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Statistical Analysis Of Crude Oil Storage Tank Volume Measured Using Manual Strapping (MSM) And Electro-Optical Distance Ranging Methods

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***Abstract*—The Manual Strapping (MSM) and Electro-Optical Distance Ranging methods are employed in the oil and gas industries for the determination of the volume of storage tanks at selected tank depths. The results of the two approaches are expected to be the same but the reality is that the volumes measured at each tank depth differ significantly for the two approaches. Hence, in this study, statistical analysis of crude oil storage tank volume measured using the MSM and the EODR method is presented based on two case study datasets with 30 paired MSM and EODR volume dataset along with another 1765 volume data points obtained using the EODR method. In the paired datasets, the MSM recorded tank volumes ranging from 10711 bbls to 4161536 bbls for tank depths ranging from 0 mm to 15460 mm. Similarly, the EODR method recorded tank volumes ranging from 10900 bbls to 649610 bbls for tank depths ranging from 0 mm to 15460 mm. In addition, the EODR 1765 tank volume data points has volumes ranging from 10900 bbls to 739850 bbls for tank depths ranging from 0 mm to 17640 mm. The means' difference confidence interval at 95 % confidence level for the paired MSM and EODR volume dataset are 599282.6864 and 1507433.447 which shows that the two means are significantly different since the means' difference confidence interval does not bracket zero. Again, the means' difference confidence interval at 95 % confidence level for the 30 data points MSM tank volume dataset and the EODR 1765 tank volume data points are 422678.3752 and 1478688.734 which shows that the two means are significantly different since the means' difference confidence interval does not bracket zero. The statistical analysis shows that the two approaches do not give the same tank volume readings for any given tank depth and so it requires additional steps to harmonize the tank volume measurements from the two approaches.**

Keywords—Statistical Analysis, Crude Oil Storage Tank Volume Measured Using Manual Strapping (MSM), Means Difference Confidence Interval, Electro-Optical Distance Ranging Methods

1. Introduction

Precise calibration of crude oil storage tanks is vital for accurate inventory management, fiscal accounting, and loss control in the oil and gas sector [1,2]. To guarantee accurate volume determination, tanks must be calibrated upon installation and re-certified periodically, typically every five years [3]. In Nigeria, NUPRC-licensed contractors must perform all initial and subsequent calibration exercises.

Traditionally, the Manual Tank Strapping Method (MSM) has been the standard for determining the circumference and, consequently, the capacity of storage tanks [4,5,6]. MSM is labor-intensive and requires personnel to work at heights to measure horizontal planes along each course [7,8,9]. While highly regarded as the conventional "ground truth," manual measurements are subject to human error, such as tape sagging or inaccuracies in ensuring proper tension, and pose significant safety risks to personnel [10,11].

In recent years, the industry has shifted toward, and in some cases mandated, more automated, precise, and safer techniques, such as the Electro-optical Distance Ranging (EODR) method, which uses total stations to measure internal radii and calculate capacities in accordance with API MPMS standards [13,14]. EODR offers advantages in speed, safety, and precision, particularly in defining the capacity table, the volume per height table used by Automatic Tank Gauging (ATG) systems [15].

However, despite the increased precision and safety, the adoption of EODR is sometimes hindered by concerns regarding cost and technical expertise, leading to a reliance on both methods within the Nigerian oil sector. Although both methods, when properly applied, satisfy the 95% minimum efficiency required by standards, they often yield different volume calculations at various levels. Accordingly, this study aims to address this discrepancy by performing a statistical analysis of datasets obtained from both MSM and EODR methods in an oil production field. By aligning the EODR dataset with the MSM "ground truth" and applying necessary corrections (hydrostatic head effect, tank shell temperature, deadwood, and tilt) in accordance with NUPRC and API procedures, this research evaluates the accuracy, safety, and efficiency of both methods for inventory management.

2. Research Design and Data Source

This study employs a quantitative, comparative research design, analyzing historical calibration data from crude oil storage tanks within an oil production field in Nigeria. The datasets (MSM and EODR) were obtained from official, certified calibration reports approved by the regulatory commission for the oil industry. These datasets include tank dimensions, circumference measurements at different courses, and final capacity (strapping) tables, which are vital for inventory management, product loss tracking, and revenue accounting.

