UNIVERSITI TEKNIKAL MALAYSIA MELAKA

DEVELOPMENT OF INDIRECT MULTI-SPLIT AIR-CONDITIONING SYSTEM USING PROPYLENE GLYCOL AS SECONDARY REFRIGERANT

This report is submitted in accordance with the requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor of Mechanical Engineering Technology (HVAC) with Honours.

by

MOHAMAD FAISAL BIN MURAT
B071410089
920505-01-6553

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APPROVAL

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfilment of the requirements for the degree of Bachelor of Mechanical Engineering Technology (Refrigerant and Air-Conditioning System) with Honours. The member of the supervisory is as follow:

Mr. Amir Abdullah bin Muhamad Damanhuri

(Project Supervisor)

ABSTRACT

Nowadays, the mechanical vapour compression system used for this purpose use large amount of electrical power that is produced in great proportion by fossil fuel combustion which is cause of the global warming. So improvement of performance of the system is important to increase refrigerating effect or to improve performance of vapour compression refrigeration system. Any substance must be wisely evaluated for the global impact on the global environment. The interest in application of secondary refrigerant system in air conditioning and refrigeration is to reduce refrigerant losses and the chance for lower installation and operation costs. Developed indirect air conditioning system using 1HP, R-22 as primary refrigerant. Indirect air conditioning system using the propylene glycol as a secondary refrigerant and the ratio for secondary refrigerant was mixture with 1 litre water and 1, 1.5, 2, 2.5 and 3 litre of glycol accordingly. The data have be taken used the thermocouples type-K in this experiment is cooling coil temperature difference of direct and indirect refrigeration system and COP performance of direct and indirect refrigeration system plot at the mollier chart. The average for increment of coefficient of performance (COP) 1 HP multi-split unit air-conditioner with usage of propylene glycol as a secondary refrigerant is 33.38%. The prototype of multi-split air conditioning with propylene glycol in this project increased the COP of the air-conditioner system in between 13.64% - 59.38% and the results indicate that propylene glycol is also the ideal fluid to be used as a secondary refrigerant at the air conditioning system. The maximum temperature achieve from this project was 6°C and the air-conditioning able to produce thermal comfort temperature for occupants which are 22°C - 24°C.

ABSTRAK

Sistem pemampatan wap mekanikal yang digunakan pada masa kini, menggunakan kuasa elektrik dengan jumlah yang besar yang dihasilkan dalam nisbah hebat oleh pembakaran bahan api fosil, yang merupakan punca pemanasan global. Oleh yang demikian, peningkatan prestasi sistem adalah penting untuk meningkatkan kesan penyejukan atau untuk meningkatkan prestasi wap sistem penyejukan mampatan.. Ia juga perlu dinilai untuk kecekapan tenaga, kos, keberkesanan, keselamatan dan faktor-faktor lain. Oleh itu peningkatan prestasi sistem adalah penting untuk meningkatkan kesan penyejukan atau meningkatkan prestasi sistem penyejukan mampatan wap. Kepentingan dalam penggunaan sistem penyejuk sekunder dalam penyaman udara dan penyejukan dikurangkan kerugian penyejuk dan peluang untuk kos pemasangan dan operasi yang lebih rendah. Sistem penyaman udara tidak langsung yang dibangunkan menggunakan 1HP, R-22 sebagai penyejuk utama dan sistem penyaman udara tidak langsung menggunakan "propylene glycol" sebagai penyejuk sekunder. Data yang diambil dalam eksperimen ini adalah perbezaan suhu gegelung penyejukan sistem penyejukan langsung dan tidak langsung dan prestasi COP sistem penyejukan langsung dan tidak langsung. Rata-rata untuk peningkatan pekali prestasi (COP) 1 penghawa dingin unit berpecah udara HP dengan penggunaan propylene glikol sebagai penyejuk sekunder adalah 33.38%. Prototaip penghawa dingin berpecah dengan "propylene glycol" dalam projek ini meningkatkan COP sistem penghawa dingin di antara 13.64% - 59.38% dan hasilnya menunjukkan bahawa propylene glikol juga cecair ideal untuk digunakan sebagai penyejuk sekunder di sistem penghawa dingin. Suhu maksimum yang diperoleh daripada kajian ini ialah 6 ° C dan penyejat telah dapat memenuhi suhu keselesaan terma bagi penghuninya iaitu 22 ° C - 24 ° C.

