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October 19, 2004

Dr. Andrew Rawicz
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Re: ENSC 340 Functional Specification for *TemperSure*

Dear Dr. Rawicz,

Please find attached a copy of the Tempero *TemperSure* functional specification. With the *TemperSure* system installed, a user can set the desired temperature for the shower and *TemperSure* will maintain that temperature. In addition, the temperature-sensing module can be detached and used as a portable scalding prevention device. Our purpose is to eliminate the cases of scalding of children.

Our functional specification provides a set of high-level requirements for system functionality at both the proof-of-concept and production phases of system development. It is a key document for our design engineers, our project manager, and our marketing personnel who will use the functional specification as a guide for research and development activities.

If you have any questions or comments please to contact us by e-mail at temperogroup@yahoogroups.com. Alternatively, you may contact me directly by telephone at 604-254-7492.

Sincerely,

A handwritten signature in black ink that reads "Jason Wong". The signature is written in a cursive, flowing style.

Jason Wong
CEO
Tempero Systems

Enclosure: Tempero Systems functional specification for *TemperSure*

Tempero Systems

take control.

Functional Specification for a Shower Temperature Control System

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October 18th , 2004

Executive Summary

Do you hate it when you are taking a shower and suddenly, because someone in the house is doing laundry, flushing a toilet, or washing dishes, the water becomes so frigid it causes you to stop or jump out of the shower? Or consider the opposite case when the water in your shower becomes too hot and starts to burn your skin.

A study done by Health Canada [2000] shows that out of all pediatric hospital cases, about a third (32.4%) are because of injuries due to scalding by hot water because of human error [4], that is, someone had mistakenly either turned on the hot water or turned off the cold water. Another 12.3% of the cases are of children being scalded when put into water, either in the bathtub or sink, that was too hot [4]. Tempero Systems proposes to prevent such injuries which account for half (44.7%) of pediatric hospital cases with *TemperSure*.

TemperSure is a temperature control system for the shower, which consists of two value-added features: a portable scalding prevention shower head add-on, and motorized valves and solenoid valves for on-demand temperature adjustments and emergency water stoppage. With the full *TemperSure* system installed, you simply set a desired temperature on the digital display and turn on the shower. You can step into the shower without worrying about the temperature changing, not to mention the comfort of having the temperature of your shower catered to your need. If the water pressure does happen to change, *TemperSure* is equipped with motorized valves that will automatically adjust to maintain the temperature. In extreme cases where the water temperature cannot be maintained, the shower will stop running assuring you will never be scalded by water much too hot for your skin. To continue the shower, you turn on the shower as you did before starting your shower.

Tempero Systems consists of five engineering students from Simon Fraser University with backgrounds and strengths in both hardware and software. Group members also have diverse coop experience bringing diverse assets to Tempero. Most importantly, all team members are hard working individuals with great communications skills, which results in excellent team dynamics at Tempero.

We have allotted a four-month development cycle, with a completion date of December 5th, 2004, for *TemperSure*, which includes completion of a working model, functional specifications, design specifications, and a post-mortem. The costs associated with *TemperSure* are estimated, with careful allowances, at \$620 CND. Funding of *TemperSure* will come from various funds we are applying to, along with asking for donations.

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Glossary

AC	Alternating Current
ASSE	American Society of Sanitary Engineering
CE	Conformité Européene (Compliance with European Union Directives)
CSA	Canadian Standards Association
DC	Direct Current
GPM	Gallons per Minute
<i>TemperSure</i>	Shower Temperature Control System by Tempero Systems
UL	Underwriters Laboratories

1. Introduction

The requirements for a functional shower temperature control system as proposed by Tempero Systems are described in this functional specification.

1.1. Scope

This document is the functional specification for the shower temperature control system to be developed by Tempero Systems. An overview of the project and company members may be found in the *Project Proposal for a Shower Temperature Control System* available, upon request, from Tempero Systems [6].

