MADHA
Expertise | Empathy | Excellence
ENGINEERING COLLEGE

DEPARTMENT OF MECHANICAL ENGINEERING

LABORATORY MANUAL

ME3611 HEAT TRANSFER LABORATORY

YEAR/SEMESTER : III/06

REGULATION 2021

Ex.No:1	THERMAL CONDUCTIVITY OF PIPE INSULATION USING LAGGED PIPE APPARATUS
Date :	

AIM:

To determine the thermal conductivity of pipe insulation for a given lagged pipe apparatus.

APPARATUS REQUIRED:

1. Lagged Pipe Apparatus.

FORMULA:

$$T_a = \frac{T_1 + T_2 + T_3}{3}$$

$$T_b = \frac{T_4 + T_5 + T_6}{3}$$

$$T_c = \frac{T_7 + T_8 + T_9}{3}$$

$$Heat\ input, Q = V \times I \quad watts$$

$$Heat\ input, Q = \frac{2 \times \pi \times L \times (t_0 - t_i)}{ln\left(\frac{r2}{r1}\right)} \quad watts$$

Tabulation:

Heat temperature					Asbestos temperature				Saw dust temperature			
S.No	1	2	3	Avg	4	5	6	Avg	7	8	9	Avg

PROCEDURE:

1. Switch ON the unit and check if air channels of temp indicator showing proper temperature.
2. Switch ON heater using regulator and keep power input at port value.
3. Allow the unit to stabilize for about 20 to 30 minutes.
4. Now note down ammeter, voltmeter reading giving the head input temp 1,2,3 the temp of heater 4,5,6 and asbestos layer 7,8,9 and saw dust clogging.
5. Average temperature of each cylinder is taken from calculation
6. Temperature is measured by thermocouple with multiplied digital temperature indicator.
7. Experiment may be repeated for different heat input.

Result:

Thermal conductivity of lagged pipe is

i. K_1 (Asbestos) =___________________w/m° C

ii. K_2 (Saw Dust) =___________________ w/m°

Specifications:

1. Diameter of the tube = 38mm
2. Length of the tube (L) = 500mm
3. Du $200mm \times 200mm \times 750mm$
4. Number of thermocouples = 7+1
5. Temperature indicator = 0 – 300 °C
6. Heat capacity = 400 watts.

Theory:

Natural convection is a mechanism, or type of heat transport, in which the fluid motion is not generated by any external source (like a pump, fan, suction device, etc.) but only by density differences in the fluid occurring due to temperature gradients. In natural convection, fluid surrounding a heat source receives heat, becomes less dense and rises. The surrounding, cooler fluid then moves to replace it.

This cooler fluid is then heated and the process continues, forming convection current; this process transfers heat energy from the bottom of the convection cell to top. The driving force for natural convection is buoyancy, a result of differences in fluid density. Because of this, the presence of a proper acceleration such as arises from resistance to gravity, or an equivalent force (arising from acceleration, centrifugal force or Coriolis force), is essential for natural convection.

For example, natural convection essentially does not operate in free-fall (inertial) environments, such as that of the orbiting International Space Station, where other heat transfer mechanisms are required to prevent electronic components from overheating.

Viva Voice Questions:

1. Define natural and forced convection.
2. What is the significance of heat Transfer Coefficient?
3. Give the heat transfer coefficient ranges of Air and water for natural and forced convection.
4. Significance of Nusselt Number?

Ex. No: 2	HEAT TRANSFER THROUGH A VERTICAL PIPE BY NATURAL CONVECTION
Date :	

AIM:

To determine the surface heat transfer coefficient for the vertical tube losing heat by natural convection.

APPARATUS REQUIRED:

1. Natural convection apparatus
2. Stop watch

Formula Used:

$1. Heat\ input = Q = V \times I$

$$2. Average\ surface\ temperature, T_s = \left(\frac{T_1 + T_2 + T_3 + T_4 + T_5 + T_6 + T_7}{7}\right)$$

$$3. Average\ heat\ transfer\ coefficient = h_{act} = \frac{Q}{A_s(T_s - T_a)}$$

$A_s = \pi DL$ Where D = 0.038 & L= 0.5

$$4\ Coefficient\ of\ volumetric\ expansion, \beta = \frac{1}{(T_{mf} + 273)}$$

$$where, T_{mf} = \frac{T_s + T_a}{2}$$

5. *For vertical cylinder losing heat by natural convection,*

$$\frac{h \times l}{k} = 0.56(Gr.Pr)^{0.25}\ for\ 10^4 < Gr.Pr < 10^8$$

$$\frac{h \times l}{k} = 0.13(Gr.Pr)^{0.25}\ for\ 10^8 < Gr.Pr < 10^{12}$$

$$6. Gr = L^3 \times g \times \beta \times \frac{\Delta T}{v^2}\quad where, \Delta T = (T_s - T_a)$$

$$7. Pr = \frac{\mu \times C_p}{k}$$

$$8. h_{the} = \frac{Nu \times k}{L}$$

$$Nu = 0.023 \times Re^{0.8} \times Pr^{0.4}$$

Tabulation:

		Thermocouple reading (°C)							
S.No	Time(Min)	T1	T2	T3	T4	T5	T6	T7	T8

PROCEDURE:

1. Switch ON the power supply and adjust the dimmer stat to obtain the require heat input.
2. Wait till the fairly steady state is reached, which is confirmed from temperature readings (T_1+T_7).
3. Note down the surface temperature at the various points.
4. Note the ambient temperature (T_8)
5. Repeat the experiment at different heat inputs.

