RefriECO **Project Proposal for the** DualCooler

February 16, 2014

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

Re: ENSC 440/305W Function Specifications for DualCooler

Dear Dr. Rawicz,

On behalf of our team, I am enclosing the functional specification for our ENSC 440 project. Our DualCooler refrigeration system is significantly more energy efficient than the refrigeration systems available in the market at the present time. The technology will utilize the naturally cooler temperatures, of places with winter temperatures that can dip below 5°C, to cool refrigerators.

The attached functional specification provides detailed requirements for all the components necessary to build the DualCooler refrigeration system such as the microcontroller, temperature sensors, motors, ducts, filters, fans and dampers. RefriECO will use this document as a reference during the designing, development and testing of the DualCooler system. RefriECO will also make sure that all of the components will meet the minimum requirements in order to maintain safety, reliability and longevity of the product.

Our team is composed of five talented, creative and determined engineering students: Abantika Oishee, Gonsakar Gunasingam, Allan Vincent, Hasan Syed and myself. If you have any questions or concerns, please feel free to contact me by email at rravi@sfu.ca.

Sincerely,

Ranjita Ravi

Ranjita Ravi

Chief Executive Officer (CEO), RefriECO

Enclosure: Functional Specifications for DualCooler

RefriECO

DualCooler Refrigeration System

A more environmentally friendly Refrigeration System

Project Team: Ranjita Ravi
Allan Vincent
Gonsakar Gunasingam
Abantika Oishee
Hasan Syed

Contact Person: Ranjita Ravi
(rravi@sfu.ca)

Submitted To: Dr. Andrew Rawicz
Steve Whitmore
School of Engineering Science
Simon Fraser University

Issued Date: February 16, 2014

Revision: 1.2

Table of Contents

List of Figures

Glossary

ASHRAE – American Society of Heating, Refrigerating and Air-Conditioning Engineers

CFM – Cubic Foot per Minute (measure of volumetric flow)

CSA – Canadian Standards Association

NEC – National Electrical Code

Fitted Metal Duct – Metal ducts that come with the fridge that contain parts of the refrigeration system including the fan and damper.

Executive Summary

The sole purpose of the DualCooler project is to make an attempt to achieve environmental harmony in terms of energy consumption. This might not make a huge impact initially, but it's definitely a step towards a more energy efficient atmosphere, especially when it comes to the usage of energy by home appliances. We often tend to overlook the fact that every day, we are wasting enormous chunks of energy in some form or the other through machines readily available within our reach.

Our primary goal is to design an energy efficient refrigeration system in a way that it will take the air and temperature from the outside and bring it inside the fridge to cool the system, thus reducing the use of internal power components as much as possible. Considerations will be taken to design and simplify the structure for it to easily integrate with the building plan. Since all the device level integrations will be controlled internally with no difference in the basic operation, no additional learning would be necessary to manoeuvre around this new refrigerator.

The intricate system will be composed of key essential elements such as:

- Ducts – one for supply and the other for the exhaust of air
- Fans for proper air-circulation
- Filter to prevent moisture, allergens, insects etc.
- Temperature sensors to detect the temperatures outside and the inside of the refrigeration system
- Dampers to block the outside temperature and regulate the internal temperature when required
- Arduino microcontroller to control the fans, dampers and temperature sensors for the refrigeration system

The placements of the components might vary depending on how we progress with the fridge, but the fundamental gist will remain the same. Keeping future demands in mind, we would take a relatively economical approach to our design process, thus making it easier for the manufacturers to mass produce it at a lower cost but retaining an eco-friendly environment at the same time.

All the team members will contribute their skills and knowledge ensuring an efficient product, thanks to the diverse engineering backgrounds they belong to. The provided document will outline all the functional specifications and other necessary requirements for the design. After developing the initial prototype, focus would be given on other improvements that could be implemented, provided that we are not bound by time constraints. Moreover, we would abide by the CSA, NEC and ASHRAE standards and engineering safety policies.

1. Introduction

The DualCooler is a refrigeration system that uses colder winter air to cool refrigerators. It uses a system of ducts that supply the cool air to wherever the refrigerators are located. Dampers and fans control how much cool air is delivered to the fridge depending on the temperature that is required in the fridge.

