHOSPHATE (PO4[3-])	<100	MG/L

Task ID: 300138939

Method: TNX-IC(FILTER) [NH4] {MG/L}

AMMONIUM (NH4[1+])	<100	MG/L
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Task ID: 300138948

Method: TNX-IC(NA2O2/FIL) [F,CL] {MG/L}

FLUORIDE (F[1-])	<10000	MG/L
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P. 16/27

CHLORIDE (CL[1-])

<10000

MG/L

Task ID: 300138943

Method: TNX-ICP(AQ REG) [GEN] (WT%)

PHOSPHOROUS (P)	0.03	WT %
ZINC (ZN)	0.06	WT %
LEAD (PB)	<0.20 PPM	WT %
NICKEL (NI)	0.77	WT %
BORON (B)	0.66	WT %
MANGANESE (MN)	1.77	WT %
IRON (FE)	8.97	WT %
CHROMIUM (CR)	0.01	WT %
MAGNESIUM (MG)	0.05	WT %
SILICON (SI)	0.11	WT %
ALUMINUM (AL)	1.94	WT %
CALCIUM (CA)	1.04	WT %
PALLADIUM (PD)	0.01	WT %
COPPER (CU)	0.25	WT %
SILVER (AG)	<0.02 PPM	WT %
TITANIUM (TI)	0.04	WT %
ZIRCONIUM (ZR)	0.01	WT %
RHODIUM (RH)	<0.15 PPM	WT %
RUTHENIUM (RU)	0.08	WT %
STRONTIUM (SR)	0.02	WT %
NEODYMIUM (ND)	0.02	WT %
BARIUM (BA)	0.01	WT %
SODIUM (NA)	4.02	WT %
LITHIUM (LI)	0.07	WT %
VANADIUM (V)	NOT REQUESTED	WT %
POTASSIUM (K)	NOT REQUESTED	WT %
CADMIUM (CD)	NOT REQUESTED	WT %
PLATINUM (PT)	NOT REQUESTED	WT %
ANTIMONY (SB)	NOT REQUESTED	WT %
ARSENIC (AS)	NOT REQUESTED	WT %

Task ID: 300138940

Method: TNX-ICP(FILTER) [GEN] (PPM)

PHOSPHOROUS (P)	182.00	PPM
ZINC (ZN)	82.20	PPM
LEAD (PB)	6.09	PPM
NICKEL (NI)	1460.00	PPM
BORON (B)	3410.00	PPM
MANGANESE (MN)	10179.00	PPM
IRON (FE)	4.68	PPM
CHROMIUM (CR)	3.68	PPM
MAGNESIUM (MG)	198.00	PPM
SILICON (SI)	43.30	PPM
ALUMINUM (AL)	24.20	PPM
CALCIUM (CA)	6170.00	PPM
PALLADIUM (PD)	6.48	PPM
COPPER (CU)	384.00	PPM
SILVER (AG)	1.88	PPM
TITANIUM (TI)	0.52	PPM
ZIRCONIUM (ZR)	0.61	PPM
RHODIUM (RH)	6.17	PPM
RUTHENIUM (RU)	13.10	PPM
STRONTIUM (SR)	131.00	PPM

12.17/57

NEODYMIUM (ND)	9.37	PPM
BARIUM (BA)	2.41	PPM
SODIUM (NA)	25700.00	PPM
LITHIUM (LI)	403.00	PPM
VANADIUM (V)	NOT REQUESTED	PPM
POTASSIUM (K)	NOT REQUESTED	PPM
CADMIUM (CD)	NOT REQUESTED	PPM

P. 15/27

PLATINUM (PT)	NOT REQUESTED	PPM
ANTIMONY (SB)	NOT REQUESTED	PPM
ARSENIC (AS)	NOT REQUESTED	PPM

Task ID: 300138930

Method: TNX-ICP(FILTER) [RCRA] {PPM}

ARSENIC (AS)	2.630	PPM
SELENIUM (SE)	43.60	PPM
CADMIUM (CD)	0.602	PPM
LEAD (PB)	NOT REQUESTED	PPM
CHROMIUM (CR)	NOT REQUESTED	PPM
SILVER (AG)	NOT REQUESTED	PPM
BARIUM (BA)	NOT REQUESTED	PPM

