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Title: Accountability Tanks Calibration Data Analysis

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Accountability Tanks Calibration Data Analysis

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1. Introduction

MET-1 utilizes tanks to store plutonium in solution. The Nuclear Material Control & Accountability group at LANL requires that MET-1 be able to determine the amount of SNM remaining in solution in the tanks for accountability purposes. For this reason it is desired to determine how well various operators may read the volume of liquid left in the tank with the tank measurement device (glass column or slab). The accuracy of the measurement is then compared to the current SAFE-NMCA acceptance criteria for lean and rich plutonium solutions to determine whether or not the criteria are reasonable and may be met.

2. Experiment Description

Various volumes of material, as simulated by water in the experiment, are measured with a graduated cylinder and by the accountability tank measurement device. The accountability tank measurement device was used by various operators to measure this same liquid amount. The volume measured by the graduated cylinder and operator measurements are recorded in Figure 1. Figure 2 contains the experiment results.

Measured Volume (graduated cylinder) liters	Operator 1	Operator 2	Operator 3	Operator 4	Operator 5	Operator 6	Operator 7	Operator 8	Operator 9
22.85	23	22.9	22.9	22.9					
17.2	17.2	17.3	17.2	17.3					
9.62	8.4	8.4	8.4	8.2					
5.65	5.6	5.5	5.5	5.7					
14.47	14.2	14.1	14.2	14.2					
22.85	22.6	22.5	22.6	22.6					
20.01	19.8	19.8	19.8	19.8					
14.01	13.5	13.7		13.4					
3.49	3.4	3.3		3.4					
19.54	19.5	19.5	19.5	19.5	19.5				
11.54	11.4	11.25	11.3	11.3	11.4				
7.54	7.4	7.4	7.4	7.4	7.4				
37.33	37.6	37.8				37.7	37.7	37.7	
27.86	28.4	28.1				28.4	28.4	28.4	
14.3	14.6	14.6				14.6	14.7	14.6	14.6
37.33	37.7	37.8				37.8	37.8	37.8	37.8
23.03	23.3	23.2				23.3	23.3	23.35	23.3
9.47	10.1	10				10.1	10	10.1	

Figure 1: Experimental Data – all volumes in liters.

There are a total of 82 (by operator 18+18+10+12+3+6+6+6+3 = 82) measurements.

The graduated cylinder volume uncertainty is .1% and is considered to be zero in the analysis described here.

3. Volume Analysis

The data in Figure 1 are used to create residuals for each operator measurement. The residual is the operator measured volume minus the graduated cylinder volume. The residuals are listed in Figure 2.

Measured Volume (graduated cylinder) liters	Operator 1	Operator 2	Operator 3	Operator 4	Operator 5	Operator 6	Operator 7	Operator 8	Operator 9
22.85	0.15	0.05	0.05	0.05					
17.2	0	0.1	0	0.1					
9.62	-1.22	-1.22	-1.22	-1.42					
5.65	-0.05	-0.15	-0.15	0.05					
14.47	-0.27	-0.37	-0.27	-0.27					
22.85	-0.25	-0.35	-0.25	-0.25					
20.01	-0.21	-0.21	-0.21	-0.21					
14.01	-0.51	-0.31		-0.61					
3.49	-0.09	-0.19		-0.09					
19.54	-0.04	-0.04	-0.04	-0.04	-0.04				
11.54	-0.14	-0.29	-0.24	-0.24	-0.14				
7.54	-0.14	-0.14	-0.14	-0.14	-0.14				
37.33	0.27	0.47				0.37	0.37	0.37	
27.86	0.54	0.24				0.54	0.54	0.54	
14.3	0.3	0.3				0.3	0.4	0.3	0.3
37.33	0.37	0.47				0.47	0.47	0.47	0.47
23.03	0.27	0.17				0.27	0.27	0.32	0.27
9.47	0.63	0.53				0.63	0.53	0.63	

Figure 2: Residual volume for each operator measurement – all values in liters.

The MET-1 Detailed Operating Procedure document PA-DOP-01561, R0 lists acceptance limits for the measured volume amounts. These acceptance limits are 2% and 5% for rich and lean solutions. For each graduated cylinder volume in the data the 2% and 5% limit values were calculated. For each graduated cylinder volume (row in the Figure) plus and minus these limit values are plotted along with the residuals in Figure 3.

