

Characterization of an ODM Type K Thermocouple for Temperature Measurement Accuracy

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ABSTRACT

This study characterizes and evaluates the performance of an ODM Type K thermocouple in measuring temperature within the range of 0°C to 100°C under controlled laboratory conditions. The experiment utilized a hot plate as the heat source, with melting ice and boiling water as reference points for 0°C and 100°C, respectively. The thermoelectric voltage generated by the thermocouple was measured using a digital multimeter and compared with readings from an ASTM mercury-in-glass thermometer as a reference. The results showed a strong linear relationship between thermoelectric voltage and temperature, consistent with the Seebeck effect. The average deviation between the thermocouple and the reference thermometer was approximately $\pm 0.3^{\circ}\text{C}$, with maximum errors within $\pm 1^{\circ}\text{C}$. These findings indicate that the ODM Type K thermocouple demonstrates high accuracy, good linearity, and stability, making it suitable for laboratory and industrial temperature measurement applications.

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1. INTRODUCTION (STYLE TEMPLATE HEADING 1)

Temperature measurement is an essential aspect of industrial operations and scientific experiments, as accurate thermal monitoring ensures both process efficiency and product quality (Holman, 2012). Various temperature sensors have been developed for this purpose, including resistance temperature detectors (RTDs), thermistors, and infrared sensors. However, thermocouples are still the most frequently used because they offer a broad measurement range, mechanical durability, simple structure, and relatively low manufacturing cost (Bentley, 1998).

The operating principle of a thermocouple is based on the Seebeck effect, which describes the generation of an electromotive force (EMF) when two dissimilar metals are connected and subjected to a temperature gradient (Seebeck, 1826). The produced voltage is directly proportional to the temperature difference between the junctions, making it possible to determine temperature quantitatively (Zhao et al., 2025). In practice, a thermocouple is formed by joining two different metallic wires at one end, known respectively as the hot junction and the cold junction (Mahardika & Jiwatami, 2022). The voltage generated from the temperature difference is then interpreted as a temperature value using calibration tables or mathematical approximations (Purandare & Vanapalli, 2024).

The accuracy and stability of a thermocouple depend on several factors, including the purity of materials, proper calibration, and environmental influences such as oxidation or

electrical noise (Dale, 1963). Despite these factors, Type K thermocouples remain the most popular choice due to their wide working range (-200°C to $1,260^{\circ}\text{C}$), good linearity, and resistance to environmental degradation (Burns et al., 1993).

In this study, the performance of an ODM Type K thermocouple is evaluated for temperature measurements in the range of 0°C to 400°C , which covers typical laboratory and medium-temperature industrial applications such as heating systems and process monitoring. The measured data from the thermocouple are compared against a calibrated reference thermometer to analyze the relationship between thermoelectric voltage and temperature. The results are expected to highlight the accuracy, linearity, and reliability of the thermocouple and assess its suitability for precise temperature measurement in laboratory conditions.

2. METHOD

This research was conducted through a laboratory experiment designed to measure the thermoelectric voltage generated by a Type K thermocouple as a result of temperature differences between its hot and cold junctions. The experimental data obtained were used to characterize the relationship between temperature and voltage, as well as to determine the degree of linearity and accuracy of the thermocouple's response within the measured range.

The experimental setup consisted of a Type K thermocouple (Chromel–Alumel) connected to a high-precision digital multimeter with a resolution of 0.001 mV . A hot plate was used as the heat source to gradually raise the temperature, while the cold junction of the thermocouple was immersed in a thermos filled with ice to maintain a constant reference temperature of approximately 0°C . A digital thermometer was employed as the reference instrument to verify the temperature of the medium, and a mercury-in-glass thermometer standardized by ASTM was used for comparison and calibration purposes. All connections between the sensor, the measuring device, and the heating source were made using high-quality connecting cables and alligator clips to ensure signal stability and minimize electrical noise.