2.1 Data Collection and Data Alignment

The Manual Tank Strapping Method (MSM): The MSM is regarded as the traditional ground-truth method, MSM data was gathered by physically measuring the circumference of each tank course using calibrated steel tapes. Test points were sighted along the horizontal plane, and vertical measurements were taken to determine the bottom profile. On the other hand, the Electro-Optical Distance Ranging (EODR): The EODR data was gathered using a total station scanner, which calculates internal radii by measuring slope distances, horizontal angles, and vertical angles relative to reference target points, following the regulatory commission procedural guidelines. Both data collection methods ensured accuracy by incorporating corrections for shell deformation from hydrostatic pressure, certified shell temperature, deadwood, and tilt.

2.2 Data Alignment

The final capacity tables (strapping tables) were developed in accordance with API MPMS (American Petroleum Institute Manual of Petroleum Measurement Standards) to provide the volume-per-height relationship for each tank, enabling automatic computation of crude oil stock. For an accurate point-to-point comparison, the EODR data was synchronized with the MSM reference set. Disparities in height increments were addressed through interpolation and augmentation, which standardized the depths across both datasets for volumetric analysis. This study employed a comparative statistical framework to evaluate the agreement between MSM and EODR volume measurements. The analysis integrated descriptive measures for dispersion and inferential methods, using confidence intervals—to validate the significance of inter-method discrepancies.

2.3 The statistical analysis

This study employed a comparative statistical framework to evaluate the agreement between MSM and EODR volume measurements. The analysis integrated descriptive measures for dispersion and inferential methods, using confidence intervals—to validate the significance of inter-method discrepancies. The statistical analysis is conducted using the following steps:

Step 1: Data Pairing: Data sets consisting of 30 distinct measurements were collected. To ensure a direct, valid comparison of volume measurements at identical levels, the data were aligned by tank depth (Step 1: Data Pairing). This pairing method allows for a paired-sample analysis, reducing the influence of external variability in tank levels.

Step 2: Descriptive Statistics: Descriptive statistics were calculated to identify the initial variability, central tendency, and distribution of both data sets. For both the 30-point MSM data and the corresponding 30-point EODR data, the mean, range, and standard deviation were computed (Step 2: Descriptive Statistics).

Step 3: Confidence Interval Analysis (95% CI): To determine the precision and reliability of the measurements, a 95% confidence interval (CI) of the mean difference was calculated (Step 3: Confidence Interval Analysis). This analysis was conducted in two parts: Paired Comparison: 30-point MSM data versus 30-point EODR data.and Extended Comparison: 30-point MSM data versus the 1765-point EODR data set.

Step 4: Significance Testing: The significance of the difference between the MSM and EODR methods was assessed by examining the 95% CI of the means' difference (Step 4: Significance Testing). The criterion for a statistically significant difference was established as the 95% CI failing to bracket zero. Consequently, the difference between the means is considered statistically significant if both the lower and upper bounds of the confidence interval are either strictly positive or strictly negative, indicating a systematic deviation rather than random error.

3. Results and discussion

3.1 Results of the Data Alignment by Tank Depth

Data alignment results by tank depth are summarized in Figure 1 and Table 1. As illustrated in the Figure 1 scatter plot, the MSM and EODR volumes track closely and maintain a linear relationship up to a depth of approximately 3,050 mm. Beyond this point, the MSM volume exhibits a sharp gradient increase, significantly outpacing the EODR volume. Statistical analysis in Table 1 further highlights these disparities: the MSM mean (1,321,851.5 bbls) and range (4,150,825 bbls) are substantially higher than those of the EODR, despite a shared mean tank depth of 6,234.3 mm.

