REFRIGERATION & AIR CONDITIONING

LABORATORY MANUAL

DEPARTMENT OF MECHANICAL ENGINEERING

UNIVERSITY OF ENGINEERING & TECHNOLOGY

LAHORE (KSK CAMPUS)

Submitted by:

Name:

Registration No.:

Submitted to:

Preface

In most of the engineering institutions, the laboratory coursework constitutes an integral part of the senior course Refrigeration & Air Conditioning at the undergraduate level. The experiments to be performed in a laboratory should be ideally designed in such a way so that the understanding of basic principles as well as the visualization of different phenomenon encountered in applications could be covered.

The objective of this manual is to familiarize the students with practical skills, measurement techniques and interpretation of results. It is intended to make this manual self-contained in all respects, so that it can be used as a laboratory manual. In all the experiments, the relevant theory and general guidelines for the procedure to be followed have been given. Moreover, tabular sheets for entering the observations have also been provided while graph sheets have also been included wherever necessary.

It is suggested that the students should complete the computations in the laboratory itself. However, the students are advised to refer to the relevant text before interpreting the results and writing comments. The questions provided at the end of each experiment will reinforce the students to understand the subject and also help them to prepare for viva-voce exams.

General Instructions to Students

- Read the lab manual and any background material needed before you come to the lab. You must be prepared for your experiments before coming to the lab. In many cases you may have to go back to your textbooks to review the principles dealt within the experiment.
- Actively participate in the lab and don't hesitate to ask questions. Utilize the teaching assistants. You should be well prepared before coming to the laboratory, unannounced questions may be asked at any time during the lab.
- Carelessness in handling lab equipment may result in serious injury to the individual or any effect to the equipment. Do not run near moving machinery. Always remain alert for strange sounds. Guard against entangling clothes in moving parts of machinery.
- Students must follow the proper dress code inside the laboratory. To protect clothing from dirt, wear a lab apron. Long hair should be tied back.
- Calculator, graph sheets and drawing accessories are mandatory.
- While performing the experiments, proceed carefully to minimize any water spills, especially on the electric circuits and wire.
- Make your workplace clean before leaving the laboratory. Maintain silence, order and discipline inside the lab.
- Cell phones are not allowed inside the laboratory.
- Any sort of injury must be reported to the instructor immediately.

TABLE OF CONTENTS

List of Experiments

Lab Session No.	Objectives
Lab Session No. 1	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.
Lab Session No. 2	1. Production of heat pump performance curves with different inlet and outlet temperature. Water as a heat source. Heat Pump water-water. 2. Lay out of steam compression cycle in a diagram P-H and comparison with the ideal cycle. Water as a heat source. Heat Pump water-water. 3. Preparation of the performance curves of the heat pump based on the properties of the refrigerant and at different condensations and evaporation temperatures. Water as heat source. Heat pump water-water
Lab Session No. 3	1. Demonstration of water circuit and ammonia circuit in the cycle using Electric Operation (Generator). 2. Demonstration of water circuit and ammonia circuit in the cycle using Gas Operation (Gas-Burner)
Lab Session No. 4	1. Investigation of the effects upon the surface temperature of either face of the module with increasing power. (Peltier Effect) 2. Investigation of the effect upon heat transfer direction of reversing the polarity of the power supply to the module. (Thomson or Lenz Effect) 3. Investigation of the variation in open circuit voltage across the module due to the variation in surface temperature difference. (Seeback Effect) 4. Investigation of the power generating performance of the module with a steady load and increasing temperature difference. 5. Estimation of the coefficient of performance of the module when acting as a refrigerator.
Lab Session No. 5	1. Demonstration of the Basic Refrigeration Cycle by using Automatic (Constant Pressure) Expansion Valve as a Flow Control. Demonstration of the Basic Refrigeration Cycle by using Internally Equalised Thermostatic Expansion Valve and the Externally Equalised Thermostatic Expansion. 2. Demonstration of Pressure/ Temperature Relation using Evaporator Pressure Regulator and function of Capillary Tube as a Flow Control. 3. Demonstration of the Dual Temperature Operation by using Capillary Expansion Device and Internally Equalised Thermal Expansion Valve. 4. Demonstration of the Reversed cycle operation, Causes of Excess Discharge Pressure and demonstration of water Cooled Condenser.
Lab Session No. 6	1. Observation of the process within forced draught cooling tower. 2. Determination of all end state properties of air and water from tables or charts and

	the application of the steady flow equation to selected systems to draw up energy and mass balances. 3. Investigation of the effect of cooling on "approach to wet bulb" and Relationship between Cooling Load and Cooling Range. 4. Investigation of relation between air velocity and i) Wet bulb approach ii) Pressure drop through the packing. 5. Investigation of the effect of packing density on the performance of the cooling tower.
Lab Session No. 7	1. Description of MIMIC diagram and component of simulator. And Observation of boiler, chiller, main AHU, VT circuit, DHW and controlling them through potentiometer and illuminated switches.

List of Figures

List of Tables

LAB SESSION NO: 01

REFRIGERATION AND AIR CONDITIONING LABORATORY

MECHANICAL HEAT PUMP

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.

OBJECTIVE NO: 2

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

OBJECTIVE NO: 3

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

OBJECTIVE NO: 4

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

DEPARTMENT OF MECHANICAL ENGINEERING &TECHNOLOGY
UNIVERSITY OF ENGINEERING AND TECHNOLOGY LAHORE (KSK CAMPUS)

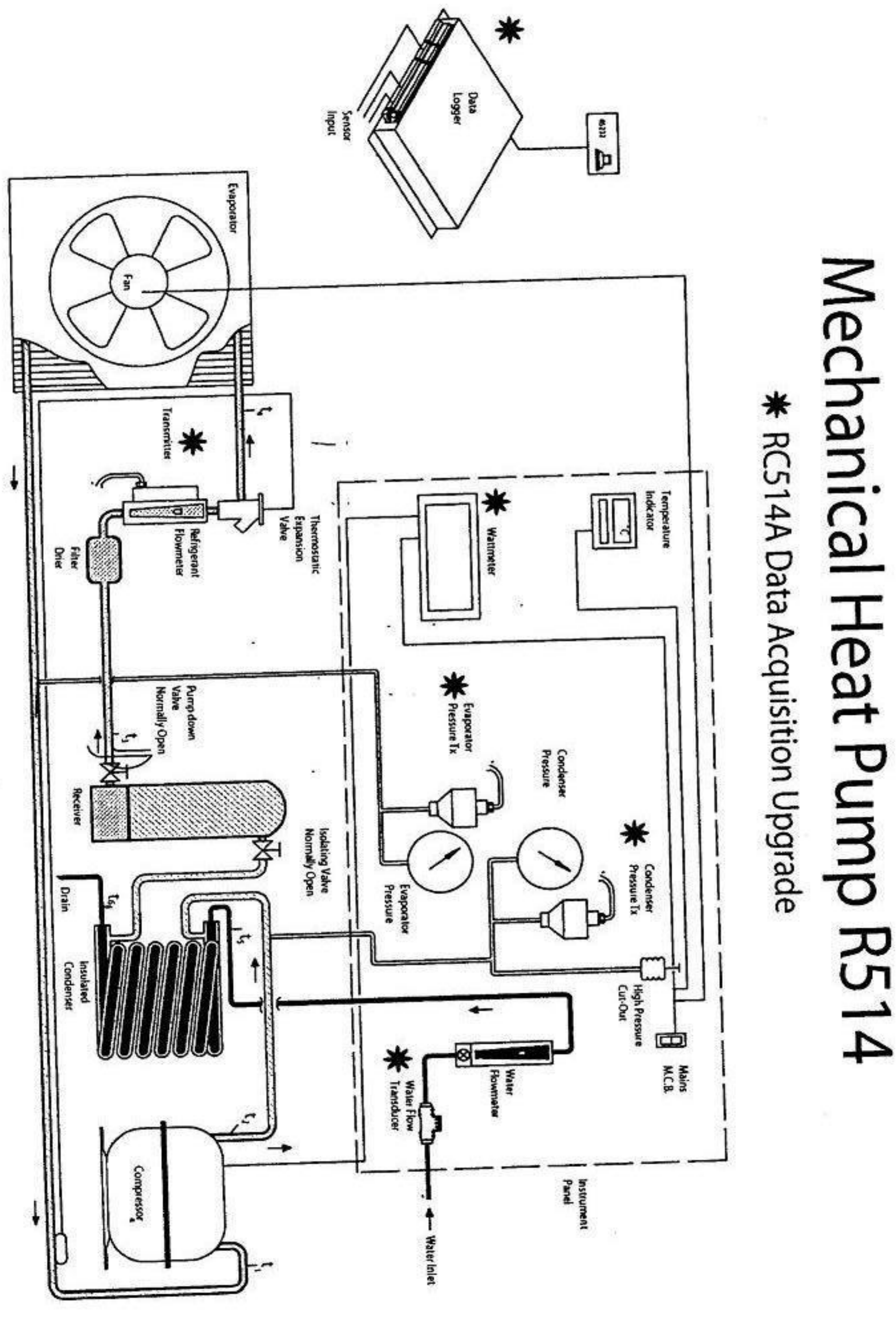


Figure 1.1:: Schematic Diagram of Mechanical Heat Pump

1.1OBJECTIVE NO : 01

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

1.1.1 APPARATUS:

Mechanical Heat Pump

1.1.2 SCHEMATIC DIAGRAM:

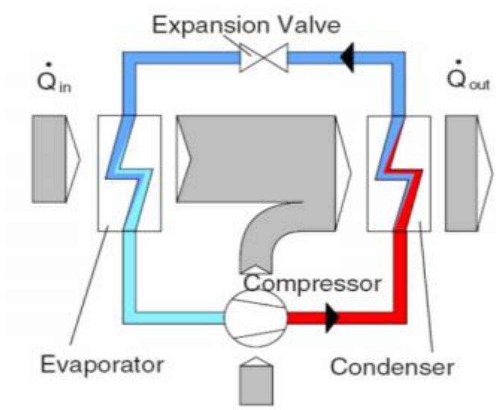


Figure 1.2: Vapor Compression Refrigeration Cycle

1.1.3 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. 1.2 (a), 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,

As shown in Fig. 1.2 (b), 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').

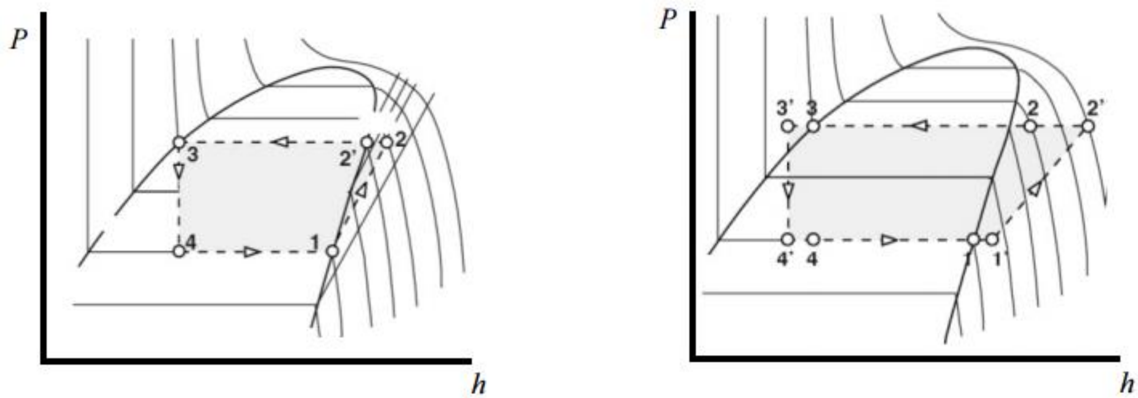


Figure 1.1: Pressure-enthalpy diagram of an (a) ideal refrigeration cycle (b) real refrigeration cycle

1.1.4 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.

1.1.5 CALCULATIONS:

Work input rate across compressor $w_{com} = 4500/X$ (I)

Heat Output across condenser $q_{con} = m_w \times C_{p\,w}(T_6 - T_5)$ (II)

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

Table 1.0.1: Observations and calculations of operating parameters of Mechanical Heat Pump

Sr. No	Condenser water flow rate (g/s)	Condenser Water temperatures outlet/inlet (°C)		Time per rev of energy meter (s)	Compressor work input rate (kW)	Heat Output across condenser (kW)	COP of heat pump (ND)
	m_w	T_6	T_5	X	w_{com}	q_{con}	
1							
2							
3							
4							

1.1.6 SPECIMEN CALCULATION: (for first set of readings)

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

800 Flashes Per kilo-watt-hour (kWh) corresponds 3.6 x 10^6 Joules (J) i.e. 1 kWh

1Flash Per kilo-watt-hour (kWh) corresponds (3.6 x 10^6) / 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 (w_{com}) = 4500/X.

(w_{com})= _____ kW

Heat output rate (q_{con}) = m_w x C_P x ($T_6 - T_5$).

(q_{con}) = _____ 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

1.1.7 COMMENTS:

1. 2 OBJECTIVE NO: 02

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

1.2.1 APPARATUS:

Mechanical Heat Pump

1.2.2 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.

1.2.3 CALCULATIONS:

Heat Transfer from Refrigerant = $m_r (h_2 - h_3)$ (I)

Heat Transfer to water = $m_w C_p (T_6 - T_5)$ (II)

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

Enthalpy change of R134a = $m_r (h_2 - h_1)$ (IV)

Table 1.0.2: Observations and calculations of operating parameters of Mechanical Heat Pump

Sr. No	Pressure at Comp. suction (kN/m^{-2})	Pressure at Comp. delivery (kN/m^{-2})	Temp. at Comp. suction (^oC)	Temp. at Comp. delivery (^oC)	Temp. at Cond. outlet (^oC)	Temp. at Ex. Valve outlet (^oC)	Water mass flow rate g/s^{-1}	Ref. mass flow rate g/s^{-1}	Time Per rev. (s)	Cond. Water Temps. In/Out	
	P_1	P_2	T_1	T_2	T_3	T_4	m_w	m_{ref}	X	T_5	T_6
1											
2											
3											
4											

1.2.4 SPECIMEN CALCULATIONS: (for first set of readings)

Draw the points on p-h diagram as follows

(1) Is located by the intersection of P_1= ________________and T_1= ____________

(2) Is located by the intersection of P_2= ________________and T_2= ___________

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

P_2=_______, (S_{2s}=S_1)

(3) Is located by the intersection of P_3 = _______________ and T_3= _________

(4) Is located by the intersection of T_4 = _______________ and h_3=h_4

The following readings were taken from p-h diagram

h_1 = h_2 = h_{2s} =

h_3 = h_4 = v_1 = v_1 =

1.2.5 ENERGY BALANCE:

Condenser

Heat Transfer from Refrigerant = m_r (h_2 –h_3) =_____________

Heat Transfer to water = m_w C_p (T_6 – T_5) = ______________

Compressor

Electrical Power input to Compressor = 4500/ X = _______________

Enthalpy change of R134a = m_r (h_2 –h_1)

1.2.6 COMMENTS:

1.3 OBJECTIVE NO: 03

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

1.3.1 APPARATUS:

Mechanical Heat Pump

1.3.2 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.

1.3.3 CALCULATIONS:

Work input rate across Compressor $w_{com} = 4500 / X$ (I)

Heat Transfer in Condenser $q_{con} = m_r \times (h_2 - h_3)$ (II)

Heat Transfer in Evaporator $q_{evap} = m_r \times (h_1 - h_4)$ (III)

Coefficient of Performance $COP = q_{con} / w_{com}$ (IV)

Table 1.0.3: Observations and calculations of operating parameters of Mechanical Heat Pump

Sr. No	Pressure at 1 kN/m^{-2}	Pressure at 2 kN/m^{-2}	Temp at 1 (^oC)	Temp at 2 (^oC)	Temp at 3 (^oC)	Temp at 4 (^oC)	Ref. flow rate (g/s^{-1})	Time Per rev. (s)	Cond. Water Temps. In/Out		H.T. In Evap (W)	H.T. in Cond (W)	Comp Input (W)	COP
	P_1	P_2	T_1	T_2	T_3	T_4	m_{ref}	X	T_6	T_5	q_{evap}	q_{cond}	w_{com}	
1														
2														
3														
4														

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

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

(5) Is located by the intersection of P_1 = ___________ and T_1= _______
(6) Is located by the intersection of P_2 = ___________ and T_2= _______
(7) Is located by the intersection of P_3 = ___________ and T_3= _______
(8) Is located by the intersection of T_4 = ___________ and $h_3=h_4$

The following readings were taken from p-h diagram

h_1 = h_2 = $h_3 = h_4$ =

Work input rate across Compressor w_{com} = 4500 / X (I)

w_{com} =

$\mathbf{w_{com}}$ =

Heat Transfer in Condenser $q_{con} = m_r \times (h_2 - h_3)$ (II)

q_{con} =

$\mathbf{q_{con}}$ =

Heat Transfer in Evaporator $q_{evap} = m_r \times (h_1 - h_4)$ (III)

q_{evap} =

$\mathbf{q_{evap}}$ =

Coefficient of Performance COP = w_{com} / q_{con} (IV)

COP =

COP =

PLOTS: Draw the following plots:

4- COP Vs Condenser water outlet temperature
5- Compressor power input rate Vs condenser water outlet temperature
6- Heat output rate Vs condenser water outlet temperature
7- Heat Transfer in Evaporator Vs condenser water outlet temperature

1.3.5 COMMENTS:

1.4 OBJECTIVE NO: 04

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

1.4.1 APPARATUS:

Mechanical Heat Pump

1.4.2 PROCEDURE:

Switch on the vapour-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.

