

Abstract

When anesthetized, infants are unable to regulate their own body temperature. Current MRI compatible infant warmers on the market are extremely expensive, leading to many physicians to use crude and/or insufficient methods to retain an anesthetized infant's body temperature. Therefore, "The Sleeping Bag" was developed. It was inspired by the swaddling of the baby, as it is made out of a soft, fabric material in which the baby will be wrapped. The inside of the blanket is lined with an insulating fabric, allowing for the retainment of heat and the posterior contains a pocket in which a Cardinal Health Porta-Mattress is placed. A venting system was put in place by installing side zippers that can be adjusted in between scans. The results of the various tests done showed that the device retained heat for a two hour duration. Improvements can still be made to enhance the functionality and the aesthetics of the device.

Background

- Infants are anesthetized while undergoing MRI scans
- Body temperature decreases due to vasodilation, dry anesthesia gases, and small weight-to-surface-area ratio
- Current methods of retaining body heat: Cardinal Health Porta-Warming Mattress and inserting baby in a plastic bag
- Similar product on market: 3M Bair Hugger - not MRI-compatible



Figure 1.1 Visual depiction of the bore of an MRI scanner, as well as the head shield the infant warmer must accommodate [2]



Figure 1.2 3M Bair Hugger [4]



Figure 1.3 Cardinal Health Porta-Warming Mattress [1]

Problem Statement

- Anesthetized infants are unable to regulate body temperature
- If a child gets too cold, the scan needs to be stopped in order to warm them back up
- Device needed to keep infants warm and eliminate scan stoppage
- Client's current techniques do not keep infant warm enough
- Devices on market are extremely expensive
- Device needs to be MRI compatible, able to maintain an infant's body temperature for up to two hours, under \$500

Design Criteria

Material Criteria

- MRI compatible (non-ferromagnetic material)
- Comfortable on infants' skin
- Aesthetically pleasing
- Insulating: able to retain heat
- Cost effective
- Durable: able to withstand multiple washes

Material	Outer Layer		Inner Layer	
	Fleece	Wool	Insul-Brite	Quilted Cover Fabric (Cotton)
Pros	-Durable -Inexpensive -Comfortable -Aesthetics -Insulating -Breathable	-Great heat retention -Wicks away moisture	-Great heat retention	-Inexpensive -Insulating -Comfortable -Durable
Cons	-Absorbs moisture	-Expensive -Itchy	-Not MRI compatible	-Absorbs moisture (not wicked away)

Functionality Criteria

- MRI-compatible
- Is able to maintain a temperature of 36.5°C +/- 0.5°C
- Cannot increase surrounding environment temp over 22.0°C
- Easily sterilized or disposable
- Accommodate average length of 6 month old baby (~26.5 inches) [3]
- Overall cost under \$500
- Allows for the insertion for addition tubing the infant may require
- Aesthetically pleasing

Final Design



Figure 2.1 Sleeping Bag with Front Zipper and Side Vents Open

Figure 2.2 Sleeping Bag with Front Zipper Closed and Side Vents Open



Figure 2.3 Pocket for Cardinal Health Porta-Warming Mattress
The pocket is located between the fleece and insulating layers. The pocket holds a Cardinal Health Porta-Warming Mattress which allows for active heat application to the baby without direct contact to the baby's skin.



Figure 2.4 The Cardinal Health Porta-Warming Mattress
The pad is used by many hospitals as a source for heat in the MRI. The pad is placed in the pocket of the Sleeping Bag and applies heat to the baby's backside. The heating pad applies heat at an average temperature of 30.33°C over a span of two hours.



Figure 2.5 Side Vent-Open
These vents, located on both sides and controlled by a zipper mechanism, allow for the removal of heat if the baby becomes too warm. The vents can easily be activated in between scans and the zippers can be put at any desired position.

