

**K.S.R. COLLEGE OF ENGINEERING (Autonomous)  
DEPARTMENT OF AUTOMOBILE ENGINEERING**

**Course Name: AUTO MOTIVE FUELS AND LUBRICANTS**

**Course Code : 20AU416**

**Year/Semester: II/IV**

**Course Outcomes: On completion of this course, the student will be able to**

- C01: Recognize the manufacturing processes of fuels and lubricants.
- C02: Evaluate the properties and testing of fuels.
- C03: Identify the fuels and alternative fuels for engines with their performance and emission characteristics.
- C04: Discuss the engine friction and various types of lubrication mechanism.
- C05: Examine the need of lubricants, factors influencing the lubricants and testing of lubricants.

**Program Outcomes (POs)**

**Engineering Graduates will be able to:**

- PO1 Engineering Knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
- PO2 Problem Analysis:** Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
- PO3 Design/Development of Solutions:** Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
- PO4 Conduct Investigations of Complex Problems:** Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
- PO5 Modern Tool Usage:** Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.
- PO6 The Engineer and Society:** Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.
- PO7 Environment and Sustainability:** Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
- PO8 Ethics:** Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
- PO9 Individual and Team Work:** Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
- PO10 Communication:** Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and

write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

**PO11 Project Management and Finance:** Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

**PO12 Life-long Learning:** Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

**Program Specific Outcomes (PSOs)**

**PSO1 Proficiency Core:** Apply the concepts of electro-mechanical systems, analyse the various automobile components and use design tools specific to automobile industry.

**PSO2 Problem Troubleshooting Skills:** Diagnose the automotive system failures and repair / replace the components / systems.

**COURSE FACULTY**

**HoD**

**PRINCIPAL**

**K.S.R. COLLEGE OF ENGINEERING (Autonomous)****Vision of the Institution**

- We envision to achieve status as an excellent Educational Institution in the global knowledge hub, making self-learners, experts, ethical and responsible engineers, technologists, scientists, managers, administrators and entrepreneurs who will significantly contribute to research and environment friendly sustainable growth of the nation and the world.

**Mission of the Institution**

- To inculcate in the students self-learning abilities that enable them to become competitive and considerate engineers, technologists, scientists, managers, administrators and entrepreneurs by diligently imparting the best of education, nurturing environmental and social needs.
- To foster and maintain mutually beneficial partnership with global industries and Institutions through knowledge sharing, collaborative research and innovation.

**DEPARTMENT OF AUTOMOBILE ENGINEERING****Vision of the Department**

- To build long tradition of excellence to be the leading Automobile Engineering program in partnership with our students, alumni, industry and government. The department shall provide the students with educational experiences that will enable them to become leaders in their profession and society. The department shall also maintain and develop world-class research programs that complement our educational mission, address the evolving needs of industry and society, and contribute to economic and social development in the State of Tamil Nadu, across the nation, and around the world.

**Mission of the Department**

- To serve students, industry and society by fulfilling the missions of discovery, learning, and engagement through the creation and dissemination.
- To apply Engineering methods, knowledge, and professional standards relevant to the practice of Automobile Engineering in the many aspects of modern life where it plays a crucial role.

**Programme Educational Objectives (PEOs) of B.E. - Automobile Engineering**

**PEO 1: Employability and Higher Studies:** Graduates are knowledgeable in the areas of Automobile industries and successful in their professional career.

**PEO 2: Sustainable Engineering Solutions to the Society:** Graduates continue significant work in their chosen career, and demonstrate social and ethical responsibility.

**PEO 3: Interpersonal and Ethical Proficiency:** Graduates perform both independently and as a member of a team in project management.

**COURSE FACULTY****HoD****PRINCIPAL**

**KSRCE/QM/7.5.1/33B/AE**

**KSR COLLEGE OF ENGINEERING, TIRUCHENGODE-637 215**  
**(An Autonomous Institution Affiliated to Anna University, Chennai)**  
**DEPARTMENT OF AUTOMOBILE ENGINEERING**

**Year / Sem** : II / IV  
**Course Code & Name** : 20AU416 – AUTOMOTIVE FUELS AND LUBRICANTS  
**Faculty Name** : Dr. M.SIVAKUMAR

**COURSE / LESSON PLAN SCHEDULE**

**A) TEXT BOOK:**

T1. V.Ganesan, “Internal Combustion Engines”, Tata McGraw-Hill Publishing Co.  
T2. M.L.Mathur and R.P.Sharma “A course in internal combustion engines”, Dhanpat Rai Publications

**B) REFERENCE BOOK:**

R1. K.K.Ramalingam, “Internal Combustion Engines”, Scitech Publications  
R2. Roger F. Haycock and John E. Hiller, “Automotive Lubricants Reference Book”, SAE International, 2004.  
R3. Francis, W – Fuels and Fuel Technology, Vol. I & II

**C) LEGEND**

L - Lecture	PPT - Power Point
T - Tutorial	BB - Black Board
OHP - Over Head Projector	PP - Pages
T <sub>x</sub> - Reference	E <sub>x</sub> - Extra

Sl. No	Lecture Hour	Topics to be covered	Teaching Aid Required	Books No. / Page No
<b>UNIT - I REFINERY OF FUELS AND LUBRICANTS</b>				
1	L1	Introduction to Structure of Petroleum	PPT / BB	T1 – 147, 148 - 150
2	L2	Refining Process - Distillation	VIDEO / BB	T1 – 151 - 152
3	L3	Cracking Processes, Catalytic reforming	PPT / BB	T1 – 152
4	L4	Polymerization, Alkylolation, Isomerisation, finishing process - Blending	PPT / BB	T1 – 152
5	L5	Products of refining process	PPT / BB	T2 – 272 - 274
6	L6	Products of refining process	PPT / BB	T2 – 272 - 274
7	L7	Manufacture of lubricating oils base stocks	PPT / BB	R2 – 46 - 52

