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CALIBRATION THERMOCOUPLE K-TYPE ON THE RANGE TEMPERATURE -10°C TO 30°C USING ASTM THERMOMETER AS REFERENCE

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Abstrak: *This research focuses on the calibration of four type K thermocouples in the temperature range -10°C to 30°C, using chamber water bath with high precision. The calibration process is carried out by comparing thermocouple readings with readings from ASTM standard thermometers, with data acquisition managed using National Instruments hardware and LabVIEW software. The results of research on the accuracy of type K thermocouples show a shift in linearity and uncertainty values/ uncertainty are within acceptable engineering tolerances. A linear correction equation for each thermocouple is derived to minimize measurement error, ensuring that the thermocouple provides reliable temperature readings for applications within the specified range. This research shows the importance of using high-precision calibration systems, such as ASTM thermometers, to improve thermocouple measurement accuracy, providing a comprehensive solution for precision temperature measurements.*

Keywords: Calibration, Thermocouple, LabView

INTRODUCTION

Thermocouples are one of the most commonly used temperature sensors in industry and research. Advantages of Thermocouples, such as measurement range *temperature* wide range, fast response time and high resistance to extreme environmental conditions, making it the preferred choice in many engineering applications. However, Thermocouple measurement accuracy is often affected by factors such as aging, material errors and environmental conditions, so a precise calibration process is required to ensure the resulting data can be trusted.

Thermocouple calibration aims to correct measurement errors by comparing the reading results against a reference standard that has high accuracy, such as an ASTM thermometer. A proper calibration method is essential to ensure that the measurement results *temperature* remains in accordance with international standards. The literature shows that *water bath chamber* often used as a calibration medium because of its stability *temperature* high power and uniform heat distribution.

Previous studies have highlighted the importance of using appropriate devices in thermocouple calibration. For example, a study by Smith et al. (2021) shows that stability *temperature* in *water bath chamber* can reach ±0.01 °C, making it an ideal tool for calibration *temperature* low to medium. On the other hand, research by Li and Wang (2020) highlights the importance of suitable standard thermometers, such as ASTM, which have very small measurement uncertainties.

However, although there have been many studies examining the effectiveness of individual elements of the calibration system, the combination of Thermocouples, *water bath chamber*, ASTM thermometers, and NI modules in one unified system are rarely discussed comprehensively. Therefore, this research aims to bridge this gap by integrating these elements into one efficient and accurate calibration system.

Type K thermocouples, which are one of the most commonly used types of thermocouples, are often used in industrial applications because of their range *temperature* wide operation, namely -200 °C to 1260 °C. However, the accuracy of type K thermocouples in *temperature* low to moderate is often a concern due to the effects of nonlinearity and material instability. Several studies, such as those conducted by Ahmad et al. (2020), shows that type K thermocouples can experience deviations of up to ±2 °C if they are not calibrated regularly.

Water bath chamber provides the temperature stability necessary to ensure an accurate calibration process. The study by Zhao et al. (2018) revealed that distribution *temperature* in *water bath chamber* has a significant influence on the calibration results. This research will use *water bath chamber* with control *temperature* high precision to ensure even heat distribution.

ASTM thermometers as a reference standard offer very high accuracy in measurements *temperature*. Research by Nelson et al. (2022) shows that ASTM thermometers have a smaller level of uncertainty compared to sensors *temperature* others, making it a reliable reference tool in the calibration process. The use of ASTM thermometers in this research aims to minimize systematic errors during the calibration process.

National Instruments provides customizable data acquisition modules for a variety of sensor types, including Thermocouples. This module enables real-time data collection with a high degree of precision. The study by Kumar et al. (2019) highlighted that the use of NI modules can increase calibration efficiency by reducing the time required for manual data processing.

LabVIEW, as a data acquisition and control software, offers a user interface that enables monitoring *temperature* directly and automatic data processing. Research by Smith and Brown (2021) shows that using LabVIEW can improve data consistency and reliability in experiments involving multiple sensors *temperature*.

This research aims to produce a thermocouple calibration system that is not only accurate but also efficient and easy to implement. With a comprehensive approach, this research will provide practical guidance for technicians and researchers in ensuring that the type K thermocouples they use work in accordance with international standards.

