UNIVERSITI TEKNIKAL MALAYSIA MELAKA

DESIGN OF BACKUP SYSTEM FOR SOLAR-POWERED AIR CONDITIONING BY USING CONDENSED AND EVAPORATED ACCUMULATOR

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Engineering Technology (Refrigeration and Air-Conditioning System) with Honours.

By

MUHAMAD AZRI BIN AZMAN

B071310651

940505-03-6173

FACULTY OF ENGINEERING TECHNOLOGY

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DECLARATION

I hereby, declared this report entitled "Design of Backup System for Solar-Powered Air Conditioning by Using Condensed and Evaporated Accumulator" is the result of my own research except as cited in references.

Signature :………………………

Name : MUHAMAD AZRI BIN AZMAN

Date : 12 DECEMBER 2016

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APPROVAL

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Engineering Technology (Refrigeration and Air-Conditioning System) (Hons.). The member of the supervisory is as follow:

………………………………

(Norain Binti Idris)

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ABSTRAK

Di Malaysia, iklim panas dan lembab membuatkan permintaan terhadap penyaman udara yang tinggi untuk mengurangkan suhu di dalam rumah. Walau bagaimanapun, penggunaan kuasa elektrik oleh penyaman udara adalah agak tinggi. Oleh itu, terdapat satu teknologi alternatif yang menggunakan tenaga boleh diperbaharui seperti solar untuk mengurangkan bil elektrik. Solar photovoltaic biasanya bertindak sebagai sumber kuasa yang menjana arus terus kepada sistem elektrik. Kuasa elektrik yang dijana daripada panel photovoltaik itu boleh digunakan untuk memberi kuasa kepada penghawa dingin. Penyaman udara berkuasa solar biasanya memerlukan bateri sebagai sistem sokongan. Bateri mengeluarkan kuasa elektrik apabila panel photovoltaik itu tidak lagi menjana elektrik kerana hari mendung atau pada waktu malam. Kajian ini memberi tumpuan kepada sistem sokongan untuk penyaman udara berkuasa solar dengan menggunakan tangki penerima untuk mengimpan cecair refrigerant bertekanan tinggi. Sistem sokongan ini akan berfungsi apabila hari mendung atau diwaktu malam denagn melepaskan cecair refrigerant bertekanan tinggi dari tangki penerima. Satu prototype telah direka dengan menggunakan perisian Solidwork. COP dari prototype adalah 3.57. Satu experimen telah dibuat untuk mencari jumlah keseluruhan jisim refrigerant yang diperlukan untuk menampung sistem sokonagn selama satu jam dan jumlah jisim refrigerant adalah 18.9kg iaitu bersamaan dengan lima biji tangki penerima. Kesimpulannya, tangki penerima boleh digunakan sebagai sistem sokongan kepada penyaman udara berkuasa solar.

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ABSTRACT

In Malaysia, the hot and wet climate is the reason of high demand of the usage of air conditioner. However, the electrical power consumption by air conditioners are high. Therefore, there is an alternative technology that uses renewable energy like solar to reduce electrical bill. Solar photovoltaic commonly acts as the power source that generates direct current to electrical system. The electrical power that is generated from the photovoltaic panel could be used to power up the air conditioner. The solar power air conditioners usually required battery as their backup system. The battery bank discharges the electrical power whenever the photovoltaic modules do not generates electric due to cloudy days of or during nights. This project therefore focuses on the backup system for solar-powered air conditioner by using readily condensed refrigerant and evaporated refrigerant. The condensed refrigerant from condenser will be stored in a receiver in high temperature and high pressure. While the accumulator will store the evaporated refrigerant from the evaporator at low temperature and low pressure. This backup system will run whenever the solar photovoltaic modules cannot provide electricity to compressor. The prototype is designed by using SolidWord software. The COP of the backup system prototype is 3.57. An experiment has been done to determine the total mass of the refrigerant required to backup the system for one hour operation and the total mass for refrigerant is 18.9 kg which is equal to five receiver tanks. As the conclusion, the receiver tanks can be used as the backup system for solar-powered air conditioner.

