LAB MANUAL FOR RAC LAB

(MECHANICAL ENGINEERING - 5TH SEM)

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GOVT. POLYTECHNIC NABARANGPUR

INSTRUCTIONAL MANUAL
OF
MECHANICAL HEAT PUMP TEST RIG

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Manufactured By:-

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CYCLE OF OPERATION

The Method of operation of the heat pump can be explained by reference to the schematic diagram. The working fluid or heat transfer medium is the refrigerant **R-134A** . and the heat source and heat sink is cold running water.

The sealed compressor rated at 1/3 tr & operating on either 220v. 50Hz or acts as an external energy source. The super heated refrigerant is compressed and pumped through insulated copper pipes to condensing coil at pressure P and temperature T. This coil is immersed in cold flowing water in the stainless steel condensing tank. The refrigerant pressure remains substantially constant at P while passing through the coil but falls in temperature from T2 to T3 losing its super heat and all of its latent heat or heat or change of phase to the water. It reaches the refrigerant flow meter as a sub cooled liquid still at pressure P and temperature T. The function of the silica get drier is to eliminate water not liquid refrigerant.

The refrigerant now expends through the Thermostatic expansion valve or capillary where it expands to a lower pressure P and commences to boil. The boiling temperature or wet vapor temperature T is measured before the refrigerant passes through copper evaporator coil. This coil is also immersed in coil flowing water in the stainless steel evaporating tank during its passage through the coil the refrigerant absorbs from the water the latent heat of evaporation or heat of change of phase and in addition may receive some further heat to super heat the refrigerant to temperature T. The boiling or evaporation process occurs at constant pressure P. The super heated vapor refrigerant leaves the evaporator to return to the compressor through insulated copper pipes to begin the cycle again.

The heat source and sink water is taken from the cold mains supply and passes through a small pressure reducing valve to ensure a standard flow rate by reducing mains pressure fluctuations. Separate control valves are used to adjust the flow of water to the condensing and evaporating tanks. The water flow rates through the stainless steel tank are determined by flow meter. An annular tank design is employed to reduce thermal inertia.. Pressures are measured by refrigerant Pressure gauges. Electrical power input to the heat pump compressor is measured by an integrating watt-hour meter, where power consumed is a direct function of the speed of the rotating disc a very accurate power figure can be obtained.

INTRODUCTION

It has been estimated that at least 85% of the refrigeration processes in use today are powered by Vapour compression system. The applications embrace so many varied disciplines that an introductory appreciation to the principles involved is now frequently required in the education of the non engineering professions. Such as catering; public health; architects; the food storage transport and food processing industries. An improved understanding of refrigerating techniques is also being demanded of engineers themselves particularly in the fields of building services and environmental control.

The mechanical heat pump is designed solely for educational purposes and yields data in a quantitative and qualitative from in a manner easily understood by the student regardless of his level of interest in the subject. The equipment is compact bench mounted and instrumented sufficiently for students to make measurements and perform calculations at a variety of educational levels up to and including university standard. All instruments are located at the actual point of measurement and connecting pipes are open to view to allow conveniently describe the sequence of events occurring in the refrigeration cycle an indication of the experimental capability of the equipment is given in the worked examples which range from the elementary up to advanced thermodynamics and professional refrigeration standard.

TECHNICAL DETAIL

1. **COMPRESSOR: -** Hermetically sealed compressor to work on 220V AC 50 HZ

   Operate on **Refrigerant R-134 A** with standard electrical accessories.

2. **CONDENSER: -** Water-cooled with Stainless steel Tank from Inner and Outer with glass Wool Insulation.

3. **EXPANSION VALVE: - Danfoss Make** Thermostatic exp valve with adjustable evaporator Load screw on suction line is Provided.

4. **EVAPORATOR:-** Water Cooled Evaporator with Stainless steel Tank from Inner and Outer and glass Wool Insulation.

