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Temperature Controller of Infant Incubator using Arduino

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Abstract:- The factors affect the child within incubator are mainly the temperature, humidity. The organization of temperatures one of the basic criteria for building a stable environment for the child. This digital temperature controller uses an Arduino board as its primary controller. It can regulate any heating device's temperature within predetermined ranges and shows the device's status, including on and off, as well as its current temperature. A temperature controller is an instrument that regulates temperature, as the name suggests. The temperature controller receives data from a temperature sensor and outputs data to a control element, like a fan or heater. In order to regulate process temperature precisely and with minimal operator intervention, a temperature control system uses a controller that receives input from a temperature sensor (such as a thermocouple, RTD, or DHT22). After comparing the actual temperature to the set-point—the desired control temperature—it outputs the result to a control element.

Keywords:- *Temperature, Control, Infant Incubator, Arduino.*

I. INTRODUCTION

The paper written by Thomas et al. (1857) was the first to be published on the use of incubators in the care of preterm infants. In order to keep the infant warm and maintain a steady temperature, he came up with the idea to run a cradle zinc known as an incubator at this point. In order to minimize transdermal respiration and water loss and to maximize the body's heat storage, temperature is one of the most crucial parameters that must be kept constant. This is where the neonatal incubator is used to maintain the proper temperature, humidity, and oxygenation levels for newborns or preterm infants. Thus offers the most protection from outside aggression like noise and pathogens. This development is due to technological progress, seen in these last years. Furthermore, the current commercial devices use a classical control to control the incubator environments such as the on-off or PID control. Premature infants are born before the organs are mature enough to allow normal postnatal survival. As the premature infants are at risk to develop hypoxia, hypothermia and many other associated adverse conditions, they need special care and attention. One of the major problems that newborns face is improper thermoregulation. The temperature inside the mother's womb is 38ºC (100.4ºF). Leaving the warmth of the womb at birth, the wet new born finds itself in a much colder environment and immediately starts losing heat. In the first 10-20 minutes, the new born who is not thermally protected may lose enough heat for the body temperature to fall by (2-4ºC) (3.6-7.2ºF), with even greater falls in the following hours if proper care is not given. If heat loss is not prevented and is allowed to continue, the baby will develop hypothermia and is at increased risk of developing health problems and of death. Therefore an infant incubator is necessary which attempts to create the necessary environment for the baby's survival.

Worldwide every year over 4 million infants die within a month of birth. Of this number, 3.9 million belong to the developing world. Some (25%) of this deaths are caused due to complications of prematurity, most often due to improper heat regulation, water loss and neonatal jaundice. An infant incubator provides stable levels of temperature, relative humidity and oxygen concentration. The question remains if use an advanced control strategy, can provide a suitable environment for the new born and maintaining the required temperature and humidity that are set by the doctor without significant variation over time whatever disturbance

Controlling both temperature and humidity are processed by the use of the PID controller. Industrial motion control systems and processes frequently employ proportional-integral-derivative (PID) controllers. PID controllers remain the standard in over 90% of control systems today. Optimizing the parameters is the most important step in using a PID controller. In modern engineering, self-tuning PID controllers offer great convenience. The fundamental concept of a self-tuning system is to create an algorithm that will automatically alter the system's parameters to satisfy a specific need or circumstance.

II. INCUBATOR

Infant Incubators are now used in all hospitals around the world to prepare a suitable ambient condition for the new born. An incubator shown in figure (1.1), is a device in which an infant may be kept for certain period in a controlled environment for medical care. The incubator should include an AC-powered heater, a fan circulating the warmed air, a container for water to add humidity, a control valve through which oxygen may be added, and access ports for nursing care [1].

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In the first day's period after birth, the absolute humidity must be monitored so that evaporative heat loss is kept to a minimum as well as water loss through the skin. Heat losses and gains of the new born body are difficult to monitor. The premature infants lose heat via evaporative, conductive, convective and radiation means [2].

About 28 days after his birth, the newborn was placed in an incubator, where he received clinical care through a special glass. Nurses fed the baby, took his weight, took care of him, performed small procedures, and took an X-ray without repositioning him. To keep the premature baby safe, the inside environment of the incubator was controlled using a variety of control mechanisms. [3].