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LIST OF ABBREVIATIONS SYMBOL AND NOMENCLATURE

AC	-	Alternative Current
COP	-	Coefficient Performance
DC	-	Direct Current
fT	-	Feet
PV	-	Photovoltaic
KWH	-	Kilowatt Hour
P	-	Power
V	-	Voltage
°c	-	Celsius
R	-	Refrigerant
%	-	Percentage
TES	-	Thermal Energy Storage
TR	-	Ton of Refrigerant
VCR	-	Vapor Compression Refrigerant

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CHAPTER 1

INTRODUCTION

1.0 Introduction

This chapter discusses about the overview and related information of backup system for solar-powered air conditioning by using refrigerant liquid receiver and accumulator. This chapter includes the background study, problem statement, objective and scope of the study.

1.1 Air conditioning System

Most of nowadays buildings and houses are require a good ventilation and air conditioning system to achieve the desire thermal comfort. Over the past century, the average temperature on the earth surface has increased by 1 degree Fahrenheit due to hot climate and global warming (Wang 2005). Therefore air conditioning is a must appliance in every building and houses to overcome the hot climate problem. There are many types of air conditioning system that commonly used in commercial and residential building such as individual system, space system, unitary package system, central system and air system. Almost all of the system stated above is using vapor compression refrigerant cycle where the system require compressor, condenser, expansion valve and evaporator. Gajdhar, 2015 stated that vapor compression refrigerant cycle have four processes which are isentropic compression in a compressor,

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constant-pressure heat rejection in a condense, throttling in an expansion device and constant-pressure heat absorption in an evaporator.

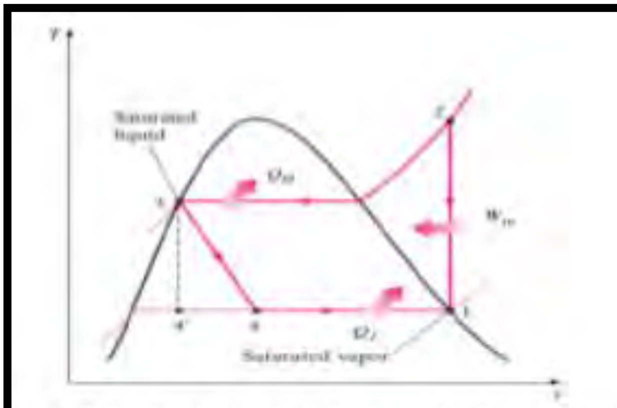

Fig. 1 T-S diagram for vapour compression refrigeration system

Figure 1.1 T-S Diagram for VCR cycle (Gajdhar 2015)

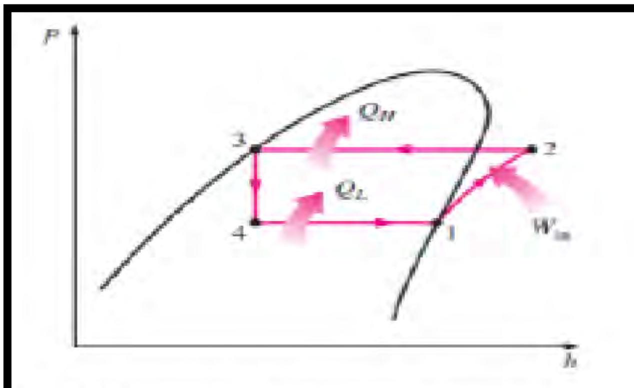

Fig. 2 P-H diagram for vapour compression refrigeration system

Figure 1.2 P-H Diagram for VCR Cycle (Gajdhar 2015).

In an ideal vapor-compression refrigeration cycle, the refrigerant enters the compressor at state 1 as saturated vapor and is compressed isentropic ally to the condenser pressure. During the isentropic compression process, the temperature of the refrigerant increases than temperature of surrounding medium. The superheated vapor at state 2 enters the condenser and the heat is rejected to surrounding by condenser. The saturated liquid refrigerant leaves the condenser at state 3. The saturated liquid refrigerant at state 3 is throttled to the evaporator pressure by passing it through an expansion valve or capillary tube. The temperature of the refrigerant drop below the temperature of the refrigerated space during this process. The refrigerant enters the evaporator at state 4 as a low-quality saturated mixture, and it completely evaporates by absorbing heat from the refrigerated space. The refrigerant leaves the evaporator as saturated vapor and return to compressor to complete the cycle (Gajdhar 2015).