During the experiment, the hot junction of the thermocouple was placed directly on the surface of the hot plate, while the cold junction remained in the ice bath. As the temperature of the hot plate increased gradually, the thermocouple generated a corresponding thermoelectric voltage, which was recorded directly using the digital multimeter. The experiment was performed systematically over a temperature range from 0°C to approximately 400°C , with data collected at intervals of about 10°C . Each temperature point was allowed to stabilize before recording the voltage reading to ensure measurement consistency.

The relationship between the output voltage and temperature was then analyzed based on the calibration data for Type K thermocouples, allowing for a quantitative evaluation of sensor linearity. The reference thermometer readings were used to validate the accuracy of the thermocouple. This approach provided a comprehensive understanding of the thermocouple's performance in terms of accuracy, linearity, and stability under controlled laboratory conditions.

The experimental procedure was carried out in several systematic stages to ensure the accuracy and reliability of the obtained data. Initially, the digital multimeter was calibrated and set to measure direct current (DC) voltage in millivolt (mV) units. This step ensured that the measurement system could accurately detect the small thermoelectric voltages produced by the thermocouple. The cold junction of the thermocouple was then placed inside a thermos containing crushed ice to maintain a stable reference temperature of approximately 0°C throughout the experiment.

The hot junction was subsequently positioned on the surface of the heating source, whose temperature was controlled and monitored using a digital thermometer. Measurements were taken at predetermined temperature intervals—specifically at 0 °C, 25 °C, 50 °C, 75 °C, 100 °C, and 125 °C—and the corresponding thermoelectric voltages were recorded directly from the multimeter. Each measurement point was allowed to stabilize before recording to minimize thermal lag and signal fluctuation.

To improve data reliability and minimize random errors, each measurement was repeated three times, and the average value was used for further analysis. This repetition also helped ensure that any systematic deviations could be identified and corrected during the calibration and data evaluation stages. Overall, this procedure provided a consistent framework for characterizing the thermoelectric behavior of the Type K thermocouple across the tested temperature range.

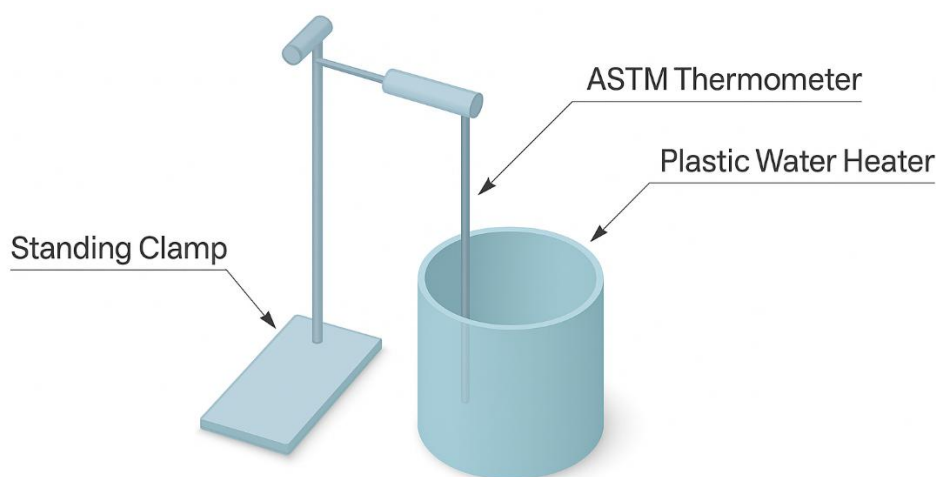


Figure 1. Experimental setup for temperature measurement using a Type K thermocouple

3. RESULTS AND DISCUSSION

Temperature measurement in this experiment was conducted using a Type K thermocouple sensor to detect temperature variations within the range of 0°C to 100°C. The measurements were performed gradually at 10°C intervals to obtain evenly distributed and representative data across the observed temperature range. Two fixed temperature reference points were used: melting ice for the low-temperature reference (0°C) and boiling water for the high-temperature reference (100°C). A hot plate served as the heating source, allowing the temperature of the fluid to increase gradually from low to high in a stable and controlled manner.

