Department of Mechanical Engineering

Indian Institute of Technology New Delhi

II Semester -- 2018 – 2019

MCL 241 Energy systems and Technologies

Reciprocating I.C. Engines Laboratory

List of Experiments:

1. TESTING OF FUELS : FLASH AND FIRE POINT
2. TESIGNG OF FUELS: VISCOSITY OF LIQUID FUELS
3. Study of SSSF Combustion Systems : Case Study of a single cylinder four stroke diesel engine.
4. Performance test and Morse test on a four-stroke four-cylinder petrol engine at constant speed.

5. Study of Engine parts, engine models and valve timing.

Experiment 1: TESTING OF FUELS : FLASH AND FIRE POINT

1. Introduction

The flash and fire points of a liquid fuel specimen are the indicators of its flammability. In general, **flash point** is the lowest temperature of the test specimen, corrected to a barometric pressure of 101.3 kPa, at which the application of an ignition source causes the vapor of the test specimen to ignite momentarily and the flame to propagate across the surface of the liquid under the specified conditions of test. It is important to realize that the value of the flash point is not a physical constant but is the result of a flash point test and is **dependent** on the apparatus and procedure used. **Fire point** may be considered as the lowest temperature of the liquid at which vapor combustion and burning commences. A fire point happens when an ignition source is applied and the heat produced is self-sustaining, as it supplies enough vapors to combine with air and burn even after the removal of the ignition source.

2. Flash and fire point in engine perspective

Gasoline has a flash point around -43^0 C whereas diesel has flash points higher than 52^0 C. Lower flash points are the indicators of good flammability and volatility. Therefore, gasoline makes faster vapour formation than diesel and instantly catches fire when spark, an external flame source, is provided. However, as its autoignition temperature is high (in low compression ratio gasoline engine perspective), which is in the order of 247-280^0 C, it does not ignite prematurely due to the residual heat generated during compression stroke and heat transfer from wall. On the contrary, the

higher flash point of diesel indicates poor vaporization tendencies and lesser tendency to ignite subjected to external flame source. However, as the autoignition temperature of diesel is low (in high compression ratio diesel engine perspective), which is in the order of 210^0 C, diesel autoignites easily with the residual heating during compression stroke and heat transfer from wall without the need of an external flame source such as spark plug. Poor vaporization tendency of diesel is dealt with in-cylinder swirl and high pressure injection.

Vegetable oils have significantly high flash points which are in the order of diesel fuels and higher. Hence their vaporization and mixing are a huge challenge for direct engine applications. Therefore, vegetable oils are transesterified to produce fatty acid methyl esters or biodiesel which has comparable flash point for direct compression ignited diesel engine application. In the alcohol category, methanol has a flash point of around 12^0 C and autoignition temperature of 470^0 C. Similarly, ethanol has 16^0 C flash point and autoignition temperature around 365^0 C indicating their close proximity to gasoline fuel and potential alternative fuel application in spark ignited engines.

3. Penskey Martens Flash Point Apparatus Laboratory test

3.1 Objective: To determine the flash and fire point of a given sample using Pensky-Martens flash point apparatus and determination of experimental repeatability.

3.2 Apparatus and consumables required:

a) A Pensky-Martens flash point apparatus.
b) Thermometer of suitable range.
c) Test samples.

