Modular Incubation System for the Developing World

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Motivation: Combat infant hypothermia

- Hypothermia contributes to 18% - 42% of 4 million annual infant deaths in the developing world [1].
- Current solutions (e.g., incubators and kangaroo care) can be expensive, high maintenance, or impractical.
- Hospitals lack sufficient staff, space, and funding.
- Mulago Hospital in Kampala, Uganda:
  - Two nurses for 60 neonates per day in the NICU
  - Only two (out of 20) incubators working

The lack of affordable and functioning incubators in low-resource settings makes it difficult to effectively combat infant hypothermia in the third world.

Objective: Provide a warm and safe environment

Our modular system is an innovative, effective, and viable solution against infant hypothermia.

Functional Requirements

1. Increase infant temperature
   - Based on gestation, age, and weight of the baby
   - Controlled heating to achieve normal temperature range of 36.5-37.5 ºC [2,3]
2. Maintain temperature range
   - Continuous monitoring of infant temperature
   - Feedback mechanism
   - Alarm LED which signals infant overheating or fever

Constraints

- Affordable
- Biocompatible and safe
- Durable
- Easy to maintain and Repair
- Easy to sterilize and Clean
- High controllability
- High infant visibility
- Intuitive
- Easy to use
- Versatile

Cost: Readily available and cheap components

Other Products

- Incubator: >$15000
- Van Hemel Incubator: $500

Our Device

Component	Cost ($)
Mat	14.36
Heating Unit	44.32
Electronics & Misc	39.33
Total	**98.01**

Table 1. Manufacturing cost

Modularity ($50)

- Thermostat heater
- Microcontroller ($0.50)
- Tubing
- No pump
- No bucket

Sterilization

- Water: bleach
- PVC sheet and tubing: ethanol

Our Solution: Warm water circulation system

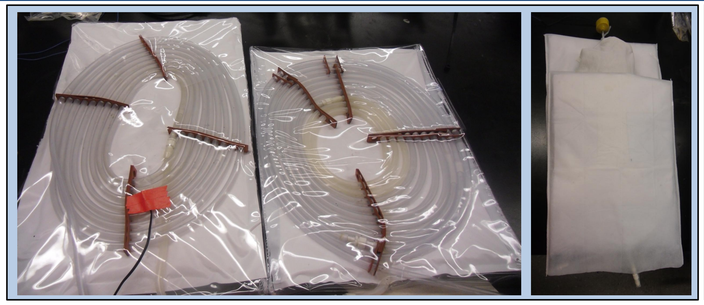

Figure 1. Mat prototype

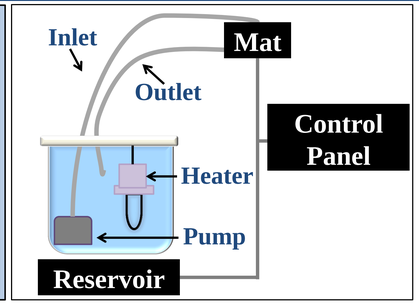

Figure 2. System diagram

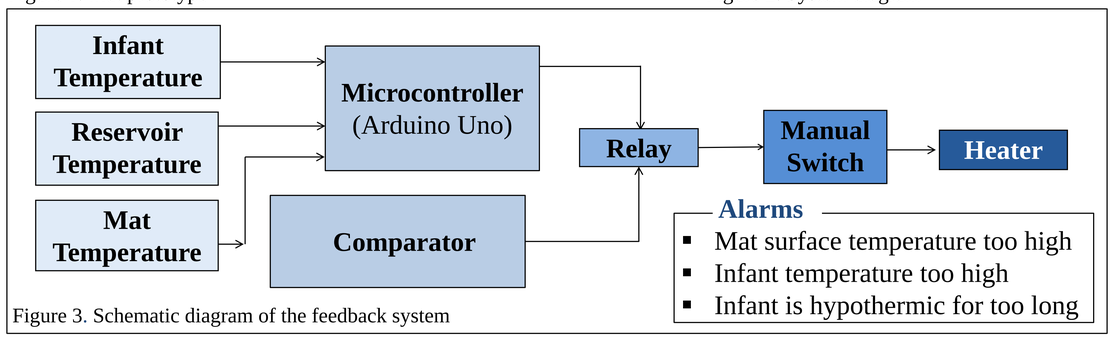

Figure 3. Schematic diagram of the feedback system

Feedback Algorithm

1. Heats and maintains the reservoir at a certain temperature
2. Once the mat reaches the set temperature, feedback switches to maintaining mat temperature
3. Monitors the temperature of the infant and maintains it at 37 ºC