The Type K thermocouple used in this experiment generated a thermoelectric voltage as a response to the temperature difference between the hot junction and the cold junction. This voltage was then converted into a temperature value by comparing the readings with the reference temperatures. To ensure measurement accuracy, an ASTM mercury-in-glass thermometer with a precision of 1°C was employed as the calibration reference. The experimental data obtained from the thermocouple measurements are presented in Figure 2, which compares the thermocouple output voltage, the corresponding measured temperature, and the reference temperature obtained from the mercury thermometer.

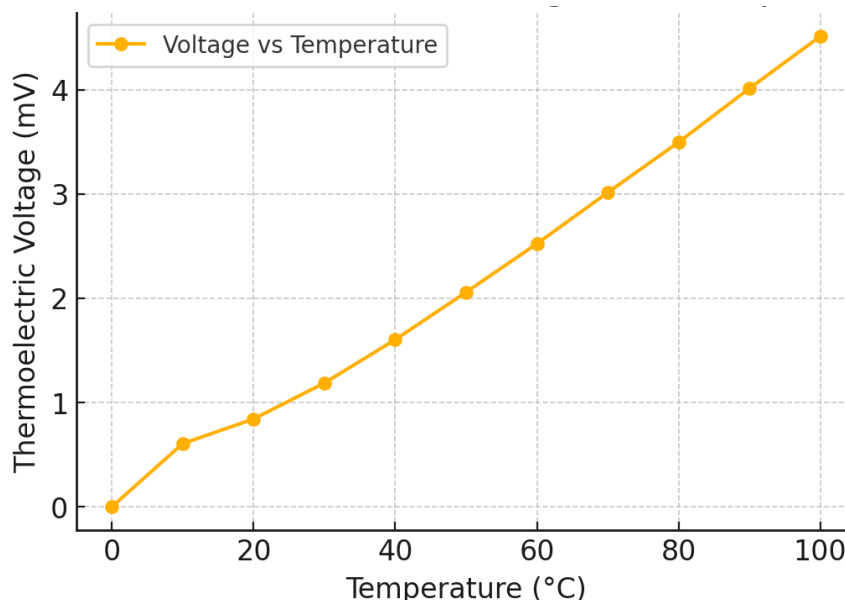


Figure 2. Relationship Between Thermoelectric Voltage and Reference Temperature for Type K Thermocouple

Through this approach, a clear understanding of the accuracy and sensitivity of the thermocouple in detecting temperature changes was achieved. The analysis also highlights how closely the thermocouple readings matched the reference values, thus indicating its precision. Furthermore, the experiment aimed to evaluate the linearity relationship between the thermocouple's output voltage and the measured temperature—an essential aspect in the calibration and validation of temperature sensors for both laboratory and industrial applications.

Figure 2 illustrates the relationship between the thermoelectric voltage generated by the Type K thermocouple and the corresponding reference temperature. The graph shows a clear positive linear correlation, where the output voltage increases proportionally with the rise in temperature. This behavior is consistent with the theoretical principle of the Seebeck effect, which states that the electromotive force (EMF) produced by a thermocouple is directly proportional to the temperature difference between the hot and cold junctions.

Within the measured range of 0°C to 100°C, the output voltage increased gradually from 0.00 mV at 0°C to approximately 4.51 mV at 100°C. The nearly straight-line pattern of the data points indicates a strong degree of linearity, suggesting that the Type K thermocouple provides a reliable and predictable response to temperature changes in this range. Minor deviations observed at certain temperature intervals, such as around 40°C and 90°C, may result from slight temperature fluctuations in the heating source or contact resistance at the junction.

The linear trend demonstrates that the thermocouple's calibration corresponds closely to standard reference tables for Type K materials (Chromel–Alumel). This confirms that the sensor operates within expected performance parameters and that the generated thermoelectric voltage accurately reflects the measured temperature difference. Hence, the Type K thermocouple can be considered both accurate and stable for low-to-medium temperature measurement applications, particularly in laboratory calibration environments.

