A Simple Method for the Calibration of an Open Surface Water Bath

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Abstract. Calibration and testing of open surface water bath is a new technique and may be used for other liquid bath testing. Due to some critical circumstances the bath is not covered by the manufacturing company so is prone to the effects of surrounding environmental conditions. Due to this effect, bath temperature is not stable and calibration and testing cannot be performed under these conditions. For this type of calibration the reference instruments should measure temperature with very high levels of accuracy. A Platinum Resistance Thermometer (PRT), with super thermometer (indicator), is used for high accuracy calibration. Oil-filled flasks are used as a secondary medium to calibrate the bath and to reduce the evaporation, and instability in the temperature measurements. Therefore, on the basis of stable temperature with good precision and minimum uncertainty, the proposed method is found to be suitable for the calibration of open surface water baths.

Keywords: Calibration, water bath, uncertainty measurement

1. Introduction
Open surface water baths are commonly used in a number of applications in all fields of science and technology especially in medical and textile laboratories. Temperature, humidity, atmospheric pressure, and dust particles are the main factors which adversely affect the accuracy of water bath’s temperature. Therefore, water bath needs calibration prior to use. Unfortunately, a little data is available in which calibration of such type of equipment is considered. Calibration is a process in which, the performance of an instrument is compared against standards of known uncertainty and error to detect or correct / adjust any variation from the required performance specifications. In other words, it is a process of verifying the operational integrity of an instrument. In this study three different types of oil were used as a secondary medium to calibrate the bath to reduce the evaporation, and instability in the temperature measurements of water. Traceability in the measurements is achieved using a standard reference thermometer, whose value is traceable to the NIST USA. Generally, the fitness of the proposed or newly developed methods is assessed through method validation studies. As there is a lack of a simplified standard method for the calibration of such type of bath; the compliance of the proposed method was assessed by uncertainty measurement. The data was produced on overall performance of water bath. The individual factors which influenced the uncertainty associated with the results of the proposed method were identified and corrected.

The aim of the present work is to propose a novel, simple and accurate method for the calibration of open surface water baths, which is special type of water bath use in chemical, Medical and textile industries where Thousands of important tests are performed with the help of water bath. So the proposed method is a technique to check and verify the performance of open surface water bath which is the basic requirement of ISO (International organization for standardization) clauses.
2. Experimental Work

2.1. Materials

PRT (Platinum Resistance Thermometer) with super thermometer (indicator) cropico made was used as a secondary standard reference device. PRT has secondary Standard sensor according to ITS-90. And supper thermometer indicator is highly precise device having three decimals readability, which is more accurate as compare to bath. Three types of oil (transformer oil, cooking oil, Hello carbon 0.8 grades) were selected as a reference medium for temperature measurements. All samples of oil were of commercial grade and purchased from local markets.

Selection of oil is very important because flashing point is considered. Flash point of transformer oil is around 200°C, cooking oil is around 300°C, and hello carbon 0.8 can be used till 100°C. Above these temperatures, flash point could be occurring. So oil should be used below the flash point.

2.2. Method

Water bath has been filled with water as per method described by the manufacturer. A 250 ml cylinder was filled with oil (transformer oil/ cooking oil/ Hello Carbon 0.8) up to a certain level and a PRT has been clipped into the cylinder in such a position that the insertion level of PRT (defined by the manufacture) immersed in the oil. PRT is the secondary standard device in the hierarchy of international temperature standard (ITS-90). The PRT was fixed in the cylinder so that it was held away from the sides and base of the cylinder. Two more cylinders with the same setup have been inserted in the water bath at equal distances (Fig. 1). Water bath has been set at 43.05°C. A stirrer is used to ensure the uniformity in the temperature. The temperature of the oil has been observed after allowing a sufficient time (at least 30 minutes) or after stability of temperature depends upon the condition. The bath indicates that it has reached the set-point (read out temperature) and stabilized. When the temperatures stabilize on bath and the reference indicator, value has been observed. Repeat this observation at least 3 to 5 times for observed the variation. Most occurring value may be observed if variation. Correction factor has been applied on all the measurements using conversion the error of each sensor.

Figure 1: Schematic representation of the proposed method for the calibration of open surface water bath
3. Results & Discussion

The set temperature, readout temperature, and observed temperature of transformer oil, cooking oil, and Hello Carbon 0.8 grade, are shown in Table 1-4 respectively. Mean value and standard deviation in the results were estimated using well-known statistical formula. Generally, two types of error are estimated in the measurements. First is random error, which is always present due to operator’s handling, or changes in the environmental conditions. To minimize this type of error replicate measurements were taken and their average value was calculated. Second type of error is systematic error. It is typically present due to instrumental, physical, and human limitations. This error was calculated by the formula and estimating overall (expanded) uncertainty in the measurements during calibration of water bath. All the Uncertainty measurements were performed using equation (1) to (3) as described in EURACHEM / CITAC guide.

