Density Measurement of Bunker Fuels

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Density is one of the most important physical properties in the characterisation of bunker fuels. It also has an influence on other properties such as ignition quality and specific energy of the fuel. Accurate and precise determination of density is therefore important in the characterization of fuel for various applications. It is a parameter which has an impact on assessing the quality of the fuel and which has a significant impact on bunker fuel delivery quantity calculations at measured temperatures. Since bunker fuels are ordered by weight but measured upon delivery by volume, density measurement is the parameter which enables the correct and accurate determination of the quantity of bunker fuel deliveries. Veritas Petroleum Services tracks density differences for our customers during bunker fuel deliveries and see a clear bias for overstating density on bunker delivery notes, leading to fuel delivery shortages.

The composition of a fuel has an influence on the determination of density. Compositional factors such as the presence of high concentration of waxes, asphaltenes and incompatible nature of a fuel, makes the measurement sometimes lead to erroneous results. The tendency of a fuel to retain water molecules in an emulsified form, where water cannot be separated also has an impact on the accurate determination of density. Measurement devices and their calibration accuracies do matter, especially as density is a temperature dependent property. There are various International standard methods available to measure the density of fuels. The purpose of this article is to assess how well these methods correlate.

Veritas Petroleum Services (VPS) undertook extensive research to evaluate the correlation of various International Standards used in the industry for the determination of the density of fuels. The intention of this article is not to comment on which method is better than the other but to evaluate whether any correlation exist between these methods, since all such methods are widely used in the petroleum industry. The scope of the research work was to determine the density of fuel oils and diesel oils across different ranges and characteristics, by three International standard methods (Manual hydrometer, Digital density meter and Stabinger Viscometer) validating all the results generated in order to evaluate the precision, accuracy, bias and the coefficient of determination (R^2).

Following are the three International methods evaluated for this study

- Crude petroleum and petroleum Products – Determination of density – Oscillating U-tube method (ISO 12185 /IP 365/ ASTM D4052)

- Crude petroleum and liquid petroleum Products – Laboratory determination of density – Hydrometer method (ISO 3675/IP 160 /ASTM 1298)

- Standard test method for dynamic viscosity and density of liquids by Stabinger Viscometer and the calculation of Kinematic Viscosity (ASTM D 7042)

Two different types of Hydrometers traceable NIST and five different density ranges of fuels which included fuel oils and diesel fuels were selected for the comparison study. Following are the type of hydrometers and density ranges of the fuels used for the study.

- Long Stem Hydrometers (LSH) (Five different ranges 0.800 to 1.050 gm/ml)
- Short Stem Hydrometers (SSH) (Five different ranges 0.800 to 1.050 gm/ml)

Five different density ranges of fuels selected to cover the entire range were also tested in the following automatic density meters.

- Anton Paar automatic digital density meter (DMA)
- Anton Paar Stabinger Viscometer (SVM)

The methodology in measuring density is different and each process was thoroughly evaluated to minimize the uncertainty of measurement associated. Sampling is also very important since each technique is different. Fuel oils are complex in nature and compared to marine diesels additional care was taken where sampling was concerned. The comparison was basically done between a conventional manual system and automated testers.

Automatic density measurement is done by introducing a small quantity of oil (approximately 1 to 2ml) in to the oscillating sample tube and the density is measured by the change in the mass of the tube which creates the change in the oscillating frequency.

In the manual hydrometer system, the sample, hydrometer cylinder, hydrometer and the thermometer are brought to approximately same temperature of measurement and the measurement is carried out after the stabilization.

The basic principle behind the density measurement by automatic density meter and Stabinger viscometer is the same. The reason for including the Stabinger Viscometer also for this study is due to the fact that the stabinger viscometer measures the viscosity and density of the sample in a single run and to make sure that the uncertainty of measurement is within the 95% confidence level in comparison with the other methods.

Apart from the coefficient of determination for comparing each method, an individual validation of each method was also performed and the precision results were well within the precision of the published standard density methods.

