PROJECT COMPLETION REPORT

FOR

SHORT TERM RESEARCH GRANT

STUDY OF HEAT EXCHANGER EFFECTS ON CAR AIR-CONDITIONING SYSTEM

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ABSTRACT

Internal or suction line heat exchangers (IHX) are used in some car air conditioning systems with basic objective to optimize the liquescence process of the refrigerant before entering the expansion device. This purpose is achieved by exchanging thermal energy between the cool gaseous refrigerant in the low pressured suction line and the warm liquid refrigerant in the high pressured liquid line in the A/C system. These devices can have either positive or negative influences on the Coefficient of Performance (COP) of the car air conditioning system, depending on the working fluids, the operating condition and the configuration of heat exchanger. The finding from the experimental test indicated the COP of the system with adoption of IHX will be up to 7.92% increment than the system without adoption of IHX if rotational speed of engine was increased.

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TABLE OF CONTENTS

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CHAPTER I

INTRODUCTION

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1.1 Background Study

Internal heat exchanger (IHX) also known as Suction-line/Liquid-line heat exchanger (SLHX) is a derivation from the traditional heat exchangers. Its purpose/concept is similar with other type of heat exchangers, which is a device to build for efficient transfer heat from one place to another. However, it has several notable differences with other traditional heat exchanger in term of size, shape, structure, usage, etc.

Nowadays, the developments of internal heat exchanger are rapid. It has an important role on air-conditioning system based on the vapor compression cycle. The internal heat exchanger often use in automotive air conditioning, with the basic objective of assuring the sub-cooling of refrigerant before entering the expansion device. This process is achieved by exchanging enthalpy (energy) between the cool gaseous refrigerant in the suction line and the hot liquid refrigerant at liquid line. However, according to previous research result, the devices can have positive or negative influences on the overall efficiency, depending on it design and configuration.

1.2 Objectives

The project objectives are:

i. To fabricate the internal heat exchanger.
ii. To find the heat profiling distribution.
iii. To find the Coefficient of Performance for the system.
iv. To find internal heat exchanger effects on car fuel consumption.

1.3 Scope

The scopes of this project are as follow:

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i. The analysis of IHX is focused to car air conditioning system type
ii. Research will be carried out until testing and analysis
iii. Development of IHX prototype.

1.4 Problem statement

The compressor is the core of the car air-conditioning system and it is powered by the car engine. The power needed is transmitted from the engine via the serpentine drive belt, which means when the compressor are switched on, it will places extra load on the car's engine. This ultimately has a negative affect on the car's overall performance and efficiency. Hence, we expect an obvious decrease in car fuel consumption without sacrifice the usage of air conditioning via integration of an internal heat exchanger to the air conditioning system which said to be reduced the work of the compressor. Based on the previous research, the COP for the current air conditioning system is still low. Perhaps this research will gain some improvement of the COP.

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CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Heat exchanger is a device built for efficient heat transfer from one medium to another, whether the media are separated by solid wall so that they never mix, or the media are in contact**.** Heat exchanger widely used in refrigeration, air conditioning, power plants, space heating, and natural gas processing. One common example of a heat exchanger is the radiator in car, which the heat source, being a hot engine-cooling fluid, water transfers heat to air flowing through the radiator.

2.2 Flow Arrangement

Heat exchangers may classify according to their flow arrangement. In parallel-flow heat exchangers, the two fluids enter the exchanger at the same end, and travel in parallel to one another to the other side. In counter-flow heat exchangers the fluids enter the exchanger from opposite ends. The counter current design is most efficient, in that it can transfer the most heat from the heat (transfer) medium. In a cross-flow heat exchanger, the fluids travel roughly perpendicular to one another through the exchanger.

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For efficiency, heat exchangers are designed to maximize the surface area of the wall between the two fluids, while minimizing resistance to fluid flow through the exchanger. The exchanger's performance can also be affected by the addition of fins or corrugations in one or both directions, which increase surface area and may channel fluid flow or induce turbulence.

