Palestine Polytechnic University

College of Engineering & Technology
Mechanical Engineering Department

Graduation Project

Design and build up a plated ice maker

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Abstract

In this project design and build up an ice maker which is expected to produce plated ice. This unit is to be build up according to the calculations that will be shown in the calculation chapter.

This unit may be used in the university laborites to show the process of forming ice. The most important part to be designed in this project is the evaporator as the ice will have its shape.

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CHAPTER ONE

INDRODUCTION

Introduction

1.1 Introduction

This project aims to design and build up ice maker which is expected to produce an ice plate which can be then divided into cubic ice by using a special procedure. However we expected to face many problems such as providing the suitable component for our cycle. In the other hand the most important component in our cycle is the evaporator as the evaporator will decide the shape of the ice that will be produced, so we will show in details the calculation and selection of the evaporator and many shapes of evaporator that can be designed. This chapter talks about some types of ice and ice makers and why plate ice is to be produced.

1.2 Project objectives

There are some objectives that can be mentioned as follow:

1) Design and build up ice maker to produce plated ice, according to calculations and selection of every single component of the cycle (or unit). The project will be used as a laboratory device to demonstrate the ice making process and its relation with the process occurring in the refrigeration cycle.
2) In the project an important theoretical studies will be done, such as choosing the refrigerant, cycle components, condenser and evaporator……etc.
3) Study different types of ice and the physical and thermal properties of each one.
4) Study different types of ice makers especially plate ice maker.
5) Make the electrical control of this unit.

1.3 Choosing type of ice maker (or type of ice)

From previous studies ice can be classified to:

1) Flake ice (chip ice).
2) Crushed ice, consists small pieces made from crushing larger chunks of ice
3) Fluid ice (or liquid ice), it is aqueous ice mixture that contains >20% of liquid, so it may handled as fluid (pipes, pumps.....etc.)
4) Dry ice, its also called carbon dioxide snow , it is the solid phase of CO_2.
5) Ice cubes (cubic ice)

Ice makers can be classified to

1) Block ice maker that shown in fig (1.1) can produce ice with 150-170 mm thick.

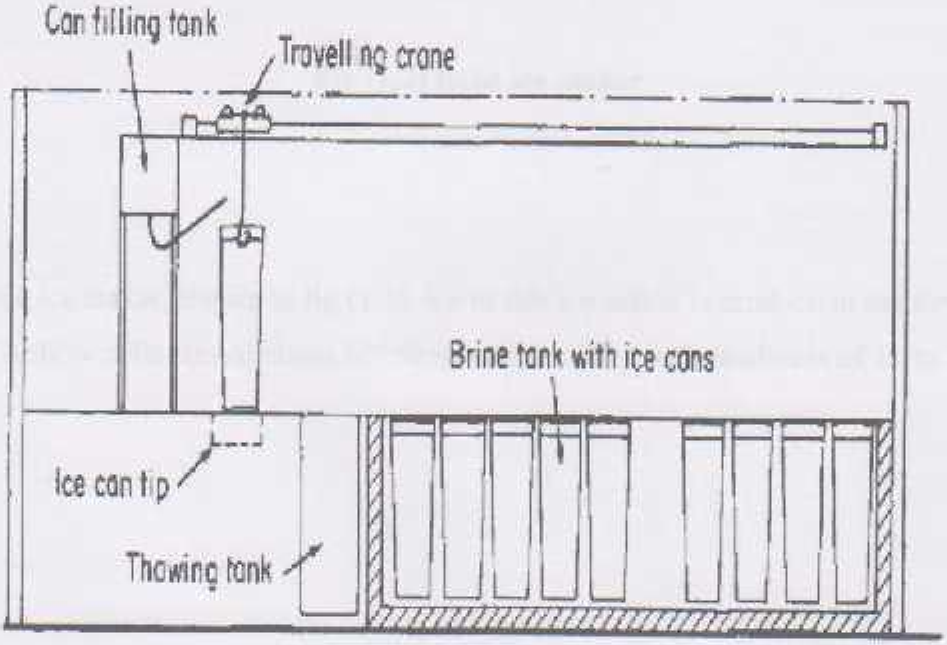


Fig (1.1) Block ice maker

2) Flake ice maker forms ice 2 to 3 mm thick (fig 1.2)

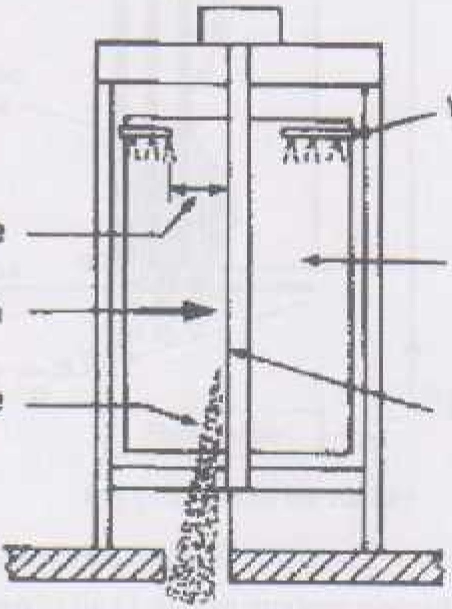


Fig (1.2) flake ice maker

3) Tube ice maker, shown in fig (1.3), ice in this ice maker is produce in the form of small hollow cylinders of about 50*50 mm thick with a wall thickness of 10 to 12 mm.

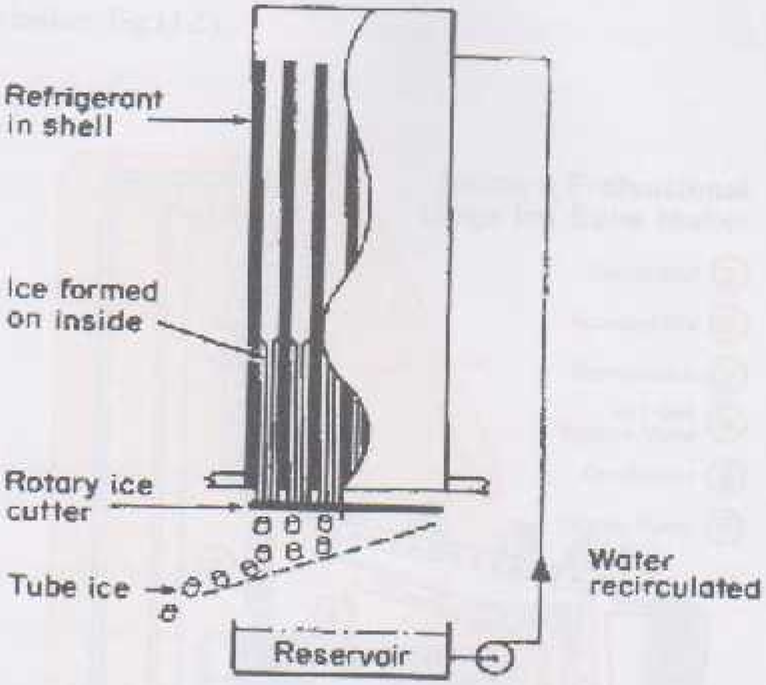


Fig (1.3) Tube ice maker

4) Plate ice maker, shown in fig (1.4), can produce plate of ice with thickness of 10 to 12 mm.

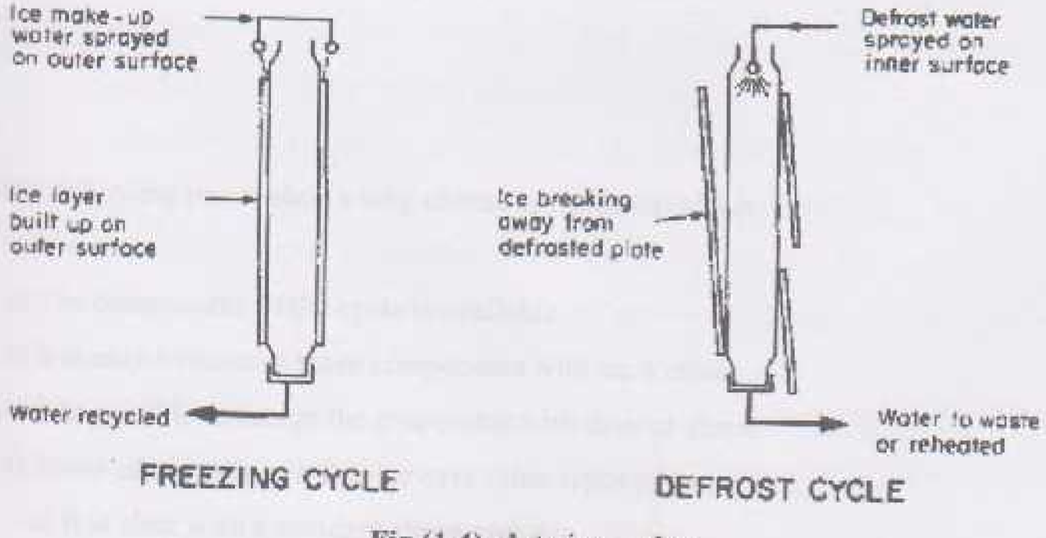


Fig (1.4) plate ice maker

5) Cubic ice maker. Fig (1.5).

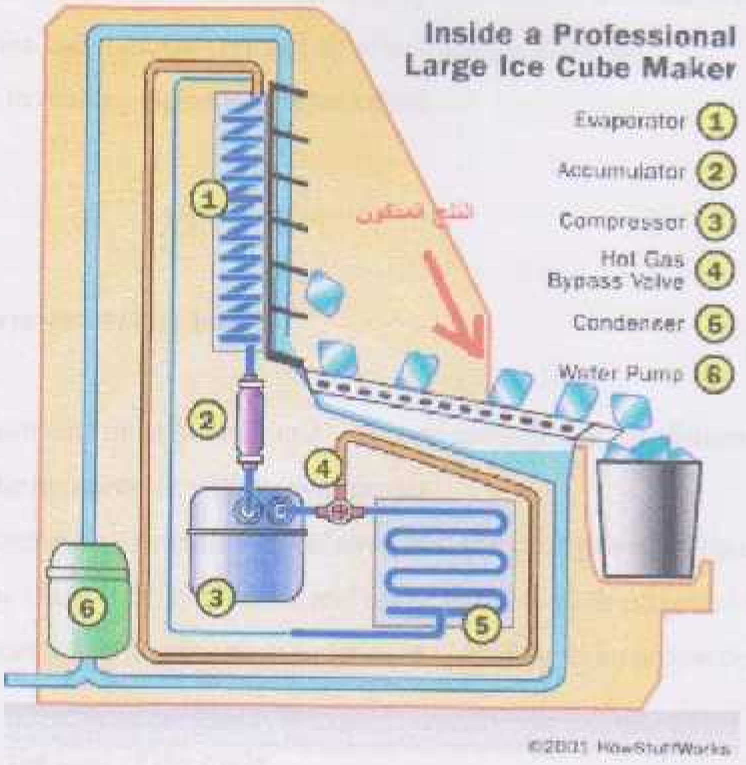


Fig (1.5) cubic ice maker

The following points shows why choosing plated ice maker.