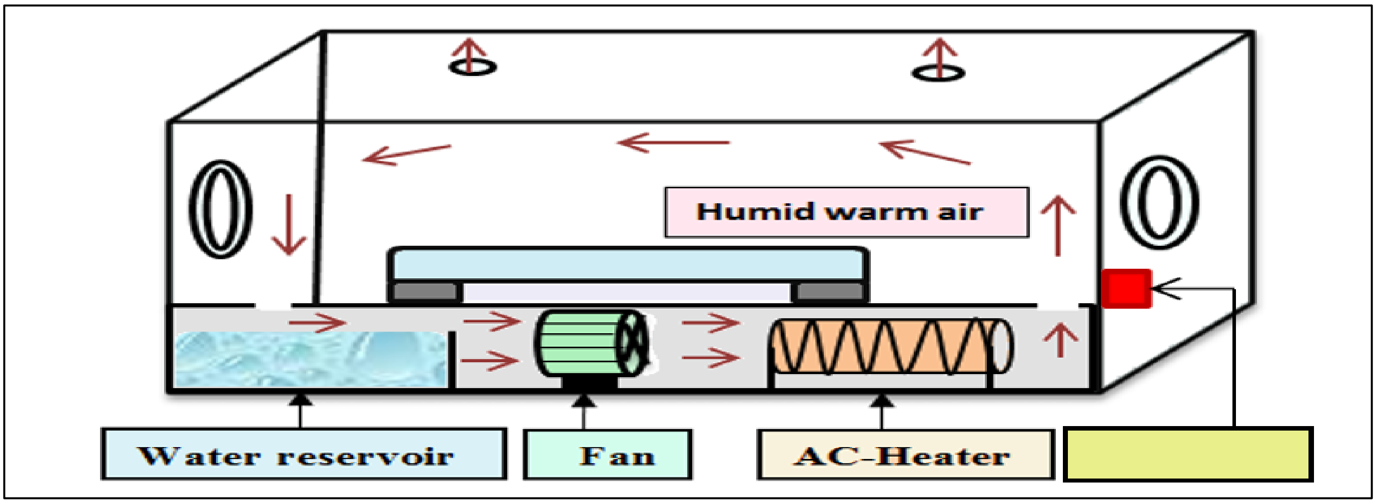

Fig 1: Baby Incubator

- *Main Functions of Infant Incubators:*

- Temperature Control : is temperature control which is required to achieve thermo-neutrality in infant's body
- O2 Concentration Control
- Breathing Gas Filtration
- Humidity Control

- *Types*
- Portable
- Standard

- *Principle*

Typically, the infant incubator is a cart with a little mattress on top that is protected from the elements by a stiff, transparent plastic cover.

In addition to offering a clean environment, the incubator chamber shields the infant from handling too much, noise, dust, and infections.

The infant is kept at a consistent temperature by use of an incubator heater that is equipped with a temperature sensor affixed to its skin.

An air-blown electric heating and humidification system, located beneath the infant, heats and humidifies the incubator chamber to the ideal temperature and humidity [4].

