International Journal of Science and Engineering Applications
Volume 8–Issue 08,348-352, 2019, ISSN:-2319–7560

A Study on COP of Existing Ice Plant

Soe Myat Thu
Department of Mechanical Engineering
Technological University (Mawlamyine)
Mawlamyine, Myanmar

Thant Zin Win
Department of Mechanical Engineering
Technological University (Mawlamyine)
Mawlamyine, Myanmar

Hti Lar Tun Kyi
Department of Mechanical Engineering
Technological University (Mawlamyine)
Mawlamyine, Myanmar

Abstract: Refrigeration is the process of removing heat from substance or space to reduce its temperature and transferring that heat to another substance or refrigertion is providing and maintaining the temperature below that of the surrounding temperature.To produce this effect requires certain machinery, hence, the method is called mechanical refrigeration.One of applications of refrigeration is ice plant.10 tons per day of block ice plant is studied for COP improvement.This plant is located in Yangon, Myanmar.Design calculation of compressor, evaporator and COP of exsiting ice plant are determined. Ammmonia is used as refrigerant in this plant. To improve COP of ice plant, refrigerant changing can be considered. If R-22 or R-134a is used, COP improvement occurs. COP with R-22 is 3.88. COP with R-134a is 3.94.

Keywords: refrigeration, mechanical refrigeration;ice plant; COP, Ammonia, R-22, R-134a

---

1. INTRODUCTION

The methods of production of cold by mechanical processes are quite recent. Long back in 1748, William Coolen of Glasgow University produced refrigeration by creating partial vaccum over ethyl ether.But he could not incompletement his experience in practice. The first devlopment took place in 1834 when Perkins proposed a hand-operated compressor machine working on ether. Then in 1851 came Gorrie's air refrigeration machine, and in 1856 Lande developed a machine working on ammonia.

The pace of development was slow in the beginning when steam engines were the only prime movers known to run the compressors. With the advent of electric motors and consequence higher speeds of the compressors, the scope of applications of refrigeration widened.

2.CLASSIFICATION OF ICE PLANTS

Ice plants are usually classified by the type of ice they produce; hence there are block ice plants, flake ice plants, tube, slice or plate ice plants and so on. A further subclassification may be made of plants depending on whether they produce dry subcooled ice or wet ice. Generally, subcooled ice is produced in plants that mechanically remove the ice from the cooling surface. Most flake ice plants are examples of this type. Wet ice is usually made in plants that use a defrost procedure to release the ice. The defrost partially thaws the ice where it makes contact with the cooling surface and unless the ice has been reduced to a temperature substantially below 0°C (subcooled) the surface will remain wet. Tube ice and plate ice plants are examples of this type.

2.1 Block Ice Plant

The traditional block ice plant forms the ice in cans which are submerged in a tank containing circulating sodium or calcium chloride brine. The dimensions of the can and the temperature of the brine are usually selected t give a 24 hour production time and batches of cans are emptied and refilled in sequence during that period. Ice block weight can range from 12 to 150 kg depending on requirements; 150 kg is regarded as the largest size of block one man can conveniently handle.

The size of tank required is related to the daily production. Table 2 describes the approximate size of the freezing tank (ice-making tank) for 135 kg standard ice cans.

Table. 1 Standard sizes of ice can

Capacity	A (mm)	B (mm)	C (mm)	Standard Freezing Time
11kg (25lbs)	100	260	580	4.5 ~ 5 Hrs
22kg (50lbs)	130	300	815	8 ~ 9
45kg (100lbs)	190	405	815	17~ 20
90kg (200lbs)	290	570	815	40 ~ 48
135kg (300lbs)	290	570	1145	40 ~ 48
135kg (300lbs)	280	560	1250	37 ~ 45

Table. 2 Standard sizes of Freezing Tank

Nominal Daily Ice-making Capacity (ton)	Number of Ice-Cans to be accommodated	Dimensions of Freezing Tank			System
		Length (m)	Width (m)	Depth (m)	
5	10 × 8 =80	6.30	3.65	1.20	Single-Can
10	12 × 14 = 168	10.30	5.00	1.20	Twin-Can
20	16 × 20 = 320	14.20	6.30	1.20	Twin-Can
30	20 × 24 = 480	16.50	7.85	1.20	Multi-Can
40	26 × 25 = 650	17.50	10.00	1.20	Multi-Can

