HEAT TRANSFER LABORATORY

EXPERIMENT NO. 01

AIM

Heat transfer through a composite or multilayer walls.

OBJECTIVE

1. To determine the overall conductance and compare it with the standard values.
2. To plot a graph between temperature versus distance.

THEORY:

In heat transfer, conduction (or heat conduction) is the transfer of thermal energy between neighboring molecules in a substance due to a temperature gradient. It always takes place from a region of higher temperature to a region of lower temperature, and acts to equalize temperature differences. Conduction takes place in all forms of matter, viz. solids, liquids, gases and plasmas, but does not require any bulk motion of matter. In solids, it is due to the combination of vibrations of the molecules in a lattice and the energy transport by free electrons. In gases and liquids, conduction is due to the collisions and diffusion of the molecules during their random motion.

If we want to identify the conductivity of a given material then we can find its conductivity using the experiment.

Also we can find the application of any given material in industry based on the value of the conductivity already known from the experiment. With composite systems it is convenient to work with an overall heat transfer coefficient, which is defined by an expression analogous to Newton's law of cooling

FORMULAE USED

$$\frac{Q}{A} = -K\frac{dT}{dx}$$

$$\frac{L}{kA} = \sum_{i=1}^{n}\frac{l_i}{k_i A_i}$$

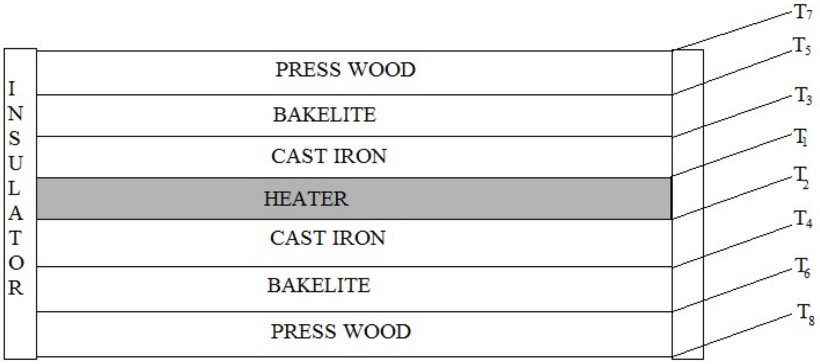
Where Q is rate of heat transfer,

A is cross sectional area,

$\frac{dT}{dx}$ is temperature gradient,

K is thermal conductivity of the material.

DIAGRAM



COMPOSITE WALL APPARATUS

Figure: 01

PROCEDURE

1. Fix the value of voltage and current, and maintain a constant input heat flow rate.
2. Maintain the value of voltage and current at a constant value throughout the experiment.
3. Take the value of the temperatures in the thermocouples.
4. Then for two successive readings for the same material note the difference in the value of temperature.
5. Check whether the difference between the value in the temperature decreases. If the difference goes on decreasing, it means steady state is reaching.
6. As steady state approach decreases the interval in which the readings are noted.
7. Decrease the time interval first to about fifteen and then to ten minutes so that the temperature remains constant for different materials throughout that time interval.
8. This is the steady state and use readings at this point for calculations.

SPECIFICATION

Slab Sizes

Cast Iron : 300 mm diameter and 25 mm thickness
Bakelite : 300 mm diameter and 19 mm thickness
Press Wood: 300 mm diameter and 12 mm thickness

OBSERVATION AND CALCULATION TABLE

Voltage: Current:

TIME	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8

CALCULATIONS

Area of slab= $\frac{\Pi \times 0.3^2}{4} = 0.0706 m^2$

$$Q = \frac{V \times I}{2}$$

& $\frac{Q}{A} = \frac{V \times I}{2A}$

First side of heater:

Assume mean conductivity is k_{m_1}

Then, $k_{m1} = \frac{Q(L_1 + L_2 + L_3)}{2A(T_1 - T_7)}$

Then, thermal conductivities of different slabs are:

$$(k_{ci})_1 = -\frac{Qdx}{Adt}$$

$$(k_b)_1 = -\frac{Qdx}{Adt}$$

$$(k_{pw})_1 = -\frac{Qdx}{Adt}$$

Since we know that:

$\frac{Q}{A} = -K\frac{dT}{dx}$ & $\frac{L}{kA} = \sum_{i=1}^{n} \frac{l_i}{k_i A_i}$ (Fourier's Law)

$$\frac{L}{k'_{m1}A} = \frac{L_1}{(k_{ci})_1 A} + \frac{L_2}{(k_b)_1 A} + \frac{L_3}{(k_{pw})_1 A}$$

$\frac{L}{k'_{m1}} = \frac{L_1}{(k_{ci})_1} + \frac{L_2}{(k_b)_1} + \frac{L_3}{(k_{pw})_1}$ (Assuming mean conductivity is k'_{m1})

$$k_{m1} \cong k'_{m1}$$

Similarly, considering 2nd side of heater

Assume mean conductivity is k_{m_2}

Then, $k_{m1} = \frac{Q(L_1 + L_2 + L_3)}{2A(T_2 - T_8)}$

Then, thermal conductivities of different slabs

$$(k_{ci})_2 = -\frac{Qdx}{Adt}$$

$$(k_b)_2 = -\frac{Qdx}{Adt}$$

$$(k_{pw})_2 = -\frac{Qdx}{Adt}$$

Since we know that

$$\frac{Q}{A} = -K\frac{dT}{dx} \quad \& \quad \frac{L}{kA} = \sum_{i=1}^{n}\frac{l_i}{k_i A_i} \qquad \text{(Fourier's Law)}$$

$$\frac{L}{k'_{m1}A} = \frac{L_1}{(k_{ci})_2 A} + \frac{L_2}{(k_b)_2 A} + \frac{L_3}{(k_{pw})_2 A}$$ (Assuming mean conductivity is k'_{m_2})