1.2. Intended Audience

The functional specification is intended for use by all members of Tempero Systems. The project manager shall refer to the functional requirements as concrete measures of progress throughout the development phase. Design engineers shall refer to these requirements as overall design goals to be kept in focus from design to implementation of a module. Test engineers shall seek to confirm the similarity of functionality outlined in this document and actual system functionality. Marketing staff shall use this document as a guide to promoting the system to potential markets and consumers.

1.3. Classification

Throughout this document, the following convention shall be used to denote functional requirements:

[R n - p] A functional requirement.

where n is the functional requirement number, and p is the priority of the functional requirement as denoted by one of three values:

- I The requirement applies to the proof-of-concept system only.
- II The requirement applies to the final production system only.
- III The requirement applies to both the proof-of-concept system and the final production system.

2. System Requirements

2.1. System Overview

The *TemperSure* system is a feedback control system that may be modeled as shown in the functional block diagram in Figure 1 below.

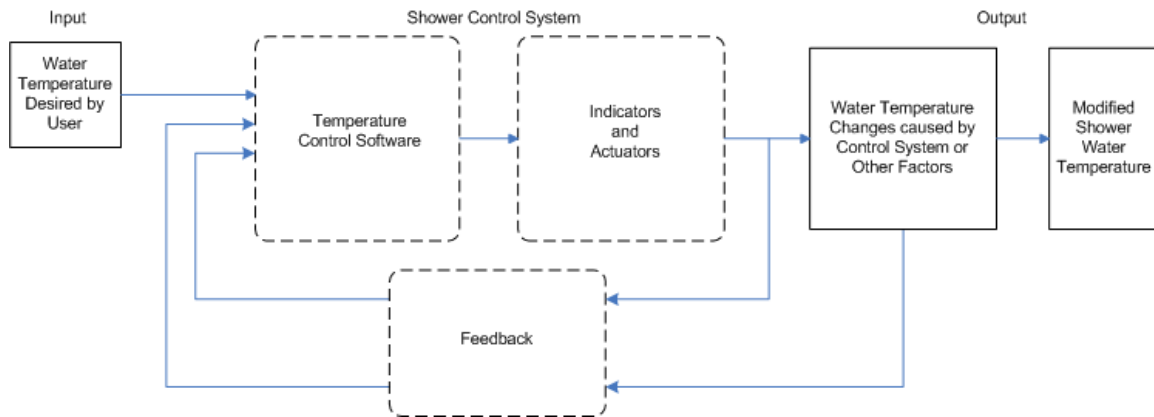


Figure 1: *TemperSure* Functional Block Diagram

TemperSure, an electronically controlled bath system, allows users to control the water temperature via a digital control panel. It includes two electronically controlled valves for adjusting the flow rate for hot and cold water, a microcontroller for signal processing, and a control panel for usability. Water temperature is monitored through a temperature-sensing unit located in between the shower pipe and the showerhead.

In addition to the evident user conveniences, the temperature-sensing unit, located just before the showerhead, is also a portable scalding prevention device. When water temperature reaches above a safe temperature, a built-in solenoid valve will shut off the water supply to prevent the user from being scalded.

2.2. Electrical Requirements

[R1-III] The motorized valves, control panel, and user interface will be powered by a power supply requiring 120 V AC.

[R2-II] The temperature unit will be battery powered.

2.3. Mechanical Requirements

[R3-III] The minimum flow rate must be in and out of the system must be 2.0 gallons per minute (GPM).

[R4-III] The change in flow needs to be quick enough to keep the water temperature within one degree of error. In cases when the incoming water temperatures are near insufficient to provide the desired output temperature, a more lenient temperature range is acceptable on this requirement.

- [R5-III] The unit shall be capable of operating in temperature ranges of 0°C to 50°C.¹
- [R6-III] When the temperature exceeds a threshold temperature, the water flow will cease.

2.4. Environmental Requirements

- [R7-II] The system shall operate normally under typical bathroom temperatures.
- [R8-II] The system shall operate normally under typical bathroom humidity conditions.

2.5. Standards

The *TemperSure* temperature control system shall comply with the following:

- [R9-II] CSA standards [2]
- [R10-II] UL standards [7]
- [R11-II] European Union Directives (CE Marking Requirements) [3]
- [R12-II] ASSE Standard #1070-2004 *Performance Requirements for Water Temperature Limiting Devices* [1]

2.6. Reliability

- [R13-II] The system shall not contain any user serviceable parts.
- [R14-II] The mean time before failure of the system shall be 100,000 hours.

