CALIBRATION TECHNIQUE OF TEMPERATURE MONITORING CHANNEL ISOTOPE PRODUCTION REACTOR

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Abstract *The measurement of reactor fuel temperature by using Instrumented Fuel Element (IFE) are necessary for monitoring the safety limit of the reactor fuel during operation. This device uses a temperature sensor type K thermocouple-based (Ni-Cr/Ni) and placed at the hottest position of the reactor core (hot channel). Placement in these positions potentially causing damage that can lead to errors reading of the measurement results. Because the reactor safety limits directly related to temperature, then the thermocouple as a sensor, it needs to be calibrated periodically so that the measurement results send the correct value of the measures. In general, every value that is obtained through measurement has some uncertainty, even though a careful execution of the experiment applied. Therefore, the main goal of this paper is to understand the characteristics of the measurement tools by doing a proper calibration method in order to get accurate results.*

INTRODUCTION

Reactor fuel temperature measurements are needed to monitor the magnitude of the temperature value of the reactor fuel that is currently operating (1). To get accurate results. the operation of measuring devices/sensors as a data collection, transmission and analysis system, must be calibrated based on reference standards at a certain time period depending on the needs and frequency of use as shown in table 1(2).

The thermocouple as one of the components for monitoring the temperature value of the reactor fuel must produce an output value that can be properly compensated. To guarantee this, the use of thermocouples must be calibrated periodically. The goal is that measurement results can be guaranteed according to national and international standards (3).

The instrumented fuel element, also known as IFE (Instrumented Fuel Element) uses a type K (Ni-Cr / Ni) thermocouple with a temperature range of -200°C to +1200°C (4). This temperature measuring device is embedded in the fuel element and placed in the hottest position in the reactor core configuration at that time. Such extreme conditions can cause the measuring instrument to not comply with specifications (5). This is the underlying reason why calibration of instrument equipment such as thermocouples is very important to carry out so that these devices always produce accurate data in measurements(6).

Table 1. Calibration Period

No	Instrument / Sensor	Calibration Period
1.	Thermocouple	2 month
2.	Therm. controller	12 month
3.	Hygrometer	6 month
4.	Micrometer	3 month
5.	Vernier caliper	12 month
6.	Gauge block	24 month
7.	Profile proyektor	12 month

EXPERIMENTAL SECTION

A thermocouple is a temperature sensor which consists of a pair of wires made of different materials. Two different types of conductors are connected at one end while the other end is connected to a voltage meter via a copper wire. This combination of metals will later be used to measure the difference in temperature in an object to change the potential difference or electromotive force (EMF a.k.a GGL).

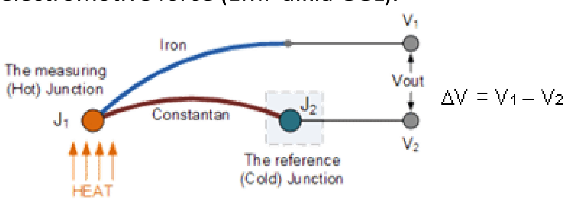

Figure 1. The working principle of a thermocouple.

The EMF generated by a thermocouple arises due to the temperature difference between the measuring point and the reference point contained in the conductor material. This conductor will experience a temperature gradient, and experience a change in voltage that is inversely proportional to the temperature difference of the object

Single Connection Thermocouples

In a single junction thermocouple, metal conductor A is connected to the positive terminal of the meter and metal conductor B is connected to the negative terminal. At the connection point there is an unknown temperature (Unknown/Tu), while the temperature on the measuring device is considered as ambient temperature (Ta).

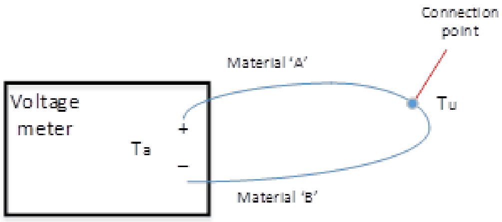

Figure 2. Single Junction thermocouple.