1.4.3 CALCULATIONS:

Volume Flow Rate at Compressor Suction $V_1 = m_r v_1$ (I)

Compressor Pressure Ratio $r_P = P_2/P_1$ (II)

Volumetric Efficiency $\eta_v = V_1 / Vs$ (III)

Where 'Vs' is compressor Swept Volume

Table 1.0.4: Observations and calculations of operating parameters of Mechanical Heat Pump

Sr. No	Compressor Suction Pressure (kN/m^{-2})	Compressor Suction Temperature (^oC)	Compressor Suction Specific Volume (m^3/kg)	Volume Flow Rate at Compressor Suction (m^3/s) x10^{-4}	Compressor Delivery Pressure (kN/m^{-2})	Ref. flow rate (g/s^{-1})	Compressor Pressure Ratio	Volumetric Efficiency
	P_1	T_1	v_1	V_1	P_2	m_r	r_P	η_v
1								
2								
3								
4								

1.4.4 SPECIMEN CALCULATION: (for first set of reading)

State point (1) may be plotted on p-h diagram to read out v_1

Volume Flow Rate at Compressor Suction $V_1 = m_r v_1$ (I)

$V_1 =$

$V_1 =$

Compressor Pressure Ratio $r_P = P_2/P_1$ (II)

$r_P =$

$r_P =$

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

$$Vs = (2800/60) \times 8.855 \times 10^{-6}\ m^3/s$$

$$Vs = 4.13 \times 10^{-4}\ m^3/s$$

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

Volumetric Efficiency $\eta_v = V_1 / Vs$ (III)

$=$

PLOTS: Draw the following plots:

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

1.4.5 COMMENTS:

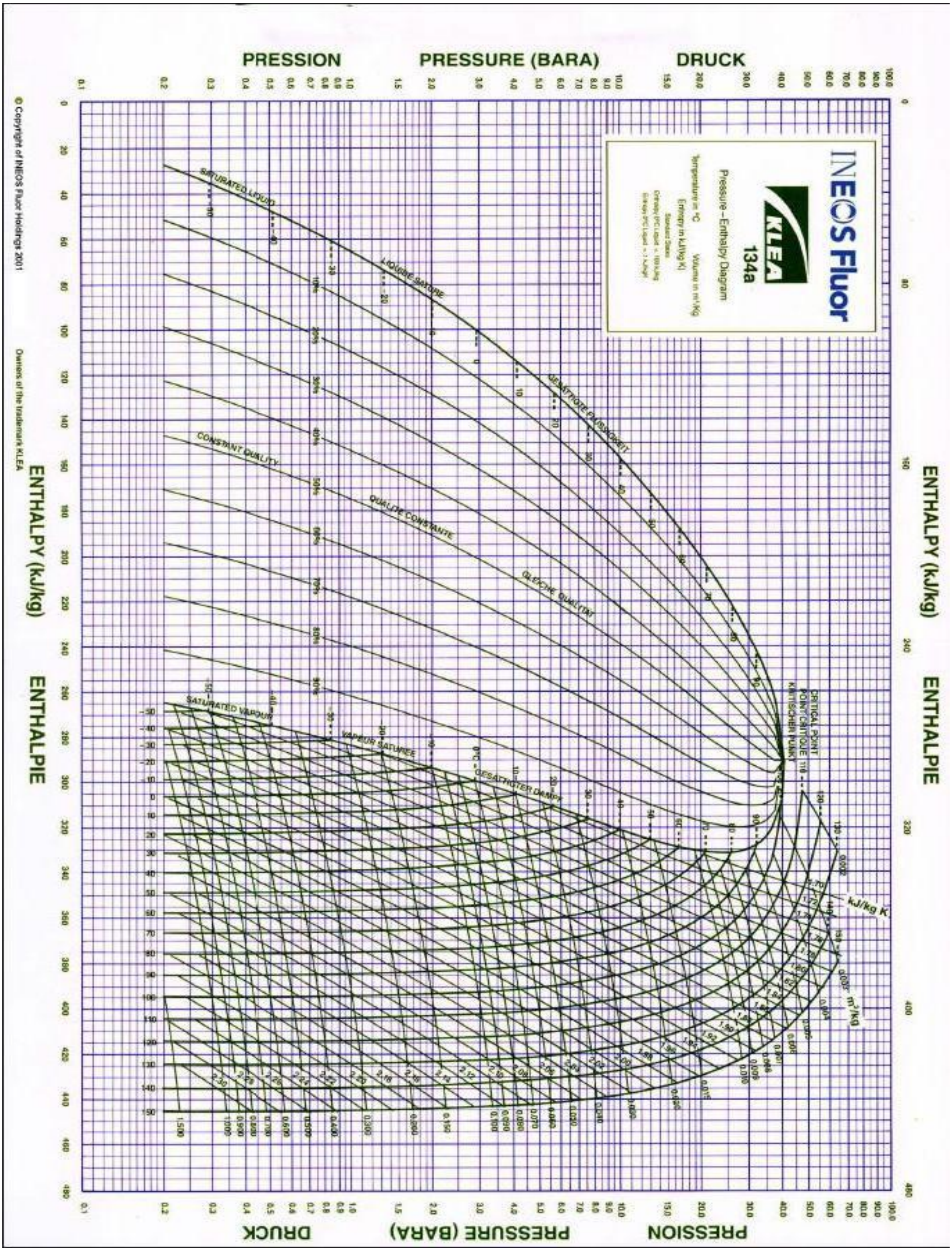


Figure 1.3: P-h Chart for Refrigerant R134a

Table 1.0.5: Observations and calculations of all operating parameters of Mechanical Heat Pump

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	$\frac{T1}{^\circ C}$						
Compressor delivery temperature	$\frac{T2}{^\circ C}$						
Condenser outlet temperature	$\frac{T3}{^\circ C}$						
Evaporator inlet temperature	$\frac{T4}{^\circ C}$						
Mass flow rate	$\frac{\dot{m}_w}{gs^{-1}}$						
Condenser inlet temperature	$\frac{T5}{^\circ C}$						
Condenser outlet temperature	$\frac{T6}{^\circ C}$						

LAB SESSION: 02

REFRIGERATION AND AIR CONDITIONING LABORATORY

REFRIGERATION BASIC UNIT

OBJECTIVE NO: 1

Production of heat pump performance curves with different inlet and outlet temperature. Water as a heat source. Heat Pump water-water.

EXPERIMENT NO: 2

Lay out of steam compression cycle in a diagram P-H and comparison with the ideal cycle. Water as a heat source. Heat Pump water-water.

EXPERIMENT NO: 3

Preparation of the performance curves of the heat pump based on the properties of the refrigerant and at different condensations and evaporation temperatures. Water as heat source. Heat pump water-water

DEPARTMENT OF MECHANICAL ENGINEERING &TECHNOLOGY
UNIVERSITY OF ENGINEERING AND TECHNOLOGY LAHORE (KSK CAMPUS)

Figure 2.1 : REFRIGERATION BASIC UNIT

2.1 OBJECTIVE: 01

Production of heat pump performance curves with different inlet and outlet temperature. Water as a heat source. Heat Pump water-water.

2.1.1 APPARATUS:

Refrigeration Basic Unit (TRLLB Equipment)

2.1.2 PROCEDURE:

Turned on the apparatus and adjust the water flow until 80% of the maximal flow, using the flow regulator C-2. Allow the stabilisation of the system. Complete the observation table with the values specified on it. Keeping the temperature constant at the water evaporator, reduce the water flow, so the temperature will rise 6℃ at the outlet of the condenser (ST-2).Allow the stabilisation of the heat pump and repeat the commentaries at similar rises of ST-2 until reaching the value of 65℃.

2.1.3 CALCULATIONS:

Specific heat of the water=4180 J/Kg˚C=4.18 J/Kg˚C ; Water density= 0.99997 g/cm^3=1.0 g/cm^3

1kWh= (1000/3600) W (J/s) ; 1lit/min= (1000/60) cm^3/sec;

M_w= (C_2 cm^3/sec) × (Water Density) ; $Q_{transfered} = M_w \times C_p \times (T_2 - T_1)$

COP = $Q_{transfered}/W_{electric}$

Table 2.0.1: Observations and calculations of operating parameters of Basic Refrigeration Unit

Parameters	Units	1	2	3	4	5
Energy consumed by compressor	W (kWh)					
Temp. at water inlet condenser	ST-5(ºC)					
Temp. at water outlet condenser	ST-6(ºC)					
Water Inlet flow in condenser	C-2(l/min)					
Inlet temp. in water evaporator	ST-3(ºC)					
Mass flow rate in condenser	M_w (g/s)					
Heat transferred to water	Q_{transf}(J/s)					
COP	----					

2.1.4 Specimen Calculations:

$W_{electric}$ = _______×kWh× (1000/3600) = ______W ; C-2=_____× lit/min× (1000/60) =_____cm^3/sec

M_w= (C_2 cm^3/sec) × (Water Density g/cm^3) ; M_w = _________**g/s**

$Q_{transferred}$=M_w*Cp*(T_6-T_5) ; $Q_{transferred}$ =__________W

COP = $Q_{transferred}$ / $W_{electric}$; COP =____________

PLOTS: Draw the following plots:

8- COP Vs condenser water outlet temperature
9- Heat output rate Vs condenser water outlet temperature

2.1.5 COMMENTS:

2.2 OBJECTIVE: 02

Lay out of steam compression cycle in a diagram P-H and comparison with the ideal cycle. Water as a heat source. Heat Pump water-water.

2.2.1 APPARATUS:

Refrigeration Basic Unit (TRLLB Equipment)

2.2.2 PROCEDURE:

Using water as heat source, adjusted the water flow in the condenser at an intermediate interval. Contacted the current to the equipment and let it to stabilize. Take note of the values required in the table.

Table 2.0.2: Observations and calculations of operating parameters of Basic Refrigeration Unit

Parameters	Units	1	2	3	4	5
Refrigerating pressure at the inlet of compressor	M-4(bar)					
Refrigerating pressure at the outlet of condenser	M-2(bar)					
Refrigerating temp. at inlet of compressor	ST-4(^oC)					
Refrigerating temp. at outlet of compressor	ST-1(^oC)					
Refrigerating temp. at outlet of condenser	ST-2(^oC)					
Refrigerating temp. at outlet of spreading valve	ST-3(^oC)					

From PH diagram we obtained the following Values;

No of Obs.	$\mathbf{h_1}$(kJ/kg)	$\mathbf{h_2}$(kJ/kg)	$\mathbf{h_3=h_4}$(kJ/kg)	$\mathbf{h_{2s}}$(kJ/kg)
1				
2				
3				
4				

2.2.3 SPECIMEN CALCULATIONS: (for first set of readings)

Draw the points on p-h diagram as follows

(9) Is located by the intersection of M-4= _______________and ST-4= ___________
(10) Is located by the intersection of M-2= _______________and ST-1= ___________
(2s) Is located by assuming constant entropy compression from state point (1) and

M-2=________, ($S_{2s}=S_1$)

(11) Is located by the intersection of M-2 = ______________ and ST-2= ________
(12) Is located by the intersection of ST-3= ______________ and $h_3=h_4$
(4′) Is located by the intersection of M-2= ______________ and $h_3=h_4$

The following readings were taken from p-h diagram

h_1 = h_2 = h_{2s} = h_3 = h_4 =

2.2.4 COMMENTS:

2.3 OBJECTIVE: 03

Preparation of the performance curves of the heat pump based on the properties of the refrigerant and at different condensations and evaporation temperatures. water as heat source .heat pump water-water

2.3.1 APPARATUS:

Refrigeration Basic Unit (TRLLB Equipment)

2.3.2 PROCEDURE:

Selected water as heat source and turned the evaporator flow to the maximal one. Adjusted the water in the condenser at a high flow and connected the equipment to the electric current. When the equipment had stabilized, took note of the pressure of the condenser (M-2) and the temperature of the evaporator (ST-3).Adjusted the water flow until ST-3 reached its initial value. Once stabilized, repeated the annotations. Repeated the trial with increase of 100KN/m^2 in the sensor SP-2 until the manometric pressure reached more or less 1400KN/m^2.Repeated the experience with other constant valve of ST-3 (in order to increase the value of ST-3, increased the water flow of the evaporator and to decrease it, decreased that flow).

2.3.3 CALCULATIONS:

Specific heat of the water=4180 J/Kg˚C=4.18 J/Kg˚C ; Water density= 0.99997 g/cm^3=1.0 g/cm^3

Density of R134a = 1225 g/cm^3 ; 1kWh= (1000/3600) W (J/s) ; 1lit/min= (1000/60) cm^3/sec

M_r= (C_1 cm^3/sec) × (Density of R134a) ; Heat produced inside the condenser=Q_1=M_r× (h_3-h_2)

M_w= (C_2 cm^3/sec) × (Water Density); Heat transferred inside the condenser to water=Q_3=Mw×Cp× (T_6-T_5)

$COP_1 = Q_1/W_{electric}$; $COP_2 = (h_{2s} – h_3)/(h_{2s} – h_1)$; $COP = Q_3/W_{electric}$

Table 2.0.3: Observations and calculations of operating parameters of Basic Refrigeration Unit

Parameters	Units	1	2	3	4	5
Energy used by compressor	W(kWh)					
Flow of refrigerant	C-1 (1/min)					
Pressure of refrigerant at condenser outlet	M-2 (bar)					
Temp. of refrigerant at compressor inlet	ST-4 (^oC)					
Temp. of refrigerant at compressor outlet	ST-1 *(^oC)*					
Temp. of refrigerant at condenser outlet	ST-2 *(^oC)*					
Temp. of refrigerant at evaporator inlet	ST-3 *(^oC)*					
Outlet temp. of water evaporator	ST-7 *(^oC)*					
Water evaporator flow	C-3 *(1/min)*					
Water inlet temp. at condenser	ST-5 *(^oC)*					
Water outlet temp. at condenser	ST-6 *(^oC)*					
Water flow at condenser	C-2 *(1/min)*					
Mass flow rate of Refrigerant	M_r (g/s)					
Mass flow rate of water in condenser	M_w (g/s)					

Sr. #	h_1(kJ/kg)	h_2(kJ/kg)	h_3=h_4(kJ/kg)	h_{2s}(kJ/kg)	Q_1(W)	Q_2 (W)	COP_1	COP_2	COP_3
1									
2									
3									
4									

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

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

(1) Is located by the intersection of M-4 = ___________ and ST-4= _______
(2) Is located by the intersection of M-2 = ___________ and ST-1= _______

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

M-1=________, ($S_{2s}=S_1$)

(3) Is located by the intersection of M-2 = ___________ and ST-2= _______
(4) Is located by the intersection of ST-3 = ___________ and $h_3=h_4$

The following readings were taken from p-h diagram

h_1 = h_2 = h_{2s} = $h_3 = h_4$ =

$W_{electric}$ = _______×kWh× (1000/3600) = ______W ; C-1=_____× lit/min× (1000/60) =_____cm^3/sec

C-2=_____× lit/min× (1000/60) =_____cm^3/sec ; M_r= (C_1 cm^3/sec) × (Density of R134a g/cm^3)

M_r = __________**g/s** ; M_w= (C_2 cm^3/sec) × (Water Density g/cm^3)

M_w = __________**g/s** ; $Q_1=M_r\times(h_3-h_2)$ =_____________W

$Q_3=Mw\times Cp\times(T_6-T_5)$=_____________ =_______________ ; $COP_1 = Q_1/W_{electric}$

$COP_2 = (h_{2s} - h_3)/(h_{2s} - h_1)$ =_____________ ; $COP = Q_3/W_{electric}$= _______________

PLOTS: Draw the following plots:

1- COP_1 ,COP_2 ,COP_3 Vs Condenser water outlet temperature
2- Heat Produced (Q_1) Vs condenser water outlet temperature

2.3.5 COMMENTS:

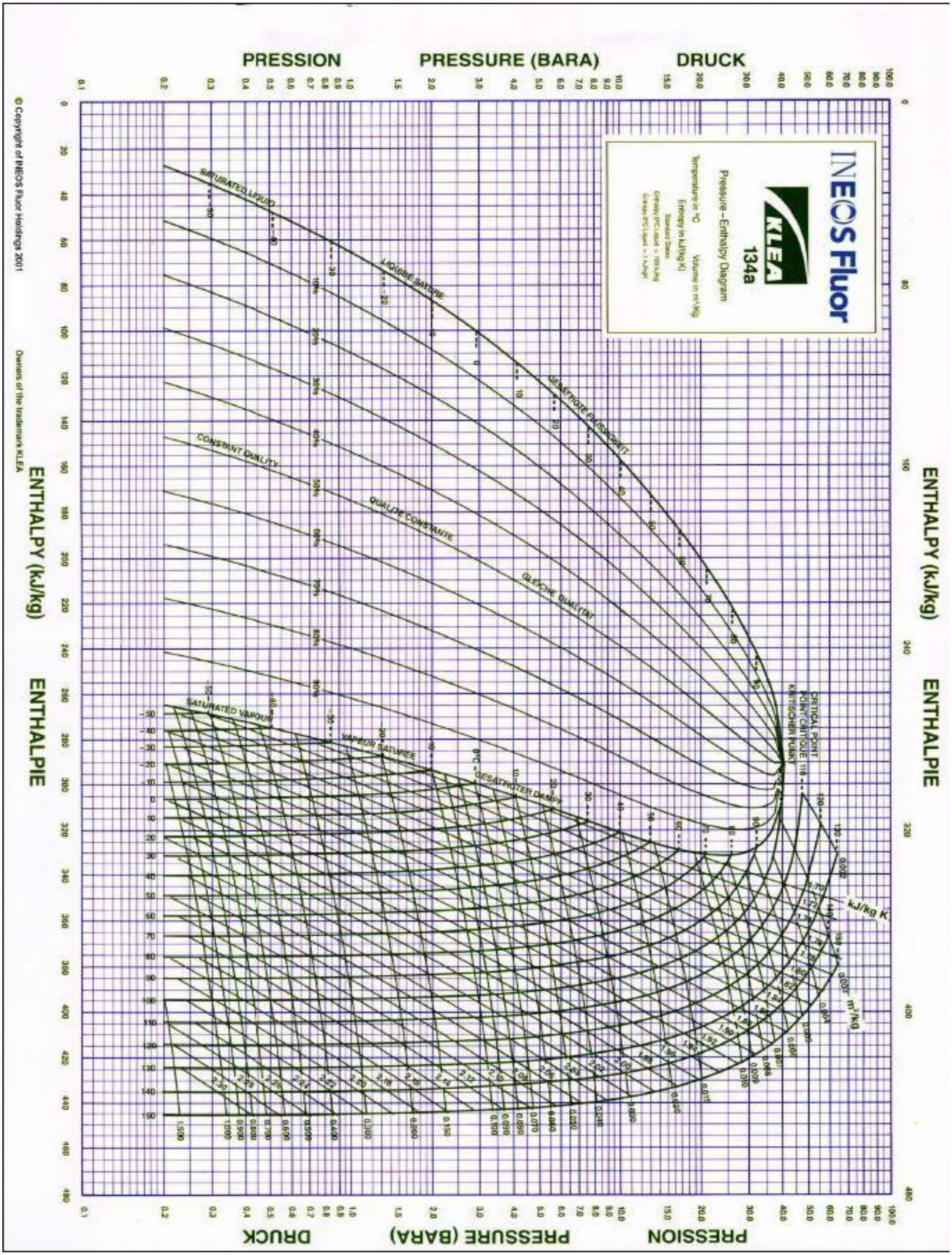


Figure 2.2: P-h Chart for Refrigerant R134A

Table 2.0.4: Observations and calculations of all operating parameters of Basic Refrigeration Unit

Atmospheric Pressure = _____________mm Hg

Atmospheric Temperature =______________˚C

Parameters	Units	1	2	3	4	5
Energy used by compressor	W(kWh)					
Flow of refrigerant	C-1 (1/min)					
Water Flow at condenser	C-2 (1/min)					
Water evaporator Flow	C-3 (1/min)					
Pressure of refrigerant at compressor outlet	M-1 (bar					
Pressure of refrigerant at condenser outlet	M-2 (bar)					
Pressure of refrigerant at evaporator inlet	M-3 (bar)					
Pressure of refrigerant at compressor inlet	M-4 (bar)					
Temp. of refrigerant at compressor outlet	ST-1 *(^{o}C)*					
Temp. of refrigerant at condenser outlet	ST-2 *(^{o}C)*					
Temp. of refrigerant at evaporator inlet	ST-3 *(^{o}C)*					
Temp. of refrigerant at compressor inlet	ST-4 *(^{o}C)*					
Water inlet temp. at condenser	ST-5 *(^{o}C)*					
Water outlet temp. at condenser	ST-6 *(^{o}C)*					
Outlet temp. of water evaporator	ST-7 *(^{o}C)*					

LAB SESSION 03

REFRIGERATION AND AIR CONDITIONING LABORATORY

ABSORPTION REFRIGERATION DEMONSTRATOR 816

OBJECTIVE NO: 1

Demonstration of water circuit and ammonia circuit in the cycle using electric operation (Generator).