8	L8	Manufacture of lubricating oils base stocks	PPT / BB	R2 – 46 - 52
9	L9	Manufacture of finished automotive lubricants	PPT / BB	T2 – 507 - 508
<b>UNIT - II PROPERTIES AND TESTING OF FUELS</b>				
10	L10	Properties and Testing of fuels	PPT / BB	T1 – 111 -115
11	L11	Properties and Testing of fuels	PPT / BB	T2 – 274 - 283
12	L12	Density - Calorific value and distillation	VIDEO / BB	T2 – 276 - 277
13	L13	Vapor pressure - Flash point - Fire point - Aniline point	PPT / BB	T2 – 296
14	L14	Viscosity – Pour point – Flammability- Ignitability	PPT / BB	T2 – 299, 304
15	L15	Viscosity – Pour point – Flammability- Ignitability	PPT / BB	T2 – 303, 304
16	L16	Diesel index – API gravity	PPT / BB	T2 – 502 - 503
17	L17	Spontaneous ignition temperature, Carbon residue, Copper strip corrosion	PPT / BB	T2 – 502 - 504
18	L18	Spontaneous ignition temperature, Carbon residue, Copper strip corrosion	PPT / BB	T2 – 502 - 504
<b>UNIT - III FUELS FOR I.C. ENGINES</b>				
19	L19	Type of fuels, Liquid and Gaseous fuels	PPT / BB	T1 – 147, 148 - 150
20	L20	Desirable characteristics of SI Engine fuels	PPT / BB	T1 – 148 - 150
21	L21	Desirable characteristics of SI Engine fuels	PPT / BB	T1 – 154 - 156
22	L22	Knocking, Octane rating, Fuel requirements	VIDEO / BB	T1 – 154 - 156
23	L23	CI engine fuels, desirable characteristics	PPT / BB	T1 – 168 - 170
24	L24	CI engine fuels, desirable characteristics	PPT / BB	T1 – 156 - 157

25	L25	Diesel knock, Cetane rating, Fuel requirements	PPT / BB	T1 – 170 - 172
26	L26	Additive mechanism, requirements of additive	PPT / BB	T1 – 170 - 172
27	L27	Fuel additives – Specification of fuels	PPT / BB	T1 – 173 - 174
<b>UNIT - IV THEORY OF LUBRICATION</b>				
28	L28	Engine Friction - Introduction	PPT / BB	T2 – 486 - 491
29	L29	Total Engine Friction	PPT / BB	T2 – 486 - 491
30	L30	Effect of engine variables on friction	PPT / BB	T2 – 491 - 495
31	L31	Effect of engine variables on friction	PPT / BB	T2 – 491 - 495
32	L32	Hydrodynamic lubrication	VIDEO / BB	T2 - 496
33	L33	Elasto-hydrodynamic lubrication	PPT / BB	T1 – 371
34	L34	Boundary lubrication, Bearing lubrication	PPT / BB	T2 – 497 - 498
35	L35	Functions of the lubrication system	PPT / BB	T2 – 498 - 499
36	L36	Introduction to design of a lubricating system	PPT / BB	T2 – 500
<b>UNIT - V LUBRICANTS</b>				
37	L37	Specific requirements for automotive lubricants	PPT / BB	R2 – 3 - 4
38	L38	Oxidation deterioration and degradation of lubricants, Additives and additive mechanism	PPT / BB	T2 – 503 - 505
39	L39	Oxidation deterioration and degradation of lubricants, Additives and additive mechanism	PPT / BB	T2 – 503 - 505
40	L40	Synthetic lubricants	VIDEO / BB	R2 – 63 - 75
41	L41	Classification of lubricating oils	PPT / BB	T2 – 505 - 507
42	L42	Properties of lubricating oils	PPT / BB	T2 – 501 - 503
43	L43	Tests on lubricants	PPT / BB	R2 – 91 - 120
44	L44	Grease, classification, properties of grease	PPT / BB	R2 – 19 – 23
45	L45	Tests used of grease.	PPT / BB	R2 – 303 - 307

**PREPARED BY**  
**(Dr. M.SIVA KUMAR)**

**HoD/AE**

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**DEPARTMENT OF AUTOMOBILE ENGINEERING**  
**20AU416 AUTOMOTIVE FUELS AND LUBRICANTS**

**UNIT – I**

**REFINERY OF FUELS AND LUBRICANTS**

**PART – A**

1. Give names of three basic liquid fuels. (CO1) (Remembering)
2. What are the characteristics of a good fuel? (CO1) (Remembering) (AU Dec'10)
3. Write the general molecular formula for paraffin olefin and naphthene? (CO1) (Remembering)
4. Draw the molecular structure of benzene. (CO1) (Understanding)
5. Draw the molecular structure of toluene. (CO1) (Understanding)
6. Give four important products of petroleum refining process. (CO1) (Remembering)
7. Define Cracking. (CO1) (Remembering) (AU Dec'10).
8. Explain hydrogenation. (CO1) (Remembering)
9. Explain polymerization. (CO1) (Understanding)
10. Explain isomerisation. (CO1) (Remembering)
11. Explain cyclization. (CO1) (Understanding)
12. Explain reformation. (CO1) (Remembering)
13. Define the term 'Hydro-treating process'. (CO1) (Remembering)

**PART – B**

1. Explain the petroleum refining process in detail. (CO1) (Remembering)
2. Briefly explain the chemical structure of petroleum. (CO1) (Remembering)
3. Give the general chemical formula of the following fuels: (i) paraffin (ii) olefin (iii) diolefin (iv) naphthene (v) aromatic. Also state their molecular arrangements and mention whether they are saturated or unsaturated. (CO1) (Remembering)
4. What do you understand by thermal cracking? How it differs from oxidizing hydrocarbons? (CO1) (Remembering)
5. Explain the manufacturing of lubricating oil base stocks and also finished automotive lubricants. (CO1) (Understanding)

**UNIT – II**

**PROPERTIES AND TESTING OF FUELS**

**PART – A**

1. **What is flash point and fire point? (CO2) (Remembering)**  
Flash Point: Flash point is the temperature at which a flammable liquid will produce, with a standardized apparatus and procedure, a mixture of its vapour and air which will ignite to give a visible flash by contact with an open flame.  
Fire Point: Fire point is the temperature at which the flash will sustain itself as a steady flame for at least five seconds.

**2. Define: Viscosity. (CO2) (Remembering)**

Viscosity of a fuel is a measure of its resistance to flow. Viscosity is important in lubrication and in pumping flow and spraying of liquids.