1) The components of the cycle is available.
2) It is easy to connect these components with each other.
3) It is possible to design the evaporator with desired shape.
4) Some advantages of cubic ice over other types of ice:
   a) It is clear with a standard shape and size.

b) It is used in many applications including hospitality (hotels, cafés, and restaurants), fresh food industry and fast food industry.

c) Cubic ice is considered to be high quality ice because it contains few impurities and minimal trapped air which makes it harder.

d) Slower in melting than other types of ice.

1.4 How the system will be built?

The system (project) must be built and designed according to the following steps

1) Choosing the compressor with known power
2) From the compressor selection calculation at different types of refrigerant had been done (by using T-S, P-V charts and using the cool pack program) to decide the most suitable refrigerant to be used a cording to its properties, COP.....etc.
3) Calculating the load of the cycle.
4) By the cycle analysis a suitable condenser had been chosen.
5) Making calculation for the most important component of the cycle which is the evaporator, and choosing the best shape for it as the shape of evaporator will decide finally the shape of the ice that will form into it.
6) Choosing the water pump that will circulate the water in the cycle and spraying water in the evaporator, so a suitable nozzle must be chosen.
7) Choosing the actuators, monitoring component and protection of the cycle, such as solenoid valve, accumulator, overload, receiver, and high and low pressure switches.
8) Deciding the best way to install the project (or the system) in table.
9) Build up the electrical wiring diagram for the system.

The project or the system is expected to work as follow:

1) Refrigeration cycle is on (compressor and the fan of condenser are on).

2) Water from the water tank is circulated by pump over the evaporator and sprayed by the nozzle.

3) The water is cooled down and gradually freezes on the evaporator plate.

4) Ice builds up till reaching required thickness.

5) Up on reaching the required thickness the water recirculating pump and condenser fan are turned off and the harvest of ice starts.

6) Ice harvest takes place by hot gas entering the evaporator directly without been condensed and this step can be done by the solenoid valve.

7) As the evaporator plate is slopped the ice plate formed on the evaporator will fall into the special box by means of gravity.

8) Then a new cycle will begin.

1.5 Time Table

The time of project is scheduled over 16 week; table (1.1) shows how the work scheduled over these weeks:

Table (1.1) Time Plan

Weeks / Task	1 2	3 4	5 6	7 8	9 10	11 12	13 14	15 16
Selection of the compressor	■							
Calculations		■						
Buying basic component of the project			■					
Writing the chapters				■				
Design of the evaporator					■			
Connecting components						■	■	
Building and testing the project.				■	■	■	■	■

1.6 Budget

Table (1.2) Budget

Equipment	Cost(NIS)
Using the internet	200
Renting room	500
Transportation	500
Printing papers	200
compressor	300
condenser	200
Con. Fan	30
Evaporator	400
accumulator	30
Stand table	500
Water pump	50
Water tank	150
Other component	200
Cycle protections	100
Ice box	150
Total	3510

1.7 Project Contents (outline)

The project is divided up in 4 chapters; the chapters follow each other logically to get the complete idea about the project

Chapter 1: Introduction to the project with pre studies and why choosing this project and how do this project works.

Chapter 2: Components of the system.

Chapter 3: Calculation and cycle analysis.

Chapter 4: Power and electrical circuit

CHAPTER TWO

COMPONENTS OF THE SYSTEM

Components of the system

2.1 Introduction

This chapter talks about the component to be used, and about the criteria for selecting each of them.

2.2 Ice maker cycle

The system to be build is shown in fig (2.1)

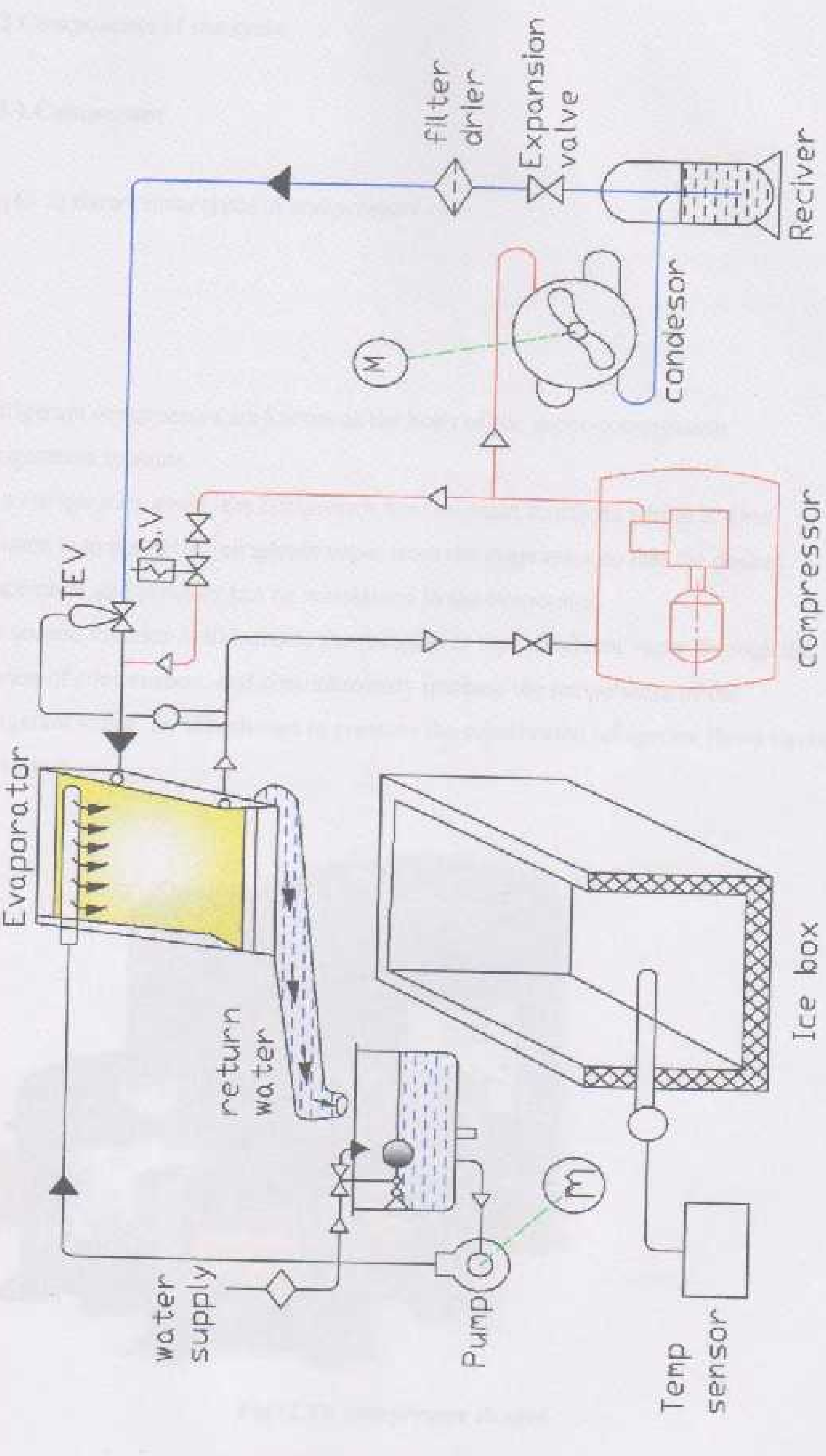


Fig (2.1) ice maker system

2.3 Components of the cycle

2.3.1 Compressor

Fig (2.2) shows some types of compressors.

Refrigerant compressors are known as the heart of the vapor-compression refrigeration systems.

In a refrigeration cycle, the compressor has two main functions within it. 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. By this change in pressure the superheated refrigerant flows through the system.

Fig (2.2): compressor shapes

Compressors can be divided in two main types:

•Positive displacement compressors, and

• Dynamic compressors.

Both displacement and dynamic compressors can be hermetic, semi hermetic, or open types. The compressor both pumps refrigerant round the circuit and produces the required substantial increase in the pressure of the refrigerant. The refrigerant chosen and the operating temperature range needed for heat pumping generally lead to a need for a compressor to provide a high pressure difference for moderate flow rates, and this is most often met by a positive displacement compressor using a reciprocating piston. Other types of positive displacement compressor use rotating vanes or cylinders or intermeshing screws to move the refrigerant. In some larger applications, centrifugal or turbine compressors are used, which are not positive displacement machines but accelerate the refrigerant vapor as it passes through the compressor housing. These various compressor types are illustrated in Figure (2.3)

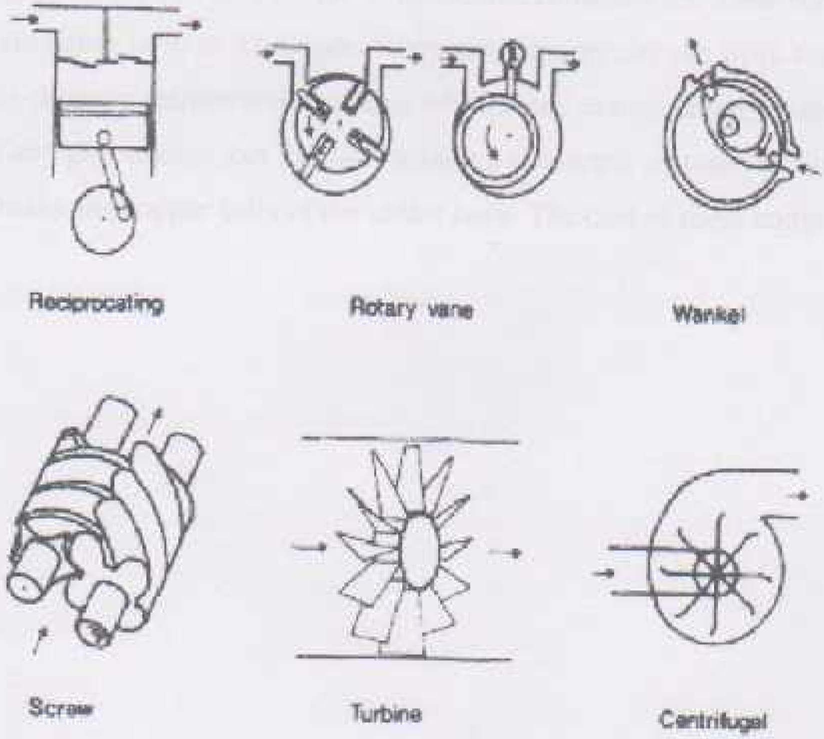


Fig 2.3: some type of compressor

In this project the compressor that will be used is hermetic (fig 2 4)

Compressors are preferable on reliability grounds to units primarily designed for the smaller range of temperatures required in air conditioning or cooling applications. In small equipment where cost is a major factor and on-site installation is preferably kept to a minimum, such as hermetically sealed motor/compressor combinations ,there are no rotating seals separating motor and compressor, and the internal components are not accessible for maintenance, the casing being factory welded.
In these compressors, which are available for small capacities, motor and drive are sealed in compact welded housing. The refrigerant and lubricating oil are contained in this housing. Almost all small motor-compressor pairs used in domestic refrigerators, freezers, and air conditioners are of the hermetic type. An internal view of a hermetic type refrigeration compressor is shown in Figure (2.4). The capacities of these compressors are identified with their motor capacities. For example, the compressor capacity ranges from 1/12 HP to 30 HP in household refrigerators. Their revolutions per minute are either 1450 or 2800 rpm. Hermetic compressors can work for a long time in small-capacity refrigeration systems without any maintenance requirement and without any gas leakage, but they are sensitive to electric voltage fluctuations, which may make the copper coils of the motor burn. The cost of these compressors is very low.

