Temperature Calibrator Using Thermocouple Based on Microcontroller

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Abstract

Calibration is very important to know the temperature uniformity inside the tool. One of them is at the temperature sterilizer, a dry heating sterilizer which is sterilizing the device using a high heat oven. The purpose of this study is to develop a temperature Calibrator tool as a refinement of previously made tools by measuring temperatures more than one point in order to achieve a calibration process that complies with the standard. The working method of a temperature calibration device is that the sensor will detect the temperature which then enters the IC ATMEGA 328 that has been given the program and processed in such a way that the output will be displayed on the LCD 4x20 character in the form of temperature measurement of the device. Based on the results of comparative data between the module and the comparison tool "8 Channel Thermocouple Temperature Recorder" from the BPFK Surabaya, it has the largest difference of 40C and the percentage error (1,6%) and the smallest difference of 10C and the percentage error (0,16%).

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I. INTRODUCTION

Dry heating sterilization is sterilizing the appliance using a high-heat oven, for example sharp metal tools, or tools from glass that are heat resistant. Dry heating sterilizers can also be used to sterilize endodontic instruments and endodontic dressings. Sterilization of the oven by flowing dry air is less efficient as a heat conductor than hot steam at the same temperature, so a higher temperature is needed than the use of autoclaves for sterilization. The recommended temperature is to maintain at a temperature of 1600C for 2 hours. Exposure for 1 hour to 1700C is also effective. [1]. Meanwhile, according to Dickson Kho, 2015, Thermocouple (Thermocouple) is a type of temperature sensor that is used to detect or measure temperature through two different types of metal conductors and are combined at the ends resulting in a "Thermo-electric" effect[2]. This Thermo-electric effect on Thermocouples was discovered by an Estonian physicist named Thomas Johann Seebeck in 1821, where a metal conductor given a gradient difference in heat would produce an electric voltage. Some of the advantages of Thermocouples that make it popular are the fast response to changes in temperature and also the wide operating temperature range, which ranges between -200C to 2000C. In addition to fast response and a wide temperature range, Thermocouples are also resistant to shock / vibration and are easy to use. Furthermore, according to the calibration guidelines referring to the AS 2853 1986 document: Enclosure-Temperature-controlled-performance testing and grading Calibration is carried out to determine the uniformity of temperature in the room of the device to be calibrated and as a reference to determine the appropriateness of the tool for certain use purposes[3].

In connection with the above explanation, currently on the campus of the Surabaya Department of Health's Electromedical Engineering Department for the learning process calibration activities use a temperature calibrator with thermocouple and thermohygrometer, but the temperature detection results are still less linear. The temperature calibrator with thermocouple and thermohygrometer was once made by Mochammad Sofyan in 2016 which was equipped with a conversion of temperature units on temperature gauges, but the absence of data storage and sensors used was only one point.

Then in 2017 the tool was developed by Aviliana Kusuma Bintari, which has been equipped with data storage, but the sensors used are still just one point, while temperature measurements are carried out at locations of certain measuring points to determine the uniformity of temperature inside the device. Refer to AS 2853 1986 document: Enclosure-Temperature-controlled-performance testing and grading, with some simplifications, and other relevant documents [3].

Based on the identification of the above problems, the author intends to make a Calibrator as a refinement of the tools that have been made before by measuring the temperature more than one point so that the calibration process is in accordance with the standard.

II. MATERIALS AND METHODS

A. Experimental Setup

This study collected data for the first time in a room with 6 data collection times at 5 measurement points.

1) Materials and Tool

This study is used a thermocouple sensor. The component used to use Atmega 328 as a microcontroller.

2) Experiment

In this study, researchers measured the temperature settings of the sterilizers 500C, 1000C, and 1500C at several measurement points and compared them with temperature calibrators from BPFK.

B. The Diagram Block

In this research, When the on / off button is on, the battery will supply voltage throughout the circuit. The sensor will detect the temperature that will be displayed on the 4x20 character LCD. When pressing the conversion button is pressed then the temperature results will change from Celsius to the other temperature units. Then if the save button is pressed then the results will be saved, the save button serves to determine the exact measurement results. When pressing the memory button it displays the stored data, and the reset button functions to reset or empty the data.

