LABORATORY MANUAL

ON

ICE PLANT TEST RIG

Prepared

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AIM OF THE EXPERIMENT:

1. To Demonstrate the Ice plant.
2. To study the Basic Components of Ice plant Trainer. i.e. Compressor, Condenser, Expansion Valve, and Evaporator.
3. To Plot the vapour compression Refrigeration Cycle on Pressure Enthalpy Chart.
4. To Determine the Coefficient of Performance of Unit using Capillary Expansion valve.

Refrigeration may be defined as the process of achieving and maintaining the temperature of a system below the temperature of its surrounding.

Refrigeration is the process of removing heat from an enclosed space, or from a substance, and rejecting it elsewhere for the primary purpose of lowering the temperature of the enclosed space or substance and then maintaining that lower temperature. To satisfy the Second Law of Thermodynamics, mechanical work must be performed to accomplish this.

UNIT OF REFRIGERATION:

The practical unit of refrigeration is expressed in the terms of " Tonne of refrigeration ".

A "tonne of refrigeration" is defined as the amount of refrigeration effect produced by the uniform melting of one US ton of ice from and at 0°C in 24 hours.

1 US ton = 2000 lb = 2000 x 0.453592 kg =907.1847 kg

The latent heat of ice is 335kJ/kg and therefore one tonne of refrigeration

1TR = 907.1847 X 335 KJ / 24 hours

= 907.1847 X 335 / 24 X 60

= 211 kJ/min

In actual practice, one tonne of refrigeration is taken as 210 kJ/min or 3.5 kW

Current applications of refrigeration

Probably the most widely-used current applications of refrigeration are for the air-conditioning of private homes and public buildings, and the refrigeration of foodstuffs in homes, restaurants and large storage warehouses. The use of refrigerators in our kitchens for the storage of fruits and vegetables has allowed us to add fresh salads to our diets year round, and to store fish and meats safely for long periods.

In commercial and manufacturing, there are many uses for refrigeration. Refrigeration is used to liquify gases like oxygen, nitrogen, propane and methane for example. In compressed air purification, it is used to condense water vapour from compressed air to reduce its moisture content. In oil_refineries, chemical_plants, and petrochemical plants, refrigeration is used to maintain certain processes at their required low temperatures (for example, in the alkylation of butenes and butane to produce a high octane gasoline component). Metal workers use refrigeration to temper steel and cutlery. In transporting temperature-sensitive foodstuffs and other materials by trucks, trains, airplanes and sea-going vessels, refrigeration is a necessity.

Dairy products are constantly in need of refrigeration, and it was only discovered in the past few decades that eggs needed to be refrigerated during shipment rather than waiting to be refrigerated after arrival at the grocery store. Meats, poultry and fish all must be kept in climate-controlled environments before being sold. Refrigeration also helps keep fruits and vegetables edible longer.

Methods of refrigeration

Methods of refrigeration can be classified as *non-cyclic*, *cyclic* and *thermoelectric*.

1. Non-cyclic refrigeration

In these methods, refrigeration can be accomplished by melting ice or by subliming dry ice. These methods are used for small-scale refrigeration such as in laboratories and workshops, or in portable coolers.

Ice owes its effectiveness as a cooling agent to its constant melting point of 0 °C (32 °F). In order to melt, ice must absorb 333.1 kJ/kg (143.3 Btu/lb) of heat. Foodstuffs maintained at this temperature or slightly above have an increased storage life. Solid carbon dioxide, known as dry ice, is used also as a refrigerant. Having no liquid phase at normal atmospheric pressure, it sublimes directly from the solid to vapor phase at a temperature of -78.5 °C (-109.3 °F). Dry ice is effective for maintaining products at low temperatures during the period of sublimation.

2. Cyclic refrigeration

This consists of a refrigeration cycle, where heat is removed from a low-temperature space or source and rejected to a high-temperature sink with the help of external work, and its inverse, the power cycle. In the power cycle, heat is supplied from a high-temperature source to the engine, part of the heat being used to produce work and the rest being rejected to a low-temperature sink. This satisfies the second law of thermodynamics.

