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TEMPERATURE CONTROL AND MONITORING OF INCUBATORS USING IOT

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***Abstract*—Temperature plays an important part in our environment. Changes in temperature can affect the behaviour of human beings, plants and even materials such as semiconductors. This project is to control the temperature of a given environment such as baby incubator. Incubators provide warmth and prevent heat loss to significantly improve survival rates. The use of air-heated incubators has been the standard method of providing a stable, individualized thermal environment for the new-born infant at risk. A microcontroller is used to control the temperature in a baby incubator where the temperature had to be kept constant at 36.9 ^{0}C as in mother's womb. The system will function as stated in the programming code of Arduino in order to keep the temperature stable. A simple temperature controller which has least complex circuitry has to be designed so that it saves space and be more reliable for an incubator. Present design which uses microprocessor as main controller in digital signal processing combined with complex combinational logic circuit are redundant and needs to be improved in the sense of functionality. Hence, replacement of microcontroller with an Arduino microcontroller is prudent action due to its efficiency and reliability especially in an incubator where the life of an infant relies on.**

I. INTRODUCTION

Of the four million babies worldwide who die in the first month of life, one million die on their first day. Preterm birth is attributed, either directly or indirectly to at least 25% of neonatal deaths, and low birth weight newborns are at the greatest risk to stay warm .The current recommended method of providing infant temperature regulation in resource settings is Kangaroo Mother Care (KMC), the practice of placing newborns, directly onto the mother's chest .KMC has demonstrated benefits in terms of improved weight gain for preterm infants, earlier hospital discharge higher breast feeding rates. At The same time, KMC has also important limitations:

If the mother either dies in child birth, or is too ill after delivery, mother is unable to provide KMC.

The Majority of mothers have other obligations that prevent them from being able to provide continuous KMC .If no else is provided KMC ,a baby sent home for this care may receive it consistently at best and therefore suffer the complications of hypothermia, including respiratory distress ,acidosis, hypoglycemia, and even death

Skin to skin contact is considered a culturally inappropriate violation of privacy in some areas that rely on KMC

As a consequence at risk newborn babies in developing countries need a warm, clean environment in which to grow stronger. Incubators can help provide millions of at risk infants with shorter hospitals stays and can enable infants who might otherwise have faced a lifetime of severe disability to experience active lives.

1.1 INFANT THERMOREGULATION

Thermoregulation is a critical physiological function that is closely associated with the neonate's survival. Extremely low birth weight infants have efficient thermoregulation due to immaturity and care giver procedures such as umbilical line insertions, intubations and chest x-rays can lead to a heart loss as well. As a result infants may exhibit cold body temperatures after birth and during their first 12 hrs. of life

As a result of a high body surface area to body weight ratio, decreased brown fat stores, non-keratinized skin, and decreased glycogen supply, infants with extremely low birth are particularly susceptible to heat loss immediately after birth. Hypothermia may result in hypoglycemia apnea and metabolic acidosis.

Heat loss can occur infants with extremely low birth weight in following ways:

Conduction: The transfer of energy from the molecules of a body to the molecules of a solid object in contact with body resulting in heat loss.

Convection: The similar loss of thermal energy to an adjacent gas.

Evaporation: Evaporative heat loss is the total heat transfer by energy carrying water molecules from the skin and respiratory tract to the drier environment.

Radiation: Radiant loss is the net rate of heat loss from the body to environmental surfaces not in contact with the body

Extremely preterm infants are especially prone to these losses secondary to the poor barrier provided by their thin, poorly keratinized skin .Normal body temperature is maintained by balancing heat loss and heat gain in a changing movement. Less than 1C separates a baby from cold stress which divert energy away from growth and towards the struggle of body temperature

The Importance of maintaining the temperature of the newborn baby has been known for centuries. Thermal stress has been associated with an increase in morbidity and mortality, making early detection an important part of montaging in sick infants.

The importance of maintaining the temperature of the newborn baby has been known for centuries. Thermal stress has been associated with an increase in morbidity and mortality, making early detection an important part of monitoring in sick infants.

