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Calibration of Digital Thermometer using Sensor and Indicator Method

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***Abstract:** A Calibration has been done for digital thermometer using a sensor and indicator method. The unit under test manufactured by Fluke with 54-II type and serial number 13160058, meanwhile, the standards that used are PT100 sensor from Omega and an indicator from Additel. The calibration result from 12 setpoints shows the average correction value as 0.61 ºC with uncertainty as 0.32 ºC and K factor as 2.0 at 95% confidence level.*

***Keywords**: calibration, correction, digital thermometer, standard, uncertanity*

I. INTRODUCTION

Calibration is an activity to determine the actual value of the appointment value of measuring instruments and measuring materials by comparing against measuring standards that can be traced to national and international standards [1].

In temperature calibration [2], some terms need to be known, including:

A. *Standard*

A calibration standard [3] is a standard unit for the length, weight, time, temperature, and quantity of electricity that is set so that researchers around the world can compare their experimental results on a consistent basis.

B. *Measurement System*

The measurement system [4] consists of three stages. Those are

1. The detector-transducer stage, which detects physical quantities that carry out mechanical or electrical transformations to convert signals into more useful forms. In general, the transducer is a device that can transform a physical effect into another physical effect. However, in many cases, the physics variable is transformed into an electrical signal because in this form, the signal is easily measured.
2. An intermediate stage, which changes the direct signal by amplification, filtering or other means, to obtain the desired output.
3. The final stage that shows records and controls the measured variable.

C. *Temperature*

Temperature is an intuitive concept that states whether an object is "hot" or "cold" for most people. In the translation of the second principle of thermodynamics, the temperature is associated with heat (heat), because it was known that heat flows only from high temperature to low temperature when there are no other effects. Due to pressure, volume, electrical resistivity, expansion coefficient, etc., all depend on temperature through fundamental molecular structures, the properties change according to temperature, and changes can be used to measure temperature, so the concept of temperature is important in all branches of science physical; therefore the experimental engineers have to master the methods used for temperature measurement.

D. *Temperature Scale*

Two temperature scales [5] that are widely used are the Fahrenheit scale and the Celsius scale. Both of these scales are based on determining the amount of increase between the freezing point and boiling point of water at standard atmospheric pressure. The Celsius scale has 100 units between these two points, while the Fahrenheit scale has 180 units. The absolute Celsius scale is called the Kelvin scale, while the absolute Fahrenheit scale is called the Rankine scale. The two absolute scales are defined in such a way that they are closely related to the thermodynamic temperature scale. The zero points on both absolute scales indicate the same physical state, and the ratio of two values is always the same on both absolute scales.

$$\left(\frac{T2}{T1}\right)_{Rankine} = \left(\frac{T2}{T1}\right)_{Kelvin} \qquad (1)$$

The boiling point of water at 1 atm is arbitrarily considered 100^0 on the Celsius scale and 212^0 on the Fahrenheit scale. The relationship between the two scales was shown in the following Fig. 1.

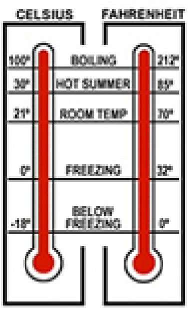

Fig. 1.Relation of Celsius and Fahrenheit Scale [5]

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Thus, it is clear that the relation below applies.

$$°F = 32{,}0 + \frac{9}{5}°C$$

$$°R = \frac{9}{5}K$$

E. *Thermoelectric Effect*

The most common electrical method for temperature measurement uses thermocouples (thermocouples). If there are two different types of metals, put together, as shown in Fig. 2.

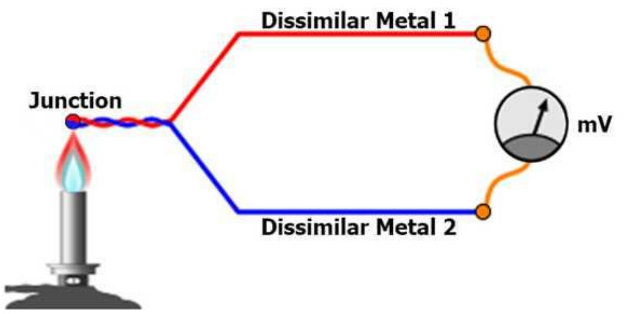

Fig. 2. A simple structure of thermocouples [6]

Then there will be an electric voltage (electromotive force) between two points A and B, which is mainly a function of the junction temperature. This phenomenon is called the Seebeck effect. If the two materials are connected to an external circuit in such a way that current flows, the voltage of electric motion can change slightly due to a phenomenon called the Peltier effect [7-9]. Furthermore, if there is a temperature gradient in one or both materials, the connection will change a little more. This is called the Thomson effect. So, there are three types of electromotive force in the thermoelectric circuit: Seebeck emf, which is caused by unequal metals; emf Peltier caused by the current flowing in the circuit; and Thomson emf, which is caused by the temperature gradient in the material.

