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February 22, 2005

Lakshman One  
School of Engineering Science  
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Re: ENSC 440 Functional Specifications for the Perfect Balance Temperature Controlled  
Mattress Pad

Dear Mr. One,

Please find attached ThermaCool's functional specifications document entitled "*Functional Specifications for a Temperature Controlled Mattress Pad*". This document outlines the functional specifications that are required of our ENSC 440 course project.

We are currently designing and building a temperature controlled mattress pad which we have designated the Perfect Balance mattress pad. Once complete, the Perfect Balance mattress pad will provide an individual with a more comfortable sleeping environment by allowing the user to specify a pre-defined mattress pad temperature. Throughout the night, the system will automatically heat or cool the mattress pad in order to meet and maintain the user's desired temperature.

The enclosed functional specifications serve as minimum requirements that are expected of the Perfect Balance mattress pad. They include aspects such as physical characteristics, operational traits, and safety standards. These specifications are essential to the successful operation of our product in normal circumstances.

ThermaCool is composed of four fourth year Systems Engineering students. Team members include Slav Bienko, David Black, Sal Daswani, and Sean Pallister. Please feel free to contact us with any questions or comments regarding our project. We can be reached by telephone at 604-943-1418 or by e-mail at [ensc440-thermacool@sfu.ca](mailto:ensc440-thermacool@sfu.ca).

Sincerely,

A handwritten signature in blue ink, appearing to read "D. Black".

David Black  
Organization Department Head  
ThermaCool Inc.

Enclosed: *The Functional Specification for a Temperature Controlled Mattress Pad*



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ThermaCool Inc.

Functional Specifications for a  
**Temperature Controlled Mattress Pad**

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***Issued date:*** February 22, 2005

***Revision:*** 4.0



## EXECUTIVE SUMMARY

Often times, people have trouble falling asleep due to non-ideal sleeping conditions. Specifically, 20% of North Americans that have trouble sleeping say that uncomfortable sleeping temperatures prevent them from achieving a good night's rest [1]. While products such as heating blankets and mattress pads have been available on the market for many years, no consumer product has yet offered the ability to cool in addition to heat the user. This is all about to change with the advent of ThermaCool's Perfect Balance temperature controlled mattress pad.

The purpose of the Perfect Balance mattress pad is to ensure a consistent and comfortable sleeping temperature all throughout the night. Whether the night is too cold or too hot, the Perfect Balance mattress pad will automatically and discreetly heat up or cool down to maintain the user's pre-defined, desired sleeping temperature.

ThermaCool has proposed to develop the Perfect Balance temperature-controlled mattress pad in two phases. In the first phase, ThermaCool will be committed to developing a prototype product to demonstrate that such a temperature controlled mattress pad is realizable. This proof-of-concept phase will be completed by mid-April 2005. In the second phase, ThermaCool will investigate the potential for minimizing costs and rendering the product more usable. After completion of the second phase, ThermaCool will have a market-ready product.

Throughout the proof-of-concept phase, ThermaCool will be anticipating the needs of a next-generation temperature-controlled mattress pad that can be brought to market as a reliable, consumer-friendly product.



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## 1 INTRODUCTION

ThermaCool is striving to achieve a subtle yet effective solution for individuals seeking better comfort and control of their sleeping conditions. In order to accomplish such a task, ThermaCool must set certain goals and functional requirements that are required of the Perfect Balance mattress pad. This document describes these needs, while distinguishing between requirements for a prototype and a market-ready product.

### 1.1 Objective

A full set of functional requirements is provided for the proof-of-concept device which will be constructed by ThermaCool. These requirements will drive the design of the Perfect Balance mattress pad prototype and will be referred to by all members of the ThermaCool team. In addition, they will serve to keep the design goals in focus during prototype construction. A set of functional requirements for the final consumer product has also been provided. Note that these requirements have been developed on the side of leniency. It is expected that a great deal of knowledge will be gained while constructing the proof-of-concept device; hence, the final consumer product's functional requirements are subject to improvement.

For an overview of the Perfect Balance mattress pad and an introduction to the company members, please refer to the *Proposal for a Temperature Controlled Mattress Pad* document [2]. This document is available upon request from ThermaCool.

### 1.2 Intended Audience

This document is intended as a reference for ThermaCool design engineers and/or subcontract design engineers hired by ThermaCool, in order to ensure proper functionality and operation of the various components that make up the Perfect Balance mattress pad. Additionally, this document may be referred to by project managers and quality assurance personnel to verify the integrity of the Perfect Balance mattress pad.

