1.0 Introduction

Multiple foetuses from single pregnancy (multigravida) often times result to premature births requiring urgent controllable environment that resemble maternal uterine condition [1]. Preterm birth defines babies born alive before 37 weeks of gestation [2], informing that such babies have less uterinal life resulting to underdevelopment and low weight [3]. Therefore, preterm babies are usually have low birth weight (LBW) which demands special neonatal care in the intensive care unit (NICU). Therefore advanced careful monitoring of a new born baby in an incubator which the environmental condition is for specific period will facilitate time for home onward [4].

Multiple births are associated with high risk of prematurity and low birth weight. Considered average recommended safe length of gestation period in triplet is within 33 weeks for infants which weighs are within range of 1,800 grams (4 pounds). Consequent development and maturation required is achieved through monitoring in vitro nursing in an incubator [5]. Other associate problems with preterm babies are mostly environmental factored. These include; the risk of hypothermia, immaturity of vital organs and inability to access enough conducive atmospheric oxygen for lung expansion and body haemostasis. Triplets are most endangered and death results frequently than expected when no cautioned attention is engendered. Therefore any additional regulation given to in vitro implanted infant
(Incubation) takes into consideration maintenance of the micro-environment temperature amidst humid atmosphere that allows ambient oxygen delivery and exhaustion of expired air out of the compartment. Observations made so far reveal that every hour, about 340 preterm birth babies dies in their first week of birth, and asphyxia has been incriminated the second cause of preterm deaths [6].

A baby incubator is a biomedical device designed with the capability to produce warmth, humidity and regulate the quantity of input oxygen into a preterm new born baby chamber for optimal condition comparable to that of mother [7]. The device keeps the premature neonate warm by allowing the flow of heated moist air through a sterilized channel surrounding the baby chamber through conduction process thereby, maintaining mother womb core temperature of (36.5°C-37°C) and humidity range of 70%–100% [8]. Incubators are usually designed for an isolated area that is entirely devoid of all kinds of contaminants and are monitored by specialized staff [9], and the first modern baby incubator was invention by Dr. Alexander Lyon. Before then, in 1883, Dr. Trainer and his intern Auvard developed a low tech version of incubator with a two tiered sawdust insulated box which is often heated by removable clay hot water bottles. This type of device was because of its success was massively produced, and it became the most popular model until late 1890s. When Dr. Lyon’s incubator remained the most advanced among the incubators exhibited, it is because definite design inclusion of thermostat which is ventilated from outside was added [10]. Further advances followed engineering efforts as recorded in 1898 of the first American incubator hospital at the trans-Mississippi exposition in Omaha [11]. Giant stride became obvious and demanding as more than ninety percent of triplets births are born preterm and with their weights less than 1500grams or 3ponds. Immediate intervention was advances in the neonatal intensive care unit (NICU) where baby incubators which were deployed with customary oxygen delivery mechanism to avoid possible cyanosis [12]. At some regions, particularly in Africa, the story has not been positively the same till late 1960s and early 1980s when demands for triplet incubator for a single pre-term infant became a major challenge. Power situation within West African region worsen usage and design advances till now.

Triplet incubator is equipment for thermo-regulation of triplet premature infants in vitro. Such triplet baby incubator is a biomedical engineered artificial womb with three baby compartments that houses preterm neonates, applicable immediately after birth to provide controlled temperature, humid air with exhaustive principle and with phototherapy light [9]. The introduction of double and triple baby incubator becomes an extremely important part in neonatal care section of hospitals and birthing centres because of obvious reasons. Further technological modifications have been to ease burden on Nurses, Mothers, installation space and solving the problem associated with power challenges.