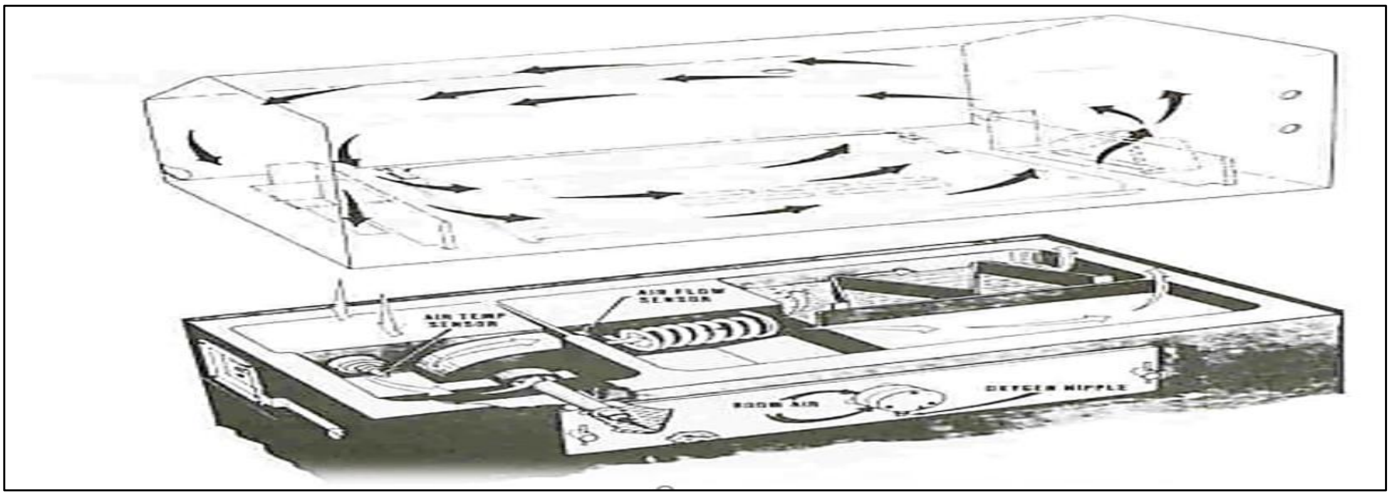

Fig 2: Principle

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➢ *Transport Incubator*

- A transport incubator is used to transfer a premature or ill infant from one hospital to another
- It is similar to the Infant Incubator but it is battery-operated

Fig 3: Transport Incubator

III. PARAMETERS CONTROL IN INFANT INCUBATOR

➢ *Temperature Control*

- Air temperature mode
- Skin temperature mode

➢ *Humidity Control*

- The percentage of vaporized water molecules in the atmosphere is known as humidity.
- This is crucial for a newborn because low humidity can lead to the baby's skin becoming dry, which can lead to several health issues.

➢ *Humidity Probe*

- Humidity transducer.
- The principle of humidity transducers is the capacitive changing types, which means that any change in humidity will result in a change in capacitance, which will then be converted, via a bridge circuit, to a change in voltage.

➢ *Oxygen Control.*

➢ *Alarms in Incubator*

- Air flow alarm (fan stop alarm)
- High temperature alarm
- Power failure alarm
- Probe alarm.
- Set temperature alarm