In estimating the overall uncertainty, it is necessary to consider each source of uncertainty and treat it separately to obtain the contribution from the source. When expressed as a standard deviation, an uncertainty component is known as standard uncertainty. Equation (1) and (2) comprises of the calculation of type A standard uncertainty, and type B standard uncertainty respectively. Type A uncertainty was estimated from repeated readings and comes from statistical data (Observation). Type B uncertainty was estimated from calibration certificate of PRT and indicator, environment, readability, drift, and etc.

\[
\text{Standard uncertainty for Type A} = \mu_A = \frac{s}{\sqrt{n}} \quad (1)
\]

\[
\text{Standard uncertainty for Type B} = \mu_B = \frac{a}{\sqrt{3}} \quad (2)
\]

Where \(s\) is the standard deviation, \(n\) is the number of observation, and \(a\) is the uncertainty of the thermometer (observed value) measurement.

The total uncertainty, termed combined standard uncertainty, is an estimated standard deviation equal to the positive square root of the total variance obtained by combining all the uncertainty components (equation (3)).

\[
\text{Combined uncertainty} = \mu_c = \sqrt{(\mu_A)^2 + (\mu_B)^2 + \cdots} \quad (3)
\]

Expanded uncertainty provides an interval within which a value of the measure and is believed to lie within a higher level of confidence. It is obtained by multiplying the combined standard uncertainty to a coverage factor (k) (equation (4)).

\[
\text{Expanded uncertainty} = U = k\mu_c \quad (4)
\]

\(k = 1, 2, \text{ and } 3\) for confidence level of 68 \%, 95 \%, and 99.7 \%, respectively.

The expanded uncertainty values for transformer oil, cooking oil, and Hello Carbon 0.8 grade were calculated as 0.378°C, 0.206°C, and 0.097°C, respectively (Table 4).

4. Conclusion

PRT secondary reference device has the prospective to be utilized for the calibration of open surface water bath using oil as a secondary medium. On the basis of the experiments conducted by three different oil samples, it is concluded that the proposed method has the potential to be utilized successfully for the calibration of open surface water bath.

5. References

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### Table 1: Temperature stability and uncertainty measurements in the results of Transformer oil

| No. | Temp. / °C | Read / °C | Observed Temp. after Applying | Correction Factor / °C | Average / °C | Error / °C | Standard deviation / °C | $U_A$ / °C |
|-----|------------|-----------|-------------------------------|-----------------------|--------------|-----------|-----------------------|----------|
| 1   | 43.05      | 43.05     | 43.257±0.007                  | 42.674±0.004          | 43.214±0.004 | 43.048     | 0.002                 | 0.325    |
|     |            |           |                               |                       |              |           |                       | 0.188    |
| 2   | 43.05      | 43.05     | 43.256±0.004                  | 42.669±0.004          | 43.213±0.004 | 43.046     | 0.061                 | 0.327    |
|     |            |           |                               |                       |              |           |                       | 0.189    |

### Table 2: Temperature stability and uncertainty measurements in the results of cooking oil

| No. | Temp. / °C | Read / °C | Observed Temp. after Applying | Correction Factor / °C | Average / °C | Error / °C | Standard deviation / °C | $U_A$ / °C |
|-----|------------|-----------|-------------------------------|-----------------------|--------------|-----------|-----------------------|----------|
| 1   | 43.05      | 43.05     | 43.271±0.003                  | 42.942±0.002          | 43.226±0.004 | 43.146     | -0.096                 | 0.178    |
|     |            |           |                               |                       |              |           |                       | 0.103    |
| 2   | 43.05      | 43.05     | 43.270±0.004                  | 43.000±0.003          | 43.215±0.003 | 43.162     | -0.054                 | 0.143    |
|     |            |           |                               |                       |              |           |                       | 0.083    |
Table 3: Temperature stability and uncertainty measurements in the results of Hello carbon 0.8

| No. | Set | Temp. | Temp. | Observation Temp. After Applying | Average | Error °C | Standard deviation °C |
|-----|-----|-------|-------|----------------------------------|---------|----------|-----------------------|
|     |     |       |       |                                  |         |          |                       |
| 1   |     | 43.05 | 43.05 | 43.212±0.003                     | 43.077±0.004 | -0.121  | 0.082                 |
|     |     |       |       |                                  | 43.224±0.003 |   0.004  | 0.047                 |
| 2   |     | 43.05 | 43.05 | 43.210±0.004                     | 43.078±0.002 | -0.120  | 0.080                 |
|     |     |       |       |                                  | 43.223±0.003 |   0.005  | 0.046                 |
| 3   |     | 43.05 | 43.05 | 43.208±0.003                     | 43.076±0.002 | -0.122  | 0.084                 |
|     |     |       |       |                                  | 43.231±0.002 |   0.007  | 0.048                 |
| 4   |     | 43.05 | 43.05 | 43.182±0.002                     | 43.074±0.002 | -0.108  | 0.075                 |
|     |     |       |       |                                  | 43.218±0.002 |   0.008  | 0.043                 |

Table 4: Expanded Uncertainty Calculation

| S. No. | Description      | UA (Max.) | UB     | UC     | U EXP  |
|--------|------------------|-----------|--------|--------|--------|
|        |                  | °C        | °C     | °C     | °C     |
| 1      | Transformer Oil  | 0.189     | 0.0058 | 0.189  | 0.378  |
| 2      | Cooking Oil      | 0.103     | 0.0058 | 0.103  | 0.206  |
| 3      | Hello Carbon 0.8 | 0.048     | 0.0058 | 0.048  | 0.097  |