50	26 × 31 = 806	21.50	10.00	1.20	Multi-Can

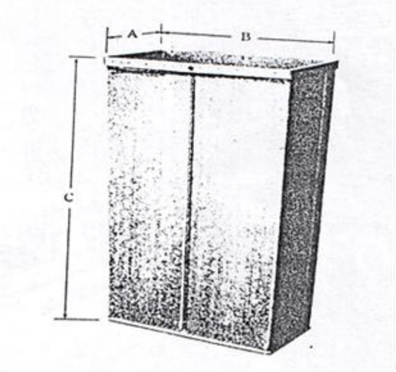

Figure 1. Ice Can

2.2. Flake Ice Plant

A sheet of ice 2-3 mm thick is formed by spraying water on the surface of a refrigerated drum and scrapping it off to form dry subcooled flakes. In some models the drum rotates against a stationary scraper on its outer surface. In others the scraper rotates and removes ice from the inner wall of a double walled stationary drum.

2.3. Tubular Ice – Inside Tube

When ice is produced inside a tube, the freezing cycle is approximately from 13 to 26 min. the tube is usually 20 to 50 mm in diameter, producing a cylinder that can be cut to desired lengths. The refrigerant temperature outside the tuber is continually dropping, with an initial temperature of -4°C and terminal suction temperature ranging from -7 to -20°C. At the end of freezing cycle, the circulating water is shut off and the ice is harvested by introducing hot discharge gas into the refrigerant in the freezing section.

2.4. Tubular Ice-Outside Tube

Tubular ice is produced by freezing a falling film of water either on the outside of a tube with evaporating refrigerant on the inside or by freezing water on the inside of tubes surrounded by evaporating refrigerant on the outside.

When ice is produced on the outside of a tube, the freezing cycle is normally from 8 to 15 min with the final ice thickness from 5 to over 13mm following the curvature of the tube. The refrigerant temperature inside the tube continually drops from an initial suction temperature of about -4°C to the terminal suction temperature in the range of -12 to -26°C. At the end of freezing cycle, the circulating water is shut off. Introducing hot discharge gas results in harvest defrost. This type of ice maker operates with refrigerants R-717, R-12, and R-22.

3. PLATE ICE PLANT

Plate ice makers are commonly defined as those that build ice on a flat vertical surface. Water is applied above freezing plates and flows by gravity over the freezing plates during the freezing cycle. Liquid refrigerant at a temperature of between -21 to -7°C is contained in internal circuiting inside the plate. The freezing cycle time governs the thickness of ice produced. Ice thickness in the range of 6 to 20mm are quite common, with freezing cycles vary from 12 to 45 min.

4. REFRIGERANTS

The working medium circulating in a refrigeration machine or heat pump is referred to as the refrigerant. A refrigerant is the substance used for heat transfer in a refrigeration system. It absorbs heat (latent heat and sensible heat) from the source at a low temperature and pressure and gives up this heat at a high temperature and pressure.

Chlorofluorocarbons (CFCs) have been used as refrigerants since 1930. Hydrochlorofluorocarbons (HCFCs) and hydrofluorocarbons (HFCs) have been introduced later as refrigerants. CFCs and HCFCs are partly responsible for depleting the ozone layer.

A chlorofluorocarbon (CFC) is an organic compound that contains only carbon, chlorine, and fluorine, produced as a substituted derivative of methane and ethane. It is an ozone-depleting compound, which is highly damaging to the environment.

Hydroclorofluorocarbons (HCFC’s) are similar to CFC’s but contain hydrogen and have a lower ozone depleting potential.Hydrofluorocarbon refrigerants (HFC’s) are composed of hydrogen, fluorine and carbon atoms connected by single bonds between the atoms; they do not deplete the ozone layer because they do not contain chlorine or bromine.

Ammonia is the cheapest refrigerant. R-12 is slightly cheaper than R-22. During the last few years, R-22 has replaced ammonia in the dairy and frozen food industry. The fact that ammonia may attack some food products has been predominant cause for the change from ammonia to R- 22 even in cold storages.

R 134-a is one of the leading candidates to replace R-12 in many of applications employing this refrigerant. R-134a is an HFC and has a zero zone depletion potential and a low green-house effect.

5. SIMPLE VAPOUR COMPRESSION CYCLE

The vapour compression cycle is used for refrigeration in preference to gas cycles; making use of the latent heat enables a far larger quantity of heat to be extracted for a given refrigerant mass flow rate. This makes the equipment as compact as possible. A liquid boils and condenses – the change between the liquid and the gaseous states – at a temperature which depends on its pressure, within the limits of its freezing point and critical temperature. In boiling it must obtain the latent heat of evaporation and in condensing the latent heat is given up.

Heat is put into the fluid at the lower temperature and pressure thus providing the latent heat to make it vaporize. The vapour is then mechanically compressed to a higher pressure and a corresponding saturation temperature at which its latent heat can be rejected so that it changes back to a liquid. The cooling effect is the heat transferred to the working fluid in the evaporation process, i.e. the change in enthalpy between the fluid entering and the vapour leaving the evaporator.

6. MAIN COMPONENTS OF REFRIGERATION SYSTEM

There are four maion components in refrigeration system.

(i) Compressor
(ii) Condenser
(iii) Evaporator
(iv) Expansion Device

6.1. Compressor

The compresors are one of the most important parts of the refrigeration cycle. The compressor compresses the refrigerant, which flows to the condensor, where its gets cooled.

Compression of the refrigerant to the suitable pressure ensures its proper condensation and circulation throughout the cycle.

6.1.1 Reciprocating Compressors

The reciprocating compressor is the most widely used, being employed in all fields of refrigeration. It is especially adaptable for use with refrigerants requiring relatively small displacement and condensing at relatively high pressures.

Reciprocating compressors are defined as open-type when one end of crankshaft protrudes ouitside of the crankcase the casing that contains the pistons and the mechanisms inside the compressors.

6.1.2 Rotary Compressors

The rotary compressors are very suitable for refrigerants having moderate or low condensing pressures.Rotary compressor is positive displacement, direct drive machines. Two designs of rotary compressors are rolling piston type and ratating vane type.

6.1.3 Centrifugal Compressors

Centrifugal compressors have a single major moving part, an impeller that compresses the refrigerant gas by centrifugal force. The gas is given kinetic energy as it flows through the impeller. This kinetic energy is not useful itself, so it must be converted to pressure energy.This is done by allowing the gas to slow down smoothly in a stationary diffusure surrounding the impeller.

6.2. Condenser

The condenser is a heat transfer surface.Heat from the hot refrigerant vapour passes through the walls of the condencser to the condensing medium. As the result of lossing heat to the condensing medium, the refrigerant vapour is first cooled to saturation and then condensed into the liquid state.

6.2.1 Types of Condenser

There are three types of condensers. The name of each type is determined by the condensing medium.

(i) Air-cooled condenser uses air as the condensing unit.
(ii)Water-cooled condenser uses water as the condensing unit.
(iii)Evaporative condenser uses air ang water as the condensing unit.

6.2.1.1 Air-cooled Condensers

The circulation of air over an air-cooled condenser may be either natural convection or by the action of a fan or blower. Where air circulation is natural convection , the air quantity circulated over the condenser is low and relatively large condensing surface is required.

Because of their limited capacity, natural- convection condensers are used only on small applications, principally domestic refrigerators and freezers.

6.2.1.2 Water-cooled Condensers

The several types of water-cooled condensers commonly used included: shell and coil condenser, shell and tube condenser and double tube condenser.

6.2.1.3 Evaporative Condensers

The evaporative condenser is defined as comprising a coil in which the refrigerant is flowing and condensing inside, and its outer surface is wetted with water and exposed to stream of air to which heat is rejected principally by evaporation of water.

6.3. Evaporator

An evaporator is any heat transfer surface in which liquid is vapourized for the purpose of removing heat from a refrigerated space or product. The capacity of any evapotator or cooling coil is defined as by the rate at which heat will pass through the evaporator walls from the refrigerated space or product to the liquid refrigerant that is vapourizing.

6.3.1 Types of Evaporator by Construction

By construction, the three principle types of evaporator are bare-tube evaporators, plate-surface evaporators and finned evaporators.

6.3.1.1 Bare-tube Evaporators

Bare-tube evaprators are usually constructed of either steel-pipe or copper tubing. Steel pipe is used for large evaporators and to be employed with ammonia. Copper tubing is utlized in the manufacture of smaller evaporators intended for used with refrigerants except with ammonia.Bare-tube coils are available in a number of sizes, shapes and designs .

6.3.1.2 Plate-surface Evaporators

Plate-surface evaporators may be used singly or in banks. The plates may be manifold for parallel flow of the refrigerant or they may be connected for series flow.Plate-surface evaporators provide excellent shelves in freezer rooms and similar applications.

6.3.1.3 Finned Evaporators

Fin sizes and spacing depend in part on the particular type of application for which the coil is designed. The size of the tube determines the size of the fin.Small tubes require small fins. Fin spacing varies from one fin per inch to fourteen fins per inch, depending on the operating temperature of the coil.

6.4. Expansion Devices

The last of basic elements in the vapour compression cycle, after the compressor, condenser, and evaporator, is the expansion device. The purpose of the expansion device is twofold: it must reduce the pressure of the liquid refrigerant, and it must regulate the flow of refrigerant to the evaporator.

7. DESIGN CALCULATION OF COMPRESSOR

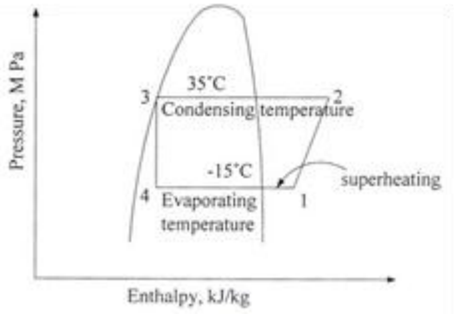

Figure. 2 Pressure Enthalpy Diagram

Open type ammonia reciprocating compressor with four cylinders is used in existing ice plant. Condensing temperature is 35˚C and evaporating temperature is -15˚C and then 10˚C superheat is assumed.

Heat rejected from water, Q_{ice}

$$Q_{ice} = m_{ice}\, c_p\, \Delta t + m_{ice}\, h_l + m_{ice}\, c_p\, \Delta t \quad (1)$$

where

Q_{ice} = heat rejected from water,
m_{ice} = total weight of block, kg,
c_p = specific heat of water
Δt = temperature difference
h_1 = latent heat of fusion

Q_{ice} is calculated from equation (1).

From R-717 chart,

h_1 = 1590 kJ/kg, h_2 = 1900 kJ/kg, $h_3 = h_4$ = 500 kJ/kg, v_1 = 0.63 m³/kg, v_2 = 0.14 m³/kg

Refrigerant flow rate $(m^{\circ}_{R}) = \dfrac{Q_{evap}}{h_1 - h_4}$ (3)

Actual volume of suction vapor compressed per minute

$$v^{\circ}_{R} = m^{\circ}_{R}\, v_1 \quad (4)$$

m°_{R} is obtained from equation (3).

To find the bore and stroke, the speed of compressor crankshaft is assumed to be 1000 r.p.m for standard revolution. L = 0.85 D is assumed for open type reciprocating compressor.

Piston displacement $V_p = \dfrac{\pi}{4} \times D^2 \times L \times N \times n$ (5)

D = Bore, L = stroke length, N = no of revolution per minute, n = no of cylinder

Calculated bore dimension is get from equation (5). And standard bore size is chosen.

After choosing standard bore and stroke, V_p is calculated again with choosen condition. Piston displacement with standard size, $V_p = \dfrac{\pi}{4} \times D^2 \times L \times N \times n$

m°_{R} is calculated again by using piston displacement with standard size.

Actual intake volume, $V_p = m^{\circ}_{R} \times v_1$ (6)

From equation (6), theoretical m°_{R} can be calculated.