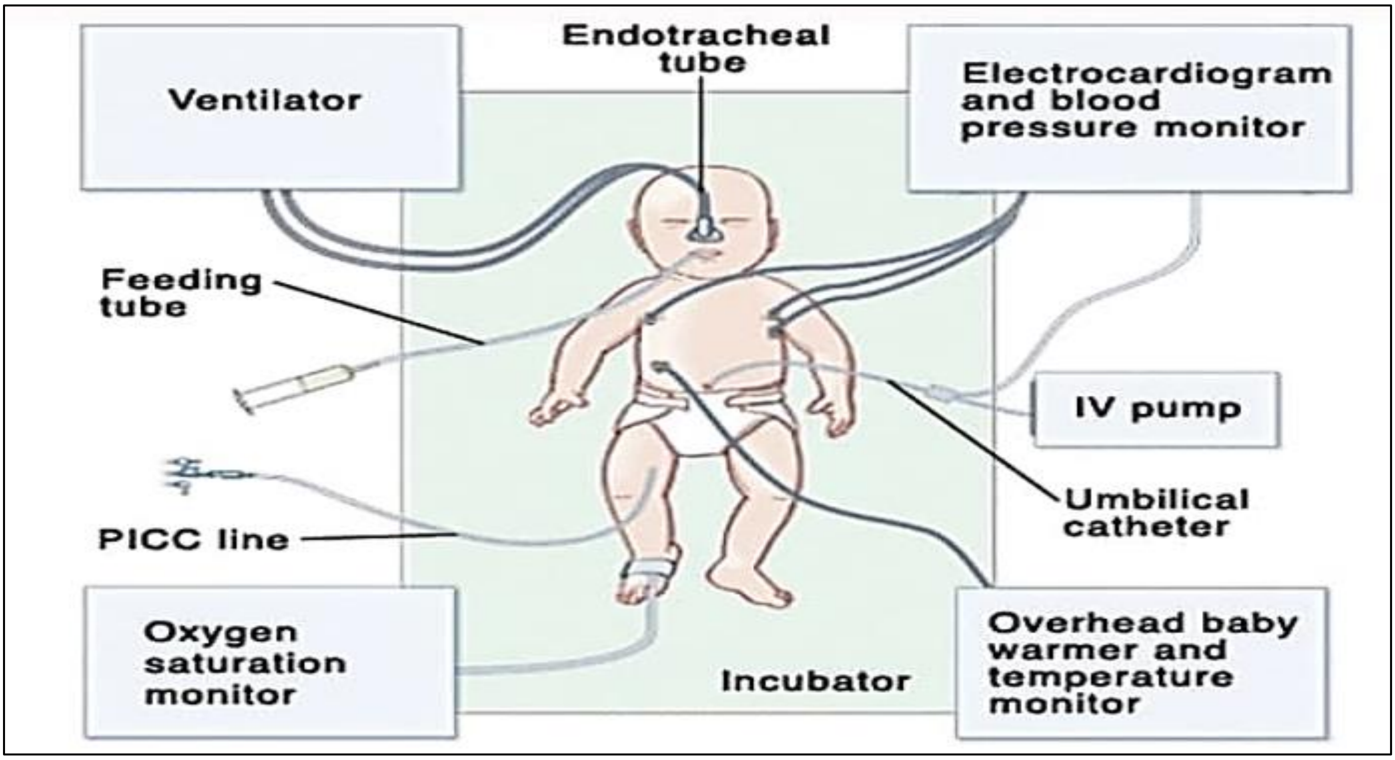

Fig 4: Schematic of Baby Inside the Incubator with all Connections

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➢ *Maintenance*

- Cleaning: Cleaning should be done at least once a week or when every time the patient is changed.
- Disinfection: If used by infected babies, after cleaning, wipe over with a chlorine-releasing agent rinse and dry thoroughly.
- Functional Czhecks: Check the Incubator exterior especially the plexi glass for any signs of damage.

IV. BLOCK DIAGRAM OF THE CONTROL OPERATION

The air inside the incubator is sensed and used to provide the feedback to the system to be turned on or off actuator according to the set point. In the control system shown in figure (5), . The sensor samples the output from the system and transforms it into an electric signal that is sent back to the controller. The controller can make any necessary adjustments to maintain the output where it belongs because it is aware of what the system is actually doing. The forward path signal is sent from the controller to the actuator, and the feedback signal—which "closes" the loop—is sent from the sensor to the controller. The system error is obtained by subtracting the feedback signal from the set point (SP) at the comparator and then deducting the actual output (as reported by the sensor) from the desired output (as specified by the set point). The discrepancy between the intended and actual values is represented by the error signal.

The controller is always working to minimize this error signal. A zero error means that the output is exactly what the set point says it should be. When the actual value below the desired value the controller is turned on the actuator. And the air inside the incubator reaches the desired value the controller is turns off the actuator.

