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Design and Development of Portable Chest Fridge Using Peltier Module

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ABSTRACT

This study aims to make cooling equipment that would have a more substantial purpose than the commercially produced ones and designed as eco-friendly. Fridge, Freezers, Air-conditioning Units, and other cooling appliances that are commonly used in offices, households, restaurants, grocery stores, and other establishments have a great impact on the daily living of humans. However, most of these machines release harmful gas, particularly chlorofluorocarbon or CFC, to the atmosphere that causes the depletion of the Ozone Layer. Moreover, these machines are not easy to transport due to their weight and size. Today, there are mini-fridges that are showcased in the market which are expensive but not equally efficient as the design we have made. Thus, this study focuses on making a model of a mini-fridge that is cost-effective, lightweight, easy to store food, and environment friendly. The design is composed of materials mixed with scrap and supplies that were bought from the local hardware. The construction of the compressor-free mini-fridge is composed of different components such as cooling module assembly, wiring assembly, and cover assembly. On the initial test, the first one and half-hour showed consistency of the ambient temperature produced by the thermoelectric module and the cost consumed in kilowatt-hour energy. It took 60 minutes to reach 6 degrees Celsius as the desired ambient temperature to cool the container. And 90 minutes to reach the same temperature when it contains food inside. This project was commended for its design and its low-cost rates of the materials used in assembling the project. However, the design was suggested to have a durable and appealing hard case which would be still a part of its development.

Keywords: *cooling equipment, eco-friendly, Fridge, Portable, peltier Module*

INTRODUCTION

Flourishing in today's fast changing world our trainees, especially in DomRac NC II, requires a range of skills rooted in standard competencies but also including such things as critical thinking, persistence, and creativity through improving and developing technology particularly in the trade area. These skills are in fact interconnected. TVET trainees have the ability to focus on continuing the progress which helps them to improve themselves, express their creativity and by working on research projects together they learn how to collaboratively solve problems and create distinct solutions. This interplay of skills is central to both the concept of extent of skills as well as to the educational strategies needed to help the trainees cultivate them. Ultimately, young and aged people today must be agile learners, able to adapt and learn new things quickly in a new fast-changing environment. This study sought to answer the following questions like how can our technology contribute to the convenience of the consumers

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without worrying about the amount of electric bill the equipment would consume? Could there be another way that we can use cooling equipment without distressing the environment (affecting the ozone layer)? And also, is there a significant difference between a commercially produced mini fridge in the market and the Portable Chest Fridge?

METHODOLOGY

1. Project Design

The design is composed of materials mixed with scrap and supplies that were bought from local hardware. The design also aims to be portable that can easily transport to other places and space saving for PERSONAL home and office use.

Table 1
List of materials

MATERIALS	
Quantity	**Item Description**
2 sets	Set electronic refrigeration modules
1 pc	Thermostat
1 pc	AC to DC power supply (12v, 15amps)
1 meter	Cold white LED strip
20 pcs	Wire terminals
20 pcs	Shrink tubes
1 pc	Power plug AC
1 pc	Power plug 12v
1 pc	Momentary push button
2 meters	Self-adhesive rubber seal
25x40 cm	Acrylic glass

2. Project Development

The construction of the compressor-free mini fridge is composed of different components such as cooling module assembly, wiring assembly and the cover assembly.

a. Planning the electronics - It is important to plan and test the different electronic parts before we start to build the research itself. When the test is a success, it is the only time that you can start the project.
b. Planning the dimension - The other first to consider before starting the project is also the dimension of the body. Make sure that the dimensions will be portable and space saving.

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c. Cutting all the necessary materials for the main compartment based on your desired dimension
   After making your dimensions, it is now appropriate to start cutting the Styrofoam and plywood for the main compartment of the mini fridge.
d. Figuring the positions of all the main components - Place and position the Styrofoam and plywood for the better position of the refrigeration module and other components.
e. Glue and assemble **-** Permanently install all the components after figuring the position by using glue, screws and other joining means of materials.
f. Connect all the wirings that were indicated to your diagram **-** After all the necessary procedure, the project is now finished and ready to start up for testing.

3. Operation and Testing Procedure

Insert the main plug to a 220VAC supply outlet then the fan in the indoor which gives the room temperature inside will automatically start the same with the outdoor fan which throws the excess heat from the peltier module for better cooling on the unit. It will initially start with the ambient temperature but in about 30 minutes of continuous running, it will start to feel the temperature difference that it will also be read at the digital thermometer for about an average of 7^0C with or without beverage inside and it will continue to go down until it reaches the set temperature.

