February 16th, 2011

Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser University
8888 University Drive
Burnaby, BC
V5A 1S6

Re: ENSC 440 Functional Specification for the Safety Add-on for Electric Stoves

Dear Dr. Rawicz,
Attached is a document describing the functional specifications for the ShutSmart product, proposed by our company **Universal Safety Solutions Inc.** The ShutSmart will facilitate the safe usage of electric stoves throughout North America. It works as an emergency response to unattended stoves that are a major cause of fires in houses. It would nullify the human errors due to common user negligence by alerting the users of unattended stoves, or by disconnecting the power supply to the stove thereby preventing any major mishaps. ShutSmart will be stove independent, in the sense that it can be installed by the user for any electric stove without making any major changes in the stove design.

Our functional specification provides a set of high-level requirements for the development and functionality of our product. It will give an in-depth idea about the product design, functionality and the developmental phases. Our company will also take into consideration the universal standards that need to be followed to produce a product of acceptable standards.

Universal Safety Solutions Inc. is a team of four hard-working and committed engineering students – Abhishek Dubey, Milad Hajihassan, Sibghat Ullah and Vikas Yadav – who bring to the table a wide spectrum of knowledge from various fields of engineering. If you have any questions or concerns regarding our project proposal, please feel free to contact me by email at vya3@sfu.ca.

Sincerely,

Vikas Yadav
Project Manager
Universal Safety Solutions Inc.

Enclosure: Functional Specification for the Safety Add-on for Electric Stoves

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Enclosure: Functional Specification for the Safety Add-on for Electric Stoves

Functional Specification for

ShutSmart – The Safety Add-on for Stoves

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ENSC 440

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ENSC 305

Issued Date:

Feb 16, 2011

EXECUTIVE SUMMARY

On January 3rd, 2009 a New Year's Day party in Port Hardy, BC, turned into a tragic event for a family, when a fire broke out in their kitchen claiming three lives and causing property damage. On investigation the cause for the fire was nailed down to an unattended stove and basic user negligence [1]. On initial thought, this sounds like a regular accident we hear about or read in the media on daily basis. But such cases are a very common occurrence in households, where a negligent user leaves the stove unattended and the lack of alert/alarms or an untimely response leads to massive fires. People often leave their stoves turned on to watch TV or pick up a phone call. Sometimes stoves are left turned on while people go away for work or some other social activity. Also, old age accompanies slower reaction times and agility in people and it is not unlikely to leave stoves unattended. In these certain conditions, the risks of fire accidents reach its zenith. Moreover, preschoolers and school aged kids often have the habit to discover new things around them and hence, they are the major victims of stove accidents. A 2002 press release from CCFMFC throws some light on how rampant such accidents are - there were 5541 reported cases of fire due to unattended stoves or delayed response. The result was 19 deaths and 81 million dollars in monetary loss [2].

This raises a critical question – with all the advanced technology available to us today, why don't we have a foolproof system of preventing such mishaps in the future? Up until now, there are some ways (vague rules) to prevent fire in your kitchen. Firstly, when you are cooking something on your stove it will be better to remain in the kitchen. Secondly, the user should turn off the stove before leaving his/her cooking station. Thirdly, make sure to check your stove and oven before leaving your house. Lastly, it will be better for users to utilize timers while cooking. They can act as a reminder or alarm to help the user keep a check on the stove regularly. Unfortunately these solutions are all cognitive rather than technological, and leave a huge margin for human error.

This document outlines the general, physical, electrical and other related functional specifications of our product, ShutSmart. We will also discuss the various universal standards which we will adhere to, in order to ensure a safe product. We aim to achieve the completion of the working product prototype by April 5th, 2011.

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GLOSSARY

AC	Alternating Current
AM	Amplitude Modulation
ASK	Amplitude Shifting Keying
CCFMFC	Council of Canadian Fire Marshals and Fire Commissioners
DC	Direct Current
FM	Frequency Modulation
LED	Light Emitting Diode
RF	Radio Frequency
USS	Universal Safety Solutions Inc.