$$\frac{L}{k'_{m1}} = \frac{L_1}{(k_{ci})_2} + \frac{L_2}{(k_b)_2} + \frac{L_3}{(k_{pw})_2}$$

$$k_{m2} \cong k'_{m2}$$

Mean thermal conductivity of different materials:-

k of Cast Iron $= \dfrac{(k_{ci})_1 - (k_{ci})_2}{2}$

k of Bakelite $= \dfrac{(k_b)_1 - (k_b)_2}{2}$

k of Pressed Wood $= \dfrac{(k_{pw})_1 - (k_{pw})_2}{2}$

RESULT

Material	**Experimental Value of Thermal Conductivity k** $\left(\frac{\text{W}}{\text{m K}}\right)$	**Literature Value of Thermal Conductivity at mean temperature** $\left(\frac{\text{W}}{\text{m K}}\right)$
Cast Iron		
Bakelite		
Pressed Wood		

Now equivalent conductivity, $k_m = \dfrac{k'_{m1} + k'_{m2}}{2}$

We know that

$$\frac{L}{k_m} = \frac{L_1}{(k_{ci})} + \frac{L_2}{(k_b)} + \frac{L_3}{(k_{pw})} \text{..............................}(A)$$

Now putting the values of conductivities, k_m(from experiment), k_b& k_{pw}(from literature) in equation A, find k_{ci}

Similarly putting the values of conductivities, k_m from experiment), k_b& k_{ci} (from literature) in equation A, find k_{pw}.

Similarly putting the values of conductivities, k_m (from experiment), k_{pw} & k_{ci} (from literature) in equation A, find k_b.

DISCUSSION

CONCLUSION

FURTHER READINGS

1. F. P. Incropera and D. P. DeWitt. *Fundamentals of Heat and Mass Transfer.* John Wiley and Sons, New York, 1985.
2. J. P. Holman. *Heat Transfer.* McGraw–Hill, New York, 1981.

HEAT TRANSFER LABORATORY

EXPERIMENT NO 02

AIM

Study of heat transfer by forced convection.

OBJECTIVE

Determine the convective heat transfer coefficient and compare it with the theoretical values, in forced convection.

THEORY

In heat transfer, Heat is carried passively by a fluid motion which would occur anyway without the heating process. This heat transfer process is termed forced convection. In forced heat convection, transfer of heat is due to movement in the fluid which results from many other forces, such as (for example) a fan or pump. 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.). 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). Forced convection phenomenon is used in the manufacture of oven. Bio-Gene Forced Convection Type Oven is used for baking, drying, conditioning, sterilizing and quality control.

The convective heat transfer coefficient, can be indirectly defined by Equation 1, in terms of the rate of convective heat transfer between the wall and the fluid, the surface area through which the energy is being transferred, A, and the difference between the wall surface and the bulk fluid temperature, $(T_{m,air} - T_\infty)$

$$q_{conv} = hA_s(T_{m,air} - T_\infty)$$

Solving for the convective heat transfer coefficient, h , yields the experimental measurement of h, requires the measurement of each of the four quantities on the right-hand side.
The heat transfer between the wall and the air is determined by.

$$q_{conv} = \rho A_c v C_p (T_{air,in} - T_{air,out})$$

Where A_c is cross sectional area of tube , A_s is surface area of tube .

From the above equations the experimental value of h is determined.

And the theoretical value can be determined by

Dittus Boelter equation, Nusselt number is given by

$$Nu_D = 0.023(\mathrm{Re})^{\frac{4}{5}}(\mathrm{Pr})^{0.3}, \quad \text{for } 0.7 \leq \mathrm{Pr} \leq 160,\ \mathrm{Re} \geq 10{,}000$$

$$\&\ Nu_D = \frac{hD}{k}$$

Prandtl number, $\mathrm{Pr} = \frac{\mu C_p}{k}$

Reynold number, $\mathrm{Re} = \frac{Dv\rho}{\mu}$

Where h is convective heat transfer coefficient,

k is conductivity of fluid,

D is diameter of the tube,

μ is viscosity of the fluid,

ρ is density of the fluid.

EXPERIMENTAL SETUP

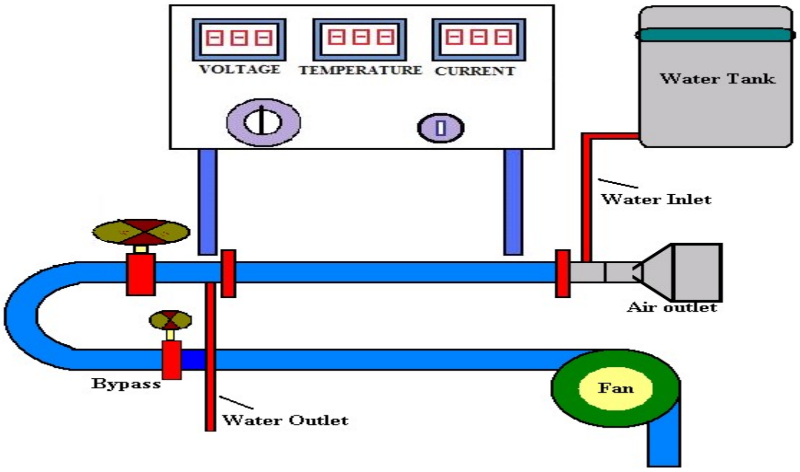


Figure: 1 Forced convection setup

PROCEDURE

1. Maintain a constant water flow rate constant.

2. Fix the value of voltage and current, and maintain a constant input heat flow rate.

3. Measure the air flow rate and maintain a constant flow rate as far as possible, throughout the experiment.

4. Note the values of the temperatures and while maintaining the above quantities constant, note the temperatures in regular interval of 15 minutes.

5. Then for two successive readings if the respective temperatures are same then that temperature is taken as the steady state temperature.