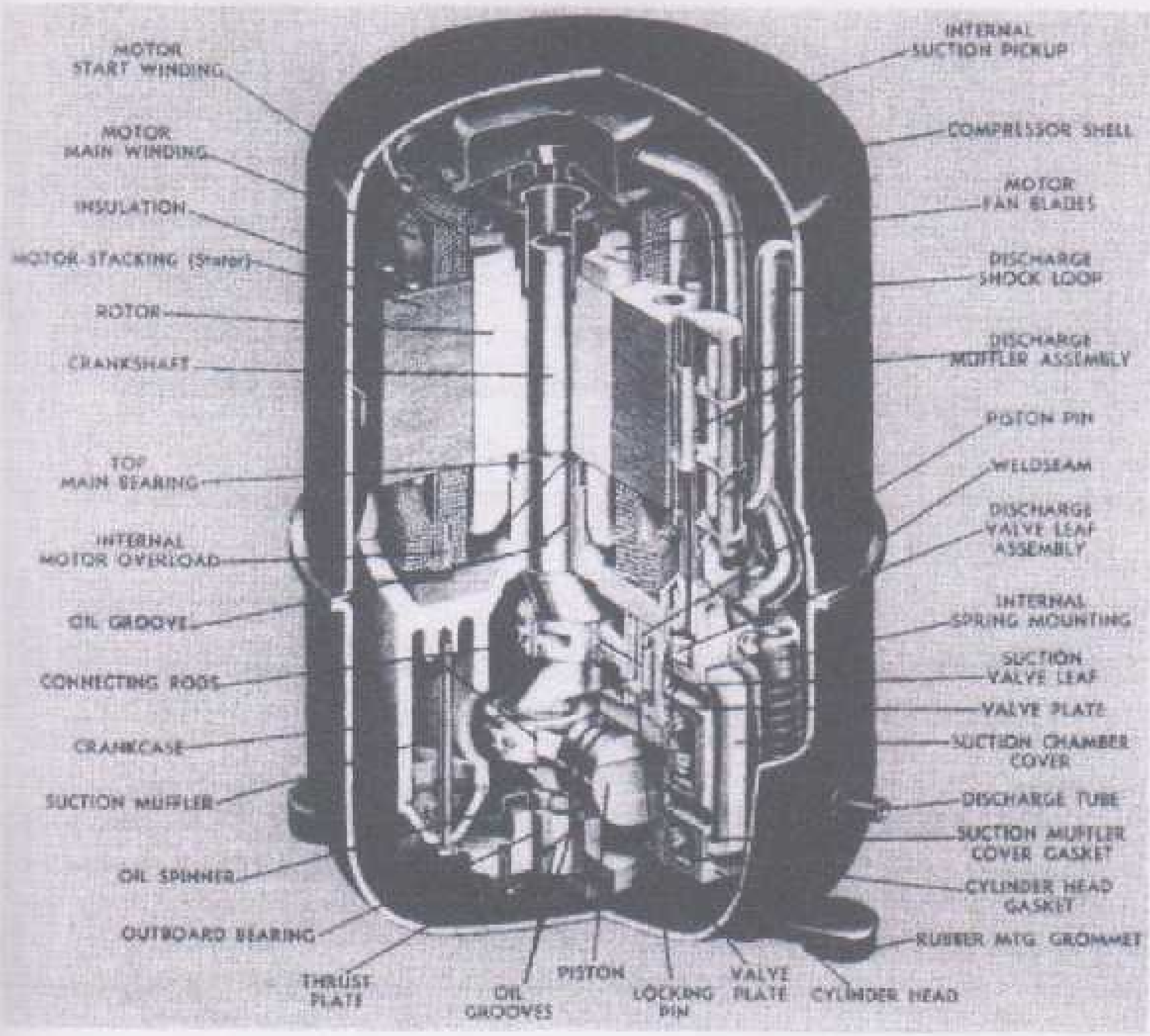


Fig (2.4) A typical hermetic reciprocating compressor.

2.3.1.1 Expectations from the compressors

The refrigerant compressors are expected to meet the following requirements:

- High reliability,
- Long service life,
- Easy maintenance,
- Easy capacity control,
- Quiet operation,
- Compactness, and
- Low cost.

2.3.1.2 Compressor selection criteria

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

- Refrigeration capacity,
- Volumetric flow rate,
- Compression ratio, and
- Thermal and physical properties of the refrigerant

For the ice maker cycle a compressor suggested to be used is single phase hermitic compressor.

2.3.2 Refrigerants

In general, refrigerants are well known as the fluids absorbing heat during evaporation. These refrigerants, which provide a cooling effect during the phase change from liquid to vapor, are commonly used in refrigeration, air conditioning, and heat pump systems, as well as process systems.

Fig (2.5): some type of refrigerant

2.3.2.1 Selection of Refrigerant

In the selection of an appropriate refrigerant for use in a refrigeration or heat pump system, there are many criteria to be considered. Briefly, the refrigerants are expected to meet the following conditions:

- Ozone and environment friendly,
- Low boiling temperature,
- Low volume of flow rate per unit capacity,
- High heat of vaporization,
- Non-flammable and non explosive.

- Non corrosive and nontoxic,
- Noncreative and non depletive with the lubricating oils of the compressor.
- Non acidic in case of a mixture with water or air,
- Chemically stable,
- Suitable thermal and physical properties (e.g., thermal conductivity, viscosity),
- Commercially available,
- Easily detectable in case of leakage, and
- Low cost

The table below shows a comparison among R12, R22 and R134

Table (2.1): comparison between refrigerants operating at the same conditions

	R12	R22	R134a
Name	Dichlorodifluoromethane	Chlorodifluorometha ne	Tetrafluoroethane
Formula	CCl_2F_2	$CHClF_2$	CH_2FCF_3
Evaporator temp (°C)	-21	-21	-21
Condenser temp (°C)	35	35	35
v (m³/s)	0.001	0.00058	0.00109
m (Kg/s)	0.009	0.0061	0.0072
Cop	3.5	3.35	3.47
Qcon (kW)	1.26	1.231	1.253
Qev (kW)	0.981	0.933	0.972
Pcom (kW)	0.280	0.280	0.280

* COP for refrigerant R12 is the highest, but R12 is phase out because its high ozone depletion potential (ODP)

The table below shows some prosperities of R12, R22 and R134a refrigerants

Table (2.2) Properties of refrigerants

	R12	R22	R134a
Name	Dichlorodifluorome thane	Chlorodifluorometha ne	Tetrafluoroethane
Formula	CCL_2F_2	$CHCL_2F$	CH_2FCF_3
Boiling point(°C)	-29.8	-40.7	-26.3

at 100 kPa			
Freezing Point(°C)at 100kPa	-29.8	-160	–103.3 °C
Critical temperature (T_c)(°C)	112	96.2	101.1
Critical pressure (p_c)MPa	4.170	4.936	4.060
Triple point temperature (T_t) °C	-157	-157.39	-103.3
Specific Volume at Patm. For sat. vapor m^3/kg	0.15940	0.21496	0.18817
Specific Volume at Patm. For sat. liquid m^3/kg	0.6720	0.7079	0.7264
Molecular Mass g/mol	120.91	86.468	102.03
Leak detection	*	*	*
Ozone depletion potential	0.82	0.05	0
Sat. pressure at +35 °C MPa	0.84	1.354	0.886
Lubricants	Mineral	Mineral Alkyl benzene	Alkyl benzene Poly ester

*** Leak Detection for refrigerant:**

•Bubble Test (Soap Solution)

•Water Immersion Method.

•Dye Interception Method

•Electronic Leak Detectors

•Ultrasonic Leak Detectors

Leaks in refrigeration units can be detected by a number of methods. The electronic detector is widely used in the manufacture and assembly of refrigeration equipment. The instrument is used to detect leaks in refrigerants except refrigerant 14 (R14). It is not recommended for use in atmospheres containing explosive or flammable vapors.

According to the above data the chosen refrigerant is R134a

2.3.3 Condenser

There are several condensers to be considered when making a selection for installation. They are 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. Some determining factors include the size and the weight of the unit, weather conditions, location (city or rural), availability of electricity, and availability of water. A wide variety of condenser configurations are employed in the process industry.

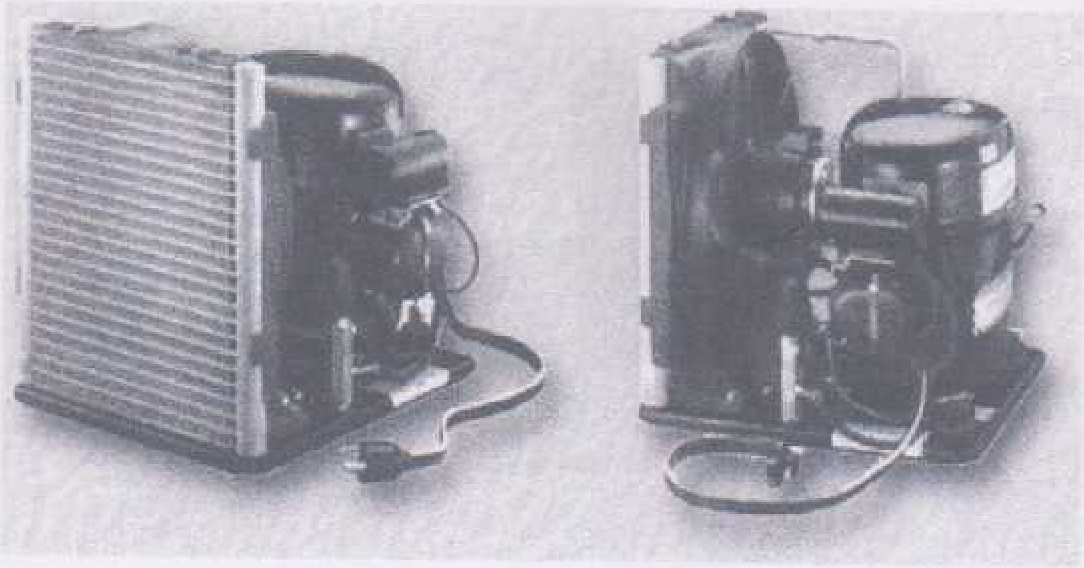


Fig (2.6) Compressor with air cooled condenser

Selection of condenser type is not easy and depends on the following criteria:

- Condenser heat capacity,
- Condensing temperature and pressure,
- The flow rates of refrigerant.
- Design temperature for air,
- Operation period, and
- Climatic conditions.

Condenser is of two types Air cooled condenser and water cold condenser, but here the concern is on air cooled one.

