Preliminary Study for the Establishment of Oscillation-Type Density Meter Calibration at NIMT

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Abstract

Density meters have been employed to measure the density of liquids and used in many areas such as chemical, petroleum, pharmaceutical and beverage applications. The advantages of density meters over other density measurement devices are their fast measurement, high accuracy and little sample needed. Although high accuracy is one of their major features, the density meters need regular calibration to ensure the accuracy of their measurement results. National Institute of Metrology (Thailand), NIMT, studied the calibration of density meters in accordance with the international standard ISO 15212-1. In this paper, the studied technique was applied to the calibration of oscillation-type density meters. The calibration performed at the temperature of 20 °C was traceable to SI unit by using traceable standard liquids with known densities. Three types of the liquids, whose densities are within the density measuring range of 700-1,600 kg/m^3, were employed. Those liquids were lube oil, water and sodium bromide in water. The calibration results were presented in terms of the deviations between the measured densities and the certified densities reported in certificates of standard liquids. Also the sources of measurement uncertainty were proposed and calculated. The calibration results showed acceptable deviations, which were within the maximum permissible errors of density meters under test.

Keywords: Density meter, calibration, standard liquid

Introduction

The use of density meters has received increasing attention in several density measurement applications. There have been several studies on the density meter calibration [1-2]. Lorefice and Sardi [1] presented a second order mathematical model with three unknown parameters used to calibrate densimeters. These parameters can be estimated by using the weighted least square method (WLS). The results from the model were tested by calibrating a commercial Solartron 7835. The sources of uncertainty were also proposed. Furtado *et al*. [2] performed calibration of oscillation-type density meter by comparison the measured density with a standard density meter. Standard density meter used was Anton Paar DMA5000. Measurements of liquid samples in both meters were performed almost simultaneously. The uncertainty budgets were also presented.

The aim of this work is to preliminarily study the calibration of oscillation-type density meters with the use of density standard liquids in accordance with ISO 15212-1[3].

Following this introduction, the theory of oscillation-type density meter is explained. Section 3 describes the experimental set-up and the method to calibrate density meter. The calibration results are presented in section 4. Section 5 illustrates the measurement uncertainties. Finally, section 6 contains some conclusions.

Theory

The density measurement of density meter is based on vibration and material deformation of oscillating system. Its oscillator is a U-shaped glass tube of constant volume filled with a fluid sample. When measuring the sample density, the U-shaped tube is excited. This results in the continuous oscillation at the characteristic frequency f of the tube with sample. This frequency changes with changing density of sample.

The density of the sample can be written in terms of the oscillation periods as shown in the following equation [4].

$$\rho = \tau^2 \frac{K}{4\pi^2 v} - \frac{m}{v} \qquad (1)$$

where ρ is sample density [g/cm^3]
τ is oscillation period [s]
v is cell volume [cm^3]
m is cell mass [g]
K is measuring cell constant [g/s^2]

In order to determine this density, it is assumed that

$$\rho = \tau^2 A - B \quad (2)$$

where A and B are adjustment constants obtaining by the adjustment with air and water.

Experimental Apparatus and Methods

Experiments were conducted to investigate method used for calibration. The equipment used for calibration consists of glass syringes, distilled water and standard liquids with known densities. The standard liquids used in this work are lube oil Larger 8, distilled water and sodium bromide in water as shown in figure 1. Their densities were obtained from certificate of calibration issued by accredited laboratory.

Figure 1. Standard liquids used for the calibrations of density meters.

In this work, the calibrations of two oscillation-type density meters were performed. Those are density meters model DMA 5000 manufactured by Anton Paar and model DE45 DeltaRange manufactured by Mettler-Toledo as shown in figures 2 and 3 respectively.

Figure 2. Density meter under test model DMA 5000 manufactured by Anton Paar.