1. INTRODUCTION

The ShutSmart is a safety add-on for electrically operated stoves used throughout North America. The purpose of this product is to incorporate a mechanism in a stove safety system, which would prevent the occurrence of any mishaps due to unattended stoves. It detects unattended stoves and initially alerts the user through audio/visual feedback. If this fails to alert the user, ShutSmart overrides the stove system and cuts off the power to the stove. The requirements for ShutSmart as proposed by Universal Safety Solution Inc. are described in this functional specification.

1.1. Scope

This document gives an in-depth analysis of the functional specifications that must be assigned to the product. This set of requirements showcases the proof-of-concept device, and also gives a fair idea about the final production device. The functional specifications are also a mean of keeping track of the development of our product, and will be a valuable asset during quality assurance testing.

1.2. Intended Audience

The functional specifications shall be used by all four members of Universal Safety Solutions Inc. The project manager shall use it as a tangible means of keeping track of the developmental phases of the project. Design engineers shall refer to the document to keep in check the designing and implementation goals that are intended for the product. Test and integration engineers shall use this document in comparing the final product with the proposed design, and assess any fallacies that might have occurred. Ergonomists shall use this document as a utility to aid in the design of the user demonstrations.

1.3. Classification

The following convention shall be used to improve the readability of this document.
[Rn-p] – A functional requirement

Where **n** is the functional requirement number, and **p** denotes the priority level of the requirement.

The priority levels are defined as follows:
I High Priority Level
II Moderate Priority Level
III Low Priority Level

2. SYSTEM OVERVIEW

The product ShutSmart to be released by Universal Safety System Inc. consists of four independent units, which are integrated together to create a stove safety-add on. ShutSmart will deal with unattended stoves, along with a joint system for smoke detection and motion detection. The three units are as follows:

A. Main Unit
B. Wireless Control Unit
C. Sensor Unit
    a. Smoke Detection System
    b. Motion Detection System

2.1. Main Unit

This will be the biggest component of our product, and will consist of a microcontroller board encapsulated in a sturdy and durable box. It would be connected to a power-source in the household, while the four-pin power line from the stove would be plugged into a four-pin power socket located on the box. The box will have alert-alarm mechanisms in the form of LEDs and a speaker which would give audio/visual feedback to the user, thereby, helping the user take appropriate action. A reset button will be incorporated to reset the system to its initial working state. It will also have a ventilation fan to maintain suitable conditions for the microcontroller and other devices. The relay mechanism on the microcontroller would turn off the power supply to the stove as required.

2.2. Wireless Control Unit

This unit will consist of a mechanical box which will be located within the stove – beneath each of the stove plates. The installation would not require any technical skills making for its user-friendly installation. The inner components will be enclosed in a durable and high-heat resistant casing made of braided-silica to prevent any damage from the stove heat. The upper segment will have two spring operated hook-pins which would mechanically break the circuit within the box when something is placed on the stove. The box will be battery operated; the battery slot will be easily accessible when a replacement is required.

2.3. Sensor Unit

This unit is made up of two components – Smoke Detection System and Motion Detection System.

2.3.1. Smoke Detection System

The wireless smoke detector will be attached to the platform located above the stove, close to the exhaust. It would act as a localized smoke alert, detecting any smoke being produced from the unattended food. Upon

detection, the system would send a signal to the microcontroller box to set off the appropriate visual/audio feedbacks to alert the inattentive user.

2.3.2. Motion Detection System

The motion detector has been incorporated to take care of the condition when a user is well aware of the situation on the stove, and does not need to be alerted about the smoke being produced, or the empty stove. It will detect motion within a certain range and put the overall system on standby indicating that the user is within control of the situation, and is alert enough to take care of any hazards. While we treat it as a separate component, the motion detector will be integrated with the smoke detector system as a single unit placed above the stove.

