I admit that I have read this thesis fully and from my observation, it fulfills the scope and quality of honoring the Bachelor of Mechanical Engineering (Thermal Fluid)

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Date : 15/12/05

IRREVERSIBILITY FACTORS OF REFRIGERATION SYSTEM

A Thesis submitted to the
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I admit that this report is solely done by me, except for some of the material which I have explain the source clearly.

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ABSTRACT

This is a paper submitted as a thesis for the final year project in Kolej Universiti Teknikal Kebangsaan Malaysia. This project is fully based on the ET 400 Refrigeration Training System where it is content the details that relevant to refrigeration system. In addition, it also contains the information about the refrigeration component, refrigerant, refrigeration cycles, and the process of refrigeration system. The motive of this project is to conduct a research regarding the irreversibility factors in term of heat transfers and to calculate the amount of heat rejected from the refrigerant through the copper pipe to the outside environment when the refrigerant is flowing from one component to another component. A method to reduce the heat transfer from the refrigerant to the outside environment through the copper pipes had been applied. The Coefficient of Performance (COP_R) before and after applying the method had been calculated and had determined either these method gives any improvement or not to the COP_R of the system.

ABSTRAK

Laporan ini telah dihantar sebagai tesis bagi projek tahun akhir di Kolej Universiti Teknikal Kebangsaan Malaysia. Laporan ini telah disiapkan dengan berpandukan ET 400 Refrigeration Training System dimana laporan ini mengandungi segala maklumat yang berkaitan dengan sistem penyejukkan. Tambahan pula, laporan ini juga mengandungi maklumat-maklumat tentang komponen-komponen peti sejuk, kitar sistem penyejukkan, maklumat-maklumat tentang bahan pendingin dan proses-proses sistem penyejukkan. Objektif laporan ini adalah untuk melakukan kajian terhadap pemindahan haba dan mengira jumlah haba yang dipindahkan daripada bahan pendingin ke persekitaran melalui paip sistem penyejukkan semasa bahan pendingin mengalir dari satu komponen ke komponen yang lain. Satu langkah untuk mengurangkan jumlah haba yang dipindahkan telah diaplikasikan. Nilai Pekali Pretasi (COP_R) sebelum mengaplikasi dan selepas mengaplikasi langkah itu telah dikirakan dan telah menentukan bahawa adakah langkah tersebut memberi sebarang kesan atau pun tidak kepada COP_R sistem tersebut.

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NOMENCLATURE

Standard

A	surface area (m^2)
c_p	specific heat ($J\ kg^{-1}\ K^{-1}$)
h	heat transfer coefficient ($W\ m^{-2}\ K^{-1}$)
k	thermal conductivity ($W\ m^{-1}\ K^{-1}$)
L	length (m)
$\dot{q}$	Heat flux ($W\ m^{-2}$)
T	temperature (K)
$\dot{m}$	Mass
h	Enthalpy
v	Specific volume
s	Entropy
d	Diameter
l	Lenght

Subscripts

COP_R	Coefficiency of performance of Refrigeration
T_{avg}	Average Temperature
T_{Surr}	Surrounding Temnperature
T_R	Temperature of refrigerant
NH_3	Ammonia
H_2O	Water
$Cp_{(vap)}$.	Specific heat vapor ($J\ kg^{-1}\ K^{-1}$)
$Cp_{(liq)}$.	Specific heat liquid ($J\ kg^{-1}\ K^{-1}$)

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CHAPTER 1

INTRODUCTION

Industrial refrigeration systems can be found in nearly every developed location in the world. Refrigeration is used in industry for cooling and freezing of products, condensing vapors, maintaining environmental condition and for cold storage. Applications for these systems include food preservation, heat removal from industrial processes such as chemical production, and numerous other special applications in the construction and manufacturing industries. The most frequently used refrigeration cycle is the **vapor-compression refrigeration cycle** [1]. Vapor compression refrigeration systems have been used to reduce the temperature of a particular substance or process for over one hundred years. However, the industrial refrigeration industry has historically paid very little attention to the energy needed to achieve the objectives of the refrigeration processes.

We all know that heat flows in the direction of decreasing temperature that is from high-temperature mediums to low-temperature. The heat transfer process occurs in nature without requiring any devices. The reverse process however cannot occur by itself. The transfer of heat from a low-temperature medium to a high-temperature one required special devices called refrigerators.

Refrigeration is defined as the process of **extracting** and **transferring heat** from a **lower-temperature** heat source, substance, or cooling medium to a **higher-**

temperature heat sink [4]. This process will remove the heat from matter which may be a solid, a liquid or a gas. The working fluid used in the refrigeration cycle is called refrigerant. Refrigeration maintains the temperature of the heat source below that of its surroundings while transferring the extracted heat, and any required energy input, to a heat sink, atmospheric air or surface water.

