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Effect of Closed and Opened the Door to Temperature on PID-Based Baby Incubator with Kangaroo Mode

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Abstract

The uneven distribution of the baby incubator temperature can cause the temperature in the baby incubator to be different at each point. The purpose of this study was to analyze the effect of the door closed and opened to the temperature at each point of sensor placement that has been determined. The study was conducted as experimental research design. In this experiment, an Incu Analyzer comparison was used as a calibrator unit, a baby skin temperature thermistor sensor, and four LM35 sensors for baby incubator room temperature with one LM35 sensor as a PID control system carried out by trial-and-error method. Based on the results of measurements was made with the design, when the chamber is open, it produces an average error value of T1 4.083%, T2 6.06%, T3 3.78%, T4 4.88%, and T5 1.48%, while when the chamber is closed, it produces an average error value T1 0.75. %, T2 0.88%, T3 1.15%, T4 0.74%, and T5 0.87%. Measurement of skin temperature using a thermometer has an average error value of 1.1%. The results showed that uneven heat transfer, lack of air distribution, different sensor placements at each point, and non-standard chamber sizes were factors that were uneven at each point. Based on the results of the study, it was found that the use of a working system on this device can be implemented to control the temperature of the baby incubator by knowing the temperature distribution at each point.

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I. INTRODUCTION

The infant mortality rate (IMR) is a benchmark in determining the degree of public health, both at the national and provincial levels. One of the major risk factors for morbidity and mortality in the first 28 days of neonatal life is hypothermia. Hypothermia in newborns is common worldwide, with a prevalence ranging from 32 to 85 percent. The results of the Indonesian demographic and health survey (IDHS) show that IMR has decreased significantly by 35 percent from 68 deaths per 1,000 live births in 1991 to 24 deaths per 1,000 live births in 2017. This figure has met the government's target of improving public health status in 2017 RPJMN 2015-2019 [1].

A baby incubator is a tool to maintain the warmth of the baby after birth so that it is able to adapt to the outdoor environment [2][3]. The main function of an incubator is to regulate room temperature, with the aim of maintaining the baby's temperature so that it does not fall into hypothermia [4]. A baby incubator is an enclosed place whose room temperature can be adjusted to warm the baby. This incubator also requires stable humidity so that the conditions in it are maintained as desired [5] [6]. A baby incubator is a tool that has a function as a treatment and temperature adjustment (warmer) for premature babies who really need a temperature that is in accordance with the temperature in the mother's womb [7]. The incidence of neonatal hypothermia is much higher in developing countries. Hypothermia is a condition where the body temperature is below normal. The normal temperature of infants in neonates is 36.5°C - 37.5°C and hypothermia is below 36°C. Therefore some studies developed infant incubator to maintain the infant body temperature [8][9][10]. Furthermore, some studies have proposed infant incubator design with modern controller such as PID or Fuzzy Logic in order to improve the stability of the chamber temperature [11] [12][13].

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Bagus Satria K, et al modified the infant incubator device using the AT89s51 by measuring the temperature on the incubator and installing temperature sensors on T1 (left side), T2 (middle part adjacent to the baby incubator temperature sensor), and T3 (side side). right) to retrieve results [14]. Wisnu Kusuma W et al. used temperature control and a series of charges on the baby incubator with room temperature settings of 32°C-37°C and humidity of 50%-70%RH [15][16]. Dian Rizal et al. carried out developments by adding a scale to determine the baby's weight. The results obtained that the average reading value based on five times of skin temperature data collection was 34.3°C while the average skin temperature reading through a thermometer comparison was 34.6°C [17]. Ruri Agung W et al. have analyzed the distribution of temperature and airflow in a baby incubator with variations in the type of wall and overhead screen with the aim of identifying the effect of wall type modification and the addition of an overhead screen incubator on the distribution of incubation room temperature and heat loss in low birth weight babies by referring to the geometry and dimensions of the incubator that is generally found in the Neonatal Intensive Care Unit (NICU) in Indonesia [18] [10]. Aziza Hannouch et al. have conducted research aimed at analyzing the effect of different environmental conditions, such as air temperature and humidity, incubator wall temperature, and airflow, on dry heat loss through convection, conduction, and radiation, and so on. Loss of latent heat due to evaporation of the skin and the respiratory process. The main indicators are metabolic heat generation, skin and core body temperature. Moreover, based on this method, different techniques are proposed to improve the hygrothermal conditions of the incubator [19]. Didem Coşkun et al. have analyzed the effect of kangaroo mode by finding that the stress level of mothers who applied kangaroo care decreased significantly compared to the stress level of mothers in the standard care group. These results indicate that kangaroo care is a very important intervention to improve the bond between mother and premature baby and increase the mother's milk production for the baby [20]. Anggraeni Dara P et al. develop the incubator with PID control and using kangaroo mode. It has a weakness in response time when the setting temperature takes a long time, which is about 20 minutes for preheating, and it is not known how the temperature is evenly distributed in the chamber [21].

