**REFRIGERATION AND AIR CONDITIONING LABORATORY**

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**Lab Session No: 1**

**Mechanical Heat Pump**

**Objectives of the Experiment:**

1. To determine the Coefficient of Performance of heat Pump and production of Heat Pump performance curves over a range of source and delivery temperatures.
2. Comparison of practical and Ideal Cycles on a P-H Diagram and determination of energy balance for Condenser and Compressor.
3. Production of Heat Pump performance curves based on the R134a properties at a variety of Evaporating and Condensing temperatures.
4. Estimation of the effect of Compressor Pressure Ratio on Volumetric Efficiency.

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**SCHEMATIC:**

Fig. 1: Vapor Compression Refrigeration Cycle

**THEORY:**

Schematic of a vapour compression refrigeration cycle is shown in Fig. 1; this cycle has the following component:

* A compressor which compresses the vapor of refrigerant. It consumes electrical power and provides the required mechanical energy (work) to the system.
* The condenser that absorbs heat (at constant pressure) from the hot and high pressure refrigerant and transfers it to the high temperature source.
* An expansion (throttling) valve that expands the liquid working medium during a constant enthalpy process.
* An evaporator facilitates the evaporation of the refrigerant while it absorbs heat from the low temperature reservoir.

The pressure-enthalpy diagram for an ideal refrigeration cycle is shown in the Fig. 2 given below, which includes the following processes:

* 1-2: Isentropic compression of the refrigerant from saturated vapour to superheated vapour (adiabatic process).
* 2-2’: Isobaric heat transfer (cooling) to the condensation temperature,
* 2’-3: Isobaric condensation, releasing the condensation enthalpy,
* 3-4: Isenthalpic expansion from saturated liquid to mixture of gas and liquid,
* 4-1: Isobaric evaporation, absorption of the evaporation enthalpy,

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Fig 2: Pressure-enthalpy diagram of an ideal refrigeration cycle

As shown in Fig. 3, the key difference between the real cyclic process and the ideal cyclic process is that in reality the compression process is not isentropic; process 1’-2’ in Fig. 3. Thus, in actual cycle more work must be expended at the compressor to achieve the same final pressure as in the ideal cycle. In addition, in the actual cycle superheating of the refrigerant is necessary prior to compression (process 1-1’ in Fig. 3) to avoid the possibility of the entry of liquid droplets into the compressor. Otherwise the compressor blades would be damaged by the impact of liquid droplets. By means of liquid sub-cooling (3-3’) the vapor portion in the mixture is reduced (compare state 4 with 4’) and more heat can be transferred in the evaporator. Hence, more evaporation heat is absorbed (4’- 1’).



Fig 3: Pressure-enthalpy diagram of a real refrigeration cycle

**PROCEDURE:**

Switch on the vapor-compression refrigeration apparatus after taking care of all necessary precautions. Allow running of the apparatus for a while so that the readings shown become stable. Change the condenser water flow rate using the knob provided, for each set of readings. Insert the values in the table of observations.

**OBJECTIVE No. 1:**

**To determine the Coefficient of Performance of heat Pump and production of Heat Pump performance curves over a range of source and delivery temperatures.**

**CALCULATIONS:**

 Work input rate across compressor wcom = 4500/ X (I)

 Heat Output across condenser qcon = mw x Cp w (T6 – T5) (II)

 Coefficient of Performance COP = Heat Output / Work Input (III)

**TABLE/OBSERVATIONS:**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Sr. No | Condenser water flow rate(g/s) | Condenser Water temperaturesoutlet/inlet(°C) | Time per rev of energy meter(s) | Compressor work input rate(kW) | Heat Outputacrosscondenser(kW) | COPof heat pump(ND) |
| mw | T6 | T5 | X | wcom | qcon |
| 1234 |  |  |  |  |  |  |  |

**SPECIMEN CALCULATION: (**for first set of reading)

The energy meter installed on the apparatus is based on the following relationship:

800 Flashes Per kilo-watt-hour (kWh) corresponds 3.6 x 106 Joules (J) i.e. 1 kWh

1Flash Per kilo-watt-hour (kWh) corresponds (3.6 x 106) / 800 Joules (J) and that equals 4500 J.

If ‘X’ is time for one Flash of Energy Meter then

Power Input = 4500/X J/s

Hence

Work Input rate (wcom) = 4500/X.

**(wcom)= \_\_\_\_\_ kW**

Heat output rate (qcon) = mw x CP x (T 6 – T5).