1.1. Scope

All the functional specifications in this document will cover both the prototype specifications that will be demoed in the first week of April as well as the retail refrigeration system for refrigerators. It covers the installation, replacement and functions of the refrigeration system for each of its main parts as well as the general specifications.

1.2. Intended Audience

The intended audience for this report are the engineers at RefriECO and the DualCooler team. It provides the basis for design specifications and will also provide guidelines for the development of this project. This report is also intended to provide information regarding the functions of the refrigeration system for the consumers of refrigerators, with the system implemented. It will also be used to create a test plan in the design specifications for the prototype as well as the retail product.

1.3. Classification of Specifications

This document will contain functional specifications based on the following convention:

[Rn.s-P]   Functional Requirements

Where **n** is the part and **s** is the functional requirement number for that part. The part, **n**, is indicative of the section the requirement is located in this document.

Furthermore, **P** is the priority functional specification for each requirement based on the following three levels:

I	**First Priority**	These requirement will be met for the prototype
II	**Second Priority**	These requirements will be met for the prototype if time permits
III	**Third Priority**	These requirements are only for implementation on the retail refrigerators

2. System Requirements

This section will cover all the requirements for the prototype as well as the production ready refrigeration system that will be used in full sized fridges.

2.1. System Overview and Description

A concept design of the refrigeration system is given below in Figure 1. The darker tubes beyond the wall are the insulated ducting that will go through the internal structure of a commercial or industrial building. The other ducting between the wall and the fridge will be metal fitted ducting that contain the fans as well as the dampers.