Based on the previous studies, it was shown that some researchers still considered to developed a standard infant incubator and less researchers studied the kangaroo infant incubator. Furthermore, the effect of the door opened and closed to the temperature has not considered yet. Therefore, the purpose of this study is to design a kangaroo infant incubator using PID controller. Additionally, this study analyzed the effect of the door position whether in the open or closed condition.

This article consists of chapter I contains an introduction, Chapter II contains Materials and Methods, Chapter III, contains Content, Chapter IV contains discussions, and Chapter V contains conclusions. The purpose of this study was to analyze the effect of distance on the temperature at each point where the sensor was placed in a baby incubator with kangaroo mode. If the distance to temperature analysis is not carried out, it will not be known how the temperature is evenly distributed in the baby incubator room, the distribution of air, and how the sensor placement affects each point of influence. Therefore, a research analysis was conducted on the effect of distance on the temperature in a baby incubator with PID-based kangaroo mode.

II. MATERIALS AND METHODS

A. Experimental Setup

This study is based on an experimental design method. Furthermore, the temperature and humidity data collection was compared with a comparison tool (INCUII).

1) Materials and Tool

In this study, four LM35 sensors were used as room temperature sensors and 1 LM35 sensor as PID control and room temperature readings, skin sensors use thermistors. A microcontroller is a value processor monitored by sensors. The DC fan functions as humidity in the chamber, which is given the command from the microcontroller. The heater functions as a heater in the chamber which is given an order from the microcontroller. The thermostat functions as a safety device if the temperature is overheated, then the thermostat disconnects the heater. A buzzer sound is activated if the temperature is overheated

2) Experiment

The LM35 sensor takes data for 10 minutes at points T1, T2, T3, T4, and T5 with the incubator temperature setting 32°C-37°C and the influence of ambient temperature 27.2°C by taking the average value five times.

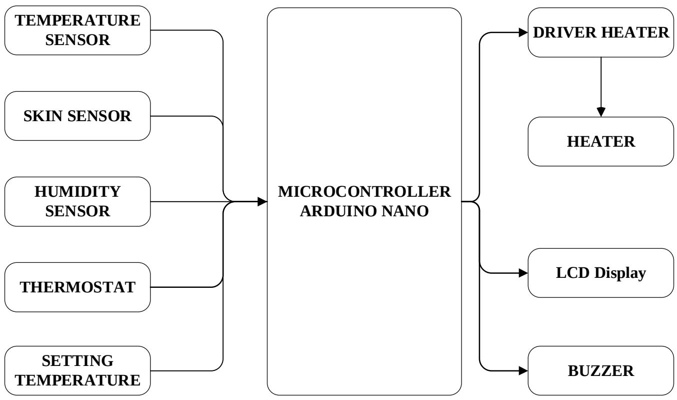

Fig 1. The diagram block of baby Incubator

B. The Diagram Block

Fig.1 is a block diagram of the baby incubator. When the device is turned on, the voltage will be lowered and rectified by the power supply to +5 VDC, +12 VDC, and ground which will be used to supply the entire circuit. The room temperature will be read by 5 LM35 sensors that function as analog data, which will be read by pins A0, A1, A2, A3, A4. A0 as PID control and A1, A2, A3, A6 as temperature monitoring and displayed on the LCD display. The temperature control circuit requires AC voltage to run the heater, then SSR is needed. The SSR output is

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the AC voltage connected to the heater. The skin temperature connected to pin A5 will process the data read from the thermistor sensor in the form of analog data that will be displayed on display.

