DEPARTMENT OF AEROSPACE ENGINEERING

ACS COLLEGE OF ENGINEERING

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ENERGY CONVERSION &HMT LAB MANUAL

(24ASL43)

(Prescribed for IV– Semester Aerospace Engineering)

ACADEMIC YEAR 2022 – 2023

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INDEX

EXPERIMENT NO. 1

ABELS'S PENSKY APPARATUS

AIM: To determine the flash and fire point of the given oil using Abel's Pensky apparatus

APPARATUS: Abel's flash and fire point apparatus, thermometers and Broom sticks and given oil

THEORY:

Flash point of the oil is the lowest temperature at which the oil gives sufficient amount of vapors resulting in flash when the flame is brought near it. Fire point of the oil is the lowest temperature at which the oil gives sufficient amount of vapors resulting continual burning of oil at least for 5 seconds when the flame is brought near to it. Abel's apparatus is used for flash points between 2.2^0 to $49^{0.}$ It consists of oil cup provided with a cover with level indicator up to, which the cup must be filled withoil.

PROCEDURE:

1. Clean the oil cup and pour a sample of oil up to the level indicated by the filling mark.
2. Before starting the room temperature is noted. The oil is heated for every 2^0rise in temperature is observed for the momentaryflash.
3. The temperature at which flash appears is the flash point and isnoted.
4. The oil is further heated till the oil catches the fire and burns continuously at least for 5sec and it is the fire point and isnoted.
5. The flame is thenputoff

OBSERVATION:

1. Type ofoil

TABULAR COLUMN:

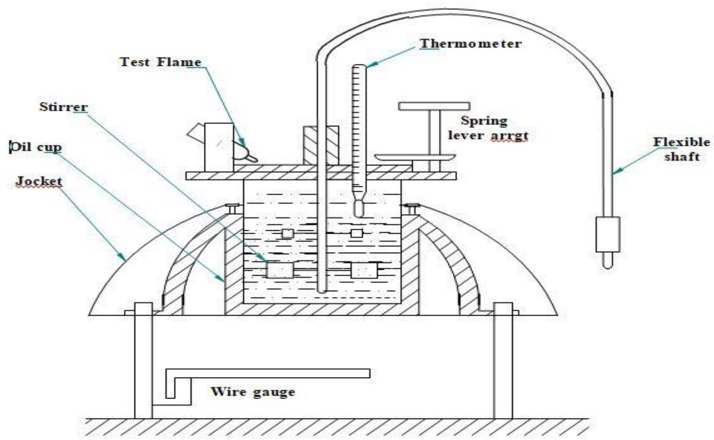
Sl. No	Heating		Cooling	
	Temperature	Observation	Temperature	Observation

RESULT:

Flash point of the givenoil is__________

Fire point of the given oilis__________

SCHEMATIC SKETCH:



TABULAR COLUMN:

Sl. No	Heating		Cooling	
	Temperature	Observation	Temperature	Observation

RESULT:

Flash point of the givenoil is__________

Fire point of the given oilis__________

EXPERIMENT NO. 2

BOYS GAS CALORIMETER

AIM:To Determine the Calorific Value of solid gaseous fuel (LPG)

APPARATUS: Experiment setup, stop watch, balancing unit.

THEORY: Experimental method is based on **heat transfer from burning known quantity of gaseous fuel** for heating known quantity of water that circulates through copper coil heat exchanger. The counter flow heat exchange takes place between the burning gas and circulating water. So, with the assumption that heat absorbed by circulating water equal to the heat released by gaseous fuel we can calculate the calorific value of burnt fuel.

The equipment consists of heat exchanger unit double walled stainless steel vessel insulted with either glass wool or ceramic wool in the annular space. Inside the inner vessel double pass copper coil and shell assemble through which the burnt fuel passes through

Based on energy balance consideration i.e., heat lost by one substance = heat gained by another substance (when the experiment stabilizes)

Heat released by the gas = heat gained by cooling water

Write the theory on following topics

- **a.** Definition of calorificvalue
- **b.** Types of calorific values and theirdefinitions
- **c.** Types of calorimeters and theirapplications

PROCEDURE:

1. Keep the gas cylinder on the weighing balance and note down the initial weight of thecylinder.
2. Connect the water supply to the inlet of the Rotameter.
3. Allow gas through the calorimeter by slowly opening the control valve of the cylinder.
4. Note the gas pressure, which passes throughcolorimeter.
5. Allow the water to circulate through thecalorimeter.
6. After getting ignition of fuel note down the mass of fuel for knowntime.
7. Note down the temperature readings after attaining steadystate.
8. Repeat the experiment for different flow rates ofwater

TABULAR COLUMN

Sl no	Volumetric flow rate of water LPM	Mass flow rate of gas kg/min	Pressure of gas Pg kg/cm^2	Inlet temperature of water T1 ^{O}C	Outlet temperature of water T2 ^{O}C	Calorific value of gas C_Vg kJ/kg	Calorific value of gas at NTP C_Vg kJ/kg

M_g= (initial wt of cylinder- final wt of cylinder)/(time taken for reduction of weight)

$C_Vg*m_g=Vw*\rho_w*Cpw(T2-T1)$

$CVg=(Vw*\rho_w*Cpw(T2-T1))/m_g$

RESULTS: Calorific value ofgiven fuel_____________kJ/kg

EXPERIMENT NO. 4

VALVE TIMING DIAGRAM

AIM: To draw the value timing diagram of the given engine
APPARATUS: Given engine, measuring tape, scale.

THEORY:

Here in this type of engines opening and closing and fuel injection do not takes place exactly at the dead center positions. The valves open slightly earlier and close after that respective dead center position. The injection (ignition) also occurs prior to the compression and piston reaches to the dead center position. All the valves operated at some degree on either side in terms of crank angles from dead center position.

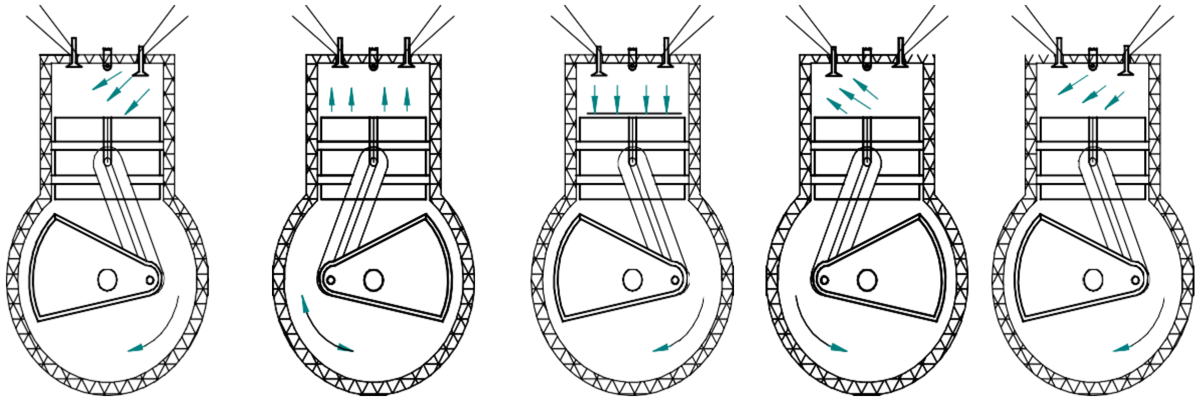
PROCEDURE:

1. Note the location of the inlet and exhaust valves of the givenengine.
2. The flywheel is turned in clockwise direction and the positions of TDC andBDC are identified with respect to the crankposition
3. The circumferential length of flywheel is measured with help of thread andruler
4. The flywheel is turned in clock wise direction and the position and inletvalve begins to open ismarker.
5. This point is measured from the initial reference mark (TDC) and this length is noted.
6. The flywheel turned in the same direction and the position of inlet valve closing and exhaust valve opening and exhaust valve closing are noted andcorresponding length with respective to the referencemarks.
7. The reading is recorded in the tabular column and corresponding angles turned (in degrees) aredetermined.

OBSERVATION:

1. Type of engine

SCHEMATIC SKETCH:



SUCTION STROKE SUCTION VALVE OPEN

COMPRESSION STROKE BOTH VALVE ARE CLOSED

IGNITION OR POWER STROKE BOTH VALVE ARE CLOSED

EXHAUST STROKES EXHAUSTVALVE OPEN

SUCTION STROKE SUCTIONVALVE OPEN

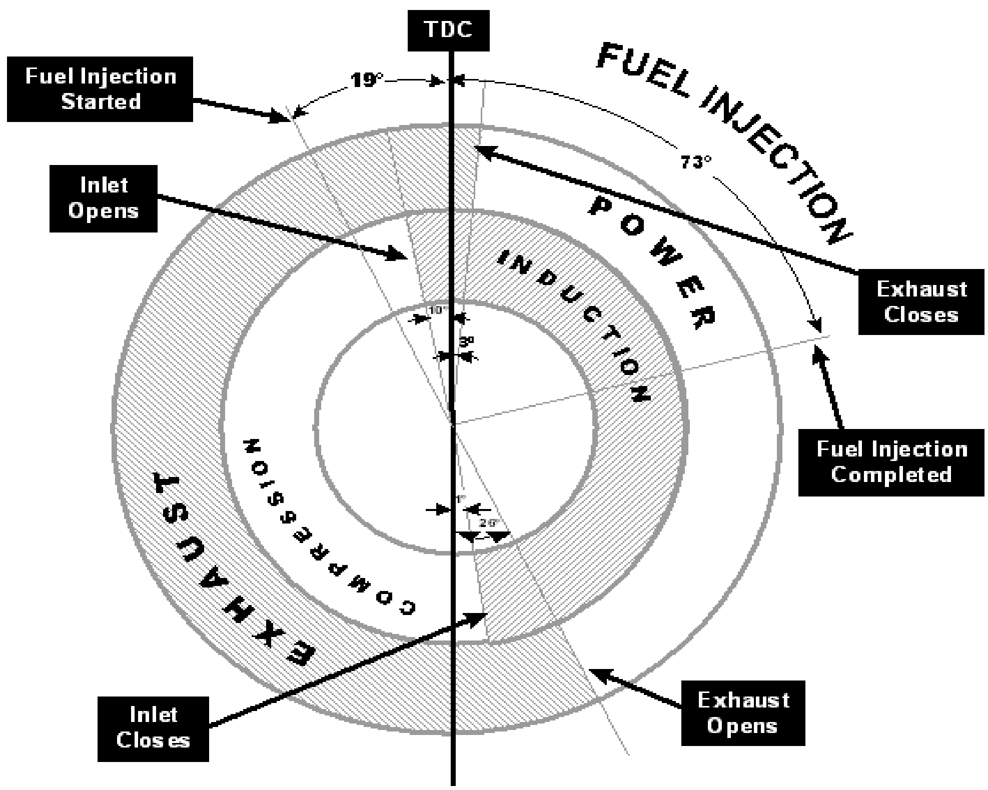


Fig. a typical Valve timing diagram

TABULAR COLUMN:

Sl. No.	Valve position	Piston position	o degree
1	IVO		
2	IVC		
3	EVO		
4	EVC		

IVO= Inlet valve open, IVC= inlet valve close

EVO= Exhaust valve open, EVC= Exhaust valve close

, Where, L = Arc length, cm

D=Flywheel diameter, m

Name of the stroke	Crank angle degree
Suction	
Compression	
Expansion	
Exhaust	

Draw the spiral diagram of the data obtained

RESULT: The opening and closing of inlet and exhaust valves are as shown in tabular column

EXPERIMENT NO. 5

PLANIMETER

AIM: To determine the area of irregular figure by using a planimeter.

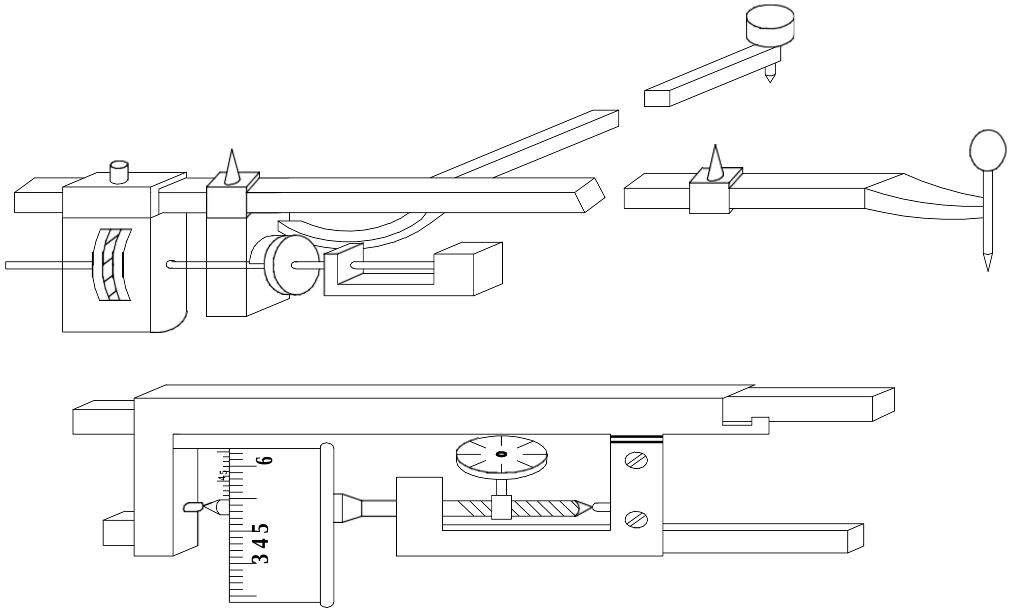
APPARATUS: Planimeter, drawing board and sheet. Drawing instruments

THEORY: They consist of a linkage with a pointer on one end, used to trace around the boundary of the shape. The other end of the linkage is fixed for a polar planimeter and restricted to a line for a linear planimeter. Tracing around the perimeter of a surface induces a movement in another part of the instrument and a reading of this is used to establish the area of the shape. The planimeter contains a measuring wheel that rolls along the drawing as the operator traces the contour. When the planimeter measuring wheel moves perpendicular to its axis, it rolls, and this movement is recorded. When the measuring wheel moves parallel to its axis, the wheel skids without rolling, so this movement is ignored. That means the planimeter measures the distance that its measuring wheel travels, projected perpendicularly to the measuring wheel's axis of rotation. The area of the shape is proportional to the number of turns through which the measuring wheel rotates when the planimeter is traced along the complete perimeter of theshape.

PROCEDURE:

1. Fix the figure whose area is to be determined on a smooth surface, preferably ona horizontal drawingboard.
2. Set the index to read 100Sq cm on the tracing arm if the area is required insquare cm.
3. Fix the anchor point inside or outside the figure such that the tracer is able totrace the whole boundary of thearea.
4. Mark a starting point on the boundary of the figure & place the tracer onthe starting point. Note the initialreading.
5. Move the tracer slowly along the boundary of the area in clock wisedirection, until it comes back to the startingpoint
6. The No. of times the zero of the dial passes the fixed index mark neither in a clockwise or anticlockwise direction during the above process should be carefully noted. Record the final reading F & compute the area by using the aboveequation.

SCHEMATIC SKETCH:



TABULAR COLUMN:

SL. NO.	Shape of the plane	A_{th} cm^2	PLANIMETER READING			A_m cm^2	% Error
			I	F	M		
1	Square						
2	Circle						
3	Triangle						
4	Rectangle						

Where

A_{th}= The theoretical area of the given shape,cm^2

I = Initialreading

F = Finalreading

M = Multiplier of planimeter, 100cm^2

A_m = Measured area of the given shapecm^2.

A_m = ()

N= No. of rotations of the disc (+ve for clockwise direction, -ve foe anticlockwise direction)

C= constant of planimeter, considered only when the anchor point is kept inside the plane

% Error= ———

RESULT:

EXPERIMENT NO. 6

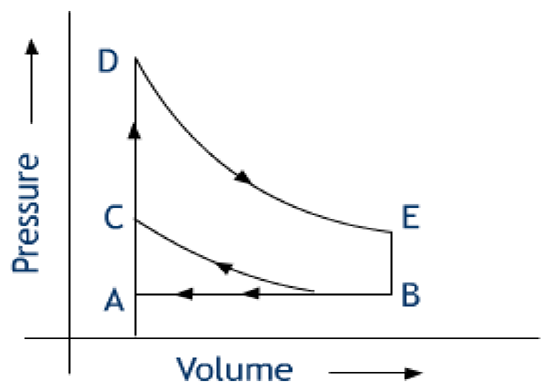
FOUR STROKE PETROL ENGINE

AIM: To determine the performance Characteristic of a 4-stroke petrol engine

APPARATUS: Four Stroke petrol engine test rig, stop watch, fuel etc.

THEORY:

The four-stroke petrol engine works on the principle of Otto (constant volume) cycle. The parts of four-stroke petrol engine are cylinder, piston, head, crankcase, connecting rod, crankshaft, spark plug, and inlet and exhaust valve. The four-stroke petrol engine may be air-cooled or water-cooled. The piston performs four strokes to complete one cycle.



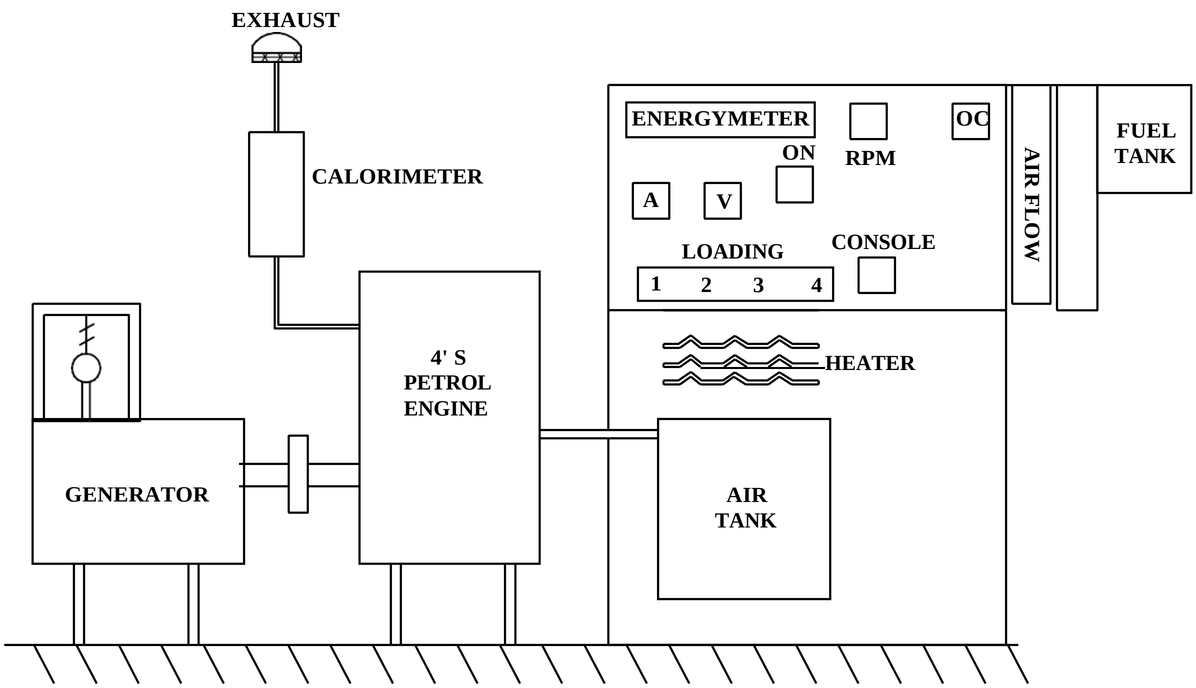
PROCEDURE:

1. Check the fuel in thetank.
2. Switch ON the power supply & console on the panel board and Ensure ignition switch inON.
3. Butkeeptheloadingswitchesinoffpositioninitially.Allowthepetrolandstart the engine by usingrope.
4. Apply the load AC generator by switching on loading switches. Allow sometime until the speedstabilizes.
5. Repeat the procedure 4 to 5 different loads at constant speed i.e., 0.5KW loadeach
6. Tabulate the corresponding readings.
7. Once the experiment is over keep the petrol control valve in closed position.And switch of the console & powersupply

OBSERVATION:

Rated speed = 3000rpm
Bore = 68.5mm
Stoke = 72 mm
Compression ration = 8.7:1
Cooling – air cooling for the cylinder
Diameter of the orifice of the air tank intake = 0.01m
C_d of orifice = 0.62

SCHEMATIC SKETCH:



OBSERVED TABULAR COLUMN:

Sl. No	E_l kW	Speed RPM	F_N	t_f Sec	Air temperature T_1	h_w m H_2O

CALCULATED TABULAR COLUMN:

V_{th} m^3/S	V_a m^3/S	η_v	m_f kg/s	m_a kg/S	A:F	BP kW	TFC Kg/hr	BSFC kg /kWh	Q_s kW	bt

Where

E_l= ElectricalLoadapplied, kW = V*I=…….

$t_{f=}$Time taken for 10cc of fuel consumption, S

h_w= Difference in monometer head, meter of water, m of H_2O

m_f = Mass of fuel kg/s

=

v_f= Volume of fuel consumed = 10cc

s = specific gravity of fuel

V_a= Actual volume of air consumed, m^3/S

√*60

C_d = Coefficient of discharge = 0.62

A_o = Area of orifice,

…… m^2

d_o = Diameter of Orifice, m

h_a = Head of the air, m

, h_w= difference in monometer reading

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

P_a= Atmospheric pressure = 101.3 kPa, R= Gas Constant for air = 0.287 kJ/kgK

Ta = Ambient temperature, K

V_{th} = Swept volume of cylinder m^3/s

V_s=

D = Diameter of cylinder in meters, L = Stroke lengthin meters

N = Number of revolutions of crank shaft per min

m_a = Mass ofairkg/s, ...kg/s

CV = Calorific value kJ/kg

BP = Brake power kW

BP = ——

T= torque applied

=F_N*R N-m, R = radius of brake drum

Qs= Heat Supplied to engine

Qs=mf*CV ……kW, CV is calorific value of fuel

BSFC = h—

TFC= total Fuel consumption in kg/ hr

= —

bt= —

A: F = —

η_{v} = 100

GRAPH:

SFC	Vs	BP
η_{bth}	Vs	BP
m_f	Vs	BP

RESULTS:

EXPERIMENT NO.

FOUR STROKE DIELSEL ENGINE

AIM: To conduct a performance test on 4 –stroke diesel engine and to draw the heat balance sheet.

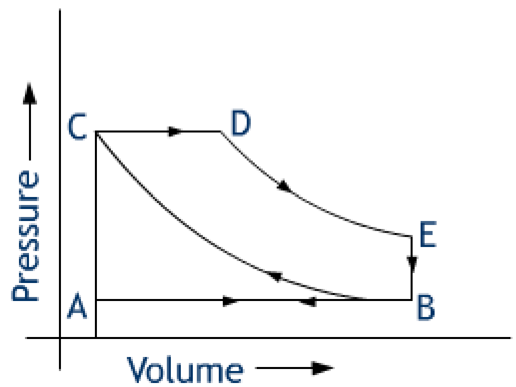
APPARATUS: Single cylinder Diesel Engine Test Rig, stop watch, fuel, beaker,etc.

THEORY:

The four-stroke diesel engine works on the principle of diesel (constant pressure) cycle. The parts of four-stroke diesel engine are cylinder, piston, head, crankcase, connecting rod, crankshaft, fuel injector, and inlet and exhaust valve. The four-stroke diesel engine may be air-cooled or water-cooled. The piston performs four strokes to complete one cycle.

The four different strokes are

a) Suctionstroke
b) Compression stroke
c) Power or Expansion stroke
d) Exhaust stroke



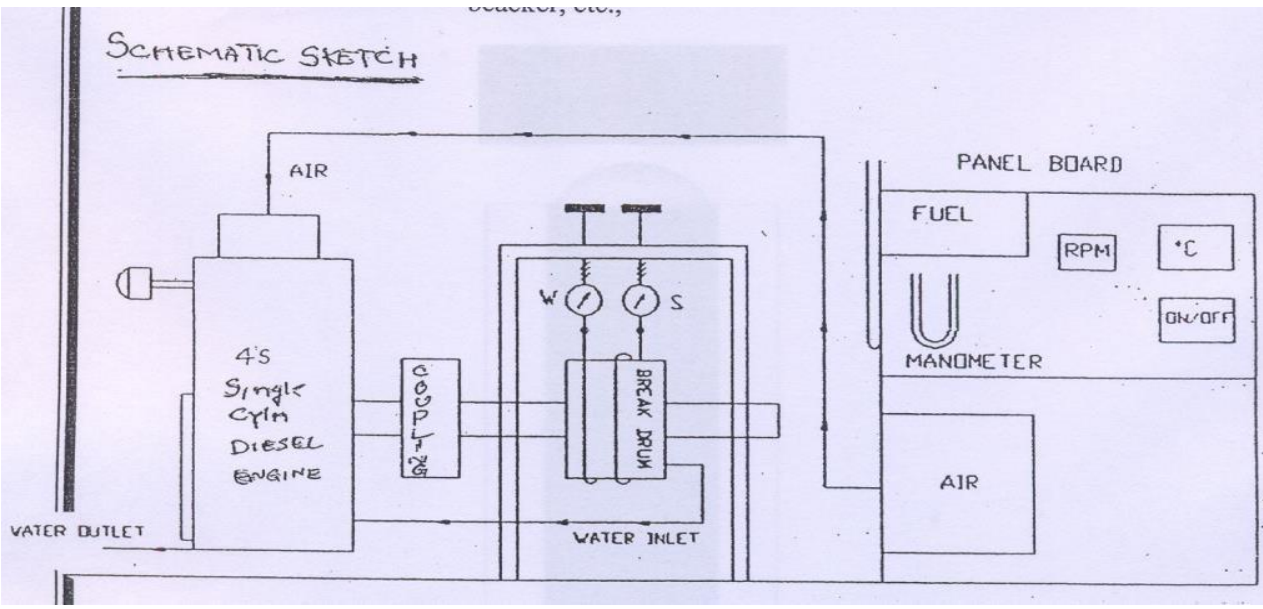
PROCEDURE:

1. Switch On the power supply to the panel board and Start the engine bycranking.
2. Maintain the speed of engine as constant and note down thespeed.
3. The engine is loaded by applying the mechanical load on the brake drum and different reading isnoted.
4. The temperature of cooling water at inlet and outlet is noted. The quantity of fuel supply is alsomeasured.
5. The load on the engine is increased gradually and different readings are noted again the experiment is conducted for different loads 2kg, 4kg, 6kg, 8kg, and 10kg.
6. Note down all the readings and calculate therequirement

OBSERVATION:

