DESIGN AND DEVELOPMENT OF A SMALL DC REFRIGERATOR

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SUPERVISOR'S DECLARATION

We hereby declare that we have checked this project and in our opinion this project is satisfactory in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering.

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STUDENT'S DECLARATION

I hereby declare that the work in this thesis is my own except for quotations and summaries which have been duly acknowledged. The thesis has not been accepted for any degree and is not concurrently submitted for award of other degree.

Signature.....

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Date: .....

To my beloved Father and Mother

Bani Bin Saemin

Norlaila Binti Siraj

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ABSTRACT

Refrigerator is a home appliance that used to preserve the quality of perishable food products. Several studies from previous researchers have show that the quality of food products directly depends on temperature and air distribution inside the storage compartment. Currently, most of the refrigerators that available in market are powered by electricity. This is became restriction to people to use refrigerator for outdoor activities such as outdoor sport, fishing activity and for medical purpose which is to deliver special medical to village. Because of that, this project introduces a design of a small DC powered refrigerator. The system of refrigerator is use the ideal vapour-compression refrigeration cycle and the component of the system is a condenser, a compressor, a capillary tube and an evaporator. The designs of prototype refrigerator more focus on design length of condenser, evaporator and capillary tube. From the *p-h* diagram, the data will be calculated using ideal gas equation and energy balance equation to find mass flow rate and the length. At the end of this fabrication result, the length of capillary tube is 2.84 metre, a condenser is 12.39 metre, and an evaporator is 9.25 metre. A small DC refrigerator has been tested but cannot work properly because of the electronic unit problem.

ABSTRAK

Peti sejuk adalah perkakasan rumah untuk menyimpan makanan supaya dapat mengekalkan kualiti produk makanan. Daripada maklumat dan kajian yang dijalankan oleh penyelidik terdahulu, kualiti produk makanan bergantung kepada suhu dan udara yang terkandung di dalam peti simpanan. Pada masa sekarang, kebanyakan peti sejuk yang berada di pasaran mengunakan kuasa elektrik. Ini telah menjadi kesukaran kepada orang ramai untuk menggunakan peti sejuk semasa melakukan aktiviti luar seperti bersukan, memancing dan keperluan untuk menghantar ubat istimewa kepada orang yang tinggal di kampung. Oleh kerana itu, projek ini mengenalkan rekaan peti sejuk kecil yang menggunakan kuasa bateri. Sistem penyejukan yang digunakan oleh peti sejuk ialah kitaran penyejukan wap termampat unggul dan komponen dalam sistem ialah pemampat, alat kondensasi, alat pengewapan dan tiub kapilari. Rekaan prototaip peti sejuk ini fokus kepada rekaan panjang yang diperlukan untuk kondensasi, pengewapan dan tiub kapilari untuk menjatuhkan tekanan. Daripada rajah *p-h*, data akan dihitung menggunakan persamaan gas dan persamaan keseimbangan tenaga untuk mencari kadar aliran jisim dan panjang. Pada pengujung hasil rekaan, panjang tiub kapilari adalah 2.84 meter, kondensasi 12.39 meter dan pengewapan 9.25 meter. Peti sejuk kecil menggunakan kuasa bateri telah diuji tetapi tidak boleh berfungsi dengan baik kerana masalah alat elektronik.

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LIST OF SYMBOLS

A	Area
Q	Heat transfer rate
ξ	Coefficient of performance
W_c	Work by compressor
P	Pressure
h	Specific enthalpy
V	Volume
R	Gas constant
T	Time
m	Mass
rpm	Rotational speed
$\dot{m}$	Mass flow rate
U	Overall heat transfer coefficient
ΔT_{lm}	Log mean temperature different
f	Friction factor
L	Length
u	velocity

LIST OF ABBREVIATIONS

DC	Direct current
COP	Coefficient of performance

CHAPTER 1

INTRODUCTION

1.1 PROJECT BACKGROUND

A refrigerator is a cooling appliance comprising a thermally insulated compartment and a mechanism to transfer heat from it to the external environment, cooling the contents to a temperature below ambient. Refrigerators are extensively used to store foods which deteriorate at ambient temperatures; spoilage from bacterial growth and other processes is much slower at low temperatures.