The fig below shows Air-cooled condensers

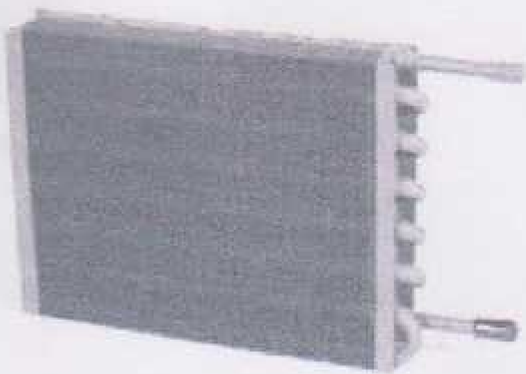


Fig (2.7): air cooled condensers

The air-cooled condensers find applications in domestic, commercial, and industrial refrigerating, chilling, freezing, and air conditioning systems with a common capacity of 20—120 tons. The centrifugal fan air-cooled condensers (with a capacity of 3-100 tons) are particularly used for heat recovery and auxiliary ventilation applications. In fact, they employ outside air as the cooling medium. Fans draw air past the refrigerant coil and the latent heat of the refrigerant is removed as sensible heat by the air stream.

The advantages of air-cooled condensers are:

- No water requirement,
- Standard outdoor installation,
- Elimination of freezing, scaling, and corrosion problems,
- Elimination of water piping, circulation pumps, and water treatment,
- Low installation cost, and
- Low maintenance and service requirement.

On the other hand, they have some disadvantages, as given below:

- High condensing temperatures,
- High refrigerant cost because of long piping runs,
- High power requirements per kW of cooling,

• High noise intensity, and
• Multiple units required for large-capacity systems.

The condenser used in this project is air cooled condenser.

2.3.4 Condenser fan

In this project fan selected with 1300 rpm and it work at 230V AC , the current needed is 0.35A

Fig (2.8): condenser fan

2.3.5 Throttling Devices

Throttling device is important to increase the velocity of refrigerant and decreasing its pressure. Fig (2.9) shows the principle of this device

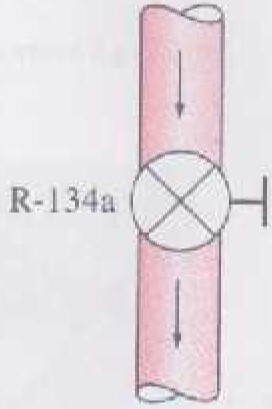


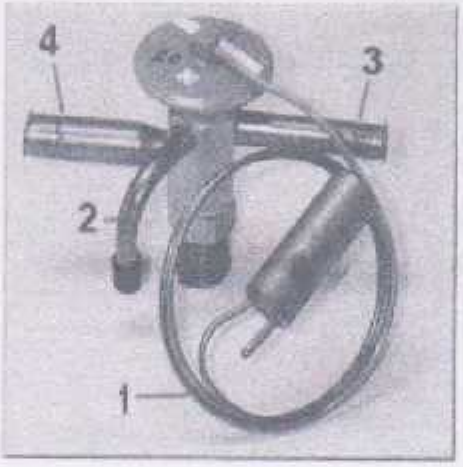
Fig (2.9) : throttling device

In practice, throttling devices, called either expansion valves or throttling valves, are used to reduce the refrigerant condensing pressure (high pressure) to the evaporating pressure (low pressure) by a throttling operation and regulate the liquid-refrigerant flow to the evaporator to match the equipment and load characteristics. These devices are designed to proportion the rate at which the refrigerant enters the cooling coil to the rate of evaporation of the liquid refrigerant in the coil; the amount depends, of course, on the amount of heat being removed from the refrigerated space. The most common throttling devices are as follows:

- Thermostatic expansion valves,
- Constant pressure expansion valves,
- Float valves, and
- Capillary tubes.

2.3.5.1 Thermostatic expansion valves

The fig below shows expansion valve fig (2.10)



1. Temperature sensor
2. External equalizer
3. From condenser
4. To coil

Fig (2.10) : expansion valve

The thermostatic expansion valves are essentially reducing valves between the high pressure side and the low-pressure side of the system. These valves, which are the most widely used devices, automatically control the liquid-refrigerant flow to the evaporator at a rate that matches the system capacity to the actual load. They operate by sensing the temperature of the superheated refrigerant vapor leaving the evaporator. For a given valve type and refrigerant, the associated orifice assembly is suitable for all versions of the valve body and in all evaporating temperature ranges. When the thermostatic expansion valve is operating properly, the temperature at the outlet side of the valve is much lower than that at the inlet side. If this temperature difference does not exist when the system is in operation, the valve seat is probably dirty and clogged with foreign matter. Once a valve is properly adjusted, further adjustment should not be necessary. The major problem can usually be traced to moisture or dirt collecting at the valve seat and orifice. Figure (2.10) shows a common type of electrically driven expansion valve

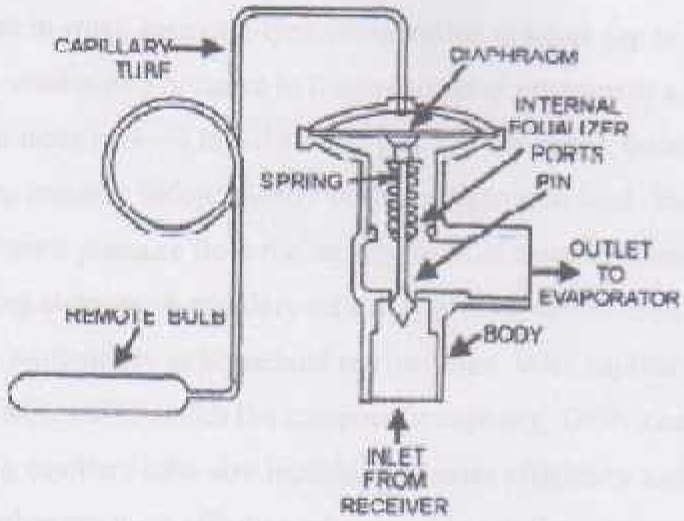


Fig (2.11) : thermostatic expansion valve

2.3.5.2 Capillary tubes

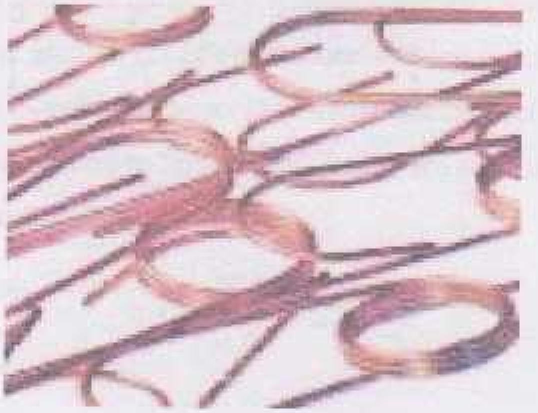


Fig (2.12): capillary tube

The capillary tube is the simplest type of refrigerant flow control device and may be used in place of an expansion valve. The capillary tubes are small-diameter tubes through which the refrigerant flows into the evaporator. These devices, which are widely used in small hermetic-type refrigeration systems (up to 30 kW capacity), reduce the condensing pressure to the evaporating pressure in a copper tube of small internal diameter (0.4—3 mm diameter and 1.5-5 m long), maintaining a constant evaporating pressure independently of the refrigeration load change. These tubes are used to transmit pressure from the sensing bulb of some temperature control device to the operating element. A capillary tube may also be constructed as a part of a heat exchanger, particularly in household refrigerators. With capillary tubes, the length of the tube is adjusted to match the compressor capacity. Other considerations in determining capillary tube size include condenser efficiency and evaporator size. Capillary tubes are most effective when used in small capacity systems.

The capillary tube is not suitable for the system because harvesting the ice in the system will be by defrosting and capillary tube is not suitable for this process, so thermo static expansion valve (TEV) will be used.

2.3.6 Receiver tank

The receiver (fig 2.13) acts as a temporary storage space and surge tank for the liquid refrigerant. The receiver also serves as a vapor seal to keep vapor out of the liquid line to the expansion valve. A pressure drop in the liquid line of a refrigeration system may cause the liquid refrigerant to flash to gas. Receivers are constructed for either horizontal or vertical installation.

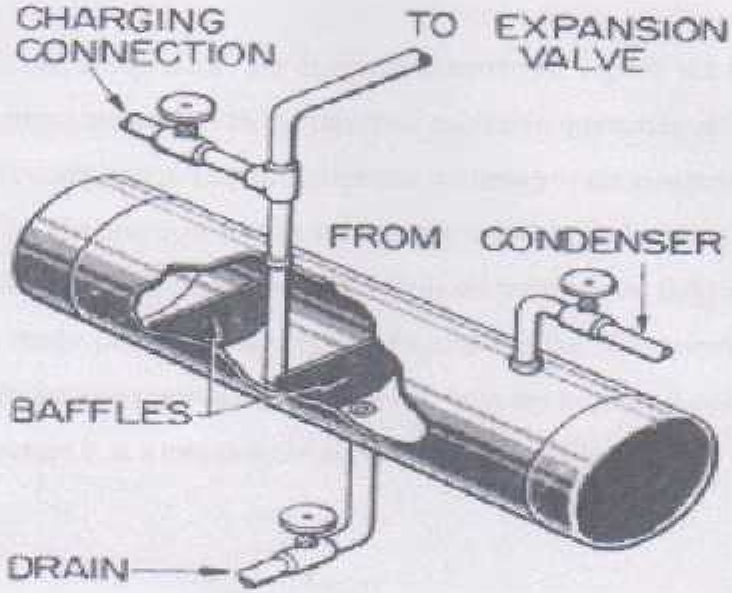


Fig (2.13) Receiver

2.3.7 Accumulators


Fig (2.14): Accumulators

It is well known that compressors are designed to compress vapors, not liquids. Many refrigeration systems are subject to the return of excessive quantities of liquid refrigerant to the compressor. Liquid refrigerant returning to the compressor dilutes the oil, washes out the bearings, and in some cases causes complete loss of oil in the compressor crankcase. This condition is known as oil pumping or slugging and results in broken valve reeds, pistons, rods, crankshafts, and the like. The purpose of the accumulator is to act as a reservoir to temporarily hold the excess oil-refrigerant mixture and to return it at a rate that the compressor can safely handle

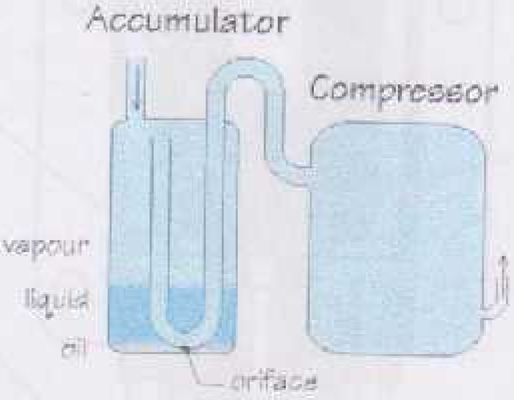


Fig (2.15): accumulator

2.3.8 Solenoid valves

Fig (2.16) : type of Solenoid valves

Fig (2.16) : type of Solenoid valves

Solenoid valves are extensively used in all types of refrigeration applications. These valves are employed as electrically operated line stop valves and perform in the same manner as hand shut-off valves. These valves are convenient for remote applications due to the fact that these are electrically operated and controlled easily

