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DEPARTMENT OF MECHANICAL ENGINEERING

SIXTH SEMESTER

LAB : MEP-61 THERMAL ENGINEERING LAB -1

PREPARED BY

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REDWOOD VISCOMETER

AIM:

To determine the kinematic viscosity and absolute viscosity of the given lubricating oil at different temperatures using Redwood Viscometer

APPARATUS REQUIRED:

1. Redwood Viscometer
2. Thermometer 0-100°c (2 Nos)
3. Stop watch
4. 50 ml standard narrow necked flask
5. Given Sample of oil

DESCRIPTION:

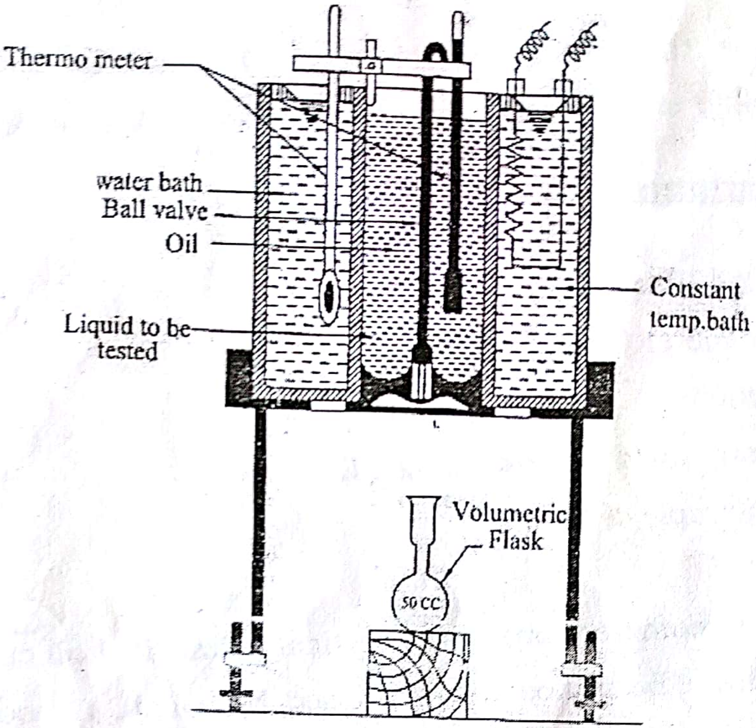
The redwood viscometer consists of vertical cylindrical oil cup with an orifice in the centre of its base. The orifice can be closed by a ball. A hook pointing upward serves as a guide mark for filling the oil. The cylindrical cup is surrounded by the water bath. The water bath maintains the temperature of the oil to be tested at constant temperature. The oil is heated by heating the water bath by means of an immersed electric heater in the water bath.

The provision is made for stirring the water , to maintain the uniform temperature in the water bath and to place the thermometer ti record the temperature of oil and water bath . The cylinder is 47.625mm in diameter and 88.90mm deep. The orifice is 1.70mm in diameter and 12mm in length, this viscometer is used to determine the kinematic viscosity of the oil. From the kinematic viscosity the dynamic viscosity is determined.

THEORY AND DEFINITION:

Viscosity is the property of fluid. It is defined as the internal resistance offered by the fluid to the movement of one layer of fluid over an adjacent layer. It is due to the Cohesion between the molecules of the fluid. The fluids which obey the Newton law of Viscosity are called as Newtonian fluid.

The dynamic viscosity of fluid is defined as the shear required producing unit rate of angular deformation.



Redwood Viscometer

OBSERVATION & TABULATION:

Room temperature TR = ... °C

Density of oil at room temperature = ... Kg/m^3

S.No	Temperature of oil °C	Time taken to fill 50ml flask in 'Sec'	Kinematic Viscosity in 'Centi Stokes'	Density in gm/cc	Dynamic (or) Absolute viscosity 'Centi Poise'

FORMULAE:

Kinematic Viscosity – in centistokes

Where,

A = 0.0026

$B = 1.72$ (or)
$A = 0.26$
$B = 172$
t = Saybolt second

Density of oil at particular temperature (ρ_t)

$$\boldsymbol{\rho_t = \rho_R - 0.00065\ (T - T_R)}$$

Where,

T = Temperature at which the density is required
T_R = Room Temperature
ρ_R = Density of oil at room temperature 0.84 (or) 0.85 gm/cm3

i.e., $\tau = \mu$ (or)

$$\mu = \frac{\tau}{du/dy}$$

where μ = Co-efficient of viscosity (or) Dynamic viscosity (or) Absolute viscosity
τ = Shear stress
du= Angular deformation (velocity gradient)

Dynamic Viscosity= $\boldsymbol{\mu = r/\rho}$

The unit of dynamic viscosity in SI system is $\frac{N-sec}{m2}$ or $\frac{kg}{m-sec}$ or poise

$1\frac{N-sec}{m2}$

= 10 Poise

The kinematic viscosity of the fluid is defined as the ratio of the dynamic viscosity toss density of the fluid . Its symbol is ‘r’

$$\boldsymbol{r = \frac{\mu}{\rho}}$$

The unit of kinematic viscosity $= \frac{m^2}{sec} = 10^4$ stokes

One hundredth part of stoke is called Centi Stoke .

PROCEDURE :

(1) Clean the cylindrical oil cup and ensure the orifice tube is free from dirt .

(2) Close the orifice with ball valve.

(3) Place the 50 ml flask below the opening of the Orifice .

(4) Fill the oil in the cylindrical oil cup upto the mark in the cup .

(5) Fill the water in the water bath.

(6) Insert the thermometers in their respective places to measure the oil and water bath temperatures.

(7) Heat the by heating the water bath, Stirred the water bath and maintain the uniform temperature .

(8) At particular temperature lift the bal valve and collect the oil in the 50 ml flask and note the time taken in seconds for the collecting 50 ml of oil . A stop watch is used measure the time taken . This time is called Redwood seconds .

(9) Increase the temperature and repeat the procedure '8' and note down the Redwood seconds for different temperatures .

GRAPH :

The following graph has to be drawn

Temperature Vs Redwood seconds

Temperature Vs Kinematic Viscosity

Temperature Vs Dynamic Viscosity

Result :

The kinematic and dynamic viscosity of given oil at different temperatures were determined.

FLASH AND FIRE POINT OF THE GIVEN OIL USING CLOSED CUP APPARATUS

AIM:

To determine the flash and fire points of the given lubricating oil by using pensky
Martin's closed cup apparatus.

APPARATUS REQUIRED:

1. Pensky Martin's closed cup apparatus with electric heater.
2. Thermometer with readings from 00C to 3600C
3. Given sample of oil.
4. Splinter sticks
5. Match box

PROCEDURE:

1. A clean and dry cup is filled with the given sample of oil up to the standard mark.

2. The lid is closed and a thermometer is inserted in the holder and the cup is placed in its position.

3. The given sample of oil is heated. As the temperature rises, vapour begins to form. The pilot flame and test flame are lit.

4. The oil is stirred by rotating the flexible extension at the rate of 1 to 2 revolutions per second by hand.

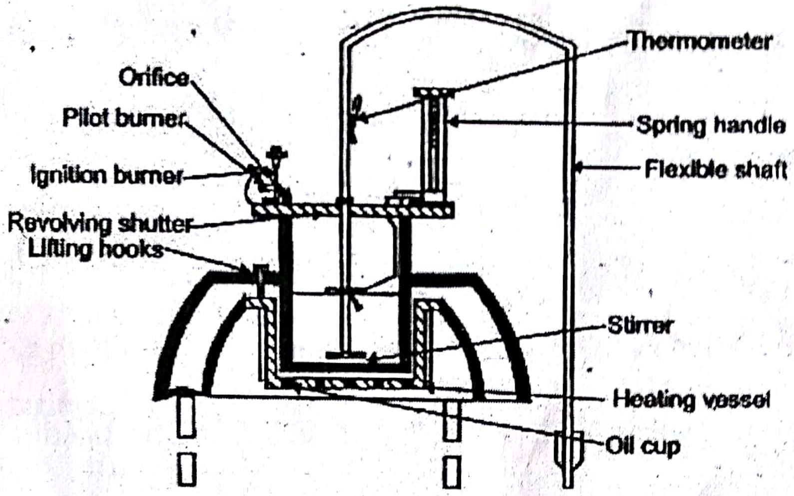
5. The test flame is applied at regular intervals. For testing, the three holes in the lid are opened by rotating the shutter handle and the flame is lowered into the hole and then the flame is quickly raised by closing the shutter.

6. Care is taken not to stir the oil during testing.

7. The temperature at which the distinct flash is visible through the port is recorded as flash point.

8. The heating is continued at the same rate after the flash point, until the vapour burns continuously at least for 5 seconds. This temperature is recorded as fire point.

9. Similar observation is made during cooling to check the values obtained.



Pensky Martin's closed cup apparatus

TABULATION:

Si.No	Temperature of the oil in °C	Observation whether flash or fire occurs (During heating)

RESULT:

For the given sample of oil,

1. The flash point is__________°C
2. The flash point is__________°C

FLASH AND FIRE POINT OF THE GIVEN OIL USING OPEN CUP APPARATUS

AIM:

To determine the flash and fire points of the given lubricating oil by using cleave land's open cup apparatus.