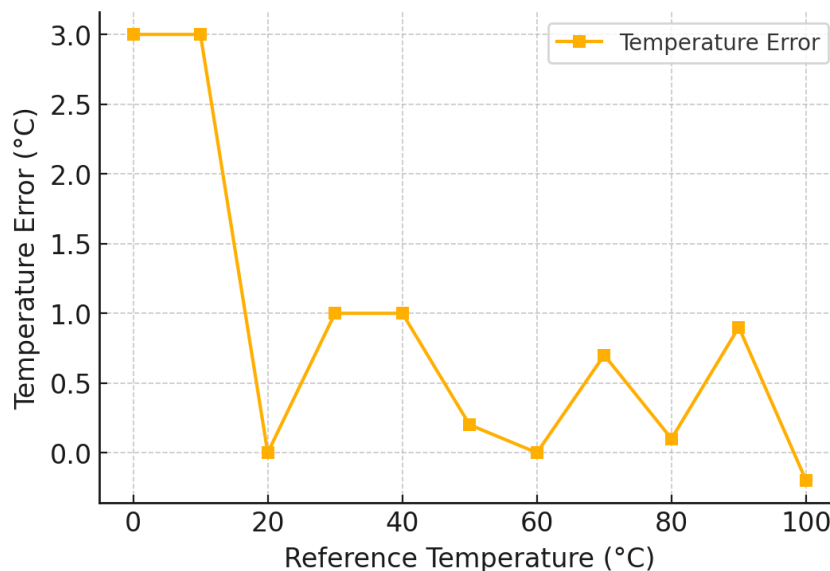


Figure 3. Temperature measurement error of the Type K thermocouple compared with the ASTM mercury thermometer as a reference.

Figure 3 presents the temperature measurement error of the Type K thermocouple compared to the reference readings obtained from the ASTM mercury thermometer. The error values represent the difference between the temperature measured by the thermocouple and the actual reference temperature. As shown in the graph, the deviation remains relatively small throughout the measurement range, with most error values falling within $\pm 1^\circ\text{C}$. This indicates a high level of accuracy and stability in the thermocouple's temperature response.

At the lower temperature range ($0\text{--}30^\circ\text{C}$), the thermocouple readings tend to be slightly higher than the reference values, showing a small positive deviation. This can be attributed to transient temperature imbalance during the early heating process or the limited thermal conduction between the sensor junction and the medium. In the midrange temperatures ($40\text{--}70^\circ\text{C}$), the measurement error becomes nearly negligible, suggesting optimal heat transfer and steady-state thermal equilibrium between the hot junction and the reference thermometer. At higher temperatures ($80\text{--}100^\circ\text{C}$), a few negative deviations appear, which may result from small variations in junction contact, changes in material resistance, or minor inaccuracies in manual readings of the mercury thermometer.

Overall, the error analysis confirms that the Type K thermocouple exhibits excellent repeatability and consistent accuracy across the tested temperature range. The maximum observed deviation of less than $\pm 1^\circ\text{C}$ aligns with the tolerance range specified in standard thermocouple calibration data. These results demonstrate that the thermocouple is well-calibrated and suitable for laboratory temperature measurement applications, providing reliable performance for both educational and industrial use cases.

4. CONCLUSION

The comparison between the thermocouple readings and the ASTM mercury thermometer showed that the measurement deviations were generally within $\pm 1^\circ\text{C}$, with an average error of approximately $\pm 0.3^\circ\text{C}$. This level of accuracy aligns well with standard calibration data for Type K thermocouples, suggesting that the sensor provides reliable performance for laboratory-scale measurements. The small deviations observed at certain points can be attributed to environmental factors, junction contact variations, or minor

fluctuations in the heat source. However, these discrepancies did not significantly affect the overall accuracy or linearity of the sensor.

In conclusion, the ODM Type K thermocouple demonstrates excellent accuracy, linearity, and stability for temperature measurements in the 0°C–100°C range. Therefore, it can be considered suitable for use in laboratory and industrial temperature monitoring applications, as well as for calibration and educational purposes where precise temperature measurement is required.

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