**3. What is pour point? (CO2) (Remembering) (AU Dec'10)**

Pour point: Pour point is the temperature below which the entire mass of the fuel, solid and liquid together, freeze and thus cause flow of fuel impossible. Pour point is usually 5 to 10°C below the cloud point.

**4. What is diesel index? (CO2) (Remembering) (AU Dec'10)**

An alternative method of expressing the quality of diesel oils is “Diesel index”. It is defined as

$$\text{Diesel index} = \frac{\text{Aniline point } (^{\circ}\text{F}) \times \text{API Gravity at } 60^{\circ}\text{F}(15^{\circ}\text{C})}{100}$$

**5. What is aniline point? (CO2) (Remembering) (AU Dec'10)**

Aniline point is the lowest temperature at which the oil is completely miscible with an equal volume of aniline. For a good quality diesel oil the aniline point is greater than 70°F.

**6. What is API gravity? (CO2) (Understanding) (AU Dec'11)**

The American Petroleum Institute gravity or API gravity is a measure of how heavy or light petroleum liquid is compared to water. Thus, the API gravity is an inverse measure of the relative density of a petroleum liquid and the density of the water, but it is used to compare the relative densities of petroleum liquids.

The specific gravity is the ratio of the weight of a unit volume of oil to the weight of the same volume of water at a standard temperature of 15°C (60°F).

$$\text{API gravity} = \frac{141.5}{\text{Specific gravity at } 15^{\circ}\text{C } (60^{\circ}\text{F})} - 131.5$$

**7. Define: flammability. (CO2) (Remembering)**

Flammability is defined as how easily something will burn or ignite, causing fire or combustion. The degree of difficulty required to cause the combustion of a substance is quantified through fire testing.

**8. Define: Ignitability. (CO2) (Remembering)**

**9. What is vapour pressure? (CO2) (Remembering)**

The volatility of petrol is also defined in terms of Reid vapour pressure. This is a measure of the vapour pressure of an oil at 38°C expressed as millimetres of mercury or in pounds per square inch pressure and indicates initial tendency of a fuel to vapour-lock.

**10. Distinguish between gross and net calorific value of a fuel. (CO3) (Analyzing) (AU Dec'10)**



### **PART – B**

1. Explain fractional distillation process with neat sketch. (CO2) (Remembering)
2. List out any five instruments used to measure properties of fuel and lubricants and Explain 'Redwood viscometer' with neat sketch. (CO2) (Remembering) (AU Dec'11)
3. Discuss the importance of (i) API gravity, (ii) Aniline point, (AU Dec'11) (iii) Flash point and Fire point, (iv) Calorific value, (v) Spontaneous ignition temperature. (CO2) (Creating)
4. Write short notes on: (i) Flammability, (AU Dec'11) (ii) Ignitability, (iii) Diesel index, (iv) Carbon residue and copper strip corrosion. (CO2) (Remembering)
5. Briefly explain the saybolt viscometer with neat sketch. (CO2) (Remembering)
6. Write short notes on: (i) ASTM distillation test, (ii) Reid vapour test. (CO2) (Remembering)
7. Explain the procedure to carry out distillation test and drawing of distillation curves. (CO2) (Remembering) (AU Dec'11)
8. What are the basic impurities in fuels and explain how it affects combustion. (CO2) (Remembering) (AU Dec'11)

### **UNIT – III** **FUELS FOR I.C. ENGINES** **PART – A**

1. **What are the characteristics of ideal diesel oil? (CO3) (Remembering) (AU Dec'10)**
2. **What are the requirements of good gasoline? (CO3) (Remembering) (AU Dec'10)**
3. **How does the viscosity of liquid fuel affect combustion? (CO3) (Remembering) (AU Dec'11)**
4. **What is highest useful compression ratio (HUCR)? (CO3) (Remembering)**  
This is the compression ratio at which a fuel test engine can be operated without detonation with any mixture strength or with any ignition timing, at a speed of 1500 rpm. Ricardo has originated this method.
5. **What is performance number of a fuel? (CO3) (Remembering)**  
It is defined as the ratio of knock limited indicated mean effective pressure (KLIMEP) with the fuel in question to the knock limited indicated mean effective pressure (KLIMEP) with iso octane when the inlet pressure used as the dependent variable. Performance number is found to be reasonably independent of engine design and closely related to the octane number.
6. **Write the difference between spark ignition engine fuels and compression ignition engine fuels. (AU Dec'10) (CO3) (Analyzing)**
7. **What is the relationship between ignition quality and antiknock characteristic of a fuel? (CO3) (Remembering)**  
A simple, linear relation exists between the characteristic numbers, octane number (ON) and cetane number (CN) as given below. These formulae are supposed to be accurate within plus or minus 5%  
$$ON = 120 - 2 CN$$
$$ON = 120 - 2.5 CN$$

Gasoline has got antiknock qualities (desirable in SI engines), but does not ignite readily. As such, gasoline is not suitable for use in diesel engines. Sharp oscillations of pressure are noted during combustion. The engine will not run smoothly.

**8. What are the important additives added to gasoline? (CO3) (Understanding)**

Number of additives is added to gasoline, during its production in the refinery, to improve its combustion and other characteristics:

- (1) Antiknock agent.
- (2) Scavenger.
- (3) Antioxidant.
- (4) Corrosion inhibitor.
- (5) Anti icing agent.

**9. What is gum formation? (CO3) (Understanding)**

Gasoline when stored during long periods, at high ambient temperatures, deteriorates in quality and produces gum. Gasoline is composed of different saturated and unsaturated hydrocarbons.

The gum formation is mainly due to the presence of unsaturated hydro carbons in the fuel and their oxidation at high ambient temperatures.

**10. What is crankcase oil dilution? (CO3) (Understanding)**

Heavier ends of gasoline fail to evaporate completely in the inlet manifold particularly at the time of starting and warm up and in cold climate. The unvapourized fuel enters the engine cylinder. This liquid fuel mixes with the lubricating oil on the cylinder walls, flows past the piston rings, drains and collects in the crankcase. The gasoline, therefore, dilutes the lubricating oil. This is called crankcase oil dilution.