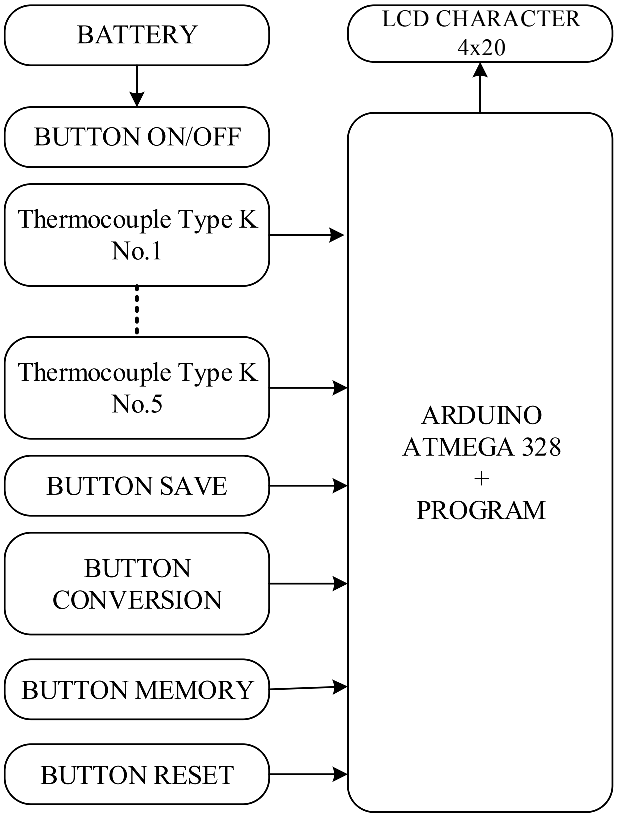

Fig. 1. The diagram block of the System Circuit

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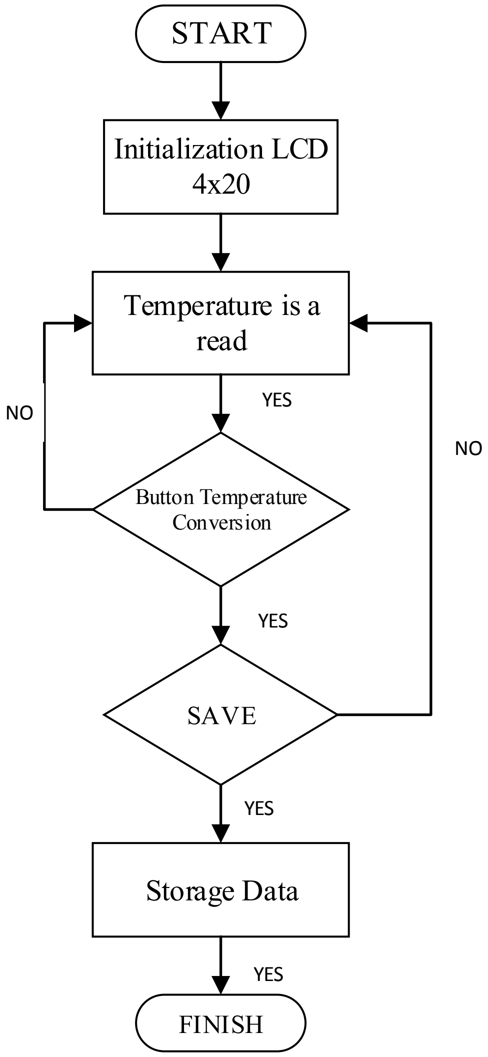

Fig. 2. The Flowchart of the Arduino Program

C. *The Flowchart*

The Arduino program was built based on the flowchart as shown in Fig. 2. When the start button is pressed the LCD will start initialization, after the initialization is complete the temperature of the readable tool is displayed on the 4x20 LCD, if the conversion button is pressed it will replace the display of the unit of measure and then save to save measured data.

D. *The Thermocouple Circuit*

The important part of this development is the thermocouple circuit and max6675 which describes in Fig. 3 (thermocouple circuit), The circuit is used to thermocouple sensor reading themperature in Celcius. Hence it will ready for digital processing using Arduino.