From the schematic image above, the following calculations can be obtained:

$VA = KA * (TU - TA)$ .... (1)

$VB = KB * (TU - TA)$ .... (2)

Where,

VA = voltage drop along wire A

KA = voltage drop per degree on wire A

VB = voltage drop along wire B

Overall, the measured voltage is VA - VB, namely:

$KA * (TU - TA) - KB * (TU - TA)$ .... (3)

or

$(TU - TA) * (KA - KB)$ .... (4)

Based on this theory, the measured voltage is a compensation for the difference in temperature at the connection point with the ambient (environment) temperature.

Double Connection Thermocouples

In a double junction thermocouple, the metal that is connected to the measuring instrument is a similar metal where the ends are connected by another type of metal. Connection point 1 (Tu1) is called Hot Junction or measuring point and connection point 2 (Tu2) is called Cold Junction or reference point.

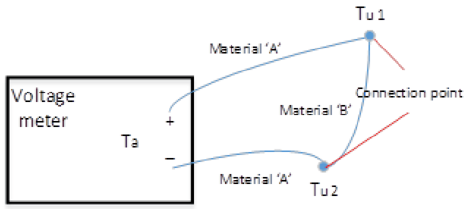

Figure 3. Pair Junction thermocouple.

The calculation in the image above is as follows:

$VA1 = KA * (TU1 - TA)$ .... (5)

$VA2 = KA * (TU2 - TA)$ .... (6)

$VB = KB * (TU1 - TU2)$ .... (7)

Overall, the measured voltage is VA - VB - VA2, namely:

$KA * (TU1 - TA) - KB * (TU1 - TU2) - KA * (TU2 - TA)$..........(8)

Or

$(KA - KB) * (TU1 - TU2)$ .... (9)

The measurement technique used based on this theory is to compare the temperature difference between the 2 junctions. When taking measurements at Hot Junction (Tu1), the reference point (Cold Junction/Tu2) must be kept at 0^{o} C.

Measurement Uncertainty

Measurement uncertainty is the process of tracing a number empirically and objectively related to the measurement results so that the number can provide a clear picture of the object or event. If the estimated value of the measurand is expressed by x, and the uncertainty of measurement for a certain level of confidence is expressed by U, then the value of the measurand, namely X, is believed to be in the range:

$x - U \leq X \leq x + U$ .... (10)

The measurement results must include an estimate showing how much error is likely to occur, within reasonable limits of possibility. This value indicates the quality of the measurement. The smaller the estimated value, the better the quality of the measurement (8).

Methods

The temperature measurement method which is very widely used requires the user to find out whether the tool has been properly calibrated and compensated. All types of measuring instruments (quantity, pressure, temperature, level) and measuring materials need to be calibrated (9). Calibration implementation must be in accordance with the flow chart as shown in the figure below.

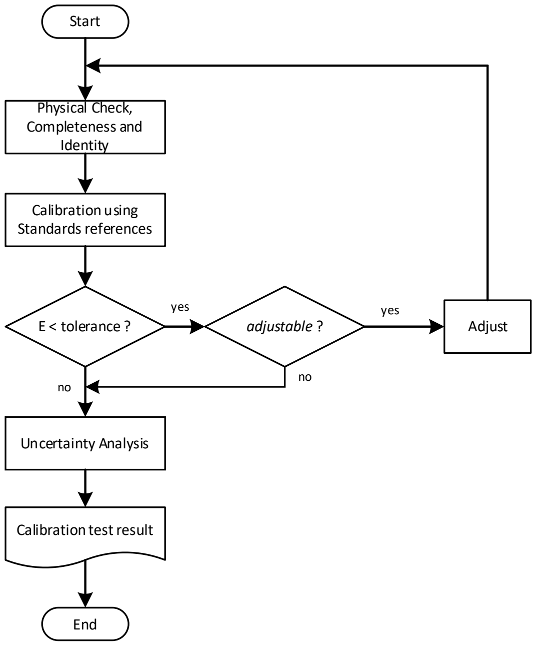

Figure 4. Calibration flow chart

Measurement Procedure

If the measurement is a single calibration, the procedure is to measure the melting point or freezing point of the thermocouple whether it is still in accordance with the standard reference. Meanwhile, if the measurement is a double calibration, the procedure is to measure using 2 standards at once and then compare the results (10). Mathematically this can be written as follows:

