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U.S. DEPARTMENT OF COMMERCE / National Bureau of Standards

Accountability Tank Volume Calibration Data

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Accountability Tank Volume Calibration Data

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ACCOUNTABILITY TANK VOLUME CALIBRATION DATA

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This paper presents the very precise data from the volume calibration of a nuclear materials input accountability tank and briefly describes the treatment of the data. The calibration system involves the use of volumetric test measures for dispensing known increments of the calibration fluid (water) into the tank, and a null-operated quartz bourdon-type differential pressure gage for measuring the differential pressure between the bottom of the bubble on the tip of a "bubbler" tube near the bottom of the tank and a port in the top of the tank. The tank is essentially a right circular cylinder with a capacity of approximately 13,600 L (3,600 gal). The height is approximately 3.4 m (11 ft) and the diameter is approximately 2.4 m (8 ft). The water volume and the differential pressure were adjusted to correspond to the reference temperature, 25.00 °C.

Key words: Accountability tank; calibration; differential pressure; volume; volumetric test measures; water calibration.

1. INTRODUCTION

An earlier paper [1] described the application of a significantly improved system for the volume calibration of nuclear materials accountability tanks. The system involves the use of volumetric test measures for dispensing known increments of the calibration fluid (water) into the tank, and a null-operated quartz bourdon-type differential pressure gage for measuring the differential pressure between the bottom of the bubble [2] on the tip of a "bubbler" tube near the bottom of the tank and a port at the top of the tank. The system was used in a very successful calibration [1] of an input accountability tank at the Savannah River Plant in Aiken, South Carolina, operated for the U. S. Department of Energy by E. I. duPont de Nemours & Co., Inc. It is the primary purpose of this paper to present the very precise data from this calibration and to briefly describe the treatment of the data. The tank volume calibration data have been used as an example in two different statistical papers on calibration [3,4].

The input accountability tank that was calibrated at the Savannah River Plant is illustrated in figure 1. It is essentially a right circular cylinder with a capacity of approximately 13,600 L (3,600 gal). The height is approximately 3.4 m (11 ft) and the diameter is approximately 2.4 m (8 ft). The major details are shown in the figure. The cooling coils are of 51 mm (2 in) outside diameter and are located in the interior of the tank. The two "headers" are cylindrical, approximately 229 mm (9 in) long and 76 mm (3 in) in diameter. The tubing above the headers is approximately 76 mm (3 in) in outside diameter.

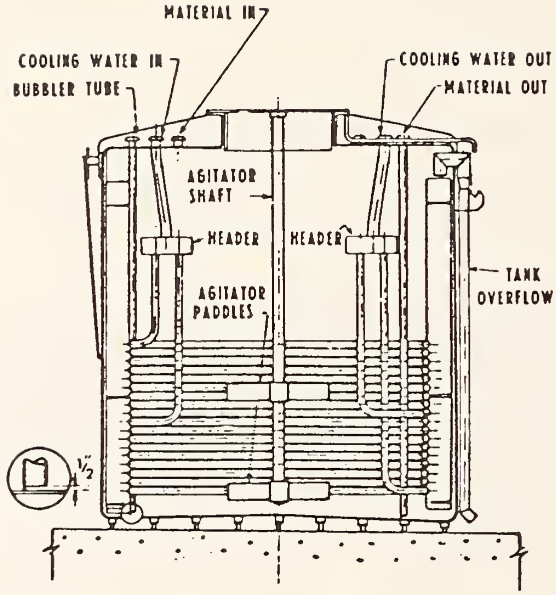

Figure 1. Sketch of an accountability tank.

2. CALIBRATION RUNS

Seven calibration runs were made, six in a "mock-up" area of the plant and one in the process location; the runs in the "mock-up" area were made prior to the installation of the tank in the process location in the canyon. The data for two of the runs (Runs 3 and 4) are not treated here due to operational problems which were analyzed and eliminated from subsequent runs [1].

In three runs (Runs 1, 5, and 7), 36 increments of water from a 378-L (100-gal) volumetric test measure were introduced into the tank. In two runs (Runs 2 and 6), the first increment was introduced from a 189-L (50-gal) test measure in order to offset the accumulated volume from Runs 1,5, and 7 by this amount. Subsequent increments in Runs 2 and 6 were of 378 L (100 gal), except that 189-L (50-gal) increments were used to arrive at the six check points, 1,890 (500), 5,300 (1,400), 8,330 (2,200), 10,200 (2,700), 12,100 (3,200), and 13,600 (3,600) L (gal) that were used throughout the series of runs to establish control and to permit monitoring of the run-to-run performance of the calibration system.