Before the invention of the refrigerator, icehouses were used to provide cool storage for most of the year. After that, the first known artificial refrigeration was demonstrated by William Cullen at the University of Glasgow, Scotland in 1748. In 1805, Oliver Evans designed refrigerator based on a closed cycle of compressed ether, represented the first effort to use simple vapor instead of vaporizing a liquid. After that, in 1857, James Harrison introduced vapor-compression refrigeration to the brewing and meat packing industries. Start of the 20th Century, all refrigerator use the vapor-compression refrigeration cycle until now.

The design for contemporary refrigerator is based on two basic laws of physics: first, that heat flows from warmer material to cooler materials and never the reverse; second, which decreasing the pressure of a gas also decreases its temperature. In the refrigeration systems typically include a compressor, a condenser, an expansion valve (capillary tube), and an evaporator. All components interconnected to form a fluid circuit. Cooling is accomplished through evaporation of a liquid refrigerant under reduced temperature and pressure.

The raw material in refrigerators today consists of several basic components: the exterior cabinet and door, the inner cabinet or liner, the insulation inserted between the two, the cooling system, the refrigerant, and the fixtures. The cabinet and door are made of aluminum or steel sheet metal that is sometimes prepainted. The inner cabinet is made of sheet metal, like the outer cabinet, or of plastic. The insulation that fills the gap between the inner and outer cabinets consists of fiberglass or polyfoam. The components of the cooling system (compressor, condenser, coils, and fins) are made of aluminum, copper, or an alloy. Freon is most commonly used refrigerant, and almost all of the large interior fixtures (door and cabinet liners) are made from vacuum-formed plastic.

Refrigerators available in market have been designed in various sizes and different applications but its limited for indoor usage since it large and powered by electricity. So, in this project focuses on designing and fabricates a small DC refrigerator which is powered by battery. Refrigerator can be used to deliver the special medicines purpose to villages by doctors. Beside that it's can be useful application in outdoor activities such as picnic and sport.

1.2 PROBLEM STATEMENT

Currently in this time, people like doing outdoor activities such as picnic, fishing and for medical purpose which is to deliver medicine to village. They need a refrigerator to keep cooling the food or medicine. This product in the market does not have to follow those people requirement.

1.3 PROJECT OBJECTIVE

The objective of this project is to design and developed a small DC refrigerator prototype for storage food when doing outdoor activities and delivered medicine purpose.

1.4 PROJECT SCOPES

This research more focus in design fabricate and test run a small DC refrigerator. Listed below are the scopes to guide this research successfully.

- Literature Study

This study is focus on theory of vapour compression system and its component, method to design the refrigerator and theory how to design refrigerator component.

- Concept and design development

This project also needs concentration in concepts development of the refrigerator and the design development.

- Engineering drawing

Engineering drawing is to represent detail design of the refrigerator prototype.

- Fabrication

To fabricate prototype of the refrigerator based on the engineering drawing that have been produced.

- Test run

Tests run the operation of the refrigerator prototype to prove that all components are able to work according to thermodynamic theory.

- Report preparation.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

The refrigerator is one of the most innovative and important inventions of the twentieth century. The basic function of a domestic refrigerator is to preserve the quality of perishable food products. Several studies have shown that the quality of food products directly depends on temperature and air distribution inside the storage chambers. Hence, unsuitable temperatures and air velocities may cause food to undergo a premature deterioration. Even if the average temperature inside the refrigerator cabinet is adequate, uncontrolled rise or fall in local temperatures may affect the quality of food products. [9]

A device described as a "refrigerator" maintains a temperature a few degrees above the freezing point of water; a similar device which maintains a temperature below the freezing point of water is called a "**freezer**". The refrigerator is a relatively modern invention amongst kitchen appliances. It replaced the common icebox which had been placed outside for almost a century and a half prior, and is sometimes still called by the original name "icebox". [9]

A typical household refrigerator is actually a combination refrigerator-freezer since it has a freezer compartment to make ice and to store frozen food. Today’s refrigerators use much less energy as a result of using smaller and higher-efficiency motors and compressor, better insulation materials, larger coil surface areas, and better door seals. [8]