2.3 Types of Heat Exchanger

2.3.1 Shell and tube heat exchanger

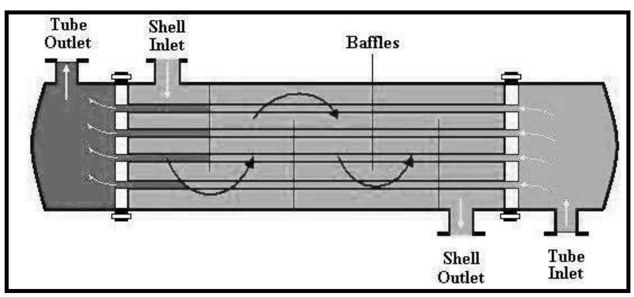

Figure 2.1: Shell and Tube Heat Exchanger

(Source: *http//www.ra.danfoss.com/TechnicalInfo*)

From the Figure 2.1, shell and tube heat exchangers consist of a series of tubes. One set of these tubes contains the fluid that must be either heated or cooled. The second fluid runs over the tubes that are being heated or cooled so that it can either provide the heat or absorb the heat required. A set of tubes is called the tube bundle and can be made up of several types of tubes: plain, longitudinally finned, etc. Shell and Tube heat exchangers are typically used for high pressure applications. This is because the shell

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and tube heat exchangers are robust due to their shape. There are several thermal design features that are to be taken into account when designing the tubes in the shell and tube heat exchangers. These include tube thickness, tube diameter, tube length, tube pitch and tube layout.

2.3.2 Plate heat exchanger

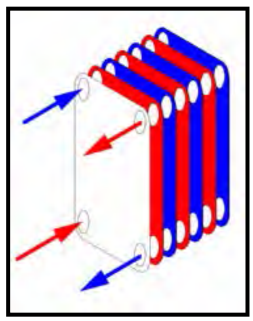

Figure 2.2: Conceptual diagram of a plate and frame heat exchanger.
(Source: *http://en.wikipedia.org/wiki/heat_exchanger*)

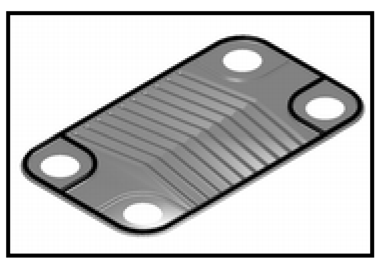

Figure 2.3: A single plate heat exchanger
(Source: *http://en.wikipedia.org/wiki/heat_exchanger*)

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Another type of heat exchanger is the plate heat exchanger shows in Figure 2.2 and Figure 2.3. One is composed of multiple, thin, slightly-separated plates that have very large surface areas and fluid flow passages for heat transfer. This stacked-plate arrangement can be more effective, in a given space, than the shell and tube heat exchanger. Advances in gasket and brazing technology have made the plate-type heat exchanger increasingly practical. In HVAC applications, large heat exchangers of this type are called plate-and-frame; when used in open loops, these heat exchangers are normally of the gasket type to allow periodic disassembly, cleaning, and inspection. There are many types of permanently-bonded plate heat exchangers, such as dip-brazed and vacuum-brazed plate varieties, and they are often specified for closed-loop applications such as refrigeration. Plate heat exchangers also differ in the types of plates that are used, and in the configurations of those plates. Some plates may be stamped with "chevron" or other patterns, where others may have machined fins and/or grooves.

2.3.3 Plate fin heat exchanger

This type of heat exchanger uses "sandwiched" passages containing fins to increase the effectively of the unit. The designs include cross flow and counter flow coupled with various fin configurations such as straight fins, offset fins and wavy fins. Plate and fin heat exchangers are usually made of aluminum alloys which provide higher heat transfer efficiency. The material enables the system to operate at a lower temperature and reduce the weight of the equipment. Plate and fin heat exchangers are mostly used for low temperature services such as natural gas, helium and oxygen liquefaction plants, air separation plants and transport industries such as motor and aircraft engines.

Advantages of plate and fin heat exchangers:

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- High heat transfer efficiency especially in gas treatment
- Larger heat transfer area
- Approximately 5 times lighter in weight than that of shell and tube heat exchanger
- Able to withstand high pressure

Disadvantages of plate and fin heat exchangers:

- Might cause clogging as the pathways are very narrow
- Difficult to clean the pathways

2.3.4 Regenerative Heat Exchanger

Other type of heat exchanger is the regenerative heat exchanger. In this, the heat (heat medium) from a process is used to warm the fluids to be used in the process, and the same type of fluid is used either side of the heat exchanger (these heat exchangers can be either plate-and-frame or shell-and-tube construction). These exchangers are used only for gases and not for liquids. The major factor for this is the heat capacity of the heat transfer matrix.