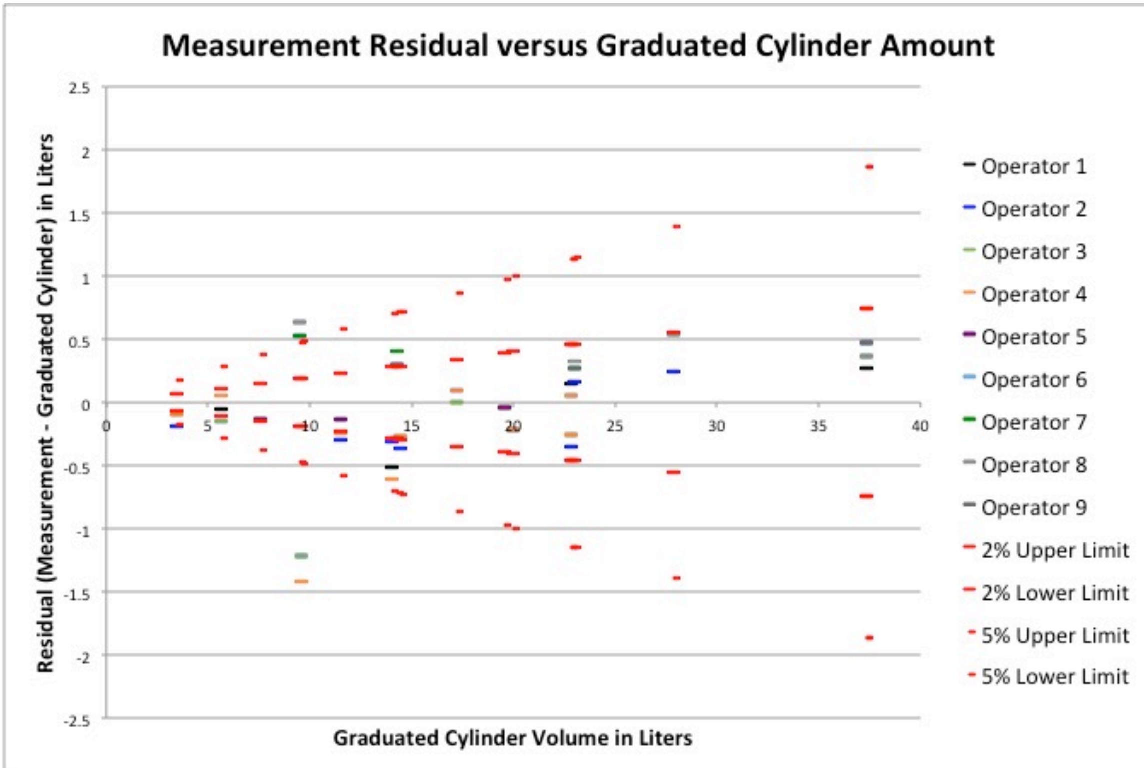

Figure 3: Residual volume for each operator measurement and limits – all values in liters.

There appear two volumes, 9.62 and 9.47 liters., with unusual measurements. For both of these volumes the operators appear to be measuring a different value. The operators are consistently off, biased, and have very low variability. After discussions about the experimental process it was determined that these two measurements were likely confused and did not represent the actual errors one would observe in an actual measurement but rather represent an experimental design problem resulting in confusion between marks on the measuring device. The measurements associated with 9.62 and 9.47 liters are determined to be outliers and are removed from the further analysis. Figure 4 is a plot of he data in Figure 3 with the outlier values omitted. The outliers were in 9 measurements. This results in 82 – 9 = 73 useful measurements.

