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مختبر

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Experiment No. (3)

a. Name of Experiment:

Lumped Heat Capacity System

b. Purposes of Experiment:

1. Knowing the free convection mode.
2. To find the values of heat transfer coefficient for free convection for vertical and horizontal cylinder.
3. Obtain an experimental data for transient condition for vertical and horizontal cylinder and compare it with experimental published data.

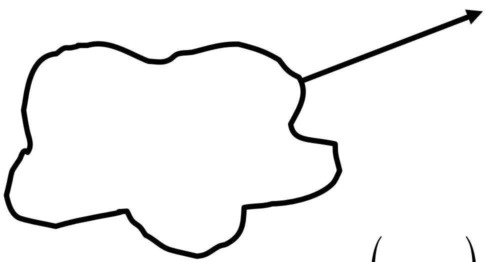
Theory of Experiment:

Lumped System Analysis

In heat transfer analysis, some bodies are observed to behave like a “lump” whose interior temperature remains essentially uniform at all times during a heat transfer process. The temperature of such bodies can be taken to be a function of time only, T(t). Heat Transfer analysis that utilizes this idealization is known as **lumped system analysis** , which provides great simplification in certain classes of heat transfer problems without much sacrifice from accuracy.

The convection heat loss from the body is evidenced as a decrease in the internal energy of the body.

$$Q = hA(T - T_\infty) = -\rho c_p V \frac{\partial T}{\partial t}$$



$$Q = hA(T - T_\infty) = -\rho c_p V \frac{\partial T}{\partial t} \quad \text{.................................} \quad (1)$$

A The surface area for convection
V The volume
ρ The density of material

With boundary conditions:

At t=0 ; T= T_i

At t>0 ; T=T

So that the solution to eq (1) is

$$\frac{T - T_\infty}{T_i - T_\infty} = e^{-\frac{hA}{\rho c_p V}t} \quad \text{..............................} \quad (2)$$

We have already noted that the Lumped- capacity type of analysis assumes a uniform temperature distribution throughout the solid body and that the assumption is equivalent to saying that "**the surface- convection resistance is large compared with the internal – conduction resistance**". Such an analysis may be expected to yield reasonable estimates when the following condition is met:

$$Bi = \frac{h(V/A)}{k} < 0.1 \quad \text{.........................} \quad (3)$$

Bi: Biot number (dimensionless number)

c. Description of Instrument:

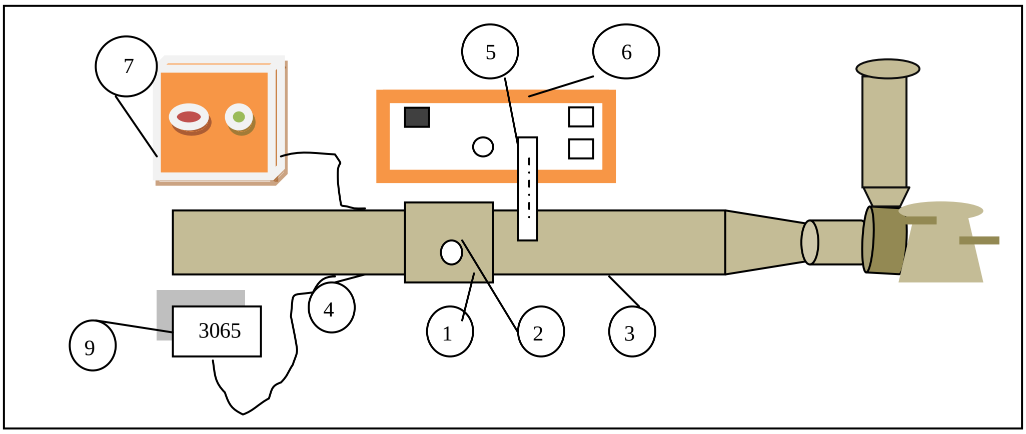


Fig (1) Lumped Heat Capacity System Instrument

1. Heater.
2. Specimen metal.
3. Horizontal duct.
4. Thermocouple.
5. Pressure drop measurement.
6. Electrical system
7. On- off switch.
8. Digital screen

d. Procedure:

1. Heating the specimen (cylinder) to 80 °C.
2. Put the specimen horizontally in the tunnel of experiment and recording the decrease in temperature with time.
3. Repeat the above steps with vertical cylinder.

e. Readings:

The heat transfer in the solid cylinder considered transient conduction and the heat loss from it (solid cylinder) to surrounding is by free convection (due to natural convection).