Task ID: 300138947

Method: TNX-ICP(NA2O2) [GEN] {WT%}

PHOSPHOROUS (P)	<0.50 PPM	WT %
ZINC (ZN)	0.13	WT %
LEAD (PB)	<0.20 PPM	WT %
NICKEL (NI)	0.73	WT %
BORON (B)	1.67	WT %
MANGANESE (MN)	1.76	WT %
IRON (FE)	8.87	WT %
CHROMIUM (CR)	0.07	WT %
MAGNESIUM (MG)	0.54	WT %
SILICON (SI)	16.70	WT %
ALUMINUM (AL)	1.98	WT %
CALCIUM (CA)	1.25	WT %
PALLADIUM (PD)	<0.15 PPM	WT %
COPPER (CU)	0.24	WT %
SILVER (AG)	<0.02 PPM	WT %
TITANIUM (TI)	0.09	WT %
ZIRCONIUM (ZR)	NOT REQUESTED	WT %
RHODIUM (RH)	<0.15 PPM	WT %
RUTHENIUM (RU)	0.05	WT %
STRONTIUM (SR)	0.03	WT %
NEODYMIUM (ND)	<0.30 PPM	WT %
BARIUM (BA)	0.01	WT %
SODIUM (NA)	NOT REQUESTED	WT %
LITHIUM (LI)	1.30	WT %
VANADIUM (V)	NOT REQUESTED	WT %
POTASSIUM (K)	NOT REQUESTED	WT %
CADMIUM (CD)	NOT REQUESTED	WT %
PLATINUM (PT)	NOT REQUESTED	WT %
ANTIMONY (SB)	NOT REQUESTED	WT %
ARSENIC (AS)	NOT REQUESTED	WT %

Task ID: 300138937

Method: TNX-SP(AS RECD) [FILTER]

VOLUME (FILT, >50ML)	30	MLS
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Task ID: 300138934

Method: TNX-SP(AS RECD) [HNO3/HCL 1:1]

SAMPLE WT (HNO3/HCL) 15 G	15.0532	G
SMPL+ACID WT (HNO3/HCL) 27 G	27.8808	G

12.19/27

Task ID: 300138933

Method: TNX-SP(DRY) [AQ REG]

SAMPLE WEIGHT (AQREG)	.2506	G
TOTAL VOLUME (AQREG)	100	MLS

P. 20/27

Task ID: 300138935

Method: TNX-SP(DRY) [NA2O2/NAOH/H2O]

SAMPLE WEIGHT (NA/OH/H2O)	.2500	G
TOTAL VOLUME (NA/OH/H2O)	250	MLS

Task ID: 300138936

Method: TNX-SP(DRY) [NA2O2/NAOH/HCL]

SAMPLE WEIGHT (NA/OH/HCL)	.2503	G
TOTAL VOLUME (NA/OH/HCL)	200	MLS

Task ID: 300138932

Method: TNX-WET(AS RECD) [DENSITY]

DENSITY	1.155	G/ML
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Task ID: 300138938

Method: TNX-WET(AS RECD) [PH]

PH	5.43	PH
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Task ID: 300138949

Method: TNX-WET(AS RECD) [TOTAL BASE{PHENDPT}]

TOT BASE	(ACID)	.04	MOLE/LITER
	PH=5.43		
PH END PT	7		PH

Task ID: 300138942

Method: TNX-WET(AS RECD) [TOTAL SOLIDS] {WT%}

TOTAL WT % SOLIDS	38.69	WT %
-------------------	-------	------

Task ID: 300138950

Method: TNX-WET(FILTER) [TOTAL BASE{PHENDPT}]

TOT BASE	(ACID)	.02	MOLE/LITER
	PH=5.43		
PH END PT	7		PH

APPENDIX B.