OBJECTIVE NO: 2

Demonstration of water circuit and ammonia circuit in the cycle using Gas Operation (Gas-Burner)

DEPARTMENT OF MECHANICAL ENGINEERING &TECHNOLOGY
UNIVERSITY OF ENGINEERING AND TECHNOLOGY LAHORE (KSK CAMPUS)

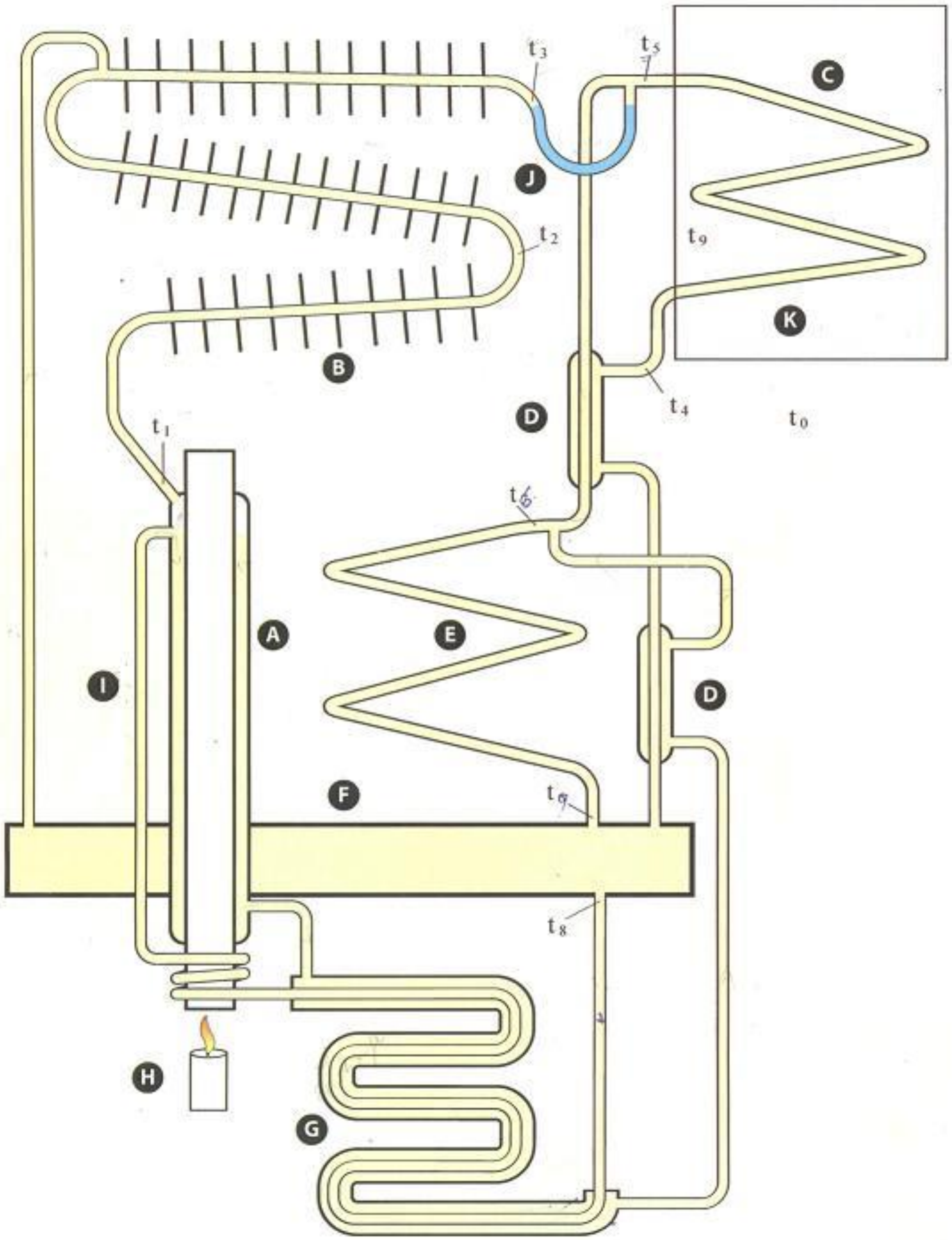


Figure 3.1: Schematic diagram of Electrolux Refrigerator

NAMES OF SCEMATIC USED IN FIG ABOVE

A	**Generator**
B	**Condenser**
C	**Evaporator**
D	**Gas Heat Exchanger**
E	**Absorber**
F	**Absorber Vessel**
G	**Liquid Heat Exchanger**
H	**Generator Heater**
I	**Vapor Pump**
J	**Liquid Trap**
K	**Cabinet**
t_0	**Ambient Temperature**
t_1	**Generator Outlet Temperature**
t_2	**Condenser Temperature**
t_3	**Condenser Outlet Temperature**
t_4	**Evaporator Inlet Temperature**
t_5	**Evaporator Outlet Temperature**
t_6	**Hydrogen + Ammonia Outlet Temperature**
t_7	**Hydrogen + Ammonia Inlet Temperature**
t_8	**Generator Inlet Temperature**
t_9	**Cabinet Temperature**

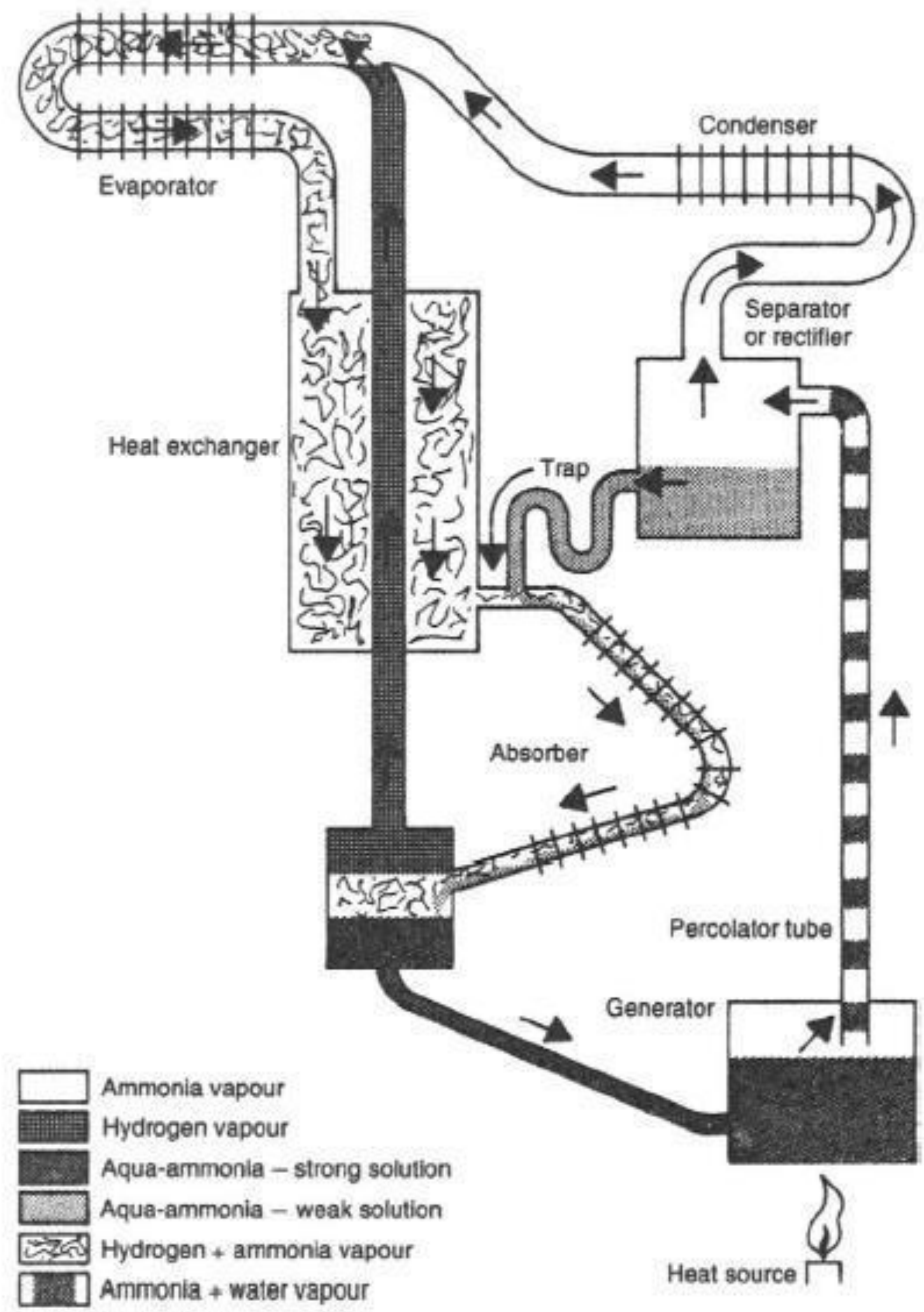


Figure *Absorption system cycle*

Fig. 3.2

Figure 3.2: Schematic diagram of absorption refrigeration system

3.1 OBJECTIVE: 01

Demonstration of water circuit and ammonia circuit in the cycle using electric operation(Generator).

3.1.1 APPARATUS:

Absorption refrigeration Demonstrator

3.1.2 Basic Principals

Absorption refrigeration operates on two fundamental principles:

1. The ability of large quantities of ammonia gas to be absorbed into cold water at low pressure and then at higher temperature and pressure to be driven out again.

2. The ability to condense ammonia vapor at a high pressure and temperature and to evaporate it at low temperature in the presence of an inert gas with the total pressure remaining constant. During the evaporation process a heat can be transferred to the ammonia.

With reference to the above principals absorption refrigerator incorporated in the Absorption Refrigeration Demonstrator operates as follows:

3.1.3 Liquid Circuit

The Absorber Vessel (F) contains approximately 65% water and 35% ammonia by weight. This solution is commonly called aqua-ammonia. The liquid from the Absorber Vessel flows through the Liquid Heat Exchanger (G) to the Vapor Pump (I) where due to the application of heat and subsequent increase in temperature some of the ammonia vapor is driven out of the solution. This vapor forms bubbles, which push the liquid up the pump tube. For this reason the device is sometimes called a **Vapor Bubble Pump**. The liquid falls downwards through the Generator (A) where it is further heated, its temperature raised to approaching 200℃ and further ammonia is driven out of the solution. This produces a weak solution that contains approximately 10% ammonia. The hot weak solution then passes from the Generator (A) back through the Liquid Heat Exchanger (G), where it gives up heat to the to the incoming strong solution entering from the Absorber Vessel (F). it then passes to the top of the Absorber Vessel.

3.1.4 Ammonia Circuit

The ammonia vapor from the Vapor Pump (I) has a temperature of approximately 150℃ when it leaves the Generator (A). Under these conditions the gas contains a quantity of water vapor that can be condensed in a water separator of rectifier positioned before the Condenser where the temperature drops be heat rejection to ambient. The pure ammonia vapor then enters the Condenser (B) at an approximate temperature of 70℃.

The condenser consists of a finned tube and heat is rejected at approximately ambient temperature. At this temperature and a pressure of approximately 256 bar the ammonia vapor condenses. The liquid ammonia passes into the tubular coil of the Evaporator © through the liquid (J) where it wets the internal surface of the evaporator tube.

3.1.5 Hydrogen Circuit

Hydrogen gas passes over the wetted surface of the evaporator tube and in the first part of the evaporator the ammonia evaporates into the hydrogen at a temperature of between -30 and -18℃. In this section of the evaporator the pressure is approximately 25 bars with the ammonia at a partial pressure of approximately 1bar and the hydrogen at a partial pressure of approx 24 bars.

As the ammonia continues to evaporate into the hydrogen the partial pressure of the ammonia gradually increases and the evaporating temperature also increases. At the end of the evaporator the ammonia has an evaporating temperature of approximately -5℃.

The weight of the mixture of hydrogen and ammonia is now considerably greater than the weight of almost pure hydrogen. The heavier mixture drops through the Gas Heat Exchanger (D) and Absorber (E) and reaches the upper surface of the Absorber Vessel (F).

In this process the gas which is rich in ammonia vapor meets the **weak solution** from the Generator (A) in the Absorber (E). The Absorber has a large surface area and a temperature close to ambient. The **weak solution** therefore remains relatively cool and absorbs the ammonia vapor from the gas.

The hydrogen being inert remains unaffected in this process but becomes more pure. The pure hydrogen is therefore able to leave the top of the Absorber Vessel (F) while the **rich solution** (water and ammonia) leaves the bottom of the Absorber Vessel to repeat the cycle.

3.1.6 OPERATING PROCEDURE:

1. Electric Operation: Turn on the main switch and the one internal lamp will light. The digital temperature indicator and digital wattmeter displays will also illuminate.

2. Refrigeration Load (Duty): This is determined by the input to the electric heating element inside the cabinet and is controlled by the evaporator input control setting. With the changeover switch in the left position the digital wattmeter displays the evaporator heat input rate.

3. Generator Power Input: This is determined by the input to the electric heating element inside the Generator and is controlled by the generator input control setting. With the changeover switch in the right position the digital wattmeter displays the generator heat input rate.

4. Energy Meter: Electrical input to drive the Generator is measured by timing the integrating energy meter.

5. Digital Temperature Indicator: This becomes operative as soon as the electrical supply is switched on. The temperature may be measured at 10 points in the circuit by selecting stations 0 to 9 on the switch. The individual temperature points referred to in the **SCHEMATIC DIAGRAM** and **UNITS AND SYMBOLS** are selected and displayed on the indicator by switching to the corresponding number on the selector switch below the indicator.

6. Digital Wattmeter: This becomes operative as soon as the electrical supply is switched on. The digital wattmeter comprises a 3/12 digit true power AC wattmeter and current transformer. The current drawn by the evaporator heater or generator is sensed by a current transformer and sent as a mA signal to the wattmeter. AV volts are also monitored by the wattmeter and processed to display energy consumption rate (Watt).

7. Thermostat: The thermostat controls the cabinet temperature. The reading is taken with the number (0-7) in the top vertical position. 0=Hot; 7=Cold; t_9 = Cabinet Temperature

3.1.7 CALCULATIONS:

200 rev of energy meter= 1 kWh; 1 kWh = 3.6×10^6 J;

COP = q_g / q_e; COP = $T_e (T_g - T_c) / T_g (T_a - T_e)$

Where:

$\mathbf{T_g}$ = Temperature of Generator = $(T_1+T_8) / 2$; $\mathbf{T_c}$ = Temperature of Condenser = $(T_3+T_2) / 2$

$\mathbf{T_e}$ = Temperature of Evaporator = $(T_5+T_4) / 2$; $\mathbf{T_a}$ = Temperature of Absorber = $(T_7+T_6) / 2$

Table 3.0.1: Observations and calculations of operating parameters of Absorption Refrigerator

Sr. No.	X (sec)	Heat Input (kWh)	q_e (W)	q_g (W)	T_0 (˚C)	T_1 (˚C)	T_2 (˚C)	T_3 (˚C)	T_4 (˚C)	T_5 (˚C)	T_6 (˚C)	T_7 (˚C)	T_8 (˚C)	T_9 (˚C)	COP
1															
2															
3															
4															
5															

3.1.8 SPECIMEN CALCULATIONS:

$\mathbf{T_g}$ = Temperature of Generator = $(T_1+T_8) / 2$ = ___________ ^OC

$\mathbf{T_c}$ = Temperature of Condenser = $(T_3+T_2) / 2$ = ___________ ^OC

$\mathbf{T_e}$ = Temperature of Evaporator = $(T_5+T_4) / 2$ = ___________ ^OC

$\mathbf{T_a}$ = Temperature of Absorber = $(T_7+T_6) / 2$ = ___________ ^OC

COP = $T_e (T_g - T_c) / T_g (T_a - T_e)$ = ______________________

PLOTS: Draw the following plots:

1- COP Vs evaporator Load
2- COP Vs condenser outlet temperature
3- Heat input rate Vs condenser outlet temperature

3.1.9 COMMENTS:

3.2 **OBJECTIVE: 02**

Demonstration of water circuit and ammonia circuit in the cycle using Gas Operation (Gas-Burner)

3.2.1 APPARATUS:

Absorption refrigeration Demonstrator

3.2.2 Basic Principals

Absorption refrigeration operates on two fundamental principles:

1. The ability of large quantities of ammonia gas to be absorbed into cold water at low pressure and then at higher temperature and pressure to be driven out again.