RESEARCH METHODS

This research calibrates five units of type K thermocouples over a range *temperature* -10°C to 30°C. The methodology applied in this research consists of several stages, as follows:

Preparation of Tools and Materials

a. Thermocouple: four K type thermocouple units.
b. aata acquisition device: Uses a National Instruments device integrated with LabVIEW software for real-time data recording.
c. Temperature controller: A water bath chamber is used for engineering *temperature* stable environment according to the measurement range.
d. Thermometer Calibrator: An ASTM thermometer as the primary calibration tool to ensure accurate temperature measurements.
e. System Settings

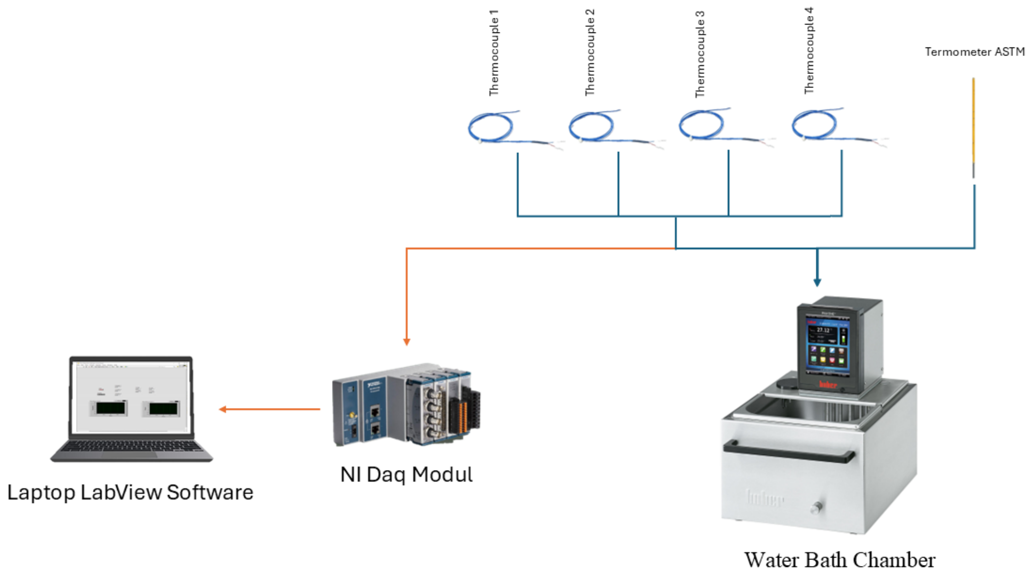

Figure 1. Schematic of the thermocouple calibration process

Calibration Preparation Process

a. The thermocouple is connected to the data acquisition device via a National Instruments compatible input module.
b. LabVIEW software is used to design the user interface and process automation of temperature data recording.
c. *Water bath chamber* prepared and tested to ensure stability *temperature* during the calibration process.

Calibration Process

a. The temperature range of -10°C to 30°C is achieved in stages using *water bath chamber*. Each temperature level is maintained for a certain time to ensure stability before measurements are taken.

b. At each temperature level, the readings from the thermocouple and ASTM thermometer were recorded simultaneously using LabVIEW.
c. Each thermocouple is tested individually to avoid data interference.
d. The temperature data from the thermocouple is compared with the temperature indicated by the ASTM thermometer.
e. The calibration result data is made into a linear graphic curve and the statistical parameters are average error and standard deviation
f. The measurement difference is analyzed to determine the uncertainty error value/ *uncertainty* calibration and generates a calibration curve for each thermocouple.
g. The calibration results are evaluated to determine the accuracy and precision of each thermocouple.

RESULT AND DISCUSSION

Thermocouple Calibration Data

Measurements were carried out on five type K thermocouple units in the temperature range -10°C to 30°C. The temperature reading data from the thermocouple is compared with the reading from the ASTM thermometer as a reference. The following is a table of average values for thermocouple data acquisition with temperature conditioning at *water bath chamber.*

Table 1. Calibration acquisition data for each thermocouple

Temperature Thermal Bath Chamber	**T Calibrator**	**Themocouple 1**	**Themocouple 2**	**Themocouple 3**	**Themocouple 4**
-10	-9,139236223	-8,66875131	-8,8368863	-8,75135	-8,816567
-5	-4,159730634	-3,77382526	-3,98578179	-3,87371	-3,958395
0	0,684930395	0,995269546	0,762180416	0,855289	0,7391344
5	5,39821084	5,624713773	5,426804231	5,45718	5,3529669
10	10,12969842	10,26486824	10,16331633	10,14542	10,032592
15	15,0368586	15,07478861	14,9891439	14,97603	14,928765
20	19,99962237	19,92073677	19,83849201	19,82309	19,779316
25	24,92905806	24,7513269	24,68235139	24,67892	24,635166
30	29,88647174	29,6055663	29,54058524	29,5421	29,489802
35	34,87406941	34,49590721	34,43811251	34,45011	34,389871
40	39,83859105	39,32832108	39,26423215	39,26934	39,187286