APPARATUS REQUIRED:

1. Cleave Land's open cup apparatus with electric heater.
2. Thermometer
3. Given sample of oil.
4. Splinter sticks
5. Match box

PROCEDURE:

1. The given oil is filled up to standard mark after cleaning the cup. A thermometer is fittedin the stand taking care to see that it does not touch any metallic part.

2. Oil is heated at the rate of 100$_0$ C per minute so that the sample gives out vapour.

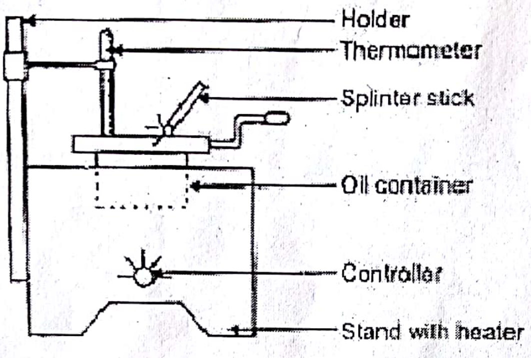
3. As the temperature of oil rises, a test flame is applied without touching the surface of the oil. The test flame is introduces again after blowing out the burnt vapour. Care is taken to ensure that the fresh flame is available for test.

4.Introducing of test flame is continued at regular intervals until the first flash is noticedwith peak flickering sound and this temperature corresponding to flash point is noted.

5. Heating is continued further until the fire point is reached. At the fire point, oil vapour ignited and burns continuously at least 5 seconds. This temperature corresponding to fire point is noted.

6. Heating is stopped and similar observations are made during cooling to check the values

obtained.



Open cup apparatus

Cleave Land's open cup apparatus

TABULATION:

Si.No	Temperature of the oil in °C	Observation whether flash or fire occurs (During heating)

RESULT:

For the given sample of oil,

1. The flash point is__________ °C
2. The flash point is__________ °C

PERFORMANCE TEST ON RECIPROCATING AIR COMPRESSOR

AIM:

To conduct a performance test on the two stage reciprocating air compressor and to determine the volumetric efficiency and isothermal efficiency at various delivery pressures

APPARATUS REQUIRED:

1. Reciprocating air compressor test rig.
2. Manometer
3. Tachometer

SPECIFICATIONS:

- Power : 5KW
- Type : Two stage reciprocating
- Cooling Medium: Air
- 3Capacity: 0.6 m/min
- Maximum Pressure: 10 Bar
- Speed : 950 rpm

BRIEF THEORY OF THE EXPERIMENT:

The two stage reciprocating compressor consists of a cylinder, piston, inlet and exit valves which is powered by a motor. Air is sucked from atmosphere and compressed in the first cylinder (Low pressure) and passed to the second cylinder (High pressure) through an inter cooler. In the second cylinder, air is compressed to high pressure and stored in the air tank.

During the downward motion of the piston, the pressure inside the cylinder drops below the atmospheric pressure and the inlet valve is opened due to the pressure difference. Air enters into the cylinder till the piston reaches the bottom dead center and as the piston starts moving upwards, the inlet valve is closed and the pressure starts increasing continuously until the pressure inside the cylinder above the pressure of the delivery side which is connected to the receiver tank. Then the delivery valve opens and air is delivered to the air tank till the TDC is reached. At the end of the delivery stroke a small volume of high pressure air is left in the clearance volume. Air at high pressure in the clearance volume starts expanding as the piston starts moving downwards up to the atmospheric pressure and falls below as piston moves downward. Thus the cycle is repeated. The suction, compression and delivery of air take place in two strokes / one revolution of the crank.

EXPERIMENTAL SETUP:

The two-stage air compressor consists of two driven by an AC motor. Air is first sucked into the low pressure (LP) cylinder and it is compressed and delivered at some intermediate pressure. The compressed air is then cooled

in the intercooler and the same is then sucked by the high pressure (HP) cylinder. Compressed air is the finally discharged to the receiver tank.

An orifice plate is mounted on one side of the air tank and which is connected with a manometer for the measurement of air flow rate. One side of the air tank is attached with a flexible rubber sheet to prevent damage due to pulsating air flow. A pressure gauge is mounted on the air tank to measure the air tank pressure. The tank pressure can be regulated by adjusting the delivery valve. A pressure switch is mounted on the air tank to switch off the motor power supply automatically when the pressure inside the tank rises to the higher limit and to avoid explosion.

PROCEDURE:

1. The manometer is checked for water level in the limbs.
2. The delivery valve in the receiver tank is closed.
3. The compressor is started and allowed to build up pressure in the receiver tank.
4. Open and adjust the outlet valve slowly to maintain the receiver tank pressure constant.
5. The dynamometer is adjusted so that the circular balance reads zero when the points at the motor pedestal coincide. This can be done by operating the hand wheel.
6. Note down the readings as per the observation table.

7. Repeat the experiment for various delivery pressures. This can be done by closing the delivery valve and running the compressor to build up higher pressure. Ensure the tank pressure is maintained constant by adjusting the outlet valve before taking the readings.

8. Tabulate the values and calculate the volumetric efficiency and isothermal efficiency.

OBSERVATION TABLE:

Sl. No	Delivery pressure (kgf/cm2)	Manometer reading (mm)			Speed		Torque Kg-m
		h1	h2	h1-h2	Motor	Comp	

SPECIMEN CALCULATION:

$$\mathbf{H_{air} = (H1 - H2/100) \times \rho_W/\rho_{air}\ m}$$

Where,

Hair = Air head causing the flow, m

h1, h2 = Manometer reading, mm

ρ_W = Density of water = 1000kg/m^3

ρ_{air} = Density of air, kg/m^3

$$\rho_{air} = \mathbf{P_a/RT}\ kg/m^3$$

Where,

Pa = Atmospheric pressure

R = Gas constant for air = 0.287 KJ/Kg.K

T = Room temperature K

$$\mathbf{V_a = Cd \times A \times (2gH_{air})^{1/2}\ m^3/sec}$$

Where,

V_a = actual volume of air compressed m3/s

C_d = Coefficient of discharge = 0.64

A = area of orifice

d = diameter of orifice = 0.02m

$$\mathbf{V1 = V_a / T_{RTP} \times T_{NTP}\ m^3/sec}$$

Where,

V1 = actual volume of air compressed at NTP m3/s

V_a = actual volume of air compressed m3/s

T_{NTP} =273 K

T_{RTP} = 273 + Room temperature in K

$$V2 = 2\pi \times D \times L \times Nc/4 \times 60 \text{ m3/s}$$

Where,

V2 = theoretical volume of air compressed m3/s

D = diameter of cylinder = 0.1m

L= stoke length = 0.085m

Nc = speed of the compressor

$$V.\ E. = V1/\ V2 \times 100\%$$

Where,

VE = volumetric efficiency

V1=actual volume of air compressed at NTP m3/s

V2=Theoretical volume of air compressed m3/s

$$Iso.P. = \ln(r) \times Pa \times Va/1000 \text{ Kw}$$

Where,

Iso. P = isothermal power

r = Pa+Pg/Pa

r= compression ratio

Pa = atmospheric pressure N/m2

Pg = pressure in the tank N/m2

$$I.P = (35/30) \times 2 \times \pi m \times (T \times 9N.81)/60000 \times \eta motor \text{KW}$$

Where,

IP = input power

Nm =motor speed rpm

T = torque on the motor kg-m

η_{motor}= 0.9

$$Iso.\ E = Iso.P./\ I.P. \times 100$$

Where,

Iso. E = isothermal efficiency

Iso. P = isothermal power

IP = input power.

GRAPH:

1. Gauge pressure Vs Volumetric efficiency
2. Gauge pressure Vs Isothermal efficiency

PRECAUTIONS:

1. The orifice should never be closed so as to prevent the manometer fluid being sucked in to the tank.

2. At the end of the experiment the outlet valve of the reservoir should be opened as the Compressor is to be started against at low pressures so as to prevent excess strain on the piston.

RESULT:

The performance test on the given air compressor test rig is conducted and the volumetric and isothermal efficiencies are determined at various delivery pressures and the characteristic curves are drawn.

CONSTANT SPEED AIR BLOWER TEST RIG:

AIM:

To conduct test on the given blower and to determine the overall efficiency using various Vanes provided.

DESCRIPTION:

The given blower is a single stage centrifugal type. Air is sucked from atmosphere at the suction side and the slightly compressed air passes through the spiral case before it comes out through the outlet. The given blower is provided with three interchangeable impellers namely straight, curved, forward curved and backward curved vanes. The vanes are pressed out of sheet metal and riveted to the shrouds. This volute contour helps in reducing eddy current losses along the path. The casing is designed such that it can separate to facilitate easy interchanging of impellers. The blower is directly coupled to a swinging field induction motor of 5HP, 2880rpm. The outlet of the blower is connected to a pipe line of 3 meters length. An orificemeter, a flow control valve and pressure toppings are provided along the pipe. Pitot tube for measuring the head is also provided on the suction and delivery of the blower. A Panel mounted on sturdy iron stands, with switch starter for the blower motor, a 3-phase energy meter to measure the input energy for the blower, and manometer to measure the flow, static and total head.