However the conventional air conditioning system consumes large amount of electricity that could lead to high electricity bill and waste of electricity. A survey by Kubota (2011) proved that the household that own an air conditioner was drastically increased from 13,000 in 1970 to 775,000 in 2000 and the percentage of increasing is 0.8% to 16.2% respectively. In 20013, the demand of air conditioner in a house was increasing to 821,000 units which 34% increase from three past years (Nagata 2015). The average daily usage of air conditioning is 6 hours a day by 65% of the air conditioning owner. This is because the modern brick houses needs air conditioning to overcome the tropical climate compare to traditional wooden houses. Therefore the electricity rate uses by air conditioner is higher than other electrical equipment which is 1167 kWh yearly.

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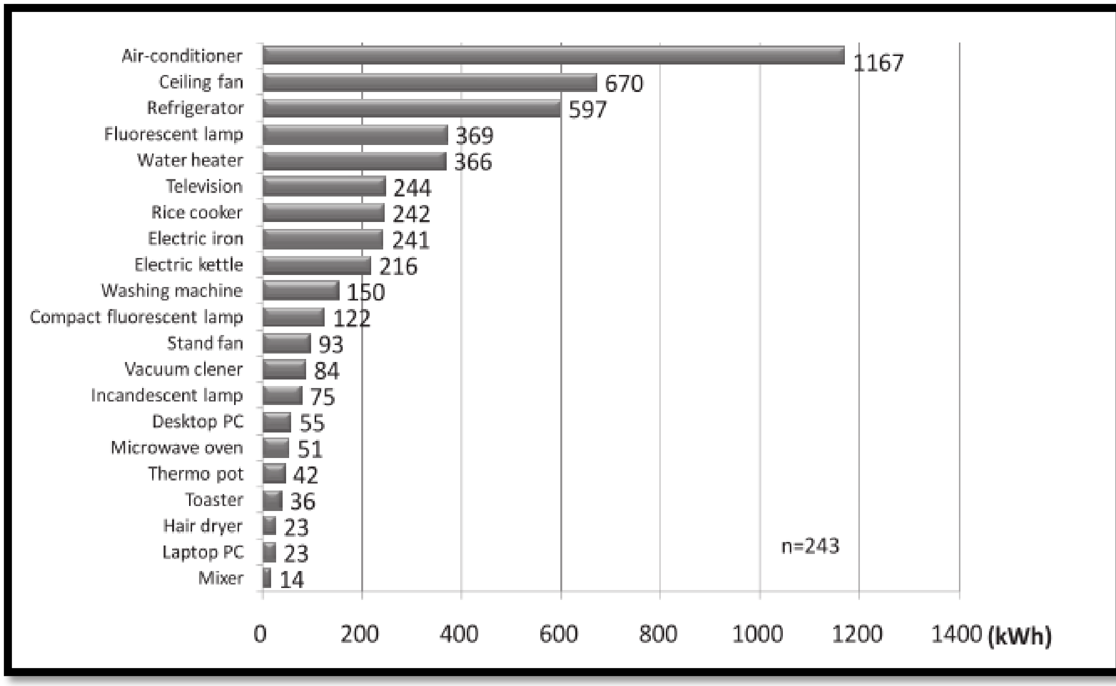
Chart 1.1 Yearly Electricity Consumption (Kubota 2011)



. There were some research and invention have done in recent years to reduce the usage of electricity by air conditioner and one of them is inverter compressor. Inverter motor compressor could varies their speed by using permanent magnet synchronous motor compare to conventional constant speed compressor (Ohyama & Member 2008). By using inverter motor compressor the speed of compressor could be reduce in order to reduce the electricity.