A *refrigeration cycle* describes the changes that take place in the refrigerant as it alternately absorbs and rejects heat as it circulates through a refrigerator.

Heat naturally flows from hot to cold. Work is applied to cool a living space or storage volume by pumping heat from a lower temperature heat source into a higher temperature heat sink. Insulation is used to reduce the work and energy required to achieve and maintain a lower temperature in the cooled space. The operating principle of the refrigeration cycle was described mathematically by Sadi Carnot in 1824 as a heat engine.

The most common types of refrigeration systems use the reverse-Rankine vapor-compression refrigeration cycle although absorption heat pumps are used in a minority of applications. It is possible to build a refrigeration system which does not contain a refrigerant, and therefore does not operate a refrigeration cycle — the most common form being thermoelectric cooling used in some portable coolers.

Cyclic refrigeration can be classified as:

1. Vapour cycle, and
2. Gas cycle

Vapour cycle refrigeration can further be classified as:

1. Vapour compression refrigeration
2. Gas absorption refrigeration

The thermodynamics of the cycle can be analyzed on a diagram as shown in Figure 2. In this cycle, a circulating refrigerant such as Freon enters the compressor as a vapour. From point 1 to point 2, the vapour is compressed at constant entropy and exits the compressor superheated. From point 2 to point 3 and on to point 4, the superheated vapour travels through the condenser which first cools and removes the superheat and then condenses the vapour into a liquid by removing additional heat at constant pressure and temperature. Between points 4 and 5, the liquid refrigerant goes through the expansion valve (also called a throttle valve) where its pressure abruptly decreases, causing flash evaporation and auto-refrigeration of, typically, less than half of the liquid.