Result:

i. Average heat transfer coefficient, h_{act}= ________________

ii. Average heat transfer coefficient, h_{the}= ______________

Specifications:

1. Outside diameter of the pipe, Do = 33mm
2. Inside diameter of the pipe, Di = 28mm
3. Length of the tube = L = 400mm
4. Blower capacity = 0.21 KW
5. Orifice diameter =14mm connected to manometer.
6. Dimmer stat range = 0-2 amps,0-230 V
7. Temperature indicator range = 0-300^{0}C
8. Voltmeter and ammeter range = 0-200 V and 0-2 amps
9. Heater = 400 Watts

Theory:

Forced convection is a mechanism, or type of heat transport in which fluid motion is generated by an external source (like a pump, fan, suction device, etc.). It should be considered as one of the main methods of useful heat transfer as significant amounts of heat energy can be transported very efficiently and this mechanism is found very commonly in everyday life, including central heating, air conditioning, steam turbines and in many other machines. Forced convection is often encountered by engineers designing or analyzing heat exchangers, pipe flow, and flow over a plate at a different temperature than the stream (the case of a shuttle wing during re-entry, for example). However, in any forced convection situation, some amount of natural convection is always present whenever there are g-forces present (i.e., unless the system is in free fall). When the natural convection is not negligible, such flows are typically referred to as mixed convection.

Viva Voice Questions:

1. Significance of Reynolds's number?
2. Difference between heat ant temperatures?
3. How is natural convection different from forced convection?
4. What is the range of values for the emissivity of a surface?
5. What is the Fourier number

Ex. No: 3	HEAT TRANSFER THROUGH A PIPE BY FORCED CONVECTION
Date :	

AIM:

To determine the surface heat transfer coefficient for the vertical tube losing heat
by natural convection.

APPARATUS REQUIRED:

1. Natural convection apparatus
2. Stop watch

Tabulation:

V = I =

		Thermocouple reading (^oC)								Manometer reading (m of water)
S.No	Time(Min)	T1	T2	T3	T4	T5	T6	T7	T8	

PROCEDURE:

1. Start the blower and adjust the flow by means of gate valve to sum desired difference in manometer level.
2. Start the heating of the test section with the help of dimmer stat and adjust desired heat input with help of voltmeter and ammeter.
3. Take readings of all the six thermocouples at an interval of 10 mins until the steady state is reached.
4. Note down the heater input
5. Calculation is done by using the convective heat transfer relations.

RESULT:

i. Surface heat transfer coefficient, h_a =________________
ii. Reynolds number, Re = _________________
iii. Nusslet number

Nu_{the} = _________________

Nu_{act} = _________________

Specifications:

Diameter of pin fin, D = 0.012m

Theory:

In the study of heat transfer, a fin is a surface that extends from an object to increase the rate of heat transfer to or from the environment by increasing convection. The amount of conduction, convection, or radiation of an object determines the amount of heat it transfers. Increasing the temperature difference between the object and the environment, increasing the convection heat transfer coefficient, or increasing the surface area of the object increases the heat transfer. Sometimes it is not economical or it is not feasible to change the first two options. Adding a fin to an object, however, increases the surface area and can sometimes be an economical solution to heat transfer problems.

Viva Voice Questions:

1. Explain Fin?
2. What are the types of fins?
3. Application of Fins?
4. Define Fin Efficiency?
5. Define Fin Effectiveness

Ex. No: 4	HEAT TRANSFER FROM A PIN FIN APPARATUS
Date :	

AIM:

To study the temperature distribution along the length of a pin fin in natural and forced convection, and to determine the heat transfer coefficient and effectiveness of the pin fin.

APPARATUS REQUIRED:

1. Pin fin apparatus

FORMULAE:

Natural convection

$$1. Average\ fin\ temperature, T_m = \frac{T_1 + T_2 + T_3 + T_4 + T_5}{5}$$

$$2. Mean\ fin\ temperature, T_{mf} = \frac{T_m + T_6}{2}$$

$$3. Mean\ film\ temperature, \beta = \frac{1}{T_{mf} + 273}$$

$$4. Grashoff\ Number, Gr = \frac{g \times \beta \times D^2 \times \Delta T}{\vartheta^2}$$