6. For the steady state, calculate the values of h experimental and compared with the theoretical value.

OBSERVATIONS

T_1: Air inlet temp., **T_7:** air outlet temp.
T_2-T_6: specimen temp., **v**= air velocity,

OBSERVATION TABLE

Time	T_1	T_2	T_3	T_4	T_5	T_6	T_7

CALCULATIONS:-

Inside diameter of tube = 40 mm. And length of tube = 300 mm.

From table

$$(T_m)_{air} = \frac{T_1 + T_2}{2} \qquad (T_\infty)_{surroundinds} = \frac{T_2 + T_3 + T_4 + T_5 + T_6}{2}$$

Air velocity = v

Now, find physical properties viz,C_p, μ & k of air at $(T_m)_{air}$ (from literature):

For theoretical *h*

$$\mathrm{Re} = \frac{Dv\rho}{\mu}$$

$$\mathrm{Pr} = \frac{\mu C_p}{k}$$

If flow is turbulent, then from Dittus Boelter equation,

$$Nu_D = 0.023(\mathrm{Re})^{\frac{4}{5}}(\mathrm{Pr})^{0.3}, \text{ But } \quad Nu_D = \frac{hD}{k}$$

$$\text{Therefore,} \quad h = 0.023(\mathrm{Re})^{\frac{4}{5}}(\mathrm{Pr})^{0.3} \times \frac{k}{D}$$

For experimental *h*

$$q_{conv} = \rho A_c v C_p (T_{air,in} - T_{air,out}) \text{ But } \quad q_{conv} = hA_s(T_{m,air} - T_\infty))$$

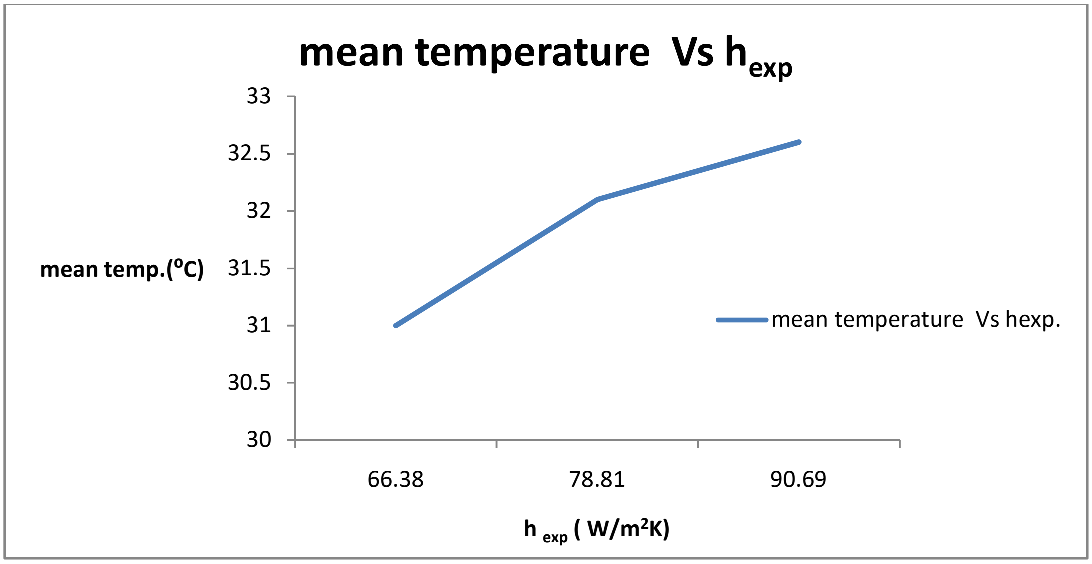
Where A_c= cross sectional area of tube, A_s=surface area of tube .

$$\text{Therefore,} \quad h = \frac{\rho A_c v C_p (T_{air,in} - T_{air,out})}{A_s (T_{m,air} - T_\infty)}$$

RESULT TABLE

$(T_m)_{air}$ **(°C)**	T_∞ **(°C)**	**Physical properties at** $(T_m)_{air}$				Re	Pr	$h_{\exp}$ $\left(\frac{W}{m^2K}\right)$	h_{theo} $\left(\frac{W}{m^2K}\right)$
		C_p $\left(\frac{kJ}{kgK}\right)$	$k\times10^3$ $\left(\frac{W}{m\ K}\right)$	$\mu\times10^7$ $(Pa.s)$	ρ $\left(\frac{kg}{m^3}\right)$				

SAMPLE GRAPH



DISCUSSION

CONCLUSION

FURTHER READINGS

1. F. P. Incropera and D. P. DeWitt. *Fundamentals of Heat and Mass Transfer.* John Wiley and Sons, New York, 1985.
2. J. P. Holman. *Heat Transfer.* McGraw–Hill, New York, 1981.

HEAT TRANSFER LABORATORY

EXPERIMENT NO 03

AIM

Study of heat transfer by natural convection.

OBJECTIVE

1. To determine the heat transfer coefficient for natural convection of air for a vertical cylinder. And compare the experimental value of heat transfer coefficient with the theoretical and literature values.

2. To plot the graph between convection heat transfer coefficient and temperature.

THEORY

Natural convection is induced by buoyancy forces which arise from density differences caused by temperature variances in the fluid. Buoyancy is due to the combined presence of a fluid density gradient and a body force that is proportional to density. We know that the density of gases and liquids depends on temperature, generally decreasing (due to fluid expansion) with increasing temperature ($\frac{d\rho}{dT}<0$).The density of air at 300K is 1.1614 kg/m^3 and at 400K is 0.8711 kg/m^3.

Free convection is used in glass making industry. To control the glass making process it is necessary to know the dynamics and mechanism of complex heat transfer in viscous semi transparent media. Free convection is used in the electronic industry, cooling process occurs with free convection on the surface of integrated circuits. Free convection between rectangular channel is often used in industry, building components and many application in engineering.

