HopeNest: Non-Electrical Neonatal Incubators for War-Stricken and Developing Territories

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Problem Statement



- Over **4 million babies** suffer from pre and post-birth complications, threatening their development and ultimately, lives.
- More than **16 million** babies were born into conflict this year, including war and development.
- Currently, there are only **1500 neonatal incubators** in all developing countries, representing 21% of all incubators in the world.

Background

Neonatal Incubators: enclosures designed to sustain an optimal environment for babies that may have trouble surviving without such an environment.


In areas without constant electricity, incubators are rendered useless, and many of their functions are unable to operate, leaving newborns without the life-saving support they desperately need. Traditional incubators are not a possibility for the survival of newborns in areas that are ridden with conflict, and have limited access to funds or resources.



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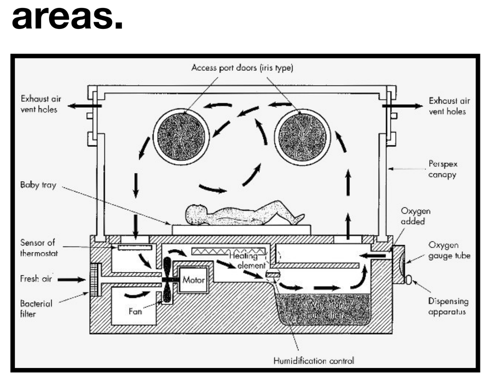
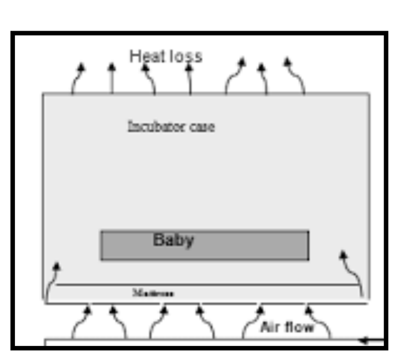
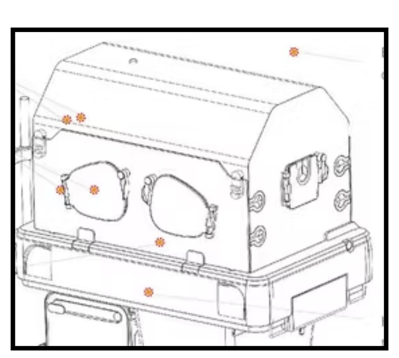
Solution and Research Objective

Develop a functional prototype of the non-electrical baby incubator tailored for deployment in war-stricken and developing areas.

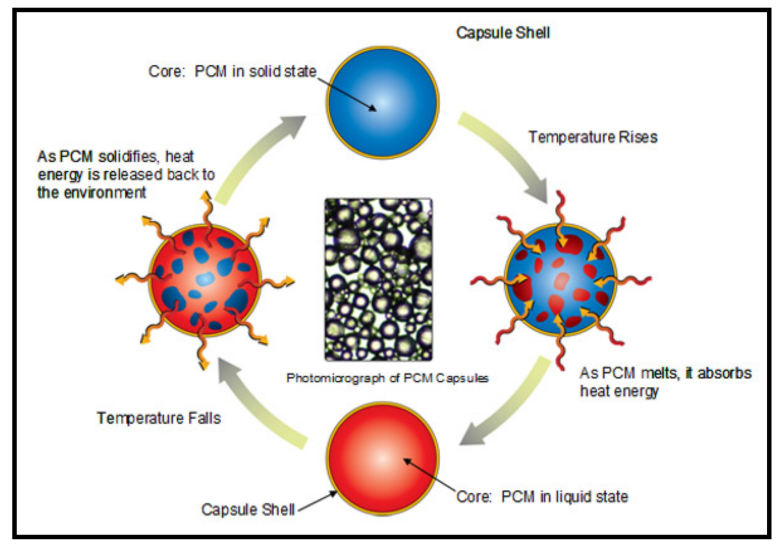





Design Criteria & Constraints

Criteria	Constraints
HopeNest should be able to maintain a temperature of 35C to 38C for an extended period of time (2+ hours).	The incubator should also be completely power-independent, requiring no electricity or external power for functionality.
To sustain skin humidity and respiratory health, the incubator should be able to maintain a humidity range from 40% to 80%.	The incubator should be practical to ship and construct; thus, the incubator should be less than 65x65x90 cm.
To restrict infections and maintain respiratory health, volatile organic materials, particulate matter, debris, and odors should be filtered.	The entire incubator should cost less than $300, including material and component parts.