2. The ability to condense ammonia vapor at a high pressure and temperature and to evaporate it at low temperature in the presence of an inert gas with the total pressure remaining constant. During the evaporation process a heat can be transferred to the ammonia.

With reference to the above principals absorption refrigerator incorporated in the Absorption Refrigeration Demonstrator operates as follows:

3.2.3 Liquid Circuit

The Absorber Vessel (F) contains approximately 65% water and 35% ammonia by weight. This solution is commonly called aqua-ammonia. The liquid from the Absorber Vessel flows through the Liquid Heat Exchanger (G) to the Vapor Pump (I) where due to the application of heat and subsequent increase in temperature some of the ammonia vapor is driven out of the solution. This vapor forms bubbles, which push the liquid up the pump tube. For this reason the device is sometimes called a **Vapor Bubble Pump**. The liquid falls downwards through the Generator (A) where it is further heated, its temperature raised to approaching 200℃ and further ammonia is driven out of the solution. This produces a weak solution that contains approximately 10% ammonia. The hot weak solution then passes from the Generator (A) back through the Liquid Heat Exchanger (G), where it gives up heat to the to the incoming strong solution entering from the Absorber Vessel (F). it then passes to the top of the Absorber Vessel.

3.2.4 Ammonia Circuit

The ammonia vapor from the Vapor Pump (I) has a temperature of approximately 150℃ when it leaves the Generator (A). Under these conditions the gas contains a quantity of water vapor that can be condensed in a water separator of rectifier positioned before the Condenser where the temperature drops be heat rejection to ambient. The pure ammonia vapor then enters the Condenser (B) at an approximate temperature of 70℃.

The condenser consists of a finned tube and heat is rejected at approximately ambient temperature. At this temperature and a pressure of approximately 256 bar the ammonia vapor condenses. The liquid ammonia passes into the tubular coil of the Evaporator © through the liquid (J) where it wets the internal surface of the evaporator tube.

3.2.5 HYDROGEN CIRCUIT

Hydrogen gas passes over the wetted surface of the evaporator tube and in the first part of the evaporator the ammonia evaporates into the hydrogen at a temperature of between -30 and -18℃. In this section of the evaporator the pressure is approximately 25 bars with the ammonia at a partial pressure of approximately 1bar and the hydrogen at a partial pressure of approx 24 bars.

As the ammonia continues to evaporate into the hydrogen the partial pressure of the ammonia gradually increases and the evaporating temperature also increases. At the end of the evaporator the ammonia has an evaporating temperature of approximately -5℃.

The weight of the mixture of hydrogen and ammonia is now considerably greater than the weight of almost pure hydrogen. The heavier mixture drops through the Gas Heat Exchanger (D) and Absorber (E) and reaches the upper surface of the Absorber Vessel (F).

In this process the gas which is rich in ammonia vapor meets the **weak solution** from the Generator (A) in the Absorber (E). The Absorber has a large surface area and a temperature close to ambient. The **weak solution** therefore remains relatively cool and absorbs the ammonia vapor from the gas.

The hydrogen being inert remains unaffected in this process but becomes more pure. The pure hydrogen is therefore able to leave the top of the Absorber Vessel (F) while the **rich solution** (water and ammonia) leaves the bottom of the Absorber Vessel to repeat the cycle.

3.2.6 OPERATING PROCEDURE:

1. Gas Operation: Turn on the main switch and the one internal lamp will light. The digital temperature indicator and digital wattmeter displays will also illuminate.

2. Refrigeration Load (Duty): This is determined by the input to the electric heating element inside the cabinet and is controlled by the evaporator input control setting. With the changeover switch in the left position the digital wattmeter displays the evaporator heat input rate.

3. Generator Power Input: This is determined by the gas flow to the burner inside the Generator and is controlled by the gas control valve on the gas meter. Up to three settings of the control may be obtained: (1) Fully open – Large blue coloured flame. (2) Two thirds open – Smaller blue coloured flame. (3) Half open – smaller yellow coloured flame

4. Burner Control: **(1)** Check that sufficient gas is available for the duration of the test. **(2)** Turn on gas supply to the unit. **(3)** Depress safety valve and fully open gas control valve on gas flow meter. **(4)** Ignite mixture at burner using the lighter supplied. **(5)** Continue pressing the safety valve button for a further 15 seconds until the flame is established and the flame detector activated. **(6)** Slightly close the gas control valve, if required. **(7)** To terminate gas operation, close the gas control valve and then the gas-isolating valve. Note that reversing this sequence may draw gas into the gas meter.

Note: **(1)** That the gas safety valve should never be depressed for periods longer than 15 seconds with the burner unlit, as this can cause a potentially dangerous build up of un-burnt gas. **(2)** If the burner does not ignite, allow sufficient time for any un-burnt gas to disperse, and then repeat the ignition steps 3-6. **(3)** After installation, changing gas cylinders, after servicing etc. the gas pipes and gas flow meter may contain some air that should be allowed to escape by depressing the gas safety valve. This will ensure that the flame lights quickly. In particular avoid letting air enter the gas flow meter as this contains a significant volume of gas.

5. Gas Flow Meter: A positive displacement meter showing the volume of gas used in $m^3\ hr^{-1}\ and\ m^3 \times\ 10^{-1}\ hr^{-1}$

6. Digital Temperature Indicator: This becomes operative as soon as the electrical supply is switched on. The temperature may be measured at 10 points in the circuit by selecting stations 0 to 9 on the switch. The individual temperature points referred to in the SCHEMATIC DIAGRAM and UNITS AND SYMBOLS are selected and displayed on the indicator by switching to the corresponding number on the selector switch below the indicator.

7. Digital Wattmeter: This becomes operative as soon as the electrical supply is switched on. The digital wattmeter comprises a 3/12 digit true power AC wattmeter and current transformer. The current drawn by the evaporator heater is sensed by a current transformer and sent as a mA signal to the wattmeter. A V volts are also monitored by the wattmeter and processed to display energy consumption rate (Watts).

8. Thermostat: The thermostat controls the cabinet temperature. The reading is taken with the number (0-7) in the top vertical position. 0=Hot; 7=Cold; t_9 = Cabinet Temperature.

LAB SESSION 04

REFRIGERATION AND AIR CONDITIONING LABORATORY

THERMOELECTRIC HEAT PUMP R534

OBJECTIVE NO: 1

Investigation of the effects upon the surface temperature of either face of the module with increasing power. (Peltier Effect)

OBJECTIVE NO: 2

Investigation of the effect upon heat transfer direction of reversing the polarity of the power supply to the module. (Thomson or Lenz Effect)

OBJECTIVE NO: 3

Investigation of the variation in open circuit voltage across the module due to the variation in surface temperature difference. (Seeback Effect)

OBJECTIVE NO: 4

Investigation of the power generating performance of the module with a steady load and increasing temperature difference.

OBJECTIVE NO: 5

Estimation of the coefficient of performance of the module when acting as a refrigerator.

DEPARTMENT OF MECHANICAL ENGINEERING &TECHNOLOGY
UNIVERSITY OF ENGINEERING AND TECHNOLOGY LAHORE (KSK CAMPUS)

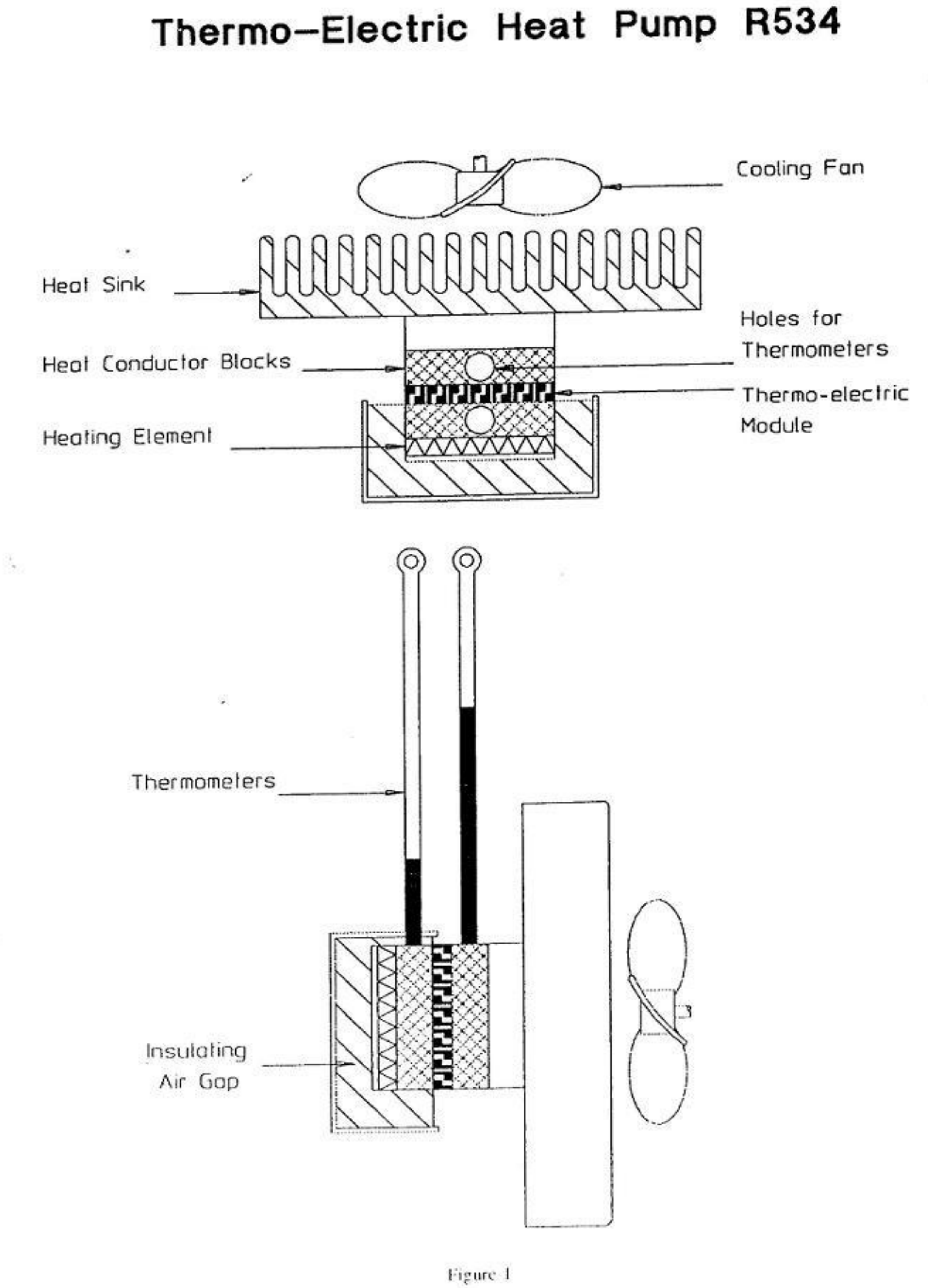


Figure 4.1: Schematic diagram of Thermoelectric Heat Pump

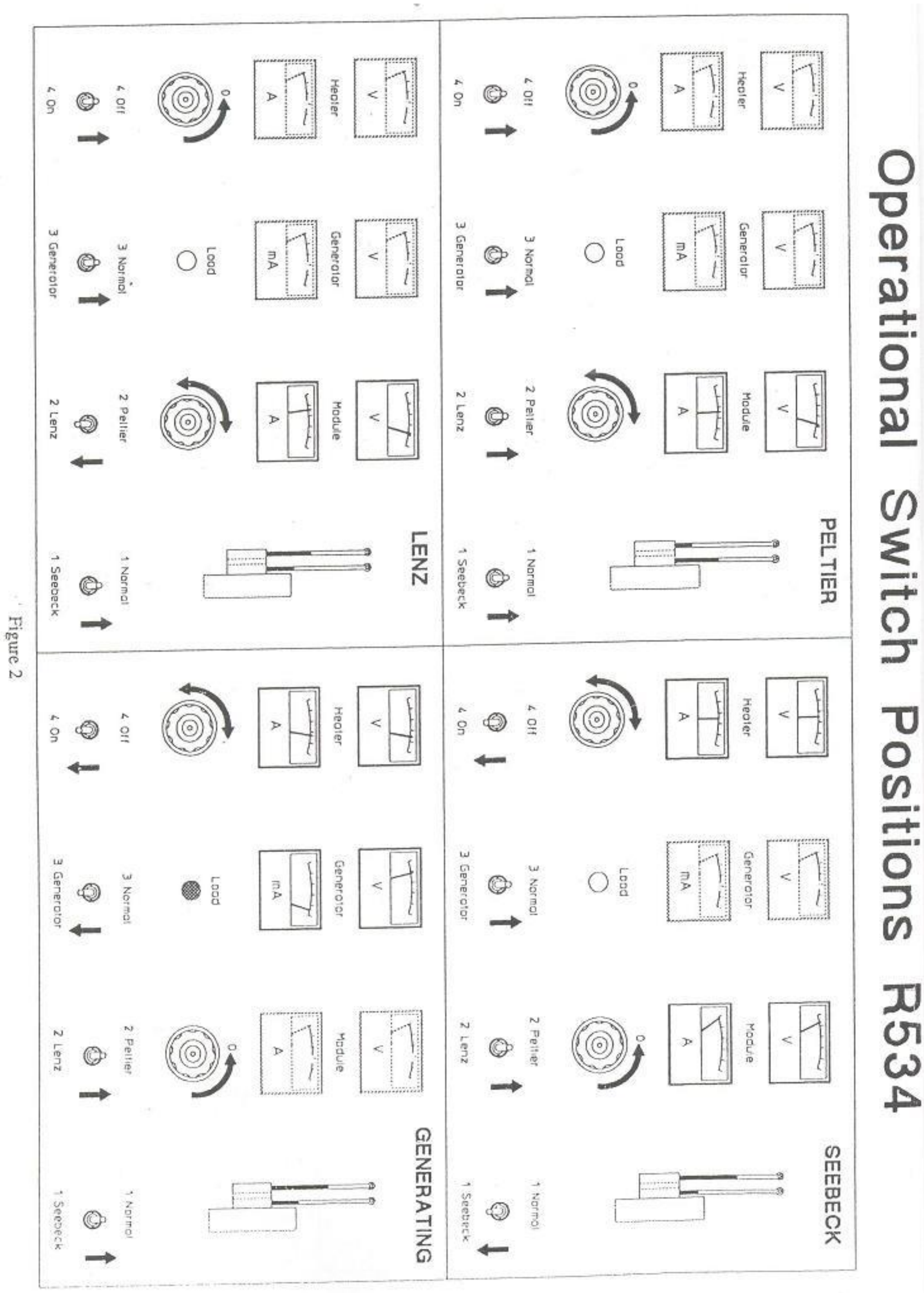


Figure 4.2: Different setup configurations of Thermoelectric Heat Pump

4.1 OBJECTIVE: 01

Investigation of the effects upon the surface temperature of either face of the module with increasing power. (Peltier Effect)

4.1.1 APPARATUS:

Thermoelectric Heat Pump

4.1.2 THEORY

<u>Thermo-Electric Module Assembly</u>

This consists of a series of PN semi-conductor junctions, forming the module, clamped between two thermal conductor blocks. These contain thermometer pockets and allow measurement of the temperature existing on each side of the module. Clamped to the conductor block on the cold side of the module is an electric resistance heater and this is covered by an insulated stainless steel box. The hot side of the module is in thermal contact with a large fan cooled heat sink which is mounted on the inside of the panel. In order to ensure good thermal contact between all of the components the mating faces are smeared with heat transfer compound on assembly and clamped together with a central relating screw.

<u>Control Switches</u>

In order to allow connection of the module and heater in various configurations, without complicated wiring alterations, all of the experimental conditions are established by sequenced switching of four multi-pole switches. Mains power is supplied to the unit through a combined double pole, miniature circuit breaker and overload cut out (5A rating) situated at the top right hand corner of the panel.

<u>Rheostats</u>

Variation of the power supplied to both the heater and thermoelectric module is achieved by two heavy duty rheostats. These are triple graded rotary units in order to achieve near linear control and use a wide silver graphite wiping conductor for long life.

<u>Load Lamp</u>

In order to demonstrate the use of the thermo-electric module in its generating role, a small low voltage lamp is mounted in the centre of the panel. As the temperature difference across the module is increased by the heater, sufficient power is generated to illuminate the lamp.

4.1.3 PROCEDURE:

Ensure mains switch is off. Ensure that the thermometers are in position in the holes in the heat conductor blocks in the thermo-electric assembly. Turn the two rheostats fully anti-clock wise. Refer to the **PELTIER** panel diagram in Figure 2 on page 3 and set the four switches at the bottom of the panel as shown. Switch on the mains switch. Increase the power input to the thermo-electric **module (PELTIRE)** in increments by turning the right hand rheostat clockwise allowing the temperature to stabilise after each increment. Monitor the relative power input by watching the **module (PELTIRE)** voltmeter and ammeter. Record $V_m, I_m, T_h, and T_c$ when temperature have stabilised.