**(qcon) = \_\_\_\_\_ kW**

Now

**COP = \_\_\_\_\_\_\_\_**

**PLOTS: Draw the following plots:**

1. COP Vs condenser water outlet temperature
2. Compressor power input rate Vs condenser water outlet temperature
3. Heat output rate Vs condenser water outlet temperature

**COMMENTS:**

**OBJECTIVE No. 2:**

**Comparison of practical and Ideal Cycles on a P-H Diagram and determination of energy balance for Condenser and Compressor.**

**CALCULATIONS:**

Heat Transfer from Refrigerant = mr (h2 –h3) (I)

Heat Transfer to water = mw Cp (T6 – T5) (II)

Electrical Power input to Compressor = 4500/ X (III)

Enthalpy change of R134a = mr (h2 –h1) (IV)

**TABLE/OBSERVATIONS:**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Sr.No | Pressure at Comp. suction(kN/m-2) | Pressure at Comp. delivery(kN/m-2) | Temp. at Comp. suction (o C ) | Temp. at Comp. delivery (o C ) | Temp.  at Cond. outlet (o C ) | Temp. at Ex. Valve outlet (o C ) | Water mass flow rateg/s | Ref.mass flow rateg/s | TimePer rev.(s) | Cond. Water Temps.In/Out |
| P1 | P2 | T1 | T2 | T3 | T4 | mw | mref | X |  T5 | T6 |
| 1234 |  |  |  |  |  |  |  |  |  |  |  |

**SPECIMEN CALCULATIONS:** (for first set of readings)

Draw the points on p-h diagram as follows

1. Is located by the intersection of P1= \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_and T1= \_\_\_\_\_\_\_\_\_\_\_
2. Is located by the intersection of P2= \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_and T2= \_\_\_\_\_\_\_\_\_\_

(2s) Is located by assuming constant entropy compression from state point (1) and

 P2=\_\_\_\_\_\_, (S2s=S1)

1. Is located by the intersection of P3 = \_\_\_\_\_\_\_\_\_\_\_\_\_\_ and T3= \_\_\_\_\_\_\_\_
2. Is located by the intersection of T4 = \_\_\_\_\_\_\_\_\_\_\_\_\_\_ and h3=h4

The following readings were taken from p-h diagram

h1 = h2 = h2s =

h3 = h4 = v1 = v1s =

**ENERGY BALANCE:**

Condenser

Heat Transfer from Refrigerant = mr (h2 –h3) =\_\_\_\_\_\_\_\_\_\_\_\_

Heat Transfer to water = mw Cp (T6 – T5) = \_\_\_\_\_\_\_\_\_\_\_\_\_

Compressor

Electrical Power input to Compressor = 4500/ X = \_\_\_\_\_\_\_\_\_\_\_\_\_\_

Enthalpy change of R134a = mr (h2 –h1)

**COMMENTS:**

**OBJECTIVE No. 3:**

**Production of Heat Pump performance curves based on the R134a properties at a variety of Evaporating and Condensing temperatures.**

**CALCULATIONS:**

Work input rate across Compressor wcom = 4500 / X (I)

 Heat Transfer in Condenser qcon = mr x (h2 – h3) (II)

 Heat Transfer in Evaporator qevap  = mr x (h1 – h4) (III)

 Coefficient of Performance COP = qcon / wcom  (IV)

**TABLE/OBSERVATIONS:**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Sr. No | Pressureat 1kN/m-2 | Pressureat 2kN/m-2 | Tempat 1(oC ) | Tempat 2(oC ) | Tempat 3(o C ) | Tempat 4(o C ) | Ref.flow rate(g/s-1) | TimePer rev.(s) | Cond.Water Temps.In/Out | H.T.InEvap(W) | H.T.in Cond(W) | CompInput(W) | COP |
| P1 | P2 | T1 | T2 | T3 | T4 | mref | X | T6 | T5 | qevap | qcond | wcom |
| 1234 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

**SPECIMEN CALCULATION:** **(**for 4th set of reading)

Draw the state points on p-h diagram as follows:

1. Is located by the intersection of P1 = \_\_\_\_\_\_\_\_\_\_\_and T1= \_\_\_\_\_\_\_
2. Is located by the intersection of P2 = \_\_\_\_\_\_\_\_\_\_\_ and T2= \_\_\_\_\_\_\_
3. Is located by the intersection of P3 = \_\_\_\_\_\_\_\_\_\_\_ and T3= \_\_\_\_\_\_\_
4. Is located by the intersection of T4 = \_\_\_\_\_\_\_\_\_\_\_ and h3=h4