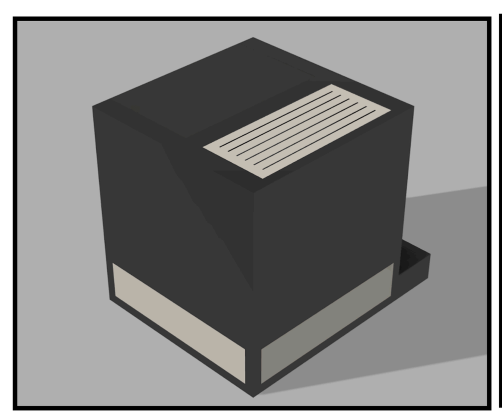
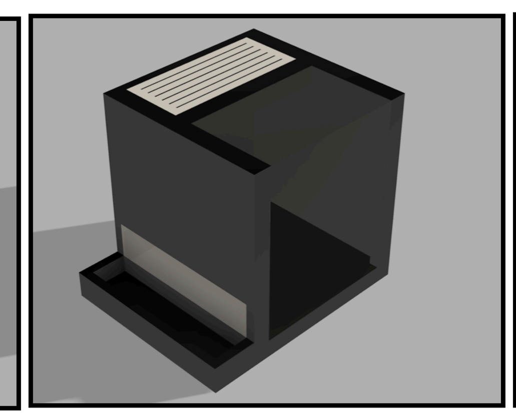
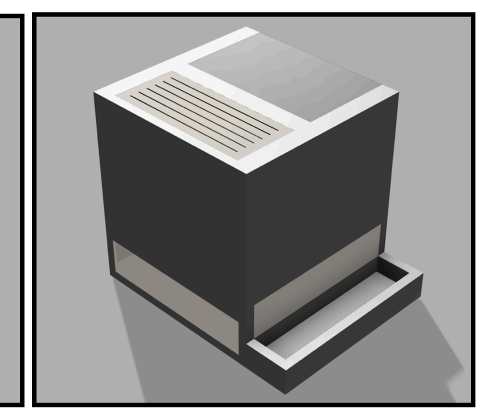
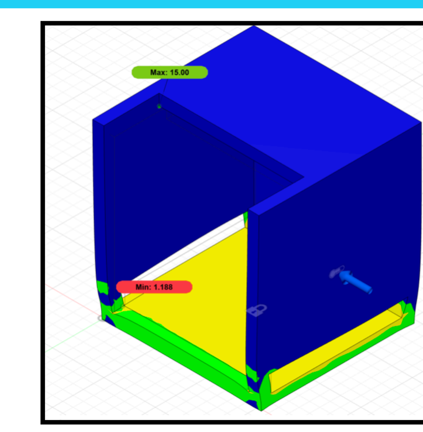
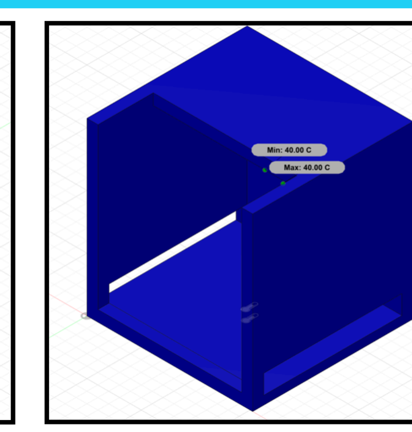
Heating System and Phase Change Material Fabrication

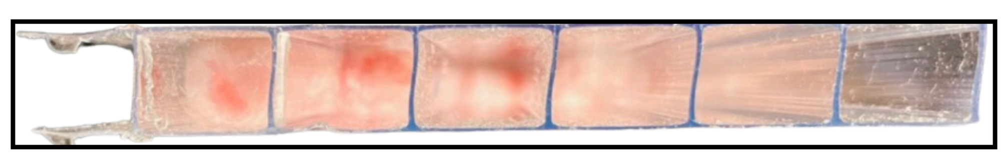


Phase change materials are substances that absorb and release large amounts of energy when they transition between different physical states, like solid and liquid, at a nearly constant temperature, making them useful for thermal energy storage and management.

- The PCM is supported by foam to improve heat distribution across the incubator. For HopeNest, paraffin wax was used. The wax is widely available with a cost of $10 per kilogram, ensuring that the overall cost of the incubator stays less than $300.
- For further heat regulation, cotton is used for absorption and foam for further insulation. The system is placed at the bottom of the incubator.