Temperature control is paramount to survival and is typically achieved with use of radiant warmers or doubted walled incubators. Hypothermia has been associated with poor outcome,

including poor outcome including chronic oxygen dependency. Immediately after birth, the infant should be dried and placed on a radiant warmer

II. CONSTRUCTION METHODS

The chamber of the infant incubator is transparent. The chamber has two compartments a larger and smaller compartment. The smaller compartment Consist of the temperature controlling unit and the larger compartment consist of the mattress where the infant is kept. The Chamber is constructed in such a way that the baby is kept away from the temperature controlling part so the baby is assured to be safe. The entire chamber is constructed using Acrylic Sheets. Acrylic is chosen becz it is more advantageous over Glass and Plastic.

2.1 ACRYLIC SHEET

Cast acrylic sheet is a material with unique physical properties and performance charecteristics.It weighs half as much as the finest optical glass, yet it is equal to it in clarity and is up to 17 times more impact resistant. Cast Acrylic sheet is made in over 250 colors, in thickness from .030'' to 4.25'' and can transmit ultraviolet light or filter it out as required.

Aircraft manufacturers use cast acrylic sheets in jets and helicopters. Because of its light and energy transmission properties architects find cast acrylic sheet ideal for skylights, sun screens and dome structures. a)

2.1.1 Expansion and Contraction

Cast acrylic sheet responds to temperature changes by expanding or contracting at a far greater rate than glass.

2.1.2 Flexibility b)

Cast acrylic sheet is more flexible than glass or many other building materials.

2.1.3 Chemical Resistance

Cast acrylic sheet has excellent resistance to attack by many chemicals. It is affected, in varying countries by benzene, toluene, carbon tetrachloride, ethyl, and methyl alcohol, lacquer thinners, ethers, ketones and esters.

2.1.4 Electrical Properties

Cast Acrylic Sheet is an excellent Insulator.

2.1.5 Light Transmission

Colorless cast acrylic sheet has a light transmittance of 92%.It is clearer than window glass and will not turn yellow. Cast Acrylic sheet is also available in a large variety of transparent and translucent colors

2.1.6 UV Light Resistance

Clear Acrylic sheet resists ultraviolet light degradation. Each acrylic sheet has a ten year Limited warranty against yellowing and light transmission.

2.1.7 Optical Clarity

Acrylic Sheets have excellent light transmission. Clearer then glass. Will not yellow after prolonged sun exposure.

2.1.8 Weather Resistance

Despite Heat, cold, sunlight, and humidity acrylic sheets maintain its original appearance and color.

2.1.9 Safety

Shatter-resistance, earthquake safe and burglar resistance.

2.1.10 Light Weight

Even With its Strength and durability, acrylic sheet is only half the weight of glass.

2.2 COMPARTMENT DESCRIPTION

2.2.1 Compartment A

The compartment A consists of the temp controlling unit which holds a heating and cooling system.

The compartment A is again divided into two sections:

2.2.1.1 Heating Unit

It consists of a 100watts bulb which is controlled by an aurduino microcontroller. The bulb is given 120V using a step down transformer so that the baby is safe .A fan which is continuously working is placed in front of the bulb with an opening to the compartment B in such a way that the warm air is forced towards the Compartment B.

2.2.1.2 Cooling Unit It consists of an aluminum vessel filled with ice.This unit is aimed to cool the system when the temperature goes beyond 37 Celsius. A reliable opening is made between the ice box and the compartment B to help cooling of compartment B. Even the fan in the heating unit also helps in cooling .The Heating unit and the cooling unit work in such a way that the temperature in the compartment B is maintained as a constant temperature.

2.2.2 Compartment B

It consists of a mattress where the infant is kept. It is Provided with super Ventilation .The chamber is provided with doors one on the top and other in front , so that the chamber can be opened and closed according to the convenience over the take care.

III. TEMPERATURE SENSING AND CONTROL

The temperature in the chamber need to sensed and read before controlling it. A sensor is placed in the compartment B where the baby is kept and the sensed temperature is given to the Aurduino Uno microcontroller.

3.1 SENSING THE TEMPERATURE

The temperature is sensed using a Thermistor.