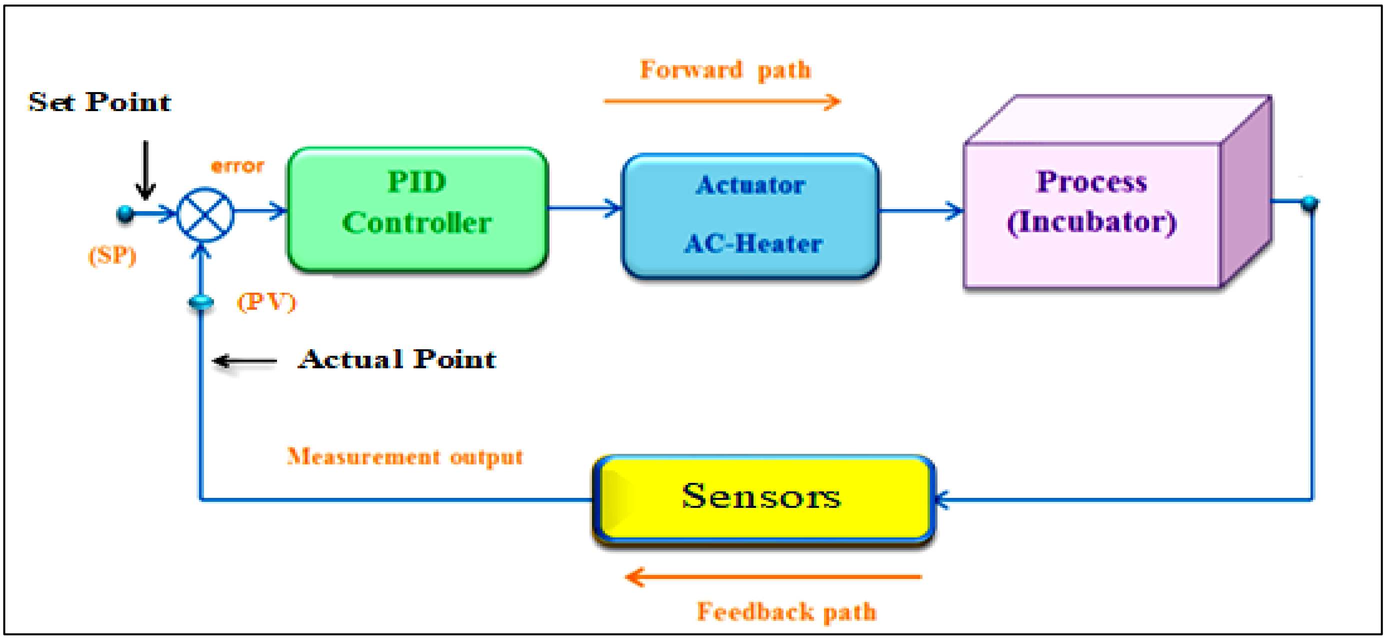

Fig 5: The Control System Operation

V. WHAT ARE THE DIFFERENT TYPES OF CONTROLLERS, AND HOW DO THEY WORK?

PID, proportional, and on-off controllers are the three primary types of controllers. The operator can utilize one type or another to operate the process, depending on the system to be controlled. This Arduino example shows how to create an on-off controller.

➢ *On/Off Control*

The most basic type of temperature control device is an on-off switch. There is no intermediate state in the device's output; it is either on or off. Only when the temperature exceeds the set-point will an on-off controller switch the output. The output for heating control is turned on when the temperature falls below the set-point and turned off when it rises over it. The process temperature will continuously cycle, going from below set-point to above set-point and back below, as the temperature crosses the set-point to alter the output stateTo prevent damage to relays and valves in situations when this cycling happens quickly, the controller actions incorporate an on-off differential, sometimes known as "hysteresis." With this differential, the output won't switch on or off again until the temperature reaches a specific point above the set-point. If the cycling above and below the set-point happens very quickly, the on-off difference keeps the output from "chattering," or making abrupt, continuous shifts. When precise control is not required, on-off control is typically utilized. It can also be used for temperature alarms, in systems that are unable to withstand repeated energy turns on and off, or in situations where the system's mass causes very sluggish temperature changes Limit controllers are one unique kind of on-off control that's employed for alarm. In order to stop a process when a predetermined temperature is achieved, this controller uses a latching relay that needs to be manually reset.[5]

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➢ *Proportional Control*

Based on a response proportionate to the difference between the variable's present value and the desired process variable (also known as the set point), proportional control is a method used in control systems. When stricter tolerances and prompt response are needed for a process variable, proportional control is employed.

