Republic of Iraq
Ministry of Higher Education
and Scientific
Al-Mustaqbal University College
Chemical Engineering and Petroleum Industries
Department

Subject: Heat Transfer Lab.

Third Class

Lecture four

Experiment Title: Free (natural) convection heat transfer from a vertical cylinder

3.1.Aim:

1. To determine the surface heat transfer coefficient for a heated vertical tube under natural convection and plot the variation of local heat transfer coefficient along the length of the tube. To determine the value of Nusselt

3.2.Theory:

The rate of heat transfer Q/t at which a hot object transfers heat to a surrounding fluids by convection is approximately proportional to the area A of the object in contact with it and to the temperature difference ΔT between them.

Newton's Law of cooling expresses the overall effect of convection by,

$Q/t = h\ A\ \Delta T$

Where, h is the convection heat transfer co efficient, depends on the shape and orientation of the object . It is used as a factor for calculating heat transfer between a fluid and a solid, between fluids separated by solids and between solids. Its unit is $Wm^{-2}\ K^{-1}$.

When a hot body is kept in still atmosphere, heat is transferred to the surrounding fluid by natural convection. The fluid layer in contact with the hot body gets heated; rise up due to the decrease in its density and the could fluid rushes in to take place. The process is continuous and the heat transfer takes place duo to the relative motion of hot cold fluid particles.

For free convection , the nusselt number is given by:

$Nu = (h * l) / k$ …………………..(1)

Where:

$Nu=0.59(Gr.\ Pr)^{0.25}$ for 104 < Gr.Pr < 108

$Nu=0.13(Gr.\ Pr)^{1/3}$ for 104 < Gr.Pr < 1012

K is the thermal conductivity of the fluid , h is the heat transfer coefficient, and L is the length of the tube.

$$Gr = \frac{g*\beta*D^3*(Ts-T\infty)}{v^2} \quad \text{(Grashof number)}$$

$$Pr = \frac{\mu*cp}{Kair} = \frac{v}{\propto} \quad \text{(prandtls number)}$$

Note:

- The **Grashof number** (Gr) is a dimensionless **number** in fluid dynamics and heat transfer which approximates the ratio of the buoyancy to viscous force acting on a fluid. It frequently arises in the study of situations involving natural convection and is analogous to the Reynolds **number**.
- The **Prandtl Number** is a dimensionless **number** approximating the ratio of momentum diffusivity to thermal diffusivity. The **Prandtl Number** is often used in heat transfer and free and forced convection calculations. It depends on the fluid properties.
- The **Nusselt number** is the ratio of convective to conductive heat transfer across a boundary. The convection and conduction heat flows are parallel to each other and to the surface normal of the boundary surface, and are all perpendicular to the mean fluid flow in the simple case.

All the properties are to be evaluated at the mean film temperature. The mean film temperature is to arithmetic average of the fin temperature and air temperature.

Nomenclature:

ρ=density of air, kg/m^3= 1.225 kg/m^3

μ=dynamic viscosity= 1.81 × 10^{-5} kg/(m·s)

C_p= specific heat, Kj/kg.k

v= kinematic viscosity, m^2/s= 1.48 × 10^{-5} m^2 /s

k= thermal conductivity of air, W/m.C

g=acceleration due to gravity, 9.81m/s^2

T_f=Mean teperature

T_∞= fluid temperature

$T_f=(Ts+T_\infty)/2$

β= coefficient of thermal expansion= $1/T_f$

$\propto$= thermal diffusivity of air= 21.70 x10^{-6} m^2/s

3.3.Apparatus Used:

Natural convection apparatus - Consists of a tube fitted vertically in a rectangular duct which is open at the top and the bottom as shown in figure below:

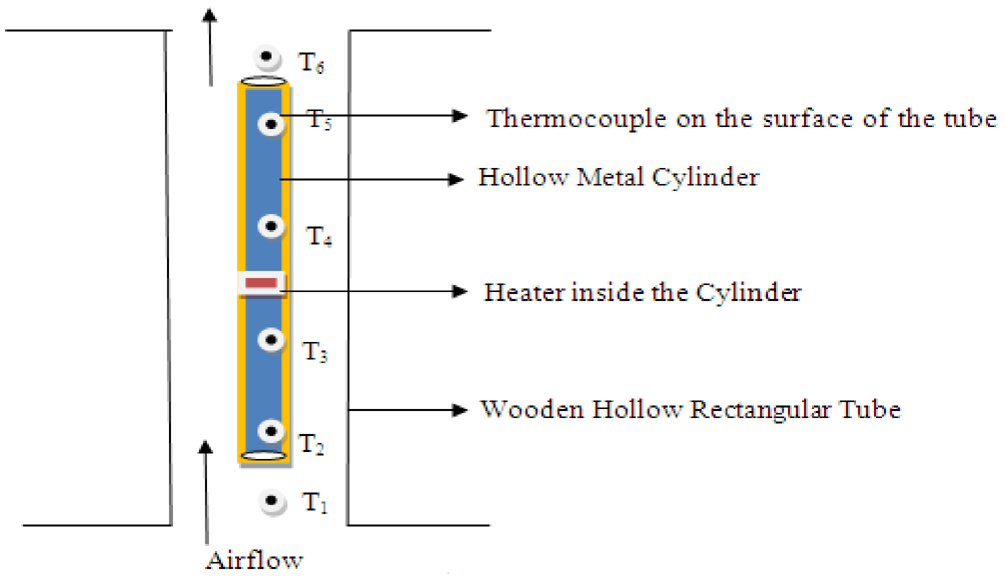

Fig: Tube Natural Convection

An electric heater is provided in the vertical tube which heats the tube surface. Heat is lost from the tube to the surrounding air by natural convection. Air around the tube gets heated up and becomes less dense, causing it to rise. This in turn gives the continuous flow of air upward in the duct. The temperature at the various locations on the surface of the vertical tube is measured using thermocouples.

1. Diameter of the cylinder (d)=38mm
2. Length of the cylinder(L) =500mm
3. Duct size 200mm*200mm*800mm
4. Multichannel digital temperature
5. Ammeter 0-2ampere.and voltmeter 0-200volts.

$$h = q / A_s (T_s - T_a) \quad \text{……………………..(2)}$$

h=Average surface heat transfer coefficient(W/m^2*C)

q= heat transfer rate(Watt)=V*I (heater input)

As=surface area of cylinder = $\pi*d*l = 0.05966\ m^2$

$$T_s = (T2+T3+T4+T5)/4$$

$T_a = T_\infty = (T1+T6)/2$ ambient temperature

3.4.Procedure:

1. Turn ON the supply and adjust the dimmerstat to obtain the required heat input(40W, 60W, 70W).

2. Measure surface temperature at steady state (T1to T6).

3. Note the ambient temperature T1&T6=Ta.

Observations & Calculations:

No	Metal Used	Volt meter readings V Volts	Ammeter readings I amps	Temperature of tube (°C)				Temperature of air (°C)	
				T_2	T_3	T_4	T_5	T_1	T_6

3.5.Calculation:

1. Calculate the average surface heat transfer coefficient(Eq. no.2) and nusselt number(Eq. no.1), grashoff number and prandtls number.
2. Calculate and plot the variation of local heat transfer coefficient along the length of the cylinder.

3.6.Discussion:

1. Discuss the effect of heat applied to the cylinder on the heat transfer coefficient for free convection.
2. Discuss the change of heat transfer coefficient along the length of cylinder.