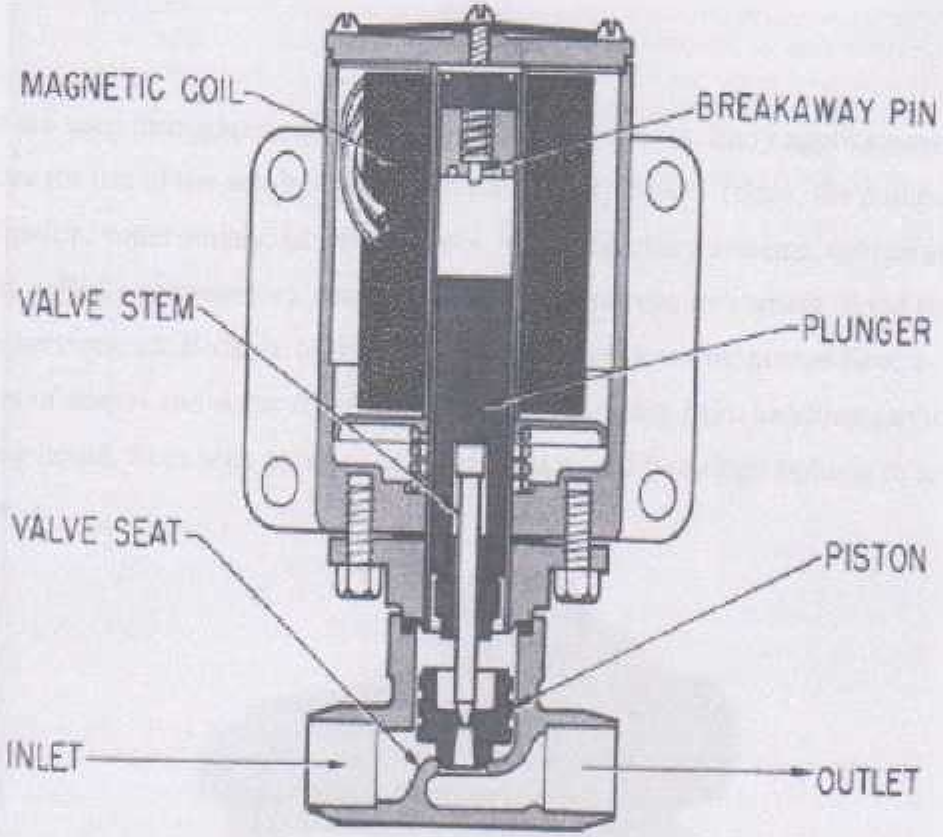


Fig (2.17): part of Solenoid valves

2.3.9 Water pump

Pumps are used throughout society for a variety of purposes. Early applications includes the use of the windmill or watermill to pump water. Today, the pump is used for irrigation, water supply, gasoline supply, air conditioning systems, refrigeration (usually called a compressor), chemical movement, sewage movement, flood control, marine services, etc.Because of the wide variety of applications, pumps have a plethora of shapes and sizes: from very large to very small, from handling gas to handling liquid, from high pressure to low pressure, and from high volume to low volume.

Fig 2.18: water pump

The pump selected in this system gives discharge of 20L/min at 1 m head.

2.3.10 Water tank

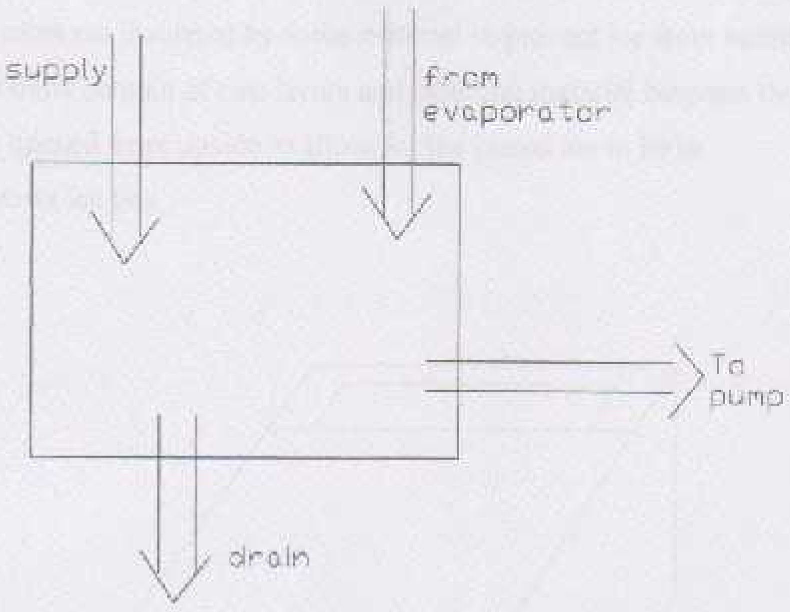


Fig 2.19 :water tank

The water tank shown in the above figure (fig 2.19) is made of thick steel. Two layers of steel and between these two layers an isolated material will be install to save the cooled water from outside temperatures.

As shown from the figure the tank most have two inputs: one for the water inlet from the supply and one for the water return from the evaporator which is usually cold. However it has two outputs: one for the pump that will circulate water to the cycle, and one for the drain to empty the water from the tank .

2.3.11 Ice box

The ice box must me insolated by some material to prevent ice from melting, so as the water tank it must contain of two layers and isolating material between them. The ice box must be opened from upside to allow for the plated ice to be in.

Fig (2.20) shows ice box

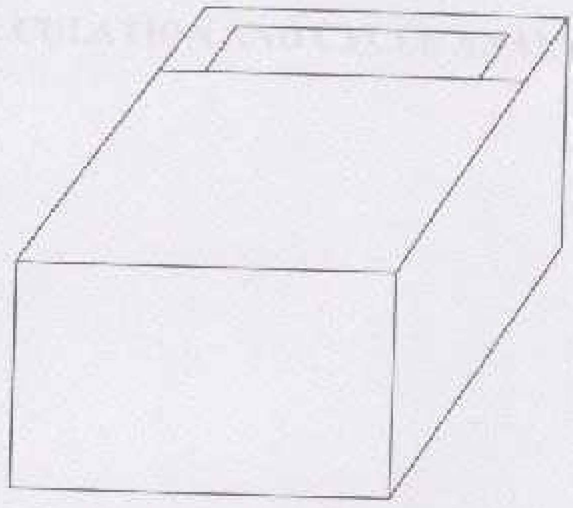


Fig (2.20) Ice box

CHAPTER THREE

CALCULATION AND CYCLE ANALYSIS

Calculations and cycle analysis

The cycle that must be done in this project it is shown in fig (3.1).

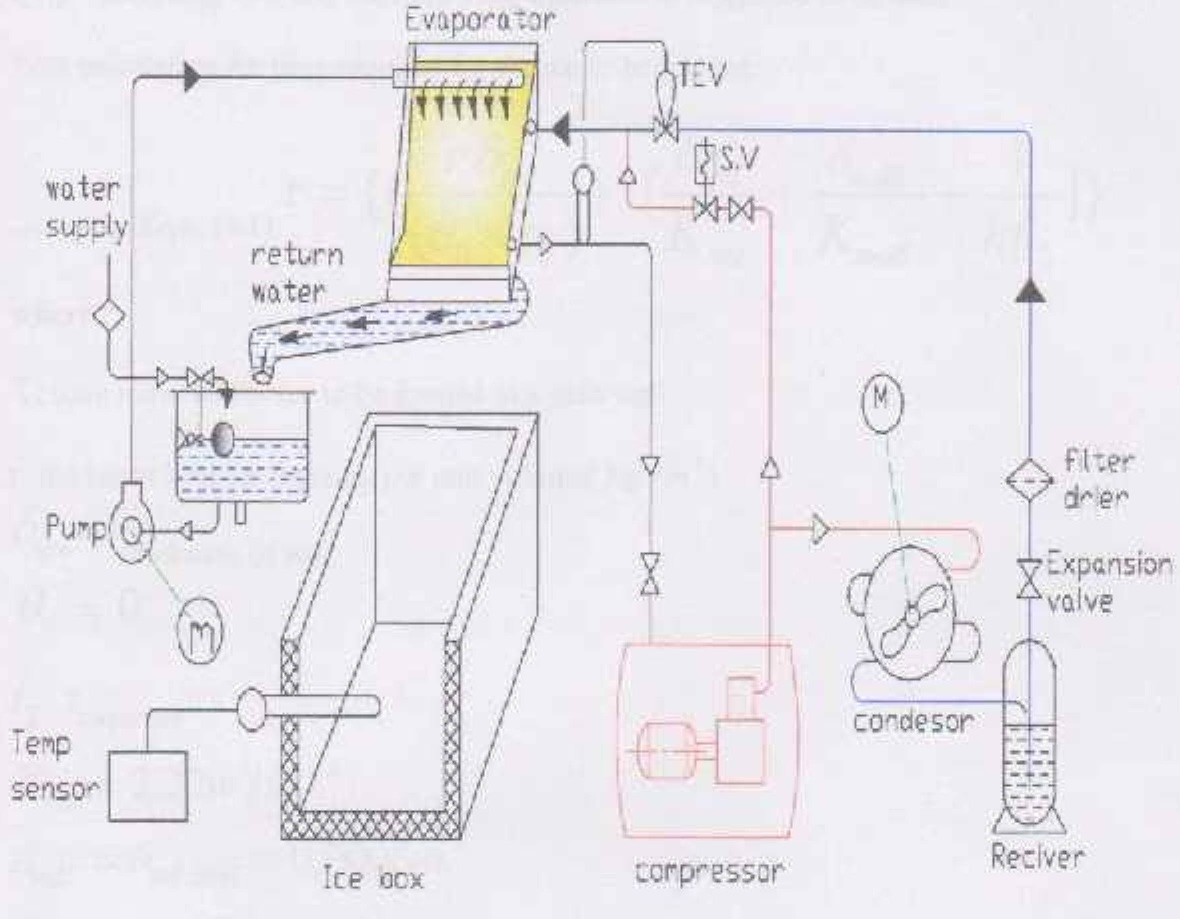


Fig (3.1) Ice maker cycle

3.1 Calculations criteria

There are two ways to do calculation of the cycle

3.1.1 Calculation by duration of ice forming

It is to decide the amount of ice to be produce and build the calculation (Qice, Qe and QC) according to it and the following equations is suggested to be used:

First calculation for time required for the ice to be formed:

.... **Equ. (3.1)** $$\tau = \{(\frac{r\delta_{ice}}{(\theta_0 - t_2)})*[\frac{\delta_{ice}}{K_{ice}} + \frac{\delta_{wall}}{K_{wall}} + \frac{1}{hf_2}]\}$$

where :

τ: time required for ice to be formed in a plan wall

r :the latent heat for freezing per unit volume(Kg/m^3)