SKETCH OF REEL TAPE LEVER ARM

APPENDIX C.
CALCULATIONS

Calculation Sheet

P.24/27

Project				Calculation No. APPENDIX C			
Subject		WET/DRY/ SOUNDING REEL TAPE FINAL REPORT				Sheet No. 1/4			
Rev	Originator	Date	Checker	Date	Rev	Originator	Date	Checker	Date
0	D. Speed	11/30/74	David B. Stelmach	11/30/74					

A. TENSION DETERMINATION

Data:

- Mass of 250 ml bottle "probe": 596.5 g
- Volume of "probe" (measured as displaced water volume): 285 cc

Calc:

At the moment the tension device actuates, a free body diagram of the "probe" is drawn:

where T = tape tension
 F_b = buoyancy force
 W = probe weight

Consistent with the initial assumption that the lever arm reacts primarily to changes in F_b , we can find the tension at which the lever arm operates:

$$T = W - F_b \quad (1)$$

$$W = 596.5 \text{ g} \times \frac{1 \text{ lb}}{453.6 \text{ g}} = 1.32 \text{ lb}$$

Archimedes' principle says that F_b is the weight of the fluid displaced by the probe.

Calculation Sheet

P.25/27

Project					Calculation No.		
		Subject					APPENDIX C		
							Sheet No. 2/4		
Rev	Originator	Date	Checker	Date	Rev	Originator	Date	Checker	Date

To calculate F_b we need an average SG value for the fluid around the bottle. Let's examine the fluff in view of the data from Figure 5. We can estimate the SG at 3" below the interface to be ≈ 1.3 . Knowing the bottle was 3" into the fluff, we see

This plot assumes a linear increase of SG with respect to depth. To calculate an average SG value, we note that 40% of the bottle sees an SG of 1.0, and the other 60% sees an average value of 1.15. Therefore,

$$0.4(1) + 0.6(1.15) = 1(x)$$

$$0.4 + 0.690 = x$$

$$x = 1.09 = SG_{ave}$$

Therefore, we can calculate F_b as:

$$F_b = 285 \text{ cm}^3 \times \frac{1 \text{ in}^3}{2.54^3 \text{ cm}^3} \times \frac{1 \text{ ft}^3}{12^3 \text{ in}^3} \times \frac{62.431 \text{ lb}}{\text{ft}^3} \times 1.09$$

$$F_b = 0.68 \text{ lb}$$

So the tape tension at actuation is

$$T = W - F_b = 1.32 - 0.68 = \underline{0.64 \text{ lb}}$$

Project					Calculation No.				
		Subject <u>APPENDIX C</u>					Sheet No. <u>3/4</u>				
Rev	Originator	Date	Checker	Date	Rev	Originator	Date	Checker	Date		

B. GUIDANCE FOR PROBE MODIFICATION

Increasing the probe length to 10", we see that we can calculate an optimum weight for that probe to achieve $T = 0.621 \text{ lbs}$
0.64 dls

$$W = T + F_b \quad [\text{from (1)}]$$

Neglecting minor machining to the probe such as a band saw cut to accommodate the steel tape and some set screw holes, we can approximate the probe as a 10" long cylinder of 1" diameter. Again, we need an average value of F_b , so we calculate with the probe half immersed in the sludge, and again assume linearity in SG vs depth:

Again, we calculate the average

$$0.5(1.0) + 0.5(1.25) = 1(x)$$

$$x = 1.13$$

Calculation Sheet

P27/27

SRS SAVANNAH RIVER SITE	Project						Calculation No.			
	Subject <u>APPENDIX C</u>						Sheet No. <u>7/4</u>			
Rev	Originator	Date	Checker	Date	Rev	Originator	Date	Checker	Date	

Calculating F_b for the probe: ($d=1$, $h=10$)

$$F_b = \left[\frac{\pi d^2 \cdot h}{4} \right] \times \frac{1 \text{ ft}^3}{12^3 \text{ in}^3} \times \frac{62.43 \text{ lb}}{\text{ft}^3} \times 1.13$$

$$F_b = 0.32 \text{ lb}$$

$$\text{So } W = T + F_b \Rightarrow 0.64 + 0.32 = \underline{0.96 \text{ lb}}$$

Setting a target weight of about 0.8-0.9 lb would allow addition of lead shot to adjust penetration into the sludge at the desired depth.

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