The humidity sensor using the DHT 22 and DHT11 sensors requires an input voltage of +5 VDC and ground. The output of the DHT 22 sensor in the form of digital data connected to digital pin 2 and the output of the DHT 11 sensor in the form of digital data connected to digital pin 3 will read and display on the LCD display. Humidity reading by DHT22 when less than 70%RH then the fan will turn on then when the humidity is more than 70%RH then the fan will turn off. Setting the temperature setting can be done by pressing the push button which is connected to digital pins 11,12,13 in the form of the Up, Down and OK buttons. The thermostat functions to cut off the heater work if the temperature in the chamber has been met. The buzzer sounds after the heater is disconnected or not working.

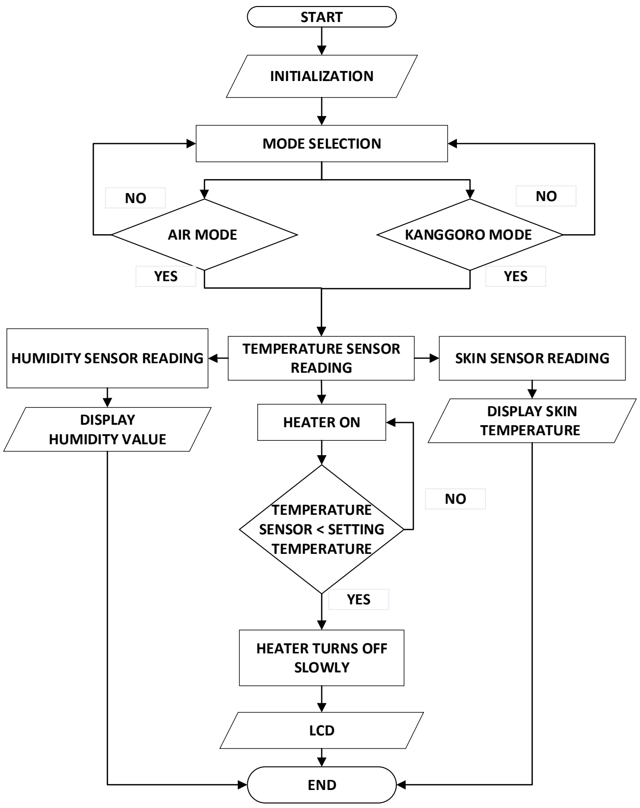

Fig 2. The flowchart of baby incubator

C. The Flowchart

Fig.2 shows a flow chart of the overall system. First of all, the initialization process and the user selects the mode; if the user opens the chamber door, then the kangaroo mode is in progress, but when the user does not open the chamber door, the air mode is in progress. Room temperature sensors, namely 5 LM35, two humidity sensors, namely DHT11 and DHT22, skin sensors, namely thermistors, the process of measuring temperature and humidity in the chamber will occur. The room temperature sensor will activate the heater; if the temperature reaches the heater will turn off, and when the temperature is less than the setting, then the heater will work. The temperature and humidity measurements will be displayed on the LCD. Furthermore, the device will stop operating after the device has finished its operation.