δ_{ice} : thickness of ice

$\theta_0 = 0$

t_2 : $t_{evaporator}$

$K_{ice} = 2.22w/mc°$

$\delta_{wall} = \delta_{stil\ steel} = 0.0006m$

$K_{stil\ steel} = 17w/mc°$

$hf_2 = 1000w/m^2c°$

Calculation of Q (load) for a plan wall

$$Q_c = Q_{ice} + Q_{water} + Q_{subcooling} + Q_{losses}$$ ....**Equ (3.2)**

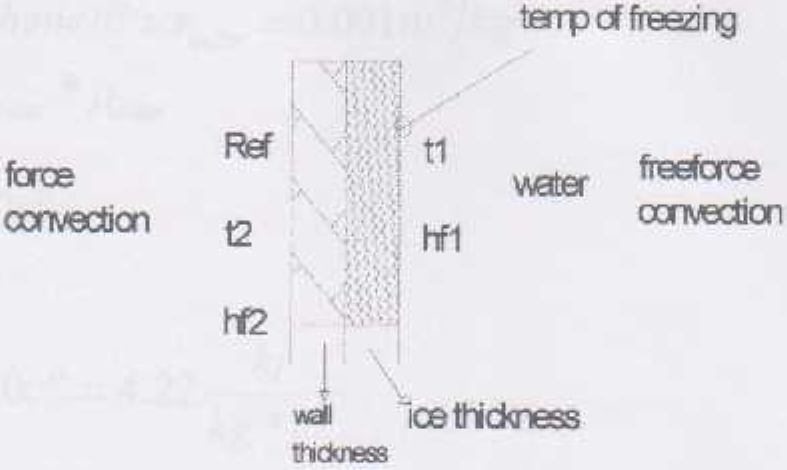


Fig (3.2) plan wall

$$Q_{ice} = \frac{m_{ice} * r}{\tau} \quad \text{............ Equ (3.3)}$$

where :

r :the latent heat for freezing per unit volume(Kg/m^3)

τ: time required for ice to be formed in a plan wall

$$m_{ice} = \rho_{ice} * V_{ice}$$

Where: m_{ice} = mass of ice

$$\rho_{ice} = 916.2(Kg/m^3)$$

V: volume of ice (m^3)

→ m = ρ*V(Kg)

$$Q_{water} = \frac{m_{water}}{\tau} * cp_{water} * (t_{water} - t_{ice})$$

.... Equ (3.4)

$$spesifc\,volume\ @\ sat_{ice} = 0.001091 m^3/kg$$

$$spesifc\,volume\ @\ sat_{water} = 0.001 m^3/kg$$

$$m_{water} = v_{water} * \rho_{water}$$

$$T_{water} = 20c^o$$

$$T_{ice} = 0c^o$$

$$Cp_{water}\ @\ 0c^o = 4.22 \frac{kj}{kg * c^o}$$

$$Cp_{water}\ @\ 20c^o = 4.183 \frac{kj}{kg * c^o}$$

$$Cp_{water\ average} = 4.306 \frac{kj}{kg * c^o}$$

$$Q_{sub\ cooling} = \frac{m}{\tau} * Cp_{ice} * \Delta t$$ ………… **Equ.(3.5)**

$$Cp = 2.027 \frac{kj}{kg * c^\circ}$$

$$\Delta t = 5c^\circ$$

$$Q_{losses} = Q_{cond} + Q_{conv}$$
$$= U * A * \Delta t$$
$$= \frac{t_{out} - t_{in}}{[1/hf_2 + \Delta x_{wall}/k_{wall} + 1/hf_1] * A}$$

where :

U : over all heat transfer coefficient

A : area

* Then we choose the suitable compressor, condenser, evaporator and pipes according to these calculations.

In this project these equation will not be used, it may use as testing for the second method.

3.1.2 Calculation by selection of compressor

In this method single phase hermitic compressor with power of 3/8 HP (220V, 50 Hz) is selected and calculation is done according to it.

As it mentioned in the previous chapter the refrigerant that will be used is R134a. calculation will be made for R134a, R12 and R22

*By using R134a

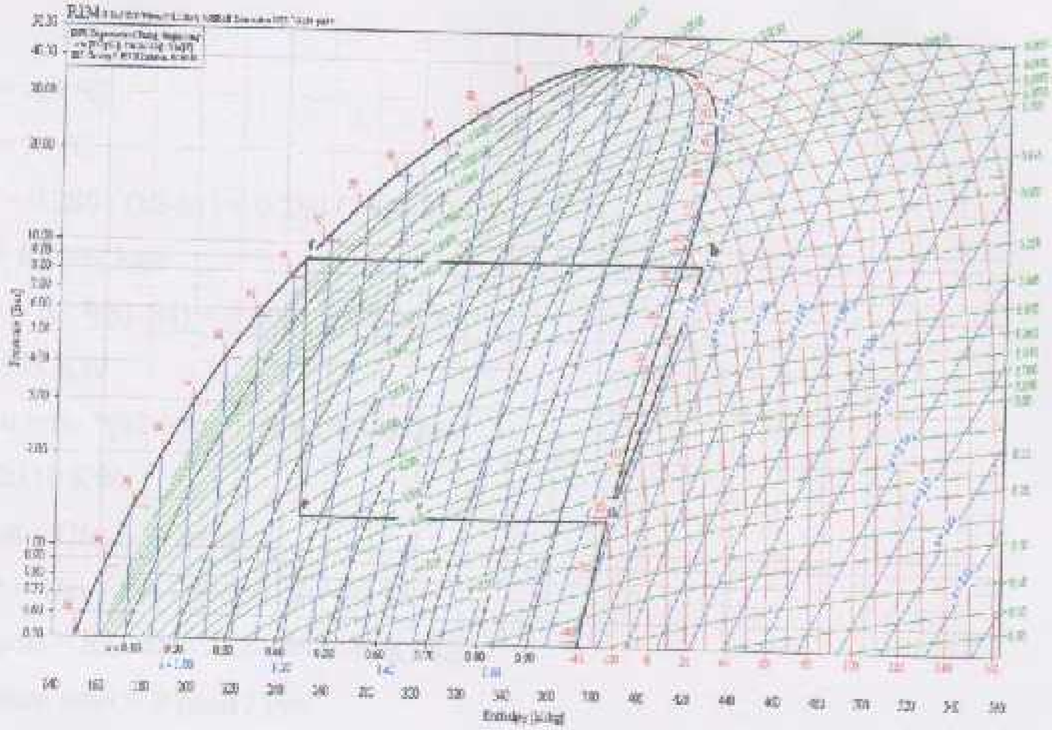


Fig (3.3) P-h Diagram for R134a

W como = 3/8 * 748= 0.280 kW

W comp = 0.280 kW
Te = -21 °C
Tc = 35 °C

W comp = m *(h2-h1)
0.280 = m*(424-385)
m· = 0.0072 kg/s
Qev = m· * (h1-h4)
= 0.0072*(385-250)
= 0.972 KW
Qcond = m· *(h2-h3)
= 0.0072*(424-250) = 1.253 KW
Q con - Qev = W comp
COP = Qev / P = 0.972/0.280 = 3.47
W cycle = h2 –h1 = 424-385 = 39 KJ/Kg
Pressure ratio = P cond / Pev
P cond = 9 bar
Pev = 1.4 bar
Pressure ratio = 9/1.4 = 6.428

*By using R22

W comp = 0.280 KW

Te = -21 °C

Tc = 35 °C

m· = 0.280 / (h2-h1) = 0.280 / (442-396)

m· = 0.0061 kg/s

Qev = m· *(h1-h4) = 0.0061*(396-243)

= 0.933 KW

Qcon = m· *(h2-h3) = 0.0061*(442-243)

= 1.2319 KW

Q con – Qev = w comp

COP = Qev / P = 0.933/0.280 = 3.35

W cycle = h2 - h1 = 442-396 = 46 KJ/Kg

Pressure ratio = P cond / Pev

P cond =15 bar

Pev = 2.3 bar

Pressure ratio = 15/2.3 = 6.5

Fig (3.4) P-h diagram for R22

*By using R12

W comp = 0.280 KW

Te = -21 °C

Tc = 35 °C

m· = 0.280 / (h2-h1) = 0.280 / (373-342)

m· = 0.009 kg/s

Qev = m· *(h1-h4) = 0.009*(342-233)

= 0.981 KW

Qcon = m· *(h2-h3) = 0.009*(373-233)

= 1.26 KW

Q con - Qev = w comp

COP = Qev / P = 0.981/0.280 = 3. 5

Fig (3.5) P-h diagram of R12

*By using R134a with superheating 10 °C + sup cooling 5 °C

hb = 394 KJ/Kg

hc = 436 KJ/Kg

hf = 193 KJ/Kg

hg = 193 KJ/Kg

Wcomp = 0.280 KW

Te = -21 °C

Tc = 35 °C

m· = 0.280 / (hc-hb) = 0.280 / (436-394)

m· = 0.0067 kg/s

Qev = m· *(hb-hg) = 0.0067*(394-193)

= 1.3467 KW

Qcon = m· *(hc-hf) = 0.0067*(436-193)

= 1.6281 KW

Q con - Qev = w comp

COP = Qev / P = 1.3467/0.280 = 4.81

a-b super heating

b-c work compressor

d-e Q condenser

e-f sub cooling

g-a Q evaporator

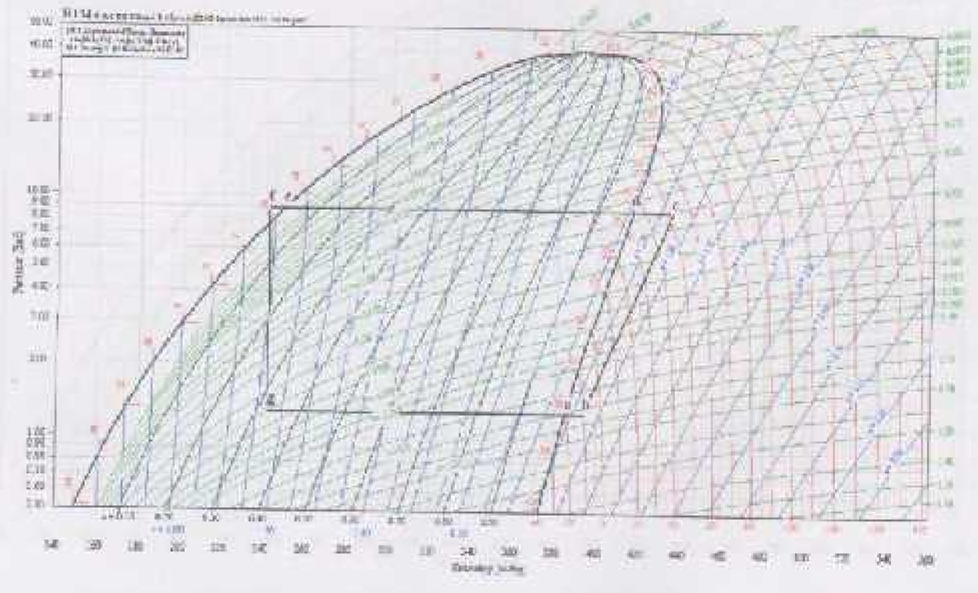


Fig (3.6) P-h diagram for R134 (super heating 10, sub cooling 5)

* By using R 134a

Tev =-15 °C

Tcon=35 °C

W comp = 0.280 KW

m· = 0.280 / (h2-h1) = 0.280 / (423-396)

m· = 0.008 kg/s

Qev = m· *(h1-h4) = 0.008*(388-249)