Despite the improvements made in several areas during the past 100 years in household refrigerators, the basic vapor-compression refrigeration cycle has remained unchanged. The alternative absorption refrigeration and thermoelectric refrigeration systems are currently more expensive and less efficient, and they have found limited use in some specialized application. [8]

A household refrigerator is designed to maintain the freezer section at -18 ^{o}C and the refrigerator section at 3 ^{o}C. Lower freezer temperatures increase energy consumption without improving the storage life of frozen foods significantly. Different temperature for the storage of specific foods can be maintained in the refrigerator section by using special-purpose compartments. [8]

Practically all full-size refrigerators have a large air-tight drawer for leafy vegetables and fresh fruits to seal in moisture and to protect them from the drying effect of cool air circulating in the refrigerator. It is common for refrigerator have a special warmer compartment for butter in the door to maintain butter at spreading temperature. Some upscale models have a temperature-controlled meat compartment maintained at -0.5^{o}C, which keeps meat at the lowest safe temperature without freezing it, and thus extending its storage life. [8]

Household refrigerators consume from about 90W to 600W of electrical energy when running and are designed to perform satisfactorily in environments at up to 43^{o}C. In the time under normal use in a house at temperature 25^{o}C, the refrigerator is running about 30 percent. [8]

For specific external dimensions, a refrigerator is desired to have a maximum food storage volume, minimum energy consumption, and the lowest possible of the consumer. The total food storage has been increased over the years without an increase in the external dimensions by using the compressor and condenser. Switching from the fiberglass insulation (thermal conductivity k = 0.032-0.040 W/m.^{o}C) to expanded-in-place urethane foam insulation (k = 0.019 W/m.^{o}C) made it possible to reduce the wall thickness of the refrigerator by almost half, from about 90 mm to 48 mm for the freezer section and from about 70 mm to 40mm refrigerator

section. The rigidity and bonding action of the foam also provided additional structure support. However, the entire shell of the refrigerator must be carefully sealed to prevent and water leakage or moisture migration into insulation since moisture degrades the effectiveness of insulation. [8]

The size of the compressor and other components of the refrigeration system are determined on the basis of the anticipated heat load (or refrigeration load), which is the rate of flow into the refrigerator. The heat load consists of the predictable part, such as heat transfer through the walls and the door gaskets of the refrigerator, fan motors, and defrost heaters, and unpredictable part, which depends on the user habits such as opening door, making ice, and loading the refrigerator. The amount of energy consumed by the refrigerator can be minimized by practicing good conservation measures. [8]

The food industry has benefited greatly from the development of mechanical refrigeration systems. Perishable products can be kept safe for longer periods of time when processing and storage environments can be maintained at constant temperatures. Refrigeration systems and their applications continue to evolve into more reliable, safer, and less operations cost.

There are several basic refrigeration techniques:

- ice box (or dry ice box)
- cold air systems
- vapor-compression: the current standard method of refrigeration used in home refrigerators, home air conditioners and heat pumps (Kelvin's idea, refrigerate the environment in the winter, store "cold" in the ground for use in the summer)
- vapor-absorption: the Electrolux refrigerator with no moving parts
- thermoelectric [12]

2.2 REFRIGERATION SYSTEM

Refrigeration systems typically include a compressor, a condenser, an expansion valve, and an evaporator; all of these components are interconnected to form a fluid circuit. Cooling is accomplished through evaporation of a liquid refrigerant under reduced temperature and pressure. Vapor refrigerant is compressed to increase its temperature and pressure. The vapor refrigerant is condensed in the condenser, lowering its temperature to induce a state change from vapor to liquid. [1]

The pressure of the liquid refrigerant is reduced through an expansion valve and flows into the evaporator to cool the area. Heat is transferred from the cooled area to the liquid refrigerant inducing a temperature increase sufficient to result in vaporization of the liquid refrigerant. The vapor refrigerant then flows from the evaporator to the compressor.