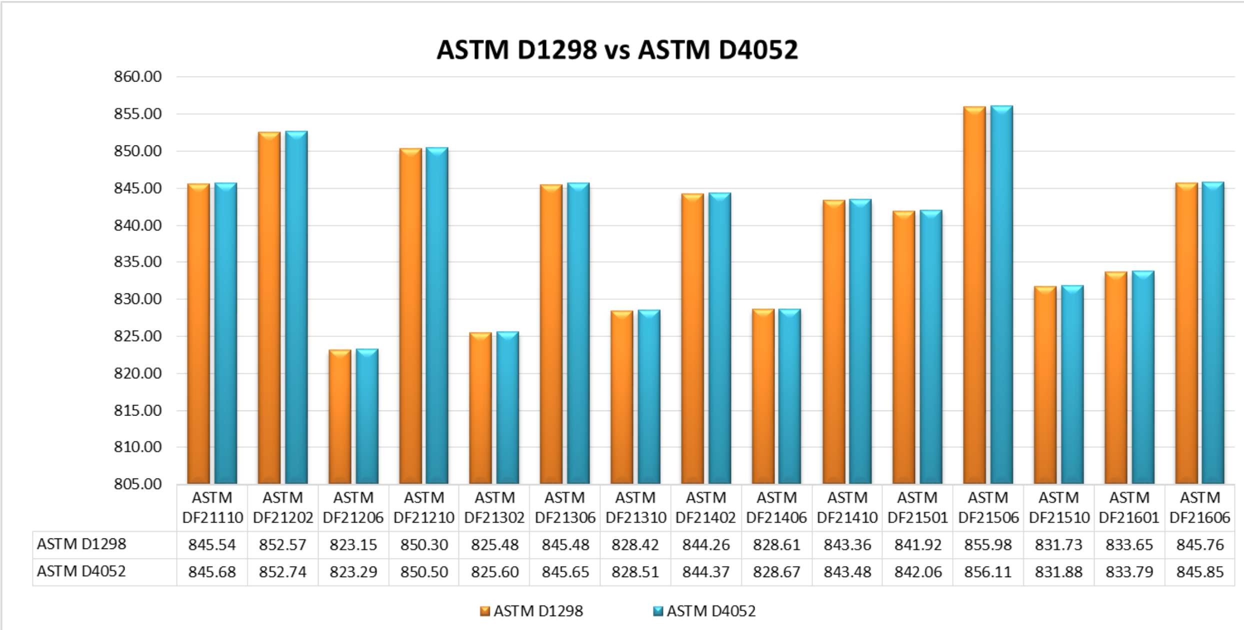
The coefficient of determination with various hydrometers versus (vs) digital density meters are given in table 1.

Table 1

Precision	Sample Matrix	Methods Compared	Coefficient of Determination (R^2)
Repeatability	Fuel Oil	DMA vs SSH	0.99
		DMA vs LSH	1.00
		SSH vs LSH	1.00
		SVM vs SSH	0.99
		SVM vs LSH	1.00
Reproducibility	Fuel Oil	DMA vs SSH	0.99
		DMA vs LSH	1.00
		SSH vs LSH	1.00
		SVM vs SSH	0.99
		SVM vs LSH	1.00
Repeatability	Diesel Oil	DMA vs SSH	0.99
		DMA vs LSH	0.99
		SSH vs LSH	1.00
Reproducibility	Diesel Oil	DMA vs SSH	0.99
		DMA vs LSH	0.99
		SSH vs LSH	1.00

To evaluate the accuracy, comparison was undertaken with the ASTM proficiency test results. The ASTM proficiency density results of the diesel fuel samples by DMA (ASTM D4052) were compared with the ASTM hydrometer method (ASTM D1298). For the fuel oil samples the ASTM proficiency test results of the hydrometer method (ASTM D1298) were compared with the VPS global density average results by DMA (ASTM D4052) and SVM (ASTM D7042).

Coefficient of determination (R^2) of ASTM 4052 results with the ASTM proficiency results by ASTM D1298 for diesel fuel is given in Figure 1.



	ASTM DF21110	ASTM DF21202	ASTM DF21206	ASTM DF21210	ASTM DF21302	ASTM DF21306	ASTM DF21310	ASTM DF21402	ASTM DF21406	ASTM DF21410	ASTM DF21501	ASTM DF21506	ASTM DF21510	ASTM DF21601	ASTM DF21606
ASTM D1298	845.54	852.57	823.15	850.30	825.48	845.48	828.42	844.26	828.61	843.36	841.92	855.98	831.73	833.65	845.76
ASTM D4052	845.68	852.74	823.29	850.50	825.60	845.65	828.51	844.37	828.67	843.48	842.06	856.11	831.88	833.79	845.85

Figure 1 Coefficient of determination (ASTM D1298 vs ASTM D4052)

The coefficient of determination (R^2) of VPS global density average results by DMA and SVM with the ASTM proficiency test results by ASTM D1298 for fuel oil is given in Table 2.

Table 2

Methods Compared	**Coefficient of Determination (R^2)**
DMA vs Hydrometer	0.99
SVM vs Hydrometer	0.99

Based on the validation results of (DMA, SVM and Hydrometer), a better precision was observed in the case of density determination by digital density meter and stabinger viscometer compared to the manual hydrometer method. This may be due to the higher measurement uncertainty involved in the manual hydrometer method compared to the automatic measurement especially the uncertainty in keeping a constant temperature control on the sample, hydrometer cylinder, hydrometer and the thermometer in an open ambient temperature condition and also the manual interpretation of the observed result.

These findings support the new ISO 8217:2017 Fuel Quality Standard where the density reference method for dispute resolution has now been changed to allow parties to agree upon the test method to be used. In this context, and as conclusion to this research project, VPS would unequivocally recommend the density test method ISO 12185.