$$S_1, X_1, X_2 \ldots X_n, S_2, S_2, X_n \ldots X_2, X_1, S_1 \quad (11)$$

Where S_1 and S_2 are 2 reference standards and X_1, X_2 ... X_n are the thermocouples to be calibrated. This sequence of measurements can be repeated according to the required number of measurements by including the average value of the voltmeter resolution calibration. Likewise with the temperature value obtained from the average value of the sum of S_1 and S_2.

Error In Measurement

When performing a calibration, measurement uncertainty must also be taken into account. Below are some things that have the potential to contribute to the value of measurement uncertainty:

1. Contact is not perfect / less deep. Can cause heat conduction in the thermocouple wire.
2. Variation of temperature values at the end of the hot junction and the end of the cold junction.
3. Parasitic Thermovoltages. The voltage comes from an increase in temperature due to the use of devices such as selector switches.
4. Use of cable extensions
5. Physical changes due to mechanical stress
6. Chemical contamination
7. Changes in the composition and crystal structure of thermocouple materials.

RESULTS AND DISCUSSION

There are several approaches that can be done to calibrate thermocouple. The first way, using a standard calibrator instrument. And the second way to use self-calibrator.

Standard Calibrator Instrument

Preparations that must be done when calibrating using this method are as follows:

a. Provide standard type-K thermocouple and thermocouples to be calibrated (IFE)
b. Provide standard furnace as a heater.
c. Provide a standard calibrator along with the tools needed as a measurement reader instrument,
d. Provide compensation cables as a connecting thermocouple to the calibrator

After all the tools and materials are available, all the equipment according to the installation of the equipment, as shown in Figure 5.

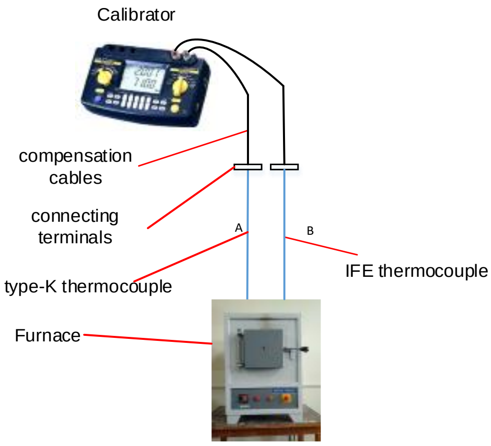

Figure 5. Standard method installation scheme.

The steps for carrying out the calibration using the calibrator are as follows:

a. Insert the standard K-type thermocouple and the K-type thermocouple to be calibrated into the furnace (heater)
b. Connect a standard K-type thermocouple and the K-type thermocouple to be calibrated to the instrument calibrator
c. Determine the measurement value of the calibrated tool at least 10 points.
d. Observe the standard calibrator and then record the value of the standard K-type thermocouple (A)
e. Observe the standard calibrator and then record the value of the calibrated K-type thermocouple (B)

Using the Comparison Method

Preparations that must be done when calibrating using this method are as follows

The preparations that must be made when calibrating using this method are as follows:

a. Provide a standard K-type thermocouple
b. Provide the K-type thermocouple to be calibrated (IFE)
c. Provide indicator controllers
d. Provide calibration master 0° C (ice point)
e. Provide master calibration 100° C (boiling water)
f. Provide Heater