(1)		**(2)**	
Horizontal cylinder		**Vertical cylinder**	
T °C	t (s)	T °C	T(s)
80	0	80	0
70		70	
60		60	
50		50	
40		40	
30		30	

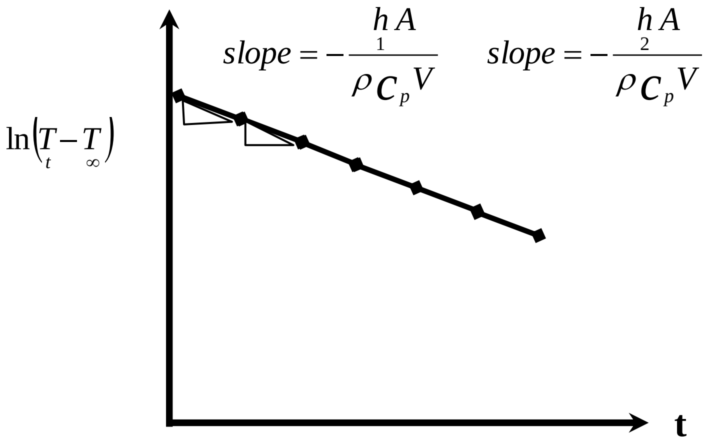
f. Calculations:

1. To find the convection coefficient, take ln to eq (2), so it becomes as line eq.

$$\frac{T - T_\infty}{T_i - T_\infty} = e^{-\frac{hA}{\rho C_p V}t}$$

$$\ln\left(T_t - T_\infty\right) = -\frac{hA}{\rho C_p V} t + \ln\left(T_i - T_\infty\right)$$

Y = m X + b



So we can determine h_1, h_2 , h_3………

2. Determine Nusselt no. (dimensionless number).

$$= \frac{hL}{k_f} \quad \text{or} \quad = \frac{hD}{k_f}$$

k_f = we can find it from properties of air at T film

$$T_f = \frac{T_s + T_\infty}{2}$$

3. determine the Rayleigh number (used for free convection)

$$Ra = Gr * \Pr$$

Grashof number Gr (dimensionless number) is a measure of the relative magnitudes of the buoyancy force and the opposing viscous force acting on the fluid (which is represents the natural convection effects).

$$Gr = \frac{\rho^2 g.\beta.\Delta T.l_c^3}{\mu^2}$$

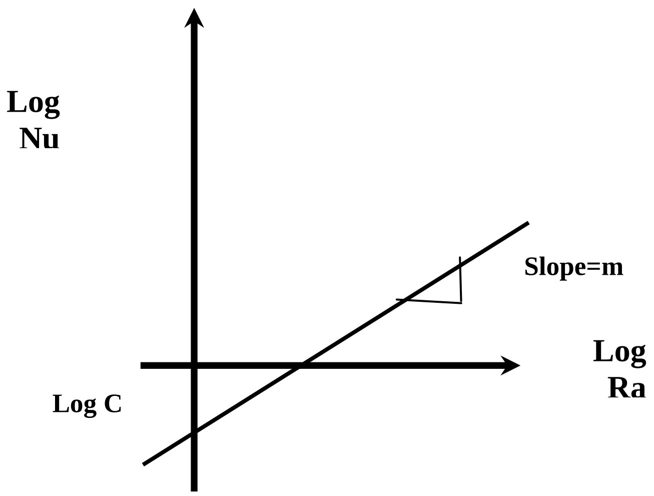
Take ρ μ from properties tables of air at T_f.

β	Volume coefficient of expansion (1/K) $= \frac{1}{T_f}$
ΔT	$=(T_s - T_\infty)$ °C
g	$=9.81\ m/s^2$
l_c	=D For horizontal cylinder (cm)
l_c	=L For vertical cylinder (cm)
Pr	$= \frac{\mu C_p}{k}$

4. Find the constant C, m and compare it. What are the causes of this contrast?

$$Nu = cRa^m$$

$$LogNu = LogC + mLog\,Ra$$



L(length of cylinder)	14cm
D	1cm
$C_{p\ AL}$	0.896 kJ/kg.°C
ρ_{AL}	2707 kg/m³
T_∞	20°C