Experimental Setup

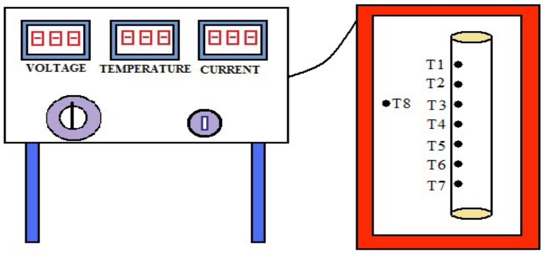


Figure: 1 Natural convection setup

Procedure

1. Switch on the apparatus and adjust the voltage and the corresponding current of the apparatus to an appropriate value.
2. Keep all the eight thermocouples at properly place.

3. Wait for 15 minutes so that the uniform heat transfer from the thermocouples starts.
4. There should not be minimum disturbances nearer to the apparatus.
5. Note down the temperatures of the thermocouples after time period of 10 or 15 minutes until the steady state is reached.
6. Now change the applied voltage and repeat the same procedure.

OBSERVATIONS

Voltage=V_1 Volts, current=$i_1$amp amp.

OBSERVATION TABLE NO.1

Time	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8

Voltage=V_2 Volts, current =i_2 amp.

OBSERVATION TABLE NO.2

Time	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8

Voltage=V_3 Volts, current =i_3 amp

OBSERVATION TABLE NO. 3

Time	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8

CALCULATIONS

Diameter of cylinder =0.045m, x=0.45 m

Surface area of cylinder (A): A= πDL=0.0636m^2

From table no.1

Wall temp. T_w: $$T_w = \frac{T_1 + T_2 + T_3 + T_4 + T_5 + T_6 + T_7}{7}$$

Surroundings temp. (T_∞): $T_\infty = T_8$

And film temp(T_f): $$T_f = \frac{T_w + T_\infty}{2}$$

$$q_w = \frac{V \times I}{A}$$

Now, find physical properties like Kinematic viscosity (ν), thermal conductivity (k) ,Thermal diffusivity (α) , $\beta = \frac{1}{T_f}$ of fluid(air) at film temp.(from literature, by interpolation)

Now

Grashof number, $Gr = \frac{g\beta q_w x^4}{k\nu^2}$ & Prandtl number, $\Pr = \frac{\nu}{\alpha}$

Nusselt number, $Nu = 0.6(Gr \times \Pr)^{0.2}$

but $Nu = \frac{h_{th} x}{k}$

$$\Rightarrow h_{th} = 0.6(Gr \times \Pr)^{0.2} \times \frac{k}{x}$$

Now, from Newton's law of cooling, $Q = h_{\exp} A(T_w - T_\infty)$

$$h_{\exp} = \frac{Q}{A(T_w - T_\infty)} = \frac{q_w}{(T_w - T_\infty)}$$

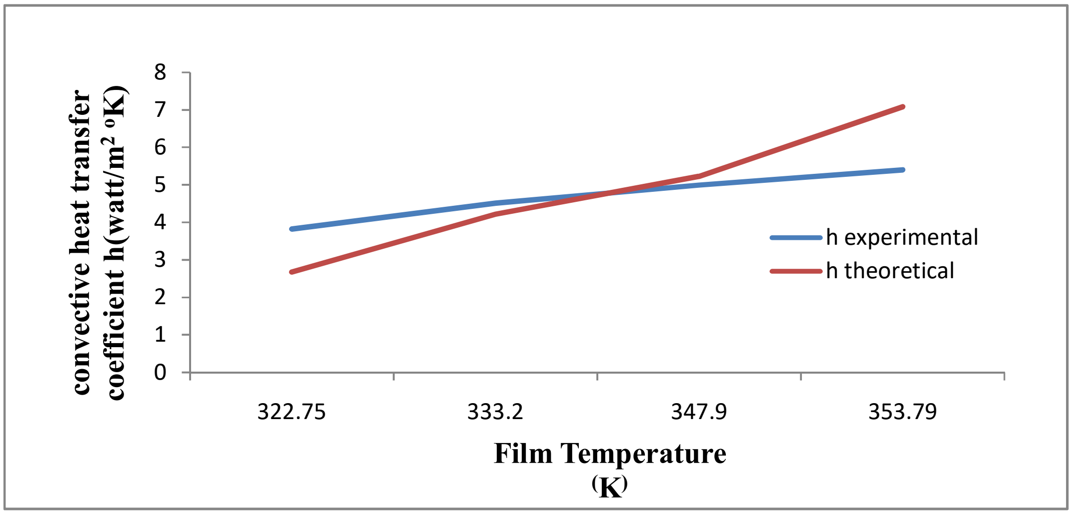
Perform the above procedure for table 2 & 3 & tabulate the results.

RESULT TABLE

Table no.	Wall Temp. $T_w (K)$	Ambient Temp. $T_\infty (K)$	Film Temp. T_f (K)	q_w $\left(\frac{W}{m^2}\right)$	Physical properties at film temp. T_f (K)		
					$\nu \times 10^6$ $\left(\frac{m^2}{s}\right)$	$k \times 10^3$ $\left(\frac{W}{m\ K}\right)$	$\alpha \times 10^6$ $\left(\frac{m^2}{s}\right)$
01							
02							
03							
04							

Table no.	Gr	Pr	$h_{\exp}$, $\left(\frac{W}{m^2K}\right)$	h_{theo}, $\left(\frac{W}{m^2K}\right)$
1				
2				
3				
4				

SAMPLE GRAPH



DISCUSSION

CONCLUSION

FURTHER READINGS

1. F. P. Incropera and D. P. DeWitt. *Fundamentals of Heat and Mass Transfer.* John Wiley and Sons, New York, 1985.
2. J. P. Holman. *Heat Transfer.* McGraw–Hill, New York, 1981.