Recently, a wide variety of incubators have become available to the paediatrician, but there is little information concerning the attributes or deficiencies of the several types [13]. Thus, triplets new born always have issues with space for incubation in hospitals, birth centres and maternity wards. Some hospitals hardly afford two or more incubators due to the cost of a standard incubator which is a viable and feasible project and the standard incubator is made for only singleton making it impossible to accommodate triplet. This always leads to high infant mortality, and is necessary to stop the mayhem through the design and fabrication of triplet baby incubator compatible with our nascent community. From the forgoing, triplet birth can be an exciting and challenging experience for a family [14].

2.0 Materials and Methods

The design and fabrication of baby incubator requires understanding of the numerous engineering principles tailored toward the appropriation of safety measures to galvanized functionality as desired. Design principles should factor in electrical conduits to service the chosen electronics circuits in uniformity, while delivery the needed physical agents for the micro-environment. Consequently fabrication should provide the detailed robust compartmental entities that are structured to minimize usurping of space hence compact built.
2.1. Sourcing and Principles of material selection for triplet baby incubator

The materials sourced and obtained were such that graded for basic engineering principles having taken into consideration the installation environment, safety, actuation, finishing lustre and durability among others. The materials were as listed in table, 1 and the descriptive uses informed. Also the design concept traced in the resolution of risk factors associated with multiple personnel usage, cost effectiveness and maintenance. Other reasons for consideration and selection of materials include compatibility with the incubator parameters (reduces heat loss in the system). The materials were locally sourced as they were readily available, affordable, and durable providing ease to yield quality equipment.

<table>
<thead>
<tr>
<th>S/N</th>
<th>Materials</th>
<th>Specification</th>
<th>Source</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Glass Perspex</td>
<td>5mm</td>
<td>Aluminium store</td>
<td>Transparent protective coverage of the chamber</td>
</tr>
<tr>
<td>2.</td>
<td>Angle Brackets</td>
<td>Aluminium</td>
<td>Aluminium store</td>
<td>Used to hold together the boards</td>
</tr>
<tr>
<td>3.</td>
<td>Mattresses</td>
<td>Foams</td>
<td>Furniture store</td>
<td>Babies sleep comfortably on the foams</td>
</tr>
<tr>
<td>4.</td>
<td>Temperature</td>
<td>Thermocouple,</td>
<td>DHT 11, and Arduino</td>
<td>More accurate and automated functions</td>
</tr>
<tr>
<td>5.</td>
<td>Fan</td>
<td>Dc fan</td>
<td>Electronic store</td>
<td>It blows the hot air and circulates it into the</td>
</tr>
<tr>
<td>6.</td>
<td>Iron steel</td>
<td>10inches length</td>
<td>Welding market</td>
<td>Is the stand of the baby incubator</td>
</tr>
<tr>
<td>7.</td>
<td>Epoxy adhesive</td>
<td>super glue</td>
<td>Art/craft shop</td>
<td>The bound is used to join perspex and board together.</td>
</tr>
<tr>
<td>8.</td>
<td>Screws</td>
<td>0.5inches screw</td>
<td>Timber market</td>
<td>To screw together Aluco Board &amp; Persplex glass.</td>
</tr>
<tr>
<td>9.</td>
<td>Distilled water</td>
<td>Stainless</td>
<td>Pharmaceutical</td>
<td>It is the water reservoir use to store water for humidification</td>
</tr>
<tr>
<td>10.</td>
<td>Heater</td>
<td>150watt, 220v</td>
<td>Electronics store</td>
<td>It is used to generate warm air</td>
</tr>
<tr>
<td>11.</td>
<td>Screen</td>
<td>16 by 2 LCD</td>
<td>Electronics store</td>
<td>It is used to display the reading in digital mode</td>
</tr>
<tr>
<td>12.</td>
<td>Drip stand with</td>
<td>Galvanized iron</td>
<td></td>
<td>For hanging of drips</td>
</tr>
<tr>
<td>13.</td>
<td>Alarm</td>
<td>Black squared shape</td>
<td>Electronic shop</td>
<td>It gives audible sound to alert the care giver.</td>
</tr>
<tr>
<td>14.</td>
<td>Transformer</td>
<td>12v stepdown</td>
<td>Electronic shop</td>
<td>Used to step down the voltage</td>
</tr>
</tbody>
</table>

Table 1: Materials used for design and fabrication of triplet baby’s incubator

2.3. Principle of Structural Development of Triplet Baby Incubator

The entire hood of the incubator was fabricated with Perspex and alumco board because of the strength desired, ease of foliage, and less density of range of $1100 – 1200\, \text{kg/m}^3$ (while glass is of density range $2420 – 2790\, \text{kg/m}^3$) [15]. Firstly, in building the main chamber cabinet alumco board with thickness of 5mm board was measured with meter rule and 25cm sawed into a length of 46cm. Secondly the structural frame work was erected with alumco board by cutting the required measurement of alumco board with hand saw, filed with sand paper, and then screwed together with angle brackets. Consequently, handrails were use in joining them together from back to the sides. The rectangular base was partitioned with alumco board 14cm each for baby space.

The compartments were made all through with transparent Perspex on the top and front sides for individual parents and nursing teams easy access of monitoring the infants and clear observatory physical performance of the infants from a distance. For sufficient contact with individual baby, 3 doors and a central access door at the top were provided to give cabinet perimeters of 120cm x 50cm x 46cm (L x B x H). The 2mm Perspex used for lining the sliding doors to the upper and lower edges
served as pillar that held the edges together. The door handles were bond with heat from gas flames and same glued to the door with adhesive bond. Underneath the hood is the base which was partitioned into two sections; the control unit section which houses the heat exchanger and the other all electrical components needed for functionality of the incubator.

The drawer sections were made from alumco board and stainless knob handles were attached, for individual baby drugs and belongings keep away from sight. Baby mattresses were of thickness 2cm and the coverings selected from fine liner cotton fabrics were hand sown to soft comfortable. Hospital paint, white and blue was applied. A total number of 22 metal and 9 plastic brackets were forged and used to structure the incubator to wholeness.

Pneumatic activity within the microenvironment is governed by size in perimeter of each compartment as against the humid warm air and to the room where incubator is installed. Therefore gas exchange between baby and cabin chamber is facilitated by exchange rate within installation room. Advisably, less visits or reduced number of adult persons in the room is for better respiratory gaseous exchange rate to the normal oxygen delivery to the babies in the triplet incubator. Considered and registered was principle of air flow through dispersion via conduction and convention when room temperature increases and when baby cabin chamber is compensatory normal. Hence respiration and control by baby rests on sealing off Leaksages and allowing airy vents for cross ventilation.

2.3.1 The Electrical Chamber
This section is underneath the base of the incubator hood and is the engine room of the baby incubator. The alumco board was used to cover this section where all the electrical components such as fan, water humidifier and the PVC pipes were housed. The compartment has an opening for ventilation (the inlet of fresh air in the electrical chamber) and a sliding open for water tank filing behind the hood. Through the opening (water inlet vent) distilled water is delivered into the tank for humidification of baby cabin chamber. The stand is made of galvanized and angle bar iron fabricated in a rectangular shape, where the base of the incubator is rested firmly. The four legs are welded support with small rolling tyres attached to it for easy mobility.

2.3.2 Device Design
The device circuit was designed and simulated on Proteus 8 (figure 1). The circuit was physically simulated on a breadboard, and then printed on circuit boards. The solar power was design to produce 1000watts, 220V by using the relationship between solar cells and output power. The device is designed to have a control system, which is a microcontroller. Gentle Press on the power button enables the system to come on with a welcome message display on the LCD and subsequently show cabin chamber temperature of the incubator. Expected operational temperature is selected through pressing of buttons at the keypad and to the command is displayed on the LCD.

If the Cabin chamber temperature of the incubator is lower than the temperature set by the nurse, the microcontroller senses it and signal to heat generation unit for increase in temperature of the

![Prototype of side views and integrated structure in the fabrication of triplet baby incubator](image-url)
baby cabin chamber. The heating elements generate the heat while the fan blows in warm moisture air through vent to circulate within the baby cabin chamber. The temperature sensor continuously measures the temperature of the baby cabin chamber. Once the temperature of the baby chamber reaches the set temperature, the microcontroller puts a signal to automatically stop further generation of heat. This maintains the temperature of the baby chamber. If the temperature of the baby chamber is increasing beyond set temperature, buzzer goes ring and the microcontroller puts signal for automatic enabling of only cooling fan to blow off hot so that cabin chamber temperature falls.

There is a time lapse structure from the time the microcontroller puts signal for heat generation unit enabling to the time the baby chamber attains the set temperature, and initial temperature of the baby chamber influences the time lapse. The closer the initial temperature to the set temperature, the faster the set temperature is attained.

**Table 2. Showing Time versus Temperature**

<table>
<thead>
<tr>
<th>S/N</th>
<th>Time (Mins)</th>
<th>Temperature (Degrees)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>24.1</td>
</tr>
<tr>
<td>2</td>
<td>5</td>
<td>26.3</td>
</tr>
<tr>
<td>3</td>
<td>10</td>
<td>28.3</td>
</tr>
<tr>
<td>4</td>
<td>15</td>
<td>30.1</td>
</tr>
<tr>
<td>5</td>
<td>20</td>
<td>32.4</td>
</tr>
<tr>
<td>6</td>
<td>25</td>
<td>34.6</td>
</tr>
<tr>
<td>7</td>
<td>30</td>
<td>36.0</td>
</tr>
<tr>
<td>8</td>
<td>35</td>
<td>37.0</td>
</tr>
<tr>
<td>9</td>
<td>40</td>
<td>36.4</td>
</tr>
<tr>
<td>10</td>
<td>45</td>
<td>37.0</td>
</tr>
<tr>
<td>11</td>
<td>50</td>
<td>36.8</td>
</tr>
</tbody>
</table>

**Table 3. Showing Water Temp. Vs Humidity**

<table>
<thead>
<tr>
<th>S/N</th>
<th>Temperature of Water (°C)</th>
<th>Humidity (%RH)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>28</td>
<td>47</td>
</tr>
<tr>
<td>2</td>
<td>30</td>
<td>53</td>
</tr>
<tr>
<td>3</td>
<td>32</td>
<td>61</td>
</tr>
<tr>
<td>4</td>
<td>34</td>
<td>78</td>
</tr>
<tr>
<td>5</td>
<td>36</td>
<td>32.4</td>
</tr>
<tr>
<td>6</td>
<td>38</td>
<td>86</td>
</tr>
</tbody>
</table>

**Figure 2: Circuit diagram of designed triplet baby incubator with renewable source**

2.3.3 Power Unit

The system power supply is from the national grid/EEDC as well as from an inverter. Power is supplied from the National grid or when the triplet incubator is installed at local area devoid of national grid, supply will be from the inverter source to a standby battery which powers the system to continue operation. The incubator system has a transformer which steps down the A.C rectified and filtered to 12v DC. A 7805 regulator is used to ensure +5v supply to the microcontroller while a 7812 regulator is used to ensure +12v for the fan and relay.

The first part of the power unit is the solar-inverter supply, which produces a power output of 1000watts, 220V. The second part of the power unit has transformer, voltage regulator (7812 and 7085), bridge diode, resistors (10K), and capacitor (2200μF). It steps down the voltage from 220V to 12V to power the Arduino board while 5V from Arduino board is supplied to power the microcontroller, liquid crystal display, and DHT11 sensors. Since the solar inverter output is 1000watts, 220V, the cur-
current output is calculated as
\[
P = IV
\]
\[
I = \frac{P}{V}
\]

