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Performance Analysis of Vapor Compression Refrigeration System for ice plant with R-22 and R-134a

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***Abstract*— This paper is the performance analysis of a vapor compression refrigeration system for ice plant. The design construction of ice plant is used to evaluate capacity of the ice plant, to calculate the required power input and coefficient of performance (COP) of the system, to reduce the refrigeration time and plot the system performance on pressure enthalpy chart. Result data of the vapor compression refrigeration system for R-22-$CHClF_2$ (monochlorodifluoro methane) and R-134a -CH_2FCF_3 (Tetrafluoro ethane) are compared.**

Keywords— vapor compression cycle, Refrigerant pressure-enthalpy chart. Brine tank, Ice-plant

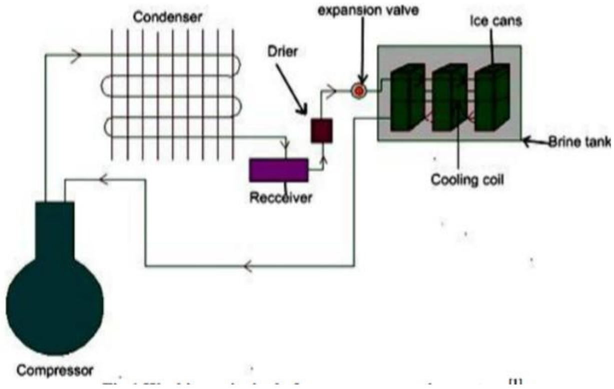
1) INTRODUCTION

An ice plant consists frame tank, brine tank and three ice-can. The layer between frame tank and brine tank is insulation and evaporator coils and three ice-can are within the brine tank. The other components of the ice plant are compressor, condenser, expansion valves, receiver, drier, evaporator and measuring gauges. Refrigerants for vapor compression refrigeration system are R-22 and R-134a.

R-22 has the ozone depletion potential (ODP)=0.05 and R-134a has zero ODP. Refrigeration is the removal of heat from a lower temperature region. The objective of the ice plant construction is to study ice formation process to understand main components and their functions, working principle of the vapor compression refrigeration system.

2) WORKING PRINCIPLE OF VAPOUR COMPRESSION SYSTEM OF ICE-PLANT

Refrigerant to the gaseous form of inhalation by the compressor, high temperature and high pressure superheated stem by the compression of the compressor and then discharge from the compressor and then discharged from the compressor of the exhaust pipe, through exhaust pipe goes into the condenser. Condenser is helpful for refrigerant to send out heat to the surrounding air, making the refrigerant from the high temperature and high pressure superheated steam condensing to middle temperature and high pressure liquid and then enter the receiver and expansion valve through the filter drier. After expansion liquid refrigerant into a low temperature and low pressure liquid refrigerant liquid into the evaporator coil and absorbs outside heat of vaporization for the saturated vapor from out of the evaporator the refrigerant into a low pressure vapor on the suction pipe and then be inhaled by the compressor to start the next cycle.



Fig(1) Working principle of vapor compression system

3) REFRIGERANT

The refrigerant is a heat-carrying medium, which undergoes the thermodynamics cycle of refrigeration (i.e compression, condensation, expansion and evaporation). In a refrigeration system, it absorbs the heat from a low-temperature medium and discards the absorbed heat to a high-temperature environment. Refrigerants may be broadly classified into following groups.

(i) Primary refrigerants and
(ii) Secondary refrigerants

The refrigerant which directly undergo the refrigeration cycle are called primary refrigerants whereas the secondary refrigerant act only as heat carrier.

(i) Selection of Refrigerant

There are contain desirable characteristics which a fluid used as a refrigerant should possess. It should be non poisonous, non explosive , non flammable operate under low pressure (low boiling point) a stable gas and parts moving in the fluid should be easy to lubricate.

In this design refrigerant R-22 or R-134a is used.

The relative ability of a substance to deplete the ozone layer is called the ozone depletion potential (ODP). R-11 and R-12 have the highest value, ODP=1.0. R-22 has ODP = 0.05 and R-134 has zero ODP.