- Calorific value of diesel =42000kJ/kg
- Specific gravity of diesel =0.8275
- Compression ratio of engine =16.5:1
- Bore =80cm
- Length of the stroke, L =110mm
- Rated speed of the engine =1200rpm
- Rated power 3.7 KW at 1500RPM
- Brake drum diameter =350mm
- Rope diameter =0.015m

SCHEMATIC SKETCH:



OBSERVED TABULAR COLUMN:

Sl. No	Applied load kg	Spring balance load kg	Net load kg	F_N N	Water flow to engine	Water flow to colorimeter	Speed in RPM	t_f Sec	T_1 °C	T_2 °C	T3 °C	T4 °C	T5 °C	T6 °C

Note: water flow rate is in LPM

CALUCLATED TABULAR COLUMN:

h_w m of water	Va m^3/s	Vth m^3/s	η_v %	ma kg/s	m_f kg/s	A:F	BP kW	BSFC kg /kWh	FP kW	IP kW	th %	th %	Q_s kW	TFC Kg/hr	η_m %

Where

Net load = (Applied load-Spring balance reading)in kgs

F_N= force applied on brake drum= Net load*g

T = Torque, N-m

T = (Net load)

Re = Effective radius =

D= Diameter of the drum=0.35m

d = Diameter of rope=…………

$t_{f=}$Time taken for 10cc of fuel consumption,

h_w= Difference in monometer head, meter of water m of H_2O

T_1 =Temperature of cooling water (common for engine and colorimeter inlet)

$T_{2=}$Temperature of cooling water at outlet

T_3=Temperature of cooling water at colorimeter outlet

T_4= Exhaust gas temperature at colorimeter inlet

T_5=exhaust gas temperature at colorimeter outlet

T_6= Air temperature (atmospheric)

m_f = Mass of fuel kg/s

=

v_f = Volume of fuel consumed = 10cc

s = specific gravity of fuel

V_a= Actual volume of air consumed, m^3/S

√

C_d = Coefficient of discharge = 0.62

A_o = Area of orifice,

d_o = Diameter of Orifice= 0.018m
h_a = Head of the air, m

ρ_w= Density of water = 1000 kg
/m^3ρ_a= Density of air , kg/m^3
P a = Atmospheric pressure = 101.3 kPa, R= Gas Constant for air = 0.287

kJ/kgK
Ta = Ambient temperature, K
m_a = Mass of air kg/s

BP = Brake power kW
BP = *(1/0.85) after accounting belt transmission efficiency,

T= F_N* r (r=0175= radius of brake drum, N = Number of revolution of crank shaft per minute

BSFC = h

Qs= Heat Supplied to engine
Qs=mf*CV ……kW, CV is calorific value of fuel
TFC= total Fuel consumption in kg/ hr

=

bt=

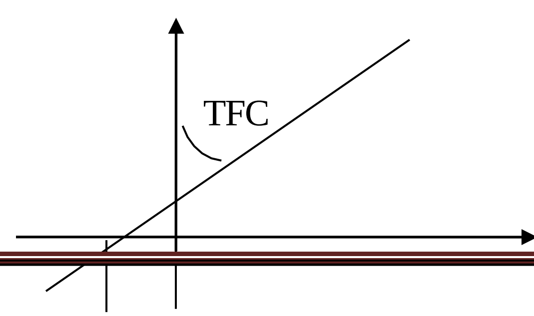
η v= 100

Vs = Swept volume of cylinder m^3/s

V_s=

D = Diameter of cylinder=0.080m
L = Stroke length=0.110m
A: F =

FP = Frictional power, kW(FromGraph)
IP = Indicated power,kW
IP = BP + FP



η_{m}= MechanicalEfficiency FP ⟷ BP

η_{m} —

Heat Balance Sheet on minute basis:

Sl. No.	Details	Heat in kJ/min	%
1	**Heat supplied Qs**		
2	Heat equivalent of BP		
3	Heat equivalent of Friction power		
4	Heat absorbed by cooling water		
5	Heat carried away by cooling waterin colorimeter		
6	Heat carried away by exhaust gasses		
7	Unaccounted heat equivalent1-(2+3+4+5)		
	Total(2+3+4+5+6+7)		

1. Heat supplied by fuel $Q_s = m_f CV$
2. Heat equivalent to Brake power = BP 60 , kJ/ min
3. Heat absorbed by cooling water, = $m_w C_{pw} (T_2 - T_1) x60$, kJ/min
   m_w=Mass of watercollected,kg/sec=V_w/t_w, kg/min
   C_{pw}= Specific heat of water=4.187kJ/kg^{0}C
4. Heat carried away by cooling water in colorimeter = $m_w\, C_p(T_3-T_1)x60$
5. Heat carried away by exhaust gas =$m_g C_{pg}(T_5-T_6)$
   m_g=Mass of exhaust gases, kg/sec = m_a+m_f
   C_{pg}=Specific heat of exhaust gases= 1.01kJ/kgK

6. Unaccounted heat equivalent=1-(2+3+4+5), kJ/min

GRAPH:

SFC Vs BP

η_{bth} Vs BP

m_f Vs BP

RESULT:

EXPERIMENT NO. 7

MORSE TEST

AIM: To determine the frictional of the given multi cylinder spark ignition engine.

APPARATUS: Enginesetup,thermometer, tachometer.

THEORY:Morse Test is applicable to multi-cylinder engines. The engine is run at desired speed and output is noted. Then one of the cylinders is cut out by short circuiting spark plug. Under this condition other cylinders "motor" this cut cylinder. The output is measured by keeping speed constant to original value. The difference in output is measure of the indicated power of cut-out cylinder. Thus for each cylinder indicated power is obtained to find out total indicated power.

PROCEDURE:

1. The engine is started and allowed to turn for sometime.
2. The engine is loaded to max. Value by using hydraulic dynamometer and throttle position is adjusted to get the desired rate speed; load and speed values arenoted.
3. Current supplied to sparkling of internal cylinder is stopped by operatinglever.
4. Load is now decreased to bring spring back to original value without altering the position.Reading of the spring balance is noteddown.
5. Now current supplied to spark plug of 2nd cylinder is stopped soon after the current supply to the spark plug of the original rated speed the load isvaried.
6. In the same manner the experiment is repeated for different out-off theengine.

SPECIFICATIONS:

Type: 4 stroke, four cylinder car engine with hydraulic loading.

Rated power= 10HP (1.36kw)

Rated speed: 1500 rpm

Distance between the centers of dynamometer to the point spring balance loading= 43.5cm

TABULAR COLUMN:

Condition of the engine	W N	N rpm	BP kW	IP kW	η_m
All cylinders firing (BP)					
Cylinder 1 is cut off (BP1)					
Cylinder 2 is cut off(BP2)					

Cylinder 3 is cut off(BP3)					

W= Load applied on the engine through dynamometer when all cylinders firing, N

W_1= Load applied on the engine when cylinder 1 cut-off,N

W_2= Load applied on the engine when cylinder 2 cut-off, N

W_3= Load applied on the engine when cylinder 3 cut-off,N

BP= Brake power of the engine when all cylinders firing, kW= WN/K

BP_1= Brake power of the engine when cylinder 1 is cut-off= W_1N/K

BP_2= Brake power of the engine when cylinder 2 is cut-off =W_2N/K

BP_3= Brake power of the engine when cylinder 3 is cut-off =W_3N/K

K= Dynamometer constant=______

R= Distance between the centers of dynamometer to the point spring balance loading,m

IP= Indicated power of the engine,kW=$IP_1+IP_2+IP_3$

IP_1= Indicated power of the cylinder 1=$BP-BP_1$

IP_2= Indicated power of the cylinder 2=$BP-BP_2$

IP_3= Indicated power of the cylinder 3=$BP-BP_3$

η_m= Mechanical efficiency

η_m= —

RESULT:

EXPERIMENTNO. 8

RED WOOD VISCOMETER

AIM: To determine the kinematic and absolute viscosities of the given oil using red wood viscometer.