3. Temperature-Sensing Unit

The temperature sensor unit serves two purposes:

- 1) To provide constant temperature feedback to the temperature control unit
- 2) To act as a portable anti-scald device that will prevent water from flowing through the shower head when water temperature rises over a certain threshold

3.1. General Requirements

- [R15-III] The water level inside the pipe must be enough to cover the temperature-sensing element.
- [R16-III] The temperature-sensing element shall experience minimal movement caused by water flow during system operation.
- [R17-III] The signal from the temperature-sensing element shall be amplified at all times.

¹ The temperature range of water *TemperSure* can deliver is dependent on the incoming water temperature. *TemperSure* will not be delivering water above 50°C, for 50°C water will cause scalding [5].

3.2. Performance Requirements

- [R18-III] The water should stop flowing within 1 second after high temperature is detected.
- [R19-II] Battery can be switched to recharge mode once the unit is used along with the whole auto shower system.
- [R20-III] Normal usage of the unit must be possible without frequent replacement of the temperature-sensing element.
- [R21-II] Users can adjust the threshold temperature for activating the safety stop valve.
- [R22-III] The unit should provide a linearly proportional output for the temperature control unit.
- [R23-II] The safety stop feature shall have the capability to be disabled via a non-prominent button within the temperature-sensing unit.

3.3. Physical Requirements

- [R24-III] Temperature-sensing element must be chosen to ensure fast response time
- [R25-II] The whole unit must be small and lightweight
- [R26-II] The whole unit must be battery powered for portability.

3.4. Testing Requirements

- [R27-II] The temperature-sensing unit shall provide accessible points for measuring voltage output from the internal temperature-sensing elements.

4. Valve Position Sensing Unit

The valve position-sensing unit consists of a set of sensors that track the position of a valve based on a predetermined reference point.

4.1. General Requirements

- [R28- III] The unit shall report the position of the motors accurate to within $\pm 5^\circ$.
- [R29- II] The unit shall consume as little power as possible to reduce power draw.
- [R30- III] The unit shall shutdown valve operations if sensors are malfunctioning.

4.2. Physical Requirements

- [R31- II] The unit must be kept small and must be composed of the least number of components as possible.

4.3. Performance Requirements

- [R32- III] The unit must respond to a read command in 25 ms.

- [R33- III] The unit must ensure all signals are genuine, i.e. false detection is not acceptable.

4.4. Testing Requirements

- [R34- I] The sensing elements inside the unit shall be accessible to facilitate replacement in case of failure.

5. Valve/Motor Control Unit

The valve/motor control unit dictates the resulting mixture of hot and cold water coming out of the *TemperSure* system. The unit will be a type of motorized valve.

5.1. General Requirements

- [R35-III] The input voltage levels shall not exceed nor be less than a required amount.
- [R36-III] The current supplied must be sufficient to run the system, but not exceed the maximum current rating.
- [R37-III] The valves shall accept two inputs of hot water and cold water.
- [R38-II] The valves must be able to handle the pressure of typical household water lines.
- [R39-III] The output will be a mixture of the hot and cold water inputs.

5.2. Performance Requirements

- [R40-I] The change in flow of water shall occur once voltage is applied.
- [R41-III] The change in flow of water shall be constant with applied voltage.

5.3. Physical Requirements

- [R42-II] The motor and valve system shall be small enough to fit into the wall of a bath/shower unit.

5.4. Testing Requirements

- [R43-III] When a specific voltage is applied, the flow of water should increase.
- [R44-III] When an opposite voltage is applied, the flow of water should decrease.

6. Temperature Control Unit

The temperature control unit acts as the primary controller for the *TemperSure* system. It shall contain the control algorithms and shall act as the interface between inputs driven

by the user and system feedback units, and outputs to the motor control, safety stop valve, and display modules.