The block diagram in Figure 1 demonstrates the overall system functionality, while Figure 2 gives a physical overview of the product system.

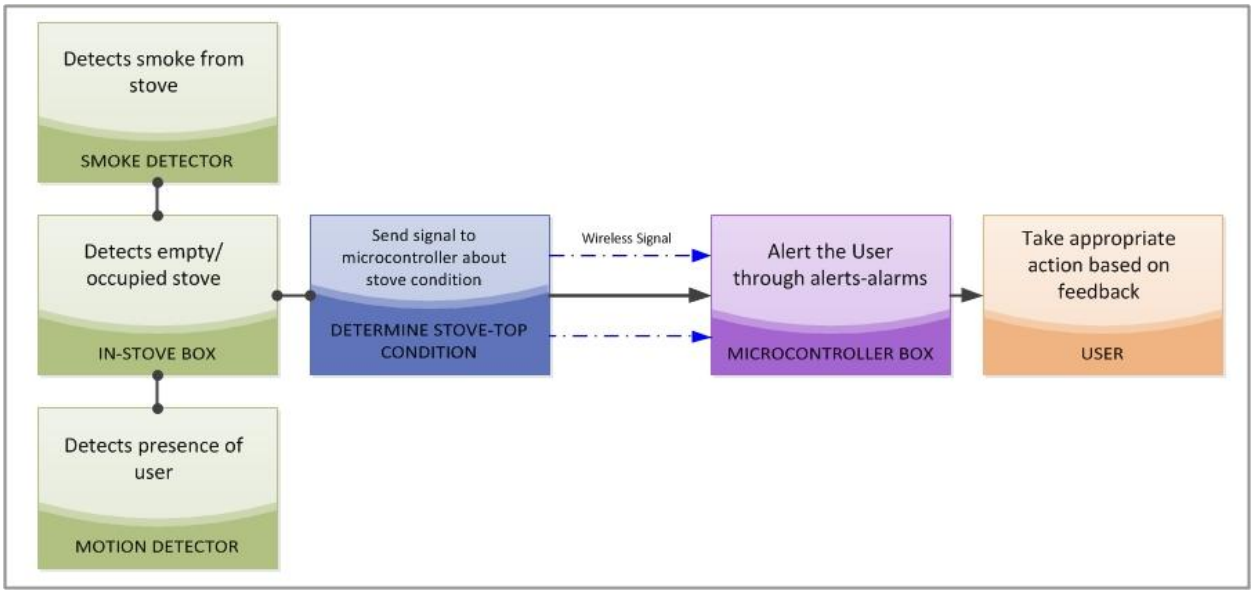

Figure 1: Block diagram of the overall system functionality of ShutSmart

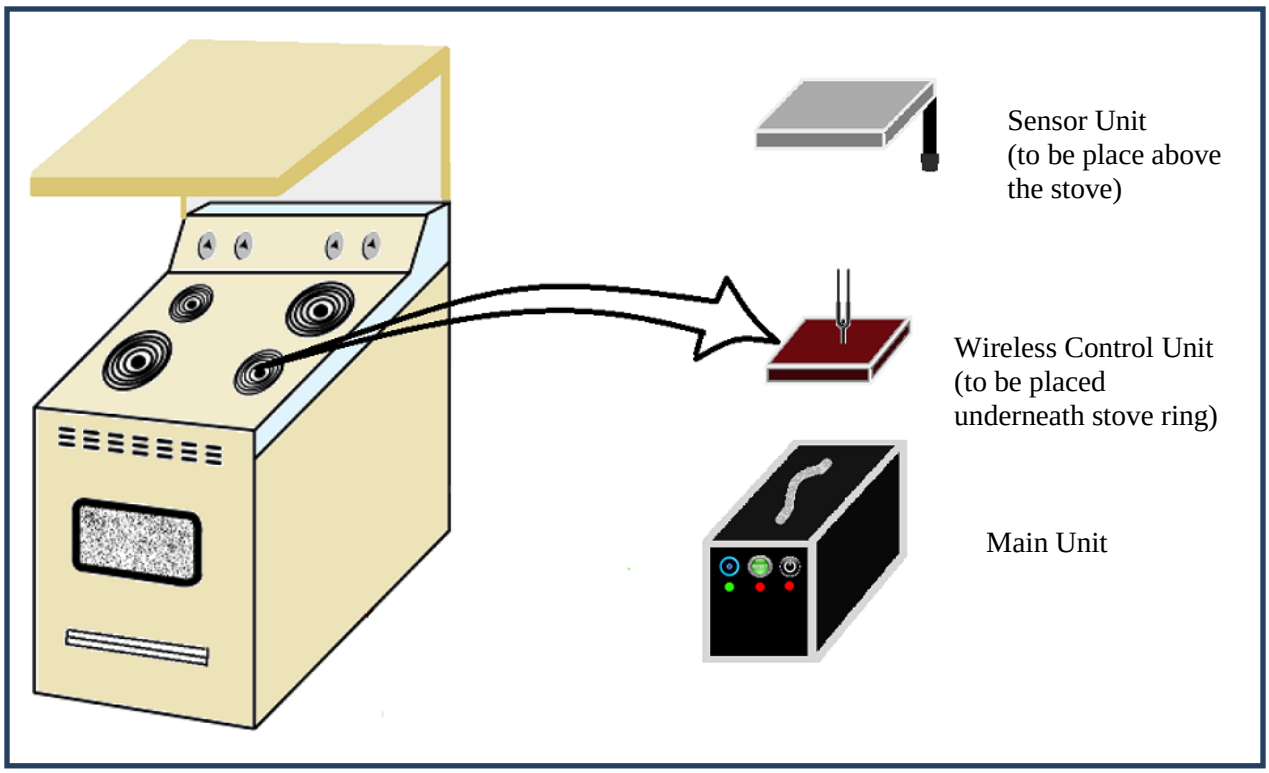

Figure 2: Physical Schematic of the complete ShutSmart system

2.4. Normal Operating Conditions

ShutSmart will be used under regular operating conditions in households. Most households in North America have an indoor heating system. Therefore, the temperature range for the main unit would be 10^{O}C to 28^{O}C. The main unit would be placed on a stable and dry platform. The wireless control device on the other hand would be susceptible to humidity and heat, and will have a durable casing to prevent any damage. The operational temperature for the wireless control unit would have a higher range as it will be located close to the stove – around 20^{O}C to 100^{O}C.

3. System Requirements

In this section, we will discuss the various system requirements of our product ShutSmart. As seen in section 2.1, we divided our product into 3 main units – the main unit, the wireless control unit and the sensor unit. We will follow this convention and talk about the product requirements pertaining to these three units. A final section with general requirements has been added which will take care of the requirements of the product as a whole.

3.1. Main Unit

Physical Requirements

[R1-I] The box shall have dimensions: 10in x 20in x 10in.

[R2-II] The box shall not weigh more than 5 pounds.

[R3-II] There shall be no buttons on the top, only a carrying strap and a company logo.

[R4-III] Box color will be black and product name will be written on the front panel in white color.

[R5-I] There shall be 3 main buttons on the front panel:

(i) Reset Device: It will operate the relay switch, i.e. once the stove has been shut off, this button will be used to turn it back on and reset all timers.

(ii) Reset Alarms: When any alarms go off, if a user is there to respond to them, the user can acknowledge his/her presence by hitting this button and all alarms will be shut off and timers will be reset.

(iii) Power (on/off): This button will be used to supply power to the whole box.

[R6-I] There shall be 3 LEDs on the front panel, which flash along with the alarm:

(i) Power: Its status will be green when the device is turned on and the LED will be 'off' when the device is not operating.