All refrigeration systems consist of different components and often times each component will be produced by a different manufacturer. Examples of components include compressors, condensers, evaporators, heat exchangers, vessels, piping, expansion valves, pumps, and filters. This equipment is connected in a sequential order to produce the refrigeration effect. The effects that each of the components has on each other and the system is often times confounded. The optimum performance of the system rarely occurs when each component is selected to operate at its optimum setting. The type of input energy can classify the refrigeration systems commonly used for air conditioning [2].

1.1 HISTORY OF REFRIGERATION

For centuries, people have known that the evaporation of water produces a cooling effect. At first, they did not attempt to recognize and understand the phenomena, but they knew that any portion of the body that became wet felt cold as it dried in the air. At least as early as the second century evaporator was used in Egypt to chill jars of water, and it was employed in ancient India to make ice [2].

The first attempt to produce refrigeration mechanically depended on the cooling effects of the evaporator of water. In 1755 William Cullen, a Scottish physician, obtained sufficiently low temperature for ice making. He accomplished this by reducing the pressure on water in a closed container with an air pump. At very low pressure the liquid evaporated or boiled at a low temperature. The heat required for a portion of water to change phase from liquid to vapor taken from the rest of the water, and at least part of the water remaining turned to ice. In 1834, Jacob Perkins, an American constructed and patented a vapor-compression machine with a compressor, condenser, an evaporator and a cock between the condenser and the evaporator. He made it by evaporating under reduced pressure a volatile fluid obtained by the destructive distillation of India rubber. It was used to produce a small quantity of ice, but not commercially.

Growing demand over the 30 years after 1850 brought great inventive accomplishments and progress. New substance e.g. ammonia and carbon dioxide, which were more suitable than water were made available by Faraday, Thilorier and others, and demonstrated that these substance could be liquefied. The theoretical background required for mechanical refrigeration was provided by Rumford and Davy, who had explained the nature of heat, and by Kelvin, Joule and Rankine, who were continuing the work begun by Sadi Carnot in formulating the science of thermodynamics [1].

Refrigeration machines appeared between 1850 and 1880, and these could be classified according to substance (refrigerant). Machines using air as a refrigerant were called compressed-air or cold-air machines and played a significant role in refrigeration history. Dr, John Gorrie, an American, developed a real commercial cold-air machine and patented it in England in 1950 and in America in 1951.

Refrigeration machines using cold air as a refrigerant were divided into two types. Closed cycle and open cycle, air confined to the machines at a pressure higher than the atmospheric was utilized repeatedly during the operation. In the open cycle, air was drawn into machine at atmospheric pressure and when cooled was discharged directly into the space to be refrigerated.

In Europe, Dr. Alexender C. Krik commercially develops a closed cycle refrigeration machine in 1862, and Franz Winxdhausen invented a closed cycle machine and patented in America in 1870. The open cycle refrigeration machines theoretically outlined by Kelvin and Rankine in the early 1850s were invented by a Frenchmen, Paul Giffard, in 1873 and by Joseph J. Coleman and James Bell in Britain in 1877.

One of the earliest of the vapor-compression machines was invented and patented by an American professor, Alexander C. Twinin, in 1853. He established an ice production plant using this system in Cleveland, Ohia and could produce close to a ton per day. In the 1860s, Tellier developed an ammonia-compression machine. In 1872, David Boyl made satisfactory equipment for ice making and patented it in 1872 in America. Nevertheless, the most important figure in the development of ammonia-compression machines was Linde, who obtained a patent in 1876 for one which was installed in Trieste brewery the following year. In the late 1860s, P.h Van der Weyde of Philadelphia got a patent for a compression unit which feature a refrigerant composed of petroleum products. In 1875, R.P Pictet at University of America developed refrigerating equipment that used carbon dioxide. Carbon dioxide compression machines became important, because of the gas's harmlessness, in installations where safety was the primary concern, although they were not used extensively until the 1890s. Between 1880 and 1890 ammonia-compression installations became more common. By 1890 mechanical refrigeration had proved to be both practical and economical for the food refrigeration industry. Europeans provided most of the theoretical background for the development of mechanical refrigeration, but Americans participated vigorously in the widespread inventive activity between 1850 and 1880 [2].