In each of the calibration runs for each increment of water transferred to the tank from a volumetric test measure, the following were determined (after operation of the agitator) from instrument readings and instrument calibration data: temperature of the water in the test measure, temperature of the water in the tank, differential pressure, ambient air pressure, and ambient air relative humidity. The volume of water introduced in each transfer was determined from the calibration volume of the test measure, the test measure sight gage reading, and the temperature of the water in the test measure.

3. TREATMENT OF THE DATA

The calibration runs were made with water temperature in the vicinity of 22 $^{\circ}$C. The water volume, V, and differential pressure, P, were adjusted to correspond to the reference temperature, 25.00 $^{\circ}$C. V was adjusted using the relationship

$$V_{25} = V_c \rho_c / \rho_{25} , \qquad (1)$$

where V_{25} and V_c are volume corresponding to the reference temperature and the calibration temperature, respectively; ρ_{25} and ρ_c are density of water at the reference temperature and the calibration temperature, respectively. The table of Wagenbreth and Blanke [5] was used to determine ρ_{25} and ρ_c for the temperatures.

The differential pressure, P, was adjusted [6] using the equation

$$P_{25} = P_c \, [1 - 2\alpha \, (25.00 - t)] , \qquad (2)$$

where α is the coefficient of linear thermal expansion of the stainless steel of which the tank was fabricated (taken to 15.9×10^{-6} $(°C)^{-1}$), and t is temperature in degrees Celsius.

The inside diameter of the connecting tubing used for the differential pressure measurement system installation in the "mock-up" area was smaller than that in the process location with resulting pressure drops which represented systematic errors in differential pressure. To <u>estimate</u> the magnitude of these systematic errors and to make <u>corrections</u> for them, the differential pressure in the "mock-up" area runs was interpolated using the equation

$$P_I = P_{25} + (V_7 - V_x)(\Delta P/\Delta V)_x , \qquad (3)$$

where P_I is the interpolated differential pressure corresponding to V_7, a value of volume in the process location run at the reference temperature, V_x is a volume in a "mock-up" area run near V_7, and $(\Delta P/\Delta V)_x$ is the "rate" of change of differential pressure with volume in the "mock-up" area run. The differences, $(P_I - P_7)$, where P_7 is the process location run differential pressure corresponding to V_7, were computed. $(P_I - P_7)$ was essentially constant for each run except for the first three points of each which were treated separately; therefore, the negative of the <u>mean</u> $(P_I - P_7)$ was applied as a correction to each of the values of P_{25}.

The temperature of the water in the tank, adjusted volume, and corrected differential pressure are tabulated in Tables 1-5. The transfer number refers to the increment of water dispensed into the tank, volume is given in m^3 recalling that 1 m^3 is equivalent to 1,000 L.

4. HEEL VOLUME

The heel volume, the volume of water in the tank below the "bubbler" tip, was estimated by extrapolation from the first three points in Runs 1 and 3 and the first five points in Runs 2 and 6. The mean of the four estimates is 101.4 L and the estimate of the standard deviation of the mean is 0.7 L.

5. ACKNOWLEDGMENTS

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Table 1. Calibration Data Adjusted to 25 °C for Run No. 1

Transfer No.	Water Temp. (°C)	Volume (m^3)	Diff. Pressure (Pa)
1	22.31	0.37884	630.6
2	22.41	0.75755	1473.1
3	22.46	1.13642	2375.6
4	22.46	1.51528	3263.5
5	22.45	1.89414	4154.2
6	22.50	2.27302	5044.9
7	22.47	2.65191	5934.7
8	22.48	3.03084	6820.2
9	22.53	3.40977	7713.1
10	22.51	3.78871	8603.8
11	22.53	4.16762	9491.9
12	22.54	4.54660	10383.8
13	22.55	4.92553	11263.5
14	22.57	5.30445	12143.8
15	22.56	5.68339	12994.4
16	22.58	6.06229	13816.8
17	22.61	6.44116	14636.4
18	22.62	6.82009	15449.8
19	22.65	7.19901	16263.0
20	22.82	7.57791	17078.4
21	22.80	7.95687	17891.7
22	22.77	8.33576	18703.9
23	22.74	8.71469	19519.2
24	22.68	9.09361	20334.8
25	22.69	9.47253	21149.1
26	22.64	9.85149	21963.7
27	22.62	10.2305	22781.4
28	22.61	10.6094	23597.1
29	22.58	10.9883	24411.9
30	22.58	11.3671	25226.9
31	22.56	11.7459	26040.9
32	22.54	12.1248	26855.2
33	22.53	12.5037	27669.4
34	22.53	12.8826	28486.4
35	22.53	13.2616	29301.4
36	22.51	13.6405	30116.1