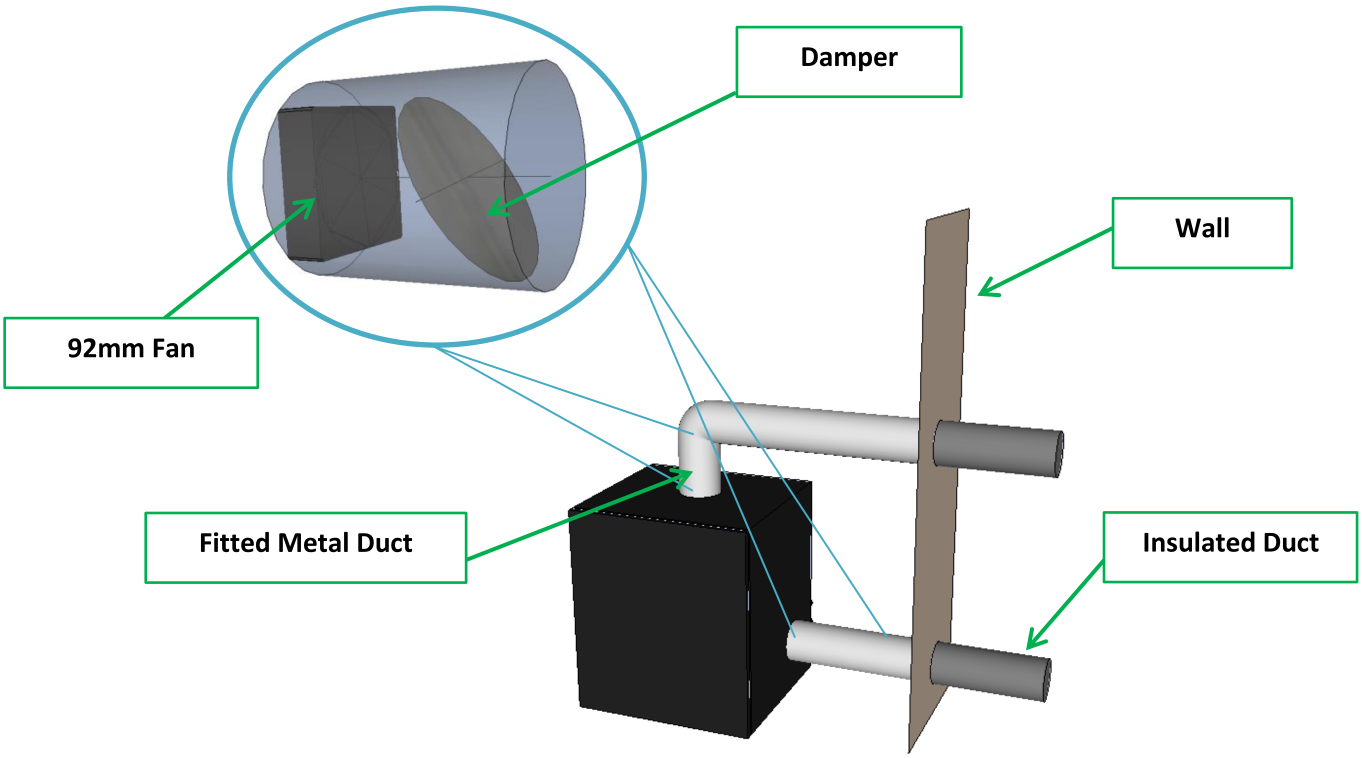

Figure 1: Conceptual Design of Refrigeration System on a mini fridge prototype

The microcontroller is the main part of the refrigeration system and will control the internal temperature, by comparing various inputs and sending the appropriate signals to the respective outputs. The diagram in Figure 2 below, outlines the inputs and outputs that the microcontroller will interface with.

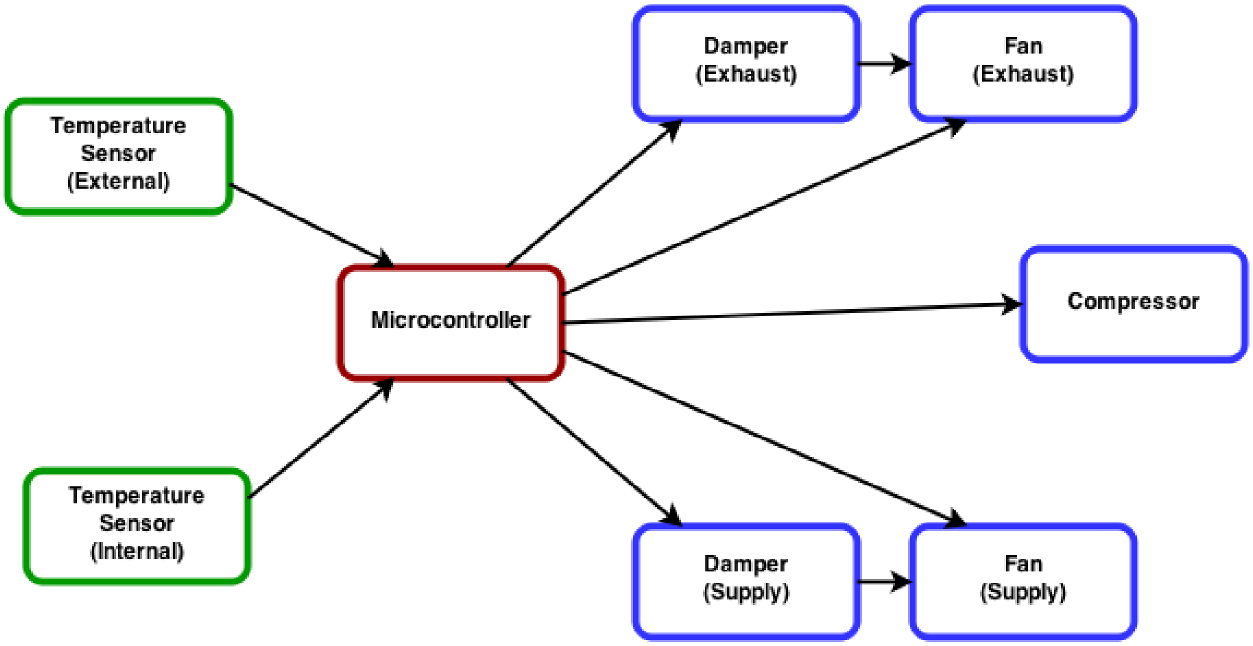

Figure 2: Microcontroller Interface

Depending on the input conditions, the microcontroller will either turn on or shut off the dampers and compressor and turn on or off the fans.