3.3 Methodology and procedure

3.3.1 Preparation of samples
a) Samples should be in reasonably fluid state before testing. For asphalts and other viscous materials, preheating should be done to ensure fluidity before testing.
b) Samples may be warmed with constant heating rate. However, under no circumstances, should be heated above a temperature that lies 16^0 C below the expected flash point.
c) Samples containing dissolved water may be dehydrated with calcium chloride or by filtering through a suitable filter paper. If the same is not done, its consequence on experimental results and repeatability should be duly inferred.
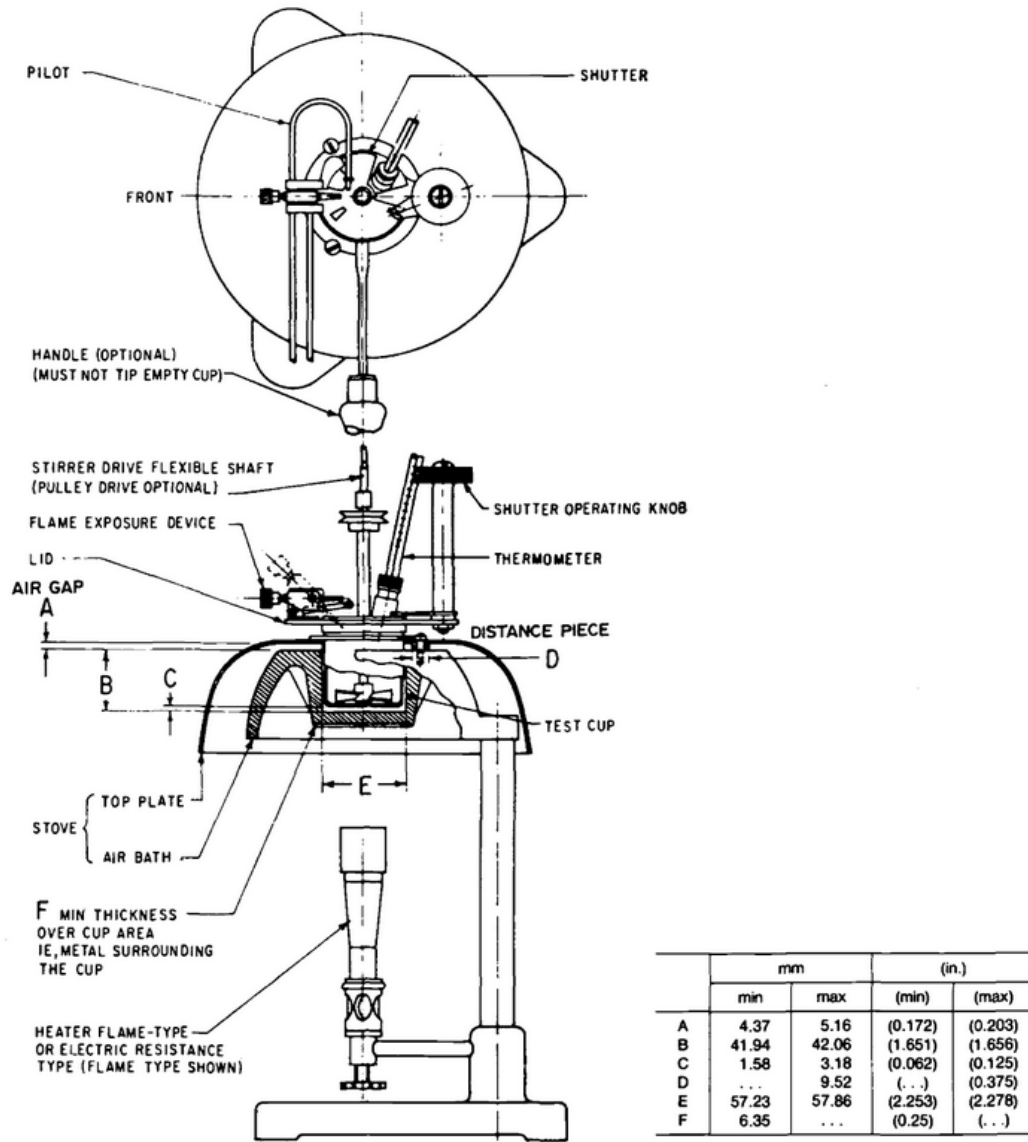
3.3.2 Generalized procedure

a) Clean and dry all parts of the cup thoroughly.
b) Fill the cup with the sample to be tested to the level indicated by the filling mark.
c) Place the lid on the cup and set the latter on the stove.

d) Insert the thermometer and supply heat with the help of the rheostat switch to ensure temperature rise rate not more than 5 to 6^0 C per minute.

e) Turn the stirrer with 90 to 120 rpm in a downward direction.

f) Provide the test flame time to time and start nearly 17^0 C below the expected flash point of the sample with 0.5 to 1^0 C gap.

g) Lower the test flame to the vapour space of the cup for 5s and allow it to be there for 1s. After that move the test flame up as quickly as possible and shut down the lid for vapour build up.

h) Do not stir the sample while providing the test flame.

i) Denote the flash point and fire point accordingly.

j) For **suspension of solids**, follow the procedure as mentioned below.
   - ✓ Bring the materials to be tested to a temperature of 15 ± 5^0 C or 11^0 C lower than estimated flash point.
   - ✓ Completely fill the space between the cup and the interior of the air_bath with water at the temperature of the tester and the sample.
   - ✓ Turn the stirrer at 250 ± 10 rpm in a downward direction.
   - ✓ Raise the temperature throughout the duration of the test at a rate not less than 1^0 C or more than 1.5^0 C per minute.
   - ✓ The rest of the procedures same as the generalized one.

3.4 Results and brainstorming

a) Compare the average of the observations with the known value of the sample.

b) Determine the repeatability of the results of the same sample and compare it to the standard which is 2^0 C for below 105^0 C and 6^0 C for above 105^0 C samples.

c) If the repeatability is not compliant to the standard, provide the reasoning.

Figure 1: Standard sketch for Pensky-Martens flash point apparatus

	mm		(in.)	
	min	max	(min)	(max)
A	4.37	5.16	(0.172)	(0.203)
B	41.94	42.06	(1.651)	(1.656)
C	1.58	3.18	(0.062)	(0.125)
D	. . .	9.52	(. . .)	(0.375)
E	57.23	57.86	(2.253)	(2.278)
F	6.35	. . .	(0.25)	(. . .)

NOTE—Lid assembly may be positioned either right or left-handed.