(ii) Ozone Depletion

Ozone(O_3) gas consists of three atoms of oxygen per molecule. It is a vigorous oxidizing agent and it cleans the air in the atmosphere. Ozone is present in a layer in the earth's atmosphere, known as the stratosphere, about 11-50 km above the earth's surface. The ozone layer blocks out most of harmful ultraviolet (UV) radiation coming from the sun. The ozone layer has been progressively depleting. One chlorine atom can destroy 100,000 ozone molecules by a continuous chain reaction.

The effects of depletion of ozone layer over the earth include the following

1. The ultraviolet rays in the solar radiation will reach the earth surface and cause an increase in skin cancer (most deadly form of cancer).
2. An increase in eye diseases.
3. Reduction in immunity against disease.
4. Harmful effects on crops timber wild life and marine life.

(iii) Eco-friendly Refrigerants

Refrigerants that are friendly to the ozone layer in the atmosphere that protects the earth from harmful ultraviolet rays are called eco-friendly refrigerants. R-134a (CH_2FCF_3) Tetrafluoro ethane is a chlorine-free refrigerant and thus it is on eco-friendly refrigerant.

The chlorine refrigerants react with the ozone layer and try to destroy the ozone layer in the upper atmosphere by continuous chain reaction. Hydrocarbons (HC_s) and hydro fluorocarbon groups provide an alternative to chlorinated refrigerant. They contain no chlorine atom and therefore, have zero ozone depletion potential. R-22 has ODP= 0.05 and R-134a has ODP zero.

(iv) Refrigeration Load

Refrigeration load is the amount of heat which must be removed per unit time frame the cold region. It is also known as the refrigeration capacity. It is measured in Tones of Refrigeration and is designed as RE.

(v)Coefficient of Performance (COP)

The coefficient of performance of VCS is the ratio of the refrigerating effect (RE) to the working input to the compressor.

$$COP = \frac{\text{Refrigerating Effect}}{\text{work input}} = \frac{RE}{Wc}$$

$$= \frac{h_1 - h_4}{h_2 - h_1}$$

Work input to the compressor = Wc = (h_2-h_1) kJ/kg
Refrigerating effect =RE = (h_1- h_4) kJ/kg

(vi) Design Dimension and Specification of Ice-Plant

Frame size	=123 cm x 64 cm x 63cm
Brine tank	= 102 cm x 41 cm x 51 cm
Ice-can	= 31cmx13cmx 31cm
over size	= 215 cm x 100cm x 80 cm

Evaporator coil

Material	- copper tube
Diameter	- 12.7 mm
Length	-1524 cm

Condenser coil

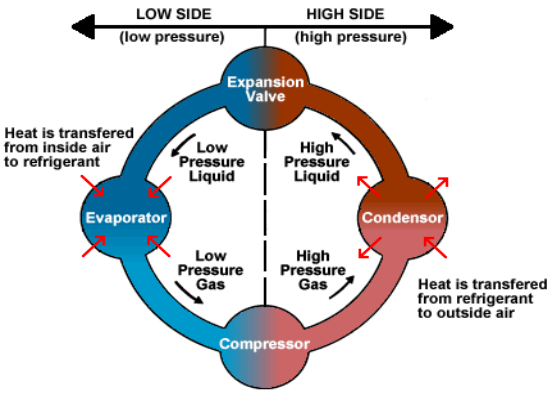
Material	– copper tube
Diameter	-9.525 mm
Length	-1584 cm

Compressor	–Rotary type (810W)
Expansion device	– manual expansion valve
Primary Refrigerant	- R-22 (or)R-134a
Secondary refrigerant	- Brine