**11. What is octane number of fuel? (CO3) (Remembering) (AU Dec'10)**

It is defined as the percentage, by volume of iso-octane in a mixture of iso-octane and normal heptane, which exactly matches the knocking intensity of the fuel in a standard engine under a set of standard operating conditions.

**12. What is cetane number of fuel? (CO3) (Remembering)**

It is defined as the percentage by volume of normal cetane in a mixture of normal cetane and  $\alpha$  – methyl naphthalene which has the same ignition characteristics as the test fuel when combustion is carried out in a standard engine under specified conditions.

## **PART – B**

1. What is vapour lock? How is it related to ASTM distillation curve of the fuel? (CO3) (Remembering)
2. Discuss the effect of volatility on (i) starting, (ii) warm-up, (iii) carburettor icing and (v) acceleration. (CO3) (Understanding)
3. Write short notes on: (i) ASTM distillation test, (ii) Reid vapour test. (CO3) (Understanding)
4. What will be the consequence if a diesel fuel is used in the SI engine? (CO3) (Understanding)
5. Explain the procedure to carry out distillation test and drawing of distillation curves. (AU Dec'11) (CO3) (Understanding)
6. What are the basic impurities in fuels and explain how it affects combustion. (AU Dec'11) (CO3) (Understanding)

**UNIT – IV**  
**THEORY OF LUBRICATION**  
**PART – A**

**1. What causes friction between two bodies which are in contact? (CO4) (Remembering)**

Friction is the resistance to relative motion between two bodies which are in contact with each other. Friction is caused by the interlocking of the projections and depressions of the two surfaces.

**2. What is coefficient of friction? (CO4) (Understanding)**

The amount of friction developed by any two bodies in contact is called coefficient of friction. This is found by dividing the force required to slide the weight over the surface by the weight of the object.

**3. What is mechanical friction and fluid friction in engines? (CO4) (Remembering)**

In an engine, part of the power produced by way of combustion of fuel is used to overcome friction. Power is used to overcome 1. Mechanical friction between the moving parts and in the bearings and 2. Fluid friction associated with pumping losses, i.e. energy utilized in sucking the fresh fluid into the engine cylinder and exhausting the products of combustion out of the cylinder.

**4. What are the four groups of mechanical losses in an engine? (CO4) (Understanding)**

- (i) Direct frictional losses
- (ii) Pumping losses
- (iii) Power loss to drive the components to charge and scavenge
- (iv) Power loss to drive other auxiliary components.

**5. What are the factors which influence pumping and friction losses in an engine? (CO4) (Remembering)**

In an engine, the pumping and frictional losses depend on the following:

- 1. Compression ratio.
- 2. Cycle of operation
- 3. Single or double acting
- 4. Size and number of cylinders
- 5. Piston speed / engine speed
- 6. Precision used in manufacturing and assembling parts.
- 7. Jacket water temperature
- 8. Method, quality and quantity of lubrication
- 9. Condition of air filter and exhaust muffler.

**6. What is corrosive wear? (CO4) (Understanding)**

Corrosion is a chemical attack on the cylinder liner surfaces and piston rings by the vapour or acids, formed by the products of combustion. The extent to which the corrosive materials are formed depends on the following: (1) Quality of fuel used, (2) Completeness of combustion, (3) Jacket cooling water temperature, (4) Exhaust back pressure, (5) Quality of lubricating oil.

**7. What is abrasive wear? (CO4) (Understanding)**

This type of wear is mainly due to force of friction between two rubbing surfaces. This friction is due to surface roughness. To reduce abrasive wear, both intake air fuel and

lubricating oil must be kept free from abrasive materials. To achieve this end, filtering equipments must have adequate capacity and must be maintained at maximum efficiency.

**8. What is the purpose of lubrication? (CO4) (Remembering)**

1. To reduce friction between the moving parts.
2. To reduce wear of the moving parts.
3. To act as a seal and prevent leakage between the parts such as pistons, rings and cylinders.
4. To carry away much of the heat generated by friction, by flowing between the moving parts.
5. To keep down the temperature of the moving parts and thus prevent seizure.
6. To conserve power that would otherwise be wasted in overcoming excessive friction.
7. To wash away acidic accumulation and the abrasive metal worn from the friction surfaces.

**9. What are the different methods by which the engine parts are lubricated? (CO4) (Remembering)**

1. Gravity system: (a) Drop oilers, individual as sight feed oil cups and common supply tank with feed tubes to different points. (b) Wick oilers, (c) Hand oiling cans.
2. Mechanical system: Splash lubrication
3. Pressure system: (a) Wet sump, (b) Dry sump, and (c) Semi pressure system.

**10. What is fluid film lubrication? (CO4) (Understanding)**

Fluid film lubrication occurs when a copious supply of oil of suitable viscosity is fed into a bearing and the two surfaces move relative to each other at moderate speeds. Then, the two surfaces are physically separated.

**11. What is boundary lubrication? (CO4) (Remembering)**

Boundary lubrication sets in during bearing operation as herein: In fluid film lubrication, with any given oil, the clearance in a bearing at the point of maximum pressure becomes smaller with increased load or reduced speed. When the load or speed reaches a certain value, the oil film becomes too thin to keep the rubbing surfaces apart. Then metal to metal contact may occur. This condition is called boundary lubrication.

**12. What are the blowby losses? (CO4) (Understanding)**

It is the phenomenon of leakage of combustion products (gases) from the cylinder to the crankcase past the piston and piston rings. It depends on (i) the compression ratio, (ii) inlet pressure, (iii) the condition of the piston rings.

**13. What are the effects of blowby losses? (CO4) (Remembering)**

Blow by results following:

- (i) Loss of compression and hence reduction in compression pressure.
- (ii) Undue heating of piston, rings and cylinder wall.
- (iii) Carbonization of oil in the ring grooves.
- (iv) Sticking of ring in the ring groove of the piston.
- (v) Contamination of lubricating oil.

**14. By what means blowby can be reduced? (CO4) (Understanding)**

Blowby can be reduced by the following means:

- (i) Adding compression rings.
- (ii) Reducing the width of the ring face (axial width)
- (iii) Providing an inner spring ring behind the top compression ring.