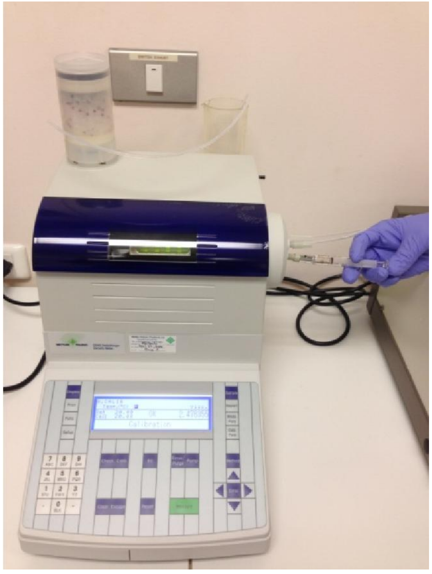


Figure 3. Density meter under test model DE45 DeltaRange manufactured by Mettler-Toledo.

The density meters under test have U-shaped tube sensor of known volume and mass. This sensor needs to be thoroughly cleaned and dried before making the density measurements.

To measure the density of standard liquid sample, the liquid was injected to the tube using a syringe as shown in figures 2 and 3. It is note that the entire tube needs to be filled with liquid and no gas bubble presents in the tube. The amount of liquid needed is at least 1.5 mL [5] for Anton Paar density meter and 1.2 mL [4] for Mettler-Toledo density meter. The U tube was excited and kept oscillating at frequency *f* as described in the previous section.

The calibration was performed at the temperature of 20°C by using three standard liquids having different densities. However the density check with air and distilled water should be performed before making the measurement of standard liquids.

In the density measurements, the densities of each liquid were measured three times by using the density meters under test. The mean value of each liquid ($\bar{\rho}$) is determined from the following equation.

$$\bar{\rho} = \frac{1}{3}\sum_1^3 \rho_i \quad (3)$$

Calibration Results

In this section, the calibration results using the system shown in figures 2 and 3 are presented.

Tables 1 and 2 present the calibration results of Anton Paar and Mettler Toledo density meters respectively. The calibration results are the deviations between standard densities and measured densities. The deviations are given in kg/m^3. The standard densities were obtained from certificates of standard liquids. The standard densities for lube oil, distilled water and sodium bromide in water are 823.934, 998.204 and 1249.076 kg/m^3 respectively. The measured densities were calculated as the arithmetic mean of three repeated calibrations as shown in equation 3. It can be seen from Tables 1 and 2 that the calibrations using lube oil show maximum deviations, which are 0.062 and 0.029 kg/m^3 for density meters model DMA5000 and DE45 DeltaRange respectively. The calibrations using distilled water show minimum deviations, which are 0.001 and 0.004 kg/m^3 for density meters model DMA5000 and DE45 DeltaRange respectively.

Table 1: Calibration results of density meter model DMA5000 manufactured by Anton Paar.

Standard	Standard Density (kg/m^3)	Displayed Density from DUT (kg/m^3)	Deviation (kg/m^3)
Lube Oil	823.934	823.996	0.062
Ditilled Water	998.204	998.205	0.001
Sodium bromide in water	1249.076	1249.086	0.010

Table 2: Calibration results of density meter model DE45 DeltaRange manufactured by Mettler Toledo.

Standard	Standard Density (kg/m^3)	Measured Density from DUT (kg/m^3)	Deviation (kg/m^3)
Lube Oil	823.934	823.963	0.029
Distilled Water	998.204	998.208	0.004
Sodium bromide in water	1249.076	1249.084	0.008

Measurement Uncertainty

The sources of uncertainty for calibrating oscillation-type density meters are shown in tables 3.

There are three sources of measurement uncertainty for the calibration of oscillation-type density meter. Those are uncertainty of reference liquids, resolution of density meter under test and repeatability of measured density. The uncertainty of reference liquids is obtained from certificate of the liquids. The uncertainty of all liquids used in this work is 0.01 kg/m^3. The resolutions of density meters model DMA 5000 and DE45 DeltaRange are 0.001 kg/m^3 and 0.01 kg/m^3 respectively. The repeatability of measured density varies between 0.0004 kg/m^3 and 0.0078 kg/m^3. The expanded uncertainty for the calibration of both density meters are shown in table 4. It can be seen that the maximum expanded uncertainty is 0.019 kg/m^3.