DEDICATION

To my beloved parents especially my beloved father Murat bin Musa and my beloved mother Badariah binti Ismail, I acknowledge my sincere thankfulness and gratitude to them for their love, dream and sacrifice throughout my life. I am really thankful for their sacrifice had inspired me from the day I learned how to read and write until what I have become now. I cannot find the appropriate words that I could properly describe my appreciation for their devotion, support and faith in my ability to achieve my dreams. Lastly, I would like to send my gratitude to any person that constribute to my final year project whether it is directly or indirectly. I would like to acknowledge their comments and suggestions, which are crucial for the successful completion of this study.

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First and foremost, all praise to almighty Allah S.W.T for giving me the strength, health, knowledge and patience to successfully complete the Final Year Project (FYP) report on a given time. I have to thank to my father Murat bin Musa and my mother Badariah binti Ismail, for their blessing, love support me from behind and also pray for me to success in life. I would like to address my deepest feeling appreciation t my respectful supervisor, Mr. Amir Abdullah bin Muhamad Damanhuri for their encouragement, comment, guidance and enthusiasm along the time to develop and manage this report properly and successfully. Special thanks to my friends that have been through thick and thin throughout the completion of this project. This project report might be impossible to complete without all of their help. Last but not least, thank you to everyone that directly and indirectly involved in helping me finishing this final year project report. Thank you.

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CHAPTER 1

INTRODUCTION

1.0 Introduction

Air-conditioning system usage has been prominent nowadays through the world used by the people or community and air-conditioning system are attractive more prevalent in building. The residential air-conditioning has increased positively or theatrically with the initiation of central air. The air-conditioning of commercial type has changed a lot in the past years as the increasing of the rising of the energy costs. The energy consumed by an air-conditioning is taken very seriously by those involved in the design and operation of these buildings. The goal must to be make available thermal comfort for occupants, while diminishing energy consumption. The residential air-conditioning sector account for the largest amount of refrigerant released into the atmosphere (Hesse, 1996) .The amount of refrigerant charged in air-conditioning system is too large, and they typically contain a large number of connections, valve, tubes and other possible for leaks (Francis, Maidment, & Davies, 2017). This situation commanded to the development secondary refrigerant system for air-conditioning and various companies currently supply such system. Proper choice of the essential and secondary refrigerant is basic so as to accomplish the best execution (Menon, 1995). The interest for utilization of secondary refrigerant system in air conditioning and refrigeration is lessened refrigerant misfortunes and the shot for bring down establishment and operation costs is advancing this development (Francis et al., 2017).. Commercial refrigeration system are known to be prone to high leaks rates and to consumed large amount of electricity (Abdelaziz et al., 2012).The commercial air conditioning sector accounts for the largest amount of refrigerant released into the atmosphere (Zhao, Jianbo, Haizhao, & Lingchuang, 2017). The capacity of the primary refrigerant is currently constrained just to be a working fluid noticeable all around air conditioning system and the capacity of transporting thermal energy from the adapted spaces is presently expected by the secondary refrigerant.

1.1 Energy

Improvement in insulation, compressor efficiency and optimisation of the refrigerant charge have reduce energy consumption significantly in recent years (Binneberg, Kraus, & Quack, 2002). The control system has to make sure that the refrigeration on condition that by the refrigeration cycle matches the essential cooling capacity. In science field, energy is a property of which can be exchanged to different object or changed over into various structures. But most of the time the system will work immediate the closed door mode. The power consumption in this very low capacity mode will have the largest impact on the power bill (Binneberg et al., 2002).

1.2 Problem Statement

Electricity would cost a lot of energy and resource and cause natural resource progressively worried. Nowadays, many of the people installed their house with split unit air-conditioning system. The power consumption at the system very low capacity mode will have the largest impact on the power bill (Perini, Bazzocchi, Croci, Magliocco, & Cattaneo, 2017). Theoretically, any fluid can be used as a refrigerant. Air used in an air cycle refrigeration system can also be considered as a refrigerant (Melinder, 2010). Conversely, in this project the attention is mainly focused on propylene glycol used as refrigerants in vapour compression refrigeration systems.