Table 4.0.1: Observations and calculations of operating parameters of Thermoelectric Heat Pump (Ambient Temperature= 20°C)

TEST NO									
Hot Side Temperature	T_H (˚C)								
Cold Side Temperature	T_C (˚C)								
Heater Voltage	V_h (Volts)								
Heater Current	I_h (Amps)								
Heater Power	$V_h \times I_h = W_h$ (Watts)								
Module Voltage	V_m (Volts)								
Module Current	I_m (Amps)								
Module Power	$V_m \times I_m = W_m$ (Watts)								
Module Output	V_m (Volts)								
Load Current	I_L (Amps)								
Load Power	$V_m \times I_L = W_L$ (Watts)								
Module COP as Refrigerator	$\frac{Wh}{Wm}$								

PLOTS: Draw the following plots:

10- Power input to module Vs hot side Temperature.
11- Power input to module Vs Cold side Temperature.
12- Power input to module Vs T_H-T_C

4.1.4 COMMENTS

4.2 OBJECTIVE: 02

Investigation of the effect upon heat transfer direction of reversing the polarity of the power supply to the module. (Thomson or Lenz Effect)

4.2.1APPARATUS:

Thermoelectric Heat Pump

4.2.2 PROCEDURE:

Ensure mains switch is off. Ensure that the thermometers are in position in the holes in the heat conductor blocks in the thermo-electric assembly. Turn the two rheostats fully anti-clock wise. Refer to the **LENZ** panel diagram in Figure 2 on page 3 and set the four switches at the bottom of the panel as shown. Switch on the mains switch. Increase the power input to the thermo-electric **module (LENZ)** in increments by turning the right hand rheostat clockwise allowing the temperature to stabilise after each increment. Monitor the relative power input by watching the **module (LENZ)** voltmeter and ammeter. Record $V_m, I_m, T_h, and T_c$ when temperature have stabilised.

Table4.0.2: Observations and calculations of operating parameters of Thermoelectric Heat Pump (Ambient Temperature= 20°C)

TEST NO									
Hot Side Temperature	T_H (˚C)								
Cold Side Temperature	T_C (˚C)								
Heater Voltage	V_h (Volts)								
Heater Current	I_h (Amps)								
Heater Power	$V_h \times I_h = W_h$ (Watts)								
Module Voltage	V_m (Volts)								
Module Current	I_m (Amps)								
Module Power	$V_m \times I_m = W_m$ (Watts)								
Module Output	V_m (Volts)								
Load Current	I_L (Amps)								
Load Power	$V_m \times I_L = W_L$ (Watts)								
Module COP as Refrigerator	$\frac{Wh}{Wm}$								

PLOTS: Draw the following plots:

1- Power input to module Vs hot side Temperature.
2- Power input to module Vs Cold side Temperature.
3- Power input to module Vs T_H-T_C

4.2.3 COMMENTS:

4.3 OBJECTIVE: 03

Investigation of the variation in open circuit voltage across the module due to the variation in surface temperature difference. (Seeback Effect)

4.3.1APPARATUS:

Thermoelectric Heat Pump

4.3.2 PROCEDURE:

Ensure mains switch is off. Ensure that the thermometers are in position in the holes in the heat conductor blocks in the thermo-electric assembly. Turn the two rheostats fully anti-clock wise. Refer to the **SEEBACK** panel diagram in Figure 2 on page 3 and set the four switches at the bottom of the panel as shown. Switch on the mains switch. Increase the power input to the heater **(SEEBACK)** in increments by turning the right hand rheostat clockwise allowing the temperature to stabilise after each increment. Monitor the relative power input by watching the heater **(SEEBACK)** voltmeter and ammeter. Record $V_m, T_h, and\ T_c$ when temperature have stabilised.

Table 4.0.3: Observations and calculations of operating parameters of Thermoelectric Heat Pump (Ambient Temperature= 20℃)

TEST NO									
Hot Side Temperature	T_H (˚C)								
Cold Side Temperature	T_C (˚C)								
Heater Voltage	V_h (Volts)								
Heater Current	I_h (Amps)								
Heater Power	$V_h \times I_h = W_h$ (Watts)								
Module Voltage	V_m (Volts)								
Module Current	I_m (Amps)								
Module Power	$V_m \times I_m = W_m$ (Watts)								
Module Output	V_m (Volts)								
Load Current	I_L (Amps)								
Load Power	$V_m \times I_L = W_L$ (Watts)								
Module COP as Refrigerator	$\frac{Wh}{Wm}$								

PLOTS: Draw the following plots:

1- Temperature difference across Module Vs Module Voltage.

4.3.3 COMMENTS:

4.4 OBJECTIVE: 04

Investigation of the power generating performance of the module with a steady load and increasing temperature difference.

4.4.1 APPARATUS:

Thermoelectric Heat Pump

4.4.2 PROCEDURE:

Ensure mains switch is off. Ensure that the thermometers are in position in the holes in the heat conductor blocks in the thermo-electric assembly. Turn the two rheostats fully anti-clock wise. Refer to the **GENRATING** panel diagram in Figure 2 on page 3 and set the four switches at the bottom of the panel as shown. Switch on the mains switch. Increase the power input to the heater **(GENRATING)** in increments by turning the right hand rheostat clockwise allowing the temperature to stabilise after each increment. Monitor the relative power input by watching the heater **(GENRATING)** voltmeter and ammeter. Record $V_m, I_L, T_h, and\ T_c$ when temperature have stabilised.

Table 4.0.4: Observations and calculations of operating parameters of Thermoelectric Heat Pump (Ambient Temperature= 20°C)

TEST NO									
Hot Side Temperature	T_H (˚C)								
Cold Side Temperature	T_C (˚C)								
Heater Voltage	V_h (Volts)								
Heater Current	I_h (Amps)								
Heater Power	$V_h \times I_h = W_h$ (Watts)								
Module Voltage	V_m (Volts)								
Module Current	I_m (Amps)								
Module Power	$V_m \times I_m = W_m$ (Watts)								
Module Output	V_m (Volts)								
Load Current	I_L (Amps)								
Load Power	$V_m \times I_L = W_L$ (Watts)								
Module COP as Refrigerator	$\frac{Wh}{Wm}$								

PLOTS: Draw the following plots:

1- Temperature difference across Module Vs Load Power.

4.4.3 COMMENTS:

4.5 OBJECTIVE: 05

Estimation of the coefficient of performance of the module when acting as a refrigerator.

4.5.1 APPARATUS:

Thermoelectric Heat Pump

4.5.2 PROCEDURE:

Ensure mains switch is off. Ensure that the thermometers are in position in the holes in the heat conductor blocks in the thermo-electric assembly. Turn the two rheostats fully anti-clock wise. Refer to the **PELTIRE** panel diagram in Figure 2 on page 3 and set the four switches at the bottom of the panel as shown but reset the **heater (PELTIRE)** switch to **ON.** This will allow the heater **(PELTIRE)** to be activated at the same time as the module **(PELTIRE)** is cooling. Switch on the mains switch. Increase the power input to the heater and module simultaneously in increments such that the cold side temperature is maintained at ambient conditions. Hence it may be assumed that no heat is absorbed from the atmosphere and that all of the heat input from the heater is absorbed by the module in its refrigerating mode. When the temperature are stable record $V_H, I_H, v_m\ I_m, t_H\ and t_c$.

Table 4.0.5: Observations and calculations of operating parameters of Thermoelectric Heat Pump (Ambient Temperature= 20°C)

TEST NO										
Hot Side Temperature	T_H (°C)									
Cold Side Temperature	T_C (°C)									
Heater Voltage	V_h (Volts)									
Heater Current	I_h (Amps)									
Heater Power	$V_h \times I_h = W_h$ (Watts)									
Module Voltage	V_m (Volts)									
Module Current	I_m (Amps)									
Module Power	$V_m \times I_m = W_m$ (Watts)									
Module Output	V_m (Volts)									
Load Current	I_L (Amps)									
Load Power	$V_m \times I_L = W_L$ (Watts)									
Module COP as Refrigerator	$\frac{Wh}{Wm}$									

PLOTS: Draw the following plots:

1- Module Input power to maintain Hot side at Ambient Temperature Vs Variation of Module Refrigerating COP wit increasing Load.

4.5.3 COMMENTS:

LAB SESSION: 05

REFRIGERATION AND AIR CONDITIONING LABORATORY

REVERSED CYCLE REFRIGERATION AND AIR CONDITIONING TRAINING UNIT

OBJECTIVE NO: 1

Demonstration of the Basic Refrigeration Cycle by using Automatic (Constant Pressure) Expansion Valve as a Flow Control.

OBJECTIVE NO: 2

Demonstration of the Basic Refrigeration Cycle by using Internally Equalised Thermostatic Expansion Valve and the Externally Equalised Thermostatic Expansion.

OBJECTIVE NO: 3

Demonstration of Pressure/ Temperature Relation using Evaporator Pressure Regulator and function of Capillary Tube as a Flow Control.

OBJECTIVE NO: 4

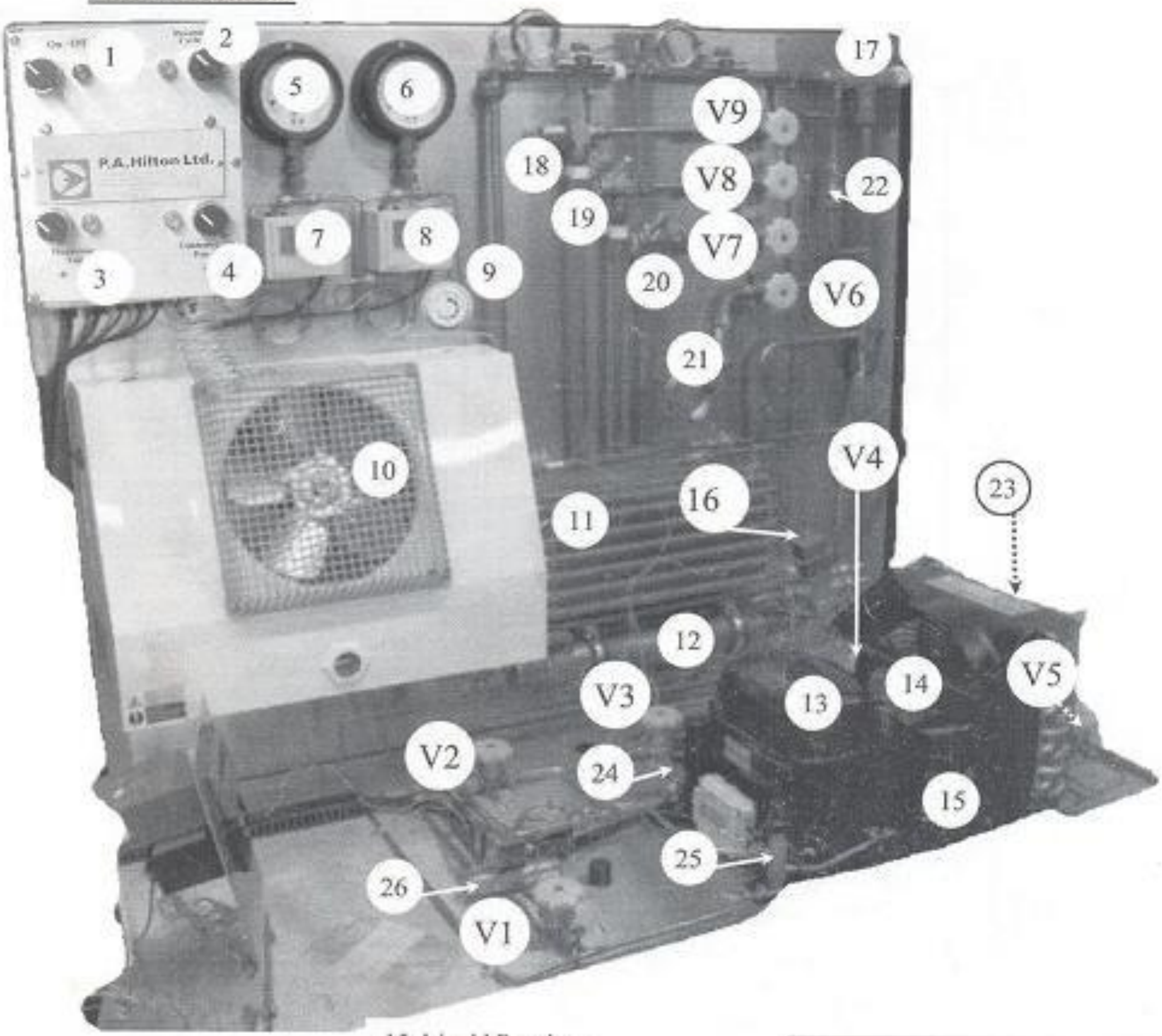
Demonstration of the Dual Temperature Operation by using Capillary Expansion Device and Internally Equalised Thermal Expansion Valve.

OBJECTIVE NO: 5

Demonstration of the Reversed cycle operation, Causes of Excess Discharge Pressure and demonstration of water Cooled Condenser.

DEPARTMENT OF MECHANICAL ENGINEERING &TECHNOLOGY
UNIVERSITY OF ENGINEERING AND TECHNOLOGY LAHORE (KSK CAMPUS)

Pictorial Schematic



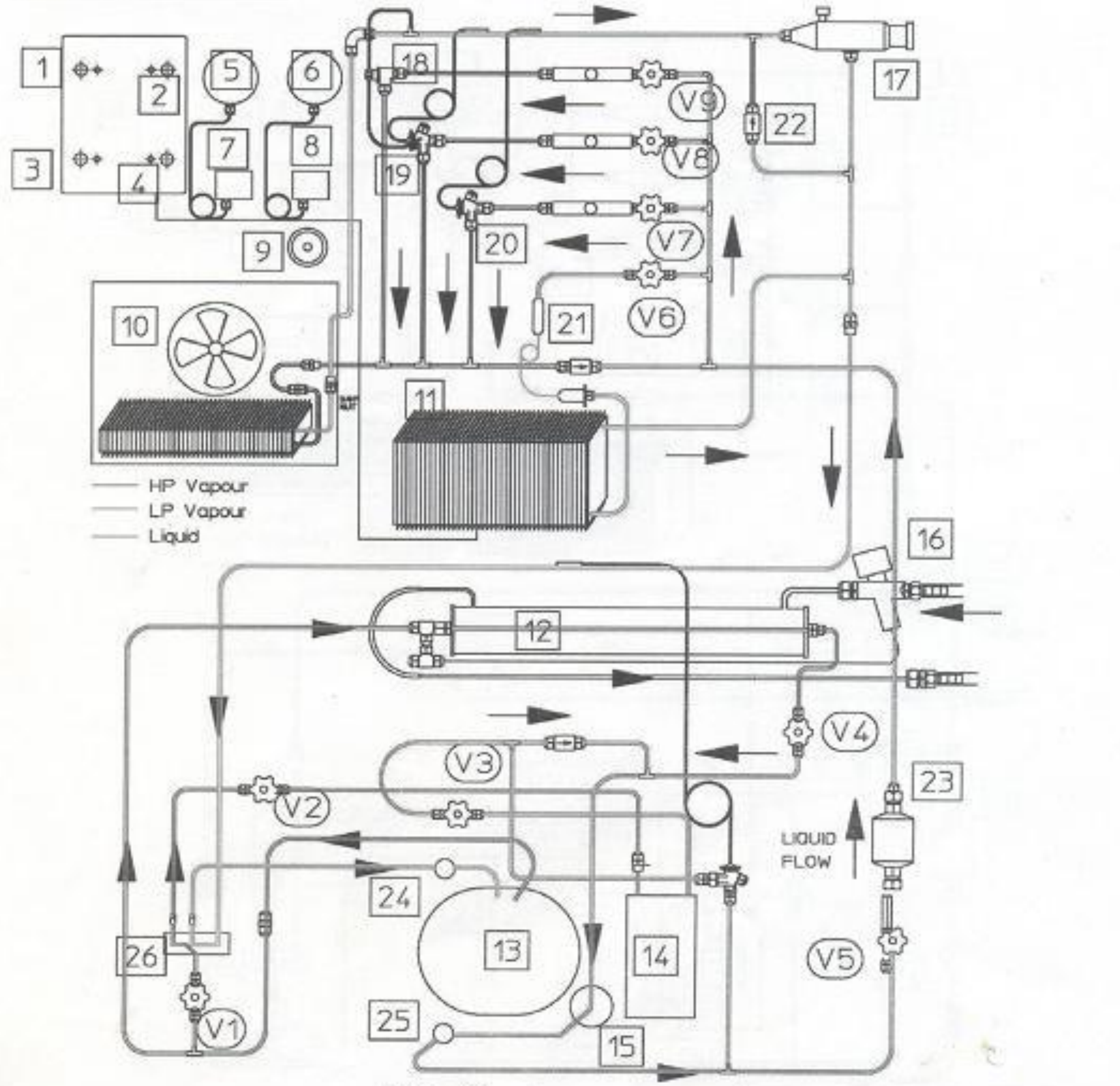
1. Main Switch
2. Reverse Cycle switch
3. Evaporator Fan Switch
4. Condesner fan Switch
5. LP Gauge
6. HP Gauge
7.LP Switch
8. HP Switch
9. Thermostat
10. Forced Air Evaporator
11. Convection Evaporator
12. Water Cooled Condenser
13. Hermetic Compressor
14. Air Cooled Condenser
15. Liquid Receiver
16. Water Cooled Condenser Pressure Control
17 Forced Air Evaporator Pressure Regulator
18. Automatic(Constant Pressure) Expansion Valve
19 Externally Equalised TEV
20. Internally Equalised TEV
21. Capillary Tube
22. Non-Return Valve
23. Filter-Drier
24. Suction Service Valve
25. Liquid Service Valve
26. Reversing Valve

HAND VALVES

V1. Discharge to Reversing valve(26)
V2. Discharge to Air Cooled Condenser(14)
V3. Between Condenser(14) and Receiver(15)
V4. Water Cooled Condenser (12) Discharge
V5. Main Liquid Line
V6. Capillary Expansion Device
V7. Internal Equalised TEV
V8. External Equalised TEV
V9. Automatic (Contant Pressure) valve