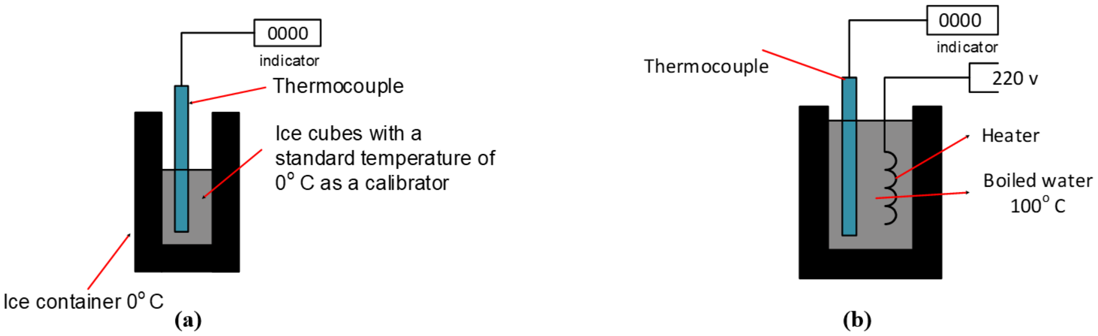

Figure 6. Comparison method installation scheme, a. 0o C, b.100o C

The steps for carrying out the calibration using the comparison method are as follows:

a. Insert a standard K-type thermocouple into the ice container
b. Observe the digital indicator and then record the value of the standard K-type thermocouple (A)
c. Put a standard K-type thermocouple into boiling water
d. Observe the digital indicator then note the value of the calibrated K-type thermocouple (B)
e. Perform the steps a to d for the K-type thermocouple to be calibrated (IFE)

Verification

After taking measurements using method 1 or 2 above, it is necessary to verify. The following are the verification steps performed:

a. Calculate the magnitude of the deviation, where deviation = A-B
b. Calculate the value of the measurement uncertainty if possible
c. Compare the obtained deviation with the allowable tolerance
d. If the deviation obtained is greater than the allowable tolerance, make adjustments if necessary and possible.

Records of Calibration Results

Records of data on the results of calibration tests are proof that calibration activities have been carried out. The points contained in the records must be clear and easy to trace (11). These points are as follows:

a. Records must be easy to verify data or calculation results

b. Meet the requirements contained in the testing quality standards
c. The temperature range performed in the calibration
d. Information regarding environmental conditions
e. Evaluation results of uncertainty measurement

Nama Alat :	Instrumen standar kalibrator :
Type/Range :	1. Nama alat
No. Identifikasi :	2. Tipe
Toleransi :	
Pembuat :	Lokasi Kalibrasi :
Lokasi :	Suhu Ruang :
Fasilitas :	No Inventaris :

No	A (°C) Standar	B (°C) Pengukuran	D = A - B Deviasi	± (°C) Toleransi	Ket
1.					
2.					
⋮					
9.					
10.					
Tanggal :			Hasil :		

Figure 7. Calibration Record Sheet.

Discussion

In carrying out thermocouple calibration, regardless of the type of method used, it is necessary to ensure the following 3 things:

1. Obtain the results of a comparison of the difference in values and the average error of the measuring instrument/sensor being tested.
2. Make sure the deviation value is less than or equal to the tolerance
3. Calculating the value of measurement uncertainty to get the level of confidence and coverage factor

CONCLUSION

The output of a thermocouple depends on the temperature difference between the measuring (or "hot") junction and the reference (or "cold") junction. Any uncertainty in the reference junction temperature causes an uncertainty in the calculated temperature of the measuring junction. While Cold Junction compensation typically measures the temperature of the reference junction to an accuracy of ± (0.5 to 0.1) °C, immersing the reference junction into ice point controls will changes the temperature accuracy to 0.00 °C ± 0.01 °C (more accurately) (2). Therefore, the calibration is required to process all the available measurements regardless of their precision. By knowing the function of the system, errors and uncertainties can be minimized statistically.

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