(ii) Burn: This red color LED will flash, if an alarm goes off because of the smoke detector.

(iii) Stove: This red color LED will flash, if a stove was simply left on and unattended, while nothing was being cooked.

[R7-II] There shall be a few holes on the front panel for propagating alarming sounds.

[R8-II] There shall be ventilation openings on either side of the box.

[R9-I] There shall be two input sockets at the back panel:

(i) AC/DC power adapter to power the box

(ii) Stove power plug

[R10-I] The box output shall go to the power socket in the wall.

[R11-II] There shall be a fan at the back whose diameter shall be no more than 5 inches.

Electrical Requirements

[R12-I] The 3 phase plug in the unit shall be of a rating 1.5 times that of the stove.
[R13-I] Microcontroller shall operate at 15 volts DC supply using an AC to DC adapter.
[R14-I] The FM receiver shall take no more than 5 volts.
[R15-I] The RF wave received shall have a peak to peak value close to 3 volts.
[R16-I] The relay gates shall respond to 5 volts (tolerance of ± 0.2 volts).
[R17-II] The ventilation fan at the back shall operate at 5 volts DC.
[R18-II] All LEDs shall consume at most 3 volts.
[R19-I] Power cords shall have the capability to handle high currents of up to 60 amperes.

Safety Requirements

[R20-I] Power cord shall be well-coated with a double layer of insulating material as it shall be carrying high amounts of currents.
[R21-II] The frequency of receiver shall be under 433 MHz to avoid interference with other devices.
[R22-II] A heat sink shall be used to avoid overheating of the device.
[R23-I] Relays shall open and close without arcing.
[R24-I] Relays shall generate minimal EMF.

Environmental Requirements

[R25-II] Most of the material used shall be recyclable.
[R26-II] All components used are digital; so no harmful substances will be released in the environment.
[R27-III] Double layer insulation on high current carrying wires will avoid heat dissipation into surroundings.
[R28-III] No extra noise will be generated besides the alarms and minimum sound of the fan (same amount of sound as a laptop fan, which is almost negligible).

3.2. Wireless Control Unit

Physical Requirements

[R29-I] The box shall have dimensions of 3.5in x 4in x 1in.
[R30-I] The weight of the box shall not exceed 1 pound.
[R31-I] The box shall be enclosed in a heat resistant material – braided silica.
[R32-I] Push pins shall be height adjustable to compensate stoves which have burning ring up to 10 inches away from the base of the stove.
[R33-II] Battery remover slot will be towards the bottom of the box.
[R34-II] A simple on/off button will be provided to control the power to the box.

Electrical Requirements

[R35-I] The overall unit shall withstand heat of up to 100 degrees Celsius.
[R36-I] The thermistors which shall be placed above the box shall withstand up to 125 degrees Celsius.
[R37-I] The overall circuitry shall transmit 2.7 – 3.0 volts if the thermistor is detecting heat on an unattended stove.
[R38-III] The ground shall be used to avoid current leakage to the surface of the stove.

Mechanical Requirements

[R39-I] The push pins shall be designed in Y-shape to balance out pressure of all kinds.
[R40-II] The push pins which will stick out shall be designed in such a way, that they are height-adjustable.
[R41-I] The circuit shall be mechanically control and shall break when the pins are pushed in.
[R42-II] The overall box shall be held together with 4 screws in the four corners.

3.3. Sensor Unit

Physical Requirements

[R43-I] The dimensions of this unit shall be 6in x 6in x 3in.
[R44-I] The weight of the unit shall not exceed 2 pounds.
[R45-I] It shall be placed directly above the center of four stove rings on the exhaust panel.
[R46-II] Strong double sided adhesives shall be used to place the unit above the stove.
[R47-II] Additional brackets will be provided to mount the device, if the user is not comfortable in mounting with adhesives.
[R48-III] The color of the unit will vary depending on the colors for smoke detector and motion sensor available at the time.
[R49-I] The unit shall have a heat resistant covering made of high tensile strength to withstand high amounts of heat from the stove.
[R50-II] A filter shall be provided to collect the dust and carbon chemicals, which will need to be replaced once to twice a week depending on the stove use.