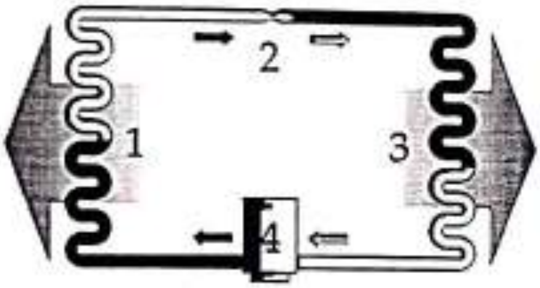
HEAT PUMP

A **heat pump** is a machine or device that moves heat from one location to another via work. Most often heat pump technology is applied to moving heat from a low temperature *heat source* to a higher temperature *heat sink*.[1] Common examples are:

- Food refrigerators and freezers
- Air conditioners and reversible-cycle *heat pumps* for providing thermal comfort
- Water chillers
- Drinking fountains that provide chilled water

The term 'heat pump' is a slight misnomer; heat is not 'pumped', but instead is 'moved' by these devices. According to the second law of thermodynamics heat cannot spontaneously flow from a colder location to a hotter area; work is required to achieve this.Heat pumps differ in how they apply this work to move heat, but they can essentially be thought of as heat engines operating in reverse. A heat engine allows energy to flow from a hot 'source' to a cold heat 'sink', extracting a fraction of it as work in the process. Conversely, a heat pump requires work to move thermal energy from a cold source to a warmer heat sink. Since the heat pump uses a certain amount of work to move the heat, the amount of energy deposited at the hot side is greater than the energy taken from the cold side by an amount equal to the work required. Conversely, for a heat engine, the amount of energy taken from the hot side is greater than the amount of energy deposited in the cold heat sink since some of the heat has been converted to work.

One common type of heat pump works by exploiting the physical properties of an evaporating and condensing fluid known as a refrigerant.



A diagram of a simple heat pump's vapor compression refrigeration cycle:

1) condenser, 2) expansion valve, 3) evaporator, 4) compressor.

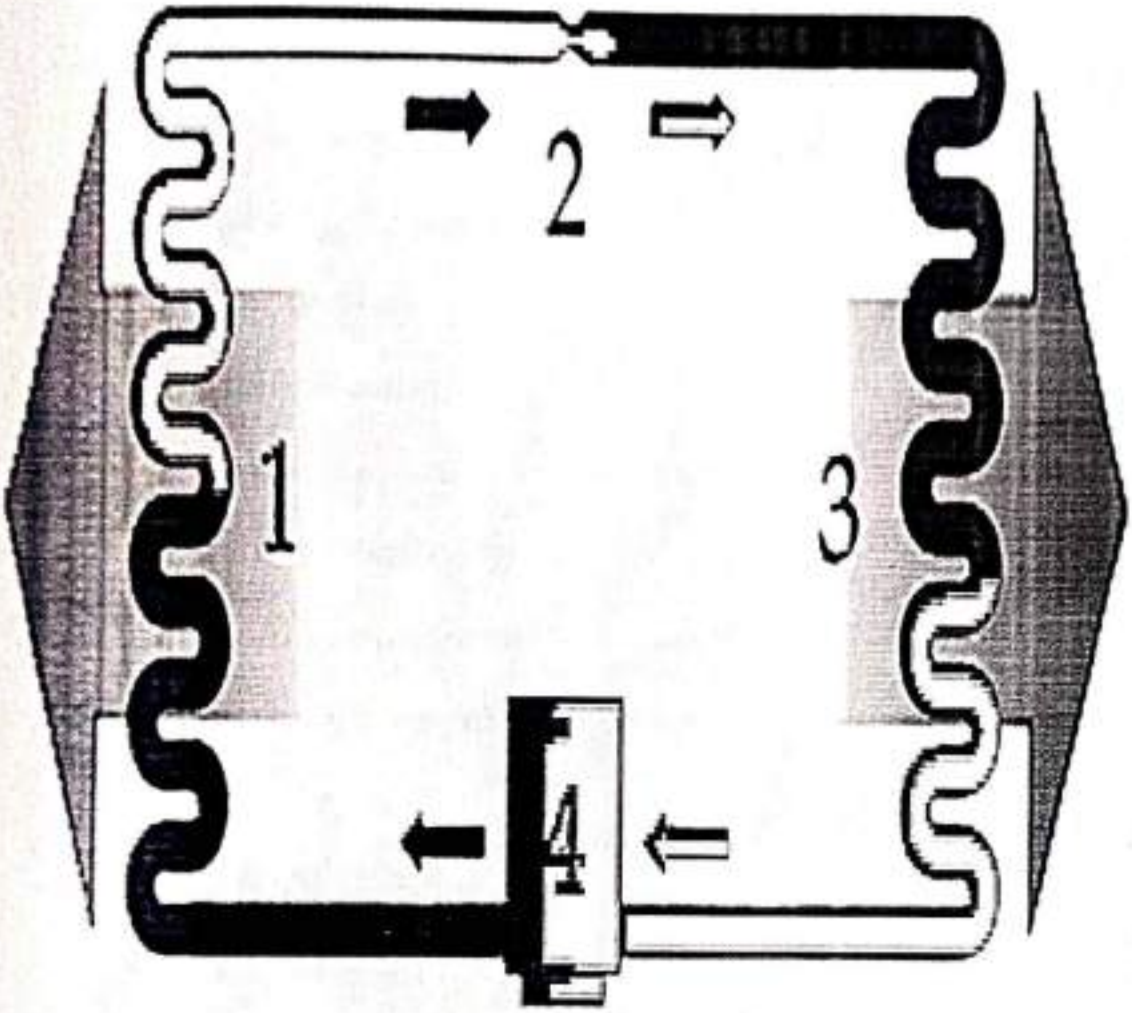
The working fluid, in its gaseous state, is pressurized and circulated through the system by a **compressor**. On the discharge side of the compressor, the now hot and highly pressurized gas is cooled in a heat exchanger called a **condenser** until it condenses into a high pressure, moderate temperature liquid. The condensed refrigerant then passes through a pressure-lowering device like an **expansion valve, capillary tube,** or possibly a work-extracting device such as a *turbine*. This device then passes the low pressure, barely liquid (*saturated* *liquid*) refrigerant to another heat exchanger, the **evaporator** where the refrigerant evaporates into a gas via heat absorption. The refrigerant then returns to the compressor and the cycle is repeated.