4. Evaluation Procedure

Upon starting the unit by plugging to an outlet, observe first the functionality of the mini fridge by monitoring the digital thermometer at the back part of the unit. When the thermometer reading starts to go down, it only means that the module is starting to cool and you can confirm it by feeling or touching the module itself or by the appearance itself when the cover starts to have moisture. After confirming that the unit is in normal operation, we can now start to put some beverages in and start to get the parameters, which can be seen in the result and discussion part.

RESULTS AND DISCUSSIONS

1. Project Description

Peltier module or thermoelectric module is a thermal control module that produces heating and cooling effects by applying a certain current. In this project, it only maximizes the cooling part that is attached in the inside of the container that gives cool temperature that passes through the beverages inside the mini-fridge.

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Figure 1
Shows the picture of mini fridge

2. Project Structure

The portable chest fridge has a dimension of 40cm (L) by 9cm (W) by 11.5 (H) and has a capacity of 4 liters in volume.

3. Project Capabilities and Limitations

The project can only cool up the beverages inside the container with not less than an average of 5 degree Celsius starting 90 minutes from the time it was being plugged in, but based on the table and diagrams below, the electric efficiency was maximized because the operation is being powered by an DC power supply.

4. Project Evaluation

The table 2 shows that the first one and half-hour without in it, shows consistency of the ambient temperature produced by the thermoelectric module and the cost consumed in kilowatt-hour energy.

Table 2
Consistency of the ambient temperature produced by the thermoelectric module

Time in Minutes	Average Inside Fridge Ambient Temperature in ^{0}C	Electric Consumption	
		kWh	Cost per kWh
First 30 minutes	6.5^{0}C	0.072 kWh	P 0.576
In 60 minutes	6.1^{0}C	0.069 kWh	P 0.552
In 90 minutes	5.8^{0}C	0.071 kWh	P 0.568

You would see that the energy produced was very low for that amount of kilowatt-hour when compared to the conventional fridge using a compressor and a refrigerant as a cooling mode.

The next table 2 shows that the first one and half-hour with beverage bottles and some variety of sweet bar products in it, shows consistency of the ambient temperature produced by the thermoelectric module and the cost consumed in kilowatt-hour energy.

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Table 3

Consistency of the ambient temperature produced by the thermoelectric module and the cost consumed in kilowatt-hour energy

Time in Minutes	Average Inside Fridge Ambient Temperature in ^{0}C	Electric Consumption	
		kWh	Cost per kWh
First 30 minutes	7.2^{0}C	0.072 kWh	P 0.576
In 60 minutes	6.7^{0}C	0.071 kWh	P 0.568
In 90 minutes	6.0^{0}C	0.071 kWh	P 0.568

It took a long time to reach the maximum temperature produced by the first table but the electric consumption would be the same at a very low cost because it runs with a DC electric.

Table 4

Comparison between TEC system and VCR system

Comparison between TEC System and VCR System

Parameter	TEC	VCR
Cooling method	Non-cyclic refrigeration	Vapor compression cycle
Cooling/heating capacity	Low	High
Electricity consumption	Less	High
COP	0.38-0.45	2.6-3.0
Noise level	Quiet	Noisy
Working Fluid	Electrons	Refrigerant (R-134a)

Refrigeration is the process of removing heat from a room to bring it to a temperature lower than the ambient temperature. The "Peltier cooling module," which employs thermoelectric refrigeration, tries to provide cooling by exploiting thermoelectric effects rather than more prevalent conventional methods such as the "vapour compression cycle" or "vapour absorption cycle" in this context. Prior to the experiment, this project aims to provide insight into how to choose the right refrigeration system for the job.

Table 1 compares the thermoelectric cooling (TEC) system to the vapor compression refrigeration (VCR) system based on the parameters (Gaikwad et. al, 2016). According to the study, the COP of TEC is lower than that of VCR. Peltier coolers are typically utilized in tiny applications with little cooling demand and low efficiency due to their lower COP. Thus, a thermoelectric refrigerator should be chosen when a low cooling capacity is needed. (Muzakir, 2011, #)

