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Calibration of Temperature Measuring Instrument Using Sensor Thermocouple Type-K Based on PLC ARN500

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Abstract. Technological advances are very fast, not spared in the field of measuring electrical quantities which are now growing. The development of this measuring tool is very useful for everyday life as well as in large industrial environments. In this final project the author calibrates measuring instruments with sensors that use a type-k thermocouple based on PLC using the calibration method using linear regression. at the testing stage, 5 times the testing phase was carried out and obtained for a correlation coefficient value R^2 = 0.9985 and an uncertainty value of 0.146 ºC and the tool designed for this is a fairly fast tool in the measurement stage it only takes ± 1 second for drastic temperature changes so you can say this gauge is not affected by the previous temperature.

Keywords: Calibration, Linear Regression, PLC, Type-K Thermocouple

1.0 Introduction

The topic of measuring electrical quantities is currently seeing tremendous technological improvement. The creation of this measurement device is highly advantageous for both daily life and the industrial sector, particularly in large-scale industries. Measurement requires the use of an instrument to ascertain a specific quantity or variable. [1, 2].

Precision and accuracy are essential for measurement. Accuracy refers to the degree of closeness between a measured value and the true value of a variable. Precision refers to the degree of consistency in obtaining similar measuring outcomes. Any measuring equipment can be deemed reliable provided it has undergone a tool calibration, which is a test specifically designed to assess its accuracy [3, 4].

Calibration is a set of actions aimed at establishing the accurate value of measuring devices and materials by comparing them with standardized measuring instruments, which can be either national or worldwide standards [5]. Calibration is the process of verifying the accuracy of a measuring device by comparing the values it indicates with the real values of the measured quantity [6].

Hence, it is imperative to develop a tool with a high level of precision in measuring accuracy [7]. A Calibrator is a tool that serves as a benchmark for other measuring devices, ensuring standardization. The Temperature Calibrator utilizes the

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GM1312 temperature sensor as a benchmark for precise measurement and standardization. The calibrated analog sensor measuring devices used in this case are of the thermocouple type K, equipped with Arn500 PLC hardware. The GM1312 device is capable of measuring temperature within a range of -200˚C to +1372˚C [8].

An ideal measuring device must meet two criteria: firstly, it should be unaffected by past temperature values, and secondly, it should produce a prompt temperature reading. Assuming that the temperature measuring device was earlier employed to gauge elevated temperatures, it was then utilized to assess lower temperatures without delay. Subsequently, the temperature measuring device must promptly deliver a precise measurement of low temperatures without compromising the precision of the collected data [9].

Accurate and consistent measurement results are crucial in different applications, including scientific research, industrial production, and quality testing. Therefore, high calibration precision is required to ensure that instruments or equipment may be used with trust. To attain a high level of calibration precision, it is necessary to have dependable calibration standards, accurate measuring methodologies, a consistent environment with controlled circumstances, and have calibration conducted by well-trained and experienced staff.

The precision of the analytical measurement method can be assessed by determining its linearity, which is shown by a correlation coefficient value exceeding 0.995 [10]. Therefore, the calibration that we do can be considered viable as it has surpassed the minimum correlation coefficient threshold.

2.0 Materials and Method

The materials and equipment used are Thermocouple type-K, ARN500 PLC, amplifier, RTT RS485, Arduino NANO, i2c LCD, supporting device, outseal, modbus pool (master), and arduino.

This test is both measuring instruments measuring the boiling point temperature of water with a capacity of 1 liter and then the results of the measurements will be analyzed, the calibration test method uses linear regression, for the following test stages:

a. Looking for accuracy value 1
b. Finding the correlation value
c. Find the accuracy and precision value of stage 2
d. Measurement speed testing