3.1.1 Thermistor

Thermistor is inexpensive, easily obtainable temperature sensors. They are easy to use and adaptable. They respond quickly. Circuits with Thermistors can have reasonable out voltages not the millivolt outputs thermocouples have. Because of these qualities, thermistors are widely used for simple temperature measurements. They are not used for high temperatures, but in the temperature ranges where they work they are widely used. Thermistors are temperature sensitive resistors. All resistors vary with temperature, but thermistors are constructed of semiconductors material with a resistivity that is especially sensitive to temperature. However, unlike most other resistive devices, the resistance of a thermistor decreases with increasing temperature. That's due to the properties of the semiconductor material that the thermistor is made for some, that may be counterintuitive, but it is correct. Here is a graph of resistance as a function of temperature. That's due to the properties of the semiconductor material that the thermistor is made from.

For some that may be counterintuitive, but it is correct. Here is a graph of resistance as function as a function of temperature for a

typical thermistor. Notice how the resistance drops from100 kW to a very small value in a range around room temperature.

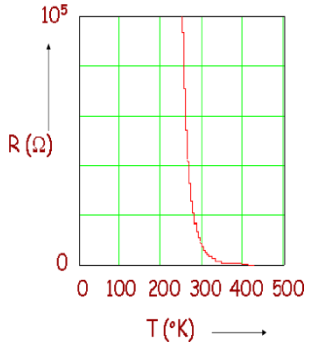

Figure 4.2 Resistance Characteristics with temperature

3.2 Reading the Temperature

The temperature sensed by the Thermistor is given to Aurduino Uno which is connected to a laptop/charger. A program is written and uploaded to the Aurduino which makes the temperature to be displayed on the monitor in volts i.e., volts equal to 31 Celsius, 3.1 Volts equal to 32 Celsius and so on. The programming part is discussed in upcoming unit.

The connections given to Aurduino Uno is shown below

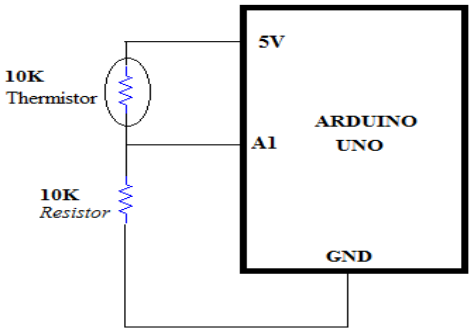

Figure 4.3 Circuit for temperature Sensing

3.3 TEMPRATURE CONTROL

Aurduino Uno is controller used here. The program is written to control the bulb. When the Temperature in the chamber falls down below 37 Celsius the bulb glows and whenever the temperature in the chamber goes beyond 37 Celsius the bulb automatically switch off. An icebox placed in the compartment a helps in cooling the chamber if the temperature goes beyond the temperature.

The circuit is given below:

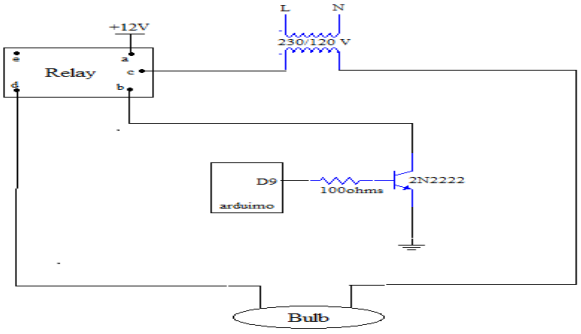

figure 4.4 Circuit for Temperature control

The Relay here acts as a switch and 12V DC supply is given to relay .TheStep down transformer here transforms the 230V power supply to 120V.

3.3.1 Relay

A relay is an electrically operated switch .Many relays use an electromagnet to operate a switching mechanism mechanically, but other operating principles are also used. Relays are used where it is necessary to control a circuit by a low power signal or where several circuits must be controlled by one signal. The First relays were used in long distance telegraph circuits, repeating the signal coming from one circuit and re-transmitting it to another. Relays where used extensively in telephone exchanges and early computers to perform logical operations.

3.3.1.1 Basic Design and operation

A simple electromagnetic relay consists of a coil of wire wrapped around a soft iron core, an iron yoke which provides a low reluctance path for magnetic flux, a movable iron armature .The armature is hinged to the yoke and mechanically linked to one or more sets of moving contacts. It is held in place by a spring so that when the relay is de energized there is an air gap in the magnetic circuit. In this condition One of the two sets of contacts in the relay picture is closed and the other set is option .The relay in the picture also has a wire connecting the armature to the yoke .This ensures continuity of the circuit between the moving contacts on the armature, and the circuit track on the printed circuit board via the yoke, which is soldered to the PCB When the coil is energized with direct current , a diode is often placed across the coil to dissipate the energy from the collapsing magnetic field at deactivation, which would otherwise generate a voltage spike dangerous to semiconductor circuit components .Some automotive relays include diode inside the relay case .Alternatively a contact person network consisting of capacitor and resistor in series may absorb the surge. If the coil is designed to be energized with AC current a small copper “shading ring” can be crimped to the end of the solenoid creating a small out of phase current which increases the minimum pull on the armature during AC cycle.