**15. What are full flow and bypass pressure lubrication system? (CO4) (Understanding)**

The full flow lubrication system forces all of the oil through the oil filter before the oil reaches the parts of the engine. It is the most common.

The bypass lubrication system does not filter all of the oil that enters the engine bearings. It filters some of the extra oil not needed by the bearings.

**16. What is petroil lubrication in two stroke engine? (CO4) (Understanding)**

The lubrication system most widely used in two stroke engines is the “PETROIL” type. In this system fuel and lubricating oil are mixed in proper proportion (from 12:1 to 50:1 as per manufacturers specification or recommendations) and put in the fuel tank. Good mixing of fuel and oil occurs due to the agitation in the fuel tank while the vehicle is moving. This fuel oil mixture is metered into the crankcase via the carburetor jets.

**PART – B**

1. Explain the various frictional losses in an engine. (CO4) (Understanding) (AU Dec’11)
2. Discuss the importance of engine friction. (CO4) (Remembering)
3. Discuss the components into which the total engine friction can be divided. (CO4) (Remembering)
4. Explain the six classes of mechanical friction and the various factors affecting them. (CO4) (Understanding)
5. Explain the various mechanism of lubrication and their functions. (CO4) (Remembering)
6. What are the various components to be lubricated in an engine and explain how it is accomplished? (AU Dec’11) (CO4) (Understanding)
7. Sketch the schematic block diagram of forced lubrication system of automotive engines and explain how constant pressure is maintained over wide speed range and over wear and tear. (CO4) (Understanding)
8. Explain in detail about boundary lubrication and hydrodynamic lubrication. (AU Dec’10) (CO4) (Understanding)
9. Explain in detail about elastohydrodynamic lubrication and bearing lubrication. (CO4) (Understanding)

**UNIT – V**  
**LUBRICANTS**

**PART – A**

1. What are the functions of lubricants? (CO5) (Understanding) (AU Dec’10, Dec’11)
2. Why lubricating oils are treated? List any two treatment process for lubricating oil? (AU Dec’11) (CO5) (Remembering)
3. What are the three types of greases? (CO5) (Remembering)
4. State the properties of synthetic lubricants. (CO5) (Understanding)
5. Mention the names of two instruments which are used for the measurement of viscosity of lubricating oil. (CO5) (Understanding)
6. What is dropping point of grease?
7. Define: Grease. (CO5) (Remembering)
8. What is multi-grade oil? (CO5) (Remembering)

9. Indicate the requirements to be fulfilled by the lubricating oil? (CO5) (Remembering)
10. What is the significance of flash and fire points of a lubricant.
11. What is splash lubrication? (CO5) (Remembering)
12. What is pressure lubrication? (CO5) (Understanding)
13. What is wet sump lubrication? (CO5) (Understanding)
14. What is dry sump lubrication? (CO5) (Understanding)

### **PART – B**

1. Write note on classification of lubricants and explain the properties of lubricating oils. (AU Dec'10) (CO5) (Understanding)
2. Explain how graphite and molybdenum act as lubricants. (AU Dec'11) (CO5) (Remembering)
3. Explain the functions of lubricants and their additive for use in automotive IC engine. (CO5) (Understanding)
4. What are the various desired properties of a lubricant and explain how additives help to achieve the desired properties. (CO5) (Remembering)
5. List out any five instruments used to measure properties of fuel and lubricants and explain 'Redwood viscometer' with neat sketch. (AU Dec'11) (CO5) (Remembering)
6. Briefly explain the saybolt viscometer with neat sketch. (CO5) (Understanding)
7. What do you understand by (i) carbon residue, (ii) oiliness, (iii) Stability of engine oil?
8. Explain the drop point test on grease using grease drop point apparatus with a neat sketch. (CO5) (Understanding)
9. How greases are classified? (CO5) (Understanding)
10. Explain the desired properties of greases. (CO5) (Remembering)
11. Sketch the schematic block diagram of forced lubrication system of automotive engines and explain how constant pressure is maintained over wide speed range and over wear and tear. (CO5) (Understanding)
12. Clearly explain the various wet sump lubrication system. Compare wet sump and dry sump lubrication system. (CO5) (Remembering)

SEMESTER - IV

20AU416

**AUTOMOTIVE FUELS AND LUBRICANTS**

L	T	P	C
3	0	0	3

**Prerequisite: -****Course Outcomes : On successful completion of the course, the student will be able to****Cognitive Level**

CO1: Recognize the manufacturing processes of fuels and lubricants.

Remember

CO2: Evaluate the properties and testing of fuels.

Understand

CO3: Identify the fuels and alternative fuels for engines with their performance and emission characteristics.

Understand

CO4: Discuss the engine friction and various types of lubrication mechanism.

Understand

CO5: Examine the need of lubricants, factors influencing the lubricants and testing of lubricants.

Understand

**UNIT - I REFINERY OF FUELS AND LUBRICANTS****[ 09 ]**

Introduction to Structure of petroleum, refining Process-Distillation, cracking processes, Catalytic reforming, alkylation, isomerisation and polymerization, finishing process- blending, products of refining process. Manufacture of lubricating oil base stocks, manufacture of finished automotive lubricants.

**UNIT - II PROPERTIES AND TESTING OF FUELS****[ 09 ]**

Properties and testing of fuels- density, calorific value, flash point, fire point, distillation, vapour pressure, spontaneous ignition temperature, viscosity, pour point, flammability, ignitability, diesel index, API gravity, aniline point, carbon residue, copper strip corrosion.

**UNIT - III FUELS FOR I.C. ENGINES****[ 09 ]**

Types of fuels, liquid and gaseous fuels, desirable characteristics of SI engine fuels, knocking, octane rating, fuel requirements. CI engine fuels, desirable characteristics, diesel knock, cetane rating, fuel requirements. Additive - mechanism, requirements of additive, fuel additives – specifications of fuels.

**UNIT - IV THEORY OF LUBRICATION****[ 09 ]**

Engine friction: introduction, total engine friction, effect of engine variables on friction, hydrodynamic lubrication, elasto hydrodynamic lubrication, boundary lubrication, bearing lubrication, functions of the lubrication system, introduction to design of a lubricating system.

**UNIT - V LUBRICANTS****[ 09 ]**

Specific requirements for automotive lubricants, oxidation deterioration and degradation of lubricants, additives and additive mechanism, synthetic lubricants, classification of lubricating oils, properties of lubricating oils, tests on lubricants. Grease, classification, properties, test used in grease.

**Total = 45 Periods****Text Books :**

- 1 Ganesan. V, Internal Combustion Engines, Tata McGraw Hill Education, New Delhi, Fourth Edition, 2012.
- 2 Mathur M.L. and Sharma R.P, A Course in Internal Combustion Engines, Dhanpat Rai and sons, New Delhi, 2014.

**Reference Books :**

- 1 Roger F. Haycock and John E. Hiller, Automotive Lubricants Reference Book, SAE International, 2004.
- 2 Brame J.S.S. and King J.G, Fuels Solids, Liquids, Gaseous, Edward Arnold, London, 1961.
- 3 Lansdown A.R, Lubrication: A practical guide to lubricant selection, Pergamon press, Oxford, 1982, ISBN: 9780080267272
- 4 Paul Richards, Automotive fuels reference book, SAE International, New York, Third Edition, 2014.

## **20AU416 AUTOMOTIVE FUELS AND LUBRICANTS**

### **Unit – I**

#### **REFINERY OF FUELS AND LUBRICANTS**

##### **FUELS – INTRODUCTION**

- ❖ The study of the fuels for IC engines has been carried out even since these engines came into existence.
- ❖ Heat engine is a device which converts heat energy into mechanical energy.
- ❖ The chemical reactions which permit the release of heat energy are quite fast but the time taken in preparing a proper mixture of fuel and air depends mainly upon the nature of the fuel.
- ❖ The heat energy is derived from the fuel, a fundamental knowledge of types of fuels and their characteristics is essential in order to understand the combustion phenomenon.
- ❖ The characteristics of the fuel used have considerable influence on
  - the design,
  - efficiency, output and
  - particularly, the reliability and
  - Durability of the engine.
- ❖ Further, the fuel characteristics play a vital role in the atmospheric pollution caused by the engines used in automobiles.

##### **PROPERTIES OF FUELS:**

- ❖ High energy density
- ❖ Good combustion qualities
- ❖ High thermal stability
- ❖ Low deposit forming tendencies
- ❖ Compatibility with the engine hardware
- ❖ Good fire safety
- ❖ Low toxicity
- ❖ Low pollution
- ❖ Easy transferability and onboard vehicle storage



## CHEMICAL STRUCTURE OF PETROLEUM

Petroleum as obtained from the oil wells is predominantly a mixture of many hydrocarbons with differing molecular structure.

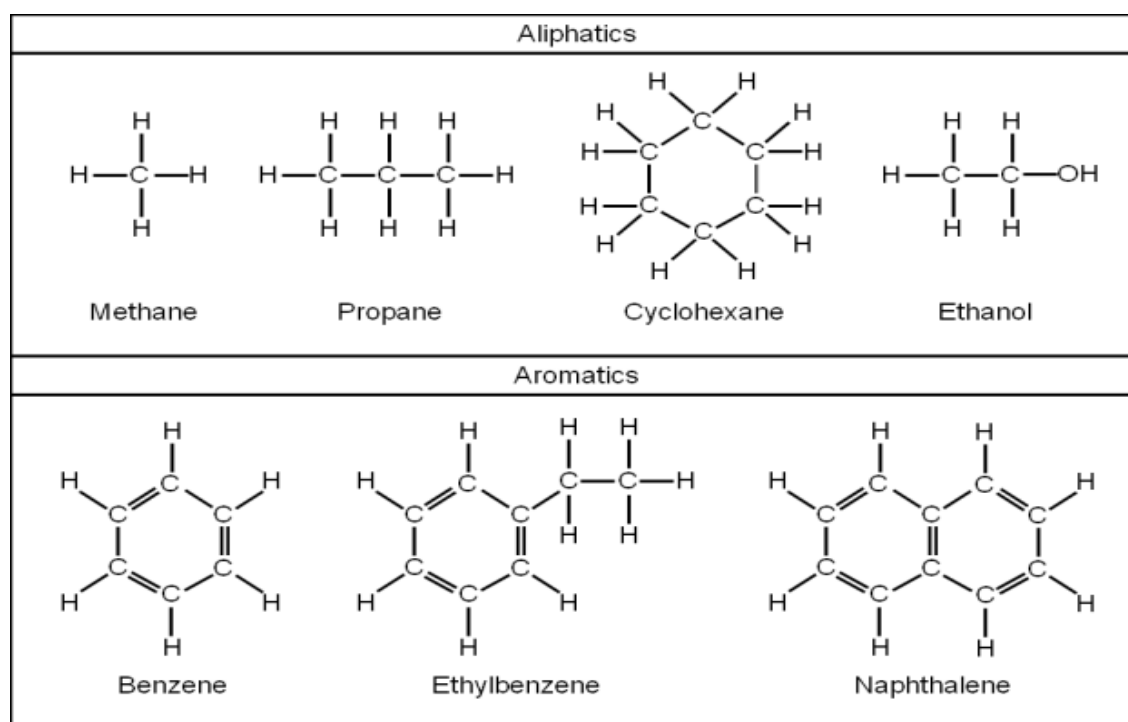
It also contains small amounts of sulphur, oxygen, nitrogen and impurities such as water and sand.

The carbon and hydrogen atoms may be linked in different ways in a hydrocarbon molecule and this linking influences the chemical and physical properties of different hydrocarbon groups.

Most petroleum fuels tend to exhibit the characteristics of the type of hydrocarbon which forms a major component of the fuel.

The basic families of hydrocarbons, their general formulae and their molecular arrangement are shown in table.