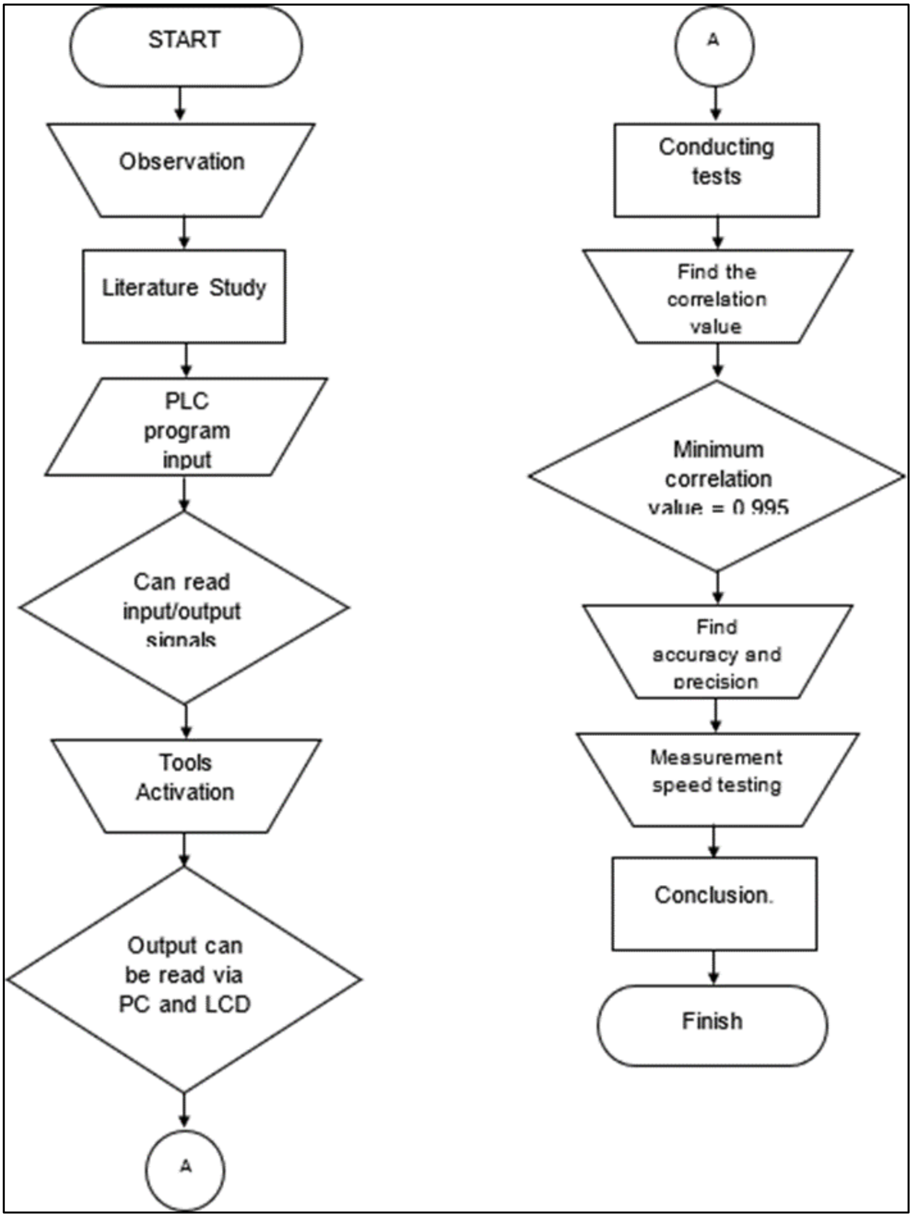

Fig. 1. Flowchart

3.0 Results and Discussion

In this study, the test protocol and data analysis of the test results will be covered. To conduct this test, the components to be tested are first assembled using an

Arduino PLC for data gathering [11]. A few of the major parts that will be tested are shown in figure 2, including the PLC-Arduino, LCD, sensor, amplifier, and cable circuit.