1.1.1 Renewable Energy

Besides the inverter motor compressor, there were also alternative energy source that could be used to run the air conditioner. Renewable energy sources such as solar, wave, wind and biomass could produce electricity to run the air conditioning system. This environmental friendly green energy is quite famous in nowadays developed countries like Japan, America, German, Russia and so on. Malaysia also developing renewable energy especially in Photovoltaic (PV) solar that widely apply at Solar Enclave Setia Eco Park, KLCC Tower and

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Cypark Resourc Bhd, Pajam (Chen 2012). However the usage of solar powered air conditioner for resident is not a common thing yet. Even the product of solar powered air conditioner is available in market but It is too expensive for the installation and maintenance (Khor et al. 2012).

The backup system that usually used for air conditioning system is Thermal Energy Storage (TES). TES is a technology that stores the thermal energy by cooling or heating the storage medium in a storage tank that can used on later time as the backup system for cooling or heating application (Renewable & Agency 2013). For solar powered air conditioning system requires battery to store charge from the PV solar panel. Therefore the battery is an important component for solar powered air conditioning to provide electric power to air conditioner system. Battery used for storing the electrical charge from PV panel and also acted as the backup system for solar air conditioner during the cloudy days and night (Qdah 2015).

In this research the receiver is used as the backup system for solar powered air conditioner. The design receiver in this research act similar to TES system where the thermal energy will be stored in the receiver and will discharge It when the battery is no longer supplies the electrical to the compressor. In conventional air conditioner system, receiver is install after the condenser. Meanwhile if the air conditioner system has no receiver the refrigerant will directly flows to the capillary tube or expansion valve (Subcooling et al. 2010).

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1.2 Problem Statement

The development of air conditioning technology in this era is quite advanced in all over countries. Many inventions and modifications have been achieved in order to upgrade the efficiency of conventional air conditioning system. The conventional air conditioner with constant speed compressor consumes a large amount of electricity. Therefore, one of the alternative method to reduce the power consumption by air conditioner is by using the renewable energy such as solar powered air conditioner. The solar powered air conditioner requires battery as the power supply and backup during the cloudy day. However the battery itself has their limitation such as lifespan, quantity, capacity and cost in order to cover up the air conditioner system during cloudy day and night. Therefore, this research will design a prototype of backup system for a solar air conditioner by using refrigerant receiver and accumulator to reduce the usage of battery or no battery needed during the cloudy day and night.

1.3 Objective

This study should be able to achieve those objectives:

a) To design and to build a backup system for solar-powered air conditioner by using condensed (liquid refrigerant receiver) accumulator.

b) To calculate COP of the system and to determine the liquid capacity require to backup one hour of the cooling process.

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1.4 Scope

Scope is the limitation of the project to be designed by identifying some equipments and apparatus to be used in this project. This project will be carried out at Faculty of Engineering Technology UTeM. The PV solar module in the Renewable Energy Laboratory will be used in this project as the power source for the prototype. This design project is applying for air conditioning with vapor compression refrigerant cycle. The backup system for the design prototype will used liquid refrigerant receiver and refrigerant accumulator. A scale down prototype will be designed by using 1 Hp compressor and other related component for the system.

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CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

This chapter will focus on the theory and terms mainly related to this research, which is about refrigerant receiver tank and accumulator tank as the backup system for the solar power air-conditioning. The sources of theory are from previous research and related articles. This chapter aim to give better understanding about this research and to give strong evidence, support and reason why this research should be done. There are some numerous studies have been conducted about the solar power air conditioning, but there is still lack of studies focusing o the backup system for solar photovoltaic during the night or cloudy days. Thus, this research aims to reveal the ability of the backup system from the refrigerant receiver tank and accumulator tank to run the air conditioning system.