HEAT TRANSFER LABORATORY

EXPERIMENT NO 04

OBJECTIVE

To determine the emissivity of gray body.

THEORY

Radiation is the process in which heat flows from high temperature body to a low temperature body when the two bodies are separated from each other in space, even when a vacuum exist between them the term radiation is generally applied to all kinds of electromagnetic phenomena. Thermal radiation is that radiation emitted by body as a result of its temperature.

The total amount of radiation emitted by a body per unit area per unit time is called the total emissive power (E).The emissive power of a body depends on its temperature and the characteristics of the surface of the body. The emissive power of a body is given by Stefan-Boltzmann law as,

$$E = \varepsilon \sigma T^4$$

Where,

E=Emissive power

σ=Stefan-Boltzmann constant

ε=emissivity of the body

For a black body emissivity is unity i.e. ε=1

INDUSTRIAL APPLICATION

1. A method for monitoring the temporal variation of surface spectral emissivity used to thermal infrared multispectral scanner.
2. We can calculate the amount of solar energy received by the earth the daily and hourly records of the amounts of solar radiations received at any given location over the earth surface are essential for the design and optimization of heat transfer system utilizing solar energy [2].
3. The above information are also useful for architectural, agricultural, biological and other purposes [2].
4. The radiation heat transfer between two surfaces can be reduced significantly if a radiation shield of low emissivity material is placed between them.
5. The selection of the material for use in the jackets for the radiation shield to be used in places of high radiation emission, as in nuclear power plants.
6. The emissivity of the tanks helps us in deciding the material of the tank for storing radioactive elements.

FORMULA USED

$$Q = \varepsilon A \sigma (T_{gb}^4 - T_c^4)$$

$$Q = \varepsilon A \sigma (T_{bb}^4 - T_c^4)$$

$$\Rightarrow \varepsilon = \frac{(T_{bb}^4 - T_c)}{(T_{gb}^4 - T_c)}$$

Where Q is the net heat radiated from the body.

σ is the Stefan-Boltzmann constant.

ε is emissivity of the body.

A is the area of the black body and gray body.

T_{gb} is the gray body temperature.

T_{bb} is the black body temperature.s

T_c is the chamber temperature.

EXPERIMENTAL SETUP

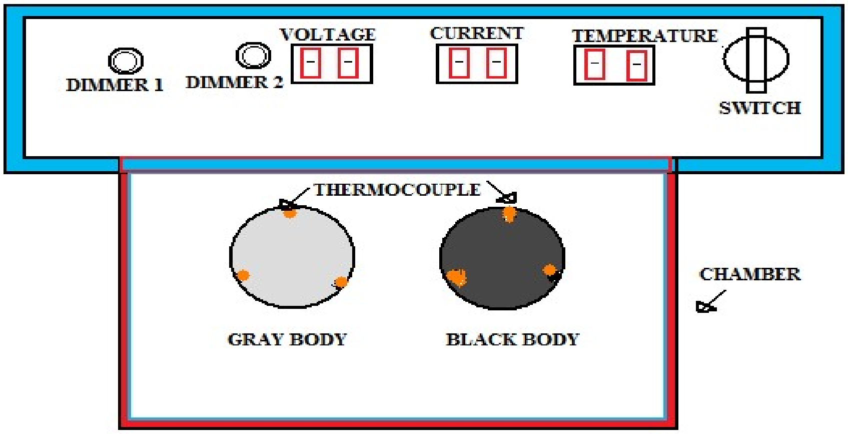


Fig 1. Apparatus for Finding Emissivity of a Gray Body

PROCEDURE

1. First of all switch on the heaters, the blackbody and the gray body starts getting heated.
2. With the help of dimmer control the heat input to the black body and by the second dimmer control the heat input of gray body.
3. Now with the help of dimmer keep the voltage of both the heater constant and equal.
4. Note down the temperature of the black body and gray body after every ten minute interval till steady state is achieved.

OBSERVATION

T_1-T_3: Temperature of Gray body

T_4-T_6: Temperature of Black body

T_c=T_7: Temperature of chamber

TABLE NO. 1 Voltage: v_1 volt Current: i_1 amp

Time	T_1	T_2	T_3	T_4	T_5	T_6	T_7

TABLE NO. 2 Voltage: $_2$ volt Current: i_2 amp

Time	T_1	T_2	T_3	T_4	T_5	T_6	T_7

CALCULATIONS

TABLE NO. 3

Mean temp of gray body $T_{mg} = \frac{T_1 + T_2 + T_3}{3}$	**Mean temp of black body** $T_{mb} = \frac{T_4 + T_5 + T_6}{3}$	**Chamber temp** T_c	$\varepsilon = \frac{(T_{mb}^4 - T_c)}{(T_{mg}^4 - T_c)}$
			Mean emissivity ε =

RESULTS

DISCUSSION

CONCLUSION

FURTHER READINGS

1. F. P. Incropera and D. P. DeWitt. *Fundamentals of Heat and Mass Transfer.* John Wiley and Sons, New York, 1985.
2. J. P. Holman. *Heat Transfer.* McGraw–Hill, New York, 1981.

HEAT TRANSFER LABORATORY

EXPERIMENT NO. 05

AIM

Study of dropwise & filmwise condensation.

OBJECTIVE

Determination and comparison of heat transfer coefficient for film wise and drop wise condensation.

THEORY

Condensation occurs when the temperature of a vapour is reduced below its saturation temperature. In industrial equipment, the process commonly results from contact between the vapour and a cool surface.

Film condensation is one in which a liquid film covers the entire condensing surface, and under the action of gravity the film flows from the surface. Film condensation is generally characteristic of clean, uncontaminated surface.

If the surface is coated with a substance that inhibits wetting, it is possible to maintain a condensation known as drop wise c condensation. The drops form in cracks, pits, and cavities. The surface and may grow and coalesce through continued condensation.