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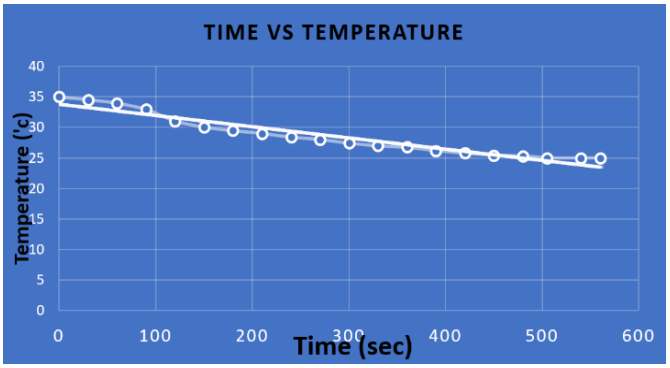
Figure 2

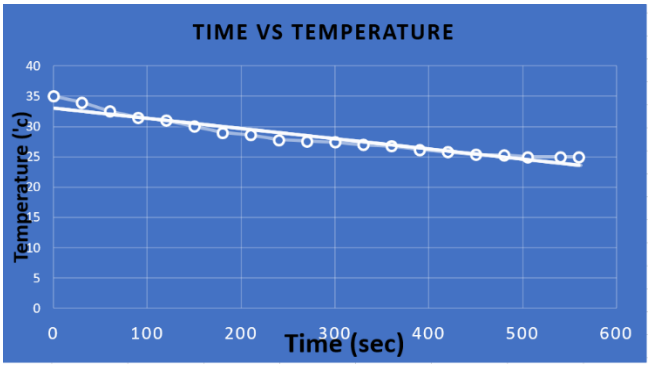
Temperature vs time graph of upper



Three Peltier exhibits a temperature decline from 35 to 23 degrees Celsius in the lower chamber over a 10-minute period in the graph above (240x270x330 i.e. 21.38L).

Figure 3

Temperature vs time graph of lower



In above graph, In the lower chamber, Three Peltier indicates a temperature decline from 35 to 23 degrees Celsius over a 10-minute period (240x270x330 i.e. 21.38L). This shows the power increases significantly with an increase in the Peltiers module with heat sinks. (Yadav, 2019, #)

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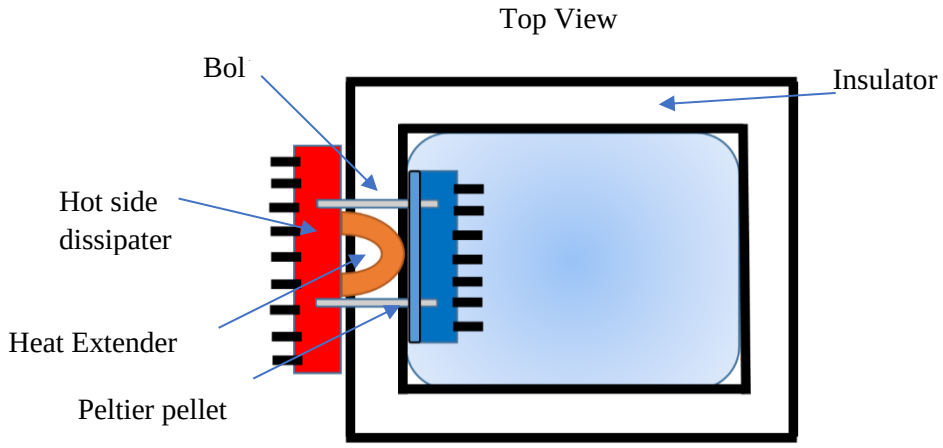
Figure 4
Thermal sketch of the thermoelectric refrigerator



For instance: It has a reduced degree of noise and vibrations, a longer useful life, does not utilize refrigerants, and provides better temperature control. A thermoelectric refrigerator with an inner volume of 55 X 103 m 3 has been designed and built. It requires a constant electric current (maximum 12 V), which makes it ideal for automotive applications since it provides the following benefits in terms of vapour compression. Because it does not require refrigerants, it is a more environmentally friendly technology because it has fewer moving parts, it is quieter and more durable (it does not need a compressor). It is more exact in temperature management since it does not need to perform start–stop cycles, allowing it to gradually alter the supply voltage.

Figure 5
Main body of refrigeration chamber

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The primary downside is that it consumes a lot of electricity. In comparison to modern compression refrigerators, thermoelectric refrigerators consume more electricity (approximately the same as a vapour compression one with an inner volume of 100 X 103 m 3). The Peltier effect has also been exploited to produce the refrigeration effect directly [6]. This can be experimentally shown by creating the setup as shown in fig. 9 The main body of the refrigeration chamber is 0.11x0.29x0.33 m3 and is well insulated to prevent heat loss to the atmosphere. There are three layers in the cross section of this chamber: two aluminum walls separated by a 3 cm thick insulating substance. Refer to figure 9. (Nikam, 2014, #)

The efficiency of refrigeration cycles was evaluated in a dimensionless parameter called COP COP is the ratio of useful cooling provided to work required in refrigeration systems.