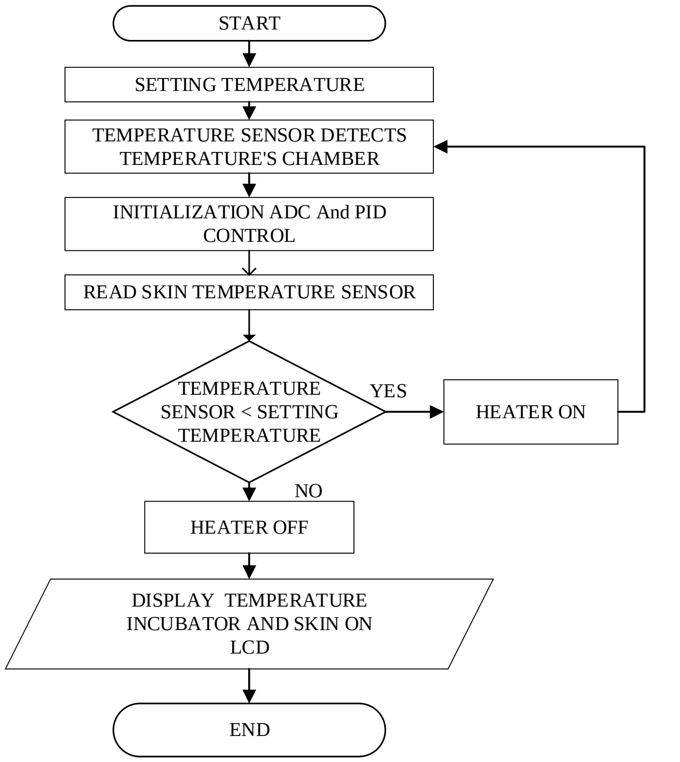

Fig 3. The Flowchart Of Temperature Control

In **Fig.3**, the LM35 sensor acts as a temperature sensor and the Thermistor sensor as a skin temperature detector; the microcontroller performs data initialization, for the temperature sensor if the data initialization is successful, the skin temperature value is displayed on the LCD if not, the sensor reads back. At room temperature, after initializing data and PID control, if the temperature sensor is less than the set temperature, the heater is on, but if the temperature sensor is more than the set temperature, the heater will be off. Next, the value of the room temperature will be displayed on the LCD display.

III. RESULTS

1) Results of microcontroller design

As shown in **Fig.4**, it is the result of the front view of the baby incubator. The author uses an LCD display for a readable display on the device. Push buttons are used for tool settings. The heater indicator for the heater marker is off or on. Then there is a buzzer test to check if the buzzer is still working or not.

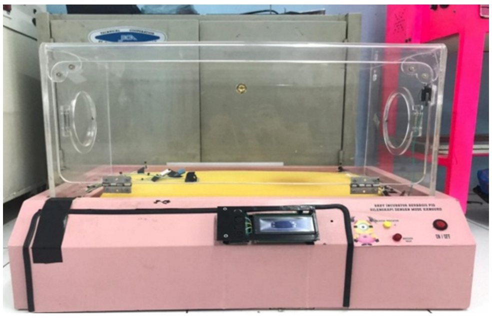

Fig 4. Baby Incubator

Fig. 5 is the result of a baby incubator made. Inside the chamber, there are 5 LM35 sensors consisting of 1 LM35 sensor as a PID control located in the middle and 4 for measuring room temperature located in the right and left corners. Inside the left side chamber there are DHT22 and DHT11 sensors for measuring the humidity of the baby incubator chamber. On the front there is a skin sensor for measuring body temperature on the skin.

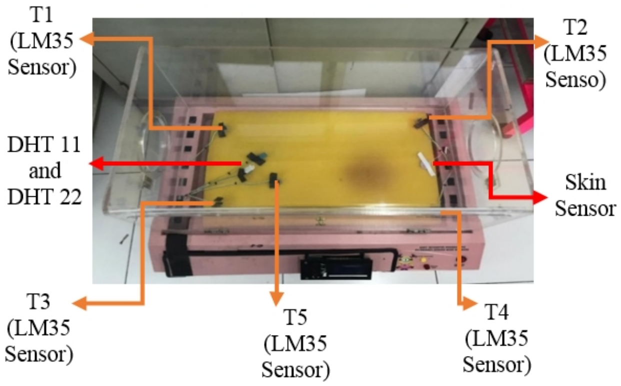

Fig 5. Sensor Point at the Baby Incubator

2) The Listing Program for Library Input and Initialization

In this paper, the software used is Arduino programming. The list of programs for Arduino is shown in **Listing Program 1.** which consists of programs to send data to a computer.