In such a system it is essential that the refrigerant reach a sufficiently high temperature when compressed, since the second law of thermodynamics prevents heat from flowing from a cold fluid to a hot heat sink. Similarly, the fluid must reach a sufficiently low temperature when allowed to expand, or heat cannot flow from the cold region into the fluid. In particular, the pressure difference must be great enough for the fluid to condense at the hot side and still evaporate in the lower pressure region at the cold side. The greater the temperature difference, the greater the required pressure difference, and consequentially more energy is needed to compress the fluid. Thus as with all heat pumps, the energy efficiency (amount of heat moved per unit of input work required) decreases with increasing temperature difference. Thus a ground source heat pump, which has a very small temperature differential, is relatively efficient. (Figures of 75% and above are quote.)

Due to the variations required in temperatures and pressures, many different refrigerants are available. Refrigerators, air conditioners, and some heating systems are common applications that use this technology.

In somewhat rare applications, both the heat extraction and addition capabilities of a single heat pump can be useful, and typically results in very effective use of the input energy. For example, when an air cooling need can be matched to a water heating load, a single heat pump can serve two useful purposes. Unfortunately, these situations are rare because the demand profiles for heating and cooling are often significantly different.

REFRIGERATION CYCLE



A diagram of a simple heat pump's vapor compression refrigeration cycle:

1) condenser
2) Expansion valve
3) Evaporator
4) Compressor.

OBSERVATIONS

T1 = Suction Temperature = ------------^{0}C
T2 = Discharge Temperature = ------------^{0}C
T3 = Throttling Temperature = ------------^{0}C
T4 = Evaporating Temperature = ------------^{0}C
P1 = Suction Pressure = ------------Bar
P2 = Discharge Pressure = ------------Bar
T5 = Water inlet Temperature to Condenser= ------------^{0}C
T6 = Water outlet Temperature to Condenser= ------------^{0}C
T7 = Water inlet Temperature to Evaporator= ------------^{0}C
T8 = Water Outlet Temperature to Evaporator= ------------^{0}C
V = Voltage (V) = ------------V
I = Current (A) = ------------A

OBSERVATION TABLE

S.NO	T1	T2	T3	T4	P1	P2

S.NO.	T5	T6	T7	T8

CALCULATIONS

P_1 = ______________ Bar (Absolute)

P_2 = ______________ Bar (Absolute)

T_1 = _______ 0 C

T_2 = _______ 0 C

T_3 = _______ 0 C

T_4 = _______ 0 C

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

H_1= _________ Kj/Kg

H_2 = ________ KJ/Kg

$H_3 = H_4$ = _______ KJ/Kg

(C.O.P.) Heat Pump = $\dfrac{H_2 - H_3}{H_2 - H_1}$

(C.O.P.) Refrigerator = $\dfrac{H_1 - H_4}{H_2 - H_1}$

$(C.O.P.)_{Heat\text{-}pump} - (C.O.P.)_{Refrigerator} = 1$.