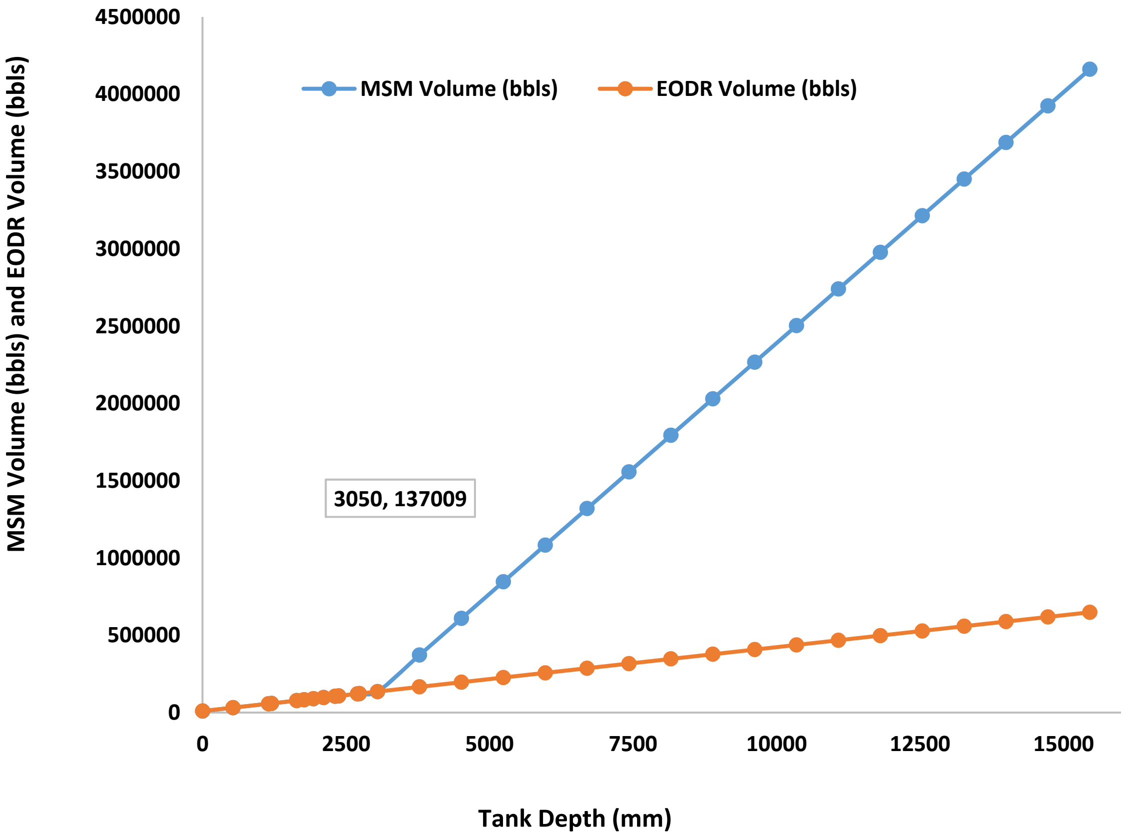

Figure 1 The scatter plot of the manually measured crude oil volume (MSM) and the electronically measured crude oil volume (EODR) versus tank depth

3.2 The Descriptive Statistics Analysis Results

The descriptive statistics analysis results presented in Table 1 reveal that the MSM Volume group exhibits significantly higher central tendency, variability, and scale compared to the EODR Volume group, indicating a much larger and more dispersed distribution of data.The average (Mean) for MSM (1,321,851.5 bbls) is nearly five times larger than that of EODR (268,493.1 bbls). Furthermore, the Median values show a massive discrepancy: while half of the EODR observations are below 212,391.5 bbls, the MSM median is 728,516 bbls. The fact that the mean is significantly higher than the median in both groups, especially in MSM, suggests that both datasets are positively skewed (right-skewed) by extremely high values.

The Standard Deviation for MSM (1,413,796.6) is roughly seven times higher than EODR (199.578.1), signifying that MSM data points are spread much further from the mean. This volatility is emphasized by the Range: MSM spans over 4.1 million bbls, while EODR spans only 638,710 bbls. The Interquartile Range (IQR) confirms this, showing that the middle 50% of MSM data (2,406,419) is far more spread out than the middle 50% of EODR data (340,477).