APPARATUS: Red wood viscometer, stop watch, 50ml standard flask, thermometer and weighing balance

THEORY:

Viscosity of a liquid is the property by the virtue of T the liquid offers resistance to any deforming force. It is the measure of reluctance of the liquid to yield by shear, absolute and kinematic viscosity of a given oil is determined by knowing Redwoods Number and seconds. Redwood second is the number of seconds required for the flow of 50 ml oil, through a standardorifice of 1.504mm the flow being induced by gravity is called redwood seconds. Redwood number of oil is comparative number w.r.t of standard oil (rape oil) at 15.5^{O}C

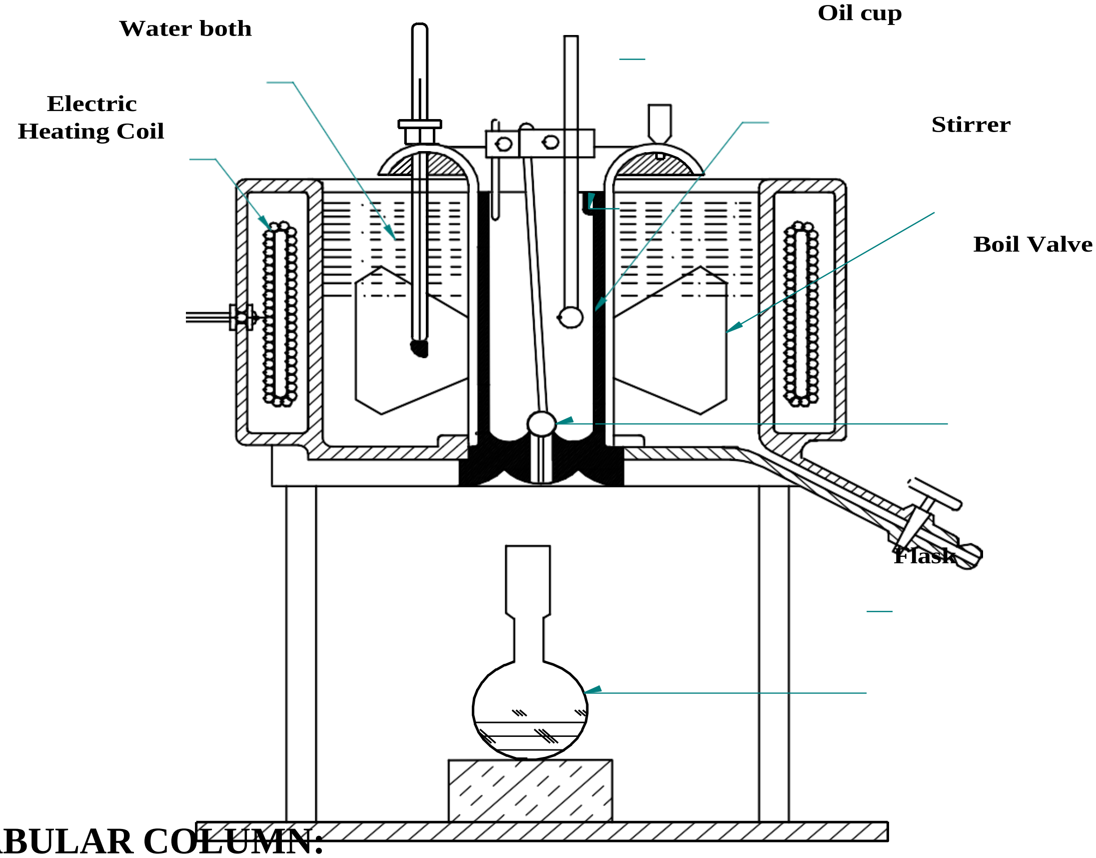
PROCEDURE:

1. The instrument is cleaned and leveled. The oil is poured into the cylinder up to the mark provided the thermometer is placedinside.
2. At the room temperature, time for flow of 50cc into the standard flask isnoted.
3. The oil is again poured into the cylinder upto the mark and the heater is switched ON
4. The temperature of oil is adjusted as required. The oil and water arecontinuously stirred during theexperiment.
5. When the temperature is steady at the desired value the contact from the orificeis removed to allow the oil to flow into 50ml standardflask.
6. The time taken for 50cc oil flow isrecorded.

OBSERVATION:

1. Type of oil

SCHEMATIC SKETCH:



TABULAR COLUMN:

Sl. No.	T ^{0}C	m_1 kg	m_2 kg	m kg	R Sec	ρ kg/m^3	S	RWN	ν m ^{2}/ S	μ N-S/m^2

Where

T= Temperature of oil, 0C

m_1= Mass of empty flask,kg

m_2 = Mass of flask with oil, kg

m = Mass of oil collected, kg = m_2-m_1

R= Time taken for collecting 50cc of oil in seconds

ρ = Density of oil, kg / m^3

S=Specific gravity of the oil,

RWN= Red Wood Number

k= constant =100 for rape oil, R1=Time taken for collecting 50cc of rape oil=535 sec at 15.5^{O}C

ν = Kinematic viscosity, m ^{2}/ S

[]

[]

μ = Absolute viscosity, N-S/m^{2}

GRAPH: 1. T v/s μ, 2. T v/s ν

RESULT: Viscosity of givenoil___________________

EXPERIMENT NO. 9

SAYBOLT VISCOMETER

AIM: To determine the viscosity of the given SAE grade sample of oil using Say bolt viscometer

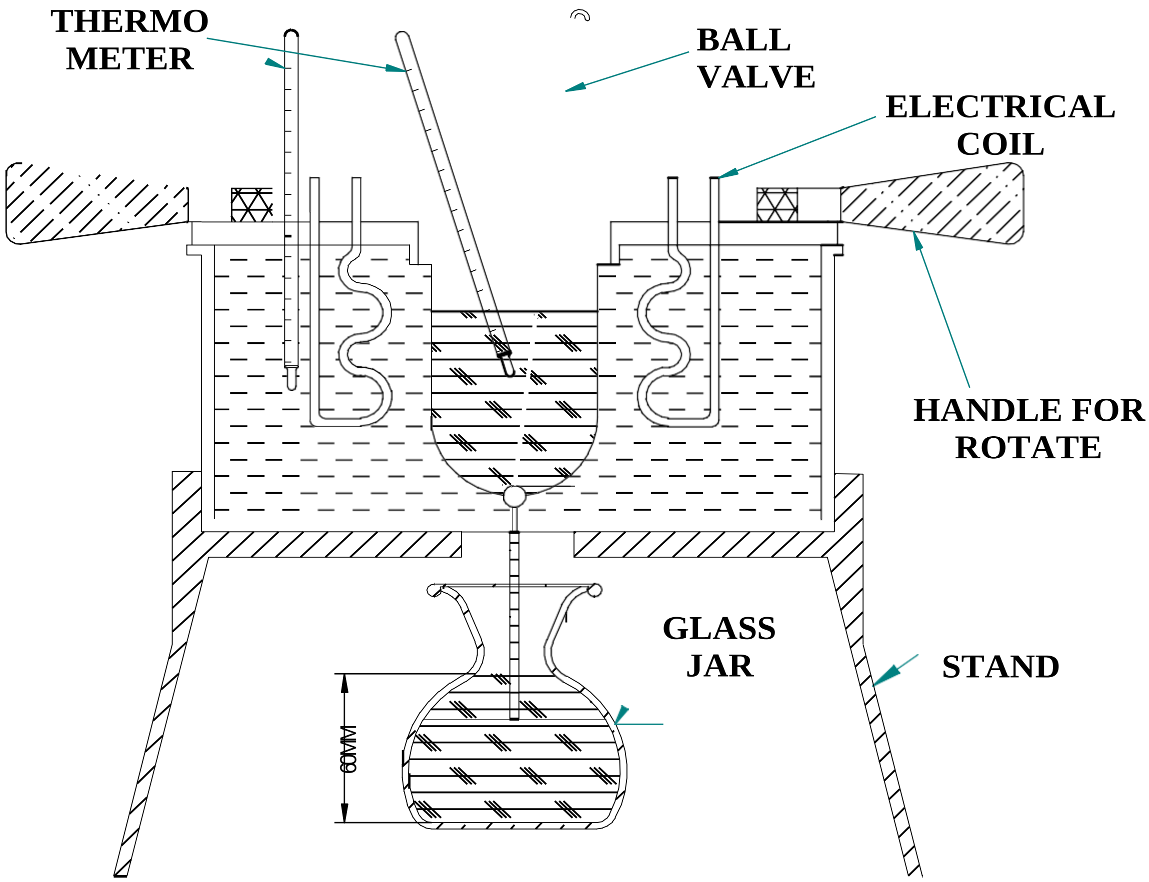
APPARATUS: Say bolt viscometer, Thermometer, Stopwatch, 60cc Flask, Balance, Measuring jar, and give SAE grade oil

THEORY:It is generally employed for viscosity determination. It consists of a cylindrical tube, the upper end of the tube is fitted with an overflow cup, while at the lower end there is a standard outlet tube of 1.675mm diameter and 12.25 mm length, below which a cork is fitted which prevents the oil flow through the outlet tube, until it is removed. The oil is surrounded by a water jacket containing a heater and a stirring devicebath.

PROCEDURE:

1. The instrument is cleaned and leveled. The oil is poured into the cylinder up to the mark provided the thermometer is placedinside.
2. At the room temperature, time for flow of 60cc into the standard flask isnoted.
3. The oil is again poured into the cylinder up to the mark and the heater isswitched ON
4. The temperature of oil is adjusted as required. The oil and water are continuously stirred during theexperiment.
5. When the temperature is steady at the desired value the contact from the orificeis removed to allow the oil to flow into 60ml standardflask.
6. The time taken for 60cc oil flow isrecorded.