1.3 Objective

These objectives should be achieved in the end of the project. Therefore, the following below are the objectives that has been considered:

1. To fabricate indirect refrigeration system using propylene glycol as secondary refrigerant attach to direct R-22 refrigeration system.
2. To study cooling coil temperature difference of direct and indirect refrigeration system using propylene glycol as secondary refrigerant.
3. To investigate coefficient of performance (COP) of direct and indirect refrigeration system.

1.4 Scope

This project limitation focus to get the 22°C - 24°C which is thermal comfort zone temperature at the both zone supplied by the evaporator. This project also used split unit air conditioning system 1.5 HP domestic. The kind of primary refrigerant use in the system R-22 then as secondary refrigerant used propylene glycol. HVAC piping encompasses many different fluids, pressures, and temperature. This project used copper pipe L-Type size 1/4 for discharge line and 3/8 thickness for suction line and both thickness is 0.51mm. For insulation copper pipe, this project used Armaflex rubber self-seal pipe wrap insulation size 1/4 and 3/8 for discharge and suction line.

1.5 Organization of the thesis

Chapter 1 explains the introduction of the project, which includes the background, problem statements, objectives and work scope of the study. In chapter 2, the chapter briefly explains the review of theories, experimental works and some findings that had been done during the past research that is related to the current project. In chapter 3, methodology and strategy to achieve the objectives is explained in detail. The working procedure, materials and apparatus are well explained.

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

The conventional fuel source are getting exhausted due to continuous use of it. Conventional energy source are not long lasting. Nowadays energy is continuously in demand and the world is on the hand facing problems with limited convenience of conventional energy source and on the hand global warming because of pollutant from fossil fuels (W. Wang, Zhang, Jiang, & Liu, 2011). Refrigeration system are indispensable of human beings in the modern life. Nowadays, the mechanical vapour compression system used for this purpose, use large amount of electrical power that is produced in great proportion by fossil fuel combustion, which is cause of the global warming. Global reducing the use of electrical energy. Electrical energy can be remarkably saved by incorporating high efficiency vapour compression refrigeration system is based on vapour compression cycle (Binneberg, Kraus, & Quack, 2002). Vapour compression refrigeration system is used in domestic or residential refrigeration. So improvement of performance of the system is important to increase refrigerating effect have to improve performance of vapour compression refrigeration system. The dynamics of air conditioning are of particular interest to energy analysts, both because of the high energy consumption of this product, but also its disproportionate impact on peak load (McNeil & Letschert, 2008). Air conditioning gets a lot of attention within the energy analysis community, and for good reason. For the developing world, an emphasis on air conditioning is even more deserved for two related reasons. First, air conditioners in developing countries are probably be installed in households where electricity consumption is still fairly low. These households will use a lot of energy for lighting, a refrigerator, possibly a washing machine, almost definitely a television and probably some other entertainment products. In such a household, the addition of an air conditioner causes a big jump in the energy consumption. The second aspect, of course, is air conditioners contribution to peak load. In Asia, one of the wealthiest economies in the world, this single endues more than any other has challenged the power grids ability to keep the lights on (McNeil & Letschert, 2008). How, then, may we expect developing countries to handle it? Many already experience chronic shortages of power. Far beyond the expense of energy generation, the capital required to add new capacity and replace worn out distribution systems will be a high barrier to meeting demand, which in turn has significant economic and social consequences. Table 2.1 shows the demand of air conditioning use in Asian countries, and it shows that the country of Malaysia is among countries with high use of air conditioners at 878 (in thousands) demand. Global warming also related about refrigerant used at the refrigeration system (Longo, Righetti, Zilio, & Bertolo, 2014). Any substance must be wisely evaluated for the global impact on the global environment. It must also assessed for energy efficiency, cost, effectiveness, safety and other factors. CFCs had been used as refrigerants for air conditioning equipment and had a significant impact on ozone layer depletion. HCFCs also used for servicing air conditioning or refrigeration. Many countries then started to switch to HFC new refrigerant that have no impact on the ozone layer. The HFC refrigerant adopted then are superior the HCFCs thanks to their zero ozone depletion potential (ODP), however they still have global warming potential (Makumbi, 2013). The interest in application of secondary refrigerant systems in air conditioning and refrigeration is reduced refrigerant losses and the chance for lower installation and operation costs is promoting this development (Melinder, 2010).