Listing Program: 1. Program to send the Baby Incubator data to a computer.

```
Int kipas =6
int pwmout = 5;
int btup = 11;
int btdown = 12;
int btok = 13;
int btupx;
int btdownx;
int btokx;
int adclm;
#define SSR_pin   5   //pin SSR
#define LM35_pin  A0  //pin LM35
#define LM35_pin1  A1  //pin LM35
#define LM35_pin2  A2  //pin LM35
#define LM35_pin3  A6  //pin LM35
adclm = analogRead(A0);
    suhu = (adclm * (5.0 / 1024.0) * 100) + 3;
    suhu = baca_suhu();
    PID();
    float sensorSuhu = analogRead(A5);
    nilaisuhu = map(sensorSuhu, 0, 1023, 0, 67);
float baca_suhu()
{
  int tmp = analogRead(A0);
  float mV = ((float(tmp) / 1024.0) * 5500 );
  float temp = mV / 10;
  return temp;
}
void suhulain(){
dht11 = dht1.readHumidity();
  const int lm35_data1 = A1;
  int nilai_analog1;
  nilai_suhu1;
  nilai_analog1 = analogRead(lm35_data1);
  nilai_suhu1 = (nilai_analog1 * 4.88);
  nilai_suhu1 = (nilai_suhu1 / 10);
  const int lm35_data2 = A2;
  int nilai_analog2;
  nilai_suhu2;
  nilai_analog2 = analogRead(lm35_data2);
  nilai_suhu2 = (nilai_analog2 * 4.88);
  nilai_suhu2 = (nilai_suhu2 / 10);
  const int lm35_data3 = A6;
  int nilai_analog3;
  nilai_suhu3;
  nilai_analog3 = analogRead(lm35_data3);
  nilai_suhu3 = (nilai_analog3 * 4.88);
  nilai_suhu3 = (nilai_suhu3 / 10);
  const int lm35_data4 = A4;
  int nilai_analog4;
  nilai_suhu4;
  nilai_analog4 = analogRead(lm35_data4);
  nilai_suhu4 = (nilai_analog4 * 4.88;
  nilai_suhu4 = (nilai_suhu4 / 10);   }
```

3) Temperature Measurement Results

The temperature differences of the infant incubator chamber when the door is open and close are measured in this study. A standard INCU analyzer was placed inside the infant chamber. This is to compare the performance of the infant incubator design. The error between the design and standard was measured by choosing some temperature setting. In this case, the temperature setting was 32 °C, 35 °C, and 37 °C for both

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conditions, namely the door is open or closed. Furthermore, the measurement points for both devices (design and INCU analyzer) were place at the TI, T2, T3, T4, and T5 location as shown in Fig. 5.

TABLE I. THE MEAN TEMPERATURE MEASUREMENT FOR TEMPERATURE SETTING AT 32 ºC CLOSED CHAMBER CONDITION

	Design (ºC)	Standard INCU II (ºC)	Error %	Correction factor (ºC)	Uncertainty (ºC)
T1	31.88	32.12	0.37	0.24	0.80
T2	32.3	32.4	0.9	0.1	0.35
T3	32.52	32	1.6	0.52	0.18
T4	32.14	31.77	0.43	0.37	0.13
T5	32.92	32.18	2.8	0.74	0.26

TABLE II. TEMPERATURE MEASUREMENT 32 OPEN CHAMBER CONDITION

	Design (ºC)	Standard INCU II (ºC)	Error %	Correction factor (ºC)	Uncertainty (ºC)
T1	32	31.75	0	0.25	0.1
T2	31.54	31.54	1.4	0	0
T3	31.29	31.58	2.2	0.29	0
T4	30.34	31.01	5.2	0.67	0.23
T5	33.19	31.80	3.7	1.39	0.5

Based on **Table 1.** and **Table 2**, when setting the temperature to 32 ℃, an average error of 1.22% is obtained when the chamber is closed and produces an average error of 2.5% when the chamber is open or in kangaroo mode.