The following readings were taken from p-h diagram

h1 = h2 = h3 = h4 =

Work input rate across Compressor wcom = 4500 / X (I)

 wcom =

 **wcom =**

Heat Transfer in Condenser qcon = mr x (h2 – h3) (II)

 qcon =

 **qcon =**

Heat Transfer in Evaporator qevap = mr x (h1 – h4) (III)

 qevap =

 **qevap =**

Coefficient of Performance COP = wcom / qcon (IV)

 COP =

 **COP =**

**PLOTS: Draw the following plots:**

1. COP Vs Condenser water outlet temperature
2. Compressor power input rate Vs condenser water outlet temperature
3. Heat output rate Vs condenser water outlet temperature
4. Heat Transfer in Evaporator Vs condenser water outlet temperature

**COMMENTS:**

**OBJECTIVE No. 4:**

**Estimation of the effect of Compressor Pressure Ratio on Volumetric Efficiency.**

**CALCULATIONS:**

 Volume Flow Rate at Compressor Suction V1 = mrv1 (I)

 Compressor Pressure Ratio rP = P2/P1 (II)

 Volumetric Efficiency ηv = V1 / Vs (III)

Where ‘Vs’ is compressor Swept Volume

**TABLE/OBSERVATIONS:**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Sr. No | Compressor Suction Pressure(kN/m-2) | Compressor Suction Temperature(o C) | Compressor SuctionSpecific Volume(m3/kg) | Volume Flow Rate at Compressor Suction(m3/s) x10-4 | Compressor Delivery Pressure (kN/m-2) | Ref.flow rate(g/s-1) | Compressor PressureRatio | Volumetric Efficiency |
| P1 | T1 | v1 | V1 | P2 | mr | rP | ηv |
| 1234 |  |  |  |  |  |  |  |  |

**SPECIMEN CALCULATION:** **(**for first set of reading)

State point (1) may be plotted on p-h diagram to read out v1

Volume Flow Rate at Compressor Suction V1 = mrv1 (I)

 V1 =

 **V1 =**

Compressor Pressure Ratio rP = P2/P1 (II)

 rP =

 **rP =**

The compressor swept volume rate (assuming that it runs at 2800 rev /min)

 Vs = (2800/60) x 8.855x 10-6 m3/s

 Vs = 4.13 x 10-4 m3/s

Where 8.855 cm 3 is the swept volume of the compressor cylinder per revolution

 Volumetric Efficiency ηv = V1 / Vs (III)

 =

 **PLOTS: Draw the following plots:**

1. Compressor Pressure Ratio **Vs** % Volumetric Efficiency

**COMMENTS:**



OBSERVATIONS TABLE FOR ALL EXPERIMENTS

Atmospheric Pressure = \_\_\_\_\_\_\_\_\_\_\_\_\_mm Hg

Atmospheric Temperature =\_\_\_\_\_\_\_\_\_\_\_\_\_\_˚C

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| No. of obs. | Test | 1 | 2 | 3 | 4 | 5 | 6 |
| Time 1 Rev. of meter | $$\frac{x}{s}$$ |  |  |  |  |  |  |
| Mass flow rate | $$\frac{\dot{m\_{r}}}{gs^{-1}}$$ |  |  |  |  |  |  |
| Compressor suction (evaporator) pressure | $$\frac{P1}{kNm^{-2}}$$ |  |  |  |  |  |  |
| Compressor delivery (condenser) pressure | $$\frac{P2}{kNm^{-2}}$$ |  |  |  |  |  |  |
| Compressor suction temperature | $$\frac{T1}{˚C}$$ |  |  |  |  |  |  |
| Compressor delivery temperature | $$\frac{T2}{˚C}$$ |  |  |  |  |  |  |
| Condenser outlet temperature | $$\frac{T3}{˚C}$$ |  |  |  |  |  |  |
| Evaporator inlet temperature | $$\frac{T4}{˚C}$$ |  |  |  |  |  |  |
| Mass flow rate | $$\frac{ \dot{m\_{w}}}{gs^{-1}}$$ |  |  |  |  |  |  |
| Condenser inlet temperature | $$\frac{T5}{˚C}$$ |  |  |  |  |  |  |
| Condenser outlet temperature | $$\frac{T6}{˚C}$$ |  |  |  |  |  |  |