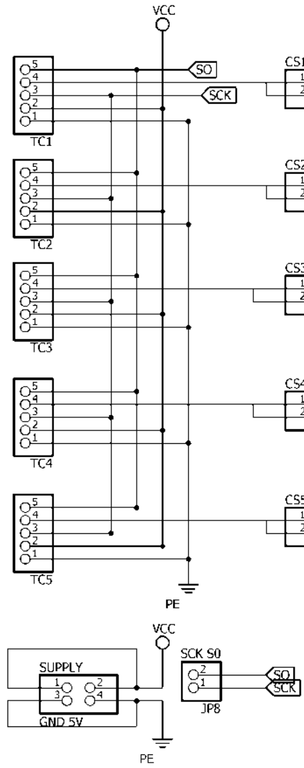

Fig. 3. Thermocouple circuit and max6675

III. RESULTS

In this study, The Module has been carried out trials on direct temperature calibrator with a comparison tool with standard tools in BPFK.

Fig. 4. The Module of Callibrator design

The picture above is a photo of a temperature calibrator module with a microcontroller-based thermocouple with a comparison device from BPFK.

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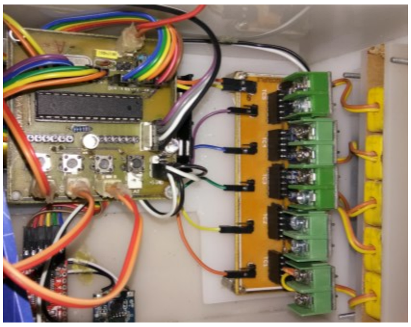

Fig. 5. The Digital part of the Module Callibrator

The Picture above circuit is a picture of the minimum system circuit with a series of thermocouple sensors.

1) The Module of Callibrator Design
microcontroller circuit as shown above to get a supply of 5 volt and 12 volt inputs connected to the thermocouple sensor.

2) The Listing Program for thermocouple sensor reading themperature in Celcius.

In this paper, is the sub-section of the Program to regulate the reading of the Celsius temperature from the thermocouple sensor at several points according to the coordinates on the character LCD. The Listing program was shown as Listing Program 1.

Listing program 1. Program to thermocouple sensor reading themperature in Celcius.

```
void loop()
{

    val1 = thermo1.readCelsius();
    val2 = thermo2.readCelsius();
    val3 = thermo3.readCelsius();
    val4 = thermo4.readCelsius();
    val5 = thermo5.readCelsius();

//celcius
  if(mark == 0){
     //lcd.clear();// clear previous values from screen (1)
     lcd.setCursor(0,0);// set cursor at character 0, line 0
     lcd.print("T1:");
     lcd.setCursor(3,0);// set cursor at character 0, line 1
     lcd.print(thermo1.readCelsius()); // print temperature in
Celsius
     lcd.print(" ");
     lcd.setCursor(8,0);// set cursor at character 9, line 1
     //lcd.print("C");

     lcd.setCursor(11,0);// set cursor at character 0, line 0
     lcd.print("T2:");
     lcd.setCursor(14,0);// set cursor at character 0, line 1
     lcd.print(thermo2.readCelsius()); // print temperature in
Celsius
     lcd.print(" ");
     lcd.setCursor(19,0);// set cursor at character 9, line 1
     //lcd.print("C");

     lcd.setCursor(8,1);// set cursor at character 0, line 0
     lcd.print("T3:");
     lcd.setCursor(11,1);// set cursor at character 0, line 1
     lcd.print(thermo3.readCelsius()); // print temperature in
Celsius
     lcd.print(" ");
     lcd.setCursor(16,1);// set cursor at character 9, line 1
     //lcd.print("C");

     lcd.setCursor(0,2);// set cursor at character 0, line 0
     lcd.print("T4:");
     lcd.setCursor(3,2);// set cursor at character 0, line 1
     lcd.print(thermo4.readCelsius()); // print temperature in
Celsius
     lcd.print(" ");
     lcd.setCursor(8,2);// set cursor at character 9, line 1
     //lcd.print("C");
     lcd.setCursor(11,2);// set cursor at character 0, line 0
     lcd.print("T5:");
     lcd.setCursor(14,2);// set cursor at character 0, line 1
     lcd.print(thermo5.readCelsius()); // print temperature in
Celsius
     lcd.print(" ");
     lcd.setCursor(19,2);// set cursor at character 9, line 1
    lcd.setCursor(0,3);
    lcd.print("Celsius         ");
 }
```

3) Conversion of Themperature
In order for the temperature reading results in the module can be converted from celsius to fahrenheit, kelvin, and reamur units. The Listing program was shown as Listing Program 2.