Future Work

- Further testing on increasingly realistic "infant-like" simulators inside of the sleeping bag
- Testing inside an live MRI with fiber optic probes
- Any final adjustments implemented from further materials/fabrication research
- Patent research

Acknowledgements

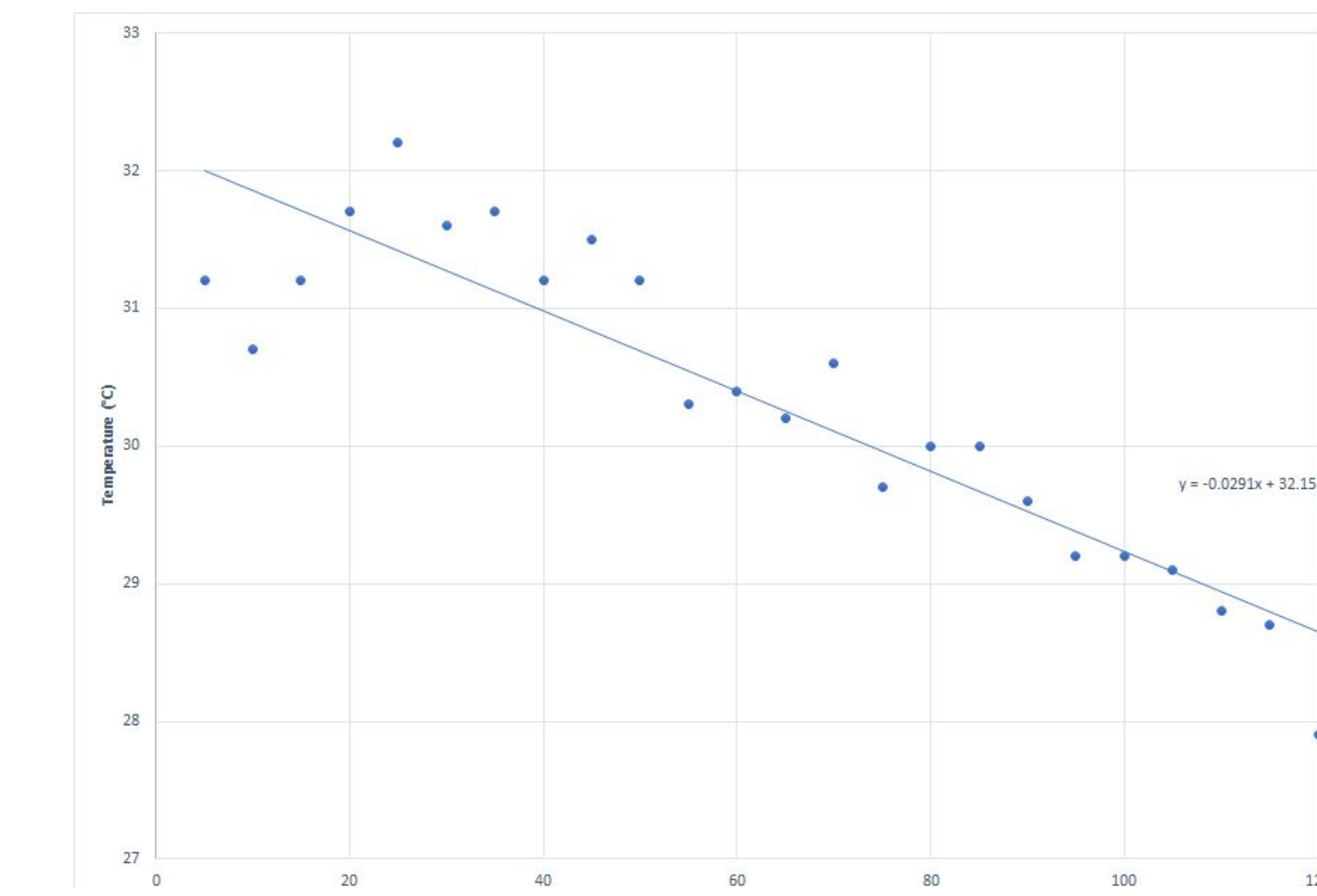
- Dr. Peter M. Popic (Client)
- Dr. John Puccinelli (Advisor)
- Thor Schroeckenthaler (Imaging Specialist)
- Karmen Wall (MRI Technician)
- UW-Madison MakerSpace
- AFCH Staff and Faculty

References

- [1] "Cardinal Health's Product Information website," mycardinalmsds.com. [Online]. Available: <http://mycardinalmsds.com/Main>. [Accessed: 05-Oct-2018].
- [2] "den32.JPG," Rick Wilking Photography. [Online]. Available: <https://rickwilking.photoshelter.com/image/I0000Fz4rRn1H5wU>. [Accessed: 05-Oct-2018].
- [3] The Bump, "6 Month Old Baby - Baby Month by Month," *What is a Lactation Consultant?*, 19-Jun-2017. [Online]. Available: <https://www.thebump.com/baby-month-by-month/6-month-old-baby>. [Accessed: 05-Dec-2018].
- [4] "3M Bair Hugger Model 775 Warming Unit - Certified Pre-Owned," MFI Medical Equipment, Inc.[Online]. Available: <https://mfimedical.com/products/3m-bair-hugger-model-775-warming-unit>. [Accessed: 05-Oct-2018].