$where, T_6 = Ambient\ temperature\ in\ 0_C$; $\Delta T = T_m - T_6$

$Nusellt's number, Nu = 1.1 \times (Gr.Pr)^{0.66}$ $\rightarrow 10^{-1} < Gr < 10^4$

$$h = \frac{Nu \times K}{D}$$

$m = mass\ flow\ rate;$ $Circumference\ of\ fin, C = \pi \times D$

$$T_1 \times Pr = T_1$$

$$T_2 \times Pr = \frac{coshm(L-x)}{cosh(mL) \times (T_1 - T_0)} + T_0$$

$Effective\ length\ of\ fin, L = 12.5\ cm$

$Thermocouple\ distance, x = 2.5\ cm$

$$5. Rate\ of\ heat\ transfer\ from\ fin, q = \sqrt{h \times c \times K \times A \times (T_1 - T_0) \times \tanh(mL)}$$

$$6. The\ effeciency\ of\ the\ fin, \eta = \frac{\tanh(mL)}{mL}$$

Forced Convection:

1. $T_{avg} = \frac{T_1+T_2+T_3+T_4+T_5}{5}$

$$T_{mf} = \frac{T_{avg} + T_6}{2}$$

2. $Volume\ flow\ rate\ of\ the\ duct, Q = C_d \times \frac{\pi}{4} d^2 \times \sqrt{2gH\frac{\rho_w}{\rho_a}}$

Where, H = difference in levels in manometer

ρ_w = density of water = 1000 Kg/m^3 ; ρ_a = density of

air at $T_{mf}T_0$ 3.

$Velocity\ of\ air\ at\ T_6, V = \frac{Q}{Duct\ cross\ sectional\ area}$ $in\ \frac{m}{s}$

4. $Velocity\ of\ air\ at\ T_{mf} = V \times \frac{T_{mf}+273}{T_6+273}$ $in\ \frac{m}{s}$

$$m = \sqrt{\frac{h \times C}{K \times A}}$$

5. $Rate\ of\ heat\ transfer, q = \sqrt{hCKA}(T_1 - T_6)\tanh(mL)$

6. $Effeciency, \eta = \frac{\tanh(mL)}{mL}$

TABULATION:

Forced convection:

S.No	V(volts)	I (amps)	Fin temperature ^{0}C					Ambient temperature T6
			T1	T2	T3	T4	T5	

Natural Convection:

S.No	V(volts)	I (amps)	Fin temperature ^{0}C					Ambient temperature T6
			T1	T2	T3	T4	T5	

<u>PROCEDURE</u>:

Procedure:

1. **Natural convection:**
   1. Start heating the fin by switching ON the heater element and adjust the voltage on dimmer stat to say 80 V (increase slowly from zero onwards).
   2. Note down the thermocouple readings 1 to 5.
   3. When the steady state is reached, record the final reading also records the ambient reading 6.
   4. Calculate the heat transfer coefficient and effectiveness of the pin fin using heat transfer relations.

2. **Forced convection:**
   1. Start heating the fin by switching ON heater element and adjust the voltage on dimmer stat equal to 100 V (increase slowly from zero onwards).
   2. Start the blower and adjust the difference of level in the manometer with help of gate valve.
   3. Note down the thermocouple reading 1 to 5 at the time interval of 5 mins.
   4. When the steady state is reached record the final reading 1 to

5 and also record the ambient temperature reading

5. heat transfer relations

6.Calculate the heat transfer coefficient and effectiveness of the fin pin using

RESULT:

i. Average heat transfer coefficient, h_{act}= _______________

ii. Average heat transfer coefficient, h_{the}= _______________

Specifications:

1. Hemisphere diameter = 200mm
2. Base plate, Bakelite diameter =240mm
3. Sleeve size diameter = 44mm
4. Test disc diameter = 20mm
5. Mass of the disc = 0.005 kg
6. Specific heat of test disc = 0.418 kj/kg^{o}c
7. No of thermocouples = 5
8. Water heater capacity = 1.5 kw

Theory:

The Stefan–Boltzmann constant (also Stefan's constant), a physical constant denoted by the Greek letter σ, is the constant of proportionality in the Stefan–Boltzmann law: the total energy radiated per unit surface area of a black body in unit time is proportional to the fourth power of the thermodynamic temperature.

The value of the Stefan–Boltzmann constant is given in SI by

$$\sigma = 5.670400(40) \times 10^{-8}\ \mathrm{W\,m^{-2}\,K^{-4}}$$

Ex. No: 5	STEFAN BOLTZMANN CONSTANT
Date :	

Aim:

To find out the relative viscosity, kinematic viscosity and absolute viscosity of oil sample

by using redwood viscometer and study the variation of viscosity with change in temperature.

Apparatus Required:

1. Stefan Boltzmann apparatus
2. Stop watch

FORMULAE:

$$1.\ Area\ or\ the\ disc, Ad = \frac{\pi \times d^2}{4}$$

$where\ d\ ,is\ the\ diameter\ of\ test\ disc\ in\ m.$

$$2.\ T_{av} = \frac{(T_1 + T_2 + T_3 + T_4)}{4}\ (K)$$

$$3.\ \sigma = \frac{m \times s \times \left(\frac{dT}{dt}\right) \times s}{Ad \times [T_{av}{}^4 - T_o{}^4]}$$

Where σ = Stefan Boltzmann constant, ms = Mass of disc in kg

dT/dt = Rate of rise in temperature.