EXPERIMENTAL PROCEDURE:

1. Fill the water in the Manometer provided for orificemeter, the levels must equal, so remove air bubbles if any.

2. Fill the water in the manometer provided for Pitot tubes, provided on the suction and delivery side, Close the cock connected to the inner pipe of the Pitot tube, and leave this column of the manometer open to the atmosphere. Open the cock connecting the static pressure end Pitot tube.

3. Close the delivery control valve, and start the unit.

4. Open the delivery valve to ¼th level.

5. Note the time taken for 10 revolution of energy meter reading.

6. Note the speed of the motor. Fixed speed

7. Note the manometer readings.

8. Repeat the experiment for different openings of the delivery valve.

SPECIFICATIONS

a) Power (P) : 5HP or 3.75KW
b) Speed (N) : 2900rpm
c) Pipe Diameter : 75mm
d) Throat Diameter : 55mm
e) Co-efficient of Discharge (Cd) : 0.6
f) Impeller Diameter : 500mm
g) Motor : Squirrel cage induction
h) Delivery Size : 75x55mm

OBSERVATION AND TABULATION

Sl No	Manometer Reading (m)			Orificemeter reading			Time for 5 pulse on e/m t	Head causing flow h1	Discharge Q	Velocity of air v	Static pressure head Hs	Dynamic head Hd	Total head H	Power output Po	Power input Pi	Efficiency
	h1	h2	h1-h2	h1	h2	h1-h2	sec	m	m^3/s	m/s	m	m	m	w	w	%

FORMULA USED

Atmospheric pressure (Pa) $= 1.013 \times 10^5$ N/m^2

Diameter of pipe (d_1) = 75mm

Diameter of throat (d_2) = 55mm

Co-efficient of discharge (Cd) = 0.6

a) Static Head (Hs)

$Hs = (h_S x\ w)/\rho_a (m)$

Where , h_S = Static pressure manometer (m)

ρ $_w$=density of water ,1000 (Kg/m3)

ρ $_a$=density of air ,1.18 (Kg/m3)

b) Head causing flow

$Ha = (Hwx\ \rho_w)/\rho_a$ (m)

Where, Hw =Orificemeter reading (m)

w = density of water ,1000 (Kg/m3)

a = density of air ,1.18 (Kg/m3)

mercury = density of mercury (Kg/m3)

c) Discharge (Q)

$$Q=\frac{Cd \times a_1 \times a_2 \sqrt{2gHa}}{\sqrt{a_1^2 \times a_2^2}}$$ (m^3/sec)

Where, Cd =Co-efficient of discharge, 0.6

a_1 =Area of cross-section of pipe (m^2)

=0.012

a_2 =Area of cross-section of throat (m^2)

=0.004

g = Acceleration due to gravity (m/s^2)

=9.81

Ha = Head causing flow

d) Velocity of air in pipe (V)

$$V=\frac{2}{A} \qquad (m/s)$$

Where, Q = Discharge (m^3/s)

A = Area of cross-section of pipe (m^2)

e) Dynamic Head (Hd)

$$Hd=\frac{V^2}{2g} \qquad (m)$$

f) Total Head (H)

$$H = Hs+Hd+Z \qquad (m)$$

Where, Z= Datum height from suction to delivery (m)

=1

g) Power output (Po)

$$Po = \rho_a x\ g\ x\ Q\ x\ H \qquad (w)$$

Where, a = Density of air =1.18 (kg/m^3)

g = Accelaration due to gravity =9.81 (m/s^2)

Q= Discharge (m)

H = total head (m)

h) Power input (Pį)

$$Pi = \frac{N\ x\ 3600x1000x\acute{\eta}\ m}{T\ x\ k} \qquad (w)$$

Where, N = no of pulse on energy meter

m = motor efficiency = 85 (%)

T= Time for 5 pulse of energy meter (sec)

k = Energy meter constant ,1600 pulse/KWH

i) Efficiency ($\acute{\eta}$)

$$= \frac{P_o}{P_i} X\ 100 \qquad (\%)$$

PRECAUTIONS

The following precautions were taken before starting the test

a). Check the test rig is under no load
b) Check the level of water in the manometer

PROCEDURE

a) Start the blower at no load condition by keeping the delivery valve closed position
b) Open the delivery valve in full open condition
c) Take the manometer readings and the time taken for n number of pulses of energy meter
d) Repeat the experiments by closing the delivery valvegradually
e) Finally take the reading at closed condition of delivery valve
f) Close the delivery valve and switch off the blower

RESULT

The following graph are plotted :

a) Total head Vs discharge
b) Efficiency Vs discharge
c) Input Vs discharge

Maximum efficiency obtained :

Maximum output :

Maximum value of air discharge :

INFERENCE

The efficiency increases gradually with increase in discharge

The input power increases

Gradually with increase in discharge

The head decreases

Gradually with increase in discharge

HEAT TRANSFER THROUGH A COMPOSITE WALL

AIM:

To determine the thermal conductivity of composite wall.

Conduction:

It is a mode of heat transfer in which energy exchange take place from the higher temperature region the lower temperature region by the kinetic motion or direct impact of molecules as in case of fluid at rest and by the drift of electrons as in case of metals.

Fourier's law:

The conduction of heat in solids or fluids is rest is governed by this law. it states that "the rate of heat flow by conduction in a given direction is proportional to the area normal to the different of the heat flow and the gradient of temperature in that direction.

$$qx = -Ka(dt/dx)$$

Thermal conductivity:

Thermal conductivity (k) is property of material and is a positive quantity. It is a measure of heat flux (heat rate/unit area)/unit temperature gradient along a specified direction.

We have negative sign if the temperature decreases in the positive x-direction, then dt is negative. To keep thermal conductivity k positive we introduce a negative sign.

Its unit is `w/mk'

Composite wall:

In many engineering applications heat transfer takes places through medium composed of several material different layer each having a different thermal conductivity.

Apparatus required:

1. Electric heating coil
2. Thermocouples
3. Voltmeter
4. Ammeter
5. Dimmer start
6. Composite wall setup

Procedure:

1. Fix the heat input to heater by varying the dimmer start.
2. The power supply is given to the heater and is adjusted to any requiredvalue. After the steady state condition is reached when there is no change in temperatures of the slabs at the interfaces

and hotter and colder sides are noted. Experiment is repeated for different power inputs.

Formulas:

1) Heat input = V*I*cosΦ in watts

2) Overall heat loss Q_L =

$$\frac{\Delta T}{1/A\ [L_1/K_1+L_2/K_2+L_3/K_3]}$$

in watts

3) Percentage of heat loss = Q_L/heat I/p*100

Where,

V-voltage in volts
I- current in Ampere
CosΦ- power factor=0.8
L_1, L2, L3- Thickness of materials wood, ms plate, copper
A- Area of the wall= π/4*d^2 in m^2
d- Diameter of the wall in m
ΔT- Temperature difference (T_{in} - T_{out})

Specification:

L_1=Thickness of wood =12mm = .012m
L_2= Thickness of ms plate=12mm = .012m
L_3= Thickness of copper= 10mm = .01m
d = Diameter of each plate = 150mm = 0.15m

Thermal conductivity of wood ,ms plate, copper
k_1 = 52.3*10-3 w/m c
k_2 = 40 w/m c
k_3 = 204 w/m c

BULATION:

	Voltmeter readings (v) volts	Ammeter Readings (Amps)	Heat input (Watts)	Plate temperature in °c				Temp. of one side Tin =T5 ° C	Temp. of other side Tout =T6	Heat loss QL watts	Percentage of heat loss
				T 1	T 2	T 3	T 4				

Result:

Total thermal resistance is found to be

Experiment Number:

Title of the Experiment: Natural Convection Heat Transfer from a Vertical Cylinder

Date of the Experiment:

OBJECTIVE [AIM] OF THE EXPERIMENT

To determine surface heat transfer co-efficient, local heat transfer co-efficient along the length of the tube and also to draw the graph between local heat transfer co-efficient and distance along the length of the tube.

FACILITIES REQUIRED AND PROCEDURE a] Facilities required to do the experiment:

Sl. No.	Facilities required	Quantity
1.	Natural convection-vertical cylinder apparatus	1

b] Theory

When a hot body is kept in a still air, heat is transferred to the surrounding by natural convection, the fluid layer in contact with the hot surface gets heated, rises up due to decrease in its density and the cold fluid rushes into take its place. The process is continuous and heat transfer takes place due to relative motion of hot and cold fluid. The surface heat transfer co-efficient of a system transferring heat by natural convection depends upon its shape, dimension, orientation and also the temperature difference between the surface and the fluid.

c] Apparatus Description

The apparatus consists of a Brass tube fitted in a rectangular duct in a vertical fashion. The duct is open at the top and bottom and forms an enclosure and serves the purpose of undisturbed surrounding. One side of the duct is made up of Perspex sheet for visualization. An electric heating element is kept in the vertical tube which in turn heats the tube to the surrounding air by natural convection. The surface temperature of the vertical tube is measured by seven thermocouple wires. The tube surface is polished to minimize the radiation losses. The temperature of the tube measured by a temperature indicator.