SCHEMATIC SKETCH:



TABULAR COLUMN:

Sl. No.	T ^{0}C	m_1 kg	m_2 kg	m kg	S Sec	ρ kg/m^3	ν m^2/ S	μ N-S/m^2

Where

T= Temperature of oil,^{0}C

m_1 = Mass of empty flask, kg

m_2 = Mass of flask with oil, kg

m = Mass of oil collected, kg = m_2-m_1

t = Time taken for collecting 60cc of oil in seconds

ρ = Density of oil, kg / m^3

ν = Kinematic viscosity, m^2/ S

ν]

[

μ = Absolute viscosity, N-S/m^2

ν

GRAPH: 1. T v/s μ, 2. T v/s ν

RESULT:

RESULT: Viscosity of given

EXPERIMENT NO.10

HEAT TRANSFER COEFFICIENT IN NATURAL CONVECTION

AIM:

To determine the heat transfer co-efficient in natural convection for vertical tube

INTRODUCTION:

Heat transfer can be defined as the transmission of energy form one region another as a result of temperature difference between them .There are three different modes of heat transfer; namely conduction, convection and radiation

Conduction: The property which allows passage for heat energy, even though their parts are not in motion relative to one another.

Convection: is the transfer of heat within the fluid by mixing one portion of fluid with another.

Heat Radiation: The property of emit or to absorb different kind of ratio of electromagneticwaves.

Out of these type of heat transfer the convective heat transfer which of concern, divides intotwo categories viz.,

Natural Convection: If the motion of fluid caused only due to difference in density resulting from temperature gradients without the use of pump or fan, then the mechanism of heat transfer is known as "natural or free convection".

Forced convection: If the motion of fluid is induced by some external means such as a pumpor blower.

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

Q=h A ∆ T, where **Q**=heat transfer rate in watts

A=surface area of heat flow in m^2

ΔT=over all temperature difference between the wall and fluid

h= convection heat transfer co-efficient in watts

This setup has been designed to study heat transfer by natural or free convection

Apparatus:

1. A metallic tube of diameter (d) 45 mm and length (L) 450mm with a electrical heater coil along the axis of the tube.

2. Seven thermocouple are fixed on the tube surface.

3.Control panel instrumentation consists of multichannel digital display

a)Temperature indicator to measure surface temperature T1 to T7 of the tube and ambient temperature T8.

b) Digital ammeter and voltmeter to measure power input to the heater.

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

5. Front transparent acrylic enclosure for safety of the tube when not in use.

OPERATIONAL PROCEDURE:

1. Keep the tube in vertical position.
2. Switch ON the mains and the control.
3. Set the regulator to set the heat input.
4. Wait for sufficient time to allow temperature to reach steady values.
5. Note down temperatures T1 to T8 using channel selector and digital temperature indicator.
6. Note down the Ammeter and Voltmeter readings.
7. Tabulate the heat input and transfer co-efficient using the procedure.
8. Calculate the convection heat transfer co-efficient using the procedure given below.
9. Repeat the experiment by changing the heat input.

Sl.NO	Heat Input			Temperature along the tube							Average tube Temperature	Ambient Temperature	Convective heat transfer coefficient	
	V	I	Q	T1	T2	T3	T4	T5	T6	T7	T_{av}	T8	h_{th}	h_{ex}

Calculations:

Determination of experimental heat transfer co-efficient: For steady state condition, heatgiven to heater = Heat lost from the tube surface by natural convection.

Therefore, **Q= h As (Ts-T∞)**

Where,

Q = (Ammeter reading) x (Voltmeter reading), in watts

D D= Diameter of tube= 45 mm

L= length of the tube = 450 mm

As=Tube surface area = π D L = m^2

Ts= (T1+T2+T3+T4+T5+T6+T7)/7 = °C

T∞= T_8 = Ambient air temperature=T8= °C

Therefore,

Heat transfer co-efficient, h_{expt}= Q/As (Ts-T∞) = W/m^2K

Determination of Theoretical heat transfer co-efficient:

The theoretical value of the natural heat transfer co-efficient is calculated given by: Note down the properties of air t from data hand book

$Tm = (Ts + T\infty)/2 =$ °C

At mean temperature properties of air should be noted down from the HMT data hand book. $\nu =$ m^2/s

k= W/mK

Pr=

$\beta = 1/(Tm + 273) =$ K^{-1}

$\Delta T = (Ts - T\infty) =$ °C

g= 9.81 m/s^2

Gr (Groshoff No.) = $(g\ \beta\ L^3 \Delta T)/\nu^2 =$

Nu = choose the equation from data book based on Gr.Pr

$Nu = \quad hL/k,$

$h_{th} = \qquad W/m^2K$

RESULTS

h_{exp}= W/m^2K

h_{th} = W/m^2K

EXPERIMENT:12

AIM :To determine the heat transfer co-efficient in forced convection for hot air flowing throughhorizontal tube

INTRODUCTION:

It is well know that a hot plate of metal will cool faster in from a fan than when exposed to still air. We say that the heat is convected away and we call the process as convective heat transfer. The velocity at which 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$Q=h\ A\ \Delta T$

Where, Q=heat transfer rate, watt

A=surface area of heat flow, m^2

ΔT=overall temperature difference between the wall and fluid in ^0C h= convective heat transfer coefficient ($W/m^{2\,0}C$).

The convective heat transfer coefficient 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 all external source of motion, movement of air would be experienced as a result of the density gradient heat near 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 coefficient are given in table below

Mode	h‟ $W/m^{2\,0}C$
Free convection	5-25
Forced convection: air , water	10-500, 100-15000

Boiling water	2500-25000
Condensation and water vapor	5000-100000

This setup has been designed to study forced convection heat transfer.

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. Heater, wattage :500 watts (approx.)
c. Regulator to control the power input to the heater
d. Volt and Ampere Meters to measure power input to the heater
e. ThermocouplesT1 and T7 to measure air temperature at the inlet and outlet of the duct. T2 - T6 to measure test specimen temperatures.
f. Channel selector
g. Digital temperature indicator
h. Blower: to blow air through the heat exchanger.
i. Orifice meter with manometer to air flow rate from the blower.
j. Control panel to house the whole instrumentation.

OPERATIONAL PROCEDURE:

1. Switch on the mains and the console
2. Start the blower first
3. Control blower flow rate toss suitable value
4. Measure the pressure drop across the orifice meter and calculated air mass flow rate.
5. Switch on the heater and adjust the power input to the heater to a suitable value using the regulator.

WORKING PRINCIPLE:

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

Where,
Q=heat transfer rate, W

Q_a = Volume flow rate of air m^3/s

P=power input to the heater

A_1=cross sectional area of the main pipe, $(\pi D^2)/4$ m^2

A_2=cross sectional area of orifice $(\pi d^2)/4$

L= length of the tube 0.5 m

D = diameter of the tube 40

mmd = orifice diameter 20

mm

ΔT=average temperature between the tube and

the air ^{0}Ch=convective heat transfer coefficient

(W/m^2K)

C_d=

Volume flow rate of air, $Q_a = (C_d\ A_1\ A_2\sqrt{2g\ h_a})/(A_1^2 - A_2^2)^{1/2}$ m^3/s

TABLE OF MEASUREMENTS:

Sl.No.	Heat Input			Manometer readings		Head of water hw	Temperatures of tube, °C					Air Temperature		Water Temperature		Convective heat transfer coefficient	
	V	I	Q	h1	h2	h1~h2	T_2	T_3	T_4	T_5	T_6	Inlet T1	Outlet T2	Inlet T1	Outlet T2	h_{th}	h_{ex}

Calculations:

Determination of experimental heat transfer co-efficient

calculations $T_s = [T_2+T_3+T_4+T_5+T_6]/5 =$ °C

$T_\infty = [T_1+T_7] / 2 =$ °C

$\Delta T = (T_s - T_\infty) =$

$\circ$

$CQ= h\ A\ (T_s - T_\infty)$

$h_{exp}= Q/(\ A\ (T_s - T_\infty)) =$ W/m^2K

Determination of Theoretical **heat transfer co-efficient** calculations

$T_m = (T_s + T_\infty)/2 =$ °C

Following properties of air from heat transfer data hand book at mean temperature are noteddown

Kinematic viscosity of air, $\nu =$ m^2/s

Thermal conductivity of air, k W/m

kPr =

Calculation of velocity of air (V):

$A_1 = \Pi/4*D^2=$ m^2, $A_2 = \Pi/4*d^2=$ m^2

$\rho_a = P/RT =$ kg/m^3

$\rho_w h_w = \rho_a h_a,\quad h_a =$ m

Q_a=[C_d A_1 A_2 √2gh_a]/(A_1^2 – A_2^2) $^{1/2}$ =

m^3/s V = Q_a/ A_1 = m/s

Re = (VD)/ν =

If Reynolds No. value is more than 2300, flow is Turbulent otherwise flow is Laminar. Usually for forced convection heat transfer experiment the value of Reynolds No. is more than 2300, hence flow is turbulent.

Choose the equation from data book based on

Reynods number.hD/k = Nu,

h_{th} = (Nu x k)/D = W/m^{2}K

EXPERIMENT NO.13
EFFECTIVENSS OF PIN-FIN

AIM:

Determine the rate of heat transfer, effectiveness and efficiency of the pin-fin

INTRODUCTION:

Fins are widely used to enhance the heat transfer (usually convective, but it could also be radiative) from a surface. This is particularly true when the surface is in contact with a gas. Fins are used on air cooled engines, electronic cooling forms, as well as for a number of other applications. Since the heat transfer coefficient tends to be low in gas convection, area is added in the form of fins to the surface to decrease the convective thermal resistance.