➢ *PID Control*

Are the most accurate and stable controller. In industrial control applications, a PID controller is a device that controls temperature, flow, pressure, speed, and other process variables. The most accurate and reliable controllers are PID (proportional integral derivative) controllers, which use a control loop feedback mechanism to control process variables.[6]

If a process variable is measured and a desired set point is set, the PID controller will compute an error value. When the load fluctuates frequently and the controller is expected to automatically adjust because of these variations in set-point, available energy, or mass to be controlled, it is advised for those systems.[5]

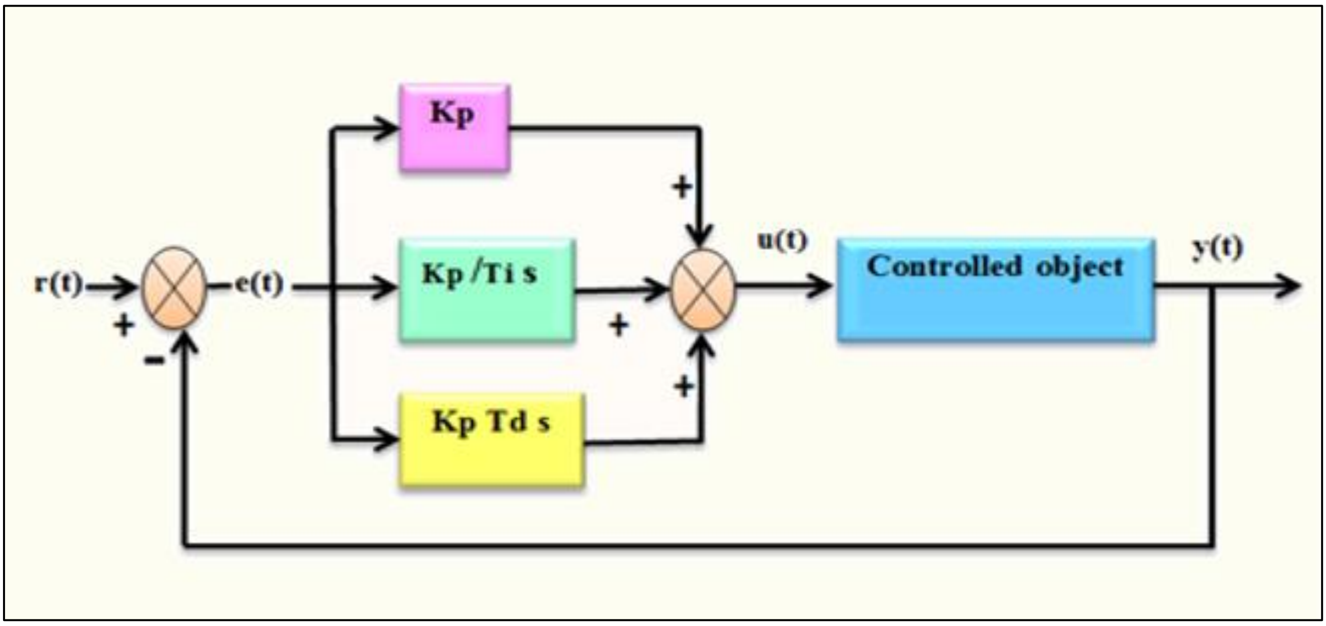

Fig 6: The PID Controller System Structure[11]

VI. FUNDAMENTALS OF TEMPERATURE CONTROL

An essential component of a baby incubator is the temperature control system. In order to keep the temperature in the incubator at the desired level, the right amount of heat energy must be supplied if the temperature drops below that point. This can be accomplished with a straightforward ON/OFF control system that will activate the heater when the outside temperature drops below a predetermined threshold and deactivate it otherwise.[7]

Thermo regulation: The capacity to maintain a normal body temperature in a variety of temperatures and environmental factors is known as thermoregulation. A physiological variable, body temperature is precisely regulated by intricate metabolic processes. The enzyme system that controls cellular activities depends on proper temperature regulation, just as cellular activity depends on a sufficient supply of oxygen. The ideal thermal state required to sustain an organism's internal functions is 37°C, or room temperature. [1]

VII. MODES OF OPERATION FOR BABY INCUBATORS

➢ *Most of the Standards Recommend Two Modes of Operation for Baby Incubators:*

- *Air Temperature Mode.*
- *Baby Skin Mode.*

- Air Temperature Mode: For many years, this mode has been extensively utilized in the nursing care of newborns. The infant is placed inside a Perspex canopy on a mattress. A heater warms the air inside the canopy, and a fan continuously moves air around. The incubator operator adjusts a thermostat that regulates the air temperature inside the canopy. Once the nurse determines that a baby needs care in an incubator, she has to decide on the right air temperature.

