

RING METHOD FOR HYDROMETER CALIBRATION

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Abstract: Ring method offers simple yet effective hydrometer calibration method with comparable performance to other hydrometer calibration methods. This work reports a ring method experimental setup for calibrating hydrometers. It uses a suitable dimension of ring to sink hydrometers in standard liquid which traceable to solid density determined by hydrostatic weighing method. The surface tension of the standard liquid density was measured by tensiometer consists of balance and Wilhelmy plate. The calibration results shown that, the range has been expanded from 0.600 g/ml up to 1.000 g/ml with uncertainty of 0.0002 g/ml. The theoretical calculation was developed and tested with experimental data. The ring method experimental setup and procedure were found to be much simpler and cheaper with a better accuracy. Furthermore, it does not use any harmful chemicals.

Keywords: Hydrometer, calibration, ring method, comparison method

1. INTRODUCTION

Calibration is a set of operation under specified conditions where the relationship between values of realized by standards and values of quantities indicated by a measuring instrument are compared. It is crucial for determining and validating the accuracy of measuring instruments. Almost all measuring instruments such as hydrometer, viscometer, liquid in glass thermometer, pressure meter and standard weight need calibration to validate their accuracy [1].

Hydrometer has gained its popularity as versatile instrument for determining liquid density and therefore, the degree of its accuracy will depend much on its calibration procedures. There are three well-known hydrometer calibration methods: hydrostatic weighing method, comparison method and ring method [2,3,4,5]. The first two become the most favored methods and are used widely by many national laboratories around the world. However secondary calibration laboratory in Malaysia mostly using comparison method since it is much simpler, easier and cheaper compare to the hydrostatic weighing methods. These advantages has motivated the National Metrology Institute of India in 1984 to do further modification and came up with a new innovative

hydrometer calibration method the so called “ring method” [4]. However, this method has limited range of calibration (0.600g/ml to 0.650g/ml) and usually used liquid petroleum as a medium which was messy and not easy to handle.

Therefore, we proposed a much simpler innovative ring method which only used distilled water as a medium but proven to be a reliable standard liquid. Furthermore, our result shown that, the calibration range has been expanded from 0.600 g/ml up to 1.000 g/ml with uncertainty of 0.0002 g/ml.

2. THEORETICAL

The ring method has been designed to further extent the calibration range in the order of 0.600g/ml to 1.000g/ml. A suitable ring was added into hydrometer stem in order to purposely sink the hydrometer into the distilled water. The calculated density, ρ_c was determined by using equation 1 and was compared with the hydrometer scale reading to obtain the scale correction.

$$\rho_c = \left[\frac{\left(M \left(1 - \frac{\rho_a}{\rho_b} \right) + \frac{\pi D S_o \cos A_o}{g} \right) (\rho_w - \rho_a)}{M \left(1 - \frac{\rho_a}{\rho_b} \right) + m_s \left(1 - \frac{\rho_w}{\rho_s} \right) + \frac{\pi D S_f \cos A_f}{g}} \right] + \rho_a \quad (1)$$

where,

- M : mass of the hydrometer in air
- m_s : mass of ring (sinker)
- g : acceleration due to gravity
- ρ_a : density of air
- ρ_b : density of standard weight
- ρ_w : density of distilled water
- ρ_s : density of ring (sinker)
- D : diameter of hydrometer stem
- S_f : surface tension of the liquid
- S_o : reference surface tension of the hydrometer
- A_o : contact angle of the liquid at the hydrometer stem
- A_f : contact angle of the liquid at the hydrometer stem

3. APPARATUS AND MEASUREMENT TECHNIQUE

First, the range and scale of hydrometers is observed in order to determine a suitable ring sinker to be used. The hydrometer is weighted in air using analytical balance (Mettler Toledo, XP504) and its stem diameter is measured using a digital micrometer. Then, the hydrometer is subjected to cleaning procedures in a mixture of distilled water and Decons 90 and then rinsed by distilled water, cleaned in alcohol and finally rinsed by distilled water.

Next, the hydrometer is immersed into distilled water and the suitable ring sinkers are inserted into its stem as shown in Figure 1. Then the standard ring sinkers mass and the hydrometer scale readings are taken. The standard ring sinker was made from stainless steel and the standard ring sinker mass was measured at Mass Laboratory, National Metrology Laboratory. The distilled water temperature is recorded by digital thermometer (ASL,F250) with an accuracy of 0.01°C. The density and surface tension of the distilled water are measured using crystal sphere [6] and tensiometer [7] respectively.