ICE PLANT TEST RIG

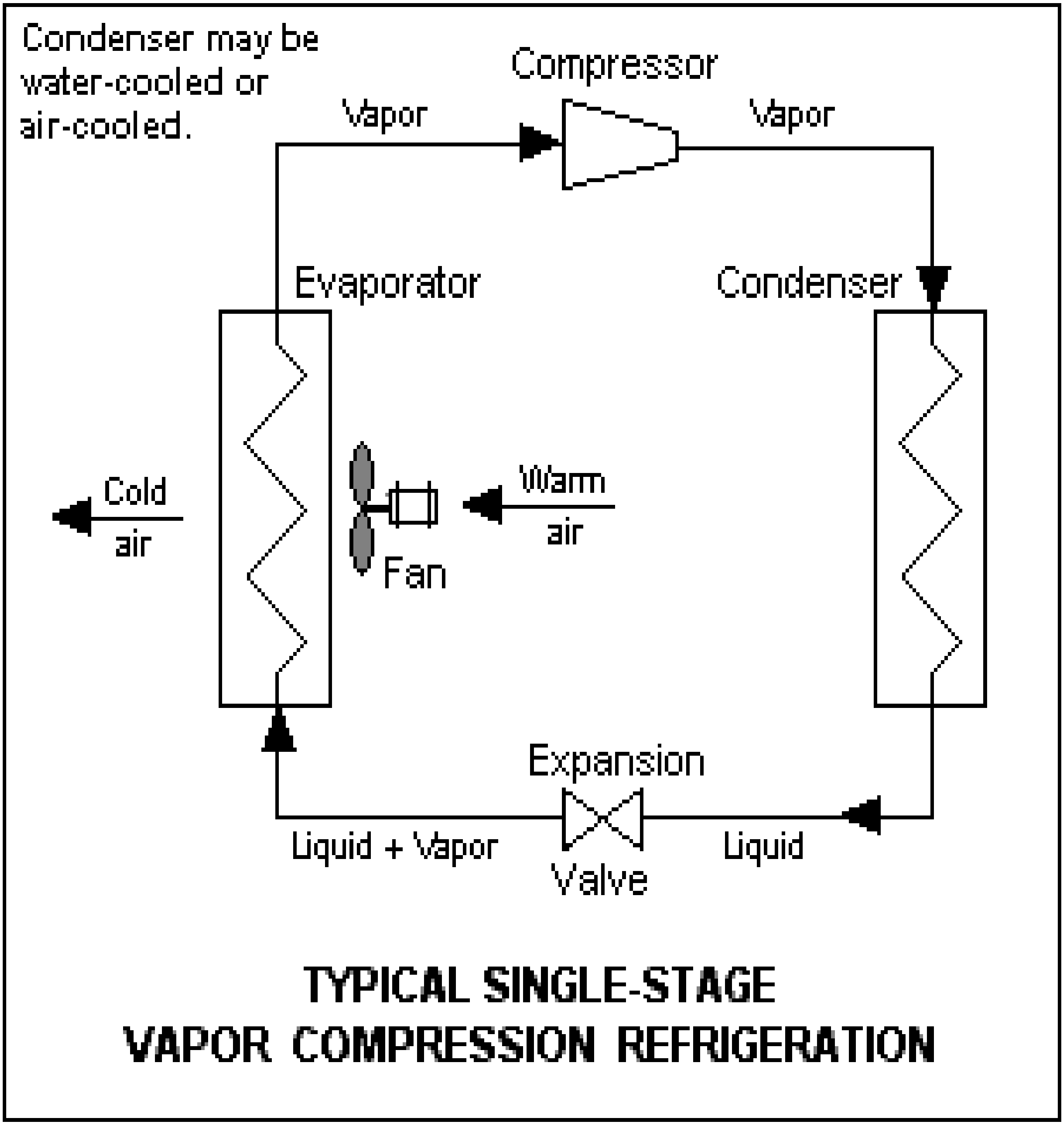

Fig. 1 Vapour compression Refrigeration Cycle

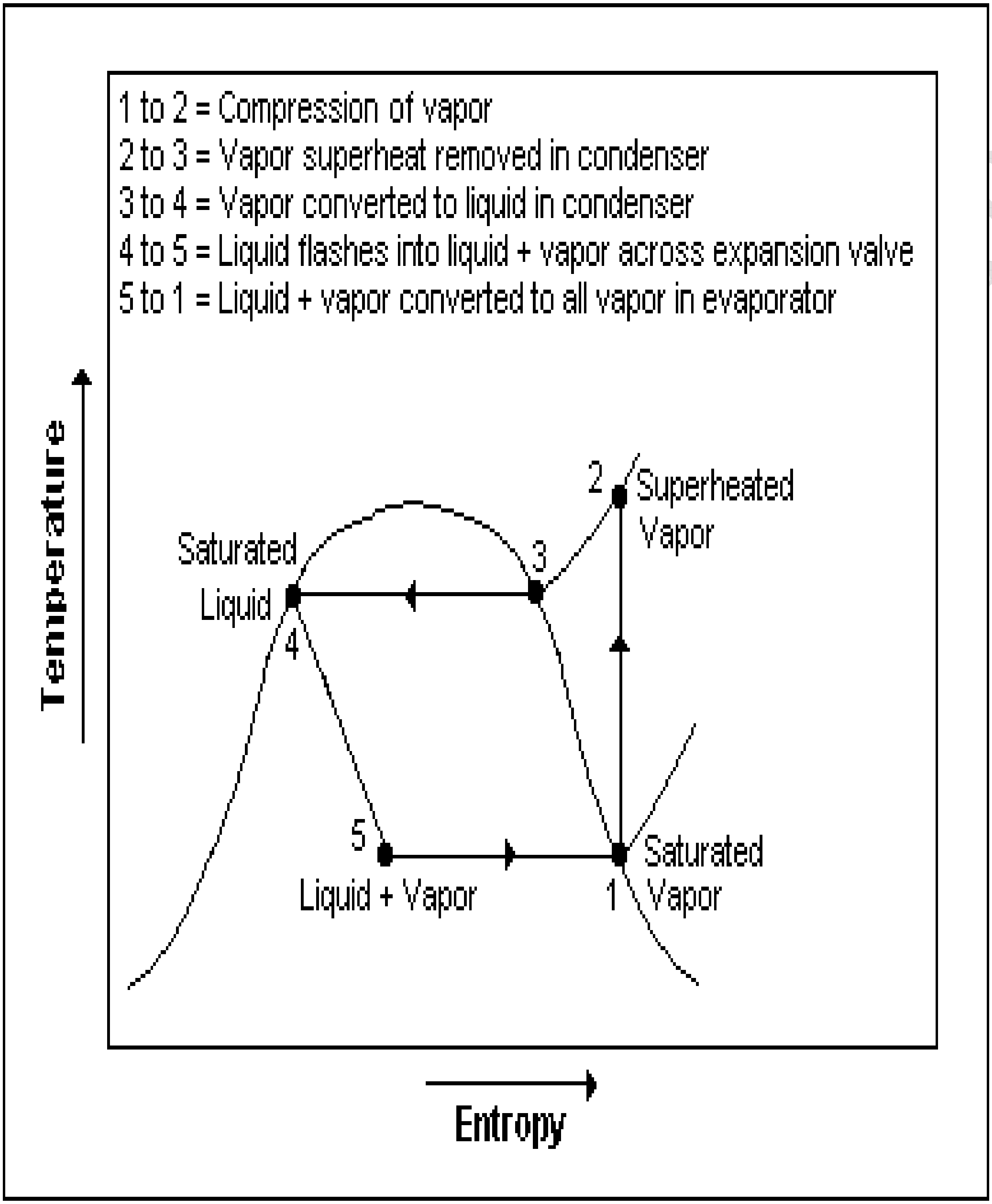

Fig. 2 Temperature–Entropy diagram for SSS Cycle

That results in a mixture of liquid and vapour at a lower temperature and pressure as shown at point 5. The cold liquid-vapour mixture then travels through the evaporator coil or tubes and is completely vaporized by cooling the warm air (from the space being refrigerated) being blown by a fan across the evaporator coil or tubes. The resulting refrigerant vapour returns to the compressor inlet at point 1 to complete the thermodynamic cycle.

The above discussion is based on the ideal vapour-compression refrigeration cycle, and does not take into account real-world effects like frictional pressure drop in the system, slight thermodynamic irreversiblity during the compression of the refrigerant vapour, or non-ideal gas behavior (if any).

INTRODUCTION TO ICE PLANT

In early days, ice was the only means for producing cold, Although mechanical refrigeration have replaced many of usages of ice now a days, still ice is used for many purpose e.g. short-term preservation of foods in cold beverage etc. Hence, manufacture of ice occupies a large portion of refrigeration applications.

Commercially, Ice is manufactured BY two methods as

1. Can Ice
2. Plate Ice

But the plate ice system have become now a days almost obsolete and most of the ice plants use can systems.

UNICOOL ICE PLANT TUTOR also uses ice can system. The cans filled with fresh water are kept in a tank, in which brine is circulated. The brine is cooled by the refrigerant, which in turn cools the water in cans and ice formation takes place.