Table 2. Calibration Data Adjusted to 25 ^{o}C for Run No. 2

Transfer No.	Water Temp. (°C)	Volume (m^3)	Diff. Pressure (Pa)
1	22.65	0.18941	218.8
2	22.14	0.56840	1039.2
3	22.16	0.94740	1929.2
4	22.13	1.32640	2819.5
5	22.11	1.70525	3712.3
6	22.15	1.89465	4152.8
7	22.16	2.08411	4601.5
8	22.16	2.46295	5489.8
9	22.17	2.84196	6382.2
10	22.18	3.22096	7269.4
11	22.19	3.59999	8158.6
12	22.20	3.97893	9052.0
13	22.22	4.35796	9940.6
14	22.22	4.73699	10825.1
15	22.23	5.11598	11704.7
16	22.26	5.30545	12145.2
17	22.30	5.49482	12581.4
18	22.32	5.87381	13407.2
19	22.33	6.25282	14227.6
20	22.34	6.63179	15045.3
21	22.35	7.01070	15858.6
22	22.36	7.38969	16673.6
23	22.38	7.76867	17487.7
24	22.41	8.14760	18301.9
25	22.43	8.33704	18709.4
26	22.45	8.52645	19116.8
27	22.48	8.90559	19931.7
28	22.48	9.28455	20748.0
29	22.48	9.66349	21561.4
30	22.49	10.0425	22376.2
31	22.50	10.2320	22786.5
32	22.52	10.4214	23193.9
33	22.56	10.8000	24008.1
34	22.58	11.1788	24822.2
35	22.59	11.5577	25635.7
36	22.60	11.9366	26449.8
37	22.61	12.1259	26856.5
38	22.64	12.3153	27264.5
39	22.64	12.6942	28078.6
40	22.65	13.0731	28896.1
41	22.66	13.4520	29709.5
42	22.67	13.6414	30116.8

Table 3. Calibration Data Adjusted to 25 °C for Run No. 5

Transfer No.	Water Temp. (°C)	Volume (m^3)	Diff. Pressure (Pa)
1	22.13	0.37880	630.2
2	22.23	0.75769	1473.4
3	22.18	1.13665	2376.5
4	22.13	1.51561	3267.4
5	22.13	1.89458	4150.6
6	22.09	2.27340	5044.4
7	22.08	2.65216	5932.4
8	22.08	3.03108	6819.3
9	22.09	3.40994	7712.5
10	22.10	3.78883	8602.9
11	22.11	4.16781	9489.8
12	22.10	4.54674	10382.6
13	22.10	4.92572	11262.6
14	22.12	5.30459	12142.0
15	22.13	5.68354	12994.1
16	22.12	6.06255	13817.3
17	22.11	6.44156	14635.6
18	22.10	6.82043	15450.1
19	22.14	7.19940	16265.8
20	22.14	7.57833	17081.0
21	22.13	7.95726	17894.5
22	22.13	8.33617	18707.3
23	22.16	8.71507	19521.2
24	22.13	9.09402	20340.5
25	22.14	9.47292	21154.1
26	22.14	9.85184	21968.3
27	22.14	10.2308	22785.2
28	22.14	10.6098	23600.1
29	22.14	10.9887	24413.6
30	22.14	11.3676	25227.5
31	22.14	11.7466	26042.0
32	22.14	12.1255	26853.8
33	22.13	12.5044	27669.4
34	22.12	12.8834	28486.4
35	22.14	13.2623	29300.9
36	22.11	13.6413	30115.4