Tabulation:

	Thermocouple readings ^0C			
S.No	T1	T2	T3	T4

S.No	time	Temp	S.No	time	Temp	S.No	time	Temp
1			20			39		
2			21			40		
3			22			41		
4			23			42		
5			24			43		
6			25			44		
7			26			45		
8			27			46		
9			28			47		
10			29			48		
11			30			49		
12			31			50		
13			32			51		
14			33			52		
15			34			53		
16			35			54		
17			36			55		

Procedure:

1. The water in the tank by the heater upto a temp of about 90 ^oc
2. The disc D is removed before the hot water in the jacket.
3. Hot water is poured in water jacket.
4. Hemispherical enclosure B & A will come to some uniform temp T in a short time after filling the hot water in jacket.
5. The thermal inertia of the hot water is quite adequate to present significant cooling in time required to conduct the experiment.
6. Enclosure will soon come to thermal equilibrium conditions.
7. Supply water till the temperature reaches constant value of T_1,T_2,T_3,T_4.
8. Note down the values of ambient temperature T_0 at intervals of 5 mins.

9. Calculations are then done using radiation relations.

Results:

Thus the Stefan Boltzmann constant is found to be = _______

Specifications:

1. Diameter of heater rod = 20mm
2. Test plate = $\varnothing\ 160mm$
3. Black plate = $\varnothing\ 160mm$ Aluminum
4. Heater for nichrome would on mica sheet
5. Heater for the above capacity of heater = 200 V each.
6. Dimmerstat for (1) 0-2 A, 0-260 V.
7. Dimmerstat for (2) 0-2 A, 0-260 V.
8. Voltmeter 100-200 V, ammeter 0-2 A

Theory:

The emissivity of a material (usually written ε or e) is the relative ability of its surface to emit energy by radiation. It is the ratio of energy radiated by a particular material to energy radiated by a black body at the same temperature. A true black body would have an $\varepsilon = 1$ while any real object would have $\varepsilon < 1$. Emissivity is a dimensionless quantity.In general, the duller and blacker a material is, the closer its emissivity is to 1. The more reflective a material is, the lower its emissivity. Highly polished silver has an emissivity of about 0.02.

Emissivity depends on factors such as temperature, emission angle, and wavelength. A typical engineering assumption is to assume that a surface's spectral emissivity and absorptivity do not depend on wavelength, so that the emissivity is a constant. This is known as the "gray body assumption".

Although it is common to discuss the "emissivity of a material" (such as the emissivity of highly polished silver), the emissivity of a material does in general depend on its thickness. The emissivities quoted for materials are for samples of infinite thickness (which, in practice, means samples which are optically thick) — thinner samples of material will have reduced emissivity.

When dealing with non-black surfaces, the deviations from ideal black body behavior are determined by both the geometrical structure and the chemical composition, and follow Kirchhoff's law of thermal radiation: emissivity equals absorptive (for an object in thermal equilibrium), so that an object that does not absorb all incident light will also emit less radiation than an ideal black body.

Most emissivities found in handbooks and on websites of many infrared imaging and temperature sensor companies are the type discussed here, total emissivity. However, the distinction needs to be made that the wavelength-dependent or spectral emissivity is the

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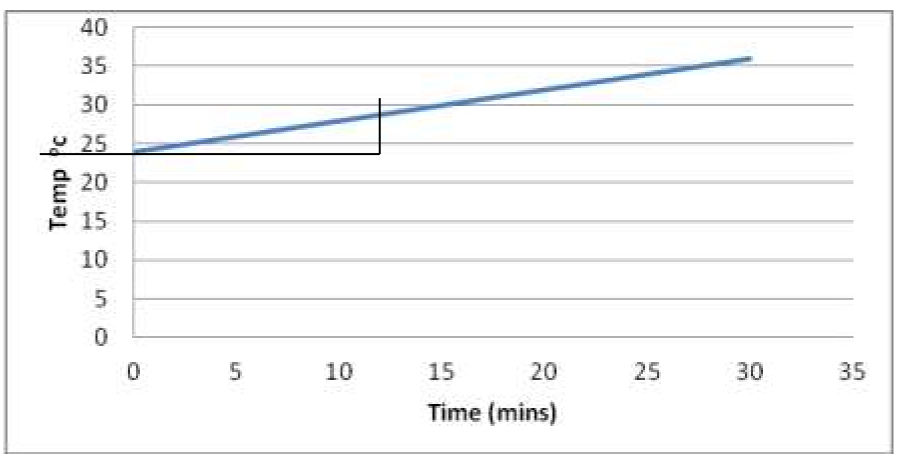


Ex.No:6	EMISSIVITY MEASUREMENT APPARATUS
Date :	

AIM: To find emissivity of the test plate calculated at various surface temperatures of plates.