4. Abel Flash point Apparatus Laboratory test

4.1 Objective: To determine the flash point of a given sample using Abel's flash point apparatus and determination of experimental repeatability.

4.2 Apparatus and consumables required:

a) An Abel flash point apparatus.

b) Suitable thermometer.
c) Test samples.

4.3 Methodology and procedure

Two methods namely, Method A for liquids flashing between -18 to 18.5^0 C and Method B for liquids in19 to 70^0 C are prescribed in the standard. The generalised procedures are accordingly narrated below.

5.3.1 Method A with procedures (-18 to 18.5^0 C)

a) Fill the water bath completely and the air chamber which surrounds the oil cup to a depth of at least 38mm with 50:50 mixture of corrosion inhibiting ethylene glycol and water mixture.
b) Cool the bath to -27^0 C or at least 9^0 C below the expected flash point of the material being tested whichever is higher. Do continuous stirring while cooling the samples.
c) Note:
   ✓ Use an alcohol thermometer to avoid mercury freezing at low temperatures.
   ✓ Liquid which crystallizes on cooling should not be cooled below crystallization points.
d) Place the cup in bath and replace the thermometer by the oil cup thermometer.
e) Pour the sample till the level reaches the point of the index gauge without agitation avoiding air bubble formation to the extent feasible.
f) Do not move the apparatus after filling and heating rate should be less than 1^0 C per minute.
g) Provide the test flame time to time after 9^0 C less from the expected flash point temperature is met. Apply test flames with every 0.5^0 C after that till flash is realized.

5.3.2 Method B with procedures (19 to 70^0 C)

a) The thermometers need not be taken care of as mercury freezing is no longer an issue.
b) Instead of ethylene glycol water mixture, plane water can be used in the bath.
c) Rest of the procedures are same as method A.

5.4 Results and brainstorming

a) Compare the average of the observations with the known value of the sample.
b) Determine the repeatability of the results of the same sample and compare it to the standard which is 1^0 C.
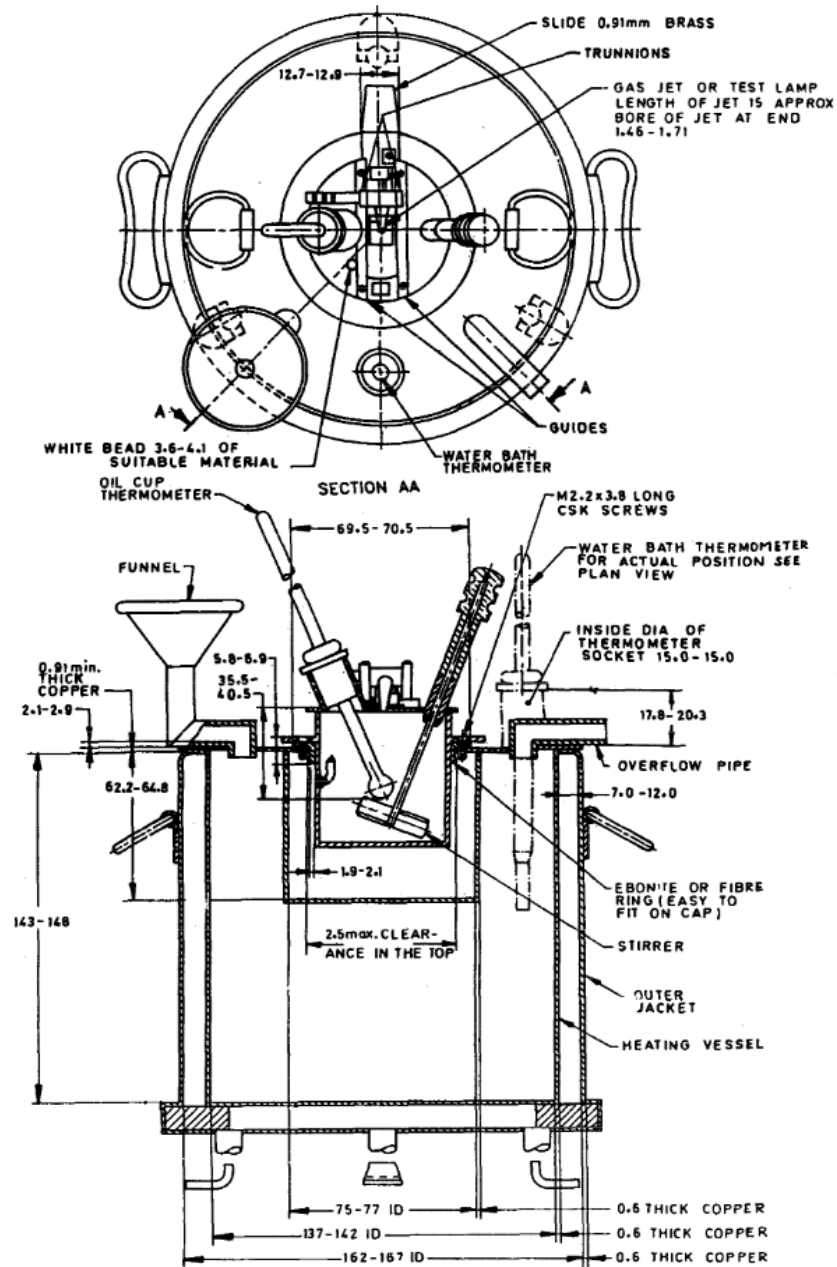c) If the repeatability is not compliant to the standard, provide the reasoning.