2.2.1 The ideal vapour-compression refrigeration cycle

Most of the impracticalities associated with the reversed Carnot cycle can be change by vaporizing the refrigerant completely before it is compressed and by replacing the turbine with throttling device. The vapor-compression refrigeration cycle is the most widely used cycle for refrigerators, air-conditioning systems, and heat pumps. It consists of four processes:

1-2 Isentropic compression in a compressor

2-3 Constant-pressure heat rejection in a condenser

3-4 Throttling in a expansion device

4-1 Constant-pressure heat absorption in an evaporator [1]

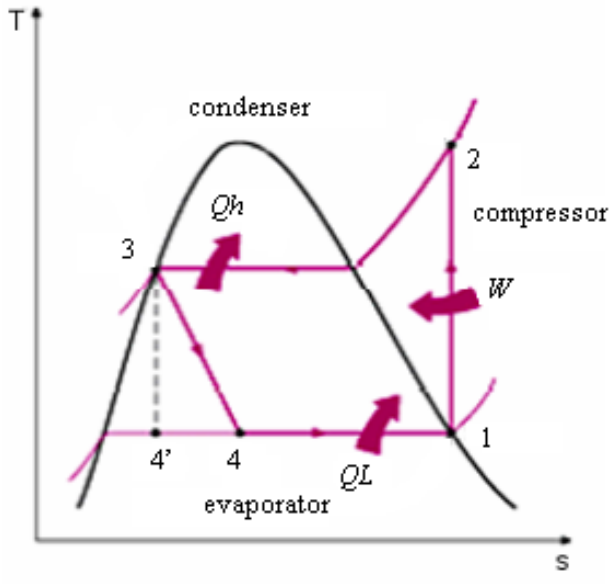

Figure 2.1: *T-s* diagram for the ideal vapor compression cycle [8]

From the figure 2.1, the cycle operated in two different pressures, P_{high} and P_{low}. The section line from state 4-1 is low pressure and state 2-3 is high pressure for the system. [1]

The ideal vapor compression cycle also can be illustrated in *P-h* diagram. In this diagram, the detail of vapor compression cycle will be explained.

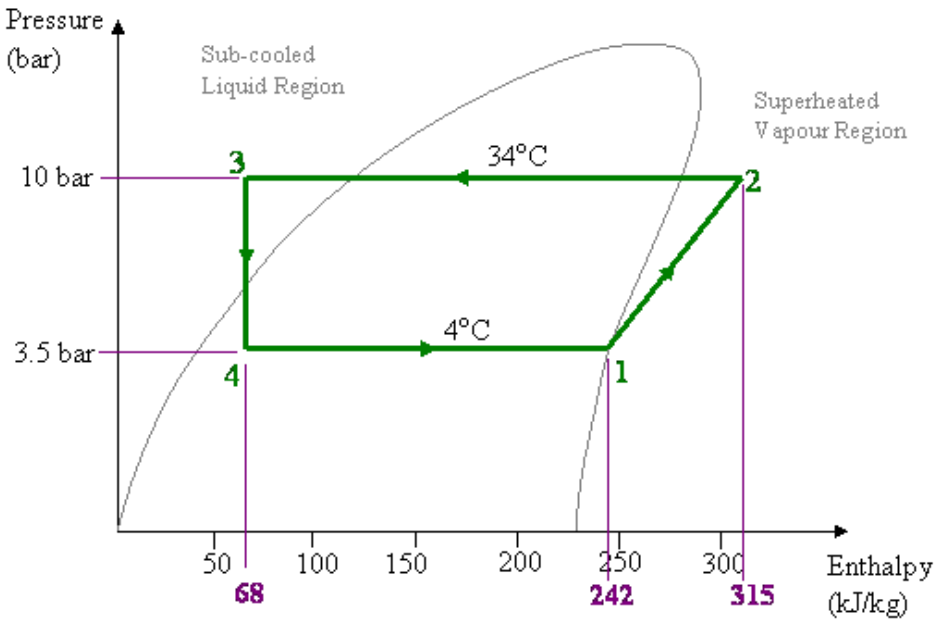

Figure 2.2: *P-h* diagram of Refrigeration Cycle for R-134a