Figure 5.1: Reversed Cycle Refrigeration Unit

Normal Operation Schematic



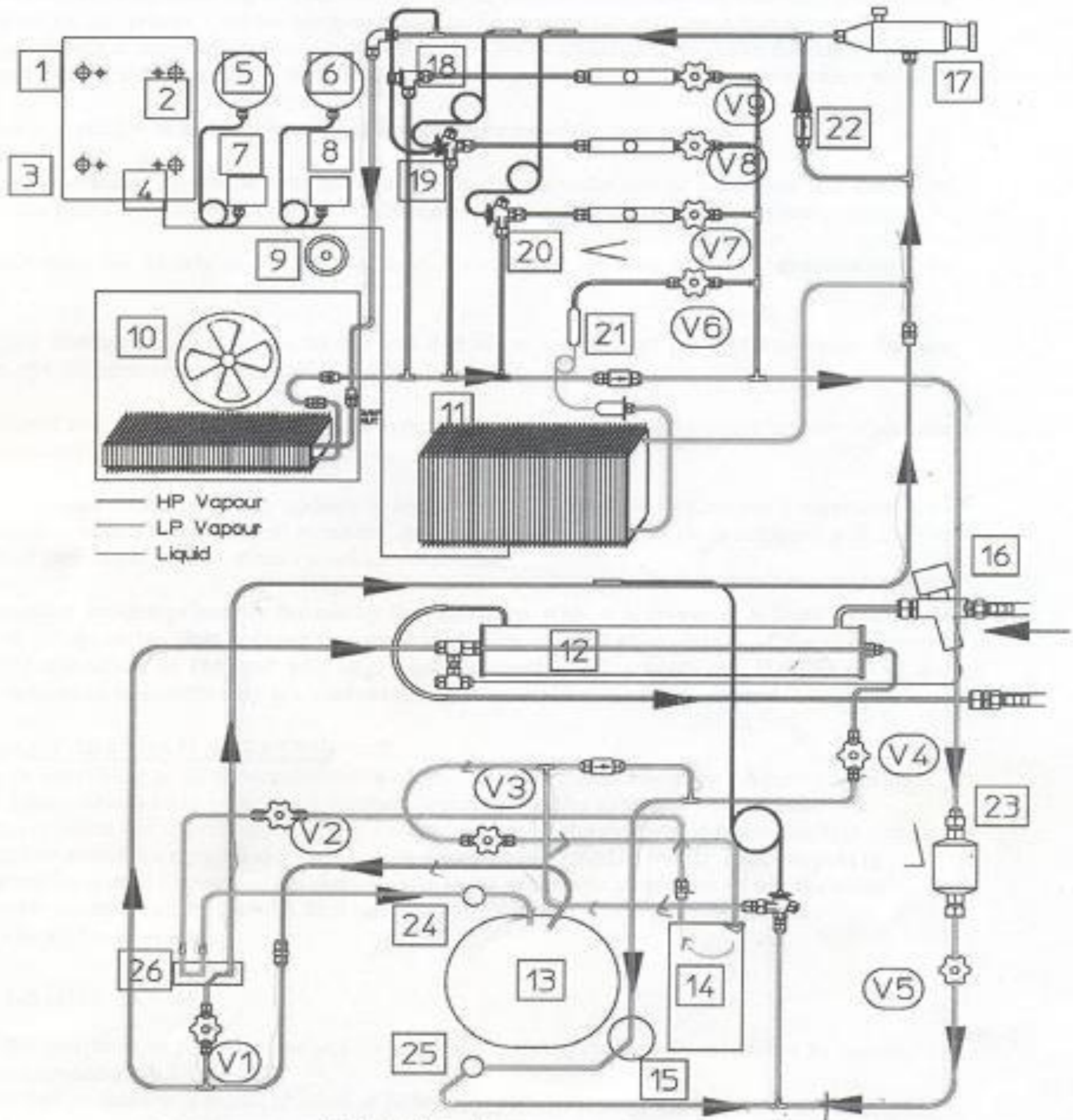
1. Main Switch
2. Reverse Cycle switch
3. Evaporator Fan Switch
4. Condesner fan Switch
5. LP Gauge
6. HP Gauge
7. LP Switch
8. HP Switch
9. Thermostat
10. Forced Air Evaporator
11. Convection Evaporator
12. Water Cooled Condenser
13. Hermetic Compressor
14. Air Cooled Condenser
15. Liquid Receiver
16. Water Cooled Condenser Pressure Control
17. Forced Air Evaporator Pressure Regulator
18. Automatic(Constant Pressure) Expansion Valve
19. Externally Equalised TEV
20. Internally Equalised TEV
21. Capillary Tube
22. Non-Return Valve
23. Filter-Drier
24. Suction Service Valve
25. Liquid Service Valve
26. Reversing Valve

HAND VALVES

- V1. Discharge to Reversing valve(26)
- V2. Discharge to Air Cooled Condenser(14)
- V3. Between Condenser(14) and Receiver(15)
- V4. Water Cooled Condenser (12) Discharge
- V5. Main Liquid Line
- V6. Capillary Expansion Device
- V7. Internal Equalised TEV
- V8. External Equalised TEV
- V9. Automatic (Contant Pressure) valve

Figure 5.2: Normal operation Schematic diagram

Sample Reverse Cycle Operation Schematic



1. Main Switch
2. Reverse Cycle switch
3. Evaporator Fan Switch
4. Condesner fan Switch
5. LP Gauge
6. HP Gauge
7.LP Switch
8. HP Switch
9. Thermostat
10. Forced Air Evaporator
11. Convection Evaporator
12. Water Cooled Condenser
13. Hermetic Compressor
14. Air Cooled Condenser
15. Liquid Receiver
16. Water Cooled Condenser Pressure Control
17 Forced Air Evaporator Pressure Regulator
18. Automatic(Constant Pressure) Expansion Valve
19 Externally Equalised TEV
20. Internally Equalised TEV
21. Capillary Tube
22. Non-Return Valve
23. Filter-Drier
24. Suction Service Valve
25. Liquid Service Valve
26. Reversing Valve

HAND VALVES

V1. Discharge to Reversing valve(26)
V2. Discharge to Air Cooled Condenser(14)
V3. Between Condenser(14) and Receiver(15)
V4. Water Cooled Condenser (12) Discharge
V5. Main Liquid Line
V6. Capillary Expansion Device
V7. Internal Equalised TEV
V8. External Equalised TEV
V9. Automatic (Contant Pressure) valve

Figure 5.3: **Reversed Cycle operation Schematic diagram**

5.1 OBJECTIVE: 01

Demonstration of the Automatic (Constant Pressure) Expansion Valve as a Flow Control and the Basic Refrigeration Cycle.

5.1.1 APPARATUS:

Reversed Cycle Refrigeration and Air Conditioning Training Unit.

5.1.2 PROCEDURE:

Open hand wheel valve V9. Ensure that V6, V7 and V8 are firmly closed. Valves V1, V2, V3 and V5 on the base OPEN, V4 is closed. Switch ON: The **main switch (1), the evaporator fan switch (3), the Condenser fan switch (4).**Ensure the **Reverse cycle switch (2)** is off. Allow the unit to run and settle down. After initial pull down, take the reading from the **LP compound** gauge (5). The **automatic (constant pressure) valve (18)** or **A.E.V**. can be adjusted by turning the slotted adjustor under the plastic cover on the left hand side of the valve, anti-clockwise to lower, clockwise to increase evaporating pressure. Observe the LP gauge pressure. Check and record the working superheat, which initially will be very wide. Check and record temperature drop across the evaporator. Allow the unit to continue to operate and at 10 minute intervals, record superheat and temperature drop reading. Particularly note variations over a time period of at least 1 hour. Use this demonstration first to teach the refrigeration cycle, first by touch, then by thermometer measurement using a single probe, quick reading thermometer.

5.1.3 THE REFRIGERATION CYCLE:

Hot, high pressure vapour from compressor discharge through the reversing valve to the condenser. Note particularly from which leg of the reversing valve the hot gas returns to the condenser. After condensation, sub-cooled but still warm liquid flows from the condenser to the receiver. From the receiver through the compressor service valve, the liquid line, drier and sight glass to the A.E.V. From compressor discharge to the A.E.V. is the High Side of the system. Passing through the A.E.V., liquid flow is throttled and the liquid drops to a los pressure and temperature. At this condition, the liquid will absorb heat from its surroundings and 'boil-off'. During boiling, the liquid absorbs latent heat. Passing through the evaporator and the suction line back to the compressor, the vapour absorbs sensible heat and becomes superheated. From the A.E.V. to compressor suction is the Low Side of the system. The changes in temperature around the system must be fully understood. If you wish to speed up the demonstration and observe the progression of the frost line, switch off the evaporator fan motor. Don't allow frost to get back to the compressor. Repeat these demonstrations using different settings of the A.E.V. Log and compare all results with those obtained earlier.

5.2 OBJECTIVE: 02

Demonstration of the Basic Refrigeration Cycle by using Internally Equalised Thermostatic Expansion Valve and the Externally Equalised Thermostatic Expansion.

5.2.1 APPARATUS:

Reversed Cycle Refrigeration and Air Conditioning Training Unit.

5.2.2 PROCEDURE :(THE INTERNALLY EQUALISED T.E.V.)

If the unit is already running from Experiment No 15. Close the hand wheel valve V9 to the **automatic expansion valve (18)**. And allow the sight glass to empty. Open the hand wheel valve V7 to **the Internally Equalized Thermostatic Expansion Valve (20)** or **TEV.** If the unit has not yet been started. Open hand wheel valve V7. Ensure that V6, V7, V8 and V9 are firmly closed. Valves V1, V2, V3, and V5 on the base OPEN, V4 is closed. Switch ON: the **main switch (1), the evaporator fan switch (3), the Condenser fan switch (4).** Ensure the **Reverse cycle switch (2)** is off.

Note and record: - (1) HP gauge (6) and LP gauge (5) readings, (2) **T.E.V (20)**. Working Superheat, (3) Temperature Drop across the Evaporator.

Because there is a pressure drop through this evaporator, the internally equalized T.E.V. will have a relatively large superheat. Turn the adjusting spindle (under the hexagonal cap on the valve) clockwise to increase, anti-clockwise to reduce superheat. Note only ¼ turn at a time and allow the system to stabilize after each adjustment. An alternative and more accurate method of measuring superheat can now be used.

NOTE: Working superheat is the difference between the temperature of the T.E.V. thermal bulb and the temperature of the evaporating liquid.

The temperature at the thermal bulb is obtained from the thermometer probe previously fitted at this location. To obtain evaporating temperature, fit a compound gauge to the Evaporator Pressure Regulator (17). This pressure reading, converted to its temperature equivalent, is an accurate measure of evaporating temperature.

NOTE: Any difference between the pressure shown on this gauge and the compound gauge fitted to the unit is pressure drop through the suction line.

Use this demonstration to explain the operation of the **Internally Equalized Expansion Valve (20)**. Particularly explain why, because of pressure drop through the evaporator, the T.E.V. has a wide working superheat. As in Experiment 15, to quickly demonstrate the frost line, switch OFF the evaporator fan.

NOTE: Temperature drop across the evaporator on the 808 will vary according to ambient conditions.

5.2.3 PROCEDURE: (THE EXTERNALLY EQUALISED T.E.V.)

If the unit is already running from exercise above. Close the hand wheel valve V7 to the **Internally Equalized Expansion valve (20).** And allow the sight glass to empty. Open the hand wheel valve V8 to the **Externally Equalized Thermostatic Expansion Valve (19)** or **TEV.** If the unit has not yet been started.

Open hand wheel valve V8. Endure that V6, V7 and V9 are firmly closed. Valves V1, V2, V3, and V5 on the base OPEN, V4 is closed. Switch ON: The **main switch (1), the evaporator fan switch (3), the Condenser fan switch (4),** Ensure the **Reverse cycle switch (2)** is off.

As before, note and record: - (1) HP gauge (6) and LP gauge (5) readings, (2) **Externally Equalized Thermostatic Expansion Valve (19).**Working Superheat, (3) Temperature Drop across the Evaporator.

Explain the difference between the internal and externally equalized T.E.V's. Particularly explain how the externally equalized T.E.V. compensates for pressure drop through the evaporator. Compare all results with those obtained with the internally equalized T.E.V. To demonstrate the frost line, switch OFF the evaporator fan. Note the difference in frost line between the two T.E.V's.

5.3 OBJECTIVE: 03

Demonstration of Pressure/ Temperature Relation using Evaporator Pressure Regulator and function of Capillary Tube as a Flow Control.

5.3.1 APPARATUS:

Reversed Cycle Refrigeration and Air Conditioning Training Unit.

5.3.2 PROCEDURE :(THE EVAPORATOR PRESSURE REGULATOR)

The Evaporator Pressure Regulator can be used to demonstrate the pressure/temperature relation. Set the unit to operate through the externally equalized T.E.V (19) as in Experiment 16. Open hand wheel valve V8. Ensure that V6, V7 and V9 are firmly closed. Valves V1, V2, V3, and V5 on the base OPEN, V4 is closed. Fit a compound gauge to the **Evaporator Pressure Regulator (17).** Adjust the Evaporator Pressure Regulator by removing the end cap and using a suitable hexagonal key.

NOTE: (a) Turn the adjusting spindle clockwise to increase evaporating pressure. (b) Over adjustment will cause quick pressure drop beyond the Evaporator Pressure Regulator and cause cycling on the low pressure switch. When correct conditions have been established, use this demonstration to reinforce appreciation of the temperature/pressure relationship, i.e. saturated conditions. Re-check and record: - (1) Working Superheated, (2) Temperature Drop across the Evaporator, (3) Gauge Readings

Explain difference in results to those previously obtained. Use this demonstration to explain the use of this important secondary control in conditions where a maintained minimum evaporating pressure, and hence temperature must not be exceeded, e.g.:- (1) Cheese Storage, (2) Liquid (water) Cooling (as water will freeze at0℃)

5.3.3 PROCEDURE :(THE CAPILLARY AS A FLOW CONTROL)

To demonstrate the capillary as a flow control: - Switch OFF the **evaporator fan switch (3).** Open hand wheel valve V6. Ensure that valves. V7, V8 and V9 are firmly closed. Valves V1, V2, V3, and V5 on the base OPEN, V4 is closed. Fit and insulate two thermometer probes:- (1) At the **convection evaporator (11)** inlet. (2) At the **convection evaporator (11)** outlet.

Initially set the evaporator thermostat (9) to cut-out at No.3 or a low number. Note that the thermostat temperature sensor is located inside the fins of the **convection evaporator (11).** Note that in a similar manner to the A.E.V., initial superheat will be very wide. The evaporator thermostat should cut-out at approx. 5℃ superheat. This will prevent frost back to the compressor. Adjust the setting of the thermostat to obtain this result. The gradual progression of the frost line around the evaporator can be easily observed. Not e especially the essential difference between the A.E.V. and the capillary: - (a) The capillary is NOT adjustable. (b) The capillary allows rapid pressure equalization during the off-cycle and is thus suitable for use on systems using a Low Starting Torque Compressor.

5.4 OBJECTIVE: 04

Demonstration of the Dual Temperature Operation by using Capillary Expansion Device and Internally Equalised Thermal Expansion Valve.

5.4.1 APPARATUS:

Reversed Cycle Refrigeration and Air Conditioning Training Unit.

5.4.2 PROCEDURE: (DUAL TEMPERATURE OPERATION)

Open valve V7 and V6 and close valves V 8 and V9. Valves V1, V2, V3, and V5 on the base OPEN, V4 is closed. This sets thee unit to operate using: - (a) The **capillary (21)** and the **convection evaporator (11).** (b) The **internally equalized T.E.V (20).** SWITCH ON the evaporator fan motor. Locate thermometer probes: - (1) Below the coil block of the forced air evaporator. (2) Pushed into the centre of the convection evaporator. Attach a service gauge to the **evaporator pressure regulator (17).** Switch on the unit and adjust the **evaporator pressure regulator (17)** to 2.4 bar g (remove the end cap and adjust with a suitable hexagonal drive key). Note and record all results.

It will be observed that the forced air evaporator maintains a near constant temperature but that the temperature of the convection evaporator continues to fall until cut-out by the evaporator thermostat. Experiment with varying settings on the **convection evaporator (11) thermostat (9).** Repeat the demonstration with alternative setting s of the Evaporator Pressure Regulator (17), for example, 2.6and 2.8 bar.g.

Repeat the demonstration: - (a) With the forced air evaporator fan OFF. (b) Using the externally equalized T.E.V (19).

At all stages, note, record and compare results. Explain the use of the Evaporator Pressure Regulator (17) in dual temperature fixtures, using only one condensing unit.

5.5 OBJECTIVE: 05

Demonstration of the Reversed cycle operation, Causes of Excess Discharge Pressure and demonstration of water Cooled Condenser.

5.5.1 APPARATUS:

Reversed Cycle Refrigeration and Air Conditioning Training Unit.

5.5.2 PROCEDURE: (REVERSE CYCLE OPERATION)

Before attempting to demonstrate Reverse Cycle Operation, set the unit to operate through the **internally equalized T.E.V (20).** With the **evaporator fan switch (3)** OFF. Valve V7 OPEN valves V6, V8 and V9 Closed. Valves V1, V2, V3, and V5 on the base Open, V4 is closed. Allow sufficient running time to allow a good frost build up on the forced air evaporator (10) coil block.

When satisfied that the correct conditions are established: - (a) Switch to reverse cycle by turning the **reverse cycle switch (2)** ON. (b) Shut OFF the feed to the internally equalized T.E.V (20) by closing valve V7.

NOTE: (1) Rapid defrosting of the forced air evaporator. (2) The change of function between evaporator and condenser.

The evaporator, now working as a condenser, will be blowing warm air. The condenser, now an evaporator, will be blowing cold air. To demonstrate frost build up on the air cooled condenser (14) now operating as an evaporator, switch OFF the **condenser fan motor switch (4).** If the compound gauge starts to fall rapidly, it indicates a shortage of liquid in the system. To correct this, open the hand wheel valve V4 in the line from the **water-cooled condenser (12).** This will pressurize the receiver and force more liquid into the system. Keep a careful watch on the high pressure gauge (6). If it starts to rise quickly, close the hand wheel valve V4 from the water-cooled condenser.

