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COMPARISONS AMONG CALIBRATION INSTRUMENTS IN THE CALDEX ACCOUNTANCY TANK CALIBRATION*

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ABSTRACT

An experiment known as the CALibration Demonstration EXercise (CALDEX) has tested volume, weight, and level measurement instruments in a 12 500-ℓ annular vessel. Data from this experiment were statistically analyzed in the following ways:

- Data from various high-precision differential pressure gauges, liquid-level determination instruments, and weighing devices were analyzed and compared.
- Incremental inputs to the tank, determined by a high-precision balance and rotary piston meter, were compared with load cell measurements and found to agree.
- Data from precision pressure gauges did not vary significantly among gauges; data from capacitive level measurement instruments did not vary either. However, data from the sonic probe were not consistent enough to make comparison meaningful.

INTRODUCTION

An experiment known as the CALibration Demonstration EXercise (CALDEX)[1] included tests on weight, volume, and level-measurement instruments in a 12 500-ℓ annular vessel. This experiment simulated a large reprocessing input accountancy tank to determine whether large differences occurred among measurements from various calibration measuring instruments and from run-to-run calibrations. As part of this goal, the collected data were analyzed statistically.

The part of the calibration exercise considered here consisted of filling and emptying the tank three times using 280 increments of approximately 44 ℓ of liquid water or a salt solution. The water temperature was obtained at three levels. Differential pressures were read by four instruments: Ruska, Crouzet, and Wallace and Tiernan electromechanical gauges, and the Hartmann and Braun transmitter. Levels of liquid in the tank were recorded by the United Kingdom Atomic Energy Agency "sonic ranger," Energia Nucleare e dell Energie Alternative time-domain reflectometry device, and the Siemens capacity probe. Cumulative weights were measured by ASEA load cells and incremental weights were recorded by a Sartorius scale.

We performed a similar calibration using a continuous flow of liquor and a similar set of instruments, except the Sartorius scales. An analysis of these data is given by Schmidt et al.[2]

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In our analysis of the incremental data, we compared the following calibration and regression equations:

- weight (kg) vs pressure (millibars) for pressure devices,
- weight (kg) vs level (m) for level-reading devices, and
- weight (kg) vs volume (ℓ) for weighing devices.

To derive these equations we screened the data for outliers and found the proper curve fits for calibration and correlations.

DATA SCREENING

Weight vs pressure data were plotted for the four pressure devices: the Ruska, Crouzet, Wallace and Tiernan (Diptron), and the Hartmann and Braun (H&B). The first three instruments seemed to perform well for all three runs and gave similar results, as exemplified in Fig. 1. Of the 280 measurements obtained for each of the three runs with the three acceptable devices, we found approximately 10% were anomalies that we either removed or corrected. Successive differences in weight (or pressure) should be nearly constant, providing a convenient tool for finding discrepancies. Similar methods were used to remove undesirable measurements for the three level devices: the sonic ranger, the time domain reflectometry (TDR) instrument, and the capacity level probe manufactured by Siemens Brennelementewerk (for convenience called Siemens BW). We obtained no measurements from the TDR. Runs 1 and 2 for the sonic ranger contained over 50% anomalous data and run 3 was a complete disaster. Siemens BW data were consistent with the acceptable pressure devices and were included

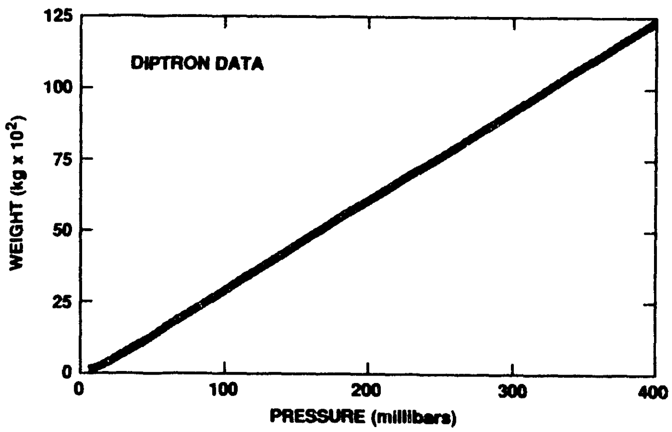

Fig. 1. Weight (kg), pressure (millibars) for the Diptron electromechanical gauge.

in the study. Finally, the ASEA load cell and rotary piston measurements were excellent, with less than 1% anomalies.