Electrical Requirements

[R51-I] The smoke detector and the motion sensor shall consume 5-6 volts at most.
[R52-II] The RF transmission shall be ASK.
[R53-I] FM transmitter shall consume no more than 2-3 volts.
[R54-I] The unit shall operate at low current of about 1.5 amperes.

Safety Requirements

[R55-II] A filter shall be used to avoid carbon particles falling back in the food
[R56-II] The FM waves frequency shall be minimal i.e. no more than 433 MHz
[R57-II] No harmful substances shall be released into surrounding as per Canadian health standards

3.4. General Requirements

Compatibility

[R58-I] The main unit shall be compatible with high power 4-pin electrical sockets used in households.
[R59-II] The wireless control unit shall be compatible with most of the open-stove designs found across North America.
[R60-II] The sensor unit shall be made compatible with the microcontroller box.

User Documentation

[R61-II] A simplified and basic installation and repair manual shall be created for the users.
[R62-III] The user manual shall use language for an audience with minimal knowledge of electrical and electronic devices.
[R63-III] The user manual shall be available in English and French to ensure a wider user base.
[R64-II] A detailed installation guide shall be prepared for technicians and vendors.

Standards

[R65-III] The stove shall conform to CSA-C22.2 No.61-08.
[R66-III] The stove shall conform to ANSI standards.
[R67-III] The stove shall conform to CGSB 37-GP-58M.

4. RELIABILITY AND DURABILITY

In this section, we will calculate and analyze the reliability factor of the four components. We will approximate the failure rate of the components using the data available from *"Military Handbook: Reliability Prediction of Electronic Equipment"* – MIL-HDBK-217F [3]. The failure rate obtained will be used to calculate the Mean Time Between Failures (MTBF) which gives the time period of a device between two failures. A reliability evaluation is critical to any product as it helps develop a safe product, pertaining to international and local standards.

4.1. Main Unit

The microcontroller box was divided into a few basic components for the purpose of calculation. Table 1 shows the failure rates and MTBF values for the components of the microcontroller box. Detailed calculations can be accessed in APPENDIX A. The external casing will be made of a durable metal and will have an insulated coating on one face (with the power supply).

Table 1: Reliability Analysis of the Main Unit

Component	Failure Rate $= \lambda f$ (Failures / 10^6 hours)	MTBF $= {}^{1}/_{\lambda f}$ (one failure in MTBF hours)
Microcontroller Board (ATMEGA 168)	2.37290	$4.22 * 10^4$
LED	0.00253	$3.95 * 10^8$
Reset Button	0.00139	$7.20 * 10^8$
Ventilation Fan	1.20000	$8.33 * 10^5$
High Current Relay	0.00856	$1.17 * 10^8$
Interconnections with Circuit	0.00520	$^{1.92}$ 10^8

4.2. Wireless Control Unit

The in-stove mechanical box was also divided into a few basic components, and the failure rate and MTBF values are shown in Table 2. Detailed calculations can be accessed in APPENDIX A. The external casing will be made of a heat-resistant material to withstand the heat from the stove.

Table 2: Reliability Analysis of the Wireless Control Unit

Component	Failure Rate $= \lambda f$ (Failures / 10^6 hours)	MTBF $= {}^{1}/_{\lambda f}$ (one failure in MTBF hours)
Microcontroller Board (MSP430)	0.036	$2.78 * 10^6$
Battery – 9V	0.03820 [4]	$2.67 * 10^6$
On/Off Button	0.00139	$7.20 * 10^8$

4.3. Sensor Unit

The failure rate of smoke alarm system was approximated to be around 19.8 Failures/10^6 hours [5].