Specification:

[1] Diameter of the tube [d] = 50 mm.

[2] Length of the tube [l] = 500 mm.
[3] Duct size = 200 mm x 200 mm x 750 mm

[4] Number of Thermocouples= 7 and are shown as [1] – [7] and as marked on temperature indicator switch.

[5] Thermocouple number 8 reads the temperature of the air in the duct.

[6] Temperature indicator 0 – 300 ^{0}C. Multichannel type, calibrated for chromel – alumel thermo couples.

[7] Ammeter = [0 – 2A]
[8] Voltmeter = [0 – 100/200V]
[9] Dimmer start = 2A/230Volt.
[10] Heater – cartridge type = 400 Watts

d] Procedure for doing the experiment:

Step No.	Details of the Step
1.	Switch on the supply and adjust the dimmerstat to obtain the required heat input.
2.	Wait till the fairly steady state is reached, which is confirmed from temperature readings [T_1 to T_7].
3.	Note down surface temperature at various points.
4.	Note the Ambient Temperature [T_8].
5.	Repeat the experiment at different heat inputs.

Precautions:

[1] Do not exceed 100 Watts.

[2] Operate the change over selector switch gently from position [1] to [8].

Formula Used:

[1] $T_s = [T_1 + T_2 + T_3 + T_4 + T_5 + T_6 + T_7] / 7$ ^{0}C

Where T_1, T_2, T_3,..........T_7 are temperature at locations 1, 2 --7 Mean film temperature $[T_{mf}] = [T_s + T_a] / 2$.

Where T_s = Average surface temperature in ^{0}C T_a = Ambient Temperature in ^{0}C.

Experiment heat transfer co-efficient [Average] $Q = hA [\Delta T]$ Watts.

Where h = Experimental convective heat transfer co-efficient [Average] W/m^{2}K.

A = Area of heat transfer πd L m^2. $\Delta T = T_s - T_a$ in ^{0}C.

T_s = Surface temperature

in ^0C. T_a = Ambient temperature in ^0C.

Q = Average rate of heat transfer by convection in [Watts]. h_{exp} [average] = $Q / A_s[T_s - T_a]$ W/m^{2}K.

[2] Local heat transfer co-efficient:

$h_{exp}[local] = Q / A[T_x - T_a]$.

Where T_x = Temperature at locations 1 to 7 in ^0K.

The local heat transfer co-efficient $h_1, h_2, h_3, \ldots\ldots\ldots h_7$ can be calculated from the above equation.

[3] Theoretical heat transfer co-efficient [Average].

Using free convection correlation for vertical cylinder.

$Nu = 0.59\ [Gr.\ Pr]^{0.25}$ for $10^4 \le Gr.\ Pr \le 10^9$.

$= 0.13\ [Gr.\ Pr]^{1/3}$ for $10^9 \le Gr.\ Pr \le 10^{12}$.

Nu = Nusselt Number.

Gr = Grash of Number.

Pr = Prandtl Number.

Grash of Number = $g \times L^3 \times \beta \times \Delta T / \nu^2$

Where g = Acceleration due to gravity = 9.81 m/s^2.

L = Characteristics dimension in meters, Here L = 0.5 m.

β = Co-efficient of thermal expansion for the fluid

$\beta = 1 / T_f$ in K.

ΔT = Temperature difference in $^0K = [T_s - T_a]$.

ν = Kinematic viscosity of the air at mean film temperature, m^2/s. [from the HMT Data book].

pr = Prandtl Number of air at T_{mf} [from the HMT Data book].

Nu = hL/K.

Where h = Convective heat transfer co-efficient in w/m^{2}K.

L = Characteristic dimension in m. L = 0.5 m.

K = Thermal conductivity of air at T_{mf} [from HMT Data book]

[4] Theoretical Local heat transfer co-efficient. h_{theo}

[Local] Gr [local] = $g \times L_x^3 \times \beta \times \Delta T / \nu^2$

Where $L_x = L_1, L_2, L_3, \ldots\ldots. L_7$ distance from the bottom of the tube in 'm'

Pr = Prandtl Number [T_{mf}] T_{mf} [local] = $[T_x + T_a] / 2$

T_x = Temperature at point 1 to 7.

ν = Kinematic viscosity at T_{mf} in m^2/s.

ΔT = Temperature difference - $[T_x - T_a]$ in ^0K.

Nu [Local] = $h_l L_l / K$.

Where h_l = Local convective heat transfer co-efficient at point 1 to 7 in w/m^{2}K.

L_l = Characterstics dimension in m.

K = Thermal conductivity of air at T_{mf} in w/m^{2}K.

Experiment Number:
Title of the Experiment: Forced Convection inside Tube
Date of the Experiment:

OBJECTIVE [AIM] OF THE EXPERIMENT

To determine the heat transfer coefficient on the given Forced Convection inside tube

FACILITIES REQUIRED AND PROCEDURE

a] Facilities required to do the experiment:

Sl. No.	Facilities Required	Quantity
1.	Forced Convection inside tube Apparatus	1

b] Description

The experimental setup consists of a tube through which air is sent in by a blower. The test section consists of a long electrical surface heater on the tube which serves as a constant heat flux source on the flowing medium. The inlet and outlet temperatures of the flowing air are measured by thermocouples and also the temperatures at several locations along the surface heater from which on average temperature can be obtained. An orifice meter in the tube is used to measure the air flow rate with a 'U tube water manometer.

An ammeter and a voltmeter are provided to measure the power input to the heater. A power regulator is provided to vary the power input to heater.

A multipoint digital temperature indicator is provided to measure the above thermocouples input.

A valve is provided to regulate the flow rate of air.

c] Procedure for doing the experiment:

Step No.	Details of the Step
1.	Switch on the main.
2.	Switch on the blower.
3.	Adjust the regulator to any desired power into input to heater.
4.	Adjust the position of the valve to any desired flow rate of air.
5.	Wait till steady state temperature is reached.
6.	Note manometer reading h_1 and h_2.
7.	Note temperatures along the tube. Note air inlet and outlet temperature.
8.	Note voltmeter and ammeter reading.
9.	Adjust the position of the valve and vary the flow rate of air and repeat the experiment.
10.	For various valve openings and for various power inputs the readings may be taken to repeat the experiments.

[1] EXPERIMENTAL METHOD:

$VI = hA\Delta t$

Where,

Δt = Average temperature of heater – Average temperature of air [^{0}C]. $A = \pi dl$

A = Area of heat transfer.

d = diameter of the tube = 0.04m

l = length of the tube = 0.5m.

h = heat transfer co-efficient [W/m^2 C] VI = Power input to heater.

[2] THEORITICAL METHOD:

$Q = C_d \times a_1 \times a_2 \sqrt{2gh_o} / \sqrt{a_1^2 - a_2^2}$ m^3/sec. h_o = head of air causing the flow.

$= [h_1 - h_2] \times [\rho_w/\rho_a]$

ρ_w = Density of water = 1000 kg/m^3. ρ_a = Density of air = 1.16 kg/m^3.

h_1, h_2 = Manometer reading in m. a_1 = Area of the tube.

a_2 = Area of the orifice.

Q = Volume of air flowing through the tube. $C_d = 0.6$

[3]VELOCITY OF AIR:

V = Q/a m/sec.

[4]REYNOLDS NUMBER:

$Re = VD/\upsilon$.

V = Velocity of air

D = Dia. of the pipe.

υ = Kinematic viscosity of air.

[5]Nu = hD/K

K = Thermal conductivity of air.

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

Re = Reynolds Number.

Pr = Prandtl Number.