Use this demonstration o explain the operation of the reverse cycle system. Fully explain the reversing valve.

Trace the refrigeration circuit. Show that the discharge gas exits from the reversing valve through the opposite leg to that in demonstration No.15. Show also that the liquid now flows through the original suction line by passing the Evaporator Pressure Regulator (17) and flows in reverse direction through the liquid line via the **non return valve (22)** to the expansion valve on the condenser. Especially stress that there is no change in the function of the compressor. Carefully tabulate and analyze all results.

5.5.3 PROCEDURE: (EXCESS DISCHARGE PRESSURE)

Explain the causes, e.g. (a) Failed Condenser Fan Motor, (b) Blocked or dirty condenser fins, (c) Condensing Unit wrongly located (e.g. air flow obstructed).

Set the unit for normal operation with the reverse cycle switch (2) OFF. Valve V8 OPEN valves V6, V7 and V9 Closed. Valves V1, V2, V3, and V5 on the base OPEN, V4 is closed. To demonstrate (a), allow the unit to operate normally through the externally equalized T.E.V as above and switch OFF the **condenser fan motor switch (4).** To demonstrate (b and c), leave the condenser fan motor running and place a sheet of stiff board across the face of the condenser. At all stages, note and record variations in both gauges.

5.5.4 PROCEDURE: (THE WATER COOLED CONDENSER)

To demonstrate the water cooled condenser: Ensure the water supply is connected and turned on. Open hand wheel valve V4 and close V2. Note that the discharge gas now goes directly to the water cooled condenser and back to the receiver. Valves V1, V3, and V5 on the base OPEN. As the air cooled condenser is not now in use, switch OFF the **condenser fan motor switch (4).** The condenser pressure may be adjusted by turning the central square nut on the top of the **water cooled condenser pressure control (16)** valve. NOTE that this operates by varying the flow rate of water to the condenser. Increased water flow will result in a lower pressure and reduced a higher pressure. It is recommended that students examine the water flow from the outlet hose. Note that after each adjustment of the valve there will be a delay before the condenser pressure stabilizes. Repeat previous experiments and compare results between air and water cooled condensers. Explain the contra flow system through the water cooled condenser and the operation of the pressure actuated water valve. Experiment and compare results with difference pressure settings of the water valve.

LAB SESSION: 06

REFRIGERATION AND AIR CONDITIONING LABORATORY

BENCH TOP COOLING TOWER

OBJECTIVE NO:1

Observation of the process within forced draught cooling tower.

EXPERIMENT NO: 2

Determination of all end state properties of air and water from tables or charts and the application of the steady flow equation to selected systems to draw up energy and mass balances.

EXPERIMENT NO: 3

Investigation of the effect of cooling on "approach to wet bulb" and Relationship between Cooling Load and Cooling Range.

EXPERIMENT NO: 4

Investigation of relation between air velocity and i) Wet bulb approach ii) Pressure drop through the packing.

EXPERIMENT NO: 5

Investigation of the effect of packing density on the performance of the cooling tower.

DEPARTMENT OF MECHANICAL ENGINEERING &TECHNOLOGY
UNIVERSITY OF ENGINEERING AND TECHNOLOGY LAHORE (KSK CAMPUS)

6.1 OBJECTIVE: 01

Observation of the process within forced draught cooling tower.

6.1.1 APPARATUS:

Bench Top Cooling Tower

6.1.2 THEORY

The Bench Top Cooling Tower behaves in a similar manner and has similar components to a full size cooling tower and may be used to introduce students to their characteristics and construction.

The Bench Top Cooling Tower should be set to operate with moderate air and water flows and with either 1.0 or 1.5kW cooling load.

After conditions have stabilized the following may be observed:

Water System

(i) The warm water enters the top of the tower and is fed into troughs from which it flows via notches onto the packing. The troughs are designed to distribute the water uniformly over the packing within minimum splashing.

(ii) The packing have an easily wetted surface and the water spreads over this to expose a large surface to the air stream.

(iii) The cooled water falls from the lowest packing into the basin and may then be pumped to a process requiring cooling (or in the Bench Top Cooling Tower, to the simulated load in the load tank).

(iv) Due to evaporation from the water, "make-up" must be supplied to maintain the quantity of water in the cooling system. The falling level in the load tank may be observed over a period of time.

(v) Droplets of water (resulting from splashing, etc.) may become entrained in the air stream and then lost from the system. This loss does not contribute to the cooling, but must be made good by "make-up". To minimize this loss, a "droplet arrester", or "eliminator" is fitted at the tower outlet. This component causes droplets to coalesce, forming drops which are too large to be entrained and these fall back into the packing.

Air System

(vi) Under the action of the fan, air is driven upward through the wet packing. It will be seen that the change of dry bulb temperature is smaller than the change of wet bulb temperature, and that at air outlet there is little difference between wet and dry bulb temperatures. This indicates that the air leaving is almost saturated, i.e. Relative Humidity -100%. This increase in the moisture content of the air is due to the conversion of water into steam and the "latent heat" for this account for most of the cooling effect.

(vii) If the cooling load is now switched off and the unit allowed stabilising, it will be found that the water will leave the basin close to the wet bulb temperature of the air entering.

According to the local atmospheric conditions, this can be several degrees below the incoming air (dry bulb) temperature.

With no load, the water would be cooled to the incoming wet bulb temperature, but this condition cannot be attained since the pump transfer about 100W to the water.

Note that under conditions of high ambient humidity the effectiveness of the cooling tower reduces due to the incoming air already being close to the saturated condition.

This is an interesting and instructive demonstration for students and explains the importance of “Approach to wet bulb” as a cooling tower parameter.

6.2 OBJECTIVE: 02

Determination of all end state properties of air and water from tables or charts and the application of the steady flow equation to selected systems to draw up energy and mass balances.

6.2.1 APPARATUS:

Bench Top Cooling Tower

6.2.2 THEORY

The Bench Top Cooling Tower should be prepared, started and allowed to stabilize under the following suggested conditions:

Orifice differential	16mm H_2O
Water flow rate	40gm s^{-1}
Cooling load	1.0kW

Note: Stability is reached when there is no further appreciable change in temperature, or flow rate).

At regular intervals over a measured period of say 10 minutes, all temperature and flow rates should be noted and the mean values entered on the observation sheet.

At the commencement of this period, fill the make-up tank to the gauge mark with distilled water. At the end of this period, refill the tank from a known quantity of distilled water in a measuring cylinder. By difference, determine the quantity of makeup which has been supplied in the time interval.

The observation may be repeated at other water or air flow rates and with another load.

Table 6.0.1: HILTON BENCH TOP COOLING TOWER OBSERVATION SHEET

Date: investigation: Atmospheric Pressure: 1010 mbar

TEST NO.	1	2	3	4	5	6
Packing installed	B					
Packing Density m^{-1}	110					
Air Inlet Dry Bulb $\frac{t1}{°C}$	20.8					
Air Inlet Wet Bulb $\frac{t2}{°C}$	17					
Air Outlet Dry Bulb $\frac{t3}{°C}$	22.9					
Air Outlet Wet Bulb $\frac{t4}{°C}$	22.7					
Water Inlet Temperature $\frac{t5}{°C}$	29.5					
Water Outlet Temperature $\frac{t6}{°C}$	23.1					
Water Make-up Temperature $\frac{t7}{°C}$ (Assumed same as ambient dry bulb temperature	20.8					
Orifice Differentia $\frac{x}{mmH_2O}$	16					
Water Flow Rate $m_{w/gs^{-1}}$	42					
Cooling Load $\frac{Q}{kW}$	1.0					
Make-up Quantity $\frac{mE}{kG}$	0.26					
Time Interval $\frac{y}{s}$	600					
Pressure Drop Across Packing $\frac{\Delta p}{\text{mm } H_2O}$						

6.2.3 SPECIMEN CALCULATIONS:

COMMENTS:

6.3 OBJECTIVE: 03

Investigation of the effect of cooling load on"wet bulb approach" and Relationship between Cooling Load and Cooling Range.

6.3.1 APPARATUS:

Bench Top Cooling Tower

6.3.2 THEORY

The Bench Top Cooling Tower should be prepared, started and allowed to stabilise under the following suggested conditions:

Water flow rate	40gm s^{-1}
Air flow manometer differential	16mmH_2O
Cooling load	0kW

While keeping the water and air flows constant, the load should be increased to 0.5 kW, and when conditions have been stabilised, the observations should be repeated.
Similar tests should be made with cooling loads of 1.0 and 1.5 kW.
The four tests may then be repeated at another constant air flow.

The test can be repeated:

1. At other water flow rates
2. At other air flow rates
3. With other packing

Table 6.0.2: HILTON BENCH TOP COOLING TOWER OBSERVATION SHEET

Date: investigation: Atmospheric Pressure: 1010 mbar

TEST NO.	1	2	3	4	5	6
Packing installed	B					
Packing Density m^{-1}	110					
Air Inlet Dry Bulb $\frac{t1}{°C}$	20.8					
Air Inlet Wet Bulb $\frac{t2}{°C}$	17					
Air Outlet Dry Bulb $\frac{t3}{°C}$	22.9					
Air Outlet Wet Bulb $\frac{t4}{°C}$	22.7					
Water Inlet Temperature $\frac{t5}{°C}$	29.5					
Water Outlet Temperature $\frac{t6}{°C}$	23.1					
Water Make-up Temperature $\frac{t7}{°C}$ (Assumed same as ambient dry bulb temperature	20.8					
Orifice Differentia $\frac{x}{mmH_2O}$	16					
Water Flow Rate $m_{w/gs^{-1}}$	42					
Cooling Load $\frac{Q}{kW}$	1.0					
Make-up Quantity $\frac{mE}{kG}$	0.26					
Time Interval $\frac{y}{s}$	600					
Pressure Drop Across Packing $\frac{\Delta p}{\text{mm } H_2O}$						

6.3.3 SPECIMEN CALCULATIONS:

GRAPH:

1. Draw Graph B/W Cooling Load and Approach to wet Bulb Temperature.
2. Draw Graph B/W Cooling Load & temperature.

6.3.4 COMMENTS:

6.4 OBJECTIVE: 04

Investigation of relation between air velocity and i) Wet bulb approach ii) Pressure drop through the packing

6.4.1 APPARATUS:

Bench Top Cooling Tower

6.4.2 THEORY

The Bench Top Cooling Tower should be prepared with the selected packed column and set to stabilise at a cooling load of 1.0kW and, at maximum air flow and with a water flow of 40gms^{-1}.

Note: To measure the pressure drop across the packing it is necessary to temporarily disconnect the plastic tube from the orifice tapping point. The tube should be reconnected to the pressure tapping point just below the packing, and another tube between the right-hand tapping on the manometer and the pressure tapping at the point of the pickings.

The test should be repeated with orifice pressure drop of 10, 4 and 1.0 mmH_2O, but with unchanged water flow rate and cooling loads.

The test may then be repeated:

1. At another constant load.
2. At another constant water flow rate.
3. Using another packing.

Table 6.0.3: HILTON BENCH TOP COOLING TOWER OBSERVATION SHEET

Date: investigation: Atmospheric Pressure: 1010 mbar

TEST NO.	1	2	3	4	5	6
Packing installed	B					
Packing Density m^{-1}	110					
Air Inlet Dry Bulb $\frac{t1}{°C}$	20.8					
Air Inlet Wet Bulb $\frac{t2}{°C}$	17					
Air Outlet Dry Bulb $\frac{t3}{°C}$	22.9					
Air Outlet Wet Bulb $\frac{t4}{°C}$	22.7					
Water Inlet Temperature $\frac{t5}{°C}$	29.5					
Water Outlet Temperature $\frac{t6}{°C}$	23.1					
Water Make-up Temperature $\frac{t7}{°C}$ (Assumed same as ambient dry bulb temperature	20.8					
Orifice Differentia $\frac{x}{mmH_2O}$	16					
Water Flow Rate $m_{w/gs^{-1}}$	42					
Cooling Load $\frac{Q}{kW}$	1.0					
Make-up Quantity $\frac{mE}{kG}$	0.26					
Time Interval $\frac{y}{s}$	600					
Pressure Drop Across Packing $\frac{\Delta p}{\text{mm } H_2O}$						

6.4.3 SPECIMEN CALCULATIONS:

6.4.4 GRAPH:

1. Draw Graph B/W Nominal Air Velocity & approach to Wet bulb.

6.4.5 COMMENTS:

6.5 OBJECTIVE: 05

Investigation of the effect of packing density on the performance of the cooling tower

6.5.1 APPARATUS:

Bench Top Cooling Tower

6.5.2 THEORY

Note that this experiment will only be possible if additional optional columns are available. The Bench Top Cooling Tower should be prepared, started and allowed to stabilise under the following suggested conditions:

Orifice differential	16mmH_2O
Load	1.5 kW
Water flow rate	30gm s^{-1}
Column installed	A

Column A should then be removed and Column B substituted. After preparation and stabilisation at the same conditions the observations should be repeated.
Finally, Column C should be installed and the observations repeated.
Note: Before removing and replacing a column, it may be desirable to carry out a series of tests at other loads, water flow rates and/or air flow rates.

Table 6.0.4: Derived Results

Packing Density	m^{-1}			
Wet Bulb Approach	K			

Table 6.5: HILTON BENCH TOP COOLING TOWER OBSERVATION SHEET

Date: investigation: Atmospheric Pressure: 1010 mbar

TEST NO.	1	2	3	4	5	6
Packing installed	B					
Packing Density m^{-1}	110					
Air Inlet Dry Bulb $\frac{t1}{°C}$	20.8					
Air Inlet Wet Bulb $\frac{t2}{°C}$	17					
Air Outlet Dry Bulb $\frac{t3}{°C}$	22.9					
Air Outlet Wet Bulb $\frac{t4}{°C}$	22.7					
Water Inlet Temperature $\frac{t5}{°C}$	29.5					
Water Outlet Temperature $\frac{t6}{°C}$	23.1					
Water Make-up Temperature $\frac{t7}{°C}$ (Assumed same as ambient dry bulb temperature	20.8					
Orifice Differentia $\frac{x}{mmH_2O}$	16					
Water Flow Rate $m_{w/gs^{-1}}$	42					
Cooling Load $\frac{Q}{kW}$	1.0					
Make-up Quantity $\frac{mE}{kG}$	0.26					
Time Interval $\frac{y}{s}$	600					
Pressure Drop Across Packing $\frac{\Delta p}{\text{mm } H_2O}$						

6.5.3 SPECIMEN CALCULATIONS:

GRAPH:

1. Draw Graph B/W Packing Area/Unit Volume & Approach to Wet Bulb.

6.5.4 COMMENTS:

LAB SESSION: 07

REFRIGERATION AND AIR CONDITIONING LABORATORY

HEATINH, VENTILATING & AIR CONDITIONING CONTROL & FAULT SIMULATOR 814B

OBJECTIVE NO: 1

Description of MIMIC diagram and components of simulator. And Observation of boiler, chiller, main AHU, VT circuit, DHW and controlling them through potentiometer and illuminated switches.

DEPARTMENT OF MECHANICAL ENGINEERING &TECHNOLOGY
UNIVERSITY OF ENGINEERING AND TECHNOLOGY LAHORE (KSK CAMPUS)

7.1 OBJECTIVE: 01

Description of MIMIC diagram and component of simulator. And Observation of boiler, chiller, main AHU, VT circuit, DHW and controlling them through potentiometer and illuminated switches.

7.1.1 APPARATUS:

Heating, Ventilation & Air Conditioning Control & Fault Simulator 814B

7.1.2 SETTING UP OF THE DEMONSTRATION UNIT

OPERATOR DISPLAY PANEL:

Note: When power is switched on, ensure that all green Differential Pressure Switches are illuminated (to alter state of lamps depress switches until they are illuminated).

1) On switching on the power the display comes up on the operators panel –DEMO CASE1
2) To access the unit press "Enter" Key
3) You now have access to the controller menu:-

(1)Info (2) Alarm (3) Boilers (4) Chiller (5) Main AHU

(6)VT Circuit (7) DHWS (8) Frost Status (9) Access Code

To scroll up and down through the menu use up (Δ) and down (∇) keys (See Diagram on Page 9)..
The flashing cursor moves as you scroll through the menu.
If you want access to any of the menus scroll until your cursor is flashing on the menu you require; e.g. –select DHWS and press "Enter" key.
It will come up as:-

Alarm DHWS
Pump Enabled
Flow Proven
Temperature
Set Point
Valve Open

Using "Δ/∇" keys select the display showing Temperature. The display now shows temperature values as set by the relevant potentiometer.
Altering the appropriate potentiometer alters the reading at the display, e.g. altering potentiometer No.9 will change the DHWS reading.
To return to the main menu, press "Home" Key.
By using the relevant function keys, alterations can be made to the five main functions as listed above.

Using Up/Down Keys select to following menus and press "Enter" Key.

7.1.3 DESCRIPTION OF MAIN MENUS

Info:

This gives the user information of the Outside and Room Temperatures, Manual Plant Enable and example of contact details (Note the contact numbers/programmers names are shown for example only).

Use “∆/∇” Keys select the page showing Outside Air and Room Temperature. By altering the relevant potentiometers (No.18 and No.38) you will see the display temperature alter. With these, temperature values can be altered to simulate changes.

Manual Plant Enable

This allows the user to switch the plant “On” or “Off”. Use the “∆/∇” keys to select the page showing Building Occupied.

If a “No. 1” is displayed, Plant is on

If a “No.0” is displayed, Plant is Off

By using the increase (+) Decrease (-) Keys (see diagram on page 9), the plant condition can be altered; e.g. – if plant is On (i.e. showing No.1) use the “-” Key to change to a No.0. Now press “Enter” Key and the plant now switches off.

Reverse the proven to switch back on (i.e. change back to No.1 and press “Enter” Key).

This is included in the exercise section of the book.

Use the “Home” Key to return to the Main Menu and now select Alarm using the “Enter” Key.

ALARM:

This display shows the alarm status of various components and will be included in the exercise section of the manual.