Listing Program 2. Program to Conversion of Themperature

```
//reamur
  if(mark == 1){
     //lcd.clear();// clear previous values from screen (1)
     lcd.setCursor(11,2);// set cursor at character 0, line 0
     lcd.print("T5:");
     lcd.setCursor(14,2);// set cursor at character 0, line 1
     lcd.print(thermo5.readCelsius() * 0.8); // print
```

```
    temperature in Celsius
     lcd.print(" ");
     lcd.setCursor(19,2);// set cursor at character 9, line 1
     lcd.setCursor(0,3);
     lcd.print("Reamur          ");
)

//Fahrenheit
  if(mark == 2){
     //lcd.clear();// clear previous values from screen (1)
    lcd.setCursor(11,2);// set cursor at character 0, line 0
     lcd.print("T5:");
     lcd.setCursor(14,2);// set cursor at character 0, line 1
     lcd.print(thermo5.readCelsius() * 1.8 + 32); // print
    temperature in Celsius
     lcd.print(" ");
     lcd.setCursor(19,2);// set cursor at character 9, line 1
     lcd.setCursor(0,3);
     lcd.print("Fahrenheit          ");
  }
//Kelvin
  if(mark == 3){
     //lcd.clear();// clear previous values from screen (1)
    lcd.setCursor(11,2);// set cursor at character 0, line 0
     lcd.print("T5:");
     lcd.setCursor(14,2);// set cursor at character 0, line 1
     lcd.print(thermo5.readCelsius() + 273); // print
    temperature in Celsius
     lcd.print(" ");
     lcd.setCursor(19,2);// set cursor at character 9, line 1
     lcd.setCursor(0,3);
     lcd.print("Kelvin          ");
}
```

4) The Listing Program to save the themperature using eeprom

In the program "save1 = EEPROM.read (addr1);" is a command to read / retrieve data from EEPROM. The parameter "addr1" is the EEPROM address that will be read. So on. "Btsavex = digitalRead (btsave);" is used for the save button, "btkonvx = digitalRead (btkonv);" is used for the conversion button, and for "btmemorix = digitalRead (btememori);" is used for the memory button. The Listing program was shown as Listing Program 3.

Listing Program 3. Program to save the themperature using eeprom

```
btsavex = digitalRead(btsave);
btkonvx = digitalRead(btkonv);
btmemorix = digitalRead(btmemori);
```

```
if(btmemorix == 1){
delay(200);
lcd.clear();
simpan1 = EEPROM.read(addr1);
simpan2 = EEPROM.read(addr2);
simpan3 = EEPROM.read(addr3);
simpan4 = EEPROM.read(addr4);
simpan5 = EEPROM.read(addr5);
simpan6 = EEPROM.read(addr6);
simpan7 = EEPROM.read(addr7);
simpan8 = EEPROM.read(addr8);
simpan9 = EEPROM.read(addr9);
simpan10 = EEPROM.read(addr10);

lcd.setCursor(0,0);
lcd.print("T1/6= ");
lcd.print(simpan1);
lcd.print("/");
lcd.print(simpan6);
lcd.print("    ");

lcd.setCursor(0,1);
lcd.print("T2/7= ");
lcd.print(simpan2);
lcd.print("/");
lcd.print(simpan7);
lcd.print("    ");

lcd.setCursor(0,2);
lcd.print("T3/8= ");
lcd.print(simpan3);
lcd.print("/");
lcd.print(simpan8);
lcd.print("    ");

}
```

5) Comparison Of Module Temperature Graphics With Comparisons

The following is the result of an error comparison on the module with a comparison device at the 50 ° C, 100 ° C, and 145 ° C temperature settings on the Hot Air Sterilizer Laboratory Oven media