Testing & Results

Analysis of Heat Distribution of the Cardinal Health Porta-Warming Mattress



- Image taken of Cardinal Health Porta-Warming Mattress with Flir Thermal Camera every 5 minutes at a distance of 2 ft for 2 hour duration
- Graph shows an average heat loss of -0.0291°C per minute
- Average Temperature: 30.33°C
- Standard Deviation: 1.135°C
- Range: (27.9°C, 32.2°C)

Figure 3.1 Heat Distribution Results

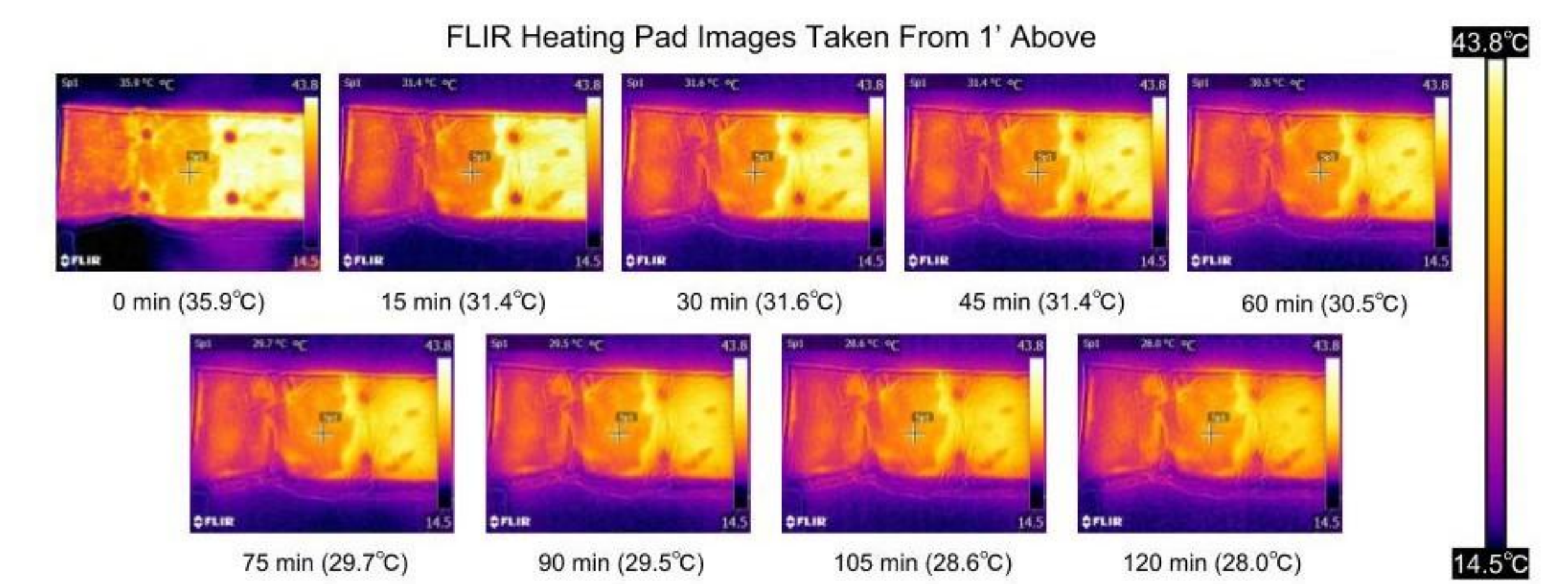
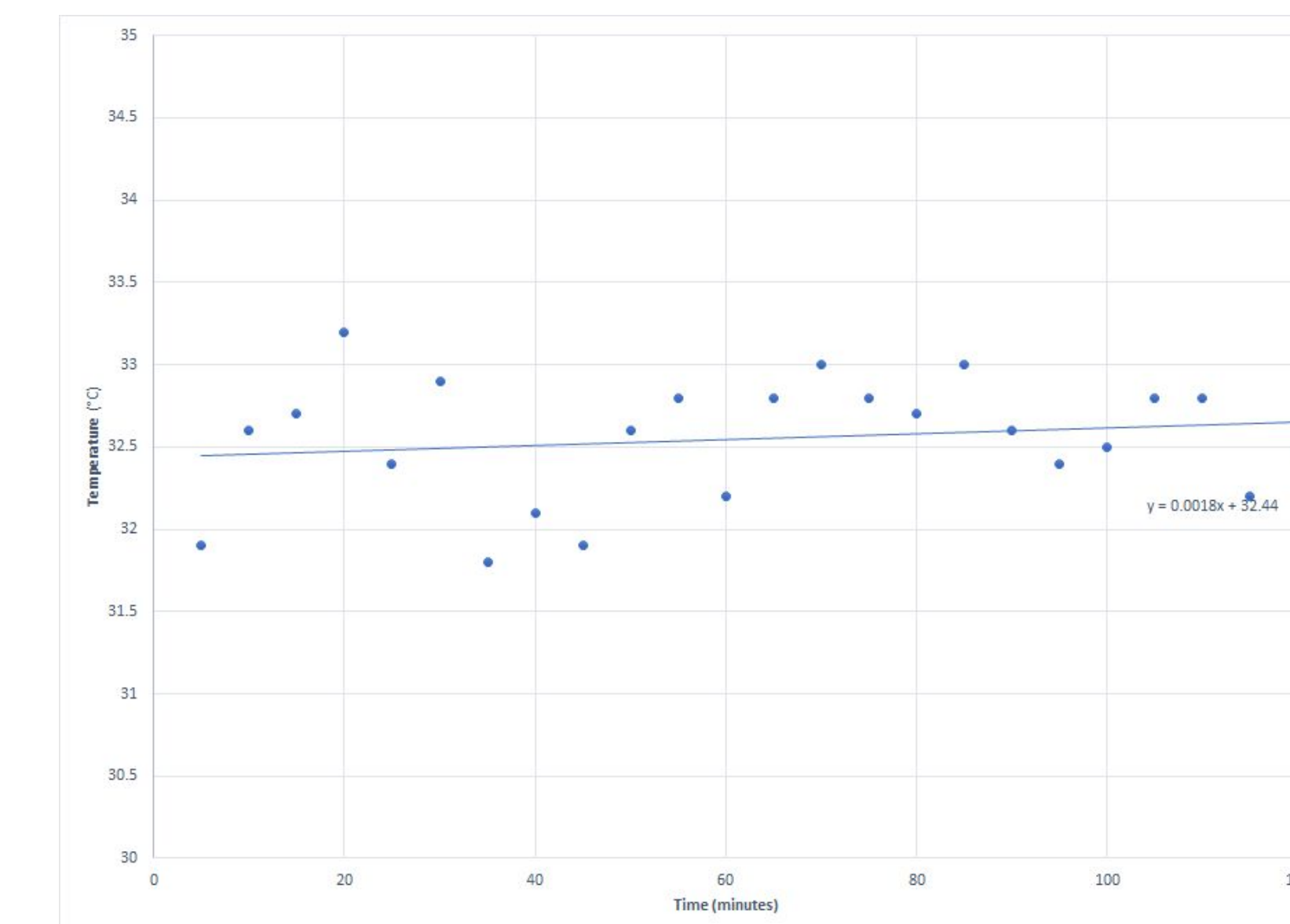


Figure 3.2 Photos of Heat Distribution Thermal Images over Two Hours in a -20°C Temperature Controlled Environment with Colors Scaled Between 14.5°C and 43.8°C

Analysis of Heat Retainment within the Sleeping Bag Results



- Activated Cardinal Health Porta-Warming Mattress was placed in the "Sleeping Bag" pocket, and a textbook (~baby weight) was placed on top of system
- Temperature of the interior environment was taken and recorded every 5 minutes via temperature gun for 2 hour duration
- Graph shows a steady retainment of heat
- Average Temperature: 32.55°C
- Standard Deviation: 0.374°C
- Range: (31.8°C, 33.2°C)