APPARATUS REQUIRED:

1. Emissivity Apparatus.

FORMULA:

$$\omega_b = V_1 \times I_1$$

$$\omega_t = V_2 \times I_2$$

$$(\omega_b - \omega_t) = (E_b - E) \times \sigma \times A \times (T_s^4 - T_a^4)$$

Tabulation:

Black plate			Test plate			Enclosure temperature ^{0}C
V_1	I_1	T_h	V_2	I_2	T_s	

PROCEDURE:

1. Gradually increase the input to the heater to black plate and adjust it to same value voltage 30, 50, 75 watts and adjust the heater input to test plate.
2. Check the temperature of the two plots with small intervals and adjust input of the plate.
3. This coil required some trial and error and one has to sufficient more than one hour to obtain steady state condition.
4. After attaining steady state condition record the temperature,

voltmeter and ammeter readings.

The same procedure is repeated for various surface temp in increasing order.

Result:

Thus the Emissivity of the given material is found as, E =______________

Specifications:

1. Inner tube material – copperInner diameter = 10.5 mm Outer diameter= 12.5mm
2. Outer tube material – G.IInner diameter = 27.5 mm Outer diameter= 33.8mm
3. Length of heat exchanger (L)= 1650mm

Ex.No7	HEAT EXCHANGER
Date:	

AIM:

To determine the effectiveness and overall heat transfer coefficient of the parallel and flow and counter flow heat exchanger.

APPARATUS REQUIRED:

1. Parallel flow counter flow apparatus.

Theory:

Parallel-flow Heat Exchanger

Figure above shows a fluid flowing through a pipe and exchanges heat with another fluid through an annulus surrounding the pipe. In a parallel-flow heat exchanger fluids flow in the same direction. If the specific heat capacity of fluids is constant, it can be shown that:

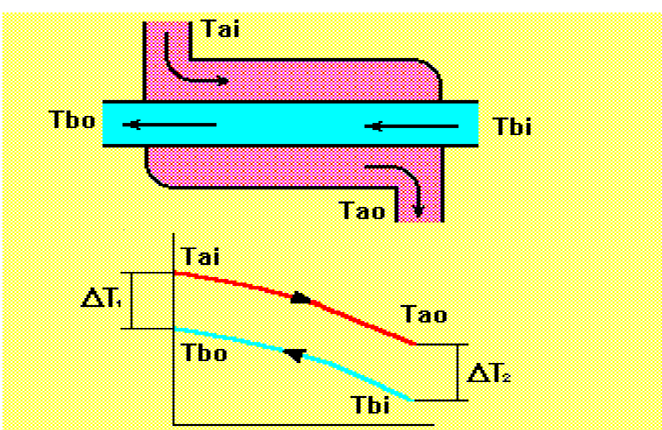
$$dQ/dt = U\ A\ \Delta T$$

where,

dQ/dt= Rate of heat transfer between two fluids U=
Overall heat transfer coefficient
A= Area of the tube
ΔT= Logarithmic mean temperature difference defined by:

$$\Delta T = (\Delta T_1 - \Delta T_2)/\ln(\Delta T_1/\Delta T_2)$$

Counter-flow Heat Exchanger



Temperature distribution along tube axis.

Figure above shows a fluid flowing through a pipe and exchanges heat with another fluid through an annulus surrounding the pipe. In a counter-flow heat exchanger fluids flow in the opposite direction. If the specific heat capacity of fluids is constant, it can be shown that:

dQ/dt=U A ΔT

where,
dQ/dt= Rate of heat transfer between two fluids U=
Overall heat transfer coefficient
A= Area of the tube
ΔT= Logarithmic mean temperature difference defined by:

ΔT=(ΔT1-ΔT2)/ln(ΔT1/ΔT2)

FORMULA:

1. $Mass\ flow\ rate, m = \frac{x \times \rho \times 10^3}{t}\left(\frac{kg}{sec}\right)$

2. $Heat\ transfer\ rate, Q = m \times c_p \times \Delta T$

3. $Heat\ transter\ rate\ from\ hot\ water, Q_h = m_h \times c_{ph} \times \Delta T_h$

$\Delta T_h = Th_i - Th_o$
$Ai = \pi \times D_i \times L$

4. $Effectiveness, \varepsilon = \frac{m_c \times C_{pc} \times (Tc_o - Tc_i)}{m_h \times C_{ph} \times (Th_o - Th_i)}$

5. $Heat\ transter\ rate\ from\ cold\ water, Q_c = m_c \times c_{pc} \times \Delta T_c$

6. $Avwrage\ heat\ transfer\ rate, Q = \frac{Q_h + Q_c}{2}$

7. $Logarthamic\ maen\ temperature\ difference, LMTD = \frac{\Delta T_i - \Delta T_o}{\ln(\Delta T_i - \Delta T_o)}$