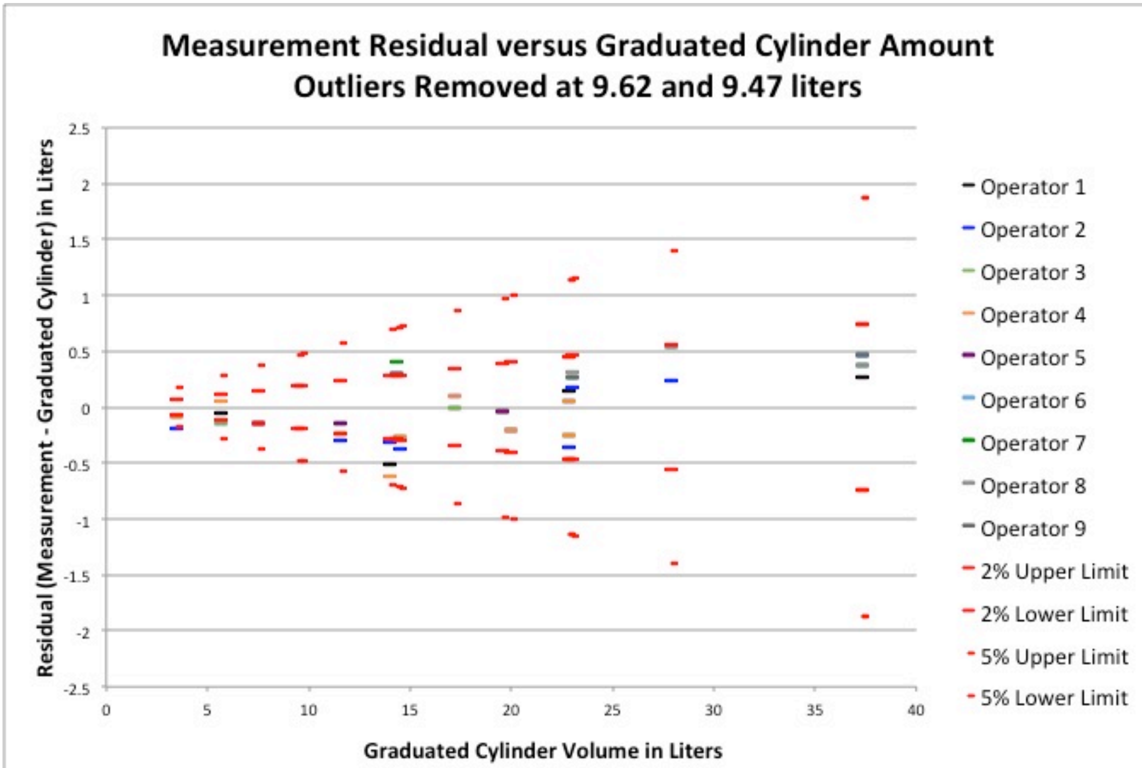

Figure 4: Residual volume for each operator measurement and limits with outliers removed – all values in liters.

Inspection of Figure 4 shows that all of the measurements are within the 2% limits for volumes greater than 15 liters. Figure 5 is a zoom in to the lower volumes of Figure 4.

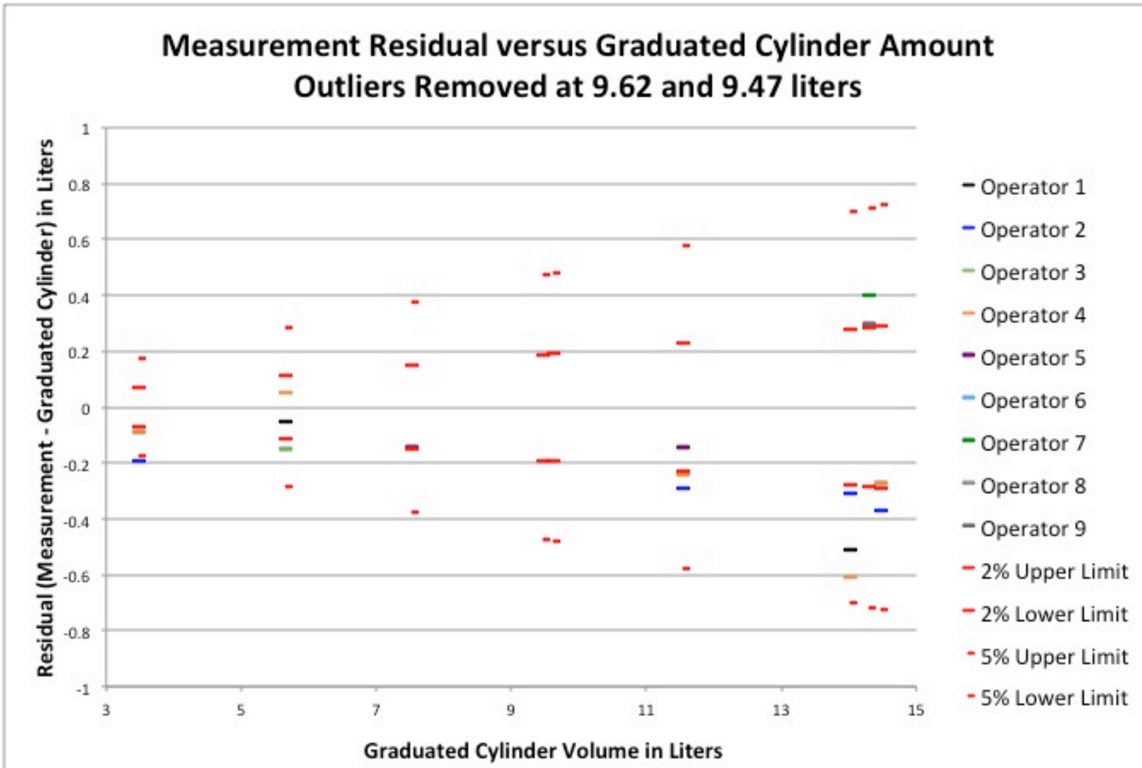

Figure 5: Zoom in to Figure 4.