Figure 2: Standard sketch for Abel flash point apparatus (All dimensions in mm)

Experiment 2: TESIGNG OF FUELS: VISCOSITY OF LIQUID FUELS

5. Introduction

Viscosity of a fluid expresses its resistance to shearing flows, where adjacent layers move parallel to each other with different speeds.
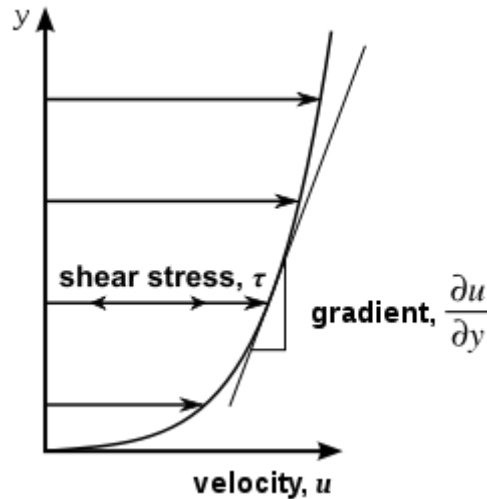
Figure 1: Typical velocity profile in the boundary layer indicating shear stress and velocity gradient.

Mathematically, viscosity is represented as

$$\mu = \frac{Shear\ stress}{Velocity\ gradient} = \frac{\tau}{\frac{\partial u}{\partial y}}$$

The above formulation represents dynamic viscosity whose unit is generally expressed as Pa.s (Pascal-second). However, in most of the flow and combustion systems, kinematic viscosity is invoked as a typical fluid characteristics.

Kinematic viscosity, which is otherwise known as momentum diffusivity, is defined as the ratio between dynamic viscosity and density. Mathematically,

$$\nu = \frac{Dynamic\ viscosity}{Density} = \frac{\mu}{\rho}$$

The unit of kinematic viscosity is expressed as m^2/s. The typical unit is Stokes. One stoke is $1cm^2$/s. The kinematic viscosity of typical engine fuels is in the order of Centi Stokes or cSt. The kinematic viscosity of some selected petroleum and alternative fuels such as gasoline, diesel, biodiesel, methanol, ethanol are 0.88cSt, 2-5 cSt, 5-7 cSt, 0.65cSt, 0.85cSt etc. respectively at 40^0 C.

6. Redwood Viscometer Laboratory test

2.1 Objective: To determine the viscosity of an oil sample expressed as time of flow in Redwood seconds at the specified temperatures and determination of experimental repeatability.

2.2 Apparatus and consumables required:

d) Redwood viscometer apparatus.

e) Thermometer of suitable range.
f) Stop watch.
g) Collecting flask.
h) Oil sample.

2.3 Methodology and procedure

2.3.1 Mode of operation

d) The flow time measurements for petroleum products should be made at temperatures of 21^0 C, 37.8^0 C, 60^0 C, 93^0 C, 121^0 C, 149^0 C and 204^0 C.
e) For fuel oils, the minimum temperature is 49^0 C. For flux oils the temperature should be 83^0 C.
f) For oil samples with Redwood seconds less than 2000, Redwood No.1 is recommended. For highly viscous fluids with greater than 2000 Redwood seconds, Redwood No.2 is recommended.

2.3.2 Sampling

k) For determination of viscosity at temperature 93^0 C or lower, heat 200mL of sample without stirring by a source not hotter than 121^0 C.
l) When a series of viscosities to be determined at several temperatures, whole procedure should be done on same sample of oil and the viscosity should be measured within 1 hour at desired temperatures.

2.3.3 General procedure

a) Clean the oil cup with a suitable solvent such as carbon tetrachloride and dry it thoroughly by using soft tissue paper or some similar material which will not leave any fluff and clean the jet hole with any fine thread.
b) Fill the bath with water for determination at temperature 93^0 C or below. For higher temperatures, suitable oil of low viscosity may be used instead of water.
c) Bath should be filled to a level not less than 10mL below the rim of oil cup at the test temperature.
d) Heat the viscometer bath to a few degree above the desired test temperature. Pour the prepared sample into the oil cup through a filter of metal gauge not coarser than BS100 mesh.
e) Adjust the temperature of bath until it reaches the test temperature. During procedure, all the contents of the bath stirred well by continuous stirring.
f) Stir the sample during the preliminary period e.g. after the ball valve closing the bottom of the jet by suitable means. Do not stir the sample during actual determination.
g) When the sample reaches the desired temperature, adjust the liquid level by allowing the sample to flow out until the surface of the sample touches the filling point.
h) Stop the time recorder at the instance when sample reaches the graduation mark of the flask and note the final reading of the oil cup thermometer.

i) Reporting the time in seconds to the nearest 0.5^0 C for values below 300s and to the nearest whole seconds for values above 200s.