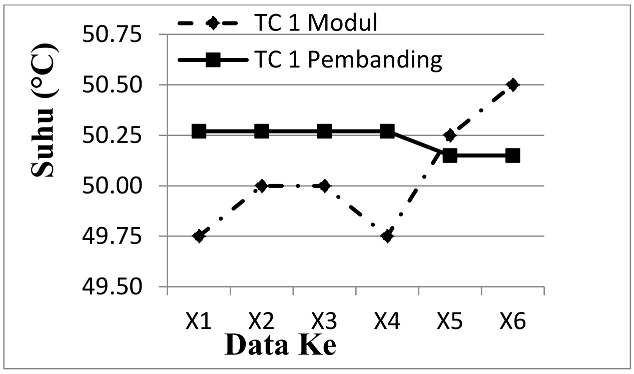

Fig. 6. Comparison of Temperature Charts of 50^0C at T1

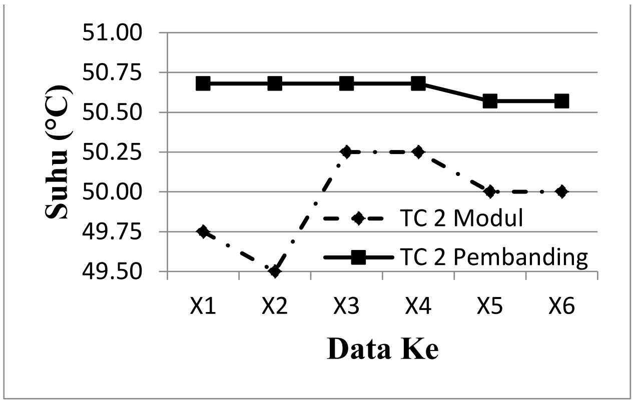

Fig. 7. Comparison of Temperature Charts of 50^0C at T2

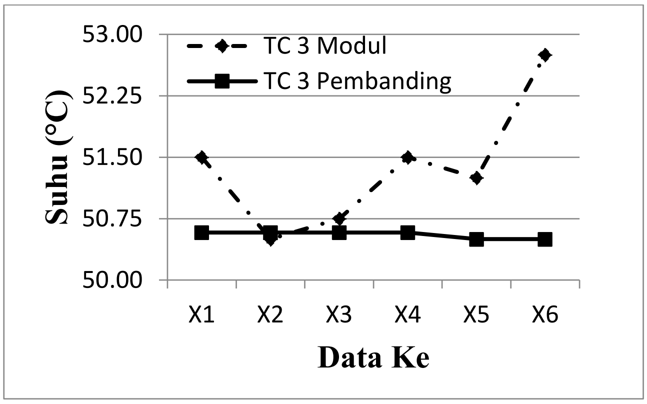

Fig. 8. Comparison of Temperature Charts of 50^0C at T3

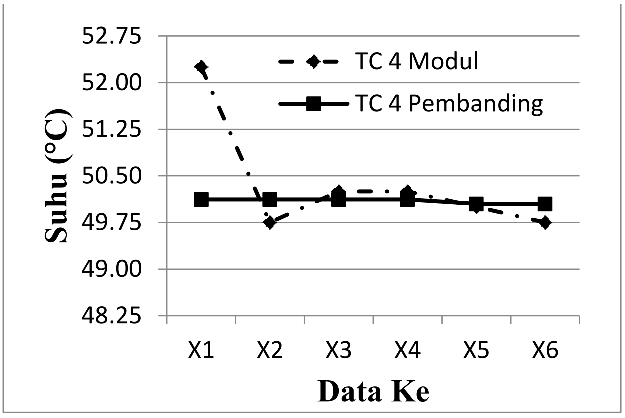

Fig. 9. Comparison of Temperature Charts of 50^0C at T4

Based on the results of the comparison data between the module and the comparative tool "8 Channel Thermocouple Temperature Recorder" from the Surabaya BPFK, at 50^0C in channel 1-4 the biggest difference is 2^0C and the smallest difference is 1^0C.