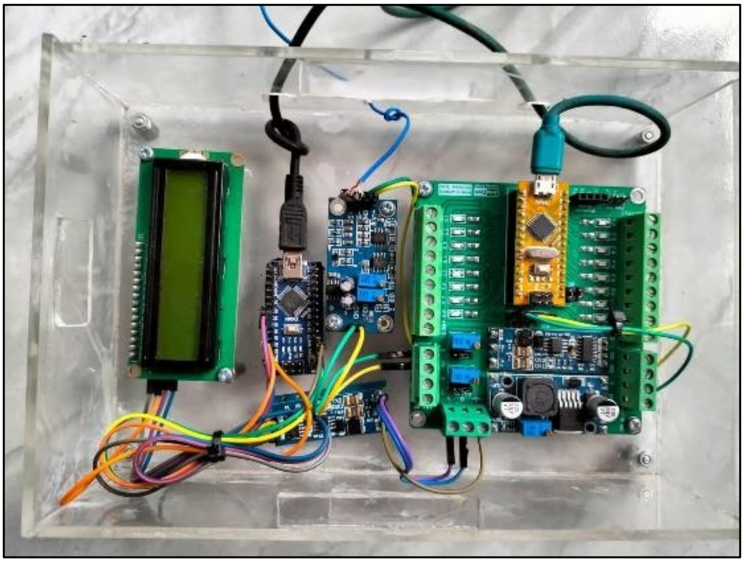

Fig. 2. Tool testing experiment.

3.1 Input Program PLC ARN 500

To input a PLC program, a supporting device with the Outseal application is used to read sensor data from thermocouples [12]. The PLC reads the voltage values from the thermocouple output, which can range up to a maximum of 5V.

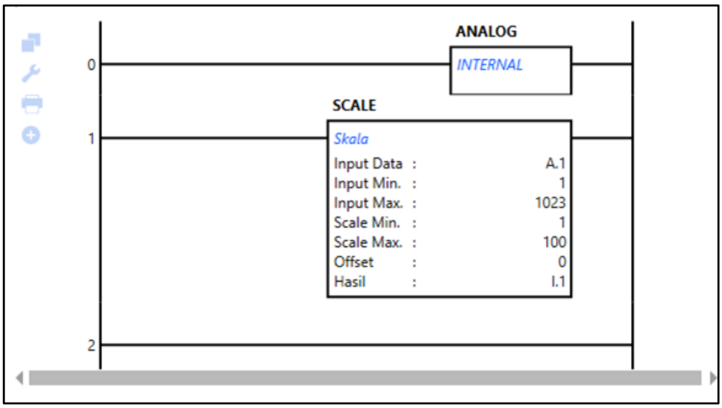

Fig.3. Input program.

3.2 Input Program Arduino Nano

This Arduino nano functions as a medium for reading signals sent by Ttl Rs458 from the PLC which later the reading results will be displayed on the i2C LCD, because the PLC cannot be directly output on the LCD, Ttl Rs458 is needed as a medium between the PLC and Arduino.

There are 2 programs used, the first uses PLX-DAQ as the initial media for plotting test data, calibration processes and finding uncertainty values and the second program to display data output to the LCD. PLX-DAQ or Parallax Data Acquisitions is an add-on for Microsoft Excel that functions to perform data acquisition from parallax. PLX-DAQ can display the data on the arduino device into excel. Any microcontroller connected to the sensor and PC serial port can send data directly to Excel [13][14]. PLX-DAQ can acquire up to 26 channels of data from each Parallax micro controller [15].

3.3 Tool Activation

The wiring used in tool activation is as follows:

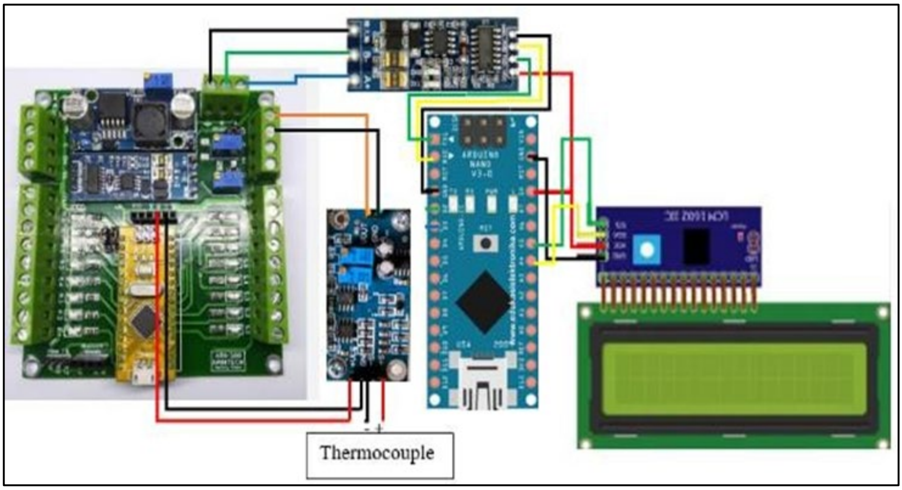

Fig. 4. Wiring diagram.