TABLE III. TEMPERATURE MEASUREMENT 35 CLOSED CHAMBER CONDITION

	Design (ºC)	Standard INCU II (ºC)	Error %	Correction factor (ºC)	Uncertainty (ºC)
T1	35.53	35.69	1.5	0.16	0.05
T2	34.95	34.75	0.14	0.20	0.07
T3	35.59	35.54	1.6	0.05	0.01
T4	34.88	34.41	0.34	0.47	0.16
T5	35.50	35.75	1.4	0.25	0.08

TABLE IV. TEMPERATURE MEASUREMENT 35 OPEN CHAMBER CONDITION

	Design (ºC)	Standard INCU II (ºC)	Error %	Correction factor (ºC)	Uncertainty (ºC)
T1	33.92	35.31	3.3	1.39	0.49
T2	32.90	34.54	6	1.64	0.6
T3	34.09	33.56	2.6	0.53	0.6
T4	34.66	32.84	1	0.64	1.82
T5	35.17	35.35	0.49	0.18	0.1

Based on **Table 3.** and **Table 4**., when setting a temperature of 35 ℃ above, an average error of 0.99% is obtained when the chamber is closed and produces an average error of 2.67% when the chamber is open or in kangaroo mode.

TABLE V. TEMPERATURE MEASUREMENT 37 CLOSED CHAMBER CONDITION

	Design (ºC)	Standard INCU II (ºC)	Error %	Correction factor (ºC)	Uncertainty (ºC)
T1	36.9	36.69	0.27	0.21	0.07
T2	36.9	36.61	0.27	0.29	0.09
T3	36.98	36.87	0.05	0.11	0.04
T4	36.73	36.83	0.72	0.10	0.03
T5	37.03	37.14	0.08	0.11	0.04

TABLE VI. TEMPERATURE MEASUREMENT 35 OPEN CHAMBER CONDITION

	Design (ºC)	Standard INCU II (ºC)	Error %	Correction factor (ºC)	Uncertainty (ºC)
T1	34.10	37.04	7.8	2.93	1.03
T2	33.79	36.69	8.7	2.9	1.03
T3	34.32	37.02	7.2	2.7	1.03
T4	35.35	36.69	4.5	1.34	0.47
T5	36.99	38.53	0	1.53	0.54

Based on **Table 5.** and **Table 6.**, when temperature setting 37 ℃ above obtained an average error of 0.27% when the chamber is closed and produces an average error of 5.64% when the chamber is open or in kangaroo mode.

4) PID Response Graph

Fig. 6 shows the response time when a temperature setting of 32 ºC takes up to 300 seconds or 5 minutes to reach a setting temperature of 32 ºC after the initial condition of the chamber is from a temperature of 28.94 ºC. Furthermore, at the initial stage, between 30 and 270 second, the temperature increased proportionally by the time.

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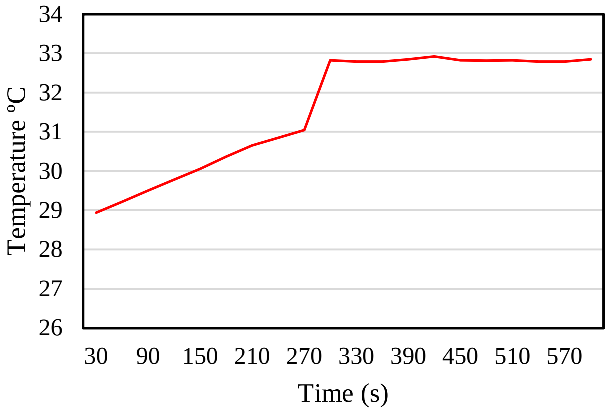