= 1.112 KW

Qcon = m· *(h2-h3) = 0.008*(423-249)

= 1.392 KW

Q con - Qev = w comp

COP = Qev / P = 1.112/0.280 = 3.9

W cycle = h2 –h1 = 423-388 = 35 KJ/Kg

Pressure ratio = P cond / Pev

P cond =9 bar

Pev = 1.8 bar

Pressure ratio = 9/1.8 = 5

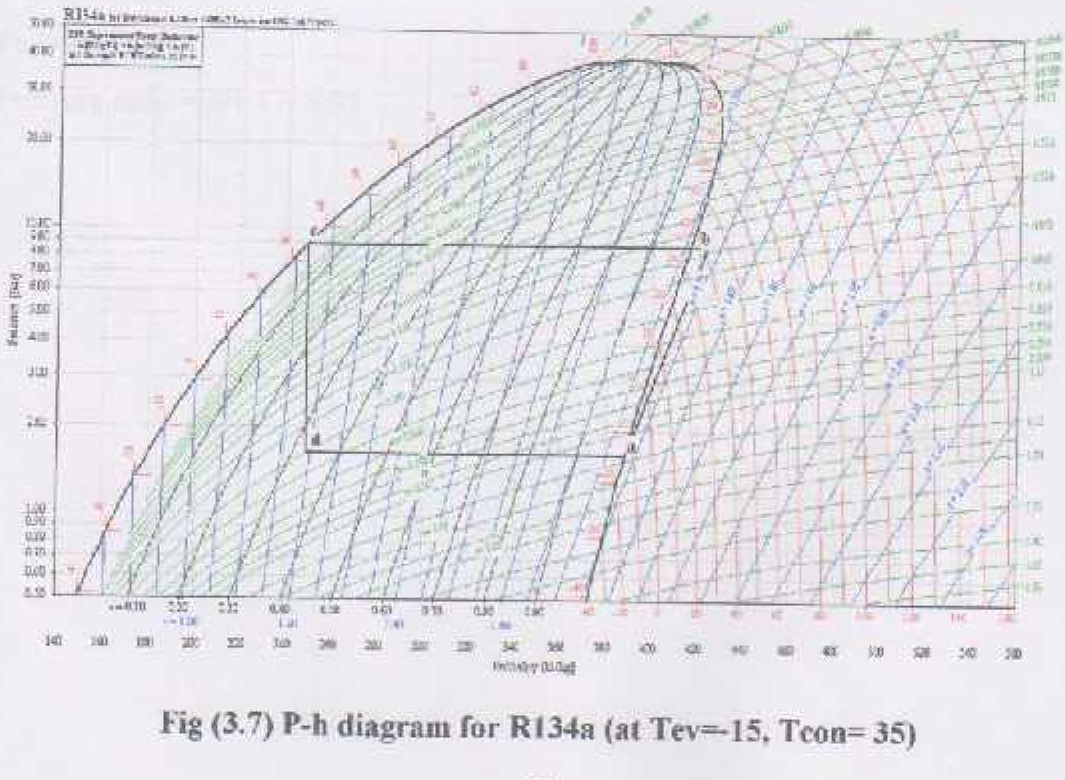


Fig (3.7) P-h diagram for R134a (at Tev=-15, Tcon= 35)

By using R134a

Tev=-21°C , Tcon =35 °C with superheating 20°C, sub cooling 5°C

h1 = 402 KJ/Kg

h2 = 445 KJ/Kg

h3 = 241 KJ/Kg

h4 = 241 KJ/Kg

W comp = 0.280 KW

m· = 0.280 / (h2-h1) = 0.280 / (445-402)

m· = 0.0065 kg/s

Qev = m· *(h1-h4) = 0.0065*(402-241)

= 1.046 KW

Qcon = m· *(h2-h3) = 0.0065*(445-241)

= 1.326 KW

Q con - Qev = w comp

COP = Qev / P = 1.046/0.280 = 3.73

W cycle = h2 –h1 = 445-402 = 43 KJ/Kg

Pressure ratio = P cond / Pev

P cond =9 bar

Pev = 1.3 bar

Pressure ratio = 9/1.3 = 6.92

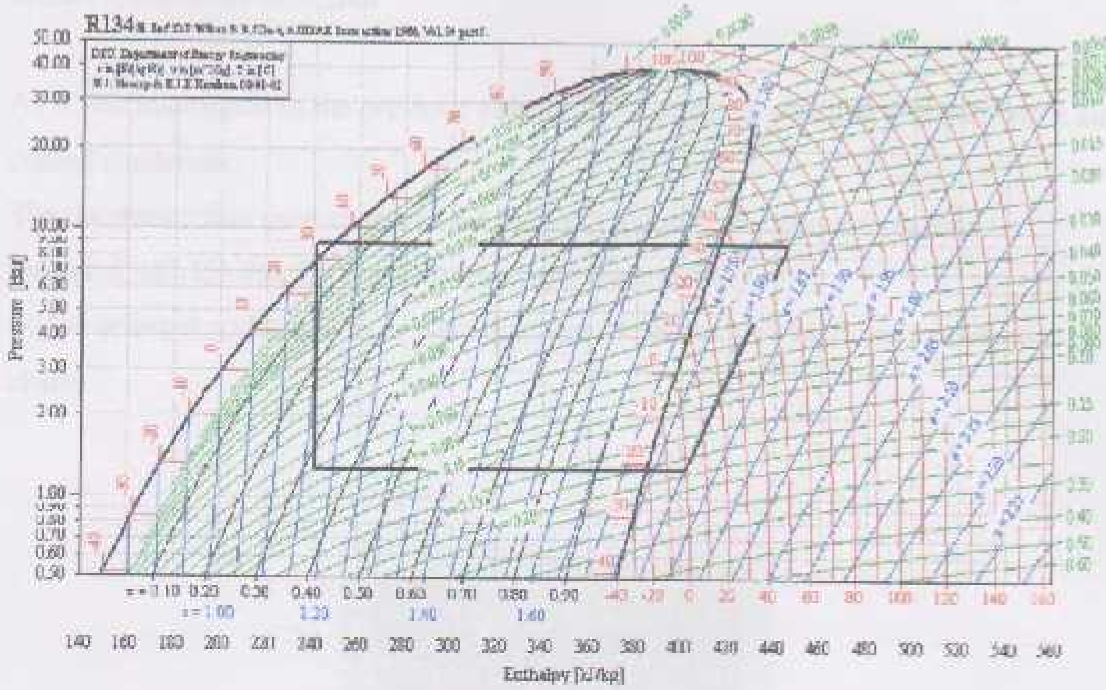


Fig (3.8) P-h diagram for R134a (20 superheating, 5 sub cooling)

From this calculations the note is refrigerant R12 have the highest COP but this refrigerant is harmful effects to the atmosphere

So the used refrigerant is R134a in the cycle with superheating 10C and sup cooling -5 and the result is:

W comp = 0.280 KW

m· = 0.0067 kg/s

Qev = 1.3467 KW

Qcon = 1.6281 KW

COP = 4.81

3.1.2.1 Condenser selection

As it was mentioned in the previous chapter the condenser type that will be used is air cooled condenser.

The condenser that used must be able to eject the heat that been calculated,

Qcond=1.253 kW (without superheating and sub cooling)

So the selected condenser must eject this heat. Selection will be from condenser charts.

Fig (3.9) air cooled condenser

However the condenser have a fan with it, to make forced convection the fan usually single phase with power 10-15 W, some times this fan has multi speeds.

3.1.2.2 Evaporator design

The evaporator will decide the shape of ice that will be produced, and this project is concerned with plated ice so the ice must be plate, however there are some suggestions for these shapes as shown in the fig (3.10)

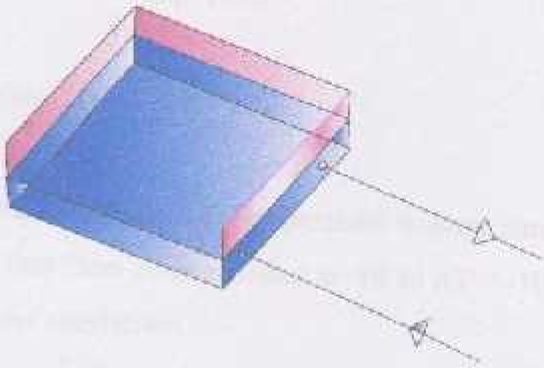


Fig (3.10)A plate evaporator without tubes

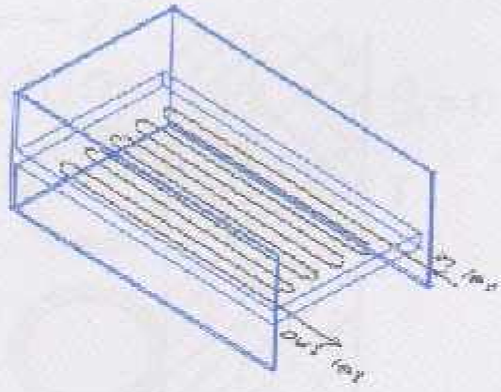


Fig (3.10)B plate evaporator with tubes into it

Fig (3.10) suggested shapes for the evaporator

In fig (3.10)A the refrigerant will boil inside the plate.
In fig(3.10)B the refrigerant will boil inside the tubes that installed under the plate.

Plate ice with tubes is selected, so we will try to make calculation to it to find the needed area for such compressor and condenser. But many problems are expected to be faced.

$Q = U*A*(\Delta T)$ .... Equ (3.6)
Where
Q = the load in evaporator, Q = 1.3467 KW
A = area of evaporator , A =???
ΔT = the change in temperature and the temperature in evaporator is -21 and temperature in the ice that form on evaporator is -10 so ΔT = -10 - -21= 11C
U = over all heat transfer coefficient.