Regardless of whether condensation is in the form of film or droplets, the condensate provides a resistance to heat transfer between the vapour and the surface .Because this resistance increases with condensate thickness which increases in the flow direction. In terms of maintaining high condensation and heat transfer rates, droplet formation is superior to film formation.

INDUSTRIAL APPLICATION

1. Condensation is used for cooling computer chips in industrial purposes. In this method the chips uses a thermosyphon containing a saturated fluorocarbon. The chip is brazed to the bottom of a cuplike container, within which heat is dissipated by boiling and subsequently transferred to an external coolant (water) via condensation on the inner surface of a thin walled tube.
2. A technique for cooling heat dissipating integrating circuits involves submerging the ICs in a low boiling point dielectric fluid. Vapour generated in cooling the circuits is condensed on vertical plates suspended in the vertical cavity above the liquid. The temperature of the plates is maintained below the saturation temperature, and during steady state operation a balance is established between the rate of heat transfer to the condenser plates and the rate of heat dissipation by the ICs.
3. Used in refrigeration.
4. Used in power plants and chemical processes plants.

EXPERIMENTAL SETUP:

Fig 1. Set up for film wise and drop wise condensation.

PROCEDURE

1. Connect a pipe from the inlet of boiler to the tap for continuous supply of water.
2. Switch on the boiler and wait until pressure in the boiler becomes 20 kg/cm^2.
3. Close the valve of filmwise condensation surface and open the valve of dropwise condensation surface.
4. Maintain a constant flow rate of water.
5. Then the stream from the boiler to the condensation chamber while constantly draining out the water from stream drier.
6. After regular interval of 10 mins, measure the volume of condensate in the condensation chamber and note down the temperature until it reaches the steady sate.
7. Again for filmwise condensation open the valve for filmwise condenser and close the valve of dropwise condenser and repeat the above procedure.

OBSERVATIONS

CASE 1: Drop-wise condensation

Water flow rate =

Steam tank pressure=

Inlet steam pressure=

Time	T_1	T_2	T_3	T_4	T_5	T_6	Volume of condensate collected(ml/min)

CASE 2: Film-wise condensation

Water flow rate =

Steam tank pressure=

Inlet steam pressure=

Time(pm)	T_1	T_2	T_3	T_4	T_5	T_6	Volume of condensate collected(ml/min)

CALCULATIONS

1. **Drop wise condensation**

   Volume of condensate collected $=\dot{Q}$

   Mass of condensate collected, $\dot{m}=\dot{Q}\times\rho$

   Therefore amount of heat required for the condensation, $Q=\dot{m}\times h_{fg}$

   Also

   $h_d\times A\times\Delta T=Q$

So, h_d can be found from above equation.

2. **Filmwise condensation**

   Volume of condensate collected $=\dot{Q}$

   Mass of condensate collected, $\dot{m}=\dot{Q}\times\rho$

   $h_{\exp}\times A\times\Delta T=Q$

   But $h_{theo}=0.943[\frac{g\rho_l(\rho_l-\rho_v)k_f^3h_{fg})}{\mu L(T_{sat}-T_s)}]$

   Properties are to be found at $T_f=\frac{T_2+T_3}{2}$

   Percentage error $=\frac{h_{theo}-h_{\exp}}{h_{theo}}\times 100$

RESULTS

DISCUSSION

CONCLUSION

FURTHER READINGS

1. F. P. Incropera and D. P. DeWitt. *Fundamentals of Heat and Mass Transfer.* John Wiley and Sons, New York, 1985.
2. J. P. Holman. *Heat Transfer.* McGraw–Hill, New York, 1981.

HEAT TRANSFER LABORATORY

EXPERIMENT NO 06

AIM

Study of heat transfer in finned tube heat exchanger.

OBJECTIVE

To determine the effectiveness and overall heat transfer coefficient for fin tube heat exchanger.

THEORY

The process of heat exchange between two fluids that are at different at different temperatures and separated by a solid wall occurs in many engineering applications. The device used to implement this exchange is termed a heat exchanger. The fin tube type heat exchanger has a cross flow arrangement in which the water flows inside the tube and hot air flows outside. In this type of heat exchanger the heat transfer resistance on the gas side dominates the heat transfer of the heat in the heat exchanger. The finned type heat exchanger is of unmixed type.

A heat exchanger is a device built for efficient heat transfer from one medium to another. The media may be separated by a solid wall, so that they never mix, or they may be in direct contact. They are widely used in space heating, refrigeration, air conditioning, power plants, chemical plants, petrochemical plants, petroleum refineries, and processing. They are useful in studying heat exchange in unmixed type of fluid.

EXPERIMENTAL SETUP:

Figure: 1 Set Up For Fin Tube Heat Exchanger

INDUSTRIAL APPLICATION

1. The finned tube type heat exchanger plays an important role in waste heat recovery process, especially, in economizers where flue gas exchanges heat with water.
2. They are mostly used for low temperature services such as natural gas, helium and oxygen liquefaction plants, air separation plants and transport industries such as motor and aircraft engines.
3. They are used in air conditioners and for refrigeration purposes.
4. This is mainly used for heating or cooling with high-viscosity products, crystallization processes, evaporation and high-fouling applications.

PROCEDURE

1. Put the water in tank and switch on the heater. Start the supply of water in the inner tube which comes out of the tube and goes back to the tube so that the temperature of water increases uniformly and constantly.
2. Wait until the temperature of water in the tank becomes sufficiently more than room temperature.
3. Switch on the blower to supply air in the annulus.
4. Open and close the respective valves to make it counter-current arrangement (approximately 70 degrees).Note down the temperatures of water inlet, water- outlet, air inlet and air outlet.
5. Go on noting the temperature after the interval of 10 minutes until it reaches the steady state.
6. Now make it parallel in arrangement and repeat the above two steps.