Theoretical refrigerating capacity, TRC

$$Q_{evap} = m^{\circ}_{R}\,(h_1 - h_4) \quad (7)$$

Theoretical compressor work done

$$W_{comp} = m^{\circ}_{R}\,(h_2 - h_1) \quad (8)$$

Motor power required

$$W_{motor} = \frac{W_{comp}}{\eta_m} \quad (9)$$

where, η_m = mechanical efficiency

Actual motor power required

$$P_{motor} = \frac{W_{motor}}{\eta_e} \quad (10)$$

where, η_e = electrical efficiency

8. CALCULATION FOR EVAPORATOR COIL LENGTH

To obtain the surface area of coil,

$$Q_{evap} = U\,A\,\Delta t \quad (11)$$

where, Q = heat absorbed by evaporator coil, kW, U = heat transfer coefficient, W/m²K, A = effective surface area of coil, m², Δt = log mean temperature difference of brine, K or ˚F

$$\Delta t = \frac{GTD - LTD}{Ln\dfrac{GTD}{LTD}} \quad (12)$$

where, GTD = greater temperature difference, K or ˚F

LTD = lower temperature difference, K or ˚F

$$A = \pi \times D \times L \quad (13)$$

9. COEFFICIENT OF PERFORMANCE (COP)

The efficiency of refrigeration systems is denoted by its coefficient of performance (COP).COP of refrigeration is calculated by the following equation.

$$COP = \frac{h_1 - h_4}{h_2 - h_1} \quad (14)$$

For R-22,

h_1 = 407.5 kJ/kg, h_2= 450 kJ/kg, h_3= h_4= 242.5 kJ/kg

By using equation (14), COP for R-22 can be calculated.

For R-134-a,

h_1 = 398.33 kJ/kg, h_2 = 436.25 kJ/kg, h_3= h_4= 248.75 kJ/kg

By using equation (14) again, COP for R-134a can be calculated.

Table 3. Calculated results of existing ice plant

Heat rejected from water, Q_{ice}	64.3 kW
Refrigeration effect (R.E)	1090 kJ/kg
Actual volume of suction vapor compressede per minute, $\overset{\circ}{v}_R$	2.4 m^3/min
Calculated bore dimension	97 mm
Choosen standard bore and stroke size	100 mm, 85 mm
Position displacement with standard size, V_P	2.67 m^3/min
Refrigerant flow rate, $\overset{\circ}{m}_R$	0.071 kg/s
Theoretical refigerating capacity, TRC	77 kW
Theoretical compressor work done, W_{comp}	22 kW
Motor power reguired, W_{motor}	28 kW
Actual motor power reguired, P_{motor}	35 kW
Evaporator coil length	232 m
C.O.P(Ammonia)	3.5

Table 4. C.O.P Comparison with superheating

No	Refrigerants	COP $T_c = 35^{\circ}C$, $T_e = -15^{\circ}C$
1	Ammonia (R-717)	3.51
2	R-22	3.88
3	R-134a	3.94

8. CONCLUSION

The study observes COP increasement when R-22 and R-134a are replaced. So, R-22 or R-134a can be used for COP improvement instead of ammonia.Accordance with COP, R-134a is the most suitable refrigerant in this plant.

9. ACKNOWLEDGMENTS

The authors would like to thank all people who give their tremendous moral supports during our study.

10. REFERENCES

[1] Arora, C.P. 1975. Refrigeration and Air Conditioning. Tata McGraw-Hill Company limited. New Delhi.
[2] C.P. Arora.,Refrigeration and Air-conditioning, Third Edition.
[3] Dossat, R.J. 1997. Principle of Refrigeration Prentice-Hall, Inc. Simon and Schuster/A Viacom Company, New Jersey.

[4] G.F. Hundy. A.R. Trrot. T.C. Welch, Refrigeration and Air-conditioning, Fourth Edition.
[5] ROY J.DOSSAT, Principle of Refrigeration, Fourth Edition.
[6] Stoeckes, W.F.1992. Ammonia Data Book. International Institude of Ammonia Refrigeration (IIAR). Washington. DC.
[7] Waterman, J.J., and Graham, J.1968. Ice in fisheries. Torry Research Station, Aberdeen.U.K.