Fail-safes

Circuitry
- Resistors to drive voltage down in case of thermistor disconnection
- Comparator in case the microcontroller fails

Code

Heater turns off if:
- Thermistor disconnects
- System overheats
- Mat overheats
- Infant overheats

Test: Raise and maintain biofluid temperature

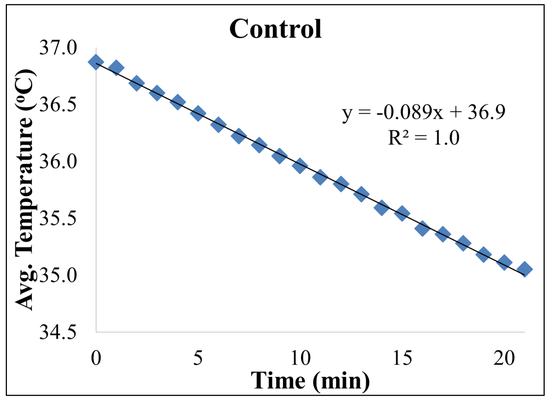

Figure 4. Average biofluid temperature (n = 2) vs. time without mat

Procedure

- The temperature of 1L biofluid model (37.0 ºC), covered with 100% cotton cloth, was monitored over time

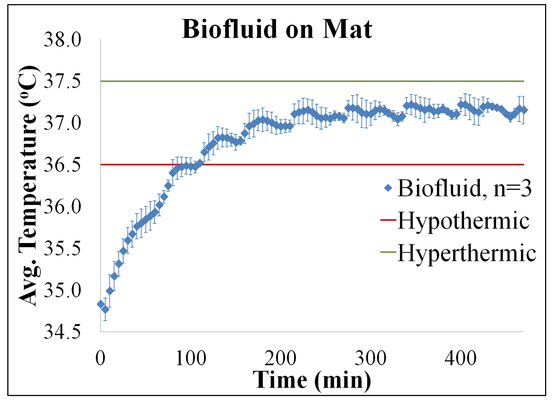

Figure 5. Average biofluid temperature (n = 3) vs. time on mat prototype.

Procedure

- 1L biofluid model (35.0 ºC) was placed on the mat and covered with fold-over component.
- The temperature of the biofluid was monitored.

Results

- Device heated and maintained the biofluid to within normal range of 36.5-37.5 ºC
  - Control (no heating): biofluid decreased from 37 ºC to 35 ºC in 20 min
  - Average of 50 min to raise temperature by 1 ºC
- Gold Standard: incubator [4]
  - Average of 85min to raise temperature by 1 ºC
- 2.3 kWh ($0.36) per day with continuous use

Long Term Business Plan

1. Obtain funding from NGOs and other charitable donations
   - Provide device at subsidized cost to customers
2. First distribute in Uganda's Hospitals and clinics
3. Sell device to other developing countries
4. Develop new prototypes

Conclusions and Future Work

Conclusions

- Effectively raises the temperature of a biofluid baby model
- Maintains the temperature of the biofluid within the normal range (36.5-37.5 ºC) for up to 8 h.
- Mat prototype was also able to raise and maintain two biofluids simultaneously when using the fold-over component as a second mat.

Future Work

- Optimize design and minimize cost and power consumption
- Implement a back-up power source (e.g., battery) in case of power failure
- Have one central heating unit to provide heat for more than two mats

References

[1] UNICEF. Progress for children: a world fit for children statistical review. New York, NY: United Nations Children`s Fund; 2007.
[2] Voorhoeve, H. Aspects of adapted newborn care in rural hospitals. University of Leiden, The Netherlands. October 2005.
[3] Hypothermia. *The Merck Manuals: The Merck Manual for Healthcare Professionals*. http://www.merckmanuals.com/professional/print/sec21/ch319/ch319d.html. Accessed March 1st, 2012.
[4] Testing done at CUMC, 4/26/2012, on Giraffe OHMEDA Medical Incubator

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