2.3.5 Tubular Heat Exchanger

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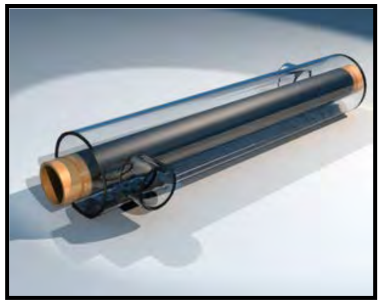

Figure 2.4: Tubular Heat Exchanger

(Source: http://en.wikipedia.org/wiki/heat_exchanger)

Tube heat exchangers shows in Figure 2.4 are designed to transfer heat energy from one liquid to another without direct contact between the two liquids, ensuring that there is no mixing. Applications that tube heat exchangers are utilized in include waste water heat recovery, process heat removal, hot tubs, air conditioning, transmission and engine coolers, oil coolers and boiler sample coolers. Tube heat exchangers serve industrial and commercial industries as well as marine, heating and cooling, automotive, aerospace, waste treatment, food processing and pharmaceutical.

2.3.6 Adiabatic Heat Exchanger

This type of heat exchanger uses an intermediate fluid or solid store to hold heat, which is then moved to the other side of the heat exchanger to be released. Examples for this heat exchanger are adiabatic wheels, which consist of a large wheel with fine threads rotating through the hot and cold fluids and fluid exchanger. This type is used when it is acceptable for a small amount of mixing to occur between the two streams.

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2.3.7 Fluid Heat Exchanger

This is a heat exchanger with a gas passing upwards through a shower of fluid (often water), and the fluid is then taken elsewhere before being cooled. This is commonly used for cooling gases whilst also removing certain impurities, thus solving two problems at once. It is widely used in espresso machines as an energy-saving method of cooling super-heated water to be used in the extraction of espresso.

2.3.8 Dynamic scraped surface heat exchanger

Another type of heat exchanger is called "(dynamic) scraped surface heat exchanger". This is mainly used for heating or cooling with high-viscosity products, crystallization processes, evaporation and high-fouling applications. Long running times are achieved due to the continuous scraping of the surface, thus avoiding fouling and achieving a sustainable heat transfer rate during the process.

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2.4 Car Air Conditioning System

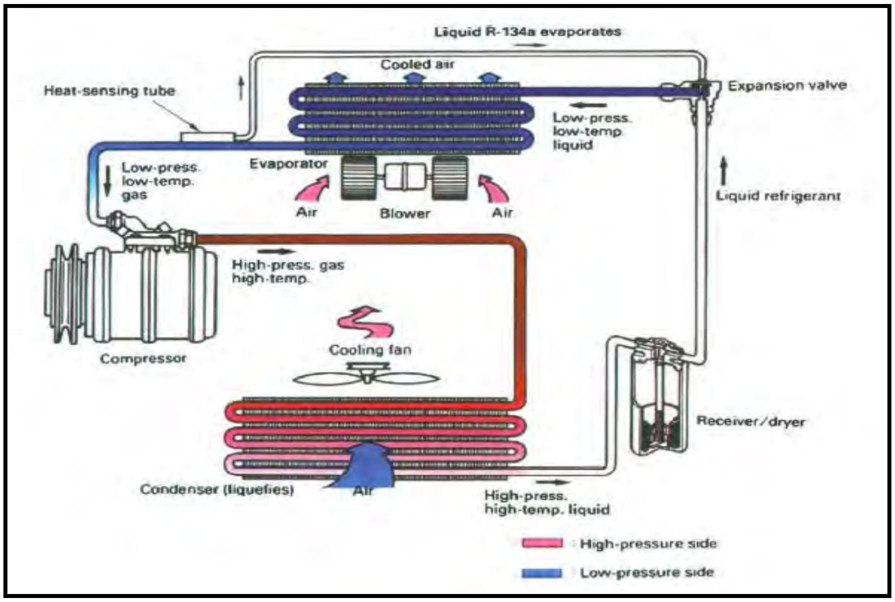

Figure 2.5 Car Air Conditioning Systems

(Source: *http//:www.visteon.com*)

From the Figure 2.5 shows the car air conditioning system. The *compressor* is the power unit of the A/C system. It is powered by a drive belt connected to the engine's crankshaft. When the A/C system is turned on, the compressor pumps out refrigerant vapor under high pressure and high heat to the condenser. After that, the *condenser* is a device used to change the high-pressure refrigerant vapor to a liquid. It is mounted ahead of the engine's radiator, and it looks very similar to a radiator with its parallel tubing and tiny cooling fins. As the car moves, air flowing through the condenser removes heat from the refrigerant, changing it to a liquid state. Then, refrigerant moves to the *receiver-drier*. This is the storage tank for the liquid refrigerant. It also removes moisture from the refrigerant. Moisture in the system can freeze and then act similarly to cholesterol in the human blood stream, causing blockage.