6.1. General Requirements

- [R45-III] The unit shall process user inputs.
- [R46-III] The unit shall process input from system feedback units.
- [R47-III] The input voltage range of the unit shall neither be below nor exceed the output voltage range of the temperature-sensing and valve position-sensing units.
- [R48-III] The output voltage range of the unit shall neither be below nor exceed the voltage range of the motor control, anti-scalding, and display units.

6.2. Performance Requirements

- [R49-II] The unit shall respond to an emergency stop command.

6.3. Safety Requirements

- [R50-III] Input voltage ranges from the temperature-sensing unit representing the current temperature shall exceed the range of safe water temperatures.
- [R51-III] Output voltage ranges of the unit representing desired temperatures shall not exceed the range of safe water temperatures.
- [R52-III] Inputs from system feedback units shall have higher priority than user inputs.
- [R53-III] The unit shall accommodate for emergency stop procedures at all times.

6.4. Physical Requirements

- [R54-III] The unit shall be powered by an external power supply.
- [R55-I] The unit shall be connected to inputs and outputs via 22 or 24 gauge solid wires.
- [R56-II] The unit shall have input and output jacks that accept standardized connectors.
- [R57-II] The unit shall be waterproof.
- [R58-II] The unit shall be compact for ease of installation.

6.5. Testing Requirements

- [R59-I] The unit shall provide logical input status accessible via software debugging measures.
- [R60-III] The unit shall provide logical input status accessible via LEDs.
- [R61-I] The unit shall provide accessible input points for voltage measurements.
- [R62-I] The unit shall provide logical output status accessible via software debugging measures.
- [R63-III] The unit shall provide logical output status accessible via LEDs.

[R64-I] The unit shall provide accessible output points for voltage measurements.

7. Piping

7.1. General Requirements

- [R65-III] The piping must be able to withstand the pressure of typical household water lines.
- [R66-III] The piping must be of the same diameter as the valves.
- [R67-III] The piping must connect the water flow from the valves to the temperature control unit.
- [R68-III] We must be able to attach a shower head at the end of the piping at the output of the temperature-sensing unit.

8. User Interface Unit

The user interface unit shall consist of a set of buttons as inputs and display elements as output. Outputs from the buttons shall be connected to the temperature control unit. The display shall be driven by outputs from the temperature control unit.

8.1. General Requirements

- [R69-III] The primary means of user input shall be via a set of push buttons.
- [R70-II] The primary means of user input shall be via an input device more sophisticated than that in the previous requirement.
- [R71-I] The primary means of graphical user feedback shall be via an electronic display.
- [R72-II] The primary means of graphical user feedback shall be via an output device more sophisticated than that in the previous requirement.
- [R73-I] The desired water temperature shall be displayed in degrees Celsius.
- [R74-II] The user may choose to display current and desired water temperature in either degrees Celsius or degrees Fahrenheit.

8.2. Safety Requirements

- [R75-III] The desired water temperature shall be displayed at all times.
- [R76-III] The emergency stop feature shall be visible at all times.
- [R77-I] Dedicated display devices shall display error status.
- [R78-III] Temperatures entered via the user input unit shall neither be below nor exceed the range of safe water temperatures.

8.3. Usability Requirements

- [R79-II] The desired water temperature shall be the only visible temperature information given on the display.
- [R80-III] The desired water temperature shall flash on the display while the system is in the process of adjusting water flow to attain such a temperature.
- [R81-II] The stop button shall be physically differentiated from all other push buttons.
- [R82-III] The desired temperature input shall be entered via two buttons, one for increasing temperature, and another for decreasing temperature.
- [R83-III] Only one push button shall be active at any time.
- [R84-III] The desired temperature shall be incremented by 1 degree Celsius when the button for increasing temperature is pressed and held for less than 2 seconds.
- [R85-III] The desired temperature shall be decremented by 1 degree Celsius when the button for decreasing temperature is pressed and held for less than 2 seconds.
- [R86-II] The desired temperature shall be incremented by 2 degrees Celsius when the button for increasing temperature is pressed and held for 2 or more seconds.
- [R87-II] The desired temperature shall be decremented by 2 degrees Celsius when the button for decreasing temperature is pressed and held for 2 or more seconds.
- [R88-II] The set of buttons or similar input device shall be able to accept direct user input of the desired temperature.
- [R89-III] Desired temperature shall be displayed in degrees Celsius with up to two significant digits with digits in the tens and ones place.
- [R90-II] Desired temperatures shall be displayed in degrees Fahrenheit with up to three significant digits with digits in the hundreds, tens, and ones place.
- [R91-II] The keypad and display shall be able to store, manage, display, and select desired temperatures and temperature ranges preset by the user.