### 1.3 Conventions

Throughout this document, functional requirements will be denoted using the following convention:

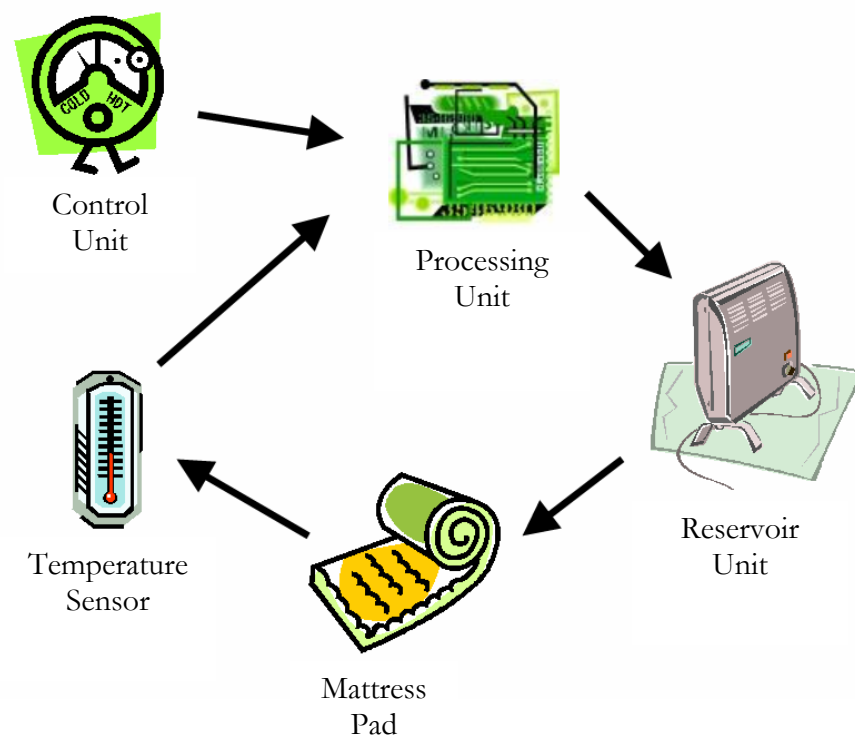
**[Rn-s]** A functional requirement.

The letter *n* will be replaced by an integer representing the functional requirement number. The letter *s* represents the stage at which the functional requirement must be implemented. These stages are distinguished as follows:

- p* The requirement applies to only the proof-of-concept stage.
- m* The requirement applies to only the market stage.
- b* The requirement applies to both the proof-of-concept stage and the market stage.

## 2 SYSTEM OVERVIEW

The Perfect Balance mattress pad will be composed of four main components; a control unit, a processing unit, a reservoir unit, and a mattress pad. Figure 1 shows the basic functions of the Perfect Balance mattress pad. A simple front panel control interface will allow the user to set the desired temperature of the mattress pad. Temperature sensors will monitor the surface temperature of the mattress pad and relay this information to the processing unit. A microcontroller inside the processing unit will then compare this temperature to the desired temperature as specified by the user. When a temperature difference is measured, the microcontroller will take the required actions to either heat or cool the water flowing through the pad. In this manner, the surface temperature of the mattress pad will be maintained at the desired temperature.



**Figure 1** – Perfect Balance Mattress Pad System Overview



### **3 GENERAL REQUIREMENTS**

#### **3.1 Durability Requirements**

**R[01-*m*]** The system will have a mean time between failure exceeding 3 years at 10 hours per day.

#### **3.2 Usability Requirements**

**R[02-*m*]** The initial setup of the system will take no longer than 20 minutes.

#### **3.3 Environmental Requirements**

**R[03-*b*]** The system will be capable of operating in the most extreme temperature conditions typically experienced indoors: between 5 and 35 °C [3].

**R[04-*b*]** The system will be capable of operating in the most extreme humidity conditions typically experienced indoors: between 25 and 85 % [3].

**R[05-*b*]** The system will be capable of operating in the most extreme air pressure conditions typically experienced in all major cities in the world: between 850 milibars and 1100 milibars [4].