3.4 Testing Process

The test that will be carried out is to compare and analyze the results of the value of the temperature measuring instrument using the type - k thermocouple sensor based on the Arn 500 PLC with the GM 1312 calibrator tool and for the media that will be tested is to measure the boiling point of water with a volume of 1L.

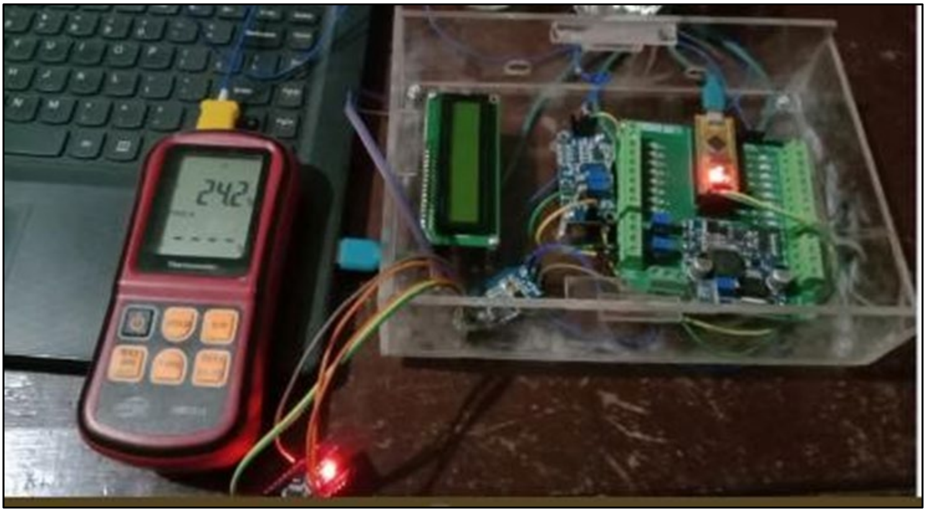

Fig. 5. Testing schematic

3.4.1 Find accuracy value of 1st stage. The test results obtained for the measurement accuracy reached a value of 0.49 at normal water temperature and 22.4 at boiling water temperature. at boiling water temperature. In the test to find the accuracy value of stage 1, the initial output value of the PLC is equaled to the initial value of the calibrator ± 30ºC at room temperature.

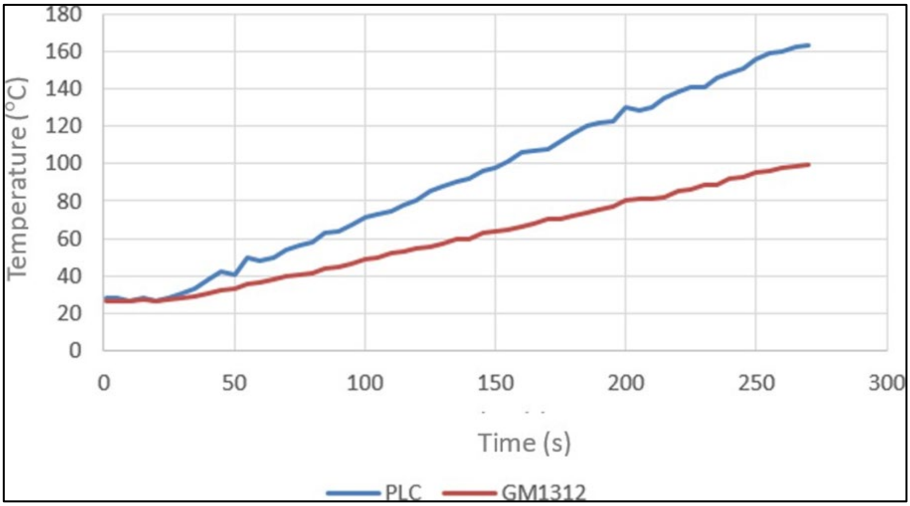

Fig. 6. Temperature vs time diagram of 1st stage.