3.3.2 Power supply +12Volts

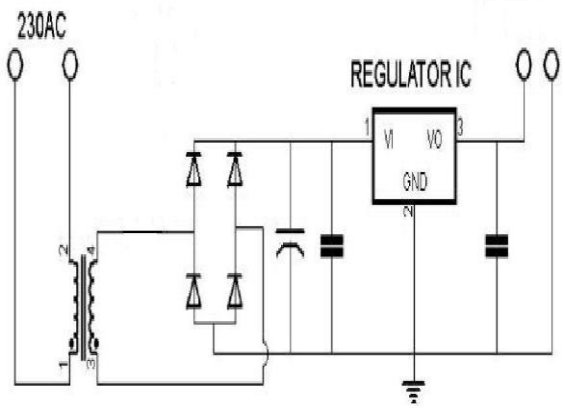

Figure 4.5 DC power Supply + 12 volts circuit

For the operation of relays 12V DC supply is required to excite them .So there is a need of 12V DC power supply. This can get from the circuit shown in Fig 4.5.The main components of this circuit are, a 230 to (18-0-18) step down transformer, bridge rectifier, capacitors, and voltage regulator (LM7812).

3.3.2.1 Center tapped transformer

In electronics, a center tap is a contact made to a point halfway along a winding of a transformer or inductor, or along the element of a resistor or a potentiometer. Taps are sometimes used on inductors for the coupling of signals, and may not necessarily be at the half way point, but rather, closer to one end .A common application of this is in the Hartley oscillator. Inductors with taps also permit the transformation of the amplitude of Alternating Current voltages for the purpose of power conversion, in which case, they are referred to as autotransformers, since there is only one winding. When a center tapped transformers is combined with a four diode type bridge rectifier, it is possible to reduce a positive and negative voltage with respect to a ground at the tap. Dual voltage supplies are important for all sorts of electronics equipment. In early vacuum tube audio amplifiers, it was sometimes used as the phase invertor to drive the two output tubes of a push pull stage. Furthermore as designers acquired more experience with transistors, they stopped trying to treat them like tubes. Coupling a class A intermediate amplification stage to a class AB power stage using a transformer doesn't make sense anymore even in small systems powered from a single voltage supply. Modern higher end equipment is based on dual supply packages which eliminates coupling. In vacuum tube amplifiers center tapped transformer is used to couple a push pull output stage to the speaker. The microphone center tapped rectifiers are preferred to the full bridge rectifier when the output DC current is high and the output voltage is low. Phantom power can be supplied to a condenser microphone using center tapped transformers.

One Method called "direct center tap" uses two center tapped transformers, one at the microphone body one at the microphone preamp. Filtered Dc voltage is connected to the microphone preamp center tap, and the microphone body center tap is grounded through the cable shield .The second method uses the same center tap transformer topology at the microphone body, but at the microphone preamp, a matched pair of resistors spanning the signal lines in series creates an "artificial center tap".

3.3.2.2 Volts center Tapped

Volts center tapped describes the voltage output of a center tapped transformer. For e.g. A 24 VCT transformer will measure 24VAC across the outer two taps, and 12 VAC from each outer tap to the center tap. These two 12 VAC supplies are 180 degrees out of phase with each other , thus making it easy to derive positive and negative 12 volt DC power supplies from them.

3.3.2.3 Linear Regulator

In electronics a linear regulator is a system used to maintain a steady voltage. The resistance of the regulator varies in accordance with the load resulting in a constant output voltage. By contrast a switching regulator uses an active advice that switches on and off to maintain an average value of output. Because the regulated voltage of a linear regulator must always be lower than input voltage , efficiency is limited and the input voltage must be high enough to always allow the active device to drop some voltage .