Commercial ice is produced by freezing potable water is standard cans placed in rectangular tanks. The tanks are filled with chilled brine, which is kept in constant motion by an agitator. The agitation helps in increasing the heat transfer from the water in the can to the chilled brine. Brine temperature is maintained by the refrigeration plant, at - 11^0 to - 10^0C. To get clear transparent ice, water in the can is agitated by the use of low pressure air through the tubes suspended from the top. Ice of potable water (treated or untreated) frozen at a temperature lower than - 12^0C can crack. Therefore brine temperature is kept at a higher level, say -11^0 to - 10^0C. Water in the ice cans placed in the brine cools rapidly up to a temperature of about 3^0 to 4^0C. Thereafter it takes more time for the water to touch o ^{0}C.

PREPARATION OF BRINE

All the ice plants use indirect refrigeration system. In this some refrigerating medium, called secondary refrigerant or brine is cooled down by direct expansion of refrigerant and it is then pumped to the space to be cooled. These systems are used where danger due to leakage of refrigerant is important and in locations of fluctuating temperatures. In addition to acting as a heat carrying medium brine should have certain other properties also. The freezing point of brine should be low enough so that it will not freeze at the lowest temperature in the cycle. Also it should be non-corrosive and should not be subject to precipitation when contaminated with refrigerant through accidental leakage.