2.4 Results and brainstorming

d) The viscosity of a given sample using Redwood viscometer should be denoted with Redwood seconds at the specified temperature.
e) Repeatability of the experiments should be duly compared at low and high temperatures.
f) Convert the Redwood seconds to cSt with the empirical formulation 100 Redwood seconds as 24.5cSt and compare with the standard values.
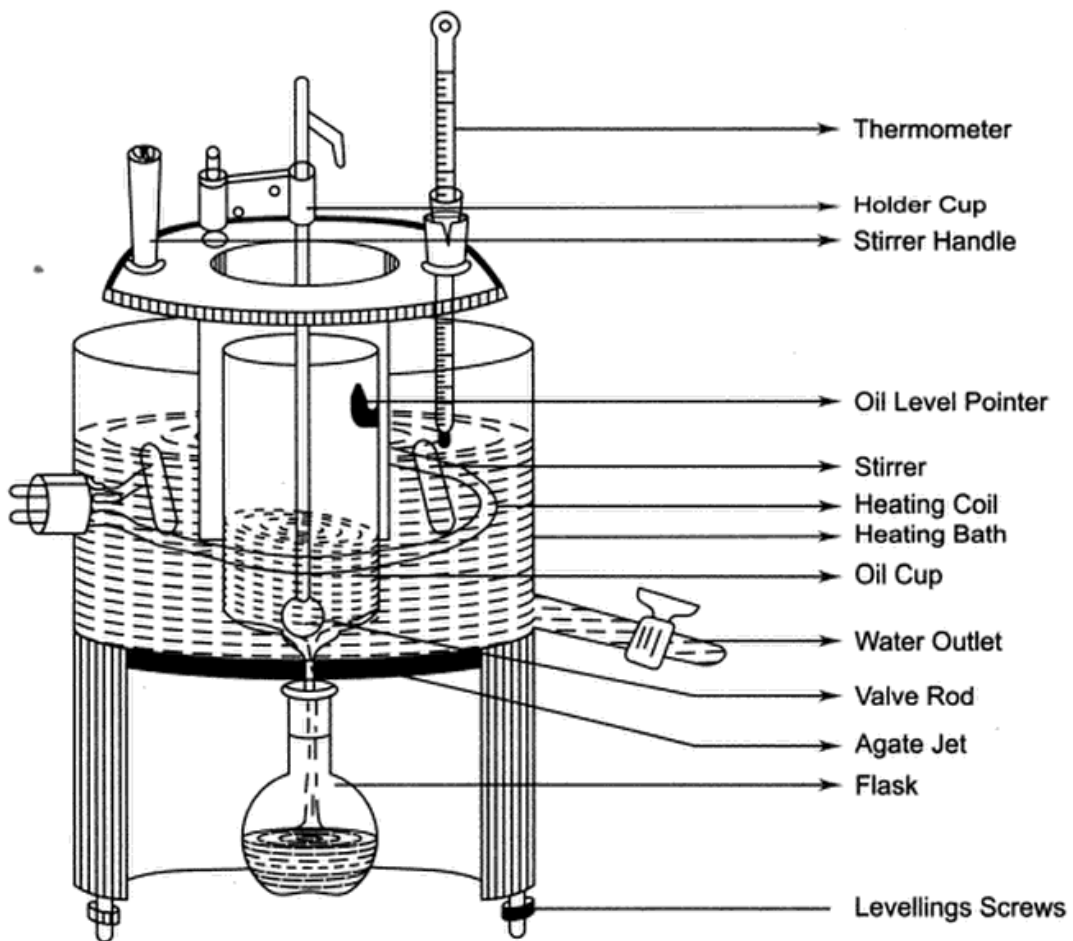

Figure 1: Graphical sketch of Redwood viscometer

7. Saybolt Viscometer Laboratory test

2.1 Objective: To determine the viscosity of an oil sample expressed as time of flow in Saybolt seconds at the specified temperatures and determination of experimental repeatability.

2.2 Apparatus and consumables required:

a) Saybolt viscometer apparatus.

b) Thermometer of suitable range.
c) Stop watch.
d) Collecting flask.
e) Oil sample.