Figure 3.3 Heat Retainment Results

Analysis of Performance of Sleeping Bag Under Various Circumstances

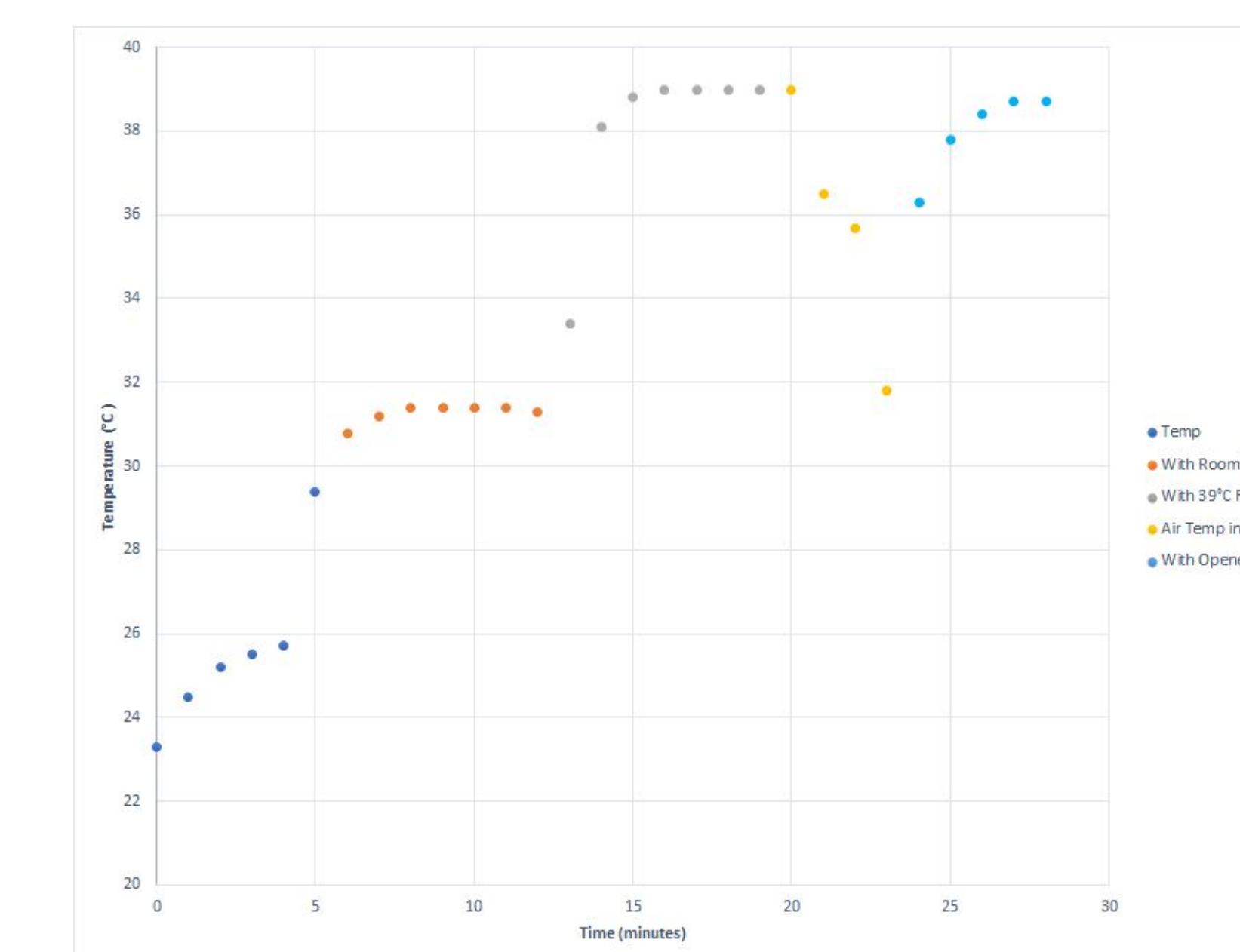


Figure 3.4 Performance Results



Figure 3.5 Sleeping Bag (right) with Fiber Optic Temperature Probe (left)



Figure 3.6 Representation of the warmer entering the MRI machine at AFCH



Figure 3.7 The Expression MR400 display monitor of real-time temperature