**R[06-*b*]** The system will not use any chemicals that are harmful to the environment.



## 4 PROCESSING UNIT REQUIREMENTS

### 4.1 Power Requirements

- R[07-*b*] The processing unit will operate off of a single 120VAC, 60Hz wall socket.
- R[08-*b*] The processing unit will not consume more than 10W of power.

### 4.2 Physical Requirements

#### 4.2.1 Dimensions

- R[09-*b*] The processing unit will be no more than 15cm in height, 20cm in width and 30cm in length, to ensure that it will fit under most beds.
- R[10-*b*] The length of the processing unit power cable will be at least 90cm in length.
- R[11-*p*] The length of the electrical cables between the processing unit and the reservoir unit will be at least 15cm in length.
- R[12-*m*] The length of the electrical cables between the processing unit and the reservoir unit will be at least 90cm in length.
- R[13-*p*] The length of the electrical cables between the processing unit and the control unit will be at least 30cm in length.
- R[14-*m*] The length of the electrical cables between the processing unit and the control unit will be at least 180cm in length.

#### 4.2.2 Weight

- R[15-*b*] The processing unit will be no more than 5kg in weight, to ensure portability.

#### 4.2.3 Layout

- R[16-*b*] All buttons on the processing unit will be located on the back of the unit.
- R[17-*b*] Electrical cables will protrude from the rear of the processing unit, to make the unit aesthetically pleasing.
- R[18-*m*] The receptacles for the control cables of the reservoir unit and the control unit will be located on the back of the processing unit.
- R[19-*b*] The processing unit will have a master *on/off* switch capable of connecting and disconnecting the 120VAC, 60Hz power source to and from the system.

#### 4.2.4 Noise

- R[20-*b*] Noise levels of the processing unit shall not exceed 50dB, to ensure a comfortable acoustic sleeping environment [5].



### 4.3 Performance Requirements

- R[21-*b*] The processing unit will provide the system with an *auto-off* feature. This feature will automatically power down the system after 10 hours of continuous operation, to prevent unnecessary power consumption.
- R[22-*b*] The unit will be able to operate for at least 10 hours continuously.

## 5 RESERVOIR UNIT REQUIREMENTS

### 5.1 Power Requirements

R[23-*b*] The reservoir unit will not consume more than 350W of power.

### 5.2 Physical Requirements

#### 5.2.1 Dimensions

R[24-*b*] The reservoir unit must be no more than 15cm in height, 30cm in width and 30cm in length, to ensure that it will fit under most beds.

R[25-*p*] The length of the water tubing from the reservoir unit to the mattress pad will be at least 30cm in length, to ensure sufficient length to reach the mattress surface.

R[26-*m*] The length of the water tubing from the reservoir unit to the mattress pad will be at least 90cm in length, to ensure sufficient length to reach the mattress surface.

#### 5.2.2 Weight

R[27-*b*] The dry weight of the reservoir unit will be no more than 5kg, to ensure portability.

#### 5.2.3 Layout

R[28-*b*] Electrical cables will protrude from the rear of the reservoir unit, to make the unit aesthetically pleasing.

#### 5.2.4 Noise

R[29-*b*] Noise levels of the reservoir unit shall not exceed 50 dB, to ensure a comfortable acoustic sleeping environment [5].

### 5.3 Performance Requirements

R[30-*b*] For safety reasons, the reservoir unit will not cool the mattress pad below 10°C.

R[31-*b*] The reservoir unit will be able to cool the mattress pad to at least 15°C.

R[32-*b*] For safety reasons, the reservoir unit will not heat the mattress pad above 40°C.

R[33-*b*] The reservoir unit will be able to heat the mattress pad to at least 30°C.

R[34-*b*] The pump must generate a flow rate of at least 1 L./min., to ensure efficient heat transfer.

R[35-*b*] The reservoir unit will operate for at least 10 hours continuously.



### 5.3.1 Response Time

R[36-*b*] The time taken to increase the mattress pad temperature by 1°C will be no more than 2 minutes.

R[37-*b*] The time taken to decrease the mattress pad temperature by 1°C will be no more than 5 minutes.

### 5.3.2 Accuracy

R[38-*b*] The water temperature must not deviate  $\pm 2^\circ\text{C}$  from the desired temperature once the desired temperature has been obtained.

## 5.4 Maintenance/Serviceability

R[39-*b*] The user will be able to drain the coolant from the reservoir, to ensure portability.