Table 1 displays the average temperature required to create a suitable thermal environment for a healthy naked baby being cared for in an incubator.

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Table 1: Average Air Temperature Needed for Healthy Baby

Birth-weight (kg)	35°C	34°C	33°C	32°C
1.0-1.5	For 10 days	After 10 days	After 3 Weeks	After 5 Weeks
1.5-2.0		For 10 days	After 10 days	After 4 Weeks
2.0-2.5		For 2 days	After 2 days	After 3 Weeks
Greater than 2.5			For 2 days	After 2 days

- Baby Skin Temperature Mode: Adhered to the skin of the body, the temperature sensor is a thermistor probe. Because it detects the temperature of the baby's skin rather than the air, the heater heats the air until the skin temperature of the baby is reached. The infant can cool down and vice versa if their skin temperature drops below the predetermined level, which is achieved by lowering the power supplied to the heater and raising the air temperature.

The recommended setting for the temperature of the abdomen in baby skin temperature mode for infants held in an incubator.

Table 2: Baby Skin Temperature

Birth-weight(kg)	Abdominal skin temperature °C
Less than 1.0	36.9°C
1.0-1.5	36.7°C
1.5-2.0	36.5°C
2.0-2.5	36.3°C
Greater than 2.5	36.0°C

FUNDAMENTALS OF HUMIDITY CONTROL SYSTEM

In an incubator, the air is heated from room temperature (20°C) to 35°C, which results in low relative humidity values of less than 20%. Avoiding this is necessary because it causes dehydration throughout the respiratory system. Moreover, air that is humid has a significantly higher capacity to conduct heat, which enhances heat transfer. Additionally, the child cannot lose water due to the humid air. As a result, the air's relative humidity needs to be maintained above 60%.

There are two main methods to humidify the air which are known as [8]:

- Passive humidifying method.
- Active humidifying method.

- Passive humidity control system: A heater is used to create humidity in the passive humidification method. Water evaporation causes the air's humidity content to rise. Given that temperature is one of the incubator chamber's physical control parameters [8].
- Active humidity control system: A humidity sensor in the control system measures the relative humidity of the air, compares it to a reference value, and uses the difference as a control mechanism for the vapor.

> *Practical Part*

- *Components Required:*

✓ Arduino Uno
✓ 16×2 LCD Display
✓ Relay
✓ 1K Resistors Qty. 4
✓ Wires
✓ Serial Protocol
✓ Push Button .2
✓ Bread Board
✓ LEDs
✓ DHT-22 Temperature and humintyed Sensor.
✓ Heater
✓ Fan
✓ Power Supply

- Arduino Uno: A microcontroller board called Arduino/Genuino Uno is built around the ATmega328P (datasheet). It contains a 16 MHz quartz crystal, 6 analog inputs, 14 digital input/output pins (six of which can be used as PWM outputs), a USB port, a power jack, an ICSP header, and a reset button.

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- 16×2 LCD Display: An electronic device that is used to display data . As the name suggests, it includes 16 Columns & 2 Rows so it can display 32 characters (16×2=32) [9].
- Relay: An electrically powered switch is called a relay. It is made up of a set of operating contact terminals and a set of input terminals for one or more control signals. Any number of contacts in any combination of make, break, and other contact forms may be present on the switch. [10].
- Push button: A push-button (also spelled pushbutton) or simply button is a simple switch mechanism to control some aspect of a machine or a process.
- Breadboard: Before completing any circuit design, circuits can be rapidly built and tested using a breadboard. There are numerous holes on the breadboard where resistors and integrated circuits (ICs) can be inserted.
- DHT-22: A simple digital temperature and humidity sensor is the DHT22. It measures the air quality around it using a thermistor and a capacitive humidity sensor before emitting a digital signal on the data pin.
- Leds: LEDs are small, powerful lights that are used in many different applications
- Heater: It is used to heat the ambient air in the incubator.220 v , 370 w , 1.6A.Infant incubator AC-heater.The stored energy is converted by a heater which acts as simple resistor that converts electrical energy into thermal energy.
- Fan:Used to circulate hot air in the surroundings that has been heated by the heater . 12volt
- serial protocol: It speeds up the transmission of instructions, When selecting the set point.