Air Filtration and Insulation Design

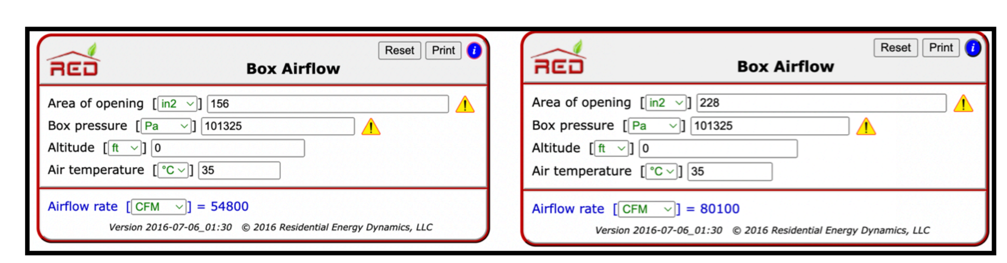






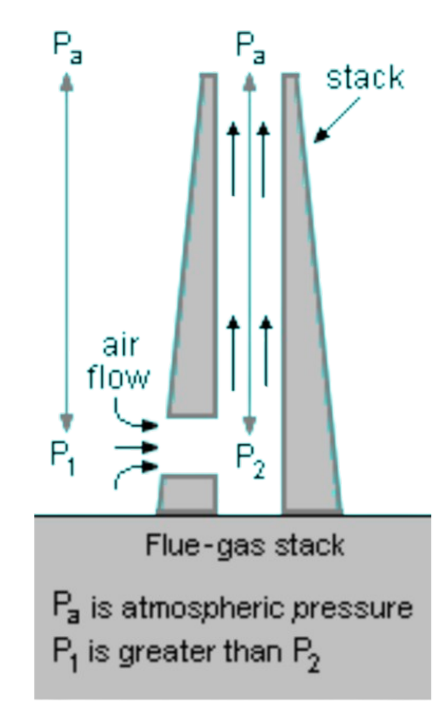


- Polycarbonate plastic was chosen for its strength, transparency, and low thermal conductivity, making it an ideal material for maintaining internal temperatures. Alumina- borosilicate fiberglass was selected as the insulating layer due to its effectiveness in reducing heat loss while also being lightweight and cost-effective.
- The incubator uses a three-layer design, with polycarbonate on the outer and inner layers and fiberglass in between. This setup ensures that the incubator retains heat effectively while also blocking external noise, creating a stable and quiet environment for the infant.

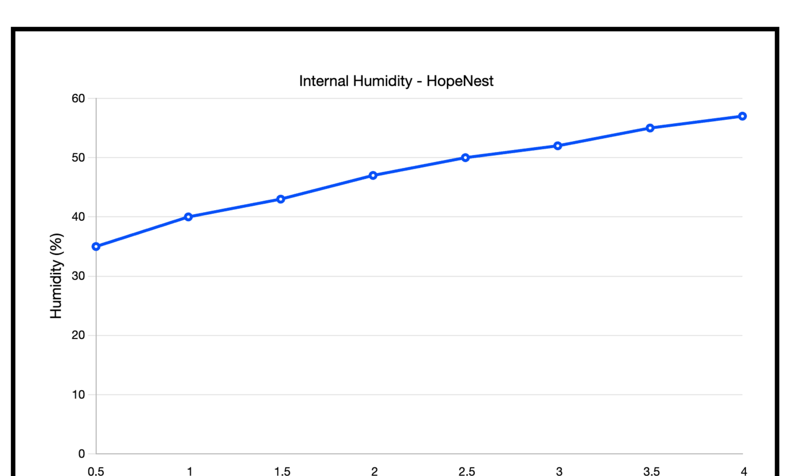
- EPA filters were selected for their high efficiency in removing particles as small as 0.3 microns, while activated carbon filters were chosen for their ability to adsorb volatile organic compounds (VOCs) and other harmful gasses. As cool air enters through the bottom, it passes through the filters, removing pollutants before circulating up and out through the top of the incubator.