EODR contains one missing value, whereas MSM is complete. Interestingly, the First Quartile (Q1) for both groups is very similar (≈ 98,000 bbls), suggesting that at the lower end of the spectrum, both groups start at a similar volume. However, as we move toward Q3 and the Maximum, MSM accelerates rapidly, indicating that the top 25%

of MSM observations are vastly larger than those in the EODR group.

Notably, the analysis indicates that MSM Volume encompasses a larger, highly variable operation with significant outliers. In contrast, EODR Volume is characterized by greater consistency and a more compact, tighter distribution, even though both datasets are right-skewed.

Table 1 The Descriptive Statistics of the Tank Depth Aligned Case Study Dataset

S/N	Groups	EODR Volume (bbls)	MSM Volume (bbls)	Depth (mm)
1	Num of observations	30	30	30
2	Num of missing values	1	0	0
3	Minimum	10,900	10,711	0
4	Maximum	649,610	4,161,536	15,460
5	Range	638,710	4,150,825	15,460
6	Mean ($\bar{x}$)	268,493.0667	1,321,851.5	6,234.3333
7	Sum	8,054,792	39,655,545	187,030
8	Standard Deviation (S)	199,578.0839	1,413,796.6301	4,830.6205
9	Q1	98,062	97,797	2,110
10	Median	212,391.5	728,516	4,875
11	Q3	438,539	2,504,216	10,350
12	Interquartile range	340,477	2,406,419	8,240

3.3 The Results Significance Testing and Means' Difference Confidence Interval at 95 % Confidence Level

The results of the means' difference confidence interval at 95 % confidence level analysis for the paired MSM and EODR volume dataset is presented in Table 2. With 30 pairs (df=29), the analysis meets the general threshold for the central limit theorem to provide a reliable t-distribution basis. The results show that the 95% confidence interval for the mean difference is [599,282.69, 1,507,433.45]. Since this interval does not include zero, we can conclude with 95% confidence that there is a statistically significant difference between the MSM and EODR volumes. Because both bounds are positive, the first variable (likely MSM) is significantly higher than the second (EODR).

The average difference ($\bar{x}_d$) is 1,053,358.07 units. Given the margin of error (MOE) of 454,075.38, the estimate is relatively broad, but the lower bound still indicates a substantial minimum expected difference of nearly 600,000 units. Also, at 1,216,036.22, the variability between individual pairs is quite high, actually exceeding the average difference itself. The error of the mean estimate is 222,016.82, which suggests that while individual pairs vary wildly, the mean estimate is stabilized by the sample size.

Table 2 The results of the means' difference confidence interval at 95 % confidence level analysis for the paired MSM and EODR volume dataset

Parameter	Value
Mean difference confidence interval:	**[599282.6864, 1507433.447]**
Margin of error (MOE):	**454075.3803**
Standard Error ($S_{\bar{x}d}$)	**222016.8229**
Degrees of freedom (df)	**29**
Average ($\bar{x}_d$):	1053358.067
Sample standard deviation (S_d):	1216036.22
Sample size (n), numer of paires:	30

4. Conclusion

This study employs a quantitative, comparative research design, analyzing historical calibration data from crude oil storage tanks within an oil production field in Nigeria. The comparative analysis confirms that both the Manual Strapping Method (MSM) and Electro-Optical Distance Ranging (EODR) yield highly accurate and reliable datasets for crude oil storage tank calibration. While traditional MSM, using calibrated steel tapes, remains the standard "ground-truth," EODR, supported by total station technology, provides a faster, safer, and equally precise alternative that complies with API MPMS standards.

Both techniques effectively incorporate necessary corrections for hydrostatic pressure, temperature, and shell deformation, meeting Nigerian Midstream and Downstream Petroleum Regulatory Authority (NMDPRA) requirements. Interpolation between EODR data and MSM references showed minimal disparity, confirming the internal accuracy of EODR measurements.

The resulting capacity tables are critical for accurate inventory and revenue management. EODR offers superior efficiency, reducing the need for direct physical contact with the tank, while maintaining high-fidelity product tracking. In summary, while MSM offers a robust historical baseline, EODR is a modern, technically equivalent, and safer solution for the Nigerian oil industry, essential for minimizing fiscal inaccuracies.

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