Fig 6. PID Response for setting temperature of 32 ºC

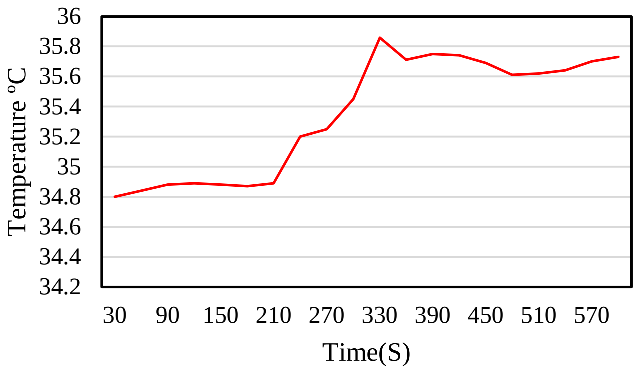

Fig 7. PID Response for setting temperature of 35 ºC

Fig.7 shows the response time when setting a temperature 35 ºC takes up to 240 seconds or 4 minutes to reach a setting temperature of 35 ºC after the initial condition of the chamber is from a temperature of 34.8 ºC.

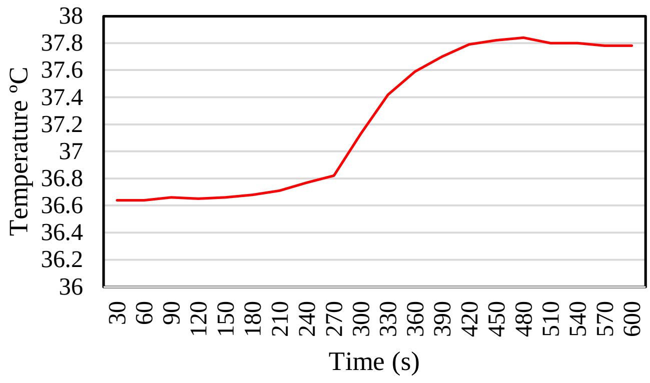

Fig 8. PID Response for setting temperature of 37 ºC

Fig. 8 shows the response time when setting a temperature 35 ºC takes up to 300 seconds or 5 minutes to reach a setting temperature of 37ºC after the initial condition of the chamber is from a temperature of 36.64 ºC.

IV. DISCUSSION

Based on the results of these data, it can be observed that the temperature value when the chamber is closed is more stable than the temperature value of the chamber in the open condition (detected at 27.2°C) at each measurement point (T1-T5). This condition can affect the temperature error value in the chamber, T1 4.083 %, T2 6.06%, T3 3.78%, T4 4.88%, and T5 1.48% while when the chamber is closed the average error value is T1 0.75%, T2 0.88%, T3 1.15%, T4 0.74%, T5 0.87%.

At point T2 when the chamber is open, the error value is greater than other points, this is caused by several factors, including the distance of the T2 sensor which is far from the heater. In addition, the air circulation in the tool is not good because the baby incubator is too small which also affects the error value. The temperature distribution in the chamber is uneven or unstable according to the setting temperature. Other factors that affect the instability of temperature distribution at 5 points, namely human error, module faults, and uneven heat transfer.

When conducting research, it can be concluded that the advantages of this baby incubator are that the temperature in the closed chamber is more stable than the open chamber (kangaroo mode), using 5 sensors at each point which functions to monitor the even distribution of each temperature at 5 points, using PID as a room temperature control, humidity in the chamber is still within the standard tolerance of 50-70%. This tool also has drawbacks, namely the size of the tool does not match the standard so that it affects air circulation in the chamber, the temperature distribution is not stable when the chamber is opened (kangaroo mode), there is still a difference in the sensor value with the comparison tool (INCUII).

V. CONCLUSION

Based on the results of the discussion and the purpose of making the module, it can be concluded that the use of PID control with the trial and error method obtained an optimal room temperature response at a value of kp of 57, ki of 8 and kd of 3.2, based on the results of measuring skin temperature with a body temperature thermometer comparison, it was obtained that – the average body temperature measurement is 35°C with an error of 0.11% against the comparison, the measurement results of sensor readings at different points T1, T2, T3, T4, and T5, the temperature distribution in the chamber is uneven or unstable according to the temperature setting, the open chamber error value at T2 is greater than the others. When the chamber is open, T2 produces an average error value of 6.06%, while when the chamber is closed, T2 produces an error value of 0.8%. It is recommended for further research to use a temperature sensor that produces a smaller error value than the LM35 and improve the air distribution system.

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ATTACHMENT

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