Measured Volume (graduated cylinder) liters	Operator 1	Operator 2	Operator 3	Operator 4	Operator 5	Operator 6	Operator 7	Operator 8	Operator 9
22.85	0.007	0.002	0.002	0.002					
17.2	0.000	0.006	0.000	0.006					
9.62	-0.145	-0.145	-0.145	-0.173					
5.65	-0.009	-0.027	-0.027	0.009					
14.47	-0.019	-0.026	-0.019	-0.019					
22.85	-0.011	-0.016	-0.011	-0.011					
20.01	-0.011	-0.011	-0.011	-0.011					
14.01	-0.038	-0.023		-0.046					
3.49	-0.026	-0.058		-0.026					
19.54	-0.002	-0.002	-0.002	-0.002	-0.002				
11.54	-0.012	-0.026	-0.021	-0.021	-0.012				
7.54	-0.019	-0.019	-0.019	-0.019	-0.019				
37.33	0.007	0.012				0.010	0.010	0.010	
27.86	0.019	0.009				0.019	0.019	0.019	
14.3	0.021	0.021				0.021	0.027	0.021	0.021
37.33	0.010	0.012				0.012	0.012	0.012	0.012
23.03	0.012	0.007				0.012	0.012	0.014	0.012
9.47	0.062	0.053				0.062	0.053	0.062	

Figure 6: Residual error fraction for each operator measurement. Pink color for outside the 5% limit, yellow color for between the 2% and 5% limits and uncolored for within the 2% limit.

Inspection of Figure 5 and Figure 6 shows that all but one of the useful measurement values fall with the 5% limits. However, 18 of the 73 useful measurements fall outside of the 2% limit.

For smaller tank volumes the 2% limit may be violated with a high likelihood. 18/73 = 25% measurements fell outside the 2% limit. It is suggested that the 2% limit is too small for smaller values of the measured volume. One solution to this issue would be to relax the 2% limit for rich liquids when the volume to be measured is under some volume, such as, 15 liters.

4. Mass Analysis

Figure 7 shows the effect of the volume error on the mass determination. This illustrates how the error starts to have a mass at higher volumes and higher concentrations. It is hard to meet the volume uncertainty limit of 2% for rich solutions and this may have a substantial mass effect for very rich solutions (see the red shaded cells of the 5 liter volume of rows 3 and 4 of Figure 7).

		Lean Solution, g/L			Rich Solution, g/L		
Total Volume (liters)	**error**	**0.1 g/L**	**1 g/L**	**10 g/L**	**20 g/L**	**50 g/L**	**100 g/L**
5	**0.5%**	0.0025	0.025	0.25	0.5	1.25	2.5
5	**1%**	0.005	0.05	0.5	1	2.5	5
5	**2%**	0.01	0.1	1	2	5	10
5	**5%**	0.025	0.25	2.5	5	12.5	25
20	**0.5%**	0.01	0.1	1	2	5	10
20	**1%**	0.02	0.2	2	4	10	20
20	**2%**	0.04	0.4	4	8	20	40
20	**5%**	0.1	1	10	20	50	100
50	**0.5%**	0.025	0.25	2.5	5	12.5	25
50	**1%**	0.05	0.5	5	10	25	50
50	**2%**	0.1	1	10	20	50	100
50	**5%**	0.25	2.5	25	50	125	250
		mass error (g Pu)					

Figure 7: Mass error in grams of Pu for various volumes and concentrations. Highlighted red color for more than 5 grams and uncolored for less than or equal to 5 grams of Pu.

5. Conclusion

The 5% limit for lean liquids is reasonable. By reasonable we mean the chance of a measurement falling outside the 5% limit is unlikely (1 of 73). A small percentage (1.3%) of usable measurements in this experiment fell outside the 5% limit.

The 2% limit for rich liquids with volume over 15 liters is reasonable. By reasonable we mean the chance of a measurement falling outside the 2% limit is unlikely, 0 of 43 usable measurements of over 15 liters in this experiment fell outside the 2% limit.

The 2% limit for rich liquids with volume under 15 liters is unreasonable. By unreasonable we mean the chance of a measurement falling outside the 2% limit is likely, 18 of 30, or 60%, usable measurements of under 15 liters in this experiment fell outside the 2% limit.

It is suggested that the limit be changed for rich liquids under 15 liters in volume. The exact form of this change is to be determined. One possibility that is reasonable from the measurement standpoint is to have rich liquids under 15 liters have a 5% limit (rather than a 2%) limit. Figure 5 gives an indication of how this rule would perform with the measurements made in this experiment. Figure 6 may be used to determine the performance of this experiment under other proposed lean rules. One may also make rules which account for the mass of Pu in the tank (as illustrated in Figure 7).