8.4. Physical Requirements

- [R92-III] The user input unit and display unit shall be combined into a single unit.
- [R93-II] The unit shall be made waterproof.
- [R94-II] The user input unit and display unit shall be compact for ease of installation.
- [R95-II] The user input unit and display unit shall be able to be relocated from the temperature control unit within the length of a typical shower or bathtub.

8.5. Testing Requirements

- [R96-I] The buttons or similar input device shall provide logical output status accessible via software debugging measures.
- [R97-I] The buttons or similar input device shall provide accessible output points for voltage measurement.

- [R98-I] The display or similar output device shall provide logical input status accessible via software debugging measures.
- [R99-I] The display or similar output device shall provide accessible input points for voltage measurement.

9. System Test Plan

The *TemperSure* system test plan consists of testing the functionality of individual modules, testing the functionality of integrated modules, and testing the functionality of the system based on typical user scenarios.

9.1. Hardware

9.1.1. Motor Control Unit Functionality

- [R100-III] Given a set of motor position logic inputs, the motor control unit shall output linearly proportional voltages required for the desired amount of motor rotation.
- [R101-III] The previous requirement shall hold when the motor control unit is connected to one or more motors.

9.1.2. Valve Sensing Unit Functionality

- [R102-III] The logic output of an individual valve sensor shall be linearly proportional to the corresponding change in the rotational position of the valve within the area of detection of the sensor.
- [R103-III] The cumulative output of the set of sensors comprising the overall valve-sensing unit shall be proportional to the overall change in the rotational position of the valve from a predefined reference point.

9.1.3. Temperature Sensing-Element Functionality

- [R104-III] The temperature measured with the temperature-sensing element shall be checked against the temperature measured using a thermometer.

9.2. Software

9.2.1. Control Software Functionality

- [R105-III] Given a set of desired user logic inputs the control software shall provide the logic outputs that are consistent with the devised control algorithm.

- [R106-III] Given a set of system feedback logic inputs the control software shall provide the appropriate logic outputs that are consistent with the devised control algorithm.
- [R107-III] Given a set of combined user logic and system feedback logic inputs the control software shall provide the appropriate logic outputs that are consistent with the devised control algorithm.

9.2.2. User Input Functionality

- [R108-III] The voltage output of each button shall be within to the required range for a logic high input.
- [R109-III] The temperature control unit shall provide reasonable and predictable behaviour for simultaneous multiple button presses.

9.3. *Integrated Units*

9.3.1. Valve Positioning Functionality

- [R110-III] When the shaft on a motor is mechanically coupled to a valve, the amount of valve movement, the corresponding output voltage of the motor control module, and the corresponding motor position logic inputs shall be determined.

9.3.2. Temperature Feedback Functionality

- [R111-III] The temperature sensor module integrated into the shower head and connected to the temperature control unit shall provide a proportional logic output when a water temperature change is provided as its input.

9.3.3. Valve Feedback Functionality

- [R112-III] The valve sensor module integrated with the motors, the valves, and the temperature control unit shall provide a proportional logic output when a rotational valve position change is provided by the DC motors as its input.

9.3.4. User Interface Functionality

- [R113-I] The system response to each user command shall not exceed 1 s when the user interface is integrated with the other system modules.
- [R114-II] The system response to each user command shall not exceed 100 ms when the user interface is integrated with the other system modules.
- [R115-III] The desired temperature given on the display of the user interface unit shall be updated instantaneously when water is being emitted from the shower head.

9.4. Typical User Usage Scenarios

User scenarios for typical usage to be followed during system testing are described below.