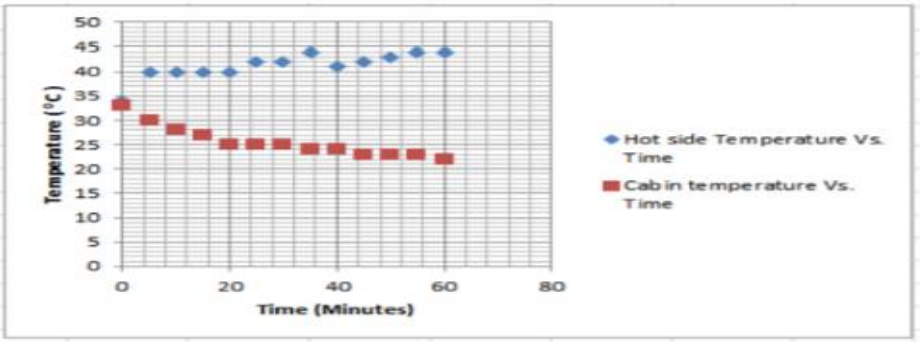
$$COP = \frac{Q_c}{W}$$

The device Seebeck voltage, thermal conductance, and electrical resistance are represented by m, Km, and Rm in the equations below.

Figure 6

Temperature (°C) vs Time (min.)

Sr. No.	Parameter	Values
1	Maximum temperature difference in ºC	22
2	Time taken in minutes	60
3	$(COP)_{theoretical}$	0.4855
4	$(COP)_{actual}$	0.3143



From result table and graphs, it can be concluded that as time goes on increasing, the temperature inside the cabin falls down gradually. At the same time, hot side temperature remains constant (near about 40°C). (k, 2018, #)

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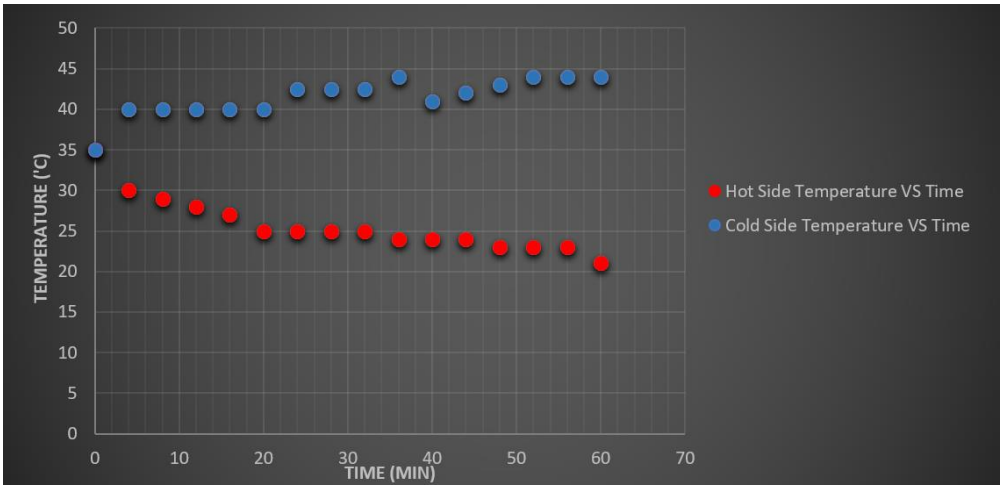

CONCLUSIONS

After trying to build this portable chest fridge, the project worked out effectively, although many Peltier fridge projects fail as they don't end up reaching the desired temperature. When the design is turned on for about 30 minutes, the temperature reaches 6-degree Celsius ambient temperature. When there is something to be cooled it takes 90 minutes to reach the same temperature. A common problem with this project is not having proper insulation or the enclosure being too big for the size of the Peltier module they are using. Unfortunately, this system is nowhere near as efficient as a standard refrigeration system with a compressor, etc., however it's very cheap and easy to build, as well as near silent. For this research, the project was found to be successful because it met the desired outcome and purpose.

RECOMMENDATIONS

This project was commended for its design and its low-cost rates of the materials used in assembling the project. In addition, it is recommended that Dc Power Refrigerators should be promoted to improve in Agro Storage, SME Business and clinical storage for sustainable development. (Raheem, 2018, #) However, the design was suggested to have a durable and appealing hard case which would be still a part of its development.

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