## 6 REMOTE CONTROL UNIT REQUIREMENTS

### 6.1 Power Requirements

R[40-*b*] The control unit will not consume more than 5W of power.

### 6.2 Physical Requirements

R[41-*b*] The control unit will have a surface area of no more than 240cm<sup>2</sup> and will be no more than 4cm thick, to ensure easy handling.

R[42-*b*] The control unit will be no heavier than 1kg, to ensure easy handling.

R[43-*b*] All buttons on the control unit will be located on the front panel of the control unit, for ease of use.

R[44-*b*] Electrical cables will protrude from the bottom of the control unit, to make the unit aesthetically pleasing.

### 6.3 Interface Requirements

R[45-*b*] There will be an interface for remotely turning *on/off* the system.

R[46-*b*] There will be an interface for increasing and decreasing the desired temperature in increments and decrements of at most 0.5°C.

R[47-*b*] There will be an interface capable of reporting the actual temperature and the desired temperature with at least 0.1°C precision.

R[48-*b*] There will be a visual cue to inform the user whether the system is currently heating or cooling the mattress pad.



## 7 MATTRESS PAD

### 7.1 Physical Requirements

- R[49-*b*] The mattress pad will be at least 50cm wide, to accommodate the width of torsos of more than 99.9% of North Americans of healthy weight [6].
- R[50-*m*] The mattress pad will be at least 155cm long, to accommodate the shoulder to toe length of more than 99.5% of North Americans [6].
- R[51-*b*] The dry weight of the mattress pad will be at most 2kg, to ensure portability.

### 7.2 Performance Requirements

- R[52-*b*] The user will be able to drain the coolant from the mattress pad, to ensure portability.
- R[53-*b*] The mattress pad must sustain a flow rate of at least 10 L/min.

## 8 REGULATORY REQUIREMENTS

- R[54-*b*]** The electrical compatibility will adhere to the CSA standard for household and similar electrical appliances: CAN/CSA-E60335-1/4E-03 [7].
- R[55-*b*]** The heating feature of the system will adhere to the CSA standard for electrically heating warming pads: CAN/CSA-C22.2 NO. 15-M91 [8].
- R[56-*b*]** The exterior housing of all system components will have blunt edges.
- R[57-*b*]** All electrical circuitry will be encased in a rigid and protective structure.
- R[58-*b*]** The exterior of the reservoir unit and the processing unit will not exceed 40°C.



## 9 DOCUMENTATION AND USER TRAINING

- R[59-*m*] A user manual will accompany the system. The user manual will be printed in languages to suit ThermaCool's intended market.
- R[60-*m*] The user manual will be published for users with minimal knowledge of technical devices.
- R[61-*m*] The user manual will contain all the information the user must know in order to setup, operate, maintain, repair and dispose of the product.
- R[62-*m*] Warranty and contact information will be enclosed within the user manual.





## 10 CONCLUSION

The requirements outlined in the document are exhaustive and cover all aspects of functionality pertaining to the Perfect Balance mattress pad. Meeting these requirements will ensure an effective and reliable product. During the design process, requirements may be altered slightly in order to facilitate a more realistic design. Nevertheless, the requirements in this document denoted with a *p* or *b* will be available as part of a prototype design by mid-April 2005. Requirements denoted with an *m* will be available as part of a future design.

## 11 SOURCES AND REFERENCES

- [1] Academy of Medical and Science Technology Prevention Clinic, “Statistics,” January 2005, [www.bergen.org/AMST/pc/Sleep%20In%20Our%20Life/statistics.html](http://www.bergen.org/AMST/pc/Sleep%20In%20Our%20Life/statistics.html).
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- [4] WorldClimate, “World Weather Conditions,” February 2005, [www.worldclimate.com](http://www.worldclimate.com).
- [5] Sonic Studio, “Decibel,” February 2005, [www.sfu.ca/sonic-studio/handbook/Decibel.html](http://www.sfu.ca/sonic-studio/handbook/Decibel.html).
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- [7] Canadian Standards Association, “Electrical,” February 2005, [www.csa.ca/electronic\\_catalogue/electrical.pdf](http://www.csa.ca/electronic_catalogue/electrical.pdf).
- [8] Canadian Standards Association, “Electrically Heating Warming Pads,” February 2005, [www.csa-intl.org/onlinestore/GetCatalogItemDetails.asp?](http://www.csa-intl.org/onlinestore/GetCatalogItemDetails.asp?).