Table 3: Sources of uncertainty for the calibration of oscillation-type density meter.

Type	Source of Uncertainty
B	Uncertainty of CRMs
B	Resolution of density meter
A	Repeatability of measured density

Table 4: Expanded uncertainty for the calibration of density meters model DMA5000 and DE45 DeltaRange.

Standard	Expanded Uncertainty (kg/m^3)	
	DMA5000 Anton Paar	DE45 DeltaRange Mettlor Toledo
Lube Oil	0.010	0.013
Distilled Water	0.010	0.019
Sodium bromide in water	0.019	0.012

In order to ensure the accuracy of the density meters under test, the compliance with the maximum permissible error was performed. This was done by comparing the calibration results with the maximum permissible error. The maximum permissible error of density meters under test is shown in table 5 [3].

Table 5: Resolution and maximum permissible error (MPE) of oscillation-type density meter [3].

Density Meter Model	Resolution (kg/m^3)	MPE (kg/m^3)
DMA5000 (Anton Paar)	0.001	0.10
DE45 DeltaRange (Mettler Toledo)	0.010	0.05

Figures 4 and 5 present the calibration results including their measurement uncertainties (■) of density meters model DMA5000 and DE45 DeltaRange respectively. The dashed lines represent the maximum permissible error limits of density metes under test. It can be seen that the maximum errors including their uncertainties of density meters model DMA5000 and DE45 DeltaRange are 0.072 kg/m^3 and 0.043 kg/m^3 respectively. They are within the permissible error limits.

Figure 4. Calibration results with their measurement uncertainties (■) of density meter model DMA5000 compared to the maximum permissible error (---).

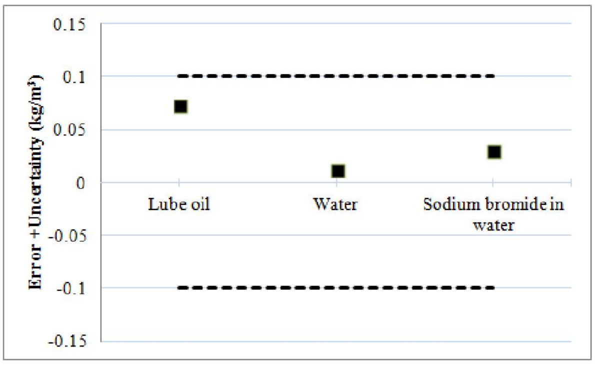
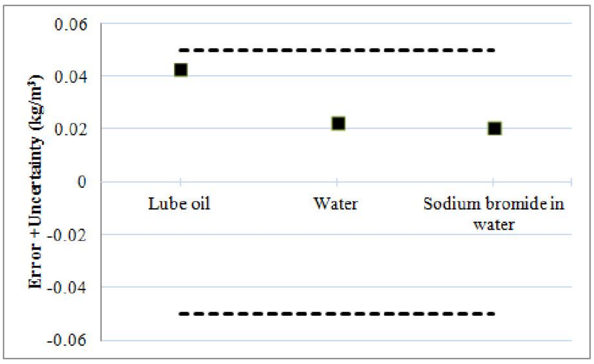


Figure 5. Calibration results with their measurement uncertainties (■) of density meter model DE45 DeltaRange compared to the maximum permissible error (---).



Conclusions

The calibrations of oscillation-type density meters at NIMT have been presented in this paper. The calibration method is based on the international standard ISO 15212-1. This method employs the traceable standard liquids with known densities to calibrate the density meters under test. Three liquids, which are lube oil, distilled water and sodium bromide in water, were used. Their densities are within range of 700-1,600 kg/m^3. The calibration results are determined in terms of the deviation of densities obtained from certificate of standard liquids and those measured by density meters under test. The sources of measurement uncertainties were proposed. Those are uncertainty of reference liquids, resolution of density meter under test and repeatability of measured density.

The calibrations of density meters model DMA5000 and DE45 DeltaRange were performed, the measurement uncertainties were determined and the calibration results were compared to the maximum permissible errors. The calibration results including their measurement uncertainties show acceptable deviations, which are within the maximum permissible errors of density meters under test.

References

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