2.3 Methodology and procedure

2.3.1 Mode of operation

a) Saybolt viscometer is used only for oils with time of flow more than 3 seconds. There is no maximum limit to the viscosity to be measured.
b) The Saybolt Furol viscometer is used for transport fuels. The phrase Furol stands for Fuel and Road oils.
c) The typical temperatures for viscosity measurements in Saybolt viscometer is 21^0 C, 37.5^0 C, 60^0 C, 82^0 C and 98^0 C

2.3.3 General procedure

a) Viscosity determination should be done in a room free from drafts and rapid changes in temperature. Typically rooms with 20^0 to 30^0 C temperature may be employed.
b) The oil tube first to be cleaned by an effective solvent such as benzol and excess solvent should be removed from the oil tube.
c) All oil should be passed through a 100 mesh wire strained before it is introduced in to the oil tube. After the tube is cleaned, a quantity of oil to be tested, sufficient to wet the entire surface of the tube, should be pour in to the tube and allowed to drain put.
d) The cork stopped shall be inserted not less than a quarter inch and not more than three quarters of an inch in to the lower end of the chamber at the bottom of the oil tube. The cork shall fit tightly enough to prevent the escape of oil.
e) The oil should be heated at a constant rate not more than 20^0 C below the temperature of the test.
f) The oil in the oil tube shall be kept well stirred with the oil tube thermometer. The bath temperature shall be adjusted until the oil temperature remains constant. After thermal equilibrium reached, no further adjustments should be made in both the temperature.
g) After the oil temperature is stabilized at the desired temperature for more than 1 minute, the thermometer is withdrawn and surplus oil is removed.
h) The receiving flask should be placed in position so that the stream of oil from the outlet tube will strike the neck of the flask up to the graduation mark on the receiving flask should not be less than 10cm from the bottom of the bath.
i) The cork shall be shaped from its position and at the same instant the timer should be stopped when the bottom of the meniscus of the oil reaches on the neck of the receiving flask.

2.4 Results and brainstorming

g) The viscosity of a given sample using Saybolt viscometer should be denoted with Saybolt seconds at the specified temperature.

h) Repeatability of the experiments should be duly compared at low and high temperatures.

i) Convert the Saybolt seconds to cSt with the empirical formulation 1cSt as 31 Saybolt seconds and compare with standard values.
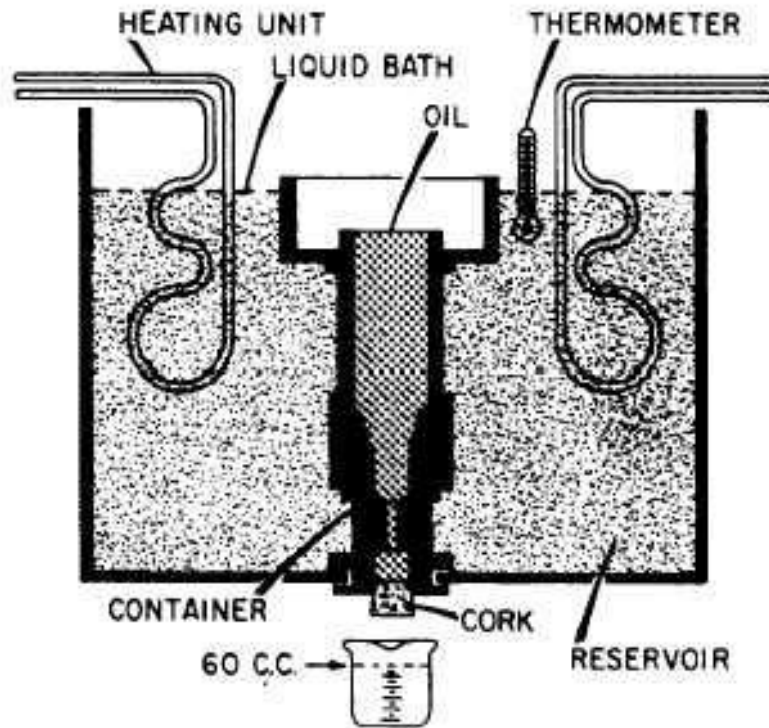

Figure 2: Graphical sketch of Saybolt viscometer

EXPERIMENT 3 : Study of SSSF Combustion Systems : Case Study of a single cylinder four stroke diesel engine

Objectives:

1. To understand the different instrumentation used to study the SSSF combustion behavior of a single cylinder four stroke diesel engine.
2. To understand the basic calculations to obtain fuel composition & other details.

Experimental Procedure:

Experiment would be conducted for three load conditions (no load, 2 kW and 4 kW) at a constant speed of 1350 rpm

- Draw a neat sketch with all major dimensions of the test rig.

- Measurement of rpm, load and fuel consumption.

- Measurement of manometer reading to calculate air flow rates.

- Measurement of temperatures.(inlet, exhaust, cylinder wall and lub oil)

- Measurement of Exhaust gas temperature and chemical composition.