TABULATION:

S.No.	Voltage [V] [Volts]	Current [A] [Amps]	Inlet Temperature of air [T_1] [^{0}C]	Outlet Temperature of air [T_6] [^{0}C]	Temperature along the duct				Manometer reading	
					T_2 [^{0}C]	T_3 ^{0}[C]	T_4 ^{0}[C]	T_5 ^{0}[C]	h_1 [cm]	h_2 [cm]
1	50	1	35	38	42	45	46	47	9	19

MODEL CALCULATIONS:

EXPERIMENTAL METHOD:

$PI = V \times I = 50$ watts $VI = h \times A \times \Delta t$

Δt = Average temperature of heater – Average temperature of air $\Delta t = 45 - 36.5$

$\Delta t = 8.5^0C$

Average temperature of heater = $T_2 + T_3 + T_4 + T_5 / 4$ = $42+45+46+47 / 4 = 45^0C$. Average temperature of air = $T_1 + T_6 / 2$

$= 35 + 33 / 2 = 36.5^{\circ}C.$

A = Area of heat transfer

$A = \pi \times d \times l$

Diameter of tube d = 0.04m

Length of the tube l = 0.5m

$A = 3.14 \times 0.04 \times 0.5$

$A = 0.0634 m^2.$

$VI = h \times A \times \Delta t$

$50 = h \times 0.0634 \times 8.5$

$h = 92.782 \, W/m^2C.$

THEORTICAL METHOD

$Q = C_d \times a_1 \times a_2 \sqrt{2gh_o} / \sqrt{a_1^2 - a_2^2}$

$h_o = [h_1 - h_2] \times [\rho_w/\rho_a] \, m^3/sec$

$\rho_w = 1000 \, kg/m^3$ $\rho_a = 1.16 \, kg/m^3.$

$h_1 = 9$

$h_2 = 19.$

$h_o = [19-9] \times [1000/1.16]$

$= 10 \times 862.069 = 86.20689 \, m.$

$C_d = 0.6$

$a_1 = \pi/4 \times d_1^2$

d_1 = Dia of pipe = 40mm = 0.04m

$= \pi/4 \times [0.04]^2$

$a_1 = 0.00125664 \, m^2.$

$a_2 = \pi/4 \times d_2^2$

d_2 = Dia of the orifice = 20mm = 0.02m.

$= \pi/4 \times [0.02]^2$

$a_2 = 0.00031416 m^2.$

$Q = 0.6 \times 0.00125664 \times 0.00031416 \times \sqrt{2 \times 9.81 \times 86.20689} / \sqrt{[0.00125664]^2 - [0.00031416]^2}$

$Q = 2.3687 \times 10^{-7} \times 411.264/1.216 \times 10^{-3}$ $Q = 0.008006376 m^3/sec.$

VELOCITY OF AIR FLOW

$V = Q / a_1$

$= 0.008006376/0.00125664$

$= 6.3713$ m/sec.

REYNOLD'S NUMBER

$Re = VD/\upsilon$.

υ - Kinematic viscosity from HMT Data book

$\upsilon = 0.00001696$

$= 6.3713 \times 0.04 / 0.00001696$

$Re = 15027$.

NUSSELT NUMBER

$Nu = hD/K$

$Nu = 0.023 \times [15027]^{0.8} \times$
$[0.698]^{0.33}$ $Nu = 43.75290799$.

$Nu = hD/K$

K - Thermal conductivity from HMT
Data book $K = 0.02856$.

$43.75290799 = h \times 0.04 /$
0.02856 $h = 31.2395763$
W/m^2C.

d] Result:

Thus the experiment of the forced convection is conducted and heat transfer coefficient are calculated.

Heat Transfer Co-efficient:

Experimental value = 92.782
W/m^2C. Theoretical value =
31.2395763 W/m^2

HEAT TRANSFER IN PIN FIN

AIM

To study the temperature distribution, heat transfer coefficient and efficiency of a pin fin in natural and forced convection heat transfer.

INTRODUCTION

Extended surfaces or fins are used to increase the heat transfer rates from a surface to the surrounding fluid wherever it is not possible to increase the value of the surface heat transfer coefficient or the temperature difference between the surface and the fluid. Fins are fabricated in variety of forms. Fins around the air cooled engines are a common example. As the fins extend from primary heat transfer surface, the temperature difference with the surrounding fluid diminishes towards the tip of the fin.

APPARATUS

The apparatus consists of a simple pin fin which is fitted in a rectangular duct. The duct is attached to suction end of a blower. One end of fin is heated by an electrical heater. Thermocouples are mounted along the length of fin and a thermocouple notes the duct fluid temperature. When top cover over the fin is opened and heating started, performance of fin with natural convection can be evaluated and with top cover closed and blower started, fin can be tested in forced convection.

SPECIFICATIONS

1) Fins – 12 mm O. D., Effective length 102 mm with 5 nos of thermocouple positions along the length, made of brass, mild steel and aluminum - one each.

Fin is screwed in heater block which is heated by a band heater.

2) Duct- 150 x 100mm cross-section, 1000mm long connected to suction side of blower

3) FHP centrifugal blower with orifice and flow control valve on discharge side.

4) Orifice – dia 22mm, coefficient of discharge $C_d = 0.64$

5) Water manometer connected to orifice meter

THEORY

Let A= Cross sectional area of the fin, m^2

P= Perimeter (circumference) of the fin, m

L= Length of the fin = 0.102 m

T_1= Base temperature of fin

T_f= Duct fluid temperature (Channel No. 6 of temperature indicator)

θ = Temperature difference of fin and fluid temperature =T- T_f

h = Heat transfer coefficient, W / m^2 ^oC K_f

= Thermal conductivity of fin material

= 110 W / m ^oC for brass

= 46 W / m ^oC for mild steel

= 232 W / m ^oC for aluminum

Heat is conducted along the length of fin and also lost to surroundings. Applying first law of thermodynamics to a control volume along the length of fin at a station which is at length ‘x’ from the base

$$\frac{d^2T}{dX^2} - \frac{h.P}{k_f.A}\theta = 0 \qquad (1)$$

$$\therefore \quad \phi = (C_1.e^{mx}) + (C_2.e^{-mx}) \qquad (2)$$

$$Where\ m = \sqrt{\frac{h.P}{k_f.A}} \qquad (3)$$

With the boundary conditions of θ = θ_1 at x = 0, $\theta_1 = T_1 - T_f$

Assuming tip is to be insulated, $\frac{d\theta}{dx} = 0$ at x = L,

Results in obtaining equation (2) in the form

$$\frac{\theta}{\theta_1} = \frac{T - T_f}{T_1 - T_f} = \frac{Cosh\,[m(L - X)]}{Cosh\,[m.L].} \qquad (4)$$

This is the equation for temperature distribution along the length of the fin. Temperatures T_1 and T_f will be known for the given situation and the value of ‘h’ depend upon mode of convection i.e. natural or forced.

EXPERIMENTAL PROCEDURE

Sl. No.	INPUT		Manometer difference	Fin Temperature °C					Duct fluid temp. °C
	V	I	H (m of water)	T_1	T_2	T_3	T_4	T_5	T_6 (T_f)

A) NATURAL CONVECTION

Open the duct cover over the fin. Ensure proper earthing to the unit and switch on the main supply. Adjust dimmerstat so that about 80 V are supplied to the heater. The fin will start heating. When the temperatures remain steady, note down the temperatures of the fin and duct fluid temperature.

Sl. NO.	INPUT		Fin temperatures °C					Duct fluid temperature °C
	V	I	T_1	T_2	T_3	T_4	T_5	T_6 (T_f)

B) FORCED CONVECTION

Close the duct cover over the fin. Start the blower. Adjust the dimmerstat so that about 100 – 110v are supplied to the heater. When the temperatures become steady, note down all the temperatures and manometer difference

CALCULATIONS

Nomenclature:

T_m = Average fin temperature = (T_1 + T_2 + T_3 + T_4 +T_5) /5

$$\Delta T = T_m - T_f$$

T_{mf} = Mean film temperature = (T_m+ T_f) /

2 ρ_a = Density of air, kg / m3

ρ_w = Density of water, kg / m3 = 1000 kg /

m3 D = Diameter of pin fin = 12×10^{-3} m d = Diameter of orifice = 22×10^{-3} m

C_d = coefficient of discharge of orifice = 0.64

μ = Dynamic viscosity of air, N-s/m^2

C_p = Specific heat of air, kJ/kg.K υ=

Kinematic viscosity, m^2/s

k_{air} = Thermal conductivity of air, W/m K

β = volume expansion coefficient = 1 /

(T_{mf}+273.15) H = Manometer difference, m of water

V = velocity of air in duct, m/s Q

= volume flow rate of air, m^3/s

V_{tmf} = velocity of air at mean film temperature

All properties are to be evaluated at mean film temperature.

NATURAL CONVECTION

The fin under consideration is horizontal cylinder losing heat by natural convection. For horizontal cylinder, Nusselt number, from data book, page number 122.

$Nu = 1.02\,(Gr.Pr)^{0.148}$ ----------for $10^{-2} < Gr.Pr < 10^{2}$

$Nu = 0.85\,(Gr.Pr)^{0.188}$ --------- for $10^{2} < Gr.Pr < 10^{4}$.

$Nu = 0.48\,(Gr.Pr)^{0.25}$ ----------for $10^{4} < Gr.Pr < 10^{7}$

$Nu = 0.125\,(Gr.Pr)^{0.333}$ --------- for $10^{7} < Gr.Pr < 10^{12}$.

Where Gr = Grashof number. $= \dfrac{g.\beta.D_3\Delta T}{\nu_2}$

Pr = Prandtl number = $\dfrac{Cp.\mu}{k_{air}}$ (take from data book.)

Determine Nusselt number.

Now, Nu = (hD)/k_{air}

Therefore, h = Nu. K_{air} /D

From h determine m from equation (3)

Using h and m, determine temperature distribution in the fin from equation (4)

The rate of heat transfer from the fin and efficiency can be calculated as,

$$Q_{fin} = \sqrt{h.P.k_f.A}\,(T_1 - T_f) \text{ and } \quad \eta = \frac{\tanh[mL]}{mL}$$

FORCED CONVECTION

For flow across Horizontal cylinder loosing heat by forced convection, from data book, page number 100.