$W.D. = \dfrac{\text{No. of blinkings}}{\text{time taken (hrs)}} \div EMC$

EMC = Energy Meter Constant = 3200 imp/KWh

AIMS

1. To Demonstrate the Window Air Conditioning Cycle.
2. To study the Basic Components of Window Air Conditioning Cycle. 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.

OBSERVATION TABLE

S.NO.	*P1*	*P2*	*T1*	*T2*	*T3*	*T4*
1.						
2.						
3.						

WHERE,

P1=SUCTION PRESSURE

P2=DISCHAGE PRESSURE

T1= TEMPERATURE BEFORE ENTERING TO COMPRESSOR

T2=TEMPERATURE AFTER EXIT FROM COMPRESSOR

T3=TEMPERATURE AFTER CONDENSOR

T4=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.*

$$C.O.P. = \frac{Q}{W}$$

Using Points (P!,T1) ; (P2,T2) ;T3and T4 Locate Points 1,2,3,4 on the P-H.

Chart for R-134and obtain the Enthalpy ValuesH1, H2, H3, H4

$$C.O.P. = \frac{H1-H4}{H2-H1}$$

Where,

VxI =Work input to the Compressor

Work input by Compressor can also be measure by the Energy Meter.

$$\text{Electrical input power, Ip} = \frac{10}{t_e} \times \frac{3600}{EMC}$$

Where, Energy Meter constant (EMC) = ____________ Imp / kw / hr.

t_e = Time revolution for Indications to Complete 10 Indications.

Taking motor efficiency as 75% we have input shaft power

SP = Elect. I.P x 0.75

SAMPLE CALCULATIONS

Pressure at Compressor discharge P_2 = 15 + 1.01 = 16.01 Bar (absolute)

Pressure at Compressor inlet P_1 = 3.2 +1.01 = 4.21 Bar (abslute)

Temperature at compressor discharge T_2 = 80^0 C

Temperature at compressor inlet T_1 = 22^0 C

Temperature at condenser outlet T_3 = 40^0 C

Locate points 1, 2, 3, 4 on p-h chart for F-22 using observed value of pressure and temperature. Line 3-4 always vertical line. Read enthalpy values at these points, as shown in fig.

C.O.P. = 153-133/159-153 = 40/6 = **6.66**

INTRODUCTION TO TEST RIG

The UNICOOL Cooling Tower consists of about 1.2 meter length of Tower made form transparent Acrylic sheet for the clear visualization fitted over the conical housing.

The Main M.S. Tank of capacity of about 80 Ltr. is provided through which centrifugal pump sucks water and delivers to the Geyser through flow meter. In Geyser the temp. of water gets increases and it sprays on the top of cooling Tower through spray nozzles over the Decking Material (Fiber).Than Water is allowed to trickle over the this Decking material closely packed in the cooling Tower. Water spreads over the fiber martial thus creating the large surface area for heat transfer between water and Air.

A Centrifugal type Blower with control valve is used to blow Air inside the cooling Tower

The falling water droplets are cooled by the air circulating through the tower.

The cooling is brought about by sensible heat transfer and by the evaporation of a portion of the Water.

The water Vapour produced by the evaporation of water is carried away by the air circulating through the tower.

SPECIFICATION OF TEST RIG

Tower :- Cross Section size 0.15m x 0.15 m x1.2 m

Tank :- M.S. of capacity suitable capacity

Heater : - 3 Kw (2 Nos.)

Temp. Indicator :- Digital with 2 Nos. PT-100 thermocouples.

Pump : - Mono block type

Blower :- Centrifugal type 2 H.P.

Flow meter :- To measure Flow rate of Water

DBT/WBT :- 2 Nos.