Family of Hydrocarbons	General Formula	Molecular Structure	Saturated / Unsaturated	Stability
Paraffin	$C_nH_{2n+2}$	Chain	Saturated	Stable
Olefin	$C_nH_{2n}$	Chain	Unsaturated	Unstable
Naphthene	$C_nH_{2n}$	Ring	Saturated	Stable
Aromatic	$C_nH_{2n-6}$	Ring	Highly Unsaturated	Most Unstable



**Paraffin series:** The normal paraffin hydrocarbons are of straight chain molecular structure.

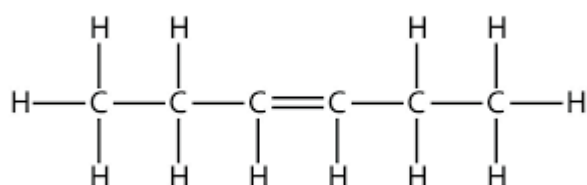
General chemical formula:  $C_nH_{2n+2}$

In these hydrocarbons the valency of all the carbon atoms is fully utilized by single bonds with hydrogen atoms. The paraffin hydrocarbons are saturated compounds and are characteristically very stable. The hydrocarbons which have the same chemical formulae but different structural formulae are known as isomers.

**Olefin series:** Olefins are also straight chain compounds similar to paraffins but are unsaturated because they contain one or more double bonds between carbon atoms.

General chemical formula:  $C_nH_{2n}$

Olefins are not as stable as the single bond paraffins because of the presence of the double bonds in their structure. These are readily oxidized in storage to form gummy deposits.



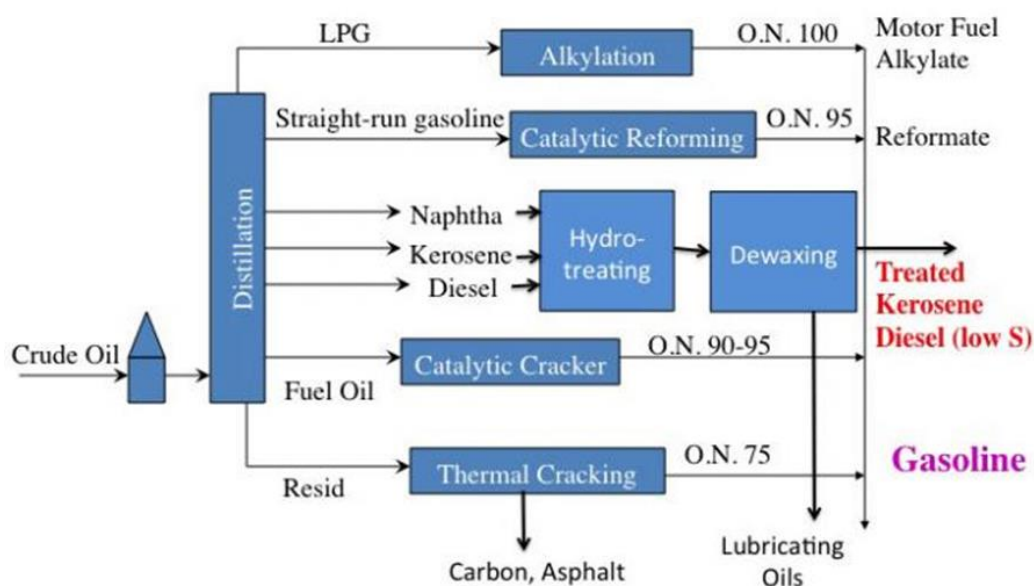
**Hexene**

**Naphthene series:** The naphthenes have the same chemical formula as the olefin series of hydrocarbons but have a ring structure and they called as cyclo-paraffins.

General chemical formula:  $C_nH_{2n}$

They are saturated and tend to be stable. The naphthenes are saturated whereas olefins are unsaturated.

## PETROLEUM REFINING PROCESS



Crude petroleum, as obtained from the oil wells contains gases (mainly methane and ethane) and certain impurities such as water, solids etc.

The crude oil is separated into gasoline, kerosene, fuel oil etc. by the process of fractional distillation.

This process is based on the fact that the boiling points of various hydrocarbons increase with increase in molecular weight.

The liquid petroleum is then vapourized in a still, at temperatures of 600°C and the vapour is admitted at the bottom of the fractionation tower.

## **PETROLEUM REFINING PROCESS**

**Cracking** consists of breaking down large and complex hydrocarbon molecules into simpler compounds with lower boiling points. Thermal cracking subjects the large hydrocarbon molecules to high temperature and pressure and they are decomposed into smaller, lower boiling point molecules.

Catalytic cracking using catalysts is done at relatively lower pressure and temperature than the thermal cracking. Catalytic cracking gives better antiknock property for gasoline as compared to thermal cracking.

**Hydrogenation** consists of the addition of hydrogen atoms to certain hydrocarbons under high pressure and temperature to produce more desirable compounds.

Polymerization is the process of converting olefins, the unsaturated products of cracking, into heavier and stable compounds.

**Alkylation** combines an olefin with an isoparaffin to produce a branched chain isoparaffin in

the presence of a catalyst



**Isomerization** changes the relative position of the atoms within the molecule of a hydrocarbon without changing its molecular formula.

**Cyclization** joins together the ends of a straight chain molecule to form a ring compound of the naphthene family.

**Aromatization** is similar to cyclization, the exception being that the product is an aromatic compound.

**Reformation** is a type of cracking process which is used to convert the low antiknock quality stocks into gasolines of higher octane rating (see section 6.6). It does not increase the total gasoline volume.

**Blending** is a process of obtaining a product of desired quality by mixing certain products in some suitable proportion.

## **PRODUCTS OF REFINING PROCESS**

**Natural gas:** It is found dissolved in petroleum or in huge amounts under earth surface in oil and gas bearing areas. It is made up mainly of the paraffin compound methane, a small amount of propane, ethane, butane and other light hydrocarbons plus some nitrogen and oxygen.

**LPG:** Propane and butane and some other light hydrocarbons after separation from natural gas, if stored under pressure, form liquid and this is called liquified petroleum gas (LPG).

**Gasoline:** It is highest liquid petroleum fraction. All materials boiling up to 200°C is generally considered as gasoline. This is mixture of a number of hydrocarbons. This covers most of fuels used for SI engines.

**Kerosene:** It is a fraction heavier than gasoline. Its boiling range is 150 to 300°C and the specific gravity range is 0.78 to 0.85. It is used in aviation gas turbines, as jet fuel and in lamps and stoves.