$Nu = 0.911\,(Re)_{0.385}.\ Pr_{0.333}$ ---------- for $4 < Re < 40$

$Nu = 0.683\,(Re)_{0.466}\ .\ Pr_{0.333}$ ---------- for $40 < Re < 4000$

$Nu = 0.193\,(Re)_{0.618}\ .\ Pr_{0.333}$ ----------for $4000 < Re < 40{,}000$

Where, $R_e = \dfrac{V_{tmf}\ .D}{\nu}$

$$V_{tmf} = \frac{V.(T_{mf} + 273)}{(T_f + 273)}$$

Velocity of air is determined from air volume flow.

$$Q = Cd\,\frac{\pi}{4}\,d^2\,\sqrt{2.g.H\,(\rho_w / \rho_a)} \quad m^3/s$$

$$V = Q / \text{Duct cross sectional area} = Q/(0.15\,X\,0.1)\ m/s$$

From Nusselt Number, find out 'h' and from 'h', find out 'm'

Now temperature distribution, heat transfer rate and effectiveness of the fin can be calculated using equations 4, 5 and 6 respectively.

CONCLUSION

1. Comment on the observed temperature distribution and calculation by theory, it is expected that observed temperatures should be slightly less than their calculated values because of radiation and non- insulated tip.
2. Plot the graphs of temperature distribution in both natural and forced convection.

PRECAUTIONS

1. Operate all the switches and controls gently
2. Do not obstruct the suction of the duct or discharge pipe
3. Open the duct cover over the fin for natural convection experiment

4. Fill up water in the manometer and close duct cover for forced convection experiment
5. Proper earthing to the unit is necessary
6. While replacing the fins, be careful for fixing the thermocouples. Incorrectly fixed thermocouples may show erratic readings

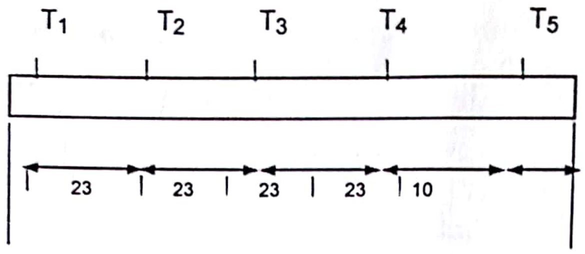


Fig.1: Thermocouple position on fin

GRAPH

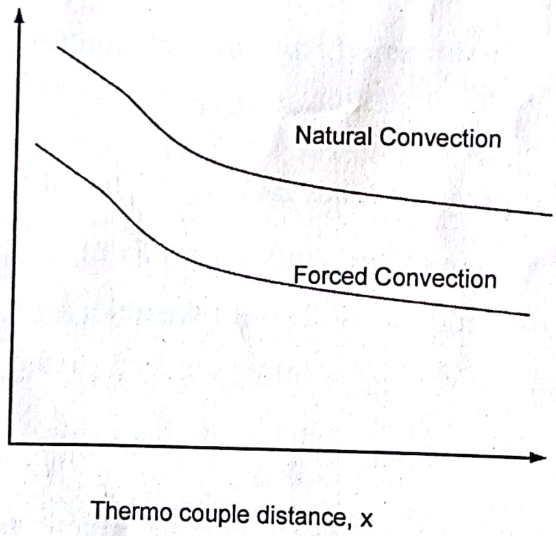


Fig 2: Variation of fin temperature along the length of fin with natural convection and forced convection.

RESULTS

Natural convection:

Heat transfer coefficient =

Efficiency of pin fin =

Forced convection:

Heat transfer coefficient =

Efficiency of pin fin =

HEAT TRANSFER THROUGH
PARALLEL FLOW & COUNTER FLOW

AIM:

To study and compare temperature distribution, heat transfer rate, overall heat transfer coefficient in parallel flow and counter flow.

APPARATUS:

Stop clock, Measuring Jar, Thermometers etc.,

SPECIFICATIONS :

Length of the heat exchanger = 1.8 m

Inner – Brass tube – I.D. = 9.5 mm, O.D. = 12 mm

Outer – G.I. Tube – I.D. = 27mm , O.D. = 33.5 mm

THEORY :

Heat exchangers are devices in which heat is transferred from one fluid to another. Common examples of heat exchangers are the radiator of a car,condenser at the back of domestic refrigerator etc. Heat exchangers are classified mainly into three categories (1) Transfer type

(2) Storage type and (3) Direct contact type.

Transfer type heat exchangers are most widely used.

A transfer type of heat exchanger is one in which both fluids pass simultaneously through the device and heat is transferred through separating walls. Transfer type of exchangers are further classified as (a) Parallel flow type - in which fluids flow in the same direction (b) Counter flow – in which fluids flow in opposite directions and (c) Cross flow type - in which fluids flow at an angle to each other.

A simple heat exchanger of transfer type can be in the form of a tube – in – tube arrangement. One fluid flowing through the inner tube and the other through the annulus surrounding it. The heat transfer takes place across the walls of the inner tube.

DESCRIPTION :

The apparatus consists of a concentric tube heat exchanger. The hot fluid i.e.,

hot water is obtained from an electric geyser and it flows through the inner tube. The cold water can be admitted at any one of the ends enabling the heat exchanger to run as a parallel flow apparatus or a counter flow apparatus. This may be done by operating the different valves provided. Temperatures of the fluids may be measured using thermometers. Flow rate may be measured using stop clock and measuring jar. The outer tube is provide with adequate asbestos rope insulation to minimize the heat loss to the surroundings.

PROCEDURE :

The thermometers are kept in position. The flow on hot water side is started.

The flow on cold water side is also started. The electric geyser is put on. The flow rate on cold water side is adjusted to 4 to 5 lt/min . The flow rates are kept same till the steady state condition is reached. The temperatures and the flow rates are measure. The experiment may be repeated for different flow rates as well as for parallel flow and counter flow heat exchanges.

OBSERVATIONS & RESULTS :

Type of flow	HOT WATER			COLD WATER			LMTD oC	Overall heat transfer coefficient	Effective- ness
	Mass Flow Mh	Inlet temp Thi	Outlet temp Tho	Mass Outlet Flow temp Mc	Inlet temp Tci	outlet temp Tco			

SAMPLE CALCULATIONS :

Parallel flow :

$Q_h = m_h\, c_h\, (T_{hi} - T_{ho})$ KW $\quad C_h = 4.1868$ KJ/Kg K

$'m_h$ = Kg/h_c

$Q_c = m_c\, c_c\, (T_{co} - T_{ci})$ KW $\quad C_c = 4.1868$ KJ/Kg K

LMTD = Logarithmic Mean Temperature Difference

$$= \frac{\Delta T_i - \Delta T_o}{\log_e \dfrac{\Delta T_i}{\Delta T_o}} \quad \text{or} \quad \frac{\text{Ø}_i - \text{Ø}_o}{\log_e \dfrac{\text{Ø}_i}{\text{Ø}_o}}$$

Where Øi = ΔT_i = Temperature difference at inlet

Øo = ΔT_o = Temperature difference at outlet

Q = A.U. LMTD. Q may be taken as average of Q_h & (

A can be taken based on outer Ø 12

$$U = \frac{Q}{A\,(\text{LMTD})}$$

$A = \pi D L = \pi \times 0.012 \times 1.8\ m^2$

$$\text{Effectiveness} : \frac{(T_{co} - T_{ci})}{(T_{hi} - T_{ci})} \quad \text{if } m_c c_c \text{ is minimum}$$

$$\frac{(T_{hi} - T_{ho})}{(T_{hi} - T_{ci})} \quad \text{if } m_h c_h \text{ is minimum}$$

For counter flow : Similar procedure

CALCULATION OF 'U' (PARALLEL FLOW)

THEORITICAL PROCEDURE :

Overall heat transfer coefficient

$$\frac{1}{U} = \frac{1}{h_i} + \frac{r_i}{K} \log_e \frac{r_o}{r_i} + \frac{r_i}{r_o} \frac{1}{h_o}$$

- It should be based on outside surface area of inner pipe.

‘h_i = Heat transfer coefficient for inner tube between hot water and inner tube

inside surface.

$$\frac{1}{U_0} = \frac{r_o}{r_i}\,\frac{1}{h_i} + \frac{r_o}{K}\,\ln\, r_o / r_i + \frac{1}{h_o}$$

For calculation of properties of water average bulk mean temperature is taken.

$$\frac{T_{hi} + T_{ho}}{2} = {}^{\circ}C$$

The properties are read from data book for water.

$$‘m_h = Av\rho = \frac{‘\pi\,(0.0095)2}{4} \times V \times \rho$$

V can be calculated $R_e = VD/v$

The empirical relation is selected from page 119 (fully developed (n= 0.3) of data book.

Then Nu can be calculated

$$Nu = \frac{h_i\, di}{K}$$

So the value of h_i can be calculated .