2.2. General Requirements

[R2.1-I]	The fridge will be cooled by the external cold air when the temperature outside is less than 5°C.
[R2.2-I]	The fridge will be supplied by clean air.
[R2.3-I]	The fridge will be cooled by the compressor only when the temperature outside is more than 5°C.
[R2.4-I]	The refrigeration system must contain all electronic components that are CSA approved.
[R2.5-III]	The retail price of the refrigeration system alone will be CDN$100.
[R2.6-III]	The refrigeration system temperature will be adjusted by a control knob.

2.3. Physical Requirements

[R2.7-I] The refrigeration system will allow the fridge to be placed 6" inches away from the wall at most.
[R2.8-I] The refrigeration system must be well insulated.
[R2.9-III] The refrigeration system will not look bulky.

2.4. Electrical Requirements

[R2.10-I] The refrigeration system must comply with CSA Rule 12-102.
"Thermoplastic insulated cables such as NMD-90 can be seriously damaged if it is flexed at temperatures lower than -10 degrees. Do not install cables in cold temperatures unless the cable is specifically approved for use at that temperature. CSA Rule 12-102" [1]

2.5. Usability Requirements

[R2.11-I] The refrigeration system must be easy to repair.
[R2.12-I] The refrigeration system must be easy to install into existing ducts in the wall.
[R2.13-I] The refrigeration system must be easy to uninstall from the wall.

2.6. Safety Requirements

[R2.14-I] Fitted metal ducts will not have any jagged edges.
[R2.15-I] The refrigeration system will contain no articles that are open to touch that are dangerous to children or other people.
[R2.16-I] The refrigeration system will contain all electrical wires and parts in an enclosed box or neatly attached to the refrigerator.
[R2.17-I] The fan is going to be in an enclosed space and will not pose any safety hazards.
[R2.18-I] The refrigeration system must not overheat at any point and cause a fire.

2.7. Sustainability Requirements

[R2.19-I] The refrigeration system will contain metal that is recyclable.
[R2.20-I] The refrigeration system will not contain any materials that cannot be disposed of safely.
[R2.21-I] The refrigeration system saves power to conserve electricity.

2.8. Environmental Requirements

[R2.22-I] The refrigeration system must comply with ASHRAE Rule 22-302.
"Liquid, moisture, or vapour, whether corrosive or non-corrosive, can collect in a surface that supports it. If any of these components is metal, the liquid or mixture can form a mixture with other substances that eventually corrodes the materials and the conductor's insulation, causing shorts that lead to fire or electric shock hazards. ASHRAE Rule 22-302"[2]

3. Duct Specifications

3.1. General Requirements

[R3.1-I] The ducts will bring in the cooler temperatures and air from the outside.
[R3.2-I] The fitted metal duct behind the fridge will be sold with the fridge.
[R3.3-I] The fitted metal duct will contain the fan, the damper and the filter.
[R3.4-III] The insulated ducts will not be sold with the fridge.
[R3.5-III] The insulated ducts will last for the lifetime of the building.
[R3.6-III] The fitted metal ducts should last for the lifetime of the fridge.

3.2. Physical Requirements

[R3.7-I] The supply and exhaust ducts will be 5 inches in diameter.
[R3.8-I] The supply and exhaust ducts will be well insulated.
[R3.9-I] The supply and exhaust ducts will fit 92mm (3.6 inches) fans inside them.

3.3. Environmental Requirements

[R3.10-I] The ducts must be made of material that is moisture resistant.
[R3.11-I] The ducts will not leak moisture from outside into the internal structures.

4. Fan Specifications

4.1. General Requirements

[R4.1-I] The fan must produce more than 50 CFM of volumetric air flow.

[R4.2-II] The speed of the fan must be controlled by the microcontroller.
[R4.3-III] The fan must be replaced every 10 years.

4.2. Physical Requirements

[R4.4-I] The fan must have a diameter that is less than 5 inches.
[R4.5-I] The fan must be positioned for easy access and replacement.