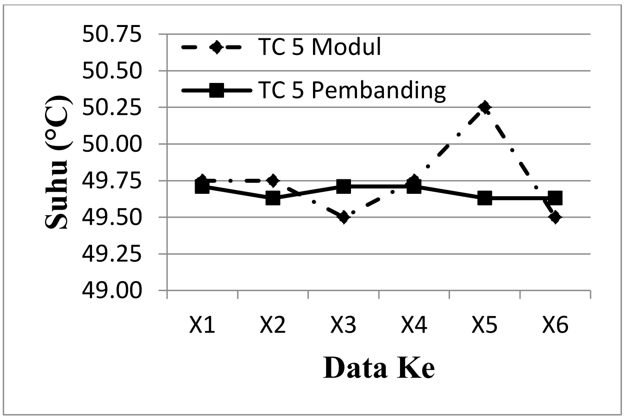

Fig. 10. Comparison of Temperature Charts of 50^0C at T5

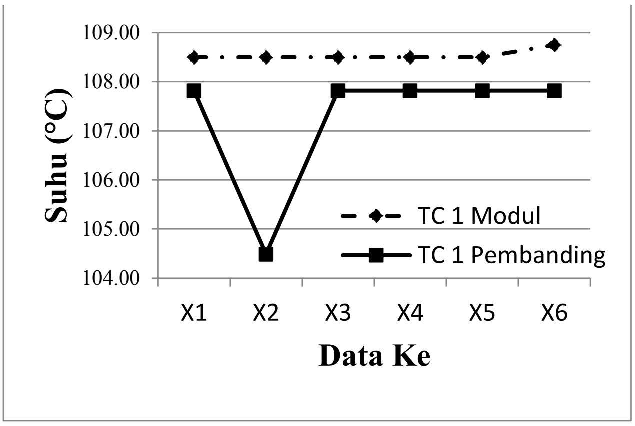

Fig. 11. Comparison of Temperature Charts of 100^0C at T1

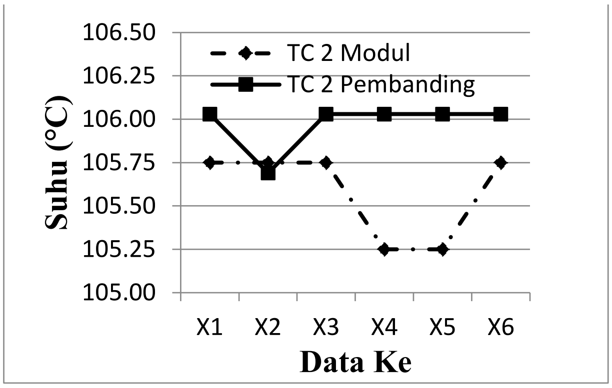

Fig. 12. Comparison of Temperature Charts of 100^0C at T2

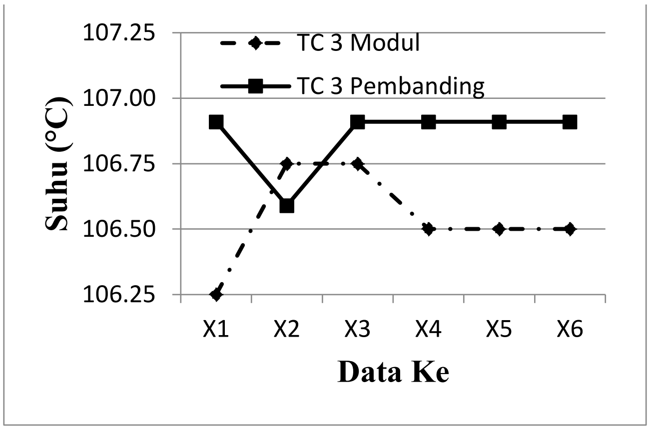

Fig. 13. Comparison of Temperature Charts of 100^0C at T3

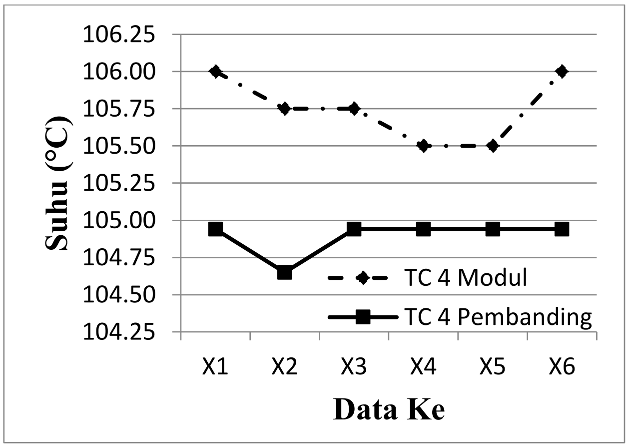

Fig. 14. Comparison of Temperature Charts of 100^0C at T4

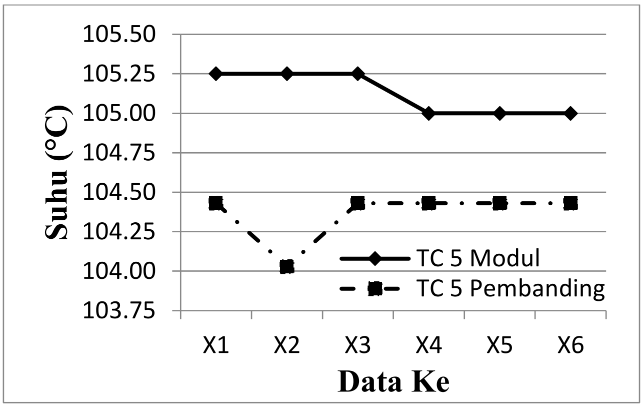

Fig. 15. Comparison of Temperature Charts of 100^0C at T5

Based on the results of the comparison data between the module and the comparative tool "8 Channel Thermocouple Temperature Recorder" from the Surabaya BPFK, at 100^0C in channel 1-5 the biggest difference is 4^0C and the smallest difference is 1^0C.