We were unable to approximate the failure rate and the MTBF value of the motion sensor due to the unavailability of sufficient information about the device which was to be used.

5. SYSTEM TEST PLAN

We will first test the three units separately and then they will be rigorously tested as a single unit. All equipment will be tested under ± 25% of the normal operating conditions. For example, if a microcontroller is supposed to withstand 100 °C, we will test it in the range of 75 °C to 125 °C. Testing procedures and precautions which must be taken while testing are outlined below for various parts of the ShutSmart:

Table 3: System Test Plan for ShutSmart

Testing part	Testing procedure	Precautions
Digital FM transmitter and FM receiver	• FM transmitter will be placed in the wireless control unit and sensor unit, while FM receiver will be placed in the Main unit. The distance between the two can vary anywhere from 1 meter to 3 meters. • Their communication should be tested from at least 0.75 meters to 5 meters. • Obstructions will be placed between the two components and tested rigorously.	▪ Microcontroller pins should be handled with diligence. ▪ Voltage should not exceed the rating of microcontroller being used which is 3.6 volts. ▪ Antennas should be formed of uniformly coiled wire.
Thermistor circuit (placed in Wireless Control Unit)	• This circuit is our key component for the functioning of overall product. We plan to initialize the circuit at a temperature of 40 °C. Therefore we will be testing its upper limit up to 60 °C. • Circuit will also be tested at low temperatures of up to 10 °C.	▪ Oven gloves must be used when removing the unit if the stove rings are still hot ▪ Wear rubber slippers at all times whenever dealing with any types of currents.
Relay gates (part of main unit)	• Relays will play a key role in shutting the stove off if a user doesn't respond to the alarms. They must be tested independently first as if they can cause damage to the microcontroller if currents leaks through them. • Current running through the stove will go up to 50 amperes. Therefore, we will be testing the relays up to at least 62.5 amperes. • We will make sure that arcing produced by relays doesn't affect the circuitry nearby.	▪ Gloves must be worn as high currents running through the unit may cause high intensity of heat. ▪ Safety goggles must be worn as arcing caused by the relay may cause damage to eyesight.
Microcontroller (main unit)	• This microcontroller will perform the basic operations our product requires. Thus it must be tested extensively under all realistic conditions. • Microcontroller will be subject to high temperatures of up to 50 °C, which is highly unlikely	▪ Voltage must not exceed the recommended voltage for the microcontroller. ▪ Gloves and safety goggles must be worn.

	with a fan running. • Microcontroller will be independently tested to control relay mechanism with no or only low currents running through relay gates. • Similarly, sensor unit will be tested independently with the microcontroller unit as there are no high voltages or high currents involved with sensor unit.	▪ Full sleeves clothing and shoes or rubber slippers must be worn.
Testing the COMPLETE product	• Finally the overall product must be tested in a real world situation. We will incorporate everything in the stove we have bought and it will be recorded on video tape. • A standard dish will be chosen to be cooked. Stove will be left unattended to have the alarms kick in, which when not responded to will trigger the auto shutoff mechanism. • A few dishes will be allowed to burn on purpose for the smoke detector testing and auto stove shut off mechanism will be tested.	▪ A fire extinguisher must be kept close by at all times. ▪ One team member will be designated to the main MCB of the house, if anything goes wrong, he will be able to bring down the electricity for the whole house.

6. CONCLUSION

The functional specification gives a distinct idea about the requirements of ShutSmart, which would unleash the product's full capabilities. We, at Universal Safety Solutions Inc. will strive hard to follow and stand by these requirements to bring out a top quality product. The development of the product will be undertaken in two phases – the working prototype development phase, and the final production phase. The prototype development phase is well underway and we are expected to have a completed working prototype of the product ready by April 5th, 2011.