OBSERVATION TABLE:-

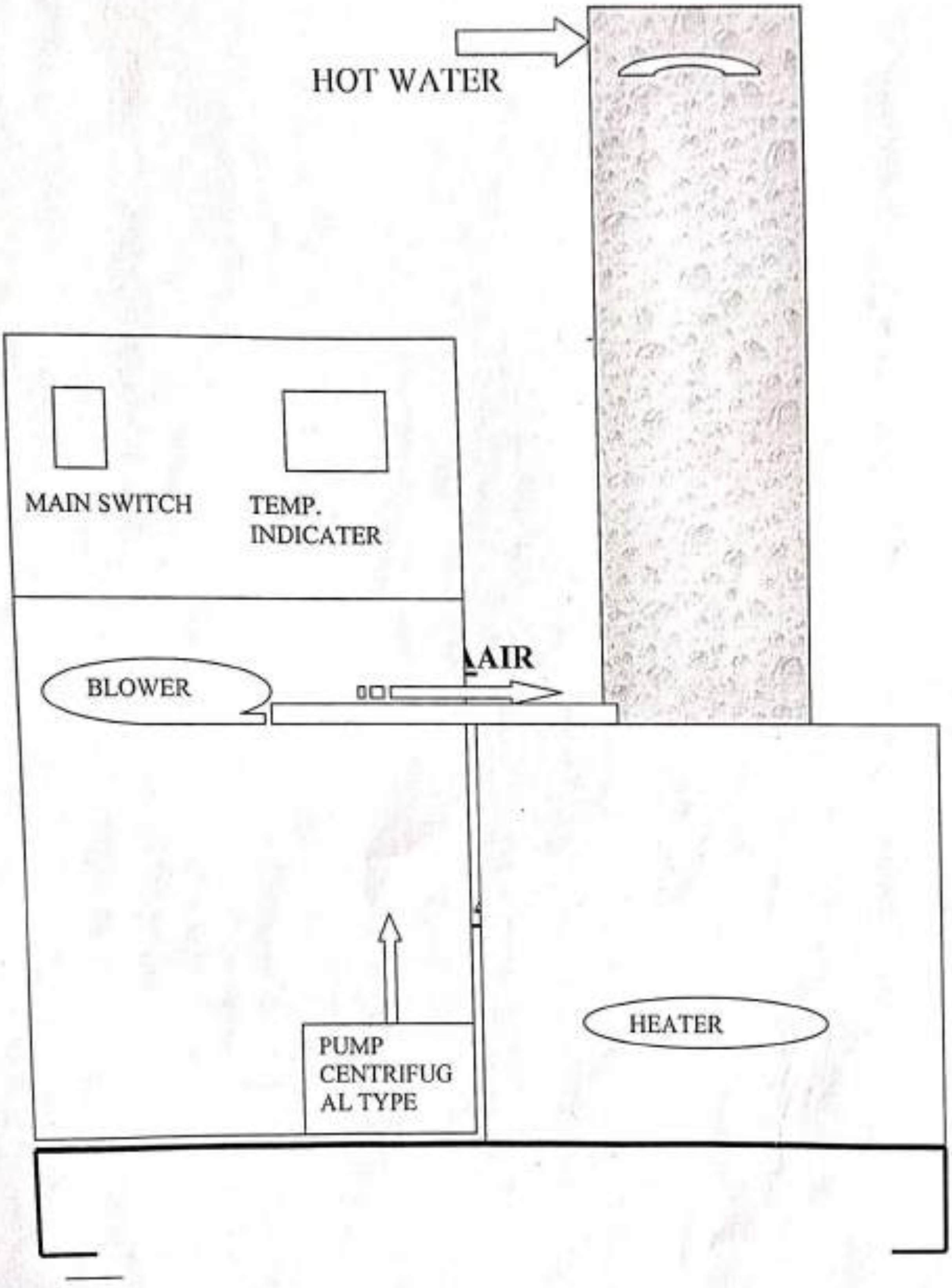
S.No.	Temp. of Water Inlet to cooling tower (T1)	Temp. of Water Outlet to cooling tower (T2)	Wet Bulb temp. of Atmospheric Air (T3)

CALCULATIONS: -

$$\text{Efficiency of Cooling Tower} = \frac{\text{Actual Cooling obtained}}{\text{Theoretical Cooling to be obtained}}$$

$$\textbf{Efficiency of Cooling Tower} = \frac{T1-T2}{T1-T3} = \_\_\_\_\_\_\_\_\_ \%$$

COOLING TOWER



AIMS

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.

OBSERVATION TABLE

S.NO.	*P1*	*P2*	*T1*	*T2*	*T3*	*T4*
1.						
2.						
3.						