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Next, as the compressor continues to pressurize the system, liquid refrigerant under high pressure is circulated from the receiver-drier to the *thermostatic expansion valve*. The valve removes pressure from the liquid refrigerant so that it can expand and become refrigerant vapor in the evaporator. Then, the *evaporator* is very similar to the condenser. It consists of tubes and fins and is usually mounted inside the passenger compartment. As the cold low-pressure refrigerant is released into the evaporator, it vaporizes and absorbs heat from the air in the passenger compartment. As the heat is absorbed, cool air will be available for the occupants of the vehicle. A blower fan inside the passenger compartment helps to distribute the cooler air. The heat-laden, low-pressure refrigerant vapor is then drawn into the compressor to start another refrigeration cycle.

The operations of the air conditioner are controlled by set of operator controls that are located in car. The operator controls typically will include an ON/OFF switch, temperature control and blower of fan speed control. Once the operator turns on the air conditioner, a control signal received by controller which can be part of vehicle computer or engine control unit (ECU). In other words, the computer controller operates the air conditioner in accordance with the settings of the operator controls.

2.5 Car Air Conditioning Components

2.5.1 Compressor

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Figure 2.6: Compressor

(Source: *http://images.search.yahoo.com/images/compressor*)

Commonly referred to as the heart of the system, the compressor as show in Figure 2.6 is a belt driven pump that is fastened to the engine. It is responsible for compressing and transferring refrigerant gas. The A/C system is split into two sides, a high pressure side and low pressure side; defined as discharge and suction. Since the compressor is basically pumped, it must have an intake side and discharge side. The intake or suction side draws in refrigerant gas from the outlet of the evaporator. Once the refrigerant is drawn into suction side, it is compressed and sent to the condenser where it can then transfer the heat that is absorbed from the inside the vehicle**.**

2.5.2 Condenser

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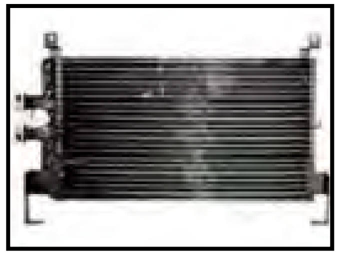

Figure 2.7: Condenser

(Source: http://images.search.yahoo.com/images/condenser)

This is the area in which heat dissipation occurs. The condenser refer in Figure 2.7, in many cases will have much the same appearance as the radiator. The condenser is designed to radiate heat. Condenser must have good air flow anytime the system is in operation. On rear wheel drive vehicle, this is usually accomplished by taking advantage o existing engine's cooling fan. On front wheel drive vehicles, condenser air flow is supplemented with one or more electric cooling fan. As hot compressed gasses are introduced into top of the condenser, they are cooled off. As the gas cools, it condensed and exits the bottom of the condenser as high pressure liquid.

2.5.3 Evaporator

Figure 2.8 Evaporator

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(Source: *http://images.search.yahoo.com/images/evaporator*)

Located inside the vehicles, the evaporator shows in Figure 2.8 serves as the heat absorption component. The evaporator provides several functions. It's primarily duty is to remove heat from the inside the vehicle. A secondary benefit is dehumidification. As warmer air through the aluminum fins of the cooler evaporator coil, the moisture contained in the air condenses on its surface. Refrigerant enters the bottom of the evaporator as low pressure liquid. The warm air passing through the evaporator fins causes the refrigerant to boil (refrigerants have very low boiling points). As the refrigerant begins to boil, it can absorb large amount of heat. This heat is then carried off with the refrigerant to outside the vehicles. Factors that are important in the design of evaporators include the size and length of the tubing, the number and size of the fins, the number of return bends and the amount of air passing through and past the fins.