Table 2.1: Asia countries air conditioner demand

(in thousands)

	2010	2011	2012	2013	2014	2015
World total	85,002	96,791	90,514	96,691	96,240	92,461
Japan	8,931	9,057	9,271	9,817	9,336	8,899
Overseas	76,071	87,734	81,243	86,874	86,904	83,562
China	32,719	40,729	32,764	35,632	34,938	32,328
Asian countries	12,005	12,217	13,065	13,672	14,538	15,146
India	3,506	3,547	3,500	3,633	3,862	4,063
Indonesia	1,532	1,638	2,030	2,246	2,286	2,202
Vietnam	702	659	917	998	1,229	1,607
Thailand	1,034	933	1,112	1,163	1,315	1,388
South Korea	1,177	1,227	1,190	1,236	1,236	1,253
Taiwan	878	922	987	952	1,014	1,014
Malaysia	829	816	871	902	898	878
Philippines	502	561	611	664	687	717
Pakistan	677	724	623	613	672	675
Hong Kong incl. Macao	575	551	538	539	538	531
Bangladesh	131	147	164	156	170	183
Myanmar	61	70	80	123	180	181
Singapore	158	162	163	163	162	158
Cambodia	65	69	77	81	85	90
Sri Lanka	55	68	79	80	81	84
Others	123	123	123	123	123	123

2.1 Principle of a basic vapour compression cycle (Direct system)

A direct refrigeration system is a vapour compression cycle or the heat pump. In the direct refrigeration system the working fluid is called the primary refrigerant. Four main components in the basic vapour compression can be distinguished evaporator, compressor, condenser and an expansion device. Once the heat from heat source is supplied, the refrigerant starts to boil evaporate and the formed vapour is introduced to the compressor. The compressor is used to compress the primary refrigerant to a higher pressure and temperature level (Palm, 2015). Later primary refrigerant is condensed in the condenser, expanded in the expansion device and returns back to the evaporator.

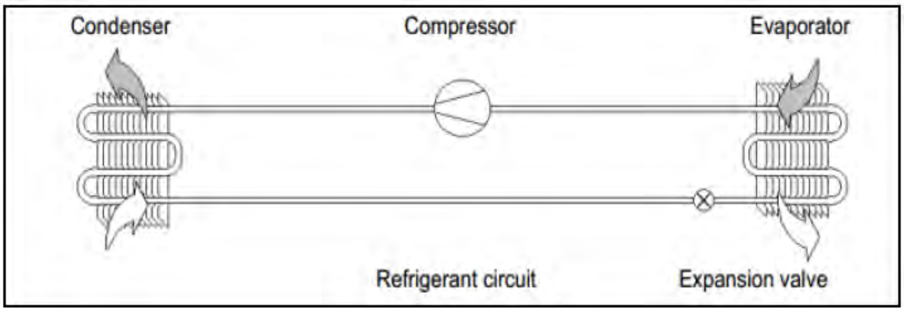


Figure 2. 1: Direct refrigeration system

2.1.1 Principle of indirect refrigeration system

The indirect refrigeration system consists of two circuits primary and secondary refrigerant used. The secondary circuit is an additional circuit where the secondary fluid is circulating to transfer heat (Melinder, 2010). The secondary circuit can be found on both hot and cold side. Different terms are used to define the fluid in the secondary loop heat transfer fluid, brine, antifreeze, secondary refrigerant, secondary fluid, secondary coolant and secondary working fluid (Palm, 2015). The secondary fluid absorbs heat from the heat source and transports it through piping to the evaporator where heat is given away to the primary refrigerant in the primary loop. In this way the primary refrigerant has no direct contact with the heat source. On the condenser side the same principle can be applied, where a secondary loop using a secondary fluid absorbs the heat rejected in the condenser (Palm, 2015).