1.2 COMPONENTS OF REFRIGERATION SYSTEM

Several mechanical components are required in a refrigeration system. There are 4 major components and some auxiliary equipment associated with these major components. The 4 major components of a refrigeration system are;

i. Compressor
ii. Condenser
iii. Evaporator
iv. Throttling device

In the selection of any component for a refrigeration system, there are number factors that need to be considered carefully, such as;

i. Compressor design.
ii. Selection of refrigerant.
iii. Selection of cooling medium.
iv. System efficiency and maintainability.
v. Type of condenser (air, water or evaporative cooled).
vi. System type (single stage, single economized, compound or cascade arrangement).

1.2.1 Compressors

In a refrigeration cycle, the compressor has two main functions within the refrigeration cycle. One function is to pump the refrigerant vapor from the evaporator so that the desired temperature and pressure can be maintained in the evaporator. The second function is to increase the pressure of the refrigerant vapor through the process of compression, and simultaneously increase the temperature of the refrigerant vapor [3]. By this change in pressure the superheated refrigerant flows through the system.

Figure 1.1: Compressor

In the selection of a proper refrigerant compressor, the following criteria are considered;

i. Compression ratio.
ii. Volumetric flow rate.
iii. Refrigeration capacity.
iv. Thermal and physical properties of the refrigerant.

1.2.2 Condenser

There are many types of condenser, such as air-cooled, water-cooled, shell and tube, shell and coil, tube within a tube and evaporative condensers. Each type of condenser has its own unique application. The determining factors for condenser are such as the weight of the unit, location (city or rural), availability of electricity and water and also the weather condition [2].

Condensers have a very large surface area. The working medium flows through the condenser and gives off its heat energy via the large surface area into the ambient air. The heat discharge can be boosted by means of two fans which blow cooling air through the ribs. Selection of condenser type is not easy and depends on the following criteria;

i. Operation period.
ii. Condenser heat capacity.
iii. Design temperature for water or air.
iv. Condensing temperature and pressure.
v. The flow rates of the refrigerant and coolant.

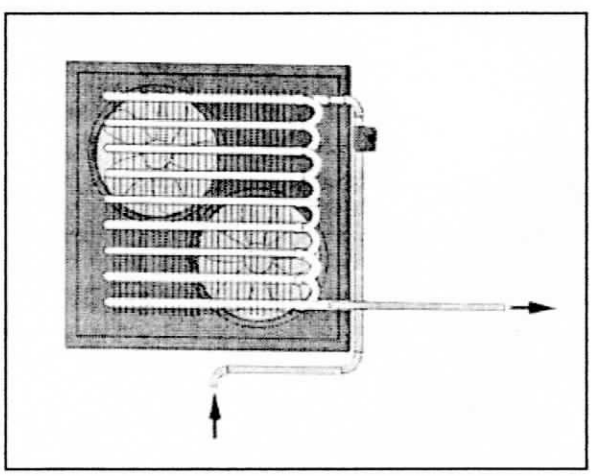

Figure 1.2: Condenser

1.2.3 Evaporator

Evaporator is one of main component in refrigeration system and it can be considered the point of heat capture. Evaporator provides the cooling effect required for any particular application. There are many different type of evaporator as there are applications of heat exchangers. Normally every system will be fixed with the suitable evaporator [2]. When the liquid refrigerant flows through the evaporator, it absorbs heat and changes from the liquid state to a saturated vapor. The vapor thus produced remains saturated as long as there is some liquid present. The vapor and liquid will be at saturation temperature and at the corresponding pressure (4.4°C and 4.8 kg/cm). Finally, by the time the refrigerant approaches the end of the evaporator, all the liquid is vaporized. Up to that point the vapor is in a saturated condition. As the vapor continues to flow through the evaporator after all the liquid has been evaporated, it continues to absorb heat. But as there is no liquid left to boil off, the temperature of the vapor rises higher then the saturation temperature (4.4°C). We then say that the vapor has become superheated.

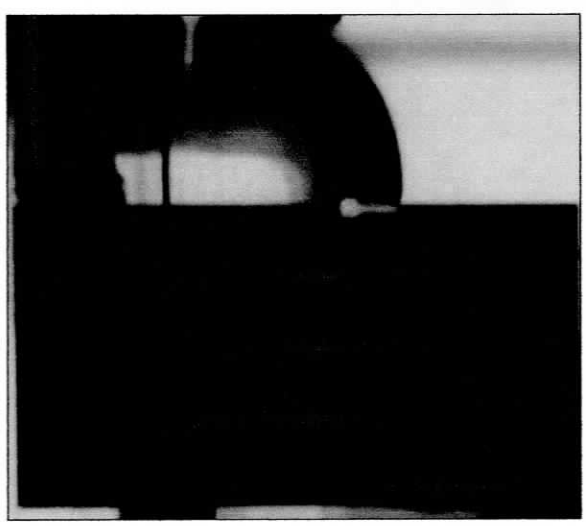

Figure 1.3: Evaporator