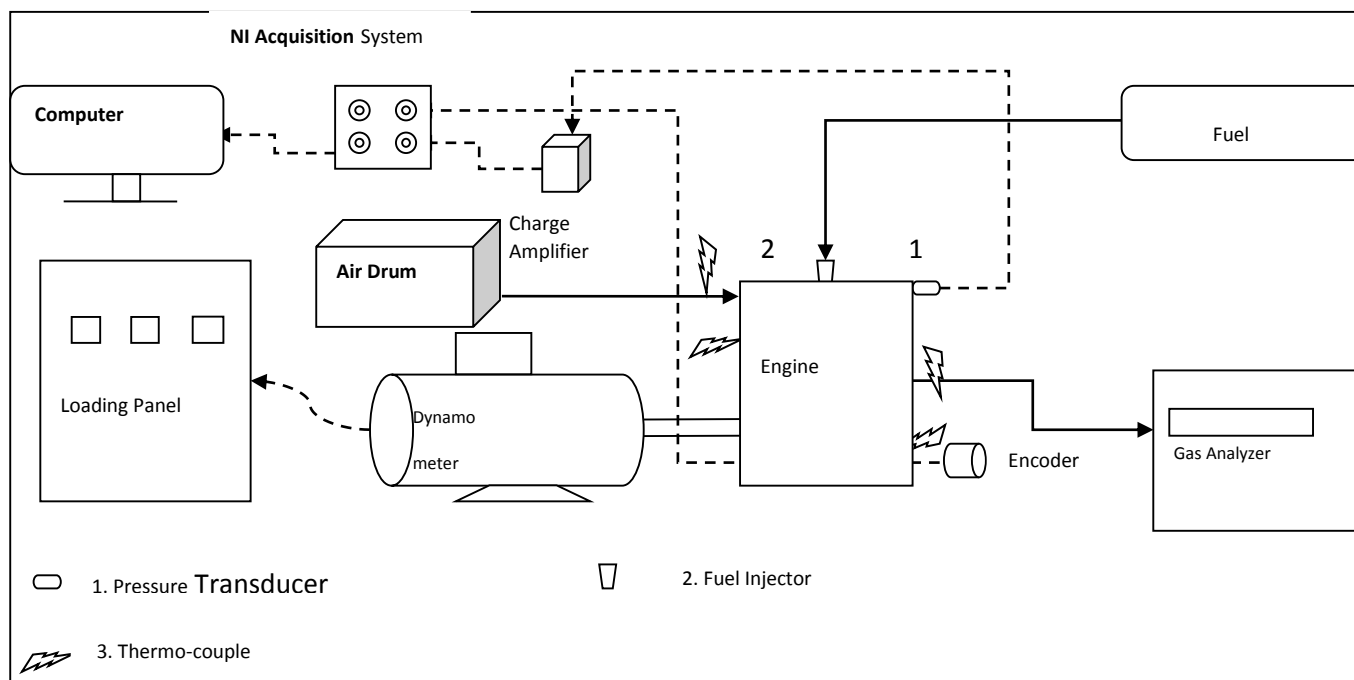| Sl. no	RPM	Fuel Cons. Mai(ml/min)	Load		Mano Reading (mm)	T_1 (°C) Intake	T_2 (°C) exhaust	CO (%)	CO_2 (%)	HC (ppm)	O_2 (%)	NOx (ppm)	Smoke (opacity
			Curr. (Amp)	Vol. (v)									

Figure: Schematic diagram of experimental test rig.

Type of engine	Kirlosker single Cylinder 4-Stroke Diesel engine
Bore(mm)	102
Stroke(mm)	116
Length of connecting rod(mm)	230
Compression ratio	17.5:1
Maximum power	7.4kW@1500 rpm

Table 1: detailed specifications of the engine

Air flow rate calculation:

$\dot{m}_a = \rho_{air} \times c_d \times A \sqrt{(2g \times \Delta h_w \times \rho_w / \rho_{air})}$

$\rho_{air} = P/(R \times T)$………………………………………………………….............................(4)

Where,

$\dot{m}_a$=mass flow rate of air in kg/sec

ρ_{air}=density of air at room temperature in kg/m^3

P=atmospheric pressure in N/m^2

R= specific gas constant in J/kg.K

T=absolute temperature

c_d=coefficient of discharge of orifice (take 0.62)

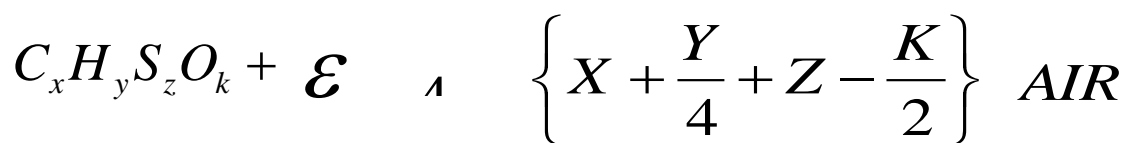A=area of orifice in m^2 (take 20 mm as diameter)