Among the three kinds of electric motion voltage contained in the thermoelectric circuit, the most needing attention is the Seebeck emf which produces the Seebeck effect because it depends on the connection temperature. If the voltage generated at the junction of two dissimilar metals is carefully measured as a function of temperature, the connection can be used to measure temperature.

II. MATERIALS AND METHOD

The calibration method used in digital thermometer calibration is the sensor plus indicator method, which refers to the JIS Z 8710 standard of 1993 [10], The digital thermometer calibration flow chart with the sensor plus indicator method is as Fig. 3 da Fg. 4.

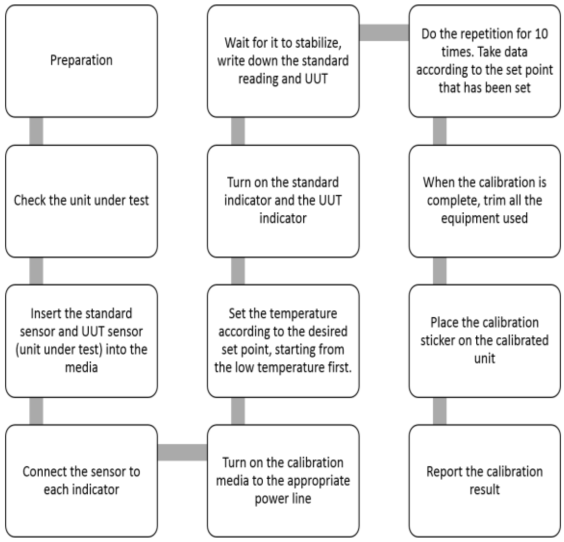

Fig. 3.A digital thermometer calibration flow chart

Fig. 4.Calibration Circuit Diagram

III. RESULTS AND DISCUSSION

A calibration has been carried out on the digital thermometer with the Fluke brand, type 54-II and serial number 1316058. This thermometer was used as a temperature measuring device with a range 0-160 ^{0}C. in this research, calibration points was set in the range into 12 points, namely 0 ^{0}C, 10 ^{0}C, 15 ^{0}C, 20 ^{0}C, 25 ^{0}C, 30 ^{0}C, 40 ^{0}C, 50 ^{0}C, 70 ^{0}C, 100 ^{0}C, 120 ^{0}C and 160 ^{0}C as shown in Table 1 – Table 6.

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Table 1. Calibration Result of Digital Thermometer for set point 0 ^{0}C and 10 ^{0}C

Set Point :	0.0 ^{0}C	Set Point :	10.0 ^{0}C
Standard (°C)	Unit Under Test (°C)	Standard (°C)	Unit Under Test (°C)
0.7095	0	10.8627	10
0.7099	0	10.8625	10
0.7103	0	10.8632	10
0.7102	0	10.8629	10
0.7099	0	10.8625	10
0.7095	0	10.8627	10
0.7098	0	10.8629	10
0.7098	0	10.8628	10
0.7103	0	10.8633	10,.0
0.7096	0	10.8631	10

Table 2. Calibration Result of Digital Thermometer for set point 15 ^{0}C and 20 ^{0}C

Set Point :	15.0 ^{0}C	Set Point :	20.0 ^{0}C
Standard (°C)	Unit Under Test (°C)	Standard (°C)	Unit Under Test (°C)
15.7936	15	20.6989	20,0
15.7939	15	20.6988	20
15.7936	15	20.6985	20
15.7938	15	20.6986	20
15.7941	15	20.6988	20
15.7944	15	20.6991	20
15.7942	15	20.6989	20
15.7943	15	20.6993	20
15.7941	15	20.6988	20
15.7943	15	20.699	20

Table 3. Calibration Result of Digital Thermometer for set point 25 ^{0}C and 30 ^{0}C