APPARATUS:

A metallic fin of circular cross section of length 'L' is fitted in the rectangular duct. The base of the fin is fixed to a heater plate for heating the fin. Thermocouples are provided on the surface of the fin. The duct is provided with a fan to contact the air flow with the help of regulator.

A multi-channel temperature indicator has been provided to monitor different temperature points. Measure the velocity of air flow over fin. Power input to the heater is given by regulating the ammeter and voltmeter.

OPERATIONAL PROCEDURE:

1) Switch on the mains and console

2) Switch on the heater and adjust the power input.

3) Wait till steady state is reached and note down all the temperature indication by the temperature indicator.

4) After conducting experiment in natural convection mode, start the blower and adjust the flow as required for forced convection.

5) Increase the power supplied to the heater as to maintain the same temperature before starting the blower.

6) Wait till steady state condition is reached and note down the temperature as well as velocity of flow.

7) Repeat the procedure for different heat inputs.

Tabular Column:

Sl.No	Heat Input			Test specimen temperature					Chamber temperature	Velocity of air, V in (m/s)
	V	I	Q	T1 (ºC)	T2 (ºC)	T3 (ºC)	T4 (ºC)	T5 (ºC)	T6	

Calculations:

1) Surface Temperature, Ts= (T1+T2+T3+T4+T5)/5
2) Atmospheric temperature, T∞ = T6=

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3) $T_{mean} = (T\infty + Ts)/2$

   At mean temperature note down the values of thermo physical properties of air from heat transfer data hand book thermo physical properties of air are (ν) kinematic viscosity, (K_{air}) thermal conductivity of air and Prandtl No.

4) Reynolds no(Red) =(v∗d)/(γ) ,where „v" is velocity of air flowing over the fin

   Based on the Reynolds no choose the value of constants C and m from the heat transfer data hand book

5) $h = K_{air}\,[C.\ Red^{m}\,(Pr)^{0.33}]/d$

6) $Q = \sqrt{(hPKA)}\ (Ts - T\infty)\ \tanh(mL)$

7) Efficiency, $\eta = \tanh(mL)/(mL)$

8) Effectiveness, $\varepsilon = \tanh(mL)/[\sqrt{(hA/PK)}]$

where, Ts=Surface temperature of fin

T∞=surrounding temperature (^{0}C)

L=length of fin =   m

d=diameter of the fin = m

$m = \sqrt{\left(\frac{hP}{KA}\right)}$, P=perimeter of fin=πd m

$A = \pi d^2/4\ m^2$

K=thermal conductivity of Al

= W/m°C

Result:

The rate of heat transfer of PIN-FIN apparatus is W.

Efficiency of the fin (η) is %.

Effectiveness of the fin (ε) is

EXPERIMENT 13
CRITICAL HEAT FLUX

AIM:

To study boiling heat transfer phenomenon across the given wire and determine critical heatflux.

INTRODUCTION:

When heat is added to a liquid from a submerged solid surface which is at temperature higher than the saturation temperature of the liquid, it is for a part of the liquid to change phase. This change of phase is called boiling. Boiling is of various types, the types depending on the temperature difference between the surface and liquid. The different types are indicated by fig(1) in which typical experimental boiling curve obtaining in a saturated pool of liquid is drawn.

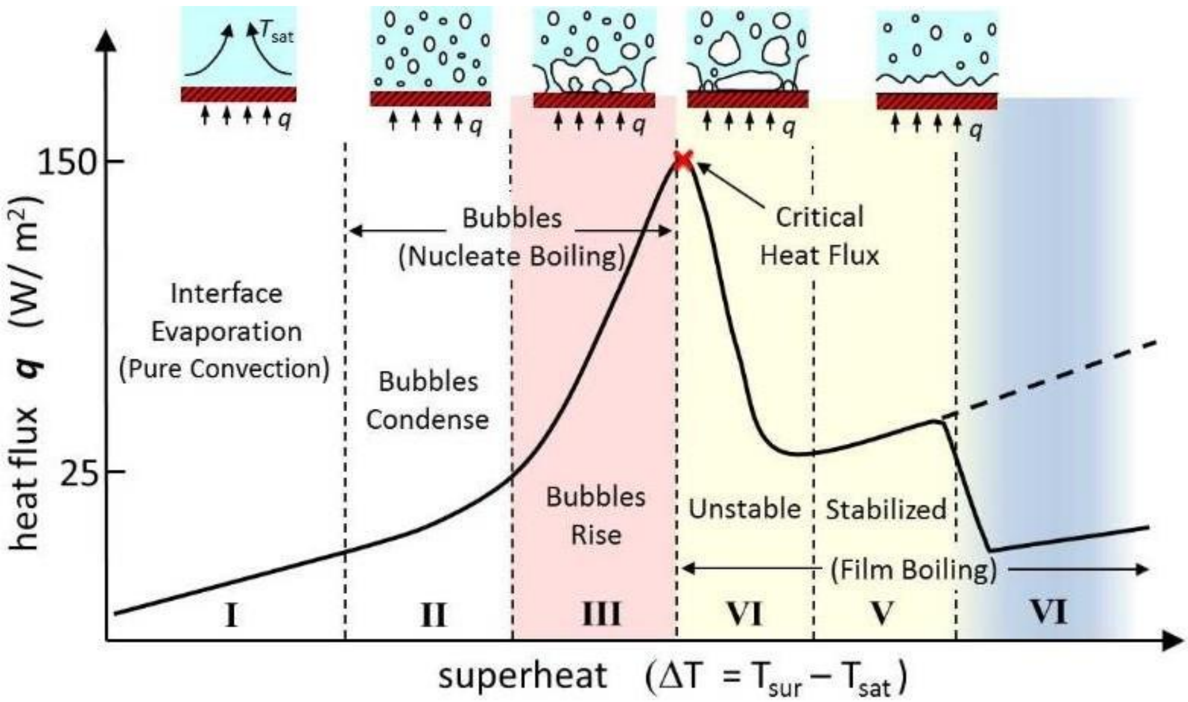

Fig1: Boiling curve

The heat supplied to the surface is plotted against (Tw-Ts), the difference between the temperature of the surface and the saturation temperature of the liquid. It is seen that boiling curve can be divided into three regions; 1. Natural convection region, 2. Nuclear boiling region,3) Film boiling region. The region of natural convection occurs at low temperature

differences. Heat transferred from the heat surface to the liquid in the vicinity causes the liquid to super heated. This super heated liquid rises to the free liquid surfaces by natural convection, where is produced by the evaporation.

As the temperature difference (Tw-Ts) is increased, nucleate boiling starts. In this region, it is observed that, bubbles start to from at certain location on the heated surface. Region 2 consists of a two parts. In the first part 2a, the bubbles are formed are very few in number of locations where they are formed increase. Some of the bubbles now rise all theway to the free surface.

With increasing temperature difference, a stage is finally reached when rate of formation of bubbles is so high, that they start to collapse, and blanked the surface with a vapour film. This is the beginning of the region 3, viz., film boiling, in the first part of this region, 3a the vapour film is unstable. So that film boiling may be occurred a portion of the heated surface area, nucleate boiling may be occurring on the remaining area. In the second part 3b, a stable film covers the entire surface. The temperature difference in this region is of the order of 1000^0C and consequently radiative heat transfer the across the vapor film is also significant.

It is observed from fig(1) that the heat flux do not increase in the regular manner with the temperature difference. In region 1, the heat flux is proportional to (Tw-Ts) where in is slightly greater than unity. When transition from natural convection to nucleate boiling occurs, the heat flux start increase more rapidly with temperature difference, the value of an increasing to about 3.at the end of the region 2,the boiling curve reached a peak(point a). Beyond this, in region 3a inspite of increasing the temperature difference, the heat flux decreases because of thermal resistance to heat flow increases with the formation of vapour film. The heat flux passes through a minimum (point b) at

differences. Heat transferred from the heat surface to the liquid in the vicinity causes the liquid to super heated. This super heated liquid rises to the free liquid surfaces by natural convection, where is produced by the evaporation.

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order of 1000^0C and consequently radiative heat transfer the across the vapor film is also significant.