VIII. METHOD

- After bringing the previously mentioned elements, we connected them together with a control circuit for the values with the required function (controlling the temperature inside the incubator).
- We got a damaged incubator cover and took care of it And connect the heater and fan inside the incubator.

Fig 7: The Incubator

- We set the desired point or degree at 37° in control.

Fig 8: The Incubator Heater Operating

- After that, we continue to operate the heater to raise the temperature at the set point while operating the fan through the power supply by setting it from 12 volts with 0.2A amps to circulate the heat inside the incubator.
- The sensor will sense the temperature inside the incubator and transfer it to the display screen.

Fig 9: Green Light Indicates the Required Temperature is Reached

- When the temperature reaches the required point, the relay will cut the circuit, As in the previous figure

IX. RESULTS

The temperature of the incubator before turning on the heater was 26.50 °C, then the heater was turned on at 11:35 Am at 11:37 Am. After two minutes, the temperature became 26.70 °C and the temperature began to increase every two minutes, as shown in the table below until the heater was separated. At 12:00 Pm the temperature has become at the set point.

Where the temperature inside the incubator was maintained for 15 minutes after the heater was separated, and then the temperature inside the incubator began to decrease until it became below the set point, which restarted the heater again.

It was the set point 37 °C , According to the change that occurred every two minutes, we will take a temperature measurement.

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Table 3: Table of Results

NO	Time (m)	Temperature (°C)
1	2	26.70
2	4	27
3	6	27.80
4	8	28.60
5	10	29.70
6	12	30.70
7	14	31.70
8	16	32.80
9	18	33.70
10	20	34.70
11	22	35.70
12	24	36.70
13	26	37.20

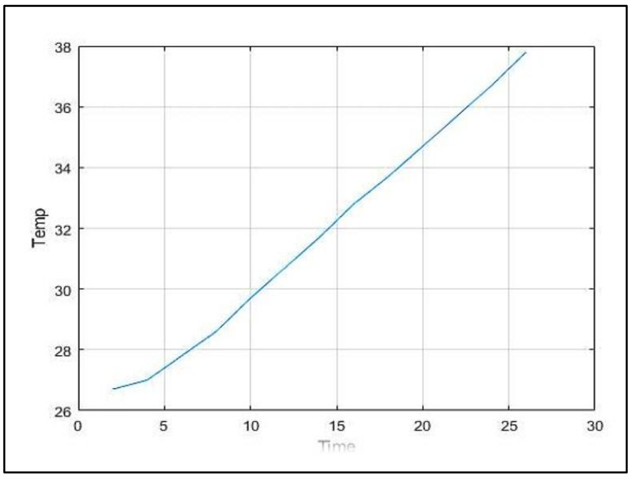

Fig 10: Diagram of the Relationship between Time and Temperature

X. CONCLUSION

We used an incubator that was damaged, so we made some modifications to it and repaired it, and we worked on putting a control circuit outside the incubator so that some of the tools used would not be affected by the temperature. Temperature 37.20 The heater was automatically disconnected from work and the temperature inside the incubator was stable for about 15 minutes and we could have had the temperature stable for more than that, but because of the incomplete insulation well. After the temperature decreased, the cutting circuit was automatically started again, due to the temperature inside the incubator being lower than the required degree until the heater is disconnected faster because it is in a state of heating faster than the start of its operation because it has been heated up .

Frequent power outages are a problem in developing nations like ours, and they must be fixed for the incubator to keep running. To run the incubator in such circumstances, a battery backup has been proposed. An alternative source of the required power is a solar panel. Therefore, the work being done now opens the door to designing and creating a full incubator that has the potential to save lives. An infant incubator that utilizes the Internet of Things is also suggested in order to remotely monitor and regulate the incubator's environment, including humidity and temperature. The outcomes of the experiment demonstrate that this system is capable of managing the intelligent baby incubator system in real-time and with reliability. Based on the analysis, the infant incubator intelligent control system should have a stable and reliable security module. The future work will center on this.

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