Table 4. Calibration Data Adjusted to 25 °C for Run No. 6

Transfer No.	Water Temp. (°C)	Volume (m^3)	Diff. Pressure (Pa)
1	21.53	0.18949	220.5
2	21.23	0.56843	1040.2
3	21.24	0.94746	1930.2
4	21.27	1.32640	2816.5
5	21.26	1.70527	3713.4
6	21.27	1.89466	4156.0
7	21.27	2.08406	4602.4
8	21.25	2.46313	5490.4
9	21.24	2.84205	6384.2
10	21.22	3.22114	7272.1
11	21.21	3.60028	8162.5
12	21.21	3.97932	9052.8
13	21.24	4.35825	9943.2
14	21.25	4.73715	10827.7
15	21.26	5.11601	11706.3
16	21.28	5.30558	12146.5
17	21.28	5.49499	12582.9
18	21.28	5.87408	13409.2
19	21.28	6.25317	14227.8
20	21.28	6.63211	15043.4
21	21.27	7.01115	15858.9
22	21.26	7.39017	16673.1
23	21.26	7.76916	17487.4
24	21.25	8.14815	18301.8
25	21.26	8.33774	18706.8
26	21.26	8.52723	19115.3
27	21.26	8.90621	19929.2
28	21.25	9.28520	20745.0
29	21.24	9.66418	21559.9
30	21.23	10.0431	22374.1
31	21.23	10.2326	22783.9
32	21.23	10.4220	23195.2
33	21.23	10.8010	24008.3
34	21.24	11.1800	24823.2
35	21.24	11.5590	25638.7
36	21.23	11.9379	26453.6
37	21.23	12.1274	26859.3
38	21.24	12.3169	27268.5
39	21.24	12.6959	28083.7
40	21.24	13.0749	28900.3
41	21.23	13.4538	29715.5
42	21.24	13.6433	30122.6

Table 5. Calibration Data Adjusted to 25 °C for Run No. 7

Transfer No.	Water Temp. (°C)	Volume (m^3)	Diff. Pressure (Pa)
1	22.03	0.37884	629.2
2	22.85	0.75767	1474.9
3	22.74	1.13646	2375.7
4	22.89	1.51523	3265.2
5	22.97	1.89401	4154.3
6	23.03	2.27272	5046.5
7	23.09	2.65154	5933.9
8	23.10	3.03029	6820.6
9	23.09	3.40919	7712.8
10	23.08	3.78805	8601.3
11	23.08	4.16693	9486.7
12	23.08	4.54579	10381.9
13	23.07	4.92470	11260.3
14	23.08	5.30359	12140.5
15	23.08	5.68248	12993.4
16	23.06	6.06140	13815.6
17	23.05	6.44025	14634.4
18	23.07	6.81913	15448.7
19	23.05	7.19798	16262.0
20	23.05	7.57684	17076.0
21	23.06	7.95565	17889.6
22	23.06	8.33453	18703.2
23	23.07	8.71340	19517.2
24	23.07	9.09241	20332.8
25	23.06	9.47135	21147.8
26	23.06	9.85020	21961.1
27	23.06	10.2291	22777.5
28	23.06	10.6079	23594.5
29	23.07	10.9868	24408.8
30	23.07	11.3656	25223.8
31	23.06	11.7445	26036.0
32	23.06	12.1234	26850.7
33	23.06	12.5024	27665.7
34	23.07	12.8813	28482.1
35	23.07	13.2602	29296.7
36	23.07	13.6391	30110.7

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This paper presents the very precise data from the volume calibration of a nuclear materials input accountability tank and briefly describes the treatment of the data. The calibration system involves the use of volumetric test measures for dispensing known increments of the calibration fluid (water) into the tank, and a null-operated quartz bourdon-type differential pressure gage for measuring the differential pressure between the bottom of the bubble on the tip of a "bubbler" tube near the bottom of the tank and a port in the top of the tank. The tank is essentially a right circular cylinder with a capacity of approximately 13,600 L (3,600 gal). The height is approximately 3.4 m (11 ft) and the diameter is approximately 2.4 m (8 ft). The water volume and the differential pressure were adjusted to correspond to the reference temperature, 25.00 °C.

12. KEY WORDS *(Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)*

Accountability tank; calibration; differential pressure; volume; volumetric test measures; water calibration.

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