8.HEAT TRANSFER IN FORCED CONVECTION

AIM OF THE EXPERIMENT:

To determine the convective heat transfer co-efficient in forced convection.

INTRODUCTION:

It is well known that a hot plate of metal will cool faster in front of a fan than when exposed to still air. We say that heat is convicted away and we call the process as convective heat transfer. The velocity at which the air blows over the hot plate obviously influences the heat transfer rate.

The Newton's law of cooling in convective heat transfer is given by,

$$q = hA\Delta T \qquad \text{--- Eq (1)}$$

Where, q = Heat transfer rate, Watts

A = Surface Area of heat flow, m^2

ΔT = Average temperature difference between the tube Heater and the surrounding air (°C).

h = Convective heat transfer co-efficient (Watts/m^2°C).

The convective heat transfer co-efficient depends upon the viscosity of the fluid in addition to its dependence on the thermal properties of the fluid (thermal conductivity, specific heat, density etc).

If a heated plate is exposed to ambient room air without an external source of motion, movement of air would be experienced as a result of the density gradient near the plate. We call this natural or free convection. If the convection is experienced the case of the fan blowing air over a plate, we call this **Forced Convection.** The approximate ranges of convection heat transfer co-efficient are given in the table below:

This set-up has been designed to study forced convective heat transfer.

Mode	'h' Watts / m^2°C
Free convection (air)	5-25
Forced convection : Air Water	10-500 100-15000
Boiling water	2500-25000
Condensation of water vapour	5000-100000

APPARATUS:

The important components of the set-up are:

(a) **Heat exchanger tube** – the tube is thermally insulated outside to prevent heat transfer losses to the atmosphere.

(b) **Band heater**, Wattage: 500 watts (approx.).

(c) **Regulator** to control the power input to the heater.

(d) **Wattmeter** to measure power input to the heater.

(e) **Thermocouples**

T_1, T_2, T_3 to measure heater surface temperatures.

T_4 and T_5 to measure air temperature at the inlet and outlet of the duct.

(f) **Channel selector.**

(g) **Digital temperature indicator.**

(h) **Blower:** To blow air through the heat exchanger.

(i) **Orifice meter and Manometer** to air flow rate from the blower.

(j) **Control panel** to house the whole instrumentation.

OPERATIONAL PROCEDURE:

a) Switch-ON the mains.

b) Start the blower first.

c) Control blower flow rate to a suitable value.

d) Measure the pressure drop across the manometer and calculate air mass flow rate.

e) Switch-ON the heater and adjust the power input to the heater to a suitable value using the regulator.

f) Wait for reasonable time to allow temperatures to reach steady value.

g) Note temperatures T_1 to T_5 using channel selector and digital temperature indicator.

T_4	=	Temperature of air at heat exchanger inlet °C.
T_5	=	Temperature of air at heat exchanger outlet °C.
T_1, T_2 and T_3	=	Surface temperatures at three locations on the heater (°C).

h) Measure power input (P, watts) to the heater.

i) Tabulate the measured temperatures and power input to the heater.

j) Calculate the convective heat transfer co-efficient using the procedure given.

k) Repeat the experiment for different values of power input to the heater and blower air flow rates.

WORKING PRINCIPLE:

The air flows from bottom to the top of the heat exchanger because of the blower action. In a steady state, power input to the heater is equal to the heat transferred to the air. This is used as the base for calculation of heat transfer co-efficient.

$$q = h\,A\,\Delta T \qquad \text{--- Eq (1)}$$

Where,	q	=	Power input to the heater = P, Watts
	h	=	Convective heat transfer co-efficient watts/m^2°C.
	A	=	Surface area of the tube heater, π d L (m^2)
	L	=	Length of the tube heater, = 0.45m.

d = Diameter of the tube heater, = 0.03m.

ΔT = $T_i - T_o$ = Average temperature difference Between the tube heater and the Surrounding air (°C)

From the measurement of T_1, T_2, T_3, T_4 & T_5 and P the convective heat transfer co-efficient can be calculated using Eq. (1).

Experiments can be repeated for different heater input power and air mass flow rates. The table of measurements and results are given below.

TABULAR COLUMN:

Sl. No.	Power in watts	Air mass flow rate in mm	T_1°C	T_2°C	T_3°C	T_4°C	T_5°C	h watts/m2°C

FORMULAE

1) Mean Temperature

$$T_{ma} = \frac{T_4 + T_5}{2} \quad {}^0k$$

2) Velocity in m/s

$$V = \sqrt{2\,g\,h\,\frac{\rho_w}{\rho_a}} \quad \text{in m/sec}$$

g = Specific gravity = 9.81 m^2/sec

h = Manometer difference in m.

ρ_w = Density of water = 1000 kg/m^3

ρ_a = Density of air = 1.147 kg/m^3

3) Mass flow rate in, kg/s

$$m = \rho_a A V$$

Where, ρ_a = Density of air = 1.147 kg/m^3

$A = \pi \times d^2 / 4 = 7.07 \times 10^{-4}\ m^2$

d = diameter of the surface = 0.03 m

V = Velocity in m/sec. = from equation (2)

4) Reynolds Number

$$R_e \quad \frac{V \times d}{\upsilon}$$

V = Velocity in m/sec

d = diameter of copper tube = 0.03 m

Heat transfer co-efficient

$$h_{\text{theoretical}} = 0.023\,(Re)^{0.8}\ (Pr)^{0.4} \left(\frac{K_{air}}{0.03}\right) \quad \text{in } W/m^2\ {}^0C$$

$$h_{\text{practical}} = \frac{m\ Cp\ dt_{air}}{A\ (dt)} = \frac{m\ Cp\ dt_{air}}{A\ (T_{mt}-T_{ma})} \quad \text{in } W/m^2\ {}^0C$$

m = mass flow rate in kg/sec = from formulae (3)

Cp = 1005 J/kg ^{o}k

A = Surface area of the tube heater, π d L in m^2

d = diameter of tube = 0.030 m

L = Length of tube = 0.45m

dt_{air} = Difference of temperature air inlet and outlet in ^{0}C

dt = Difference of mean surface temperature and mean air temperature

PRECAUTIONS:

1. Keep the variac to Zero voltage position before starting the experiment.
2. Take sufficient amount distilled water in the container so that both the heaters are completely immersed.
3. Connect the test heater wire across the studs tightly.
4. Do not touch the water or terminal points after putting the switch in ON position.
5. Very gently operate the variac in steps and allow sufficient time in between.

RESULTS: