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Experimental Investigation of Impact of Hood Shape on Performance of a Baby Incubator

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ABSTRACT: *Millions of infants in the developing world die due to inadequate health facility. One of such facilities is incubator for preterm in neonatal intensive care unit. Even temperature and moisture distribution inside an incubator has been of great interest and has necessitated investigation of varying hood shapes for an incubator. This work has thus investigated the performance of some selected incubator-hood Three hood geometries namely cuboidal hood, pyramidal hood and hemispherical hood were investigated. The three hoods were made of plexi-glass, which is non-toxic and a good thermal property; a 1.5 Watts heating element was placed inside the incubator to replace the heat loss by a premature baby. The hoods were placed on an existing baby incubator engine comptroller which houses the heater, fan, distilled water container and other accessories. The temperature and relative humidity distribution in the cuboidal hood, pyramidal hood, and hemispherical hood incubators were monitored.*

The result of the experiments showed that the cuboidal hood incubator being of a simple geometry had the optimal heat distribution and conservation. The other hoods with higher complex had reduced temperature and relative humidity distribution in the incubator.

KEYWORDS: I*ncubator, hood-geometry, preterm*

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I. INTRODUCTION

Over four million infants die annually worldwide due to inadequate health facility; of this number over 3.9 million belongs to developing world[1]. One of such facilities is incubator for premature babies in neonatal intensive care unit. Incubator is an apparatus that provides and maintains the environmental condition needed or suitable by a new born baby(neonate). Hood on the other hand is an enclosure that covers or protects someone, something, a device, a part of component from damage. Incubators are used to preserve premature infants because their thermoregulatory system is not fully developed by maintaining the temperature inside the hood at 34-37^{0}c depending on the thermal need and the gestational age of the baby. The air entering the incubator is humidified, ranging from 60 to 70 percent relative humidity and usually filtered to avoid bacteria attack on the neonate.

At birth, an infant's core skin temperatures tend to drop significantly because of heat loss from conduction, convection, radiation and water evaporation. To lose heat by evaporation, moisture from the body of the neonates will at first diffuse across the epidermis (general outer layer of the skin), then it evaporates off from the skin's surface thereby producing cooling effects on the Neonate[2]. Also, prolonged cold stress in neonates can cause oxygen deprivation, hypoglycaemia, metabolic acidosis and rapid depletion of glycogen stores.

When exposed to cold, a baby tries to conserve heat by increasing voluntary and involuntary muscular activities, increasing basal metabolism with increased oxygen in breath, peripheral vasoconstriction (narrowing of blood vessels), or shivering and non-shivering thermogenesis. Premature infants lack muscle mass which adults used in shivering and thereby generate heat when needed and also lack heat generating brown fat which makes up to 5% of the body weight in term infants.

To lose heat by evaporation, moisture from the body of the neonates will at first diffuse across the epidermis (general outer layer of the skin), then it evaporates off from the skin's surface thereby producing cooling effects on the neonate[2]. Oxygen deprivation, hypoglycaemia, metabolic acidosis, and rapid depletion of glycogen stores are caused by prolonged cold stress in neonates. All these requirements have necessitated careful design of incubators to preserve the lives of the neonates.

Midway-Locator reported that infant incubator were invented around 30years before the Pan American exposition but were not widely used by the medical community in hospitals or clinics[3]. The survival of premature neonate at this time depended on keeping the infant uniformly warm, frequent feeding and keeping the neonate free from disease.Ste'phaneTarnier as sourced from Jeffery tries to proffer solution to the challenge of endemic in Paris by finding a means of warming numerous premature infants who routinely succumbed to hypothermia on the wards of Paris' maternity hospital through the invention of incubator[4]. Sreeneath and Lohit submitted that Tarnier's invention was about ten years earlier Jeffery's submission[5].

Kangaroo method of baby incubation was developed in the 1970s by a Colombian Paediatrician Edgar Rey [6]. This is a skin to skin contact between the baby and the mother in which heat generated by the mother through peripheral vasoconstriction (narrowing of blood vessels), increased basal metabolism with increased voluntary or involuntary muscular activity or shivering/non shivering thermogenesis is passed to the premature baby. The mother holds the baby close to her chest or in her clothes. This method is not generally accepted because of possibility of infection transfer and high risk associated with it.

Prasanga and his co-workers observed that, one of the most relevant examples of prior art found was the Van Hennel Incubator (a non electric incubator) in Zambia in 1968 and powered by paraffin lambs located in a compartment below the baby to transfer heat to the air in the incubator by convection[2]. The heat source creates a thermally driven flow of air through the system and the hot air passes through a wet cloth (water saturated) to increase the humidity of the passing air thereby humidifying the chamber (hood). The set back to the general acceptance of this method of incubation is the massive size and weight, the high rate of consumption of paraffin which was about two litres per day and possibility of paraffin lamb suffocating the neonate.

Daniels and his co-workers reported that different kinds of incubators developed by medical engineers, researchers and others focussed largely on safety and efficiency [7]. Several designs (based on hood shape) of incubators have been manufactured in the developed world (as far back as 1880) and have been of profound application in paediatrics management of neonates. Different shapes/geometry of incubator hood include semi-circular, box type, pyramidal have been developed to ensure uniform heat distribution and humidity. According to Costa and his co workers, temperature, humidity, and oxygen concentration are the main parameters that must be control in the premature infant incubator system[8]. The ability to control or at least monitor these parameters were considered beneficial[9, 10]. Abbas and Steffen observed that frequent interaction with the incubator by operators may have lead to poor performance[11]. Modern incubators are now fitted with safety standards, voice and light alarm indicators of emergency[12]. In literature, the decisions on the best geometry for hood dome design remain contentious as it depends on the view and the projection of the manufacturer of the device for semi-circular, box type, pyramid and so on[13, 14, 2]. A double-wall flexi glass hood investigated by Laroia *and his co-workers* did not lead to an improvement in the performance of the investigated incubator[15]. This work is therefore aimed at investigating the humidity and temperature distribution of baby incubator with some selected hood shapes.

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II. METHODOLOGY

2.1 Material Selection

The experiment for the investigation of the impact of hood shape on the performance of a baby incubator was carried out using various classes of materials which are the materials used for fabrication of a baby incubator hood and the material used carrying out the experiment. These are listed in Table 1 below.

Table 1: Materials used for baby incubator fabrication and experimentation

INCUBATOR FABRICATION			EXPERIMENTATION	
S/N	**Materials**	**Quantity**	**Materials**	**Quantity**
1	Plexi-glass	2 Sheet	Temperature/Relative- humidity monitor	1
2	Knife	1	Hood (different shapes)	
3	Gum	8	Incubator	3
4	Measuring Tape	1	Heating Element	1
5	File	1		1

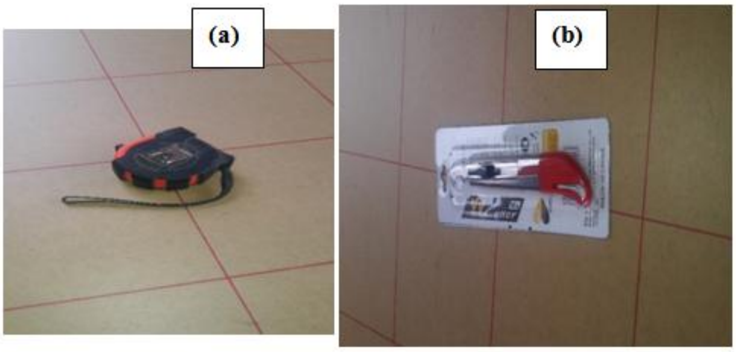

Figure 3: Measuring instruments: **(a)** Measuring Tape **(b)** Cutting knives

2.2Hood Design and Fabrication

In this present work, the three hood geometries considered for the experiment were cuboidal, pyramidal and hemispherical as shown in Fig. 4 below.

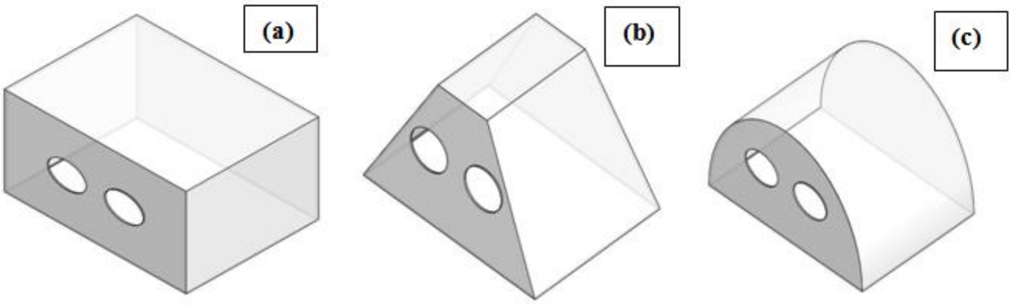

Figure 4: Designed hood diagrams: **(a)**cuboidal **(b)** pyramidal **(c)**hemispherical

2.2.1Fabrication of cuboidal hood

A sheet of plexi-glass was cut using a knife to desired specification, the edges were smoothened with a file and the parts were joined using a gum. The dimension of the cubiodal hood was obtained using the specifications from different incubator manufacturers, health organisations specification and considering infant body size as shown in Fig. 5 below. Two ports were made on the cuboidal hood by boring a hole with a knife. The ports are for easy acsess into the hood.

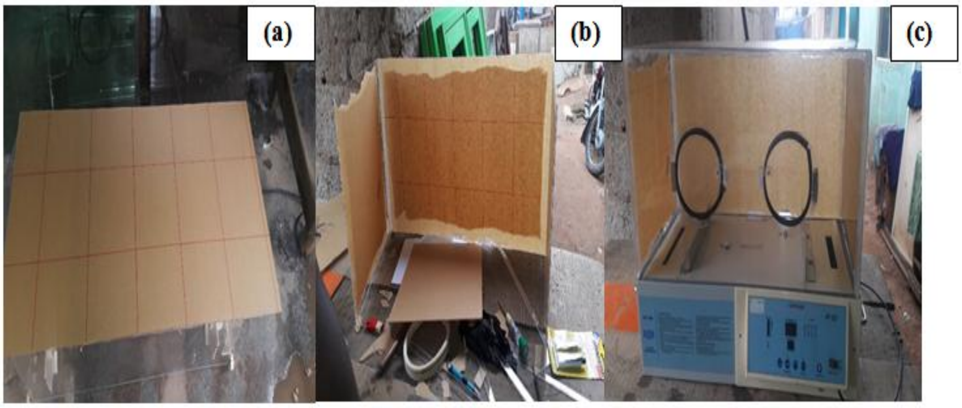

Figure 5: Assembling of cuboidal hood (a) Hood sheet (b) Hood with plexi-glass(c) Complete baby incubator with cuboidal hood

The weight and length of an infant ranges from 360g and 26cm (21 weeks gestational age) to 3.69kg and 51.cm (42 weeks gestational age). For a normal baby (proper gestational age of 37-40 weeks) the weight ranges from 2.5kg to 4kg, and premature baby (low birth weight); less than 2.5kg, very low birth weight less than 1.5kg while Based on all these informations, the cuboidal hood was fabricated with a dimension of 860mm x 400mm x 400mm and of a sheet thickness of 3mm.

2.2.2 Fabrication of pyramidal hood

The pyramidal hood was also made from plexi-glass. A sheet of plexi-glass was cut using a knife to make the parts of pyramidal hood of standard specification. The edges were smoothened with a file and the parts were joined using a gum. Two ports were made on the pyramidal hood by boring a hole with a knife. The ports are for easy access into the hood.

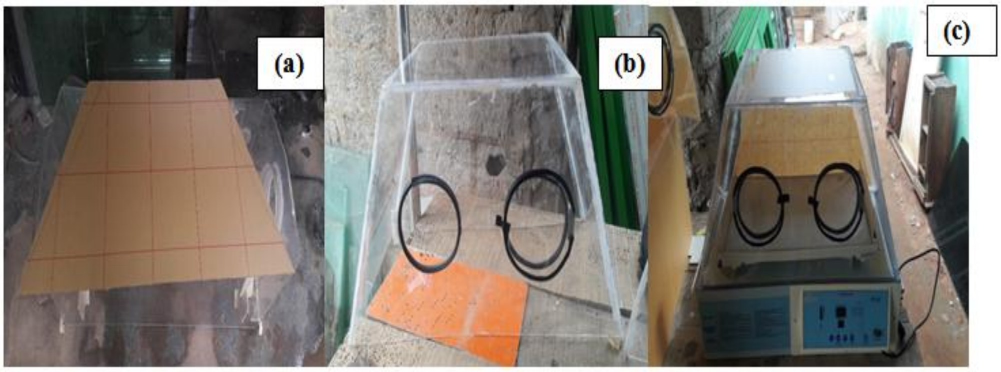

Figure 6: Assembling of pyramidal hood (a) Hood sheet (b) Hood with plexi-glass (c) Complete baby incubator with pyramidal hood

2.2.3 Fabrication of hemispherical hood

A sheet of plexi-glass was cut using a knife to make the parts of pyramidal hood of standard specification. The edges were smoothened with a file and the parts were joined using a gum. Two ports were made on the hemispherical hood by boring a hole with a knife. The ports are for easy acsess into the hood.

Figure 7: Experimental set up of baby incubator with hemispherical hood

2.4 Conduct of the Experiment

The heater in each of the incubator fabricated was put on and the thermostat set at 37^0C . Thereafter the temperature and humidity inside the incubators were monitored for 1 hr. The relative performance of each incubator was analysed.

III. RESULTS AND DISCUSSIONS

The obtained temperature and relative humidity in each of the incubator are as shown in Table 2.

From the table, it could be observed that the set hood air temperature of 37.0^0C was attained within a short while, 1320s(22min) in the cuboidal-hood incubator whereas this was never attained in the other incubators. However both the pyramidal and hemispherical hood incubator attained temperatures of about 35^0C which was considered safe for neonates. temperature increased to 37.For all the cases as could be observed in Fig. 8, the relative humidity of between the ranges of 60% -80% needed by a premature baby was obtained

Table 2: Temperature and Relative Humidity Reading in Cuboidal, Pyramidal and Hemispherical hoods

		CUBOIDAL HOOD		PYRAMIDAL HOOD		HEMISPHERICAL HOOD	
S/N	Time(s)	Temp. (^{0}C)	Relative Humidity (%)	Temp. (^{0}C)	Relative Humidity (%)	Temp. (^{0}C)	Relative Humidity (%)
1	0	29.6	78.9	29.6	78.9	29.6	78.9
2	120	30.8	78.1	30.6	77.3	30.4	77.7
3	240	32.0	76.3	31.7	76.5	31.4	77.3
4	360	33.3	73.3	32.7	75.6	32.6	77.7
5	480	34.6	71.3	33.6	74.4	33.6	76.9
6	600	35.8	69.5	34.3	73.2	34.3	76.6
7	720	36.4	68.4	34.6	72.3	34.8	76.1
8	840	36.6	67.5	34.6	72.1	34.9	75.8
9	960	36.7	67.1	34.6	72.3	34.9	76.7
10	1080	36.7	67.1	34.6	72.3	35.0	76.7
11	1200	36.9	66.2	34.7	72.3	35.2	76.8
12	1320	37.0	65.6	34.9	71.9	35.4	76.8
13	1440	37.1	64.6	35.0	71.9	35.5	76.8
14	1560	37.1	64.7	35.1	71.5	35.6	76.8
15	1680	37.0	64.8	35.1	71.4	35.7	76.8
16	1800	37.0	65.0	35.2	71.5	35.7	76.5
17	1920	37.0	65.0	35.2	71.5	35.7	76.9
18	2040	37.0	64.7	35.4	71.5	35.9	76.9
19	2160	37.1	64.7	35.5	71.1	35.9	76.5
20	2280	37.1	64.7	35.5	70.6	36.0	76.9
21	2400	37.1	64.7	35.6	70.2	36.0	77.0
22	2520	37.1	64.9	35.6	69.6	36.0	75.5
23	2640	37.1	64.9	35.8	68.8	36.1	76.4
24	2760	37.1	64.8	35.9	68.4	36.1	75.4
25	2880	37.2	65.2	36.0	68.4	36.1	75.3
26	3000	37.2	64.8	36.2	67.9	36.1	74.8
27	3120	37.2	64.8	36.2	67.9	36.1	76.4
28	3240	37.2	64.3	36.2	67.9	36.2	76.5
29	3360	37.2	64.8	36.2	67.9	36.2	77.0
30	3480	37.2	64.8	36.2	67	36.2	77.5
31	3600	37.2	64.8	36.2	67	36.2	77.5

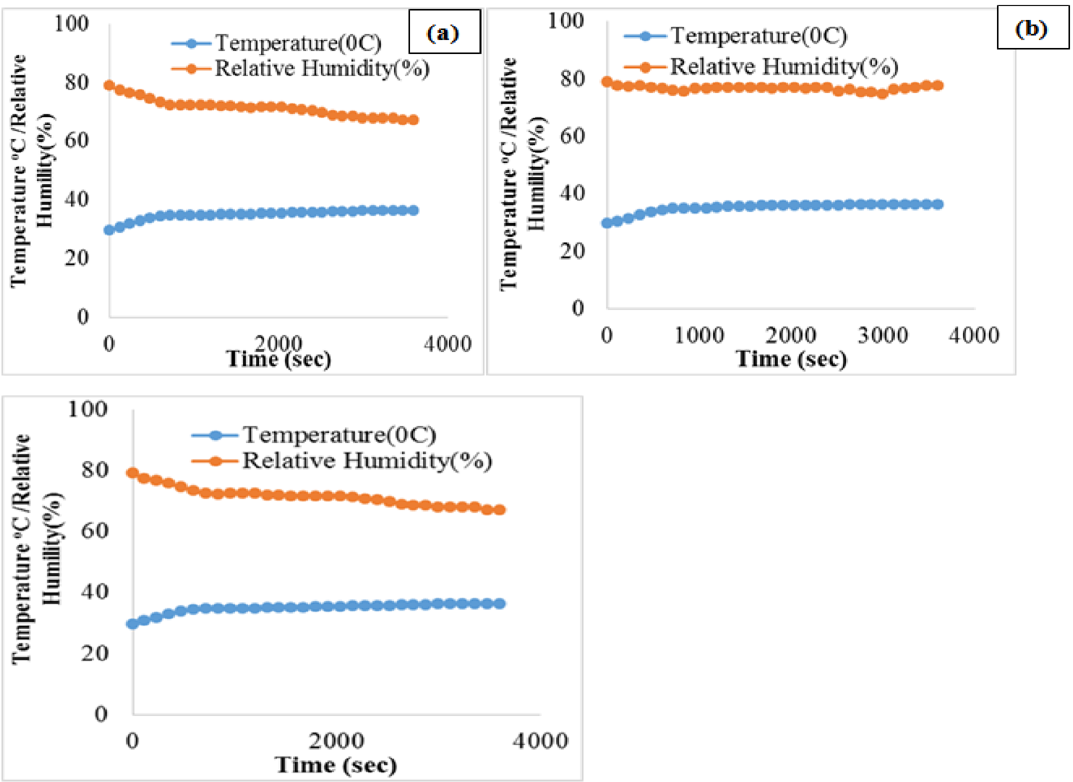

Figure 8: Temperature and relative humidity at varying time: **(a)** cuboidal hood **(b)** pyramidal hood**(c)** hemispherical hood

IV. Conclusion

Temperature, humidity, oxygen concentration and the hood geometry are the important parameters that must be considered in the design of an incubator. The decision on the best hood geometry has been contentious as it depends on the view and projection of the manufacturer of the device.

The result of the experiment showed that cuboidal hood is the best hood shape for optimal heat distribution and conservation. It is concluded that the complexity in hood geometry affects the temperature and relative humidity distribution in an incubator. Temperature and relative humidity were distributed within a short while in simple shaped hood geometry while the distribution takes a longer time in complex geometry.

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