Calculation of h_o

For calculating the properties of water at average bulk mean temperature s taken.

$$\frac{T_{ci} + T_{co}}{2} \quad (n = 0.4)$$

the properties are read from data book.

From the equation $m_c = Av\rho$

Calculate the velocity of water (cold) using

$$\frac{\pi (d_i^2 - d_o^2) V\rho}{4} = m_c$$

Reynolds number $Re = \frac{(d_i - d_o) \times V}{\nu}$; $Nu = \frac{h_o (d_i - d_o)}{K}$

di = inner Ø of outer tube

do = outer Ø of inner tube

using the empirical relation of Nusselt number may be found out and from which ho may be calculated.

The overall heat transfer coefficient may be calculated using the above given expression. K is taken in the expression of U as thermal conductivity of brass at the average temperature of cold and hot water temperatures.

The same procedure is repeated for the counter flow.

BOMB CALORIMETER

AIM

To determine the water equivalent of the calorimeter using the given sample of solid or liquid fuel of known calorific value (or) To determine the calorific value of the given solid or liquid fuel if the water equivalent of the calorimeter known.

APPARATUS

Bomb, water jacket, stirrer, calorimeter vessel, combined lid, sensitive thermometer, analytical balance with weight box, oxygen cylinder with pressure gauge, fuse wire, cotton thread, firing unit, regulating valve and crucible hand pellet press

PRINCIPLE OF OPERATION

A Bomb Calorimeter will measure the amount of heat generated when matter is burnt in a sealed chamber (Bomb) in an atmosphere of pure oxygen gas. A known amount of the sample of fuel is burnt in the sealed bomb, the air in the bomb being replaced by pure oxygen under pressure. The sample is ignited electrically. As the sample burns heat is produced and rises in the temperature. Since the amount of heat produced by burning the sample must be equal to the amount of heat absorbed by the calorimeter assembly, and rise in temperature enables the determination of heat of the combustion of the sample. If

W = Water equivalent of the calorimeter assembly in calories per degree centigrade. T = Rise in temperature (registered by a sensitive thermometer) in degrees centigrade.

H = Heat of combustion of material in calories per gram.

M = Mass of sample burnt in grams.

Then $W \times T = H \times M$

If the water equivalent of the calorimeter is to be determined, a substance like Benzoic acid has a stable calorific value can be burnt in the bomb. Assuming the calorific value of Benzoic acid and water equivalent can be determined.

CALORIFIC VALUE

Gross or higher calorific value: The total amount of heat produced when one unit mass of fuel has been burnt completely and the products of combustion have been cooled to room temperature.

Net or Lower Calorific Value: The net heat produced when unit mass of fuel is burnt completely and the products are permitted to escape.

$$LCV = HCV - \text{Latent heat of water vapour formed}$$

DESCRIPTION

i. BOMB

The bomb consists of three parts i.e. bomb body, lid and the cap. Bomb Body and the lid are made of corrosion resistant stainless steel containing Chromium, Nickel and Molybdenum. The bomb body is cylindrical vessel having a capacity of 300 ml . The walls are strong enough to withstand the normal operating pressure (30atm) to extreme high pressures (300 atm.). During burning at high pressure the nitrogen and sulphur contents are oxidized to nitric acid and sulphuric acid respectively. The corrosion resistant nature of the bomb material protects it from corrosive vapors. The bomb has lid, which is provided with two terminals. The metallic rods pass through the terminals one of which are provided with a ring for placing the crucible with a small hook and the other with a groove. Each rod is also provided with a ring to press the fuse wire attached to it. The upper side of the lid also provided with a small hook rod lifting and with a Schrader valve for filling oxygen in the bomb

ii. WATER JACKET

The water jacket is made of copper and is highly chromium plated on the inside and outside to minimize radiative losses. The jacket is filled with water.

iii. STIRRER UNIT

A stirrer is provided which is driven directly by an electric motor. The stirrer is immersed in the water. The water is continuously stirred during the experiment for uniform heat distribution.

iv. **COMBINED LID**

This is made of Borolite sheet and is provided with a hole for to keep the stirrer unit in fixed position and hole to insert the temperature sensor. It has also another hole to take out the connecting wires from the terminals on the bomb lid to firing unit.

v. **HAND PELLET PRESS**

It is used for pressing the powder into a pellet.

vi. **CRUCIBLE**

It is made of stainless steel. The fuel to be burnt is weighed in this crucible.

vii. **IGNITION WIRE**

It is recommended that platinum wire used but an alternative nichrome wire is also being offered.

viii. **FIRING UNIT**

It consists of the firing key, provision to give power to the stirrer motor, a switch for operating the stirrer motor, two indicating lamps. When the circuit is completed the indicating lamp glows. After the firing key is closed on, the fuse wire burns, the indicating lamp stops glowing indicating the burning of the fuse wire.

PROCEDURE

- About 0.5 to 1 *grm* of finely ground benzoic acid (Preferably compressed into a pellet) is accurately weighed and taken into crucible.
- Place the bomb lid on the stand provided and stretch pieces of fuse wire across the electrodes (metal rods) provided in the lid tie about 5 *cm* of sewing cotton round the wire.
- Place the crucible in position and arrange the loose end of the cotton thread to contact the Benzoic acid pellet in the crucible.
- About 10 *ml* of distilled water are introduced into the bomb to absorb vapors of sulphuric acid and nitric acids formed during the combustion and lid of the bomb is screwed
- Charge the bomb slowly with oxygen from the oxygen cylinder to a pressure of 25 atm. close the value and detach the bomb from the oxygen supply.

- Fill the calorimeter vessel with sufficient water to submerge the cap of the bomb to a depth of at least 2mm leaving the terminals projecting lower the bomb carefully in the calorimeter vessel and after ascertaining that it is gas tight, connect the terminals to the ignition circuit.
- Adjust the stirrer and place the temperature sensor and cover in position. Start the stirring mechanism, which must be kept in continuous operation during the experiment after stirring for 5 minutes note the temperature reading of the calorimeter. Close the circuit momentarily to fire the charge and continue the observations of the temperature at an interval of one minute till the rate of change of temperature becomes constant.
- Afterwards stop the stirrer and remove the power supply to the firing unit. Remove the bomb from the calorimeter and relax the pressure by opening the value. Verify that the combustion is complete and washout the contents of the bomb clean and dry.
- Calculate the calorific value of the fuel or water equivalent of the calorimeter.

OBSERVATIONS:

Weight of the empty crucible (W_1) = gm

Weight of the empty crucible + Benzoic acid pellet (W_2) = gm

Weight of the benzoic acid pellet $(W_2 - W_1)$ = gm

Weight of water taken in the calorimeter (W_3) = gm

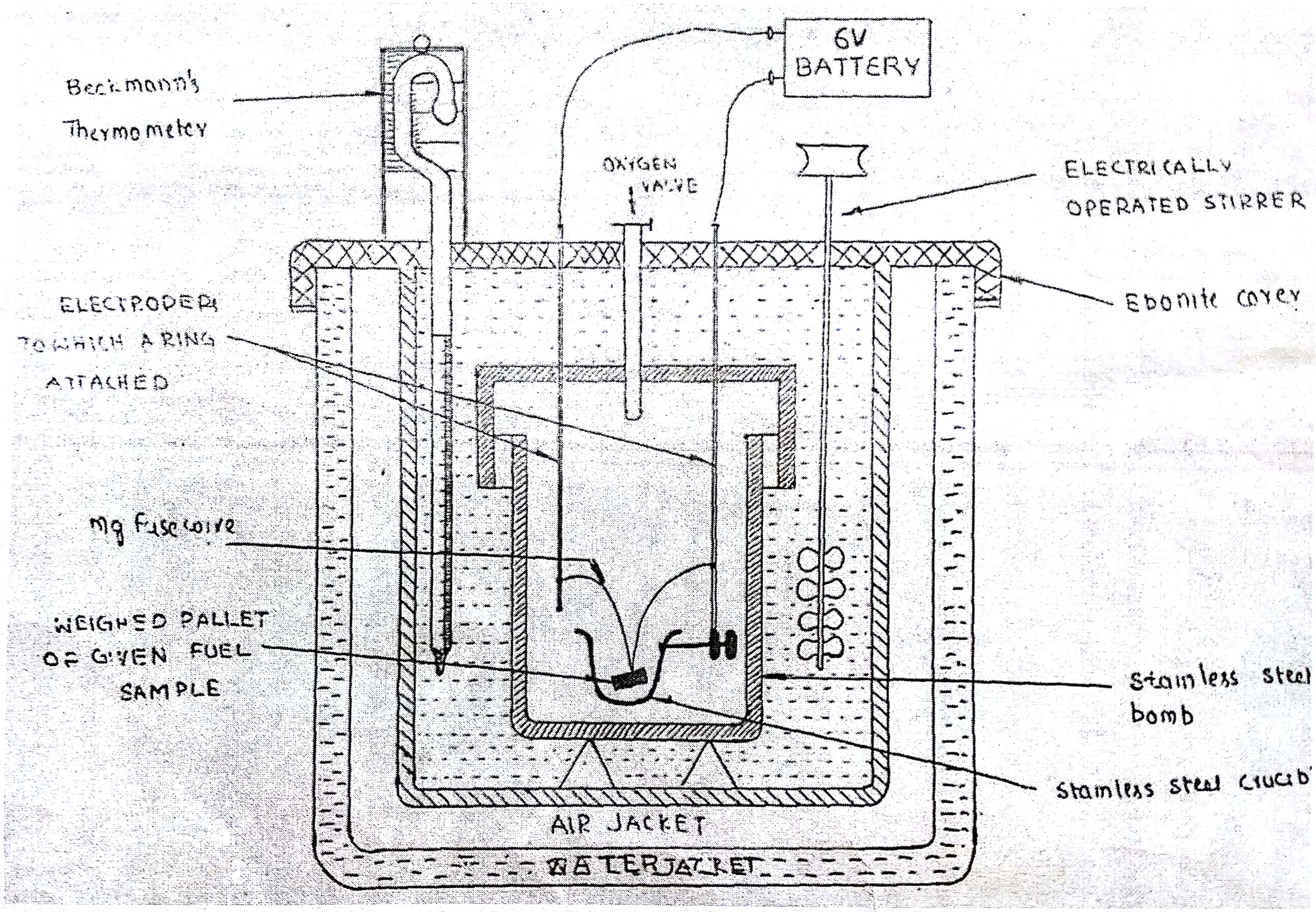
Temperature of the water just before firing (t_1) = ^{0}C