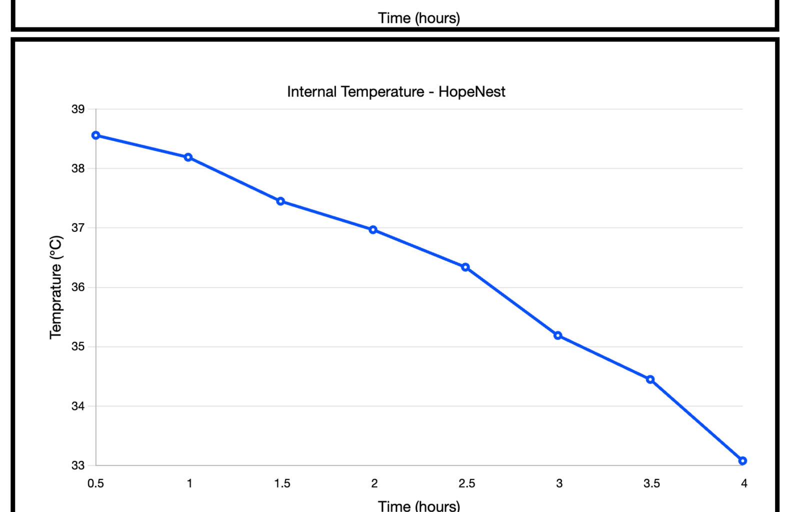
$$\frac{CFM * 60}{RoomVolume}$$





Results



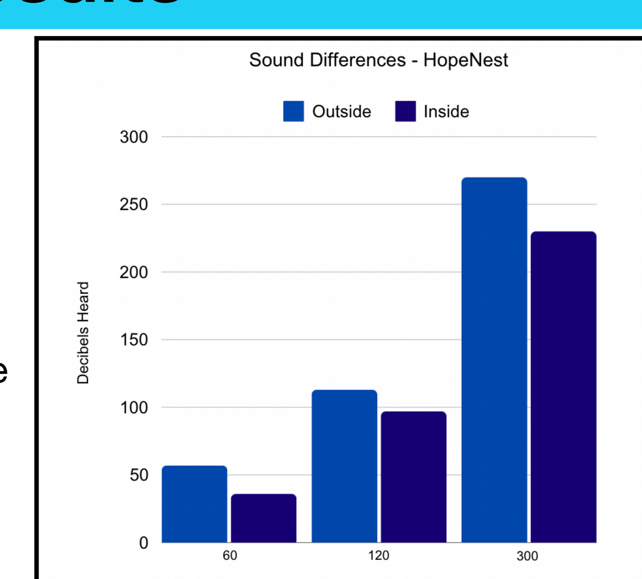


Internal Humidity

The temperature inside the incubator stays in the optimal range for 3.5 hours. Furthermore, humidity was seen to be 40% to 60% for the same time frame. The VOC level decreased dramatically as well.

Internal Temperature

The temperature inside the incubator stays in the optimal range for 3.5 hours. After that, the heating system should be reheated in hot-water until it reaches 46°C.



- In terms of cost, the incubator's materials and construction cost less than $104 (Figure 8), around 5% of the industry's lowest-costing incubator.
- HopeNest successfully maintains a temperature of 35C to 38C, humidity of 40% to 80%, and the filtration of dangerous particles, all for over 3 hours.

Paraffin Wax	$2.98
Cotton	$1.26
Polycarbonate	$24.98
Fiberglass	$9.49
Bracing	$5.00
HEPA + Carbon Filters	$35.99
Clear Viynl	$3
Velcro	$2.52
Aluminum Perforated Tape	$18.38
TOTAL	$103.60

System Testing

Experimentation Set-up

- The initial prototype was tested over 4-hour period to evaluate its ability to maintain temperature, humidity, and air quality.
- Temperature sensors and hygrometers were placed at various points within the incubator, while an air quality monitor tracked the levels of particulate matter and VOCs.
- A sound level meter was placed inside the incubator as well as outside.

Immediate Results

- The results revealed that while the temperature was maintained within the desired range for the first hour, the system began to lose heat more rapidly than anticipated after 90 minutes. While air quality improved, VOC levels remained higher than expected.

Future Work

Customization

- Explore scalability and further customization to meet diverse regional needs, ensuring that HopeNest's benefits reach every corner of the globe where traditional healthcare services are limited or non-existent.
- Implementing a human-centered interface with feedback from the system powered using the melting PCM or other chemical indicators.

Miniaturization and Power Distribution

- In the future, miniaturization of components and the development of efficient power systems would increase portability and comfort.
- Making the unit smaller and more compact for transportability while also ensuring for comfortability of the neonate.

Long-Term Use

- Conduct aging studies on paraffin wax to assess thermal cycling degradation over months of repeated use.
- Further stress tests are required to evaluate HopeNest's reliability in different environmental conditions (e.g., varying humidity, extreme cold, high-altitude regions).
- Evaluate potential material fatigue in insulation and structure over extended periods.

Conclusions

- Through rigorous design iterations, prototyping, and testing, significant progress has been made towards achieving the project's objectives of providing a cost-effective and sustainable solution for neonatal care in resource-limited settings.
- The non-electrical baby incubator prototype demonstrates promising thermal performance, humidity control, and air quality management capabilities, addressing critical factors for maintaining optimal conditions for neonates.
- The integration of passive heating and cooling mechanisms, moisture-absorbing materials, and air filtration systems has enabled the incubator to operate autonomously without reliance on electricity, making it suitable for deployment in areas with limited infrastructure.
- The non-electrical neonatal incubator represents a significant step towards addressing the critical need for accessible and effective neonatal care solutions in war-stricken and developing areas.

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