- [R116-III] For safety purposes during development, testers will remain outside the shower, contrary to the typical user location given.
- [R117-III] The status and functionality of each step in a user scenario shall be confirmed through probes of software/hardware status by test engineers during the system test phases.
- [R118-III] The tester shall ensure that the current temperature measured by the temperature-sensing unit is accurate, compared to another temperature measurement device (i.e. thermometer), at all steps of a user scenario.

[R119-III] Start of a Shower

User Location: Outside the shower

1. Turn on the system via the user interface unit by pressing the **Power** button.
2. Wait for the system to determine current water temperature. Water should be emitted from the shower head during this time.²

[R120-III] Setting Desired Temperature by Increasing Temperature Only

User Location: Inside the shower

1. Continue from Step 4 of *Start of a Shower* scenario.
2. Using only the **Increase Temperature** button on the user interface unit, enter a desired temperature within a reasonable, system-allowable range.
3. User waits for temperature to change.
4. User begins showering.

[R121-III] Setting Desired Temperature by Decreasing Temperature Only

User Location: Inside the shower

1. Continue from Step 4 of *Start of a Shower* scenario.
2. Using only the **Decrease Temperature** button on the user interface unit, enter a desired temperature within a reasonable, system-allowable range.
3. User waits for temperature to change.

²The time for arriving at the desired water temperature is dependent on the change in temperature of the incoming water. After many hours of inactive water usage, the incoming hot water will be cold. *TemperSure* will only be able to deliver the desired temperature once the incoming water is such that a mixture of water at the desired temperature can be achieved.

4. User continues showering.

[R122-III] Setting Desired Temperature via Arbitrary User Changes

User Location: Inside the shower

1. Continue from Step 4 of *Start of a Shower* scenario.
2. Using either the **Increase Temperature** button or the **Decrease Temperature** button on the user interface unit, enter a desired temperature within a reasonable, system-allowable range.
3. User waits for temperature to change.
4. User makes another arbitrary change of the desired temperature after 1 min.
5. Repeat Step 3.
6. User continues showering.

[R123-III] End of a Shower

User Location: Inside the shower

1. Continue from Step 4 of *Start of a Shower* scenario.
2. Turn off the water flowing from the shower head and power down the system via the user interface unit by pressing the **Power** button.

[R124-III] Simulation of Unforeseen Water Flow Changes

User Location: Inside the shower

1. Continue one of these scenarios:
 - a. Step 4 of *Start of a Shower* scenario.
 - b. Step 4 of *Setting Desired Temperature by Increasing/Decreasing Temperature Only* scenarios.
 - c. Step 6 of *Setting Desired Temperature via Arbitrary User Changes* scenario.
2. Flush a nearby toilet.
 - a. User should note no change, about ± 1 Celsius degree, in water temperature.
3. Turn on fully a hot water faucet of a nearby sink.
 - a. User should note no change, about ± 1 Celsius degree, in water temperature.

10. User Documentation

[R125-II] User documentation shall include a web site with general and technical support information and a user's manual, both written in English.

[R126-II] The user's manual shall be written for an audience with minimal knowledge of electronic devices and of plumbing system details.

- [R127-II] User documentation shall include an installation guide written for an audience with minimal knowledge of electronic devices and of plumbing system details.
- [R128-II] User documentation shall be in French, Spanish, German, Chinese, and Japanese to satisfy product language requirements for North American, Asian, and European markets.
- [R129-II] A detailed installation guide for installation specialists and vendors shall be created that includes information for adapting the *TemperSure* System to various plumbing system and shower configurations.

11. Conclusion

The requirements for the planned functional features of the Tempero *TemperSure* shower temperature control system have been detailed in this functional specification. A set of requirements have been provided for proof-of-concept system development, for production system development, and for essential system functionality common to both types of development. Comprehensive testing requirements for each module and an overall system test plan included in this functional specification provide a user-centered approach for measuring overall system quality.

12. References

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[7] Underwriters Laboratories. 2004. *UL's Standards for Safety – Standards Catalog*. 18 October 2004 <<http://ulstandardsinfontet.ul.com/catalog/stdscatframe.html>>.