The calculations of U (roughly)

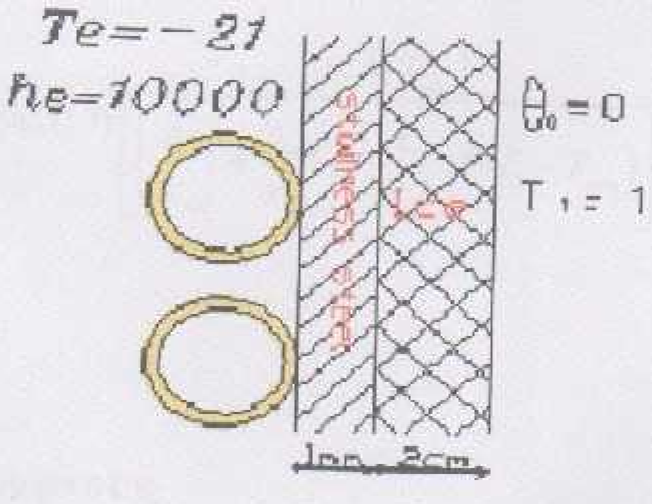


Fig (3.11) section of plate evaporator (with tubes) wall

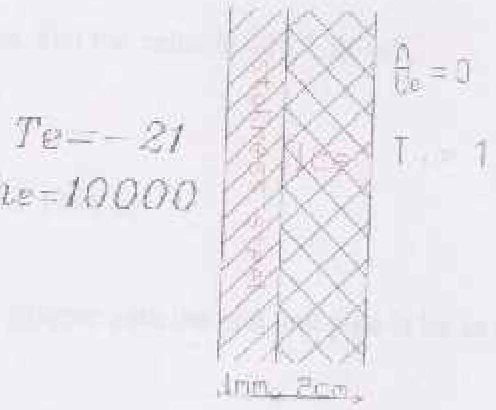


Fig (3.12) section of the evaporator

To find U value the following equation is applied:

$$U = \frac{(\theta_0 - T_{eva})}{\left[\left(\frac{\delta_{ice}}{\kappa_{ice}} + \frac{\delta_{met}}{\kappa_{met}} + \frac{1}{h_{eva}}\right) * (T_1 - T_{eva})\right]} \quad \text{............... Equ.(3.7)}$$

where

θ_0 = temp of freezing = 0 C

T_{eva} = -21 C

δ_{ice} = 0.02 m

κ_{ice} = 2.2 W/m*C

= 0.001 m δ_{mat}

20 W/ m*C κ_{mat}

= 10 000 W/ m*C h_{eva}

= 1 - - 21 = 22 $T_1 - T_{eva}$

we find U from equation and the value is 104.3 W/m*C

so we can find the area

Q = U*A*(ΔT) so A = 1.1734 m²

* Our evaporator in this project with the plat and pipe is be as the fig

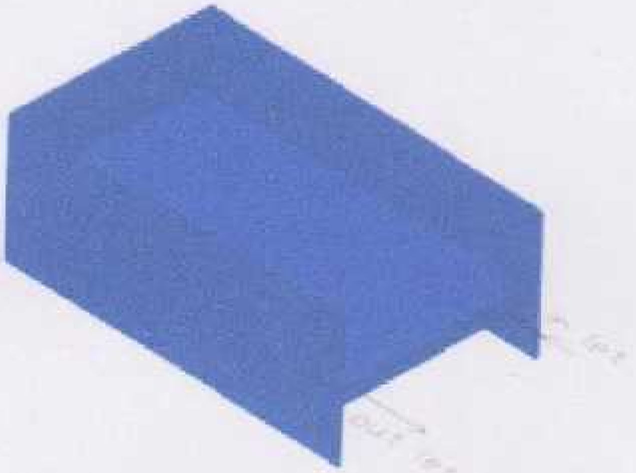


Fig (3.13) the evaporator that will be designed

Data discuss:

From the previous calculations it must be realized that the area of the evaporator is too big and illogically this is because the thickness of the ice is not constant as the value of the U is not correct. So in the project a testing evaporator will be build and to see weather it gives good results or not.

The ice plat will be formed in the plat above the pipe and when to harvest the ice a defrosting process starts till sides of ice which have contact with the plat melt and ice fall into ice box by means of gravity.

CHAPTER FOUR

ELECTRICAL CONTROL

This chapter show the electrical and power cycle of the ice maker

4.1 power circuit of ice maker

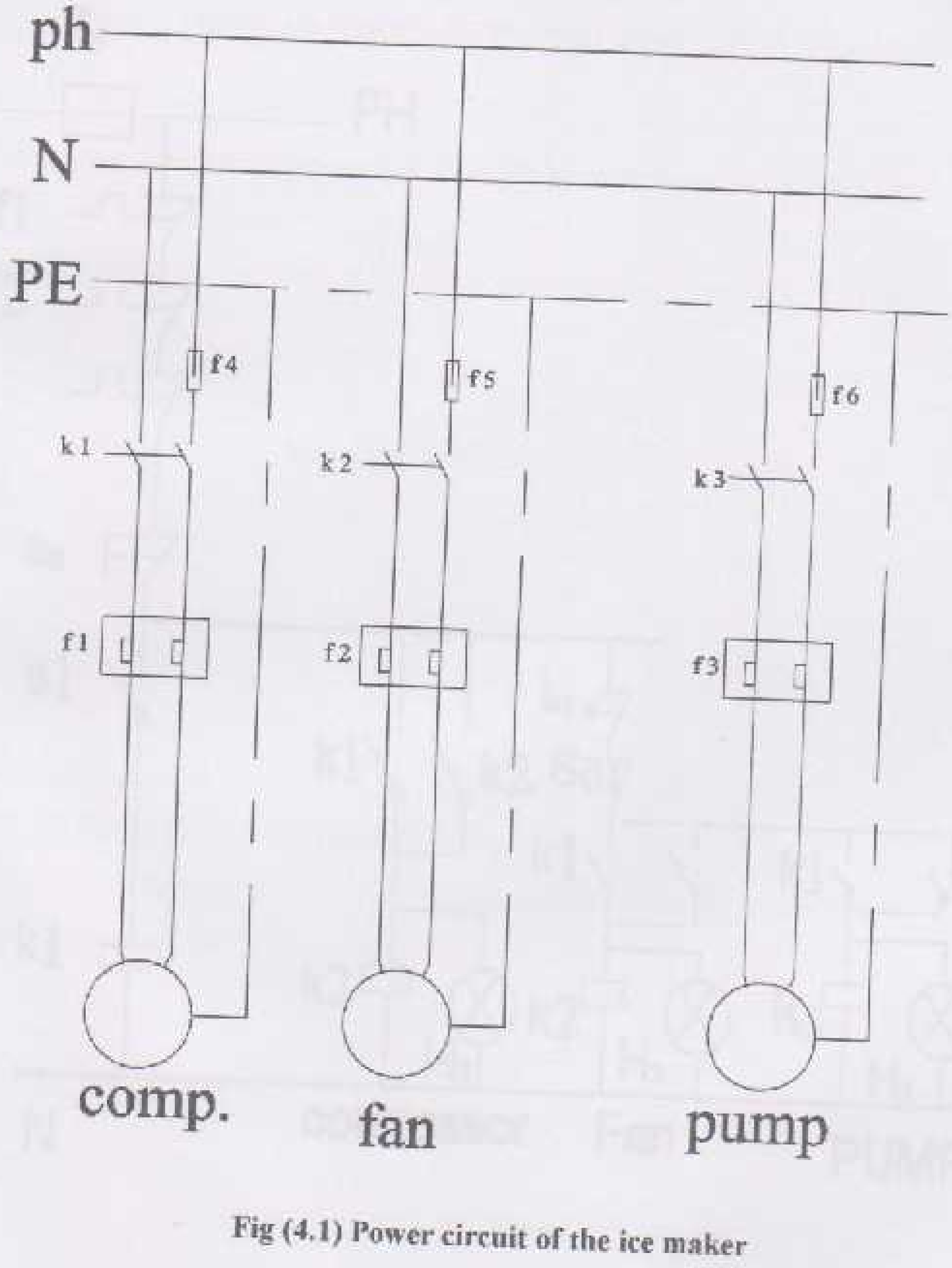


Fig (4.1) Power circuit of the ice maker

4.2 Electrical control circuit

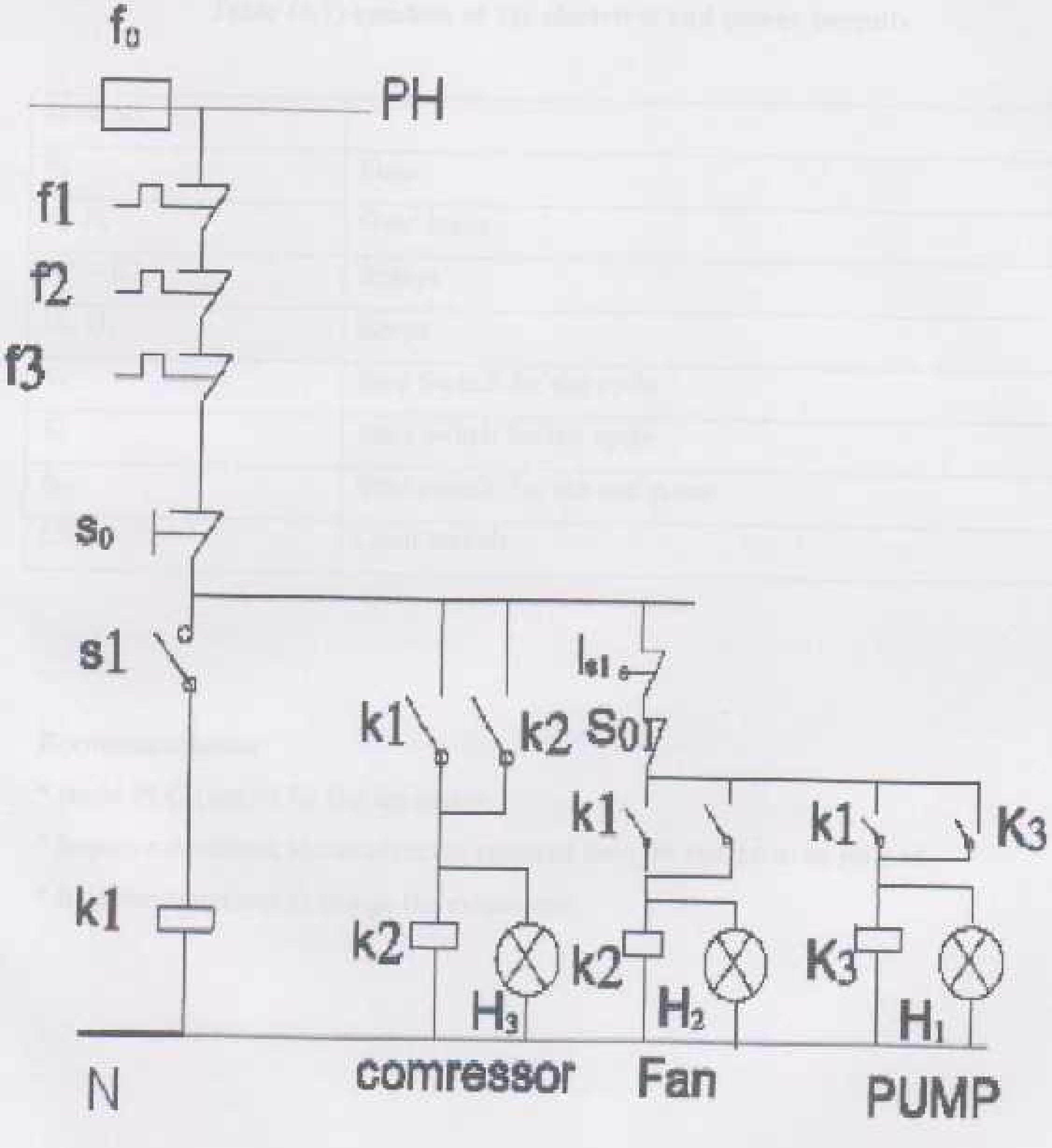


Fig (4.2) electrical control circuit of the cycle

Table of symbols

Table (4.1) symbols of the electrical and power corcuits

symbols	
F_0	Fuse
F_1. F_6	Over loads
K1 – K3	Relays
H_1. H_3	lamps
S_0	Stop Switch for the cycle
S_1	Start switch for the cycle
S_{01}	Stop switch for fan and pump
LS_1	Limit switch

Recommendation

* Build PLC control for the ice maker

* Improve equations to calculate the required time for the ice to be formed.

* Improve equations to design the evaporator.

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