Set Point :	25.0 ^{0}C	Set Point :	30.0 ^{0}C
Standard (°C)	Unit Under Test (°C)	Standard (°C)	Unit Under Test (°C)
25.6485	25	30.6238	30
25.6484	25	30.6237	30
25.6491	25	30.6238	30
25.6487	25	30.6242	30
25.6488	25	30.6246	30
25.6494	25	30.6243	30
25.6492	25	30.6244	30
25.6488	25	30.6239	30
25.6487	25	30.6245	30
25.649	25	30.6241	30

Table 4. Calibration Result of Digital Thermometer for set point 40 ^{0}C and 50 ^{0}C

Set Point :	40.0 ^{0}C	Set Point :	50.0 ^{0}C
Standard (°C)	Unit Under Test (°C)	Standard (°C)	Unit Under Test (°C)
40.8398	40	51.0562	50
40.8402	40	51.0559	50
40.8405	40	51.0562	50
40.8402	40	51.0567	50
40.8398	40	51.0564	50
40.8397	40	51.056	50
40.8395	40	51.0558	50
40.8397	40	51.0559	50
40.8399	40	51.0564	50
40.8405	40	51.0565	50

Table 5. Calibration Result of Digital Thermometer for set point 70 ^{0}C and 100 ^{0}C

Set Point :	70.0 ^{0}C	Set Point :	100.0 ^{0}C
Standard (°C)	Unit Under Test (°C)	Standard (°C)	Unit Under Test (°C)
71.1757	70	101.4711	100
71.1757	70	101.4714	100
71.1756	70	101.4718	100
71.1752	70	101.4713	100
71.1755	70	101.4714	100
71.1756	70	101.4715	100
71.1757	70	101.4718	100
71.1761	70	101.4711	100
71.1759	70	101.4713	100
71.1758	70	101.4714	100

Table 6. Calibration Result of Digital Thermometer for set point 120 ^{0}C and 160 ^{0}C

Set Point :	120.0 ^{0}C	Set Point :	160.0 ^{0}C
Standard (°C)	Unit Under Test (°C)	Standard (°C)	Unit Under Test (°C)
121.6605	120	162.9064	160
121.6608	120	162.9065	160
121.6603	120	162.9064	160
121.6611	120	162.9071	160
121.6615	120	162.9074	160
121.6612	120	162.9076	160
121.6615	120	162.9075	160
121.6607	120	162.9067	160
121.6612	120	162.9069	160
121.661	120	162.9066	160

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The method used for calibration of digital thermometer is the working method of sensor plus indicator which is sultry to the quality document MK-12.01 with the title calibration method – Sensor Plus indicator referring to JIS document Z8710:1993, Temperature Measurement – General Requirement and Guide to The Expression of Uncertainty in Measurement, ISO/IEC Guide 98-3:2008 (E) [10, 11]. The standard used is the sensor PT 100 [3] and indicator with the brand Omega (PT100) and Additel (indicator). Calibration is done in environmental conditions 25 ± 3 ºC for room temperature and 55 ± 10% RH for room humidity. The Media used in this calibration is SIKA Liquid Bath with a temperature range-30 to 165 º C which is filled with silicon oil.The work was done according to the quality procedures that have been set on the working method, then the calibration worksheet, which contains the raw data was checked. The reporting process is done by calculating the data in the existing document, which is known as MOD or Master of Data. The MOD contains the calibration calculations that are made according to the methods and references that have been established in the laboratory, then verified by the authorized officers and used for the purposes of calculation of calibration results.Based on the results of calibration calculation on Data of Master, obtained in the Table 7.

Table 7. Calibration Result

Standard (^{0}C)	Unit Under Test (^{0}C)	Correction (^{0}C)	Uncertainty (^{0}C)	Coverage Factor (k)
0.27	0	0.27	0.32	2
10.4	10	0.4	32	2
15.32	15	0.32	0.32	20
25.16	25	0.16	0.32	2
30.12	30	0.12	0.32	2
40.32	40	0.32	0.32	2
50.52	50	0.52	0.32	2
70.6	70	0.6	0.32	2
100.83	100	0.83	0.32	2
120.97	120	0.97	0.32	2
162.13	160	2.13	0.32	2

IV. CONCLUSION

Calibration of the digital thermometer was carried out at 12 set points, namely 0 ^{0}C, 10 ^{0}C, 15 ^{0}C, 20 ^{0}C, 25 ^{0}C, 30 ^{0}C, 40 ^{0}C, 50 ^{0}C, 70 ^{0}C, 100 ^{0}C, 120 ^{0}C, and 160 ºC. The average correction of the reading is 0.61 ºC and the uncertainty as 0.32 ºC with K factor as 2.0 at 95% confidence level.

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