8. $LMTD = \frac{\{(Th_i - Tc_i) - (Th_o - Tc_o)\}}{ln\{(Th_i - Tc_i) - (Th_o - Tc_o)\}}$

9. $Overall\ heat\ transfer\ coefficient, U = \frac{Q}{A \times LMTD}$

Tabulation:

	Hot water side			Cold water side		
Flow Type	Time for 1 litre of water flow(sec)	Inlet temperature T_{hi} ^0C	Outlet temperatue T_{ho} ^0C	Time for 1 litre of water flow(sec)	Inlet temperatue T_{ci} ^0C	Outlet temperature T_{co} ^0C
Parallel						
counter						

PROCEDURE:

1. Place the thermometers in position and note down their readings when they are at room temperature and no water is flowing at either side. This is required to correct the temperature.
2. Switch ON the heater.
3. Wait until the water is heated to about 80 ^oc.
4. Start the flow on hot water side.
5. Start the flow through annulus and run the exchanger as parallel flow unit.
6. Adjust the flow rate on hot water side, between the range of 1.5 to 4 lit/min.
7. Adjust the flow rate on cold water side, between the range of 3 to 8 lit/min.
8. Record the temperatures on hot water and cold water side and also the flow rates accurately.
9. Place the thermometers in position and note down their readings when they are at room temperature and no water is flowing at either side. This is required to correct the temperature.
10. Switch ON the heater.
11. Wait until the water is heated to about 80 ^oc.
12. Start the flow on hot water side.
13. Start the flow through annulus and run the exchanger as parallel flow unit.
14. Adjust the flow rate on hot water side, between the range of 1.5 to 4 lit/min.
15. Adjust the flow rate on cold water side, between the range of 3 to 8 lit/min.
16. Record the temperatures on hot water and cold water side and also the flow rates accurately.
17. Temperature is measured by thermocouple with multiplied digital temperature indicator.

Result:

1. Parallel flow:

Effectiveness = _ Overall heat transfer coefficient = ____

2. Counter flow:

Effectiveness = __________________

Overall heat transfer coefficient = ___________________

Ex.No:8	PERFORMANCE TEST ON A REFRIGERATION SYSTEM
Date :	

AIM:

To determine the COP, Refrigerant flow rate and capacity of a given refrigerant system and its control where throttling of the refrigerant is accomplished in a

i. A capillary tube.
ii. A thermostatic expansion valve.

Specifications:

1. A compressor condenser placed inside trolley and fitted with
   i. Freon-12 reciprocating compressor.
   ii. Condenser
   iii. 0.5 hp, 220 V, single phase capacitor start induction motor with condenser cooling fan.
   iv. A receiver with angle check valve.
2. Chilled water calorimeter consisting of a refrigerant S.S vessel of amply capacity placed inside a well insulated wooden box and provided with
   1. Evaporator coil.
   2. Manual stirrer
   3. Electric heater 230 V, A.C.
   4. The sensing bulb of a low temperature thermostat.
   5. A high temperature thermostat.
   6. A thermometer to measure the chilled water temperature.

The above unit is located on the trolley behind front panel.

3. A delcolam finished front panel on which are mounted the following :
   1. Capillary expansion tube with isolating valve.
   2. Thermostatic expansion valve, solenoid, thermostat, solenoid switch, indicatore and isolating valve.
   3. Drier cum strainer and sight glass for Freon-12.
   4. Mercury in glass thermometers at inlet and outlet of both evaporator and condenser.
   5. Main switch, fuses, indicator unit and compressor safety HP/LP cutout.
   6. Energy meter and selector switch to measuer the power consumed by either heater of compressor.
   7. A study trolley mounted on castor wheels with a table top and furnished with all the above.

Theory:

Refrigeration is a process in which work is done to move heat from one location to another. Refrigeration has many applications including but not limited to; household refrigerators, industrial freezers, cryogenics, air conditioning, and heat pumps. In order to satisfy the Second Law of Thermodynamics, some form of work must be performed to accomplish this. The work is traditionally done by mechanical work but can also be done by magnetism, laser or other means.

Probably the most widely used current applications of refrigeration are for the air-conditioning of private homes and public buildings, and the refrigeration of foodstuffs in

homes, restaurants and large storage warehouses. The use of refrigerators in kitchens for the storage of fruits and vegetables has permitted the addition of fresh salads to the modern diet year round, and to store fish and meats safely for long periods.

In commerce and manufacturing, there are many uses for refrigeration. Refrigeration is used to liquify gases like oxygen, nitrogen, propane and methane for example. In compressed air purification, it is used to condense water vapor from compressed air to reduce its moisture content.

In oil refineries, chemical plants, and petrochemical plants, refrigeration is used to maintain certain processes at their required low temperatures (for example, in the alkylation of butenes and butane to produce a high octane gasoline component). Metal workers use refrigeration to temper steel and cutlery. In transporting temperature-sensitive foodstuffs and other materials by trucks, trains, airplanes and sea-going vessels, refrigeration is a necessity.