Temperature of the water after firing (t_3) = ^{0}C

CALCULATIONS

Heat produced by burning of benzoic acid + Heat produced by burning of fuse wire and cotton wire etc = Heat absorbed by calorimeter.

$$(W_2 - W_1)\times C_v = (W_3 - W_e)(t_2 - t_1)$$



BOMB CALORIMETER

PRECAUTIONS

Sample should not exceed 1 gms .

Don't charge with more oxygen than is necessary.

Don't fire the bomb if gas bubbles are leaking from the bomb when it is submerged in water.

RESULT

Water equivalent of calorimeter (W_e) = gm

Calorific value of sample (C_v) = cal/gm

JUNKER'S GAS CALORIMETER

AIM

To find the calorific value of given gaseous fuel.

APPARATUS

i) Calorimeter
  a) Main calorimeter body
  b) Three thermometers
ii) Gas flow meter
  a) Main gas flow meter body
  b) Inlet / outlet nozzles
  c) Union net with washer for thermometers
iii) Pressure governor
  a) Pressure governor body
  b) Balancing beam arrangement
  c) Counter balance tube
  d) Inlet and outlet union nuts with washers and
iv) Jars 2000 ml & 50 ml

PROCEDURE

1. Pour water into the governor till water starts overflowing through the overflow passage.
2. Replace and tighten the over flow nut.
3. Insert three thermometers provided with calorimeter into the rubber corks.
4. Insert rubber corks with thermometers into their places in calorimeter.
5. Insert burner into its support rod in the bottom of the calorimeter and turn the knurled knob so that the burner is fixed tightly. The burner must go into the center of the calorimeter body.
6. Connect the calorimeter, the flow meter and the pressure governor as shown in figure using rubber tubing provided. Do not connect gas supply line. Take care to see that the water regulator of calorimeter is in OFF position.

7. Turn water regulator knob on calorimeter to ON position. Allow water to flow through the calorimeter from overhead tank/ tap. Allow water to flow for 3 to 4 min into laboratory sink, through the calorimeter.
8. Ensure that outlet tap of governor is closed. Connect gas supply line to governor inlet. Remove burner from calorimeter then open governor outlet tap. Allow gas to pass through the burner.
9. Light up the burner by holding a lighted match stick near the mesh at the top.
10. Adjust the air regulator sleeve at the bottom of the burner to get a blue, non-luminous flame. Fix the lighted burner back into position.
11. Adjust water regulator on calorimeter to get a temperature difference of 12 $_0 C$ to 15 $_0 C$ between the inlet water & outlet water as indicated by the respective thermometers at the top of the calorimeter.
12. Allow 20 to 30 min for outlet water temperature to become steady.
13. Measure the water flow rate with the help of measuring jar. Simultaneously, note the flow meter reading.
14. Note down the inlet &outlet water temperatures.
15. Repeat the test with same volume of gas 3 or 4 times and take average temperatures of inlet and outlet water.

CALCULATIONS

The formula to be used to calculate the calorific value to the test gas is as follows

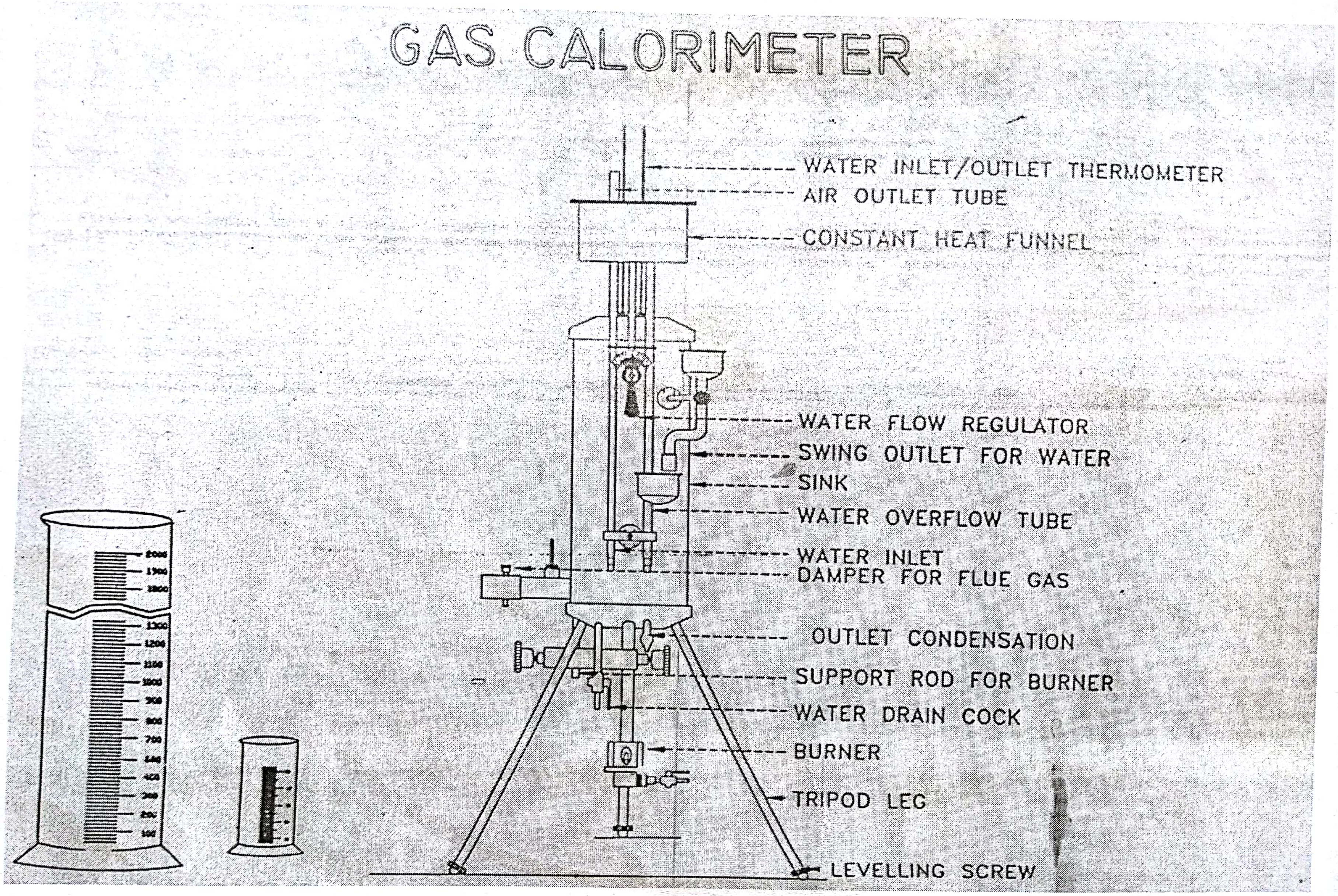
$$C.V = \left(\frac{V_w}{V_G}\right)\times(T_2 - T_1)\times 1000 \qquad Kcal/m^3$$

Where

C.V = calorific value of gas in $Kcal/m^3$

V_G = volume of gas in liters consume during test period

V_w = volume of water in liters passed during test period



JUNKER'S GAS CALORIMETER

T_2 = outlet water temperature in ^{o}C

T_1 = inlet water temperature in ^{o}C

PRECAUTIONS

1. Test reading are to be taken only after steady condition are reached
2. Formation of steam should not be allowed. If there is formation of steam, then increase the flow of water or reduce the gas flow rate
3. Water flow rate should be steady.
4. The inner float of the pressure governor should not be removed since the outlet pressure may vary when refitted.

RESULT

The calorific value gaseous fuel is ____________ $Kcal/m^3$