3.4.2 Find the correlation value. The results of this test obtained the slope value Y = 0.5371, the intercept value = 10.976 and the correlation coefficient R² = 0.9985.

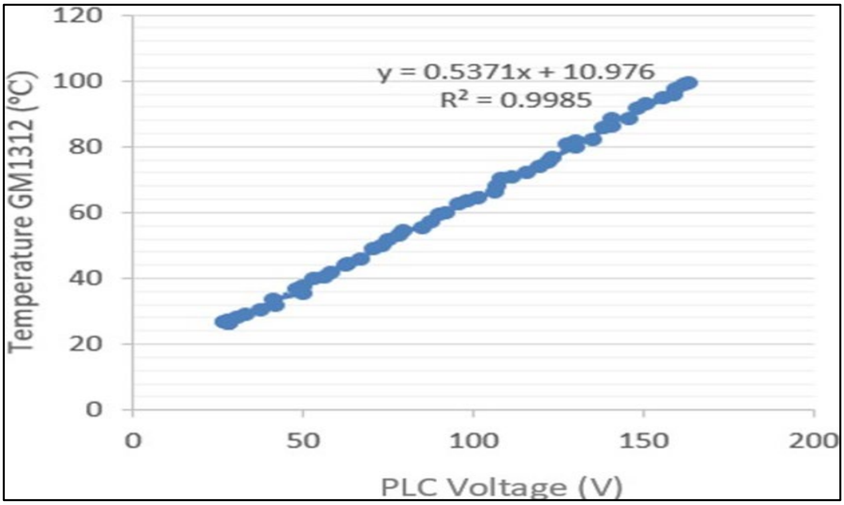

Fig. 7. Temperature vs voltage PLC diagram.

3.4.3 Find the accuracy value of 2nd stage. The measurement results in the test with the formulation included in the uncertainty value of the test measuring the boiling point of water with a capacity of 1 liter using a tool designed with a calibrator tool obtained the lowest accuracy value of 0.081ºC and the highest reached 1.22ºC.

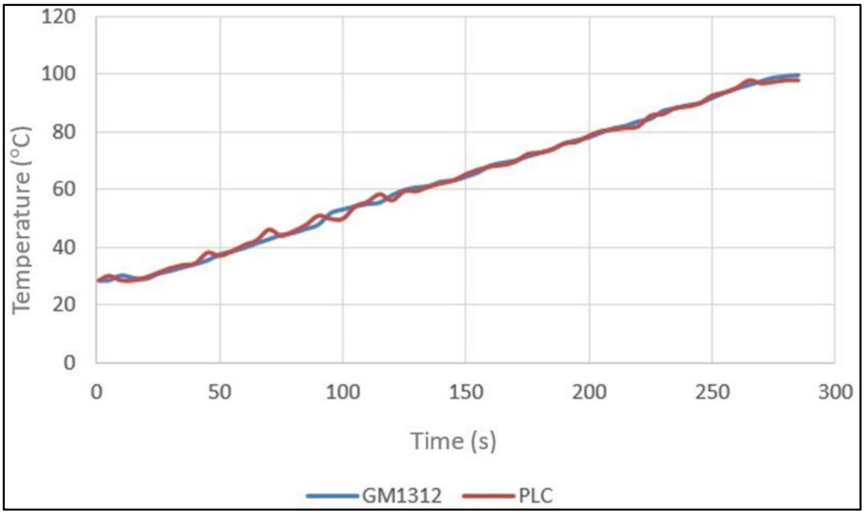

Fig. 8. Temperature vs time diagram 2nd stage.

3.4.4 Find the support accuracy value. The measurement results in this test obtained the accuracy value of the test measuring the boiling point of water with a capacity of 1 liter using a tool designed with a calibrator tool obtained the lowest uncertainty value of 0.146ºC and the highest uncertainty value reached 0.95ºC this value is taken from 3 times the measurement experiment.