The benefits include, in addition to reducing costs and environmental impacts of energy consumption:

Reducing or eliminating condensation on cold pipes.

- Protection from dangerous pipe temperatures.
- In domestic hot-water systems, the water temperature at the point of use can be closer to the temperature at the water heater, and wait time for hot water can be reduced
- Control of noise.
- Reduction of unwanted heat gain to air-conditioned spaces.

Viva Voice Questions:

2. What is refrigeration system?
3. Explain the different components involved in refrigeration cycle?
4. What is COP?
5. What is difference between COP and Efficiency?

$$Work\ done\ by\ compressor = \frac{3600 \times n}{1200 \times t_c} \quad \frac{KJ}{Sec}$$

$$2. Heat\ remove = refrigerating\ effect = \frac{3600 \times n}{1200 \times t_h} \quad \frac{KJ}{Sec}$$

$$3. Actual\ COP(Refrigerator) = \frac{heat\ removed}{work\ done\ by\ the\ compressor}$$

$$4. Theoretical\ COP(Refrigerator) = \frac{h_1 - h_4}{h_2 - h_1}$$

1. Refrigeration System.

FORMULA:

h_1, h_2, h_3, h_4 *are taken from* $R - 12$ *chart*

where, n = *number of revolutions of energy meter disc*

t_h = *time take for n revolutions of energy meter disc of heater unit*

t_c = *time take for n revolutions of energy meter disc of compressor unit*

$$5. Refrigeration\ flow\ rate = \frac{Refrigerant\ capacity}{work\ done\ by\ compressor}$$

where, Refrigerant capacity $= m(h_1 - h_2)$

m = *mass flow rate of the refrigerant* $\frac{Kg}{Sec}$

$$Relative\ COP = \frac{Actual\ COP}{Theoretical\ COP}$$

Tabulation:

Time for 5 rev of energy meter disc		Ammeter reading (Amps)	Voltmeter reading (Volts)	Temperature (^{0}C)				Pressure(bar)			
Heater t_h	Compressor t_c			T1	T2	T3	T4	P1	P2	P3	P4

PROCEDURE:

1. Select the thermostatic expansion valve line by opening the shut off valve on this line and closing the one on the capillary line. The solenoid manual switch is switched ON.
2. Start the compressor and run for some time so that the hilled water temperature t_5 is lowered to about 5^0C.
3. Note down the time (t_h & t_c) taken for a n revolutions of energy meter disc.
4. Note down the cooling coil temperature, voltage and current.
5. Measure temperature and presser at different points.
6. Calculation is done using the refrigeration relations.
7. Repeating the experiment by selecting the capillary tube as the expansion device and the solenoid manual switch is OFF.
8. Experiment may be repeated for different heat input.

Result:

1. Actual COP =___________________
2. Theoretical COP =___________________
3. Refrigerant flow rate = ___________________
4. Relative COP = ___________________
5. Refrigeration capacity =___________________

Ex.No:9	**PERFORMANCE TEST ON A AIR-CONDITIONING SYSTEM**
Date :	

AIM:

To conduct COP test on a given air-conditioning test rig.

APPARATUS REQUIRED:

1. Air-

1. $By - Pass\ factor = \frac{T_4 - T_c}{T_3 - T_c}$

conditioning system.

FORMULA:

$where, T_3\ and\ T_4 = Temperature\ before\ and\ after\ cooling\ process$

$T_c = Temperature\ of\ cooling\ water\ coil$

2. $Refrigeration\ effect = m \times C_p \times \Delta T$

$where, m = \frac{q_a}{Q_H}$

3. $q_a = \frac{3600 \times 5}{600 \times t_c}$

4. $Q_H = h_2 - h_1 + h_{w1-2}$

$where, t_c = Time\ taken\ for\ 5\ revolution\ of\ energy\ meter\ disc$

$h_1, h_2 = Enthalpy\ of\ the\ system\ 1\ \&\ 2\ (\frac{KJ}{Kg})$

5. $\Delta SH = SH_3 - SH_4$

6. $Refrigeration\ effect = m \times Q_c$

7. $Power\ input = \frac{3600 \times 5}{600 \times t_h}$

8. $COP = \frac{Refrigerating\ effect}{Power\ input}$

Theory:

Air conditioning is the removal of heat from indoor air for thermal comfort. In another sense, the term can refer to any form of cooling, heating, ventilation, or disinfection that modifies the condition of air. An air conditioner (often referred to as AC or air con.) is an appliance, system, or machine designed to stabilize the air temperature and humidity within an area (used for cooling as well as heating depending on the air properties at a given time), typically using a refrigeration cycle but sometimes using evaporation, commonly for comfort cooling in buildings and motor vehicles.

The concept of air conditioning is known to have been applied in Ancient Rome, where aqueduct water was circulated through the walls of certain houses to cool them. Similar techniques in medieval Persia involved the use of cisterns and wind towers to cool buildings during the hot season. Modern air conditioning emerged from advances in chemistry during the 19th century, and the first large-scale electrical air conditioning was invented and used in 1902 by Willis Havilland Carrier.