From the step-down transformer the current input can be calculated as;
\[E_p\text{ (voltage from the mains)} = 220V\]
\[E_s\text{ (voltage output to circuit)} = 12V\]
\[I_p\text{ (current input)} = 4.55A\]
\[I_s\text{ (current output to circuit)} = ?\]

\[
\frac{E_p}{E_s} = \frac{I_s}{I_p}
\]

Hence the ratio of the primary to secondary winding is calculated to be;
\[
\frac{220}{12} = \frac{N_p}{N_s}
\]
\[\text{ie.} \quad \frac{55}{3} = \frac{N_p}{N_s}
\]

Therefore \(N_p : N_s = 55:3\)

where \(N_p\) is number of turns in primary coil
\(N_s\) is number of turns in the secondary coil
\(E_p\) and \(I_p\) are the input voltage and current at the primary coil coming from the mains respectively.

The inverter was design to produce power of 1000W, 220V for 12V solar charge battery. The circuit below shows the schematic diagram of the inverting circuit (figure 5).

### 2.3.4 Inverter circuit diagram

The inverter is an integral part of the triplet baby incubator project. It will be operational in the absence of supply from mains AC. The inverter connection is such that it offers continued seamless operational power supply, and its unit comprised of DC battery linked to the device as in a study [16].

The schematic diagram of the inverting circuit is shown in (figure 5).
system receives immediate enabling attention from the inverter itself because the solar panel, battery and charge controller were structured to modulate serially. The circuit has the SG3524 as the processor generating the PWM pulses required figure 5.

There are three IRF3205 MOSFETs in each wing. This is to provide the required 141.5A current. The output of the transformer is 220v. This is the voltage that powers the load. In the conversion of electrical energy, the solar panel with cells composed of semi conducted materials is placed at the right angle to the sun rays. The battery charges as long as there is sunlight, and charge controller prevents over charging. The process automatically stops when the battery is fully charged.

2.3.5 Hardware Description
The hardware is composed of two sections, the heating and humidifying circuit, and mechanical framework. The heating and humidifying circuit is made up power unit, heaters, dc fan, connected to (ATMega328) microcontroller, DHT11 (temperature and humidity sensors), Liquid Crystal Display, relay, and switch are other components. The block diagram of the device heating and humidifying circuit is as in figure 6.

2.3.6 The System Software Design
The software (firmware) was designed to run by the microcontroller and is written with C++ programming language in the MPLAD IDE.

The software implements the following functions required to enable the device.
- It displays the welcome message
- It responds to the keypad when commanded
- It controls the measuring unit of incubator internal temperature
- It controls the heater and fan
- It updates the LCD.

2.3.7 Battery Capacity
The power circuit requires supply unit of inverter to accommodate battery which is rated to sustain required voltage that passes through the transformer for primary current of 70.77A for a full cycle. Therefore battery cells shelf-life is a function of material quality from which cells were made in one hand, and in another measure of current drawn from the inverter over period of time. Consequently steady supply quantity of at least \(2 \times 70.77 = 141.5\)A required to run without failure will be supported by battery rated 200AH, and should robust there be increase current draw by the device from the inverter.

2.3.8 Solar Panel Capacity
The primary job of the solar panel is to produce dc voltage to recharge the battery. Since battery capacity is 200AH, solar panel must produce 10% of this value to recharge the battery such that. \(10\% \times 200 = 20\)A from solar panel is obtained. Since the specification of a 200W solar panel is 7.9A then several solar panels must be wired in parallel in other to pro-
duce at least 20A. 
Hence   \[ Sp = \frac{Rc}{Sc} \]  
where \( Sp \) is number of solar panels required, 
\( Rc \) is required capacity and 
\( Sc \) is specific capacity 

Required capacity = 20A  
Specific capacity = 7.9A  

Hence number of solar panels required = \( \frac{20}{7.9} = 2.5 \approx 3 \). 

Therefore, a minimum of 3 solar panels are required but it can be increased in other to increase the solar panel capacity output. 