OBSERVATIONS

Copper tube outside diameter 'd_0'=22 mm.
Copper tube outside diameter 'd_i'=16 mm
Tube length (l)=1 m
Fin height 'Y' =22 mm
Fin thickness 'X'=2 mm
No. of fins 'N_f'=8
Inside diameter of outer shell = 82 mm
Hot water inlet temperature = T_1
Hot water outlet temperature = T_2
Cold air inlet temperature = T_3
Cold air outlet temperature (in co-current flow condition) = T_4
Cold air outlet temperature (in counter current flow condition) = T_5

CASE 1: Counter current flow condition (water in inner pipe, air in annulus)

Flow rate of water =

Pitot static tube head =

Time	T_1 (°C)	T_2 (°C)	T_3 (°C)	T_4 (°C)

CASE 2: Co-current flow condition (water in inner pipe, air in annulus)

Flow rate of water =

Pitot static tube head =

Time	T_1 (°C)	T_2 (°C)	T_3 (°C)	T_4 (°C)

CALCULATIONS

1. **Counter flow condition**

   For water

   $$T_W = \left(\frac{T_1 + T_2}{2}\right)$$

   Flow rate of water = v

   Density of water at T_W = ρ_w

   Therefore mass flow rate $\dot{m} = \rho_w \ v$

   Reynold No. $\mathrm{Re} = \dfrac{4\dot{m}}{\Pi D \mu}$

   If $10 \le \dfrac{L}{D} \le 400$

   Then Nusselt Number, $Nu = 0.036 \times (\mathrm{Re})^{0.8} \times (\mathrm{Pr})^{0.33} \times \left(\dfrac{D}{L}\right)^{0.055}$

   Where $Nu = \dfrac{h_w D_i}{k}$

   Prandtl number, $\mathrm{Pr} = \dfrac{\mu C_p}{k}$

   Therefore we can find h_w from above equations.

   For air Reynold number

   $$\mathrm{Re} = \frac{D_h \Delta V}{\nu}$$

Where hydraulic diameter , $D_h = \dfrac{4A_c}{\rho}$

& $\Delta V = \sqrt{\dfrac{2\rho_m g(h_2 - h_1)}{\rho_{air}}}$

Where ρ_m is the density of manometer fluid.

Now $Nu = 0.036 \times (\mathrm{Re})^{0.8} \times (\mathrm{Pr})^{0.33} \times \left(\dfrac{D}{L}\right)^{0.055}$

$$\varepsilon_{11} = \frac{1 - \exp\left(\dfrac{UA}{C_{\min}}\left(1 + \dfrac{C_{\min}}{C_{\max}}\right)\right)}{1 + \dfrac{C_{\min}}{C_{\max}}}$$

$C_{\min} = \dot{m}C_p$ & $\dot{m} = \rho u A$

Therefore we can find overall heat transfer coefficient, *U* from above equation**.**

2. **Parallel flow condition**

For water

$$T_W = \left(\frac{T_1 + T_2}{2}\right)$$

$\dot{m} = \rho_w \ v$

$\mathrm{Re} = \dfrac{4\dot{m}}{\Pi D \mu}$

$Nu = 0.036 \times (\mathrm{Re})^{0.8} \times (\mathrm{Pr})^{0.33} \times \left(\dfrac{D}{L}\right)^{0.055}$

Where $Nu = \dfrac{h_w D_i}{k}$

Therefore we can find h_w from above equations.

For air

$\mathrm{Re} = \dfrac{D_h \Delta V}{\nu}$

Where $D_h = \dfrac{4A_c}{\rho}$

& $\Delta V = \sqrt{\dfrac{2\rho_m g(h_2 - h_1)}{\rho_{air}}}$

Where ρ_m is the density of manometer fluid.

Now $Nu = 0.036 \times (\text{Re})^{0.8} \times (\text{Pr})^{0.33} \times \left(\frac{D}{L}\right)^{0.055}$

$$\frac{T_{hi} - T_{\infty}}{T_{ho} - T_{ci}} = \exp\left(-UA\left(\frac{1}{C_h} + \frac{1}{C_c}\right)\right)$$

$$C_h = (\dot{m}C_p)_{hot}$$

$$C_c = (\dot{m}C_p)_{cold}$$

where

T_{hi} =Inlet temperature of hot fluid

T_{ho} =Outlet temperature of hot fluid

T_{ci} =Inlet temperature of cold fluid

Therefore overall heat transfer coefficient, U can be found from above equation.

RESULTS

DISCUSSION

CONCLUSION

FURTHER READINGS

1. F. P. Incropera and D. P. DeWitt. *Fundamentals of Heat and Mass Transfer.* John Wiley and Sons, New York, 1985.
2. J. P. Holman. *Heat Transfer.* McGraw–Hill, New York, 1981.

HEAT TRANSFER LABORATORY

EXPERIMENT NO 07

AIM

Study of heat transfer in a double pipe heat exchanger.

OBJECTIVE

To determine the overall heat transfer coefficient for double pipe counter flow heat exchanger.

THEORY

A heat exchanger is a device that is used to transfer thermal energy between two or more fluids, between a solid surface and a fluid, or between a solid particulate and a fluid, at different place through a separating wall or into and out of a wall in a transient manner. The simplest heat exchanger one for which the hot and cold fluid moving the same or opposite direction in a concentric tube or double pipe construction.

In heat exchanger, there are usually no external heat and work interaction. Typical applications involve heating or cooling of a fluid stream of concern and evaporation or condensation of single or multi component fluid stream. In other applications the objective may be to recover or reject heat, or sterilize, pasteurize, fractionate, distill, concentrate, crystallize or control a process fluid

INDUSTRIAL APPLICATION

1. Used in space heating and air conditioning.
2. Used as a recuperator that heats air used in combustion process by extracting energy from products of combustion. It can be used to increase the efficiency of a gas turbine by increasing the temperature of air entering the combustor. [1]
3. Hot water for an industrial washing operation is produced by recovering heat from the flue gases of a furnace using heat exchangers.
4. Used in power production.
5. Chemical processing industries.