Linear regulators exist in two basic forms:

a) Series regulators
b) Shunt regulators

Series regulators are the more common form. The series regular works by providing a path from the supply voltage to the load through a variable resistance. The power dissipated by the regulating device is equal to the power supply current times the voltage drops in the regulating device.The Shunt regulators works by providing a path from the supply voltage to ground through a variable resistance .The current through the shunt regulator is diverted away from the load and flows uselessly to ground, making this from even less efficient then the series regulator. It is , however, simpler , sometimes consisting of just a voltage reference diode, and is used in very low powered circuits where the wasted current is too small to be of concern . This form is very common for voltage reference circuit.

All liner regulators require an input voltage at least some minimum higher than the desired output voltage. That minimum amount is called the Dropout voltage. A common regulator such as the 7805 has an output voltage of 5V,but it can only maintain this if the input voltage remain above about 7V before the output voltage begins sagging below the rated output .Its dropout voltage is therefore 7V-5V = 2V.when the supply voltage is less than about 2V above the desired output voltage , as is the case in low voltage microprocessor power supplies , so called Low Dropout Regulator (LDOs) must be used .

When the output regulated voltage must be higher than the available input voltage, no linear regulator will work.

3.3.2.4 Step Transformer

Step down transformer is one whose secondary voltage is less than its primary voltage. It is designed to reduce the voltage from the primary winding to the secondary winding .This kind of transformer "Steps down" the voltage applied to it.

As a step down unit, the transformer converts high voltage, low current power into low-voltage high current power. The larger-gauge wire used in the secondary winding is necessary due to the increase in current. The primary winding, which doesn't

have to conduct as much current, may be made of smaller gauge wire.

3.3.2.5 Step-down transformer consideration

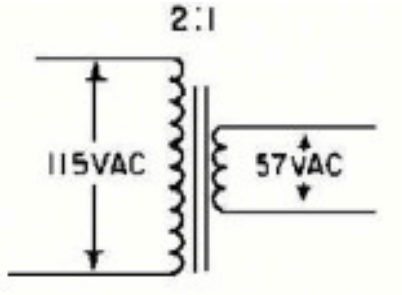

Figure 4.6 Step down transformer

It is possible to operate either of these transformer types backwards to perform the opposite function a step up can function as a step down and vice versa. One convention used in the electric power industry is the use of "H" designations for the higher voltage winding and "X" designations for the lower voltage winding.

3.3.3 Aurduino Uno kit

Aurduino is an open source electronics prototyping platform based on flexible, easy to use hardware and software. It's intended for artist, designers, hobbyists, and anyone interested in creating interactive objects or environments.

Aurduino can sense the environment by receiving input from a variety of sensors and can affect its surroundings by controlling lights, motors and other actuators. The microcontroller on the board is programmed using the Aurduino programming language (based on wiring) and the Aurduino development environment (based on Processing). Aurduino projects can be stand alone or they can communicate with software running on a computer (e.g. Flash, Processing and Max MSP)

Aurduino boards can be purchased pre-assembled or do it oneself kits. Hardware design information is available for those who would like to assemble an Aurduino by hand. There are 16 officials Aurduino that have been commercially produced to date.

The Aurduino is a microcontroller board based on AT mega 328 (datasheet). It has 14 digital input/output pins (of which 16 can be used as PWM outputs), 6 analog inputs, a 16MHz ceramic resonator, a USB connection, a power jacket, an ICSP header, and a reset button. It contains everything needed to support the microcontroller simply connect it to a computer with a USB cable or power it with an AC to DC adapter or battery to get started

The Uno differs from all preceding boards in that it does not use the FTDI USB to serial driver chip. Instead, it features the Atmegal16U2 (Atmegal8U2 up to version R2) programmed as a USB-to-serial convertor. Revision 2 of the Uno board has a resistor pulling the 8U2 HWB line to ground, making it easier to put into DFU mode. Revision 3 of the board has the following new features.

●1.0 pin out: added SDA and SCL pins that are near to the AREF pin and two other new pins placed near to the RESET pin, the IOREF that allow the shields to adapt to the voltage provided from the board. In future, shields will be compatible both with the board that uses the AVR, which operate with 5V and with the Aurduino Uno that operate with 3.3V. The second one is a not connected pin that is reserved for future purposes.

- Stronger RESET circuit.
- at mega 16U2 replace the 8U2.