4.3. Electrical Requirements

[R4.6-I] The fan must consume less than 5W.
[R4.7-I] The fan will require external power because the microcontroller can only support voltage up to 5V.
[R4.8-I] The fan wires must not come in contact with excess moisture in the ducts.

4.4. Environmental Requirements

[R4.9-I] The fan must not have blades that are corrosive to moist air.
[R4.10-I] The fan must produce less than 40dBA of noise.

5. Damper Specifications

5.1. General Requirements

[R5.1-I] The dampers in the exhaust and supply ducts will prevent back drafts.
[R5.2-I] The dampers should have controllable pivoting capabilities.
[R5.3-I] The dampers will contain some insulation to prevent air leakage when closed.

5.2. Environmental Requirements

[R5.4-I] The dampers must be made of moisture resistant material.

6. Temperature Sensor Requirements

6.1. General Requirements

[R6.1-I] The temperature sensor must be replaceable.
[R6.2-I] The sensor must be accurate to within 0.5˚C
[R6.3-I] Digital temperature sensors must be used over analog for more accurate measurements.

6.2. Electrical Requirements

[R6.4-I] The sensor will use a maximum of 5V.
[R6.5-I] The sensor will not require any external power aside from what is supplied by the microcontroller.
[R6.6-I] The sensor will have a delay of less than a minute to sense and send the message to the microcontroller.

6.3. Environmental Requirements

[R6.7-I] The sensor must be protected from direct contact with weather elements.
[R6.8-I] The sensor must sense temperatures ranging from -55°C to 125°C.

7. Damper Motor Requirements

7.1. General Requirements

[R7.1-I] The motor should be controlled down to the angle of rotation.
[R7.2-II] The motor should be easy to remove and replace.

7.2. Physical Requirements

[R7.3-I] The motor will weigh 11g and will be light enough to place on the side of the fitted metal duct.
[R7.4-I] The motor must have enough static torque to keep the damper sealed when closed.

7.3. Electrical Requirements

[R7.5-I] The motor will not require extra power aside from the power supplied by the microcontroller.

[R7.6-I] The motor will comply with NEC 430.
"Motor load outlets must be calculated in accordance with the requirements in NEC 430.22,430.24 and 440.6. When a circuit supplies refrigeration equipment, apply article 440. >>220.14I."[3]

7.4. Environmental Requirements

[R7.7-I] The motor will operate in temperatures ranging from -30°C to 60°C.

[R7.8-I] The motor must not come in contact with any moisture in the system.

8. Filter and Grill Requirements

8.1. General Requirements

[R8.1-II] The filter should be replaceable from the inside of the fridge easily.

[R8.2-III] The filter must be replaced every two years.

[R8.3-III] The filter replacement must not cost more than $10.

8.2. Physical Requirements

[R8.4-I] The filter must eliminate odour.

[R8.5-I] The filter must trap common allergens.

[R8.6-I] The filter must filter toxic substances.

[R8.7-I] The filter will prevent insects from getting into the refrigeration system.

[R8.8-III] The grill will be placed externally.

[R8.9-III] The grill must prevent animals and small rodents from entering into the ducting.

9. Microcontroller Requirements

9.1. General Requirements

[R9.1-I] The program must fit in 32kb of memory space.

[R9.2-I] The microcontroller will control the motor that opens and closes the damper.
[R9.3-I] The microcontroller will take two inputs which will be the two temperature sensors.
[R9.4-I] The microcontroller will produce three outputs which will be two motors (one for damper control and one for fan) and the third output will be to control the compressor.
[R9.5-II] The microcontroller will control when the compressor will turn on and off.

9.2. Physical Requirements

[R9.6-I] The microcontroller will be enclosed and placed out of sight behind/ inside the fridge.

9.3. Electrical Requirements

[R9.7-I] The microcontroller will receive data from the temperature sensor.
[R9.8-I] The microcontroller must be protected from electrostatic.
[R9.9-II] The microcontroller will take a maximum input voltage of 12V.

9.4. Environmental Requirements

[R9.10-I] The microcontroller operates at a temperature range between -40°C to 85°C.
[R9.11-I] The microcontroller must be isolated from any moisture in the system.