FORMULA USED

For air

$$\mathrm{Re} = \frac{\rho u D_h}{\mu}$$

Using correlation Nusselt number, $Nu = 0.036 \times (\mathrm{Re})^{0.8} \times (\mathrm{Pr})^{0.33} \times \left(\frac{D}{L}\right)^{0.055}$

which is valid for turbulent flow Re > 10,000

0.7<Pr<160

& $10 < \frac{L}{D} < 400$

Where prandtl number , $\mathrm{Pr} = \frac{\mu C_p}{k}$

Nusselt number, $Nu = \frac{hD}{k}$

For water

$$\mathrm{Re} = \frac{\rho u D_h}{\mu} \qquad (D_h = \text{hydraulic diameter})$$

$$D_h = \frac{D_o - D_i}{4}$$

Where D_o is outside diameter,
D_i is inside diameter,

Since $\dot{m} = \rho u A$

Thus $\mathrm{Re} = \frac{D_h \dot{m}}{A\mu}$

Where $A = \frac{\Pi(D_o^2 - D_i^2)}{4}$

Using correlation Nu=4.36
This is valid for
Laminar flow, constant heat flux, Pr>0.6

Where $$\frac{hD_h}{K} = NU_i = \frac{1}{\left(\frac{1}{h_i} + \frac{D_i}{2K}\ln\left(\frac{D_o}{D_i}\right) + \frac{D_i}{h_o D_o}\right)}$$

Where h_i is inside heat transfer coefficient.

Where h_o is outside heat transfer coefficient

EXPERIMENTAL SETUP

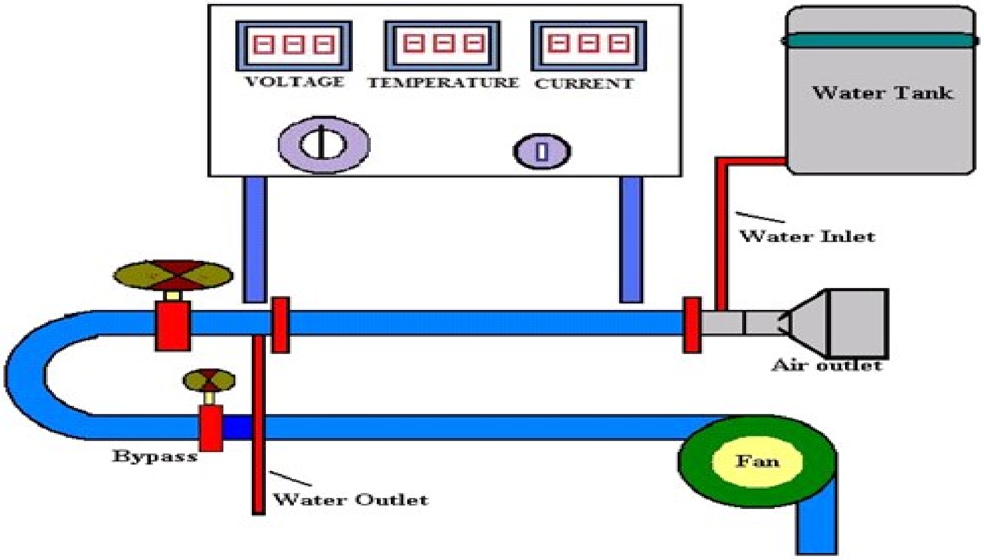


Fig 1. Double Pipe Heat Exchanger Setup

PROCEDURE

1. First put hot water in the inlet tank of known temperature and then fix and keep the flow rate constant.
2. Open the bypass and then start the motor.
3. Throughout the experiment keep the temperature constant by adding either hot or cold water as per the increase or decrease in temperature.
4. Insulate the inlet tank completely so that heat would not be dissipated through the wall to the surroundings.
5. Keep the air velocity constant for a particular set of values.
6. Note down the temperature at different points, which are inlet air and water and outlet air and water temperatures.
7. Wait for the steady state to be attained and then note down the readings

OBSERVATION

Table 1

Time	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9

CALCULATION

Specification:

Inner pipe Inner diameter d_1=25 mm

Outer diameter d_2=31.3 mm

Outer pipe inner diameter=32 mm

Pipe material: copper

Conductivity of the copper= $52\frac{W}{mK}$

Length of the pipe=400mm

CALCULATION TABLE

Properties are calculated from literature

TABLE 2

Air velocity (m/sec)	Air inlet Temp (^{0}C)	Air outlet Temp (^{0}C)	Mean air Temp (^{0}C)	Water flow rate (ml/sec)	Water inlet Temp (^{0}C)	Water outlet Temp (^{0}C)	Mean water Temp (^{0}C)	Film Temp (^{0}C)

TABLE 3

Air					**Water**						**Overall heat transfer coeff.** $\left(\frac{W}{m^2K}\right)$
Film Temp (^0C)	**Kinematic viscosity** $\nu\times10^6$ $\left(\frac{m^2}{s}\right)$	Re	*Nu*	h_{air} $\left(\frac{W}{m^2K}\right)$	**Mean water Temp** (^0C)	**Mass flow rate** $\times10^3$ $\left(\frac{kg}{s}\right)$	**Kinematic viscosity** $\nu\times10^6$ $\left(\frac{m^2}{s}\right)$	Re	*Nu*	h_{water} $\left(\frac{W}{m^2K}\right)$	

RESULTS

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1. F. P. Incropera and D. P. DeWitt. *Fundamentals of Heat and Mass Transfer.* John Wiley and Sons, New York, 1985.
2. J. P. Holman. *Heat Transfer.* McGraw–Hill, New York, 1981.