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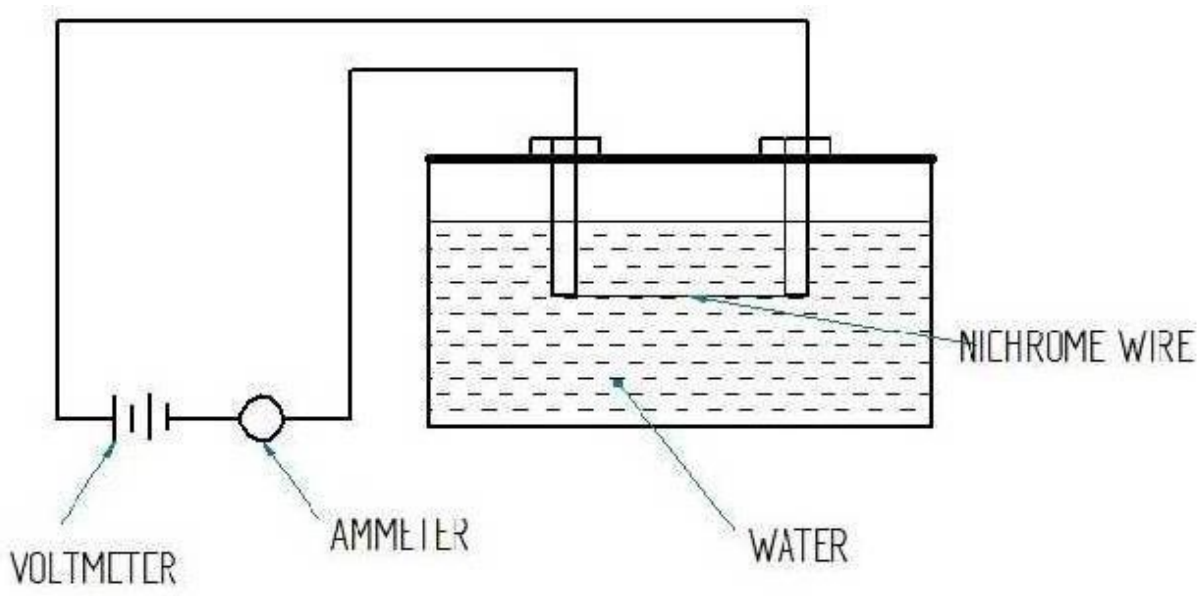
APPARATUS:

The apparatus consists of a container housing the test heater and heater coil for initial heating of the water. This heater coil is directly connected to the mains and the test heater is connected also to the main through dimmer stat and an ammeter is connected in series while avoltmeter across it to read the current and voltage. A micro controlled based peak detector has been provided to measure the maximum current during the process. The heater wire can be viewed through a poly carbonate glass window.



Specification:

- Heater for initial heating – heater coil -1.5 kW
- Test heater (R-1) nichrome wire = mm (to be measured according to wire used
- Length of wire = mm,

EXPERIMENT:

The experimental set up is designed to study the pool boiling phenomenon up to critical heat flux point. The pool boiling over the heater wire can be visualized in the different regions up to the critical heat flux point at which the wire melts. The heat flux from the wire is slowly increased by gradually increasing the applied convection to the nucleate boiling can be seen. The formation of bubbles and their growth in size and number cam be visualized followed by vigorous bubble formation and their immediate carrying over to surface.

PROCEDURE:

1. Take the sufficient quantity of distilled water in the container.
2. See that both heaters are completely submerged.
3. Connect the test wire across the studs.
4. Switch on the auxiliary heater and maintain the bulk temperature of the water in the container
5. Switch on test heater W2.
6. Very gradually increases the voltage across it by slowly changing the variac from one position to the other and stop a while at each position to observe the boiling phenomenon on wire.
7. Record the voltage and current at various intermediate stages. This can be used to find the resistance of wire, at varying temperature. Note down the resistance at room temperature can be calculated.

8. Go to increasing the voltage till wire breaks and carefully note the voltage and current at this point.
9. Repeat this experiment by altering the bulk temperature of water.

Observations:

- Diameter of test heater wire, d = mm
- Length of the test heater wire, L = mm

Note: The ammeter and voltmeter readings are to be noted down for each bulk temperature.

Tabular Column:

Voltage, V	Current, I	Heat Input Q = VxI	$q = Q/\pi dL$ (W/m^2)	Critical Heat Flux, q_c (W/m^2)

1. Keep the variac to zero voltage position before starting the experiment take sufficient amount of distilled water in the container so that both the heaters are immersed completely.
2. Connect the test heater wire across the studs.
   1. Do not touch the water or terminal points after putting the switch is in ON position.
   2. Very gradually operate the variac in steps and allow sufficient time between.
   3. After attaining the critical heat flux condition, decrease slowly the voltage and bring it to zero.

Observations:

- Diameter of test heater wire, d = mm
- Length of the test heater wire, L = mm

Note: The ammeter and voltmeter readings are to be noted down for each bulk temperature.

Tabular Column:

Voltage, V	Current, I	Heat Input $Q = VxI$	$q = Q/\pi dL$ (W/m^2)	Critical Heat Flux, q_c (W/m^2)

STEFAN BOLTZMAN CONSTANT

To determine the Stefan boltzman‟s constant.

INTRODUCTION:

The most commonly used relationship in the radiation heat transfer is the Stefan boltzman‟s law, which relates the heat transfer rate to the temperature of the hot and cold surfaces,

$Q = \sigma A (T_h^4 - T_c^4)$

Q=rate of the heat transfer , watts

σ=Stefan boltzman‟s constant=5.669×10^{-8}

watts/m^2K^4 A=surface area , m^2.

The above equation is only applicable for black bodies (for ex, a piece of metal covered with carbon black approximates this behaviour) and is valid only for thermal radiation. Other types of bodies (like a glossy painted surface or a polished metal plate) do not radiate as much as energy as the black body but still the radiation emitted follows T^4 proportionality.

This setup has been designed to determine the values of the Stefan boltzman‟s constant.

APPARATUS:

The setup consists of the following important parts,

a. Copper hemispherical enclosure.
b. Non-conducting base plate made of asbestos.
c. Thermocouples, iron – constantan type to measures temperature on the copperhemisphere T_1 and T_2 on the disc and T3 on specimen and T4 of hot water
d. Disc mounted in insulated bakelite sleeve, made of aluminium.Disc dia(D): mm, mass (m) = grams, Specific heat = kJ/kgK.

WORKING PRINCIPLE:

The enclosure is maintained at the higher temperature using heater. The disk or the test piece is inserted in to its place along with variation in its temperature (T3) with time is recorded.

The radiation energy falling on the disc (D) from the enclosure

is given by $Q_e = \sigma A_D T_e^4$……… (1)

Where,

Q_e= rate of radiation emitted on the enclosure falling on the

disc(watts) A_D=area of the disc,m^2

T_e^4 =average temperature of the enclosure recorded by thermocouples (K)

The emissivity of the enclosure and the disc are assumed unity because of black surface characteristics. The radiation energy emitted by the disc to the enclosure is given by,

$$mCp(dT/dt)_{t=0} = \sigma A_D(T_s^4 - T_D^4) \quad \text{......... (2)}$$

Where, (dT/dt),is the rate of increase in temperature (^{0}C/sec) at the instant when the discis inserted in to the setup. The stefan boltzman constant is obtained using the relationship,

$$\sigma = \frac{mCp(dT/dt)_{t=0}}{A_D(T_s^4 - T_D^4)} \quad \text{.............................. (3)}$$

OPERATIONAL PROCEDURE:

a. Switch on the mains and the console.
b. Remove the disc (D) or test piece.
c. Switch – on the heater.
d. Allow the water to reach some prescribed temperature.

a. Allow the heated water enters into the hemispherical enclosure to attain uniform high temperature –the enclosure will soon reach thermal equilibrium.
b. Measure the enclosure temperature with the thermocouple (T_1 and T_2) using channel selector and digital temperature indicator.
c. Insert disk (D) with sleeve into its position and record temperature of the disc (T_3) at different instant of time using stop watch.
d. Plot the variation of disc temperature (T_3) with time sec as shown in fig(2) and get the slope of temperature versus time variation (^{0}C/sec) at the time t=0 sec.

e. Using eq(3) calculate the Stefan boltzman‟s constants.

f. Repeat the experiments 3 to 4 and calculate the average value to obtain the better value of the Stefan boltzman‟s constant

Tabular Column:

Sl.No.	Time „t‟ (s)	Specimen Temperature „T_3‟ (°C)

Calculations:

1. Temperature of the enclosure = T_{sphere} ^{0}C
2. Mass of the test disc (m)= gm
3. Specific heat of the disc material Cp= J/kg ^{0}C
4. Obtain (dT_3/dt) using the plot of the T_3 vs t and determine the slope.

5. Calculate Stefan boltzman‟s constant using the relationship.

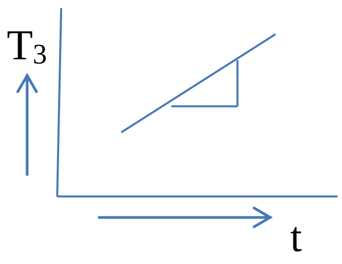


Fig 2: Plot of temperature T_3 v/s t

$$\sigma = \frac{mCp(dT_2/dt)}{A_D(T_s^4 - T_{d\,t=0}^4)} \quad W/m^2K^4$$

Sample calculations:

$A_D = (\pi/4)*D^2 =$ m^2

$dT_2 / dt =$ $^0C/s$ by plotting graph and taking slope.

T_s = Average temperature of hemispherical cup T1+T2/2 =

K$T_{3\ t=0} =$ K

Result: stefan boltzman constant $\sigma =$ W/m^2K^4

- **WORKING FOR PRACTICE**

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