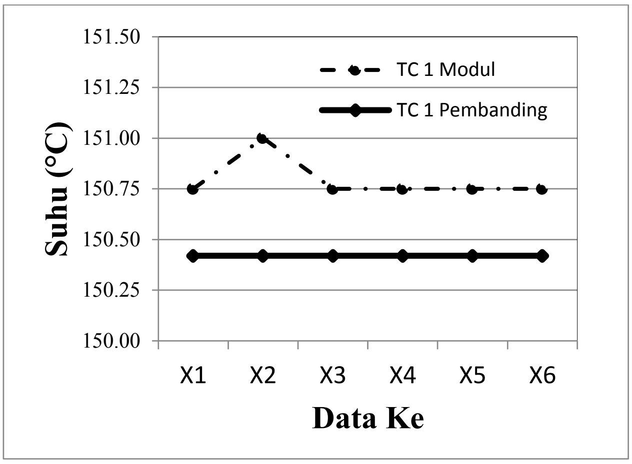

Fig. 16. Comparison of Temperature Charts of 150^0C at T1

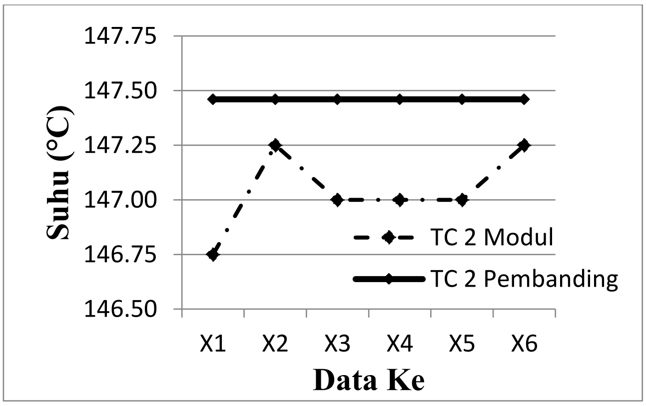

Fig. 17. Comparison of Temperature Charts of 150^0C at T2

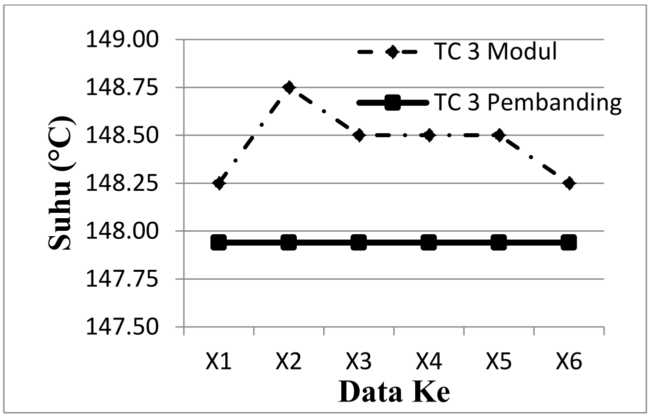

Fig. 18. Comparison of Temperature Charts of 150^{0}C at T3

Based on the results of the comparison data between the module and the comparative tool "8 Channel Thermocouple Temperature Recorder" from the Surabaya BPFK, at 150^{0}C in channel 1-3 the biggest difference is 0,71^{0}C and the smallest difference is 0,29^{0}C.

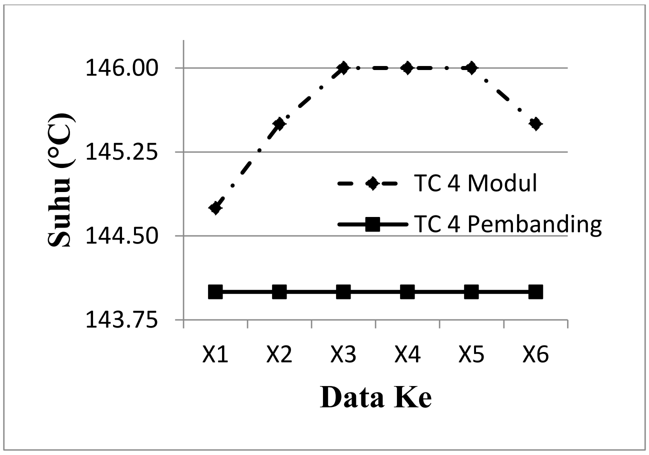

Fig. 19. Comparison of Temperature Charts of 150^{0}C at T4

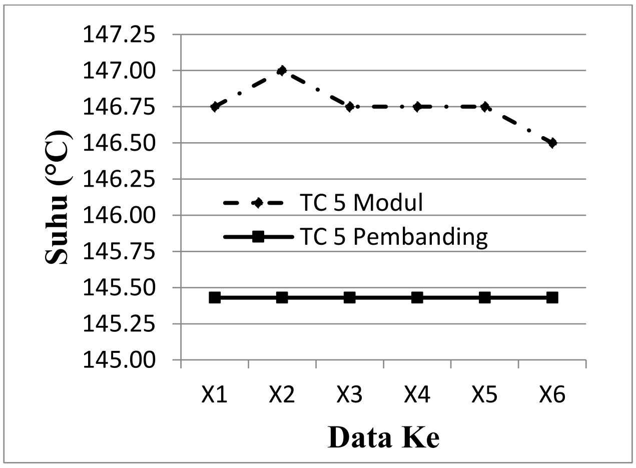

Fig. 20. Comparison of Temperature Charts of 150^{0}C at T5

6) The Error of Module and Calibrator

The value of the temperature readings shown in the module is compared with the temperature calibrator comparison device at BPFK. Errors are shown in table 1

TABLE I. THE ERROR COMPARISON RESULTS BETWEEN MODULES AND CALIBRATORS

Setting Suhu	Error				
	T1	T2	T3	T4	T5
50^{0}C	0,38	1,37	1,60	0,55	0,16
100^{0}C	1,18	0,37	0,30	0,81	0,72
150^{0}C	0,25	0,28	0,35	1,12	0,90

IV. DISCUSSION

Based on the measurement data above, it can be seen that the temperature reading results in the sterilizer are close to the temperature of the comparator.

The results of the comparison between the reading module and the standard reading of the BPFK have the largest error of 1.60 and the smallest error of 0.16 this is due to several factors, one of which is uneven temperature differences due to the distance between the heat source (heater) and the placement of different sensors- different.

V. CONCLUSION

Based on the results of the discussion and objectives it can be concluded that overall the system can function properly, and the biggest error can be seen from the temperature reading with the comparator is 1.60%, because the position of the thermocouple sensor between the modules and the comparison.

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