2.3.9 Weight and Pressure
When a body constantly exerts a force on an object, the pressure causes the object to experience gradual failure. This failure rate could be very slow or fast, depending on the amount of pressure exerted per unit time, the direct position of pressure acting on the object and the structural composition of the body. Constitutively, weight of the babies is incident on the entire incubator and the area in which the weight exerts its force can be explained when sought by Bulk modulus (\( K \)) because uniform compression is collectively exerted by the triplet babies against resistance from the materials employed at fabrication. 

Also, since the baby cabin chambers of triplet incubator maintained micro-environments often of charged air when in operation over, relative contraction strain or transverse strain to relative displaced place becomes an extension or axial strain could define the babies as load. This can better be explained by Poission’s ratio (\( \gamma \)). Increase in temperature will also cause increase in pressure because the difference in external and internal temperature would cause an increase in the internal pressure and cause gradual failure to the walls of the incubator and the stand of the incubator.

The average weight of preterm babies is 
\[ 2Kg \times 9.8 \text{ m/s}^2 = 19.6N \]
The area of the bed where the pressure is exerted \[ = 0.508m \times 0.254 = 0.129 \text{ m}^2 \]

\[ \text{Pressure} = \frac{19.6}{0.129} = 151.94 \text{ N/m}^2 \]

The total pressure for triple infants = \[ 151.94 \text{ N/m}^2 \times 3 = 454.82 \text{ N/m}^2 \]

The tensile strength (\( \sigma \)) = Reactive force, \( F \)/ Area, \( A \)

When the tensile strength of Aluco board (Aluminium composite board) is 76.8GPa, thickness is 5mm consequently the area of the base used is 0.5m\(^2\).

\[ \sigma = 76.8 \times 10^9 \text{ N/m} \]

Tensile strength to acting pressure ratio = \[ \frac{76.8 \times 9 \text{ N/m}^2}{454.82 \text{ N/m}^2} = 168858010 \]

It takes \( 5 \times 10^6 \) cycle to collapse the tensile strength of aluminium composite [17]. Since the triple infant incubator is not frequently in use, and assuming it highest use per year is twice, and then the life span period can be calculated as:

\[ \text{life span} = \frac{168858010}{5000000 \times 2} = 16.88 \text{ years} \approx 17 \text{ years} \]

Therefore, the life span of durability and reliability can be estimated up to 20 years as earlier stated.

2.3.10 Energy Balance of the Incubator
Energy balance computations are pertinent as it shows the relationship between the energy (in the form of heat) produced by the incubator from the electrical energy supplied to it, heat used by the triplets and energy losses associated with the system. The energy in question for the incubator system is heat energy.

The energy balance equation is shown below

\[ H_{\text{gen}} = \dot{F}R \]  
\[ H_m + H_{\text{gen}} = H_{\text{con}} + H_{\text{lost}} \]  
\[ H_{\text{con}} = M_{b1}C_{b1}\Delta\Theta + M_{b2}C_{b2}\Delta\Theta + M_{b3}C_{b3}\Delta\Theta + M_{\text{inc}}C_{\text{inc}}\Delta\Theta \]  

Substituting eqn 6 and 7 into eqn 8 we get 
\[ H_m + \dot{F}R = M_{b1}C_{b1}\Delta\Theta_{b1} + M_{b2}C_{b2}\Delta\Theta_{b2} + M_{b3}C_{b3}\Delta\Theta_{b3} + M_{\text{inc}}C_{\text{inc}}\Delta\Theta_{\text{inc}} + H_{\text{lost}} \]
where \( H_{in} \) = heat entering the incubator
\( H_{gen} \) = heat generated by the incubator
\( H_{con} \) = heat consumed within the incubator
\( H_{lost} \) = heat lost by the incubator system
\( I \) = electric current supplied to heating element
\( R \) = resistance of the heating element