10. User Documentation

[R10.1-I] The user documentation will contain easy step by step installation instructions.
[R10.2-I] The user documentation will also contain manufacturer information.
[R10.3-I] The user documentation will also contain important safety, hazard and maintenance information.
[R10.4-II] The user documentation will contain a brief description of each part of the refrigeration system and replacement information.
[R10.5-III] The user documentation will contain contact information of certified technicians to conduct repairs.
[R10.6-III] The user documentation must be produced in multiple languages including French and English.

11. System Test Plan

Our testing approach will consist of individual component testing and functional testing of our entire system. This will enable us to compare energy usage of our improved energy efficient method to that of the existing refrigeration methods in the current market. In our prototype, we will have mechanical components and a combination of electrical and software components to test. RefriECO will design a test plan that will assure the safety and maintainability standards of households and commercial buildings. Mechanical tests will be done mainly for air leakages and proper air circulation throughout the system. Microcontroller tests will be done to make sure it is receiving the correct signals and responding in a timely fashion. Electrical test plans need to be created to see the power consumption of our system for a considerable period of time to ensure proper estimates of a year's energy savings model.

Microcontroller must be able to:

- Receive and convert analog signal to properly map to digital data
- Respond in a timely fashion and run the compressor, if necessary, for a complete refrigeration cycle
- Supply precise current to the damper motors for efficient functioning
- Make sure signals are sent and received accurately by the motors and fans
- Ensure the wiring are safely concealed from the customers and built into the fridge and pipes

Fan and damper:

- Motors for damper and fan will be tested in parallel
- Must be able to make sure there is no air leakage when the damper is shut to closed mode
- Must minimize the inflow of harmful and contaminated particles and insects
- Must test the damper's open state for minimum interference to airflow (it turns completely parallel to the airflow)
- Must make sure that the fridge temperature is maintained when the cooling is supplied through the pipes

Temperature Sensor:

- Must make sure the temperature sensors are placed where they are not exposed to the heat from our electromechanical components
- Must check that the analog data of temperature is mapped to digital with the precision of 0.5˚C
- Make sure data is sent to the actuators in a timely manner
- Make sure the time delay is less than 1 min

Ducts:

- Make sure the moisture is not trapped in the ducts to prevent corroding
- Make sure no air/ moisture is leaked to external environment
- Make sure they are insulated through the entire cycle to prevent temperature exchange
- The influx of air should not drop more than 3 degrees from end to end of the pipe (temperature drops due to air friction and room temperature exchange)

These test cases will be mainly designed for required safety standards and product lifecycle. Our tests will be designed to meet this criteria and requirements. There will be different scenarios and test cases for commercial building where duct air supply will be shared. Our prototype will be tested for individual fridges. To improve our test cases, we would need to do further research in thermodynamics.

12. Conclusion

RefriECO is thrilled to be developing the prototype of the DualCooler energy efficient refrigeration system. The new refrigeration system will be capable of saving significant energy in the commercial and industrial market. The functional specification described in this report outlines and provides the detailed requirements necessary to build the DualCooler refrigeration system. Each component and its specifications will be followed, depending on the priority, while designing the prototype system. During the designing and development of the system, the requirements for all components given in this function specification will be used as a reference and all of the minimum requirements in order to maintain safety, reliability and longevity of the product. The test plan provided in this document will also be followed in order to test the usability, reliability and efficiency of each component. All possible test cases would also be looked upon while testing the functionality of the product.

13. References

[1] *Canadian Electrical Code Part 1, Safety standard for electrical installations: CSA standard C22. 1-12*, 22nd ed, Canadian Standards Association, Mississauga, ON, 2012.

[2] *ASHRAE Handbook,* American Society of Heating , Refrigerating and Air-Conditioning Engineers, Atlanta, GA, 2010

[3] C. R. Miller, *Illustrated Guide to the National Electrical Code,* 5th ed. Clifton Park, NY: Delmar Cengage Learning, 2011

14. Other Sources

The wonderful employees of HoneyWell Enterprises.