From the average data of thermocouple acquisition values, there are deviations in measurement accuracy. So measurement correction is needed to be more in line with the actual standard value.

Type K thermocouple data before calibration is used as a basis for obtaining a linear regression equation. The method used is to make the X axis value the value of the Type K thermocouple to be calibrated and the Y axis is the calibrator, namely the ASTM Thermometer. The following is a linear regression graph for the calibration

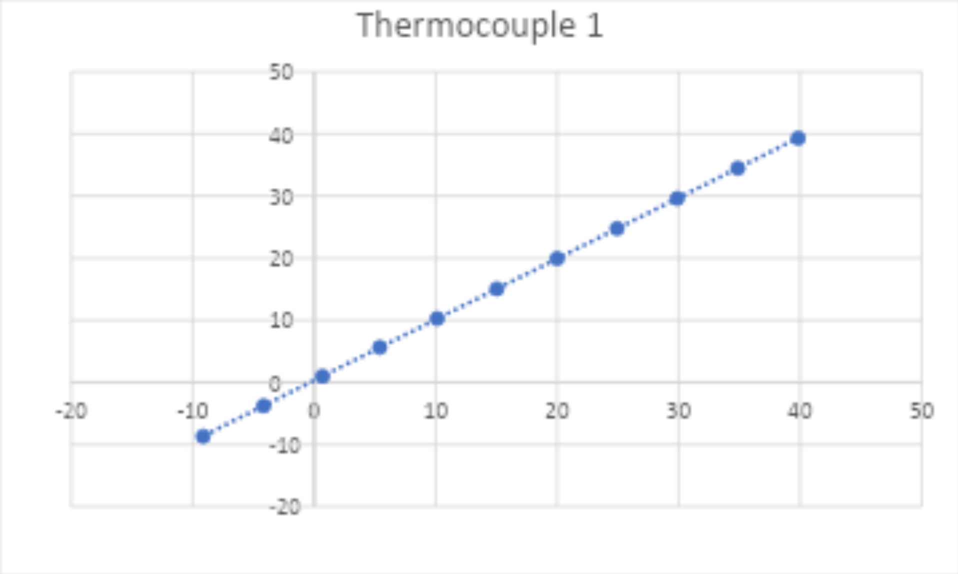

Figure 2. Linear regression graph of thermocouple calibration

From the linear regression graph line, a linear equation can be obtained as a correction value to reduce the percent error value in the Type K thermocouple. The following is data on the uncertainty error value and the correction equation for each thermocouple

Table 2. Average uncertainty table and Eq Correction of each thermocouple

	Uncertainty	Correction Equation
Themocouple 1	0,10570779	y = 0,98x + 0,3175
Themocouple 2	0,088104805	y = 0.9835x + 0.1419
Themocouple 3	0,111675691	y = 0,9814x + 0,2003
Themocouple 4	0,084284131	y = 0.9822x + 0.1153

The average uncertainty is small compared to the tolerances usually accepted for type K thermocouples, which are in the range of ±1.5°C.

CONCLUSION

In this research, four type K thermocouples were calibrated using a water bath-based temperature control environment with a measurement range of -10°C to 30°C. Calibration was carried out by comparing thermocouple readings against ASTM standard reference thermometers, as well as data acquisition using National Instruments hardware and LabVIEW software.

The main results of the research include the Uncertainty value (*Uncertainty*) thermocouple measurements are determined using statistical approaches and uncertainty propagation, including components such as measuring instrument uncertainty, environmental stability, and repeatability variations. The uncertainty values are within the acceptable range for precision engineering applications.

With low uncertainty values, these calibration results ensure that the thermocouple used provides measurements that are reliable enough for applications in the temperature range of -10°C to 30°C. Correction Equation: Obtain a linear correction equation for each thermocouple, this equation allows correction of measurement values to make them more accurate.

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