Δh_w= meno metric head in meter

ρ_w=density of liquid used in U-tube manometer in kg/m^3
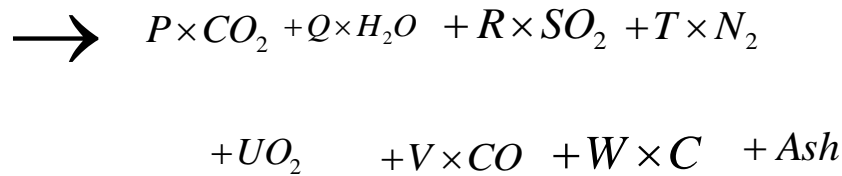
Fuel properties: Density of diesel is 0.832 kg/ltr, CV of diesel is 43 MJ/kg

Density of petrol is 0.720 kg/ltr, CV of petrol is 46 MJ/kg

Combustion Reaction Equation:

$$C_x H_y S_z O_k + \varepsilon_a \left\{ X + \frac{Y}{4} + Z - \frac{K}{2} \right\} AIR$$

$+ \text{Moisture in Air}\,(MA) \quad + \textit{Moisture in fuel} \quad + \text{Ash}\,(A)$

$$\longrightarrow \quad P \times CO_2 \; + Q \times H_2O \; + R \times SO_2 \; + T \times N_2$$

$$+ U O_2 \qquad + V \times CO \; + W \times C \; + Ash$$

First Law Analysis of a Diesel Engine (SSSF)
in molar form :

$$\dot{Q}_{CV} + \{\dot{n} \times h\}_{fuel} + \{\dot{n} \times h\}_{air} = \sum_{j=1}^{m} \{\dot{n} \times h\}_{product,j} + \dot{W}_{CV}$$

Experiment 4: Performance test and Morse test on a four-stroke four-cylinder petrol engine   at constant speed.

ENGINE SPECIFICATIONS:
Engine Type : Four cylinder Four stroke MPFI petrol engine(Maruti Zen), Bore : 0.072 m, Stroke : 0.061m Capacity : 993 cc, Power : 60 HP at 6000 rpm, Torque : 78.5 Nm at 4500 rpm and Compression Ratio :9.4:1
Measurement of:-
- Fuel consumption.
- Manometer readings for air flow.
- RPM, power output etc.
- Study of various components of petrol engine.
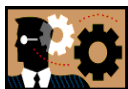
Experimental Procedure/what you should aim at: -

The purpose of Morse Test is to obtain the approximate Indicated Power of a Multi-cylinder Engine. It consists of running the engine against a dynamometer at a particular speed, cutting out the firing of each cylinder in turn and noting the fall in BP each time while maintaining the speed constant. When one cylinder is cut off, power developed is reduced and speed of engine falls. Accordingly, the load on the dynamometer is adjusted so as to restore the engine speed. This is done to maintain FP constant, which is considered independent of the load and proportional to the engine speed. The observed difference in BP between all cylinders firing and with one cylinder cut off is the IP of the cut off cylinder. Summation of IP of all the cylinders would then give the total IP of the engine under test.

What next (Things you can ponder over):-

3. Why did I do this whole experiment? (What is the technical applicability in real world?)
4. Define the Morse test?
5. What is hydraulic dynamometer?
6. What is need of measurement of speed of an I.C. Engine?
7. What is the brake power of I.C. Engines?

Submission of Report:

- A single report per group.
- All are equally responsible for the preparation of the report.
- Should answer the questions on your report.
- Each Report will be evaluated for 10 points.

References:-(Books to consult)

1. IC Engines by V Ganesan.

Experiment No 4

Objective: - Study of the valve timing diagrams of a four-stroke single cylinder diesel engine. Study on assembling and disassembling of a four-stroke single cylinder diesel engine.

ENGINE SPECIFICATIONS:
Engine Type : Single cylinder four stroke diesel engine(Kirloskar), Bore : 0.0875m, Stroke : 0.11m Capacity : 661.5 cc, Power : 6 H.P. at 1500 rpm, Torque : 2.96 kg.m at 1500 rpm and Compression Ratio :17.5:1
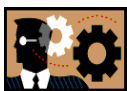**Measurement of:-**
- Top dead centre (TDC).
- Opening and closing of inlet valve.
- Opening and closing of exhaust valve.
- Study of various components of diesel engine.

Prerequisites: -

- What are various strokes to complete an engine cycle?
- Why clearance is necessary in cylinder head?

Name the parameters, which affect the opening and closing of inlet and exhaust valve.

Experimental Procedure/what you should aim at: -

In four stroke CI Engines(compression ignition engine), both the valves do not open and close exactly at dead centre positions, rather operate at some degree on either side in terms of the crank angles from the dead centre positions. The injection of the fuel is also timed to occur earlier.

What next (Things you can ponder over):-

8. Define valve timing in four-stroke diesel engine?
9. What is overlapping?
10. What do you mean by ignition?
11. What are inlet valve and exhaust valve?

Submission of Report:

- A single report per group.
- All are equally responsible for the preparation of the report.
- Should answer the questions on your report.
- Each Report will be evaluated for 10 points.

References:-(Books to consult)

2. IC Engines by V Ganesan.