The Aurduino Uno can be powered via the USB connection or with an external power supply. The power source is selected automatically. External (non-USB) power can come either from an AC-to-DC adapter (wall-wart) or battery. The adapter can be connected by plugging a 2.1mm center-positive plug into the board's power jack. Leads from a battery can be inserted in the Ground and V_{in} pin headers of the POWER connector.

Power

The board can operate on an external supply of 6 to 20 volts. If supplied with less than 7V, however, the 5V pin may supply less than five volts and the board may be unstable. If using more than 12V, the voltage regulator may overheat and damage the board. The recommended range is 7 to 12 volts. The power pins are as follows:

- **VIN:** The input voltage to the Aurduino board when it's using an external power source(as opposed to 5 volts from the USB connection or other regulated power source). You can supply voltage through this pin, or, if supplying voltage via the power jack, access it through the pin.
- **5V:** This pin outputs a regulated 5V from the regulator on the board. The board can besupplied with power either from the DC power jack (7 - 12V), the USB connector (5V), or the VIN pin of the board (7-12V). Supplying voltage via the 5V or 3.3V pins bypasses the regulator, and can damage your board. We don't advise it.
- **3V3:** A 3.3 volt supply generated by the on-board regulator. Maximum current draw is50mA.
- **GND.** Ground pins.

Memory

The ATmega328 has 32 kb (with 0.5 kb used for the boot loader). It also has 2 kb of SRAM and 1 kb of EEPROM (which can be read and written with the EEPROM library).

Input and Output

Each of the 14 digital pins on the Uno can be used as an input or output, using pin Mode, digital Write, and digital Read functions. They operate at 5 volts. Each pin can provide or receive a maximum of 40mA and has an internal pull up resistor (disconnected by default) of 20-50 K ohms. In addition, some pins have specialized functions:

- **Serial: 0 (RX) and 1 (TX).** Used to receive (RX) and transmit (TX) TTL serial data.These pins are connected to the corresponding pins of the ATmega8U2 USB-to-TTL Serial chip.
- **External Interrupts: 2 and 3.** These pins can be configured to trigger an interrupt on a low value, a rising or falling edge, or a change in value. See the attach interrupt () function for details.
- **PWM: 3, 5, 6, 9, 10, and 11.** Provide 8-bit PWM output with the analog Write function.
- **SPI: 10(SS), 11(MOSI), 12(MISO) and 13(SCK).** These pins support SPIcommunication using the SPI library.
- **LED: 13.** There is a built in LED connected to digital pin 13. When the pin is HIGHvalue, the LED is on, when the pin is LOW, it's off.

IV. PROGRAM FOR TEMPERATURE READING AND CONTROL

The program for the temperature control using Aurduino is given as follows:

```
Void step ( )
{
Serial. Begin (9600)
Pin MODE (A1, INPUT);
Pin MODE (7, OUTPUT);
}
Void loop ( )
{
Float x/=analog Read (A1);
Float v=x*5;
Float v1=v/1023;
If (v1/1023);
If (v1>3.7)
Digital write (7, LOW);
Serial.println (v1);
}
```

V. CONCLUSION

The project is developed keeping in mind the medical conditions available in rural areas. This Equipment can be effectively used by technicians in a small health care Centre. It can be lifesaving machine for low birth weight infants. The component can be easily fixed.

The chamber is sufficient enough to accommodate the baby comfortably. As the electronic part is separated from the compartment the baby is kept the baby can be assured safe. The Aurduino Uno microcontroller used here is efficient in controlling the temperature of the system. The temperature of the system can be understood from readings on the monitor.

The project is simple and efficient in maintaining the temperature of the chamber irrespective of the outside temperature and is designed at a low cost.

VI. FUTURE ENHANCEMENTS

We can incorporate the of pettier effect to control the temperature of the chamber. They can be used either for cooling (refrigeration), although in practice the main application is cooling. It can be also be used as temperature controller that either heats or cools. But pettier elements are costly and show poor power efficiency. Many researcher's and companies are trying to develop pettier cooler's that are both cheap and effiencient.If such type of pettier elements are developed we can also introduce it in Infant incubators.

For Infants affected with Jaundice bile lights can be introduced in to the chamber. Apnea monitoring can also be introduced for infants affected with respiratory disorders.

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