\( M_{b1} \) = Mass of baby 1.
\( C_{b1} \) = Heat capacity of baby 1.
\( M_{b2} \) = Mass of baby 2.
\( C_{b2} \) = Heat capacity of baby 2.
\( M_{b3} \) = Mass of baby 3.
\( C_{b3} \) = Heat capacity of baby 3.
\( M_{inc} \) = Mass of the incubator
\( C_{inc} \) = Heat capacity of the incubator
\( \Delta \Theta_{b1} \) = change in temperature of baby 1
\( \Delta \Theta_{b2} \) = change in temperature of baby 2
\( \Delta \Theta_{b3} \) = change in temperature of baby 3
\( \Delta \Theta_{inc} \) = temperature change of the incubator

2.4. Testing and Validation

The functionality of the incubator with regards to the relevant parameters, were tested and validated using the following test equipment:

Temperature functional test was carried out with digital fluke temperature tester (87V max True-rms.) which was supported with manual thermometer fixed in the chambers to ascertain and compare the temperature readings (37.5 °C). All the temperature measuring devices gave the same results as the standard required by baby incubator.

Humidity functionality test: Humidity functionality was measured and its rate of change with temperature calculated using an AcuRite 00613 psychrometer. The result gave the actual humidity range of the baby incubator set to achieve.Voltages and other electrical signals were measured, but nothing was detected in all contact areas of the human subject, meaning an expected safety, as fluke tester (87V max True-rms) was used for voltage leakage.

Practical safety check was advanced by the testing against electrical and heat hazard on infant with a dummy baby because human consent was not given for the trail. To observe the behaviour of the system, the system was tested for an hour. The temperature of the incubator readings was taken at every 5 minutes interval. At the beginning of the test, the temperature was at 25°C (room temperature) and a thermometer was used to observe the change in temperature. Also, the hygrometer was used to get the change in humidity as the temperature of the water increased by 2°C.

3.0 Results and Discussion

3.2 Results

The major concern in this project is ensuring that the temperature of the hood is controlled and maintained within the desired range of 36 - 37°C. The normal temperature of the inner chamber of the baby incubator is 24°C and when subjected to operation for 50 mins, the temperature rises to 37°C ± 1°C. The variation in accuracy of ± 1 for design triplet incubator with renewable energy source, proved to be a good performance as reported in data base DHT11 for singlet baby incubator.

The following tables below show the variation of temperature with time, (Table 2) and humidity with water temperature (Table 3) respectively. The above table 2 shows the rate at which the temperature in the baby compartment rises and falls as regulated by the microcontroller showcases that the feedback system carried out by the DTH11 temperature humidity sensor functioned as predicted in the design concept.

In table 3, the relationship between humidity and water temperature, estimates the temperature of the water to which the humidifier chamber must be kept to achieve the require humidity that satisfies the baby respiratory system.

The wholeness device was easily and robustly installed within appreciable space before the various tests to ascertain functionality and safety (figure 7).

3.2 Discussion

From the result in figure 3, it can be understood that the normal temperature of the inner chamber of the baby incubator is 24°C in relation to atmospheric condition of the environment, and when subjected to
operation for 50mins, the temperature rise to 37°C ±1°C as set. The variation in accuracy of ±1°C for the design triplet incubator with sustainable alternate energy source, gave good performance as reported in data base DHT11 for singlet baby incubator reported a study [18].

A study reported that humidity is sensed by the same sensor DHT11 [19], detailing further advantage of the sensor because it can render signal for both temperature and humidity. The fabricated triplet incubator was designed to house three preterm babies concurrently or as need may be simultaneously and function effectively by maintaining a proper environmental temperature (36 – 37°C) and humidity (75% - 86%). These parameters were maintained automatically by the microprocessor controller based system which makes the system easier to operate [19].

The inability to maintain preterm baby basic physiology for particular period of time has been associated with infant death rate increase in a region [21]. From this study it has been shown that for the device to maintain optimal body temperature 37°C (±1) in cabin chamber it requires cabin cavity humidity range of 75 – 86% within 50 minutes. This becomes necessary to prevent dehydration of infant baby as metabolic activities are sustained for life [21, 22].