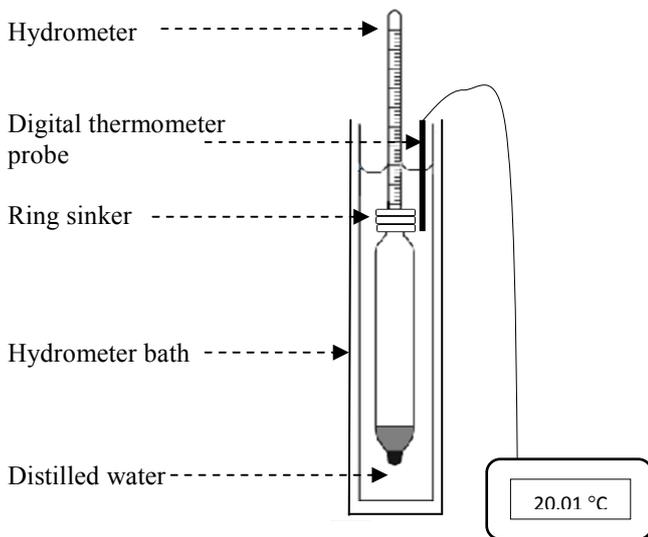


Figure 1: Calibration of hydrometer by ring method

4. ANALYSIS AND RESULT

Three hydrometer samples were calibrated using the ring method. Figure 2, 3 and 4 shows the hydrometer calibration results for the range of 0.700~0.750 g/ml (Serial Number: 3355/L), 0.800~0.820 g/ml (Serial Number: 778) and 0.900-0.950 g/ml (Serial Number: 3108/F) respectively. The correction of the hydrometers scale can be easily observed from the plotted graphs. The calibration points of the hydrometers were 0.702, 0.711, 0.720, 0.729 and 0.739 g/ml, 0.801, 0.805, 0.809, 0.813 and 0.817 g/ml, 0.910, 0.921, 0.933 and 0.945 g/ml for hydrometer range of 0.700~0.750 g/ml, 0.800~0.820 g/ml and 0.900-0.950 g/ml respectively.

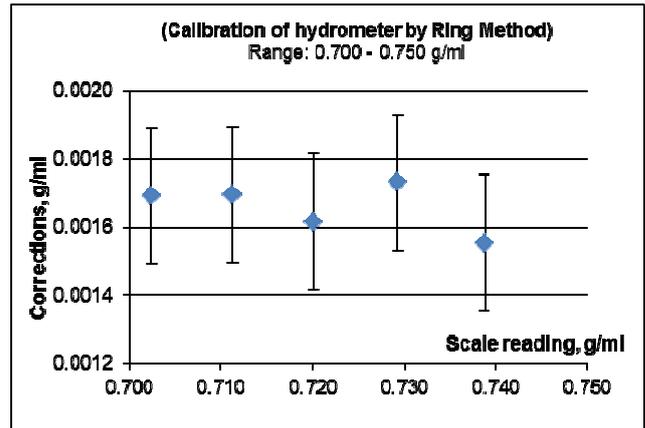


Figure 2: range 0.700~0.750 g/ml (Serial Number: 3355/L)

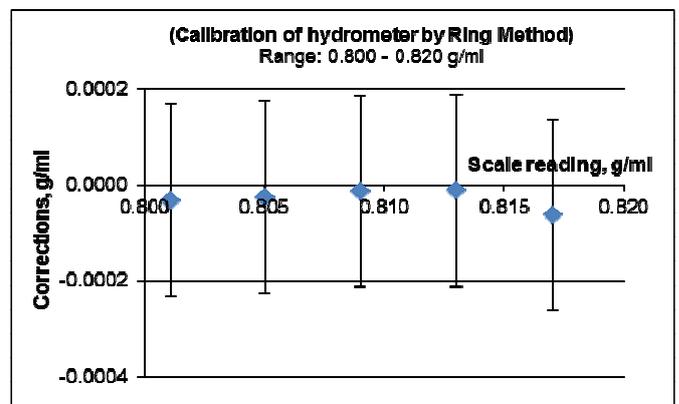


Figure 3: range 0.800~0.820 g/ml (Serial Number: 778)

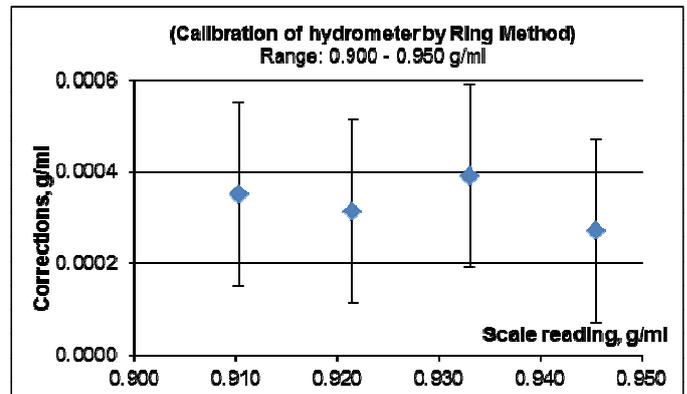


Figure 4: range 0.900-0.950 g/ml (Serial Number: 3108/F)

5. UNCERTAINTY SOURCES

Table 1 shows the analysis of expanded uncertainty at 95% confidence level. It shows a list of significant measurement uncertainties. All the parameters were obtained from equation 1 and the expanded uncertainty was found to be $2.0 \times 10^{-4} \text{ g/cm}^3$.

Table 1: Analysis of expanded uncertainty of ring method at 95% confidence level

Parameter	Uncertainty (g/ml)
Ambient Pressure(hPa)	1.1303E-08
Ambient Temp(°C)	5.7916E-08
Surface Tension(mN/m)	3.5860E-05
Liquid Temperature (°C)	3.0323E-05
Hydrometer mass (g)	4.6946E-07
Sinker mass in water (g)	4.4979E-05
Sinker temp (°C)	2.8559E-07
Density of liquid (g/mL)	9.0568E-06
Repeatability (g/mL)	7.0711E-05
Balance Reading (g)	4.9672E-06
Combined stdunc, Uc	0.000097
Expanded uncertainty U	0.0002

6. CONCLUSIONS

Calibration of hydrometer by ring method has been successfully developed. The density and surface tension of distilled water was measured using crystal sphere and tensiometer respectively. This ring method can be used for hydrometer calibration in the range between 0.600g/ml to 1.000g/ml with expanded uncertainty of 0.0002 g/ml. This method can be traceable to the base unit of mass and length and furthermore it is much simpler, lower cost and the uses of hazardous chemicals have been completely avoided.

7. REFERENCES

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