A complete description of all of the instruments can be found in Ref. 1.

CALIBRATION

Using methods described in ANSI N15.19-1989 (see Ref. 3), we found the weight-pressure curve could be divided into six regions. These regions are exemplified in a plot of residuals from a linear least-squares fit of Diptron data depicted in Fig. 2.

A summary of all of the calibration curves is given in Table I. A comparison reveals few differences among the three pressure devices. Comparisons of predictions for pressure-given weight are defined for a data point in each region in the last column. Note that the relative differences are less than 0.8% between any two instruments.

Run-to-run differences among the three runs are also small with the largest differences in absolute value occurring in regions 5 and 6. Results provided in Table II for the Crouzet show differences in weight for specified pressures.

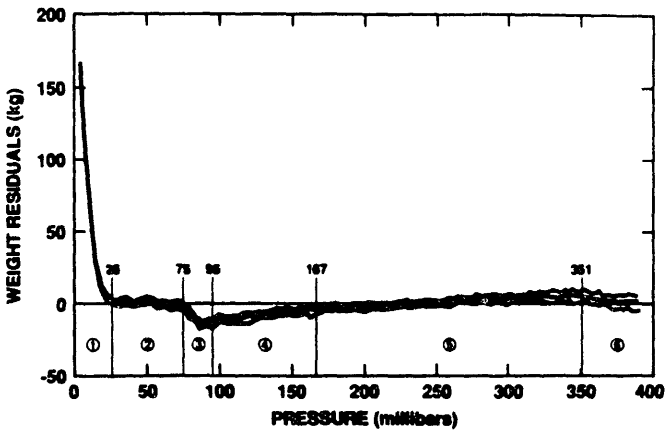

Fig. 2. Plot of residuals from weight-pressure linear least squares fit of Diptron data depicting six regions of calibration curves.

TABLE I. Summary of Calibration Curves for Pressure Instruments

Region	Diptron	Crouzet	Ruska	Comparison
1	0 < P < 26 0 < W < 558.7 W = - 0.018896 P^3 + 1.5073 P^2 - 7.3230 P + 79.9260	0 < P < 27.05 0 < W < 586.9 W = - 0.019081 P^3 + 1.4756 P^2 - 7.1593 P + 78.512	0 < P < 28 0 < W < 620.1 W = - 0.01952 P^3 + 1.5047 P^2 - 7.5656 P + 80.770	W = 300 P Diptron 17.25 Crouzet 17.39 Ruska 17.33
2	26 < P < 75 558.7 < W < 2109.2 W = 31.601 P - 262.84	27.05 < P < 74.8 586.9 < W < 2093.8 W = 31.558 P - 266.75	28 < P < 75 620.1 < W < 2107.3 W = 31.642 P - 265.79	W = 1500 P Diptron 55.78 Crouzet 55.98 Ruska 55.81
3	75 < P < 84.85 2107.2 < W < 2706.9 W = 30.429 P - 175.04	74.8 < P < 85.7 2093.8 < W < 2425.3 W = 30.408 P - 180.70	75 < P < 85.3 2107.3 < W < 2421.8 W = 30.528 P - 182.24	W = 2250 P Diptron 79.70 Crouzet 79.94 Ruska 79.91
4	84.85 < P < 167.46 2406.9 < W < 5034 W = 31.802 P - 291.54	85.7 < P < 164.16 2425.3 < W < 4922.4 W = 31.825 P - 302.17	85.3 < P < 178.2 2421.8 < W < 5382.6 W = 31.871 P - 296.78	W = 9000 P Diptron 134.95 Crouzet 135.18 Ruska 134.82
5	167.46 < P < 350.5 5034 < W < 10 841.3 W = 31.727 P - 278.98	164.16 < P < 345.26 4922.4 < W < 10 592.5 W = 31.753 P - 290.35	178.2 < P < 341.6 5382.6 < W < 10 564 W = 31.710 P - 268.09	W = 8000 P Diptron 260.94 Crouzet 261.09 Ruska 260.74
6	350.51 < P < 390 10 841.3 < W < 12 087 W = 31.534 P - 211.33	345.26 < P < 390 10 542.5 < W < 12 087 W = 31.618 P - 243.74	341.6 < P < 390 10 564 < W < 12 089 W = 31.497 P - 195.32	W = 11 000 P Diptron 355.53 Crouzet 355.61 Ruska 355.44