2.5.4 Orifice Tube

Figure 2.9: Orifice Tube

(Source: *http//specialtauto.com/air-conditioning-systems*)

From Figure 2.9, orifice tube can be found in the inlet tube of the evaporator or in the liquid lien, somewhere between the outlet of the condenser and the inlet of the

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evaporator. Most of the orifice tube in use today measure approximately there inches in length and consists of small brass tube surrounded by plastic and covered with filter screen at each end. This filter prevents debris from clogging the tube

2.5.5 Thermal Expansion Valve

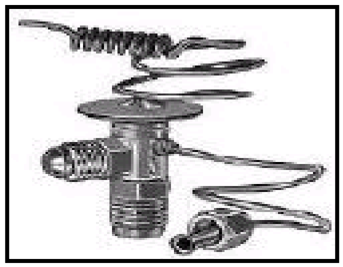

Figure 2.10: Thermal Expansion Valve

(Source: *http//specialtauto.com/air-conditioning-systems*)

From the Figure 2.10, this type of valve can sense both temperature and pressure and is very efficient at regulating refrigerant flow to the evaporator. This valve is usually located at the firewall, between evaporator inlet and outlet tubes and the liquid and suction lines. It is one of the points in air conditioning system where there is separation between a high and low pressure.

2.5.6 Receiver Drier

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Figure 2.11: Receiver Drier

(Source: *http//specialtauto.com/air-conditioning-systems*)

The receiver dries show in Figure 2.11 is used on high side of system that uses a thermal expansion valve. To ensure that the valve gets liquid refrigerant, a receiver is used. The primary function of receiver-drier is to separate out refrigerant vapor (gas) and liquid refrigerant (liquid). Allowing only liquefied refrigerant to travel onto the thermostatic expansion valve and contains a drying agents in a desiccant bag inside the container. The secondary function is to remove moisture that may have entered the system at the time of installation or repair and filter out dirt.

2.5.7 Accumulator

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Figure 2.12: Accumulator

(Source: *http//specialtauto.com/air-conditioning-systems*)

Accumulator shows in Figure 2.12 are used on system that accommodates an orifice tube to meter refrigerants into the evaporator. It is connected directly to the evaporator outlet and stores excess liquid refrigerant. The main function of accumulator is to catch and trap the liquid refrigerant from the evaporator to protect the compressor. The accumulator also contains a strainer and desiccant for refrigerant cleaning and purification.

2.5.8 Pressure Regulating Devices

Controlling the evaporator temperature can be accomplished by controlling refrigerant pressure and flow into evaporator.

2.5.9 Refrigerant

Refrigerant is the term used when referring to the fluid that is used in an automotive air conditioning system. Refrigerant is a gas used in mechanical refrigeration system. Refrigerant is any fluid or vapor that is used to transfer heat from one to area or space to another. An ideal refrigerant would have the following properties:

- Zero ozone depleting potential and zero global warming potential.
- Low boiling point.

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- High critical pressure and temperature point.
- Miscible with oil and remain chemically stable.
- Non-toxic, non-flammable.
- Non-corrosive to metal, rubber, plastics.
- Cheap to produce, use and dispose.

Refrigerant R-12 which has been used in automotive air conditioning system for many years was also used on other applications, such as domestic refrigeration. Refrigerant R-12 commonly known as R12 is a CFC (Chloro Fluoro Carbon). The refrigerant consists of chlorine, fluorine and carbon, and has the chemical symbol CCL2F2.

A benefit of R12, when it was originally designed, was its ability to with stand high pressures and temperatures (critical temperature and pressure point) without deteriorating compared to other refrigerants that were around at that time. R12 mixes well with mineral oil which circulates around an A/C system. It is non-toxic in small quantities although it does displace oxygen and is odorless in concentrations of less than 20%. R12 can also be clean or recycled. It also readily absorbs moisture. It is heavier than air when gaseous, hence the danger of suffocation. Unfortunately, it has determined that R- 12, the leading single cause of ozone-depletion. It is an environmentally harmful CFC gas (containing chlorine which destroys the atmospheric ozone layer).

An alternate refrigerant has been developing to replace of R-12. R134a is a known substitute for R12. R134a is an HFC (Hydro Fluoro Carbon). The refrigerant consists of hydrogen, fluorine and carbon, and its chemical symbol is CH2FCF3. Because the refrigerant has no chlorine it does not deplete the ozone. R134a is non-toxic, non-corrosive and does contribute to global warming; it is not miscible with mineral oil so synthetic oil, called PAG (Poly Alkaline Glycol), was developed. PAG oil is hygroscopic and absorbs moisture rapidly which means when in use you must ensure

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