To acknowledge/clear an alarm press the “Enter” Key. If there is more than one alarm use the “∆/∇” Keys to acknowledge each one.

Using the “Home” Key return to the Main Menu and now select Boilers using the “Enter” Key.

BOILERS:

This allows the user to show and adjust the temperatures, and read the status of the boilers and constant Temperature Pumps.
The Display shows:-

Boiler Demand
Boiler Flow Temperature
Boiler Return Temperature
Set Point
Boiler 1 Enabled
Boiler 1 Fault
Boiler 2 Enabled
Boiler 2 Fault
Flow Proven
Pump 1 Enabled
Pump 2 Enabled

The Flow and Return Temperatures can be adjusted by altering the relevant Potentiometers (No.6 and No. 7). By altering the potentiometer you will see the display temperature alter. With these, temperature values can be altered to simulate changes.

The status of the Boilers and Pumps can be altered by pressing the relevant DPS Switch e.g. pressing DPS1 (No.10) will show 0 for flow proven i.e. the pump is not operating, and will switch the Boilers off. Pressing DPS1 again so it is illuminated will reverse the above and the Boilers will start again.

Using the "Home "Key to return to the Main Menu and now select Chiller using the "Enter" Key.

CHILLER:

This allows the user to read the status of the Chiller and Chiller Pumps.

The Display shows:-

Pump 1 Run
Pump 2 Run
Flow Failure
Chiller Run
Chiller Fault

The Status of the Chiller and Pumps can be altered by pressing the relevant DPS Switch e.g. pressing DPS4 (No.19) will show 0 for flow proven i.e. the pump is not operating, and will switch the Chiller off. Pressing DPS4 again so it is illuminated will reverse the above and the Chiller will start again.

Using the "Home" Key return to the Main Menu and now select Main AHU using the "Enter" Key.

MAIN AHU:

This allows the user to show and adjust set points and temperatures, and read the status of the AHU plant.

The display now shows:-

Bag Filer
Panel Filler
Dampers
Cooling Valve
Heating Valve
Supply Fan Enabled
Supply Fan Flow
Extract Fan Enabled
Extract Fan Flow
Room Temperature
Room Set Point
Supply Temperature
Supply Low Limit Set Point
Extract Humidity
Extract Relative Humidity Set Point

To adjust the set points use "Δ/∇/ "Keys use the increase (+)/ decrease (-) keys. These are important values as they will be the control temperatures selected.

Now use the "Δ/∇" keys to select the page showing Room Temperature. By altering the relevant potentiometer (No. 38) you will see the display temperature alter. With these, temperature values can be altered to simulate changes.

Use the "Home" Key to return to the Main Menu and now select VT **C**ircuit using the "Enter" Key.

V T CIRCUIT:

This allows the user to show set points and adjust temperatures, and read the status of the V T Pumps.

The display now shows:-

Flow Temperature
Set Point
Valve Position
Pump 1 Enabled
Pump 2 Enabled
Flow Proven

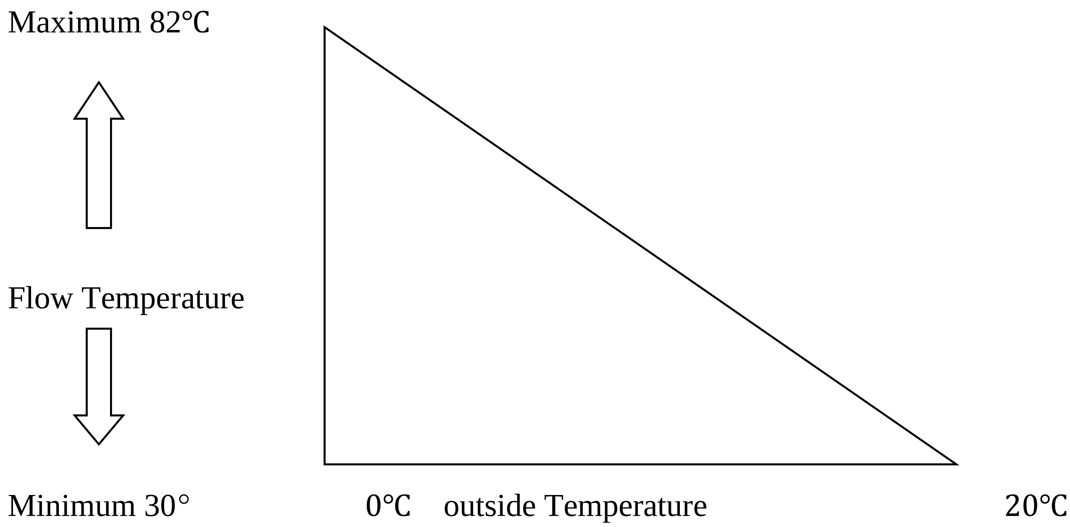
The status of the VVT Pumps can be altered by pressing the relevant DPS Switch e.g. pressing DPS (No.2) will show 0 for flow proven i.e. the pump is not operating. Pressing DPS2 again so it is illuminated will reverse the above.

Use the "Δ/∇"Keys to select the page showing Flow Temperature. By altering the relevant potentiometer
(No. 1) you will see the display temperature alter. With these, temperature values can be altered to simulate
Changes.
A compensated Heating Curve is already stored within the controller. This will give

$$60℃\ Flow\ at\ 0℃\ Out\ side\ Temperature\ and$$
$$30℃\ Flow\ at\ 20℃\ Outside\ Temperature$$

These settings are used to control the heating curve for your compensated (i.e. variable temperature) circuit.
Note: A compensator varies the flow temperature to your radiators dependant on outside conditions.

EXAMPLE OF COMPENSATION CURVE



As an example from the graph you can see that the heating curve is set to give a maximum flow temperature of 82℃ for the lowest outside temperature (i.e. the minimum design temperature) e.g. 0℃

It is also set to give a minimum flow temperature of 30℃ when the outside conditions are at 20℃.

By adjusting the Outside Temperature Potentiometer you will see the valve of the VT Circuit Set point change.

Now press the “Home” Key to return to the Main Menu and select DHWS using the “Enter” Key.

DHWS:

This allows the user to show set points and adjust temperatures, and read the status of the DHW plant.

The display now shows:-

Pump Enabled
Flow Proven
Temperature
Set Point
Valve Open

The set point for the Hot Water is set at 55℃. Use the “Δ/∇" keys to select the page showing the valve Open status. By altering the HWS Potentiometer (No.9) to lower than the set point you will see the display valve open reading change to show that the valve is open. Now turn the HWS Potentiometer to above 55℃ You will see that the reading had changed to 0, indicating that the valve has not closed.

FROST STATUS:

This allows the user to see whether the Room or Outside Frost condition is activated.

The display now shows:-

Room Frost
Outside Air Temperature Frost

By altering the relevant potentiometers (No.18. and No.38) you will see the display status with a 0 indicating no frost conditions and a 1 indicating frost conditions.

Now press the "Home" Key to return to the Main Menu and select Access codes using the "Enter" Key.

ACCESS CODES:

You will now be asked to enter an access code to enter the extended menu. Using the "+/-"keys change

Each of the four digits to 1, pressing "Enter" after each change i.e. the key strokes will be "+, Enter, +,

Enter, +, Enter,+, Enter". Now press the "Home "Key and you will find the extended menu option below the Access Code on the Main Menu.

The display now shows:-

Date and Time
Boiler Configuration
Chiller Configuration
Main AHU Configuration
VT Circuit Configuration
DHWS Configuration
Alarm Status
Manual Commands

The only items required in this section are Date and Time. All other settings should be left as set and not

Adjusted unless you are told otherwise within the exercises.

Date and Time:

Use the "∆/∇" keys to select Date and Time and press "Enter"Key.
This display allows the time and date to be entered.
Use the "Enter" Key to move the cursor, and the "=/-" Keys to set the correct date and time.
When operating times have been selected press "Home" Key to return to Main menu.
These exercise are designed to show the user how to simulate various conditions and how items of plant
React to changes.

Note: Please ensure the following before commencing.

PLANT ENABLE:

This exercise shows how to initiate start up on the plant components.

a) Press “Enter” Key to go to the Main Menu.
b) Select “Info” and press “Enter” Key.
c) Use the “Δ/∇” Keys to select the page showing:-
   Building occupied 0

   In this condition the plant is off. If the plant is on, adjust the Outside Air Temperature and Room Temperature potentiometers to read 15℃ as the plant is on under frost conditions.
   Using the “+” Key, change to a No.1. and press “Enter” Key. Now press the “Home” Key to return to the Main Menu.
   Plant initiates start up.

BOILER SEQUENCE CONTROL:

This is an application which is used when multiple boilers are the primary heat source for a heating system.
The control system brings the boilers on in sequence according to the demand for heat.

a) Select “Boilers” from the Main Menu and press “Enter” Key.
b) Use the “Δ/∇” Keys to select the page showing:-

Boiler Flow	x ℃ (Potentiometer No.7)
Boiler Return	X ℃ (Potentiometer No.6)

Set both potentiometers full anti-clockwise and both values should drop to a low value. Both green Run Lamps on the boilers should not be on (No.14 and No.16).
Slowly increase both potentiometers, keeping No.6 approximately 15℃ below No.7
When the boiler flow temperature gets close to its control point (using potentiometer No.7.) one boiler will go off.
Slowly increase potentiometer No.7 further and Boiler No. 1 will now go off. Both boilers are now off because we have achieved the desired flow temperature.
Again slowly decrease boiler flow potentiometer No.7 and both boilers now come back on because of the demand for heat.

COMPENSATED HEATING CIRCUIT:

a) Select “V.T. Circuit from the main Menu and press “Enter” Key.
b) The display will now read :-

Flow Temp	x℃
Set Point	x℃
Valve Pos	x℃

Using the potentiometers set outside temperature to 20℃ (Potentiometer No.18)
Note: To check the value of this select the “info” menu and use the Δ/∇ Keys to select the page showing Outside Air Temperature.

The set point on the VT Circuit display will now show 30℃ . this simulates the bottom end of the curve.
The variable temperature control valve (No. 4.) should be closed (i.e. 0 indication on the LED and the Display).

a) Now decrease the outside temperature slowly. You will see that the control valve is now opening to compensate for the lower outside temperature. The lower the outside temperature the more the control valve opens.

Drop the outside temperature to 0℃ and you will see that the control valve is fully open.

b) Now increase the variable temperature flow slowly (Potentiometer No.1.) As the temperature increases the control valve now closes off until your desired control temperature is achieved.

8.4. HEATING AND COOLING THE CONTROLLED SPACE:

For this exercise we now concentrate on the air conditioning system, employing dampers, cooling and heating. In this scheme the main control detector is in the room (Potentiometer No.38).
There is a duct detector in the supply duct, (Potentiometer No. 36) and this acts as a low limit.
Using "Home" to return to Main Menu.

a) Select "Access Codes" and enter the code as described above in section 7.9.
b) Select "Chiller CFG" from the Main Menu and press "Enter" key.
c) Use the Δ/∇ keys to select thepage sowing hold off set point. Use the "+/-" keys to alter this to read 15 , then press "Enter" key to store the new value.
d) Press "Home" key to return to the Main Menu. Select "Main AHU" and press "Enter" Key.
e) Use the Δ/∇ keys to select the page reading Room Temp.
This will now display the following:-

Room Temp x℃
Room SP x℃

Use the "+/-" keys to select a Room Set point of 21℃ , then press "Enter" to store the value.

f) Use the "Δ/∇ " keys to select the page reading Supply Temp.
This will now display the following:-

Supply Temp x℃
Supply Temp SP x℃

Using the potentiometer set the following temperatures

Room Temperature	21℃	(Potentiometer No.38)
Supply Low Limit Temp	18 ℃	(Potentiometer No.36)
Outside Air Temperature	15 ℃	(Potentiometer No.18)

Plant Conditions should now show the following:
Supply Fan Run
Extract Fan Run
Supply Damper Closed (i.e. low reading on LED Display No.23)
Extract Damper Closed (i.e. low reading on LED Display No.24)
Recirculation Damper Closed (i.e. low reading on LED Display No.25)
Heating Valve Closed (i.e. low reading on LED Display No.29)
Cooling Valve Closed (i.e. low reading on LED Display No.26)
Chiller Plant On (i.e. Full Recirculation On Dampers)
Note: Adjust the potentiometers lowly until the above plant conditions are shown.

We are now at the control conditions

a) Lower room air temperature to 16℃ , heating valve now opens because heat is being called back for.
b) Increase return air temperature back to 21℃ and the heating valve now closes.

Increase further and the dampers now operate in sequence. Increase further and the cooling valve now opens.

Plant Conditions:

Supply Fan Run
Extract Fan Run
Supply Damper Open (i.e. High reading on LED Display no.23)
Extract Damper Open (i.e. high reading on LED Display No.24)
Recirculation Damper Closed (i.e. high reading on LED Display No. 25)
Heating Valve Closed (i.e. 0 on LED Display No.29)
Cooling Valve Open (i.e. reading on LED Display No.26)

Economy on Refrigeration Load:

The dampers are further controlled by the outside temperature detector (Potentiometer No.18)
This economizes the refrigeration load when cooling is required.
When the temperature of the outside air is greater than that in the room, the dampers will revert to maximum recirculation with the outside air damper set in the minimum position.

a) Now increase outside air temperature (Potentiometer No.18) until it is higher then the room air temperature. The dampers now change to a recirculation position.

Supply Damper Closed (i.e. low reading on LED Display No.23)

Extract Damper Closed (i.e. low reading on LED Display No.24)

Recirculation Damper Open (i.e. low reading on LED Display No.2)

<u>Low Limited Control:</u>

Low Limit Control is achieved by a detector in the supply duct (Potentiometer No.36). its function is to prevent the entering air temperature falling to a level which might bring discomfort to the room occupants.

a) Reset all Potentiometer to original control conditions
e.g. Room Air to 21℃ (Potentiometer No. 38)
Supply Low limit to 18℃ (Potentiometer No. 36)
Outside Temperature to 15℃ (Potentiometer No.18)

Plant is now running under control conditions.

b) Slowly decrease supply low limit potentiometer (No.36) to below your set valve. The heating valve (LED Display No.29) now opens.

<u>Frost Protection</u>:

These are setting designed to prevent the plant from freezing up and to protect the room space (anti-condensation) when the plant is off.

Using “Home” Key return to Main Menu.

a) Select “Info” from the Main Menu and press “Enter” key. Use the “Δ/∇” keys to select the page showing:-
   Building Occupied

Switch plant off i.e. set at No.0 (as described earlier).

Switch Supply/Extract Differential Pressure Switches OFF

You will now see that all plant items are off.

b) Set outside temperature (Potentiometer No.18) down to 0℃ .All pumps now come on to circulate the water through the pipes to prevent freezing up.
c) Now set the room air temperature (Potentiometer No.38) down below 10 ℃ .

The Boilers now come on.

d) Now set the outside temperature and room air temperature to normal conditions. Using Potentiometer No. 18 and No. 38.
e) The plant now changes back to previous conditions i.e. all items off. (Pumps Delay Off)

7.3 AUTOMATIC CHANGEOVER AND TRIP OF PLANT COMPONENTS:

Alarm Functions—This is to show what happens if a plant component fails to trip out.

a) Set plant back to normal run conditions by changing the “Building Occupied” setting back to 1, and increasing the room temperature setting to 21℃ , and the outside temperature setting to 16℃ i.e.
   - Both Boilers On
   - All Pumps Running
   - All Green Differential Pressure Switches illuminated (Switch ON)
   - All Red differential Pressure Switches not illuminated (Switch OFF)
   - Chiller Plant On

Using “Home” Key return to Main Menu

b) Go to “Alarms” and press “Enter” Key. Acknowledge any alarms shown as already described in Section 7.2.
c) Press “Home” Key twice to set display at the operator display panel to read CASE 1.
d) Press and illuminate Boiler No.1 trip lamp (No 17). The red light comes on. The green run light goes out (No.16)

The display at the operators panel now reads:-

****ALARM***

*ALR*CASE1

This is now telling the operator that a component has failed.

Using “Enter” Key to return to Main Menu

e) Select the “Alarm” menu at the operator display panel and press “Enter” Key.

The display now reads:-

ALARM 1/1

BOILER 1

BOILER 1 FAILS

DATR-TIME-ON

This is indicating that the alarm is 1 of 1, Boiler No 1 has failed, with the relevant time and date.

To accept and acknowledge the alarm press the “Enter” Key, the on symbol has now changed to ACK.

This means the alarm has been acknowledged.

No reset the boiler switches No. 17.

Boiler restarts and the Main Menu returns to its display.

Pressing any red lamp will result in fault condition showing at the operators display panel. More than on alarm can be stored at the same time. Ensure that all alarms are acknowledged or reset before returning to normal run.

f) Use “Home” Key to return to original display:-
   CASE 1
g) Press switch DPS (No. 10) – constant temperature pumps (illumination goes out).

This will simulate a pump fault on the one that is running. Automatic changeover to the other pump comes into effect after a few seconds, which will be show by the green lights changing from one pump to another.

h) Again the display sows that an alarm has triggered. As before acknowledge and reset.

Re-illuminate switch No. 10.

i) Press all switches to simulate all faults. Acknowledge all and reset.
j) Press switch DPS8 (No.32) supply fan light goes out and as a safety interlock the extract fan also goes off. As before acknowledge and reset switch.

7.4 DOMESTIC HOT WATER CONTROL:

This is to show the On/Off control of the primary water supply to the cylinder.

a) Set domestic hot water potentiometer (No.9) to fully clockwise.
b) The LED Display on the control valve (No.5) should read 0.
c) Rotate the Potentiometer fully anti-clockwise.
d) The LED Display on the control valve should read 100 to show the valve is open.

7.5 HUMIDIFIER CONTROL:

This is to show the On/Off control of the Humidifier within the AHU.

e) Set the Return Air Humidity Potentiometer (No.37)to fully anti-clockwise.
f) The Humidifier light should be illuminated to indicate that the Humidifier is operating (No.40)
g) Rotate the Potentiometer fully clockwise.
h) The Humidifier light should switch off to indicate that the Humidifier is not operating.