7. REFERENCES

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APPENDIX A
RELIABILITY ANALYSIS CALCULTIONS

The Military Handbook – MIL-HDBK-217F was used for calculating the failure rate and the MTBF value for the various components of the product, XYZ. This section shows the calculations that were performed in order to obtain the reliability values.

I. Main Unit

- **Failure Rate of the Microcontroller Board**

$$\lambda p = (C_1 * \pi_t + C_2 * \pi_E) * \pi_L * \pi_Q$$

Parameter	Value	Remarks
C_1	**0.14**	Die Complexity Failure Rate
π_t	**0.98**	Temperature Factor at T = 85^{O}C
C_2	**0.025**	Package Failure Rate for SMT Package
π_E	**2.0**	Environment Factor for Ground Stable
π_L	**1.0**	Learning factor for years in production >=2
π_Q	**10**	Quality factor assumed – unknown screening level

$\lambda p = (0.14 * 0.98 + 0.025 * 2) * 1 * 10$
$\boldsymbol{\lambda p = 2.372}$ *Failures*$/10^6$ *hours*

MTBF $= 1 / \boldsymbol{\lambda p = 4.22 * 10^4}$ *hours*

- **Failure Rate of LED**

$\boldsymbol{\lambda p} = \lambda b * \pi_T * \pi_Q * \pi_E$
$= 0.00023 * 1.0 * 2.0 * 5.5$
$=$ **0.00253** *Failures* $/ 10^6$ *hours*

MTBF = 3.95 * 10^8 *hours*

- **Failure Rate of Reset Button**

$\boldsymbol{\lambda p} = \lambda b * \pi_{CLK} * \pi_L * \pi_C * \pi_E$
$= 0.0045 * 1.0 * 1.03 * 1.0 * 3.0$
$=$ $\boldsymbol{0.0013905}$ *Failures* $/ 10^6$ *hours*

MTBF = 7.20 * 10^8 hours

- **Failure Rate of Ventilation Fan**

$$\lambda p = \left[\frac{t^2}{\alpha_\beta^3} + \frac{1}{\alpha_W}\right] * 10^6 = \left[\frac{12^2}{216*10e15} + \frac{1}{120000}\right] * 10^6 = \mathbf{1.2}\ Failures\ /\ 10^6\ hours$$

$$\mathbf{MTBF} = \mathbf{8.33 * 10^5}\ hours$$

- **Failure Rate of High Current Relay**

$$\lambda p = \lambda b * \pi_L * \pi_C * \pi_{CYC} * \pi_F * \pi_Q * \pi_E$$
$$= 0.0060 * 1.02 * 1.00 * 0.1 * 7 * 0.10 * 2.0 = \mathbf{0.008568}\ Failures\ /\ 10^6\ hours$$

- **Failure Rate of Inter-Connections of the Circuit**

$$\lambda p = \lambda b * \pi_Q * \pi_E$$
$$= 0.0026 * 1.0 * 2.0 = 0.0052\ Failures\ /\ 10^6\ hours$$

$$\mathbf{MTBF = 1.92 * 10^8}\ hours$$

II. Wireless Control Unit

- **Microcontroller board**

$$\lambda p = (C_1 * \pi_t + C_2 * \pi_E) * \pi_L * \pi_Q$$
$$= (0.14 * 0.98 + 0.0034 * 2.0) * 0.25 * 1.0$$
$$= \mathbf{0.036}\ Failures\ /\ 10^6\ hours$$

$$\mathbf{MTBF = 2.78 * 10^6}\ hours$$

- **Mechanical On/Off Button**

$$\lambda p = \lambda b * \pi_{CLK} * \pi_L * \pi_C * \pi_E$$
$$= 0.0045 * 1.0 * 1.03 * 1.0 * 3.0$$
$$= \mathbf{0.0013905}\ Failures\ /\ 10^6\ hours$$

$$\mathbf{MTBF = 7.20 * 10^8}\ \text{hours}$$