TABLE II. Run-to-Run Differences for the Crouzet						
	Region 5			Region 6		
Run No.	Slope	Intercept	W (P = 300)	Slope	Intercept	W(P = 350)
1	31.776	-296.35	9 236.5	31.647	-252.61	10 823.89
2	31.945	-290.01	9 233.5	31.596	-239.72	10 818.98
3	31.778	-296.29	9 237.1	31.650	-253.06	10 824.44

Relative differences are less than 0.06%, which is typical for any of the three instruments.

We conclude that the instruments performed equally alike with small run-to-run differences.

LEVEL DEVICES

Linear fits through all data points were used to compare weight (kg) vs pressure (millibars) with weight (kg) vs level (m). Only the Siemens BW qualified for comparison and the results are summarized in Table III.

We conclude that the Siemens BW gave reasonably good agreement with the pressure measurements.

WEIGHING DEVICES

Data were acquired from ASEA load cells, which measured the weight of the entire tank, and by the volume measured by the rotary piston meter using results from Sartorius scales.

A least-squares linear fit through all of the data points gave

$$W = 1.0085\ (\pm 0.0001)\ V + 21.97\ (\pm 0.77)\ .$$

TABLE III. Comparison Between Pressure and Level Instruments			
Instrument	No. Data Points	Slope (SD)	Intercept (SD)
Diptron	839	31.676 (0.004)	-266.30 (0.91)
Crouzet	839	31.691 (0.004)	-274.44 (0.95)
Ruska	839	31.692 (0.004)	-265.67 (0.87)
Siemens BW	816	31.119 (0.011)	-151.41 (25.27)

This equation seems reasonable because the slope is nearly 1; however, the residual plot depicted in Fig. 3 illustrates that the following quadratic equation would be more appropriate:

$$W = 6.2361 \times 10^{-7}\ (\pm 2.94 \times 10^{-8})\ V^2$$
$$+\ 1.0162\ (\pm 3.71 \times 10^{-4})\ V + 5.7236\ (\pm 0.99)\ .$$

Our conclusion is that although the two measuring devices are compatible, the agreement could have been better.

CONCLUSIONS

- The Ruska, Crouzet, and Diptron measured differential pressure equally well.
- Siemens BW gave reliable level measurements.
- The ASEA and the rotary piston meter showed good agreement.

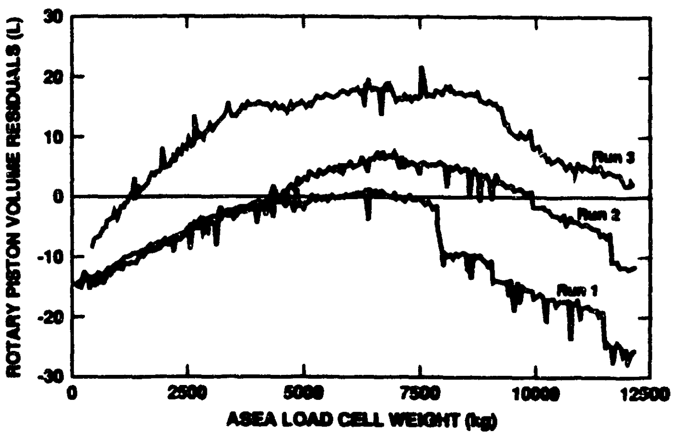

Fig. 3. Plot of residuals from rotary piston—ASEA load cell linear least squares fit.

Continuous Flow

Another study based upon continuous liquid feed in the CALDEX project gave similar conclusions to those reached for the incremental flow results presented here. See Ref. 2 for details.

REFERENCES

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