2.1 Solar-Power Air Conditioning Backup System

Most of the solar power air conditioning developed in nowadays cooling system has the backup system. There are some backup system that usually used in solar power air conditioning and one of them is desiccant cooling system. Desiccant cooling system is a heat driven cycle air conditioning where the refrigerant which is water is directly contact with air. The combination of the effect of evaporative cooling and air

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dehumidification is thermally driven cooling cycle by the desiccant. Desiccant cooling system using Water/Lithium Chloride solution as sorption material is one of the new development close to market introduction. The possibility of high energy storage by storing the concentrated solution and higher air dehumidification at the same driving temperature are the highlights of this system (Saudagar et al 2013).

Besides the desiccant cooling system, the backup system for air conditioning that usually used is thermal energy storage. Thermal energy storage is a cooling system that produce by the chillers to cool the water as the storage media in ice or water. The thermal energy storage is more like energy cost saving because it can reduce the power require by the system by supplying the cooling water to the condition space that is already cooled at night (Maccracken 2003).The thermal energy storage system also could save energy up to 10% to 20% in some instances (Hauer 2013).

The other way to backup the air conditioning system is by using battery. Battery is usually used in photovoltaic solar system to store the electrical charge power. The photovoltaic power generate electric from the sunlight and supply the electric in direct current (DC) and store it in the battery. In solar backup system, the power that could supply by the system is 2kW to 100kW (SMA 2009).

2.2 Refrigerant Receiver as the Storage Tank

Receiver is a accessory component in an air conditioning system and it is usually installed after the condenser in a typical air conditioner system. Saturated refrigerant from the condenser flows through the liquid line and enter the receiver before discharging it to the expansion valve.

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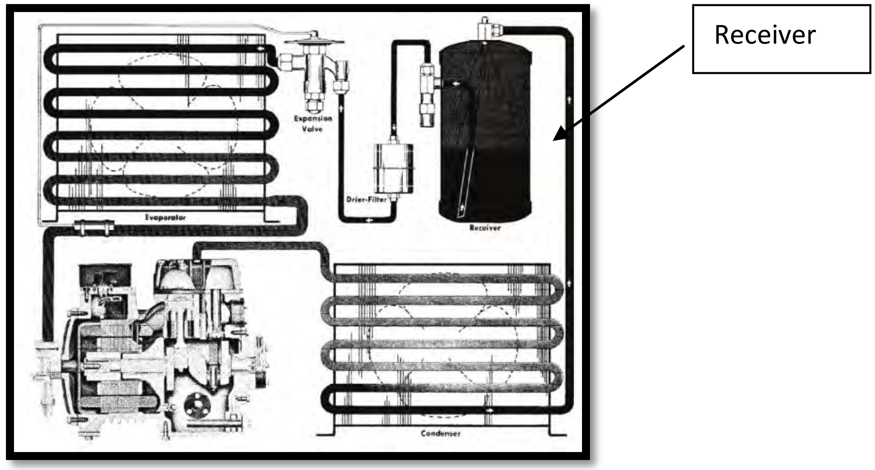

Figure 2.1 Refrigeration system with a receiver (Gajdhar 2015).

Since the receiver is installed between the condenser and expansion valve, the phase of refrigerant leaves the condenser is in saturated liquid as the refrigerant is condensed (Gajdhar 2015) in the ideal vapor compression refrigerant cycle. Referring to (Note et al. 2014), there are three function of the receiver which are to receive the variation mass of the refrigerant due operation condition, compressor capacity regulation or operation mode, to hold part of charge in reserve to compensate for small leakage and to store the total refrigerant charge when the system require servicing or repair. While (Rajapaksha & Suen 2004) the receiver is used to store the excess charge of refrigerant temporarily during the charge of operation mode and also to avoid liquid refrigerant return back to the condenser that could affect the performance of the system.