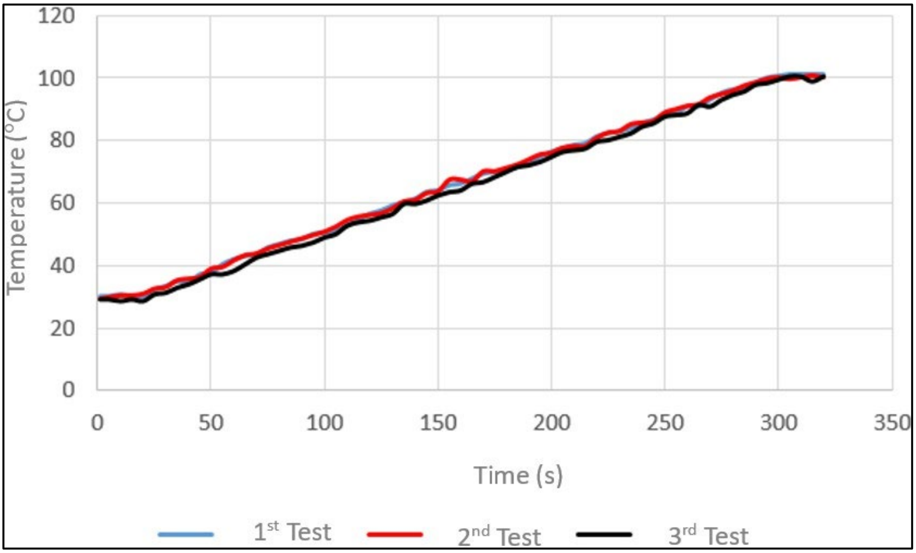

Fig. 9. Temperature vs time diagram of support accuracy.

3.4.5 Measurement speed testing. The results of testing the measurement speed can be concluded that the designed tool only requires ± 1 second per temperature transfer that has a long range, while for the calibrator tool requires ± 3 seconds per temperature measurement with a different temperature range so it can be concluded that the designed tool has a fairly fast measurement and is not affected by the previous temperature.

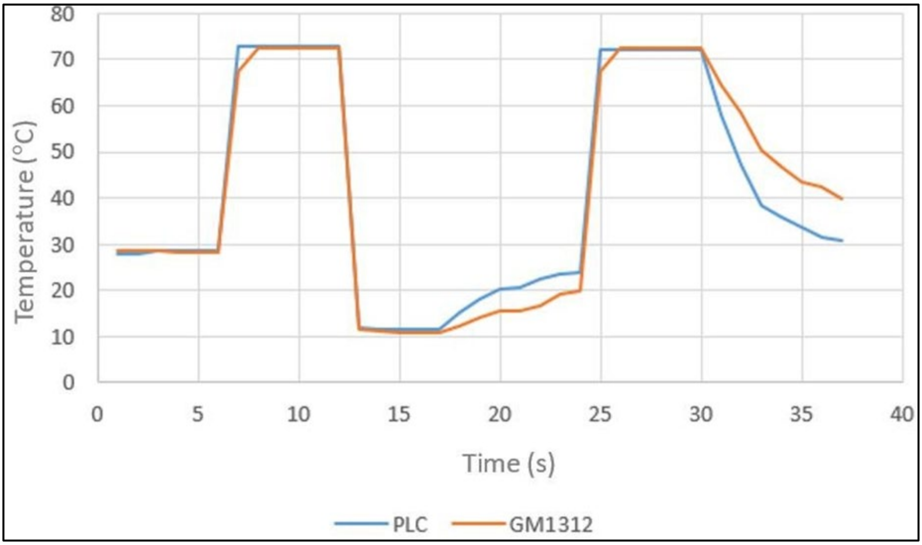

Fig. 10. Temperature vs time diagram of speed testing.

4.0 Conclusion

The results of the calibration of the Arn500 PLC-based thermocouple measuring instrument with the GM1312 calibrator tool obtained a correlation value of 0.998 and an accuracy value of 0.081ºC - 1.22ºC and an accuracy value of 0.146 □C - 0.95 □C.

The designed tool has a measurement speed of 1 second per temperature transfer, so this measuring instrument is not affected by previous temperature measurements.

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Conflict of Interest. The authors have no competing interests to declare that are relevant to the content of this article.

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