For preparation of brine, the ice cans filled with water are placed over the ice can frames and fresh water is filled in the main tank to the required level. Put about 7-10 Kg of NaCl in Main tank start the stirrer so that water is circulating in the tank. One of the disadvantages of brine is, it readily attacks the material of construction. To prevent corrosion, the main freezing tank is already coated with fiberglass lining inside. To Prevent the further effect of corrosion Brine should be Drained after Performing the Experiment.

TECHNICAL DETAIL

1 **COMPRESSOR: -** Hermetically sealed compressor 1 Tr. (Low Temp. type) to work on 220V AC 50 HZ Operate on **Refrigerant R-134 a** with standard electrical accessories.

2 **CONDENSER: -** Suitable fins and Tube type Air-cooled condenser.

3 **FAN MOTOR: -** 1/10 H.P condenser Fan motor with fan.

4 **EXPANSION VALVE: -** Capillary Expansion Valve

5 **EVAPORATOR: -** The evaporator fitted as a Small Ice plant which is made out of stainless steel from Inner and Outer. Heavy duty Insulation is provided in between the inner tank and outer tank to minimize the heat losses. and copper tubes are fitted inside the inner tank to give refrigerant effect.

CONTROLS AND STANDARD ACCESSORIES

1. Energy meter for compressor.
2. Filter drier.
3. Pressure gauges suction and discharge imported especially for R 134 a refrigerant.
4. Digital temperature indicator **(Eutech Make)** at various points in ^{0}C with PT. 100 probes.
5. Digital voltmeter.
6. Digital AMP meter for compressor.
7. 32 AMP DP switch, 15 AMP power switches for other parts.

OBSERVATION TABLE

S.NO.	P_1	P_2	T_1	T_2	T_3	T_4
1. ***2.*** ***3.***						

Where,

P_1 = Suction Pressure

P_2 = Discharge Pressure

T_1 = Temperature before Entering to Compressor

T_2 =Temperature after Exit from Compressor

T_3 = Temperature after Condenser

T_4 = Temperature after Expansion Valve

CALCULATIONS

Coefficient of Performance: - *The Coefficient of Performance is defined as the ratio of heat extracted in the Evaporator to the work done on the Refrigerant.*

$$COP = \frac{Refrigeration\ Effect}{Work\ done}$$

Using Points (P_1, T_1); (P_2, T_2); T_3 and T_4 Locate Points 1,2,3,4 on the P-H. Chart for R-134 a and obtain the Enthalpy Values H_1, H_2, H_3, H_4

$$\text{COP} = \frac{(H_1 - H_4)}{(H_1 - H_2)}$$

PRECAUTIONS:

1. Check Voltage, It should not be less than 220 Volts.
2. Always start condenser Fan Motor Before staring the compressor.
3. Check the amp. Meter for compressor. Initially it shall be 5-8 Amp. And then it will gradually decreases to 3-4 Amp. If it indicates more than 6 Amp. Check voltage for condenser fan Motor. More Amp. means more Load on the compressor.

4. Note down the readings of Suction and discharge Pressure Gauges. Absence of any reading will indicates the blockage of Pipe Line.
5. While Switching Off the machine, First Switch off the Compressor, condenser Fan motor, Components Fitted on the Panel Board then Switch off the Main switch.

SAMPLE CALCULATIONS

$P_1 =$ 0.5 Bar +1.01 Bar = 1.51 Bar (Absolute)

$P_2 =$ 10 Bar + 1.01 Bar = 11.01 Bar (Absolute)

$T_1 = 05^0C$

$T_2 = 64^0C$

$T_3 = 36^0C$

$T_4 = -6^0C$

Locate Points 1,2,3,4 on the P-H. Chart for R-134 a Refrigerant and obtain the Enthalpy Values

$H_1 = 360KJ/Kg$

$H_2 = 385KJ/Kg$

$H_3 = H_4 = 240KJ/Kg$

$$\textbf{COP} = \frac{(H_1 - H_4)}{(H_1 - H_2)} = \frac{360-240}{385-360} = \frac{120}{25} = 4.80$$

Conclusions: The experiment on Ice plant test rig was performed. The refrigerating effect, power input of the compressor and the COP of the Ice Plant was calculated. The COP of the Ice Plant was found to be 4.80