WHERE,

P1=SUCTION PRESSURE

P2=DISCHAGE PRESSURE

T1= TEMPERATURE BEFORE ENTERING TO COMPRESSOR

T2=TEMPERATURE AFTER EXIT FROM COMPRESSOR

T3=TEMPERATURE AFTER CONDENSOR

T4=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.*

$$C.O.P. = \frac{Q}{W}$$

Using Points (P1, T1); (P2, T2); T3and T4 Locate Points 1,2,3,4 on the P-H. Chart for R-22 and obtain the Enthalpy ValuesH1, H2, H3, H4

$$C.O.P. = \frac{H1-H4}{H2-H1}$$

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 10-12 Amp. And then it will gradually decreases to 5-8 Amp. If it indicates more than 12 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

P1 = 0.5 Bar +1.01 Bar = 1.51 Bar (Absolute)

P2 = 10 Bar + 1.01 Bar = 11.01 Bar (Absolute)

T1= 05^0C

T2= 64^0C

T3= 36^0C

T4= -6^0C

Locate Points 1,2,3,4 on the P-H. Chart for R-22 Refrigerant and obtain the Enthalpy Values

H1=360KJ/Kg

H2=385KJ/Kg

H3=H4=240KJ/Kg

C.O.P.=H1-H4/H2-H1= 360-240/385-360=120/25=4.80

AIMS

1.To Demonstrate the Vapour Compression Refrigeration Cycle.

2.To study the Basic Components of Simple Vapour Compression Refrigeration Cycle. 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.

OBSERVATION TABLE

S.NO.	*P1*	*P2*	*T1*	*T2*	*T3*	*T4*
1.						
2.						
3.						

WHERE,

P1=SUCTION PRESSURE

P2=DISCHAGE PRESSURE

T1= TEMPERATURE BEFORE ENTERING TO COMPRESSOR

T2=TEMPERATURE AFTER EXIT FROM COMPRESSOR

T3=TEMPERATURE AFTER CONDENSOR

T4=TEMPERATURE AFTER EXPANSION VALVE

Work done by Compressor:-

Work input by Compressor can also be measure by the Energy Meter.

$$\text{Electrical input power, Ip} = \frac{10}{t_e} \times \frac{3600}{EMC}$$

Where, Energy Meter constant (EMC) = 3200 Imp / kw / hr.

t_e = Time revolution for Indications to Complete 10 revolutions

Taking motor efficiency as 75% we have input shaft power

SP = Elect. I.P x 0.75

PRECAUTIONS

1. Check Voltage, It should not be less than 220 Volts.
2. Always use only one type of Expansion Valve at a time.
3. Always start condenser Fan Motor Before staring the compressor.
4. Open the Solenoid Valve when using the Mode of Thermostatic Expansion Valve.
5. Check the amp. Meter for compressor. Initially it shall be 5-6 Amp. And then it will gradually decreases to 2-3 Amp. If it indicates more than 5 Amp. Check voltage for condenser fan Motor. More Amp. means more Load on the compressor.
6. Note down the readings of Suction and discharge Pressure Gauges. Absence of any reading will indicates the blockage of Pipe Line.
7. Do not disturb the internal settings of L.P.H.P. Cut Out.
8. To take the reading on Rotameter, close the By Pass Valve and Open the Main line Valve of rotameter.
9. To disconnect Rotameter, Open By Pass Valve and close the Main Line Valve of Rotameter.
10. While Switching Off the machine, First Switch off the Heaters of in service , switch Off the Compressor, condenser Fan motor, Components Fitted on the Panel Board then Switch off the Main switch.

SAMPLE CALCULATIONS

$P1=20Psi=20 \times 6895x10e^{-6} = .14Mpa$ (Gauge) $=. 14+. 1=. 24Mpa$ (Absolute)

$P2=150Psi= 150x6895x10e^{-6}=1.03Mpa$(Gauge)$=1.03+. 1=1.13Mpa$ (Absolute)

$T1= 24^{0}C$

$T2= 71^{0}C$

$T3= 39^{0}C$

$T4= -6^{0}C$

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

$H1=370KJ/Kg$

$H2=390KJ/Kg$

$H3=H4=239KJ/Kg$

$C.O.P.=H1-H4/H2-H1= 370-239/390-370=131/20=6.55$