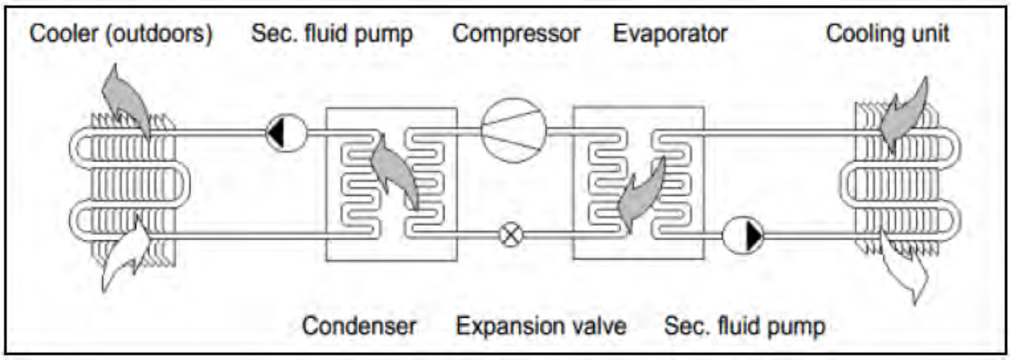


Figure 2. 2: Indirect refrigeration system

Water is a very good secondary fluid but only at temperatures above 3ºC since it freezes at temperature of 0 ºC (Hesse, 1996). Therefore, a freeze depressant additive must be used in order to take advantage of the good thermo physical properties of water. Among freeze depressant additives used with water are propylene glycol and ethylene glycol (Palm, 2015).

2.2 Performance of indoor unit as evaporator

As soon as the room wishes cooling, the indoor unit actions as an evaporator. Liquid refrigerant from the condenser is depressurized by the thermal expansion valve and becomes gas mixture liquid fluid then flows into the evaporator. Thermal expansion valve can regulates the flow rate of refrigerant by adjusting its opening rate. The mixture gas liquid refrigerant in the evaporator turn into gas gradually by absorb the heat from the air out of the evaporator. The parameter such as evaporating temperature (°C), condensing temperature (°C), air volume (m^3/h) and mass flow rate of refrigerant (g/s) all influence the performance of the evaporator and the refrigerant state at the discharge line evaporator and the refrigerant state at the outlet of evaporator, but the usually evaporator temperature (°C) and propylene glycol temperature (°C) are the aim of the system. However, to keep the compressor operating safely, it is necessary to keep the refrigerant superheated at the discharge line evaporator (Shao, Shi, Li, & Yan, 2002).

2.2.1 Types of indoor unit (Split-type)

Split-type air conditioning system with indoor and outdoor units, are becoming very popular for room cooling of residential buildings in Malaysia. It is the indoor unit common type of split unit is, wall mounted, ceiling mounted, cassette type and floor standing. Nowadays, the companies give almost important to the looks and aesthetics of the indoor unit

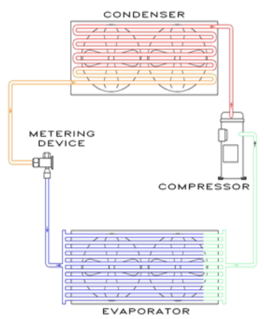
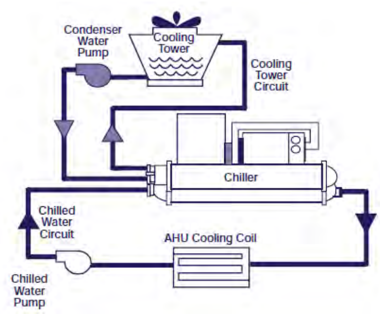
Table 2. 2 : Types of indoor unit (Split-type)

Type of indoor unit (split-type)	
Wall mounted type	
Ceiling mounted	
Cassette type	
Floor standing	

2.3 Performance of outdoor unit as condenser

The outdoor unit actions as a condenser in the refrigeration model system operates. Refrigerant from the condenser is compressed into high pressure and high temperature gas by the compressor, then flows into the condenser coil and condenses to liquid steadily. A condenser is a heat transfer device or unit used to condense a substance from its gaseous to its liquid state typically by cooling. Similarly, as the analysis in the outdoor unit, the refrigerant mass flow rate and air volume at the evaporator are the well regulated parameters that influence the capacity and refrigerant states (Zhao et al., 2017). Heating Ventilation and Air-Conditioning (HVAC) are extensively used in residential, commercial and industrial system. Due to several increased demand of water for both domestic and industrial purpose in the recent years, there has been an increased interest in the use of air cooled system as an alternative to water cooled system (Sarfraz & Bach, 2016).

Table 2. 3: Types of condenser

<table>
<tr><th colspan="2">Type of condenser</th></tr>
<tr><th>Air cooled condensing unit</th><th>Water cooled condensing unit</th></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td>Air-cooled condensing unit has a condenser that is cooled by the environment air and force convection by fan.</td><td>Water-cooled condensing unit have water cooled condenser connected with cooling tower and are usually preferred for medium and large installations where there is sufficiency of water.</td></tr>
</table>