From table 3, it is obvious that the cabin chamber humidity increases progressively with increased water temperature in humidifier. It shows that there was steam from water which vaporized to achieve the required humidity intended for the baby chamber (which is 75% to 86%). Also same table showed that the required humidity of 75% to 86% is achieved at temperature ranging from 36.5°C to 37.5°C while in a study humidity control was considered [23]. From the forgoing, the designed triplet incubator was designed with a solar panel system which served as a renewable energy source that can be deployed to rural area; while the cost effectiveness analysis shows that variation exists in the cost of fabrication and design of locally produce triplet incubator compared to imported singleton type. This was evidence to the fact that price variation existed in the cost of materials, production and procurement.

To this end, the results of the findings are valid and corroborate with the work in a region [19] in designed prototype of low cost Neonatal incubator with smart control system. In other studies [24, 25], solar power portable infant incubator designed was of one compartment while conscious effort here yielded triplet baby incubator with renewable energy source.

The triplet baby incubator houses three harmonic functions and maintains derivatives of stress and displacement expressions which were low. Therefore functions cannot be independently determined. It is better to resolve all functional problems by Legendre polynomials series because of the existence possible application of analytical methods over cavity shape limits that are between the faces. Considerably, since there is cognitive dissonance values to adduce from symmetric cavities fabricated which revealed stress – strain in the incubator, this can be addressed through resolution equation or individually and summed up because boundary materials and cavities are symmetrical. In some other studies on stress concentration around differential inhomogeneities, corners, cavities, etc [26-29] predicative values were used to resolve stress concentration in order to obtain differentials. Therefore since there is existence of analytical reasoning applicable to cavities (Baby cabin chambers) and babies themselves in this fabricate, problems originating from stress-train
retain simple geometric boundary condition can be approached by considering symmetry of stress-strain state. Hooke’s law applies better as well in this work.

Of importance is volume activity in the cabin chambers that can be considered as total force acting on the incubator.

This can be represented as:

$$\int FdV$$

where F is the force acting per unit volume and is the sum total of forces acting in the various symmetrical volumes within all geometric surrounding of the incubator cavities.

At the pneumatic state, the force is obviously surface acting in the entire volume. With complete description of resultant forces, it is integral over the collective symmetric surface because the baby’s breath is softly but constant.

Thus, it can be addressed [30],

$$\int FdV = \delta \sigma i k d V \phi \sigma i k d f k \quad 10$$

It is obvious that the surface force can present in time but as partial of integral of the sides surrounding cabin and babies in the cavities. Therefore the sum restrictive volume (force) acts on the surrounding surfaces is opposite and is given by $$\delta \sigma i k d f k$$ which describes stress-strain state in the cavity. These resultants were factored in while calculating the shelf life of triplet baby incubator. Or should cavity stresses be represented as sum of stresses from concentrated force F? Forces acting on cavity surface that opposes is axial in nature and is given as thus [30],

$$\sigma A_{ij} = \sigma_{ij} + \sum_l^n \sum_{k=1}^{\infty} \sigma_{P(k)} \quad 11$$

Since it acts on the cabin roof and in consequence is resolved thus $$\sigma_{ij} = \sigma_{ij} = 0.$$ This is because all the supposed reference points were annulled by the baby’s pneumatic activity; and design principle also resolved the force as in a study [31]

4.0 Conclusion

In conclusion, the triplet baby incubator saved space, cost and energy consumption with high performance and efficiency. Hence, it can be rolls out and deploys to electricity remote location for effective lifesaving of infants. It does not require expatriate for maintenance.

- This incubator utilizes both electricity from the grid and solar panels with easy maintenance.
- The incubator has incorporated microcontroller to achieve an advance temperature control.
- The project cost is lower hence it is economically cheaper when compared with foreign incubators in the market.

References