Air conditioners and refrigerators work the same way. Instead of cooling just the small, insulated space inside of a refrigerator, an air conditioner cools a room, a whole house, or an entire business. Air conditioners use chemicals that easily convert from a gas to a liquid and back again. This chemical is used to transfer heat from the air inside of a home to the outside air. The machine has three main parts. They are a compressor, a condenser and an evaporator. The compressor and condenser are usually located on the outside air portion of the air conditioner. The evaporator is located on the inside the house, sometimes as part of a furnace. That's the part that heats your house.

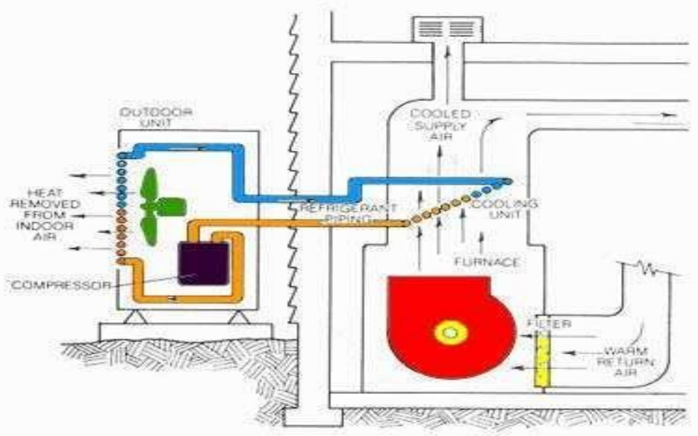
The working fluid arrives at the compressor as a cool, low-pressure gas. The compressor squeezes the fluid. This packs the molecule of the fluid closer together. The closer the molecules are together, the higher its energy and its temperature.

The working fluid leaves the compressor as a hot, high pressure gas and flows into the condenser. If you looked at the air conditioner part outside a house, look for the part that has metal fins all around. The fins act just like a radiator in a car and help the heat go away, or dissipate, more quickly.

When the working fluid leaves the condenser, its temperature is much cooler and it has changed from a gas to a liquid under high pressure. The liquid goes into the evaporator through a very tiny, narrow hole. On the other side, the liquid's pressure drops. When it does it begins to evaporate into a gas.

As the liquid changes to gas and evaporates, it extracts heat from the air around it. The heat in the air is needed to separate the molecules of the fluid from a liquid to a gas.

The evaporator also has metal fins to help in exchange the thermal energy with the surrounding air.



Central Air-Conditioning & Heating System
Graphic courtesy: Air-Conditioning & Refrigeration Institute

By the time the working fluid leaves the evaporator, it is a cool, low pressure gas.
It then returns to the compressor to begin its trip all over again.

Connected to the evaporator is a fan that circulates the air inside the house to blow across the evaporator fins. Hot air is lighter than cold air, so the hot air in the room rises to the top of a room.

There is a vent there where air is sucked into the air conditioner and goes down ducts. The hot air is used to cool the gas in the evaporator. As the heat is removed from the air, the air is cooled. It is then blown into the house through other ducts usually at the floor level.

This continues over and over and over until the room reaches the temperature you want the room cooled to. The thermostat senses that the temperature has reached the right setting and turns off the air conditioner. As the room warms up, the thermostat turns the air conditioner back on until the room reaches the temperature.

Viva Voice Questions:

1. Explain the working principle of Air-conditioning system.
2. Explain different name of refrigerant.
3. Explain the various parts in Air-conditioning system.
4. Define COP
5. Explain the thermodynamic cycle involving in the Air-conditioning system.

Tabulation:

Dry bulb temperature ^{0}C				Wet bulb temperature ^{o}C				Sp. Humidity (J/KgK)				Enthalpy (Kj/Kg)				Cooling coil temperatur e t_c	T_e (Secs)	t_h (Secs)
T 1	T 2	T 3	T 4	T_{W1}	T_{W3}	T_{W3}	T_{W4}	SH 1	SH 2	SH 3	SH 4	h 1	h 2	h 3	h 4			

PROCEDURE:

1. Switch ON the heater first and then after some time switch on the whole air- conditioning system.
2. Measure the dry bulb and wet bulb temperature at four stages and note down the readings.
3. Tabulate the cooling coil temperature in ^{0}C.
4. Measure the time taken for a 5 revolutions of energy meter disc for heater and compressor.
5. Tabulate the values and calculate the coefficient of performance of the given air- conditioning test rig.

Result:

Thus the COP of a given Air-conditioning system is = ________________

Specifications:

Air compressor

LP bore diameter	=	89.5 mm	HP bore diameter	=	63 mm
Stroke length	=	88.9 mm	Clearance Volume	=	2 mm
Speed, N	=	700 rpm	Air receiver capacity	=	0.33 m^3
Orifice diameter	=	11.9 mm	Arm distance	=	0.175 m