Receiver

outside diameter	- 7.6 cm
inside diameter	-6.8 cm
length	-30 cm

3)PERFORMANCE ANALYSIS OF VAPOUR COMPRESSION REFRIGERATION SYSTEM



Fig(2) Vapor Compression Refrigeration Cycle

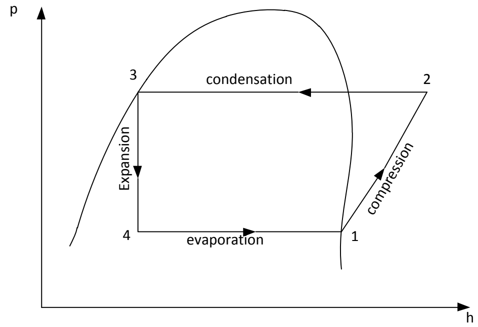


Fig (3) Pressure –Enthalpy diagram (Saturated condition)

Reading from Ice-plant
$T_{evap:}$ = -15°C
$T_{cond:}$= 30°C
Refrigerant = R-22

From pressure-enthalpy diagram
h_1 = 276 kJ/kg
h_2 = 310 kJ/kg
h_3 =112 kJ/kg
h_4 = 112 kJ/kg

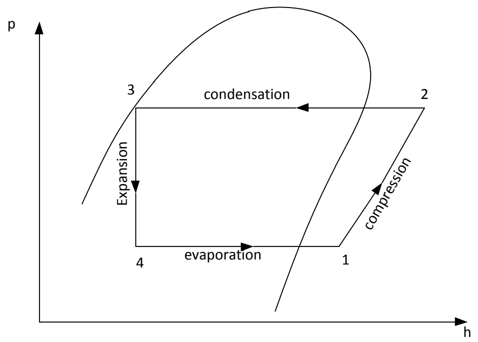
$$COP = \frac{h_1 - h_4}{h_2 - h_1} = \frac{276 - 112}{310 - 276}$$

COP = 4.8

Refrigerant =R134a
h_1 = 395 kJ/kg
h_2 = 425 kJ/kg
h_3 =242 kJ/kg
h_4 = 242 kJ/kg

$$COP = \frac{h_1 - h_4}{h_2 - h_1} = \frac{395 - 242}{425 - 395}$$

COP =5.1



Fig(4) pressure-enthalpy diagram (superheated condition)

Reading from ice-plant
evaporator pressure = 0.96 M Pa
condenser temperature = 0.17 M Pa

Refrigerant= R-22
h_1 = 280 kJ/kg
h_2 = 320 kJ/kg
h_3 =96 kJ/kg
h_4 = 96 kJ/kg

$$COP = \frac{h_1 - h_4}{h_2 - h_1} = \frac{280 - 96}{320 - 280}$$

COP = 4.6

Refrigerant= R-134a
h_1 = 402 kJ/kg
h_2 = 432 kJ/kg
h_3 =250 kJ/kg
h_4 = 250 kJ/kg

$$COP = \frac{h_1 - h_4}{h_2 - h_1} = \frac{402 - 250}{432 - 402}$$

COP = 5

4) RESULT TABLE

Table(1) Performance Analysis of Saturated condition

Refrigerant	$T_{evap:}$	$T_{cond:}$	RE (kJ/kg)	Wc (kJ/kg)	COP
R-22	-15°C	30°C	164	34	4.8
R-134a	-15°C	30°C	153	30	5.1

Table(2) Performance Analysis of Superheated condition

Refrigerant	$P_{evap:}$	$P_{cond:}$	RE	Wc	COP
R-22	0.96MPa	0.17MPa	184	40	4.6
R-134a	0.96MPa	0.17MPa	152	30	5

5) CONCLUSION

Performances analysis of vapor compression cycle is based on the evaporator temperature and pressure, condenser temperature and pressure , type of refrigerant and type of equipments (compressor, condenser, evaporator, expansion valve and copper tube). This paper is analyzed with different refrigerant R-22(monochlorodifluoro methane) and R-134a (Tetrafluoro ethane). Reasons for using R-134a over R-22,

- R-134a is a chlorine-free refrigerant and thus it is an eco-friendly refrigerant.
- R-134a has zero ozone depletion potential.(ODP=0)
- Coefficient of the performance is more than R-22 and required power is less.
- R-134a refrigerant is non-toxic and non-flammable
- It condensate easily at moderate pressure under atmospheric condition.

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