Even the receiver is not applied to all the residential air conditioning, but it is widely applied in food industry and medical drug storage where they need to preserve the quality of the food or drug in the cold room. Cold room is the storage facility where large quantities of product could be stored for longer duration at lower temperature that made from assembled of walls, ceiling and floor in any size from various sections of modular insulted panels (Gajdhar 2015). The application of the cold storage room is similar to typical refrigeration process which removing heat from a substance under controlled condition and refrigerant uses evaporation of a liquid to absorb heat

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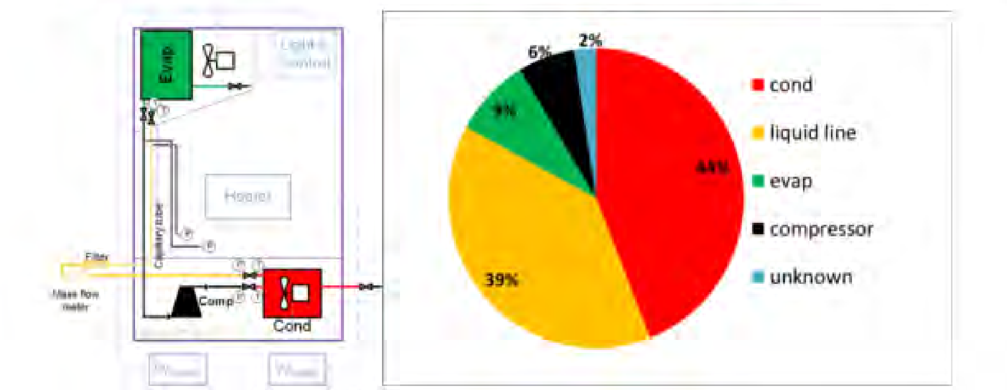
(Ubabuike & Alfred 2012). The cold storage room uses vapor compression refrigerant cycle process and most of the system require receiver.

2.2.1 Refrigerant Receiver Capacity in Air Conditioning System

The capacity of the receiver included the refrigerant charge, pressure and oil that could store inside the receiver. Charge is generally mass, which is the volume and density of the product and the higher the volume and density the higher the charge (Jiang 2014). The mass of the refrigerant charge is in lb or kg. Jiang (2014), was carried out an experiment about the charge in the small commercial refrigeration system that came out with the result that more than 80% of the charge is in the condenser and liquid line.

Table 2.1 : The Distribution Charge in the Refrigeration System (Jiang 2014)

Condenser	Evaporator	Compressor	Liquid line	Unknown	Total collected	Actual charge
146.7 (g)	28.3 (g)	20.6 (g)	129.3 (g)	8.1 (g)	333.0 (g)	355.8 (g)



From table 2.1, the refrigerant charge in the condenser and liquid line where the receiver is installed has the highest charge than other components in the system which are 44% and 39%. The liquid refrigerant should be stored in receiver before discharging to the expansion valve in saturated liquid refrigerant.

The pressure of the receiver is depends on the working pressure in the vapor compression refrigerant cycle where the pressure is varies in each phase

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and temperature of the phase (Domanski 1995). The pressure also vary in different type of refrigerant because every refrigerant has different melting and boiling point. The pressure of the refrigerant also could be determine by referring the pressure-temperature chart that usually used by technician or contractor to make trouble shooting (Charts 2006). The maximum working pressure of the receiver that available by the manufacturer can be up to 42 bar with 70 liter volume (Solutions 2015).

2.2.2 Refrigerant Receiver Selection

There are two type of receiver that available in the market which are horizontal model and vertical model that is used depends on the application. The shape of the receiver for refrigerant usually manufactured in cylinder The selection of the receiver is depends on the connection diameter, volume, refrigerant used and working pressure and maximum refrigerant charge in the system.

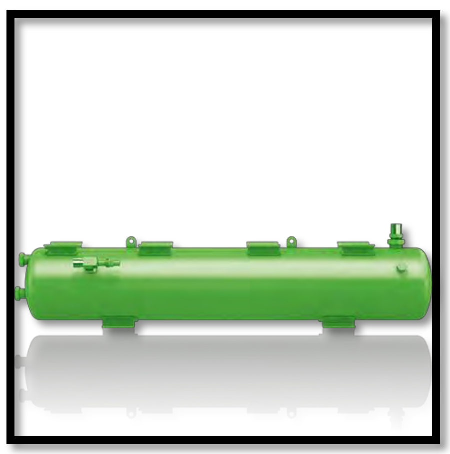

Figure 2.2 Horizontal Refrigerant Receiver

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