**Distillate:** It is slightly heavier than kerosene. These are used tractor fuels and domestic fuels. Diesel Oils: are fuels which lie between kerosene and lubricating oils. These cover a wide range of specific gravity and boiling point. Boiling ranges is 200°C to 370°C. These form of fuels for CI engines.

**Fuel Oils:** are similar to diesel fuel in specific gravity and distillation range but their composition varies in a range wider than those of diesel fuels. These are used as industrial fuels.

**Lubricating Oils:** are made up of heavy distillate of petroleum and residual oil. These are used for lubricating purposes.

**Tar and Asphalt:** are solid or semi-solid undistilled products of petroleum.

**Petroleum Coke:** is used as solid industrial fuel.

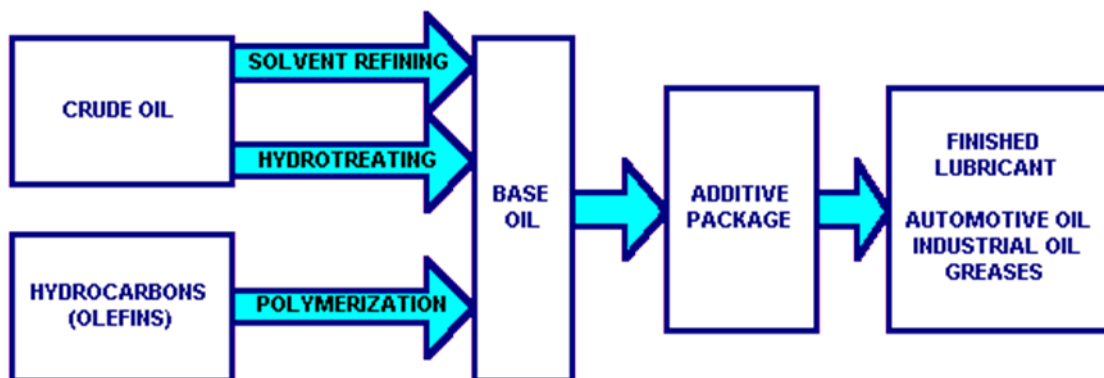
## **Manufacturing of lubricating oil base stocks and also finished automotive lubricants**

The general principles of lubricant base oil manufacturer use a series of steps to improve certain desirable lubricant properties. These include:

- Viscosity Index
- Oxidation
- Heat Resistance
- Low Temperature Fluidity

Starting from petroleum crude oil, the typical process for making lubricant base oil is the following:

- Separation of lighter boiling materials such as gasoline, jet fuel, diesel, etc.
- Removal of impurities including aromatics and polar compounds.
- Distillation to give desired base oil viscosity grades.
- Dewaxing to improve low temperature fluidity.
- Finishing to improve oxidation and heat stability.
- Refined mineral oil that contains no additives. Additives can be added to the oil to create specific properties.



### **SOLVENT REFINING PROCESS**

Light oils such as gasoline, diesel, etc., are first separated from the crude oil by atmospheric distillation. The resulting feedstock is charged to a vacuum Distillation tower where lubricant fractions of specific viscosity ranges are produced. These fractions are treated individually in a solvent extraction tower where the solvent is mixed with the lubricant fractions. This extracts up to 80% of the aromatic hydrocarbons, and other undesirable components. After removing the aromatics, the solvent extracted lube fraction is dewaxed to improve lower temperature fluidity. Finally, the dewaxed lube fractions are finished to improve their colour and stability

## **HYDROTREATING PROCESS**

The elimination of aromatics and impurities is accomplished by chemically reacting the lubricant feedstock with hydrogen in the presence of a catalyst, under conditions of high temperature and pressure.

**Several different reactions occur in this process, the principle ones being:**

- Removal of polar compounds containing sulphur, nitrogen, and oxygen.
- Conversion of aromatic hydrocarbons to saturated cyclic hydrocarbons.
- Breaking up of heavy polycyclic-paraffins to lighter saturated hydrocarbons.

The first stage removes unwanted polar compounds and converts the unsaturated feedstock into a saturated waxy lube fraction. After separation into desired viscosity grades, batches of waxy base oils are dewaxed and then passed through the second stage hydrotreater for additional saturation. This maximizes base oil stability by removing the remaining traces of polar compounds and unsaturates.

## 20AU416 AUTOMOTIVE FUELS AND LUBRICANTS

### Unit – II

#### PROPERTIES AND TESTING OF FUELS

##### PROPERTIES OF FUELS:

**Relative density:** Specific gravity is also called as relative density. It is defined as the ratio of density of a fluid to the density of standard fluid.

**Aniline point:** is the lowest temperature at which the oil is completely miscible with an equal volume of aniline. For a good quality diesel oil the aniline point is greater than 70°F.

**Pour point:** Pour point is the temperature below which the entire mass of the fuel, solid and liquid together, freeze and thus cause flow of fuel impossible. Pour point is usually 5 to 10°C below the cloud point.

**Cloud point:** The temperature below which the wax content of the petroleum oil separates out in the form of a solid is called cloud point.

**Flash Point:** The temperature at which the vapours of oil flash when subject to a naked flame is known as the flash point of the oil. If the container is closed at the time of the test it is called closed flash point, and if open it is called open flash point.

**Fire point:** is the temperature at which the oil, if once lit with flame, will burn steadily at least for 5 seconds. This is usually 11°C higher than open flash point and varies from 190°C to 290°C for the lubricants used for the internal combustion engines.

The flash and fire points indicate the temperature below which oil can be handled without danger of fire, otherwise they are of little consequence.

**Viscosity:** of a fuel is a measure of its resistance to flow. It is important in lubrication and in pumping flow and spraying of liquids. Hence, it is quite significant for diesel fuels.

Very high viscosity can render starting from cold difficult and produce undesirable high pressure in pump and fuel lines.

Too low a viscosity can cause undue wear of pump and increased maintenance.

Viscosity should be low to permit bulk flow in pumping and high enough to do necessary lubrication.

**Diesel index:** An alternative method of expressing the quality of diesel oils is “Diesel index”. It is defined as

$$\text{Diesel index} = \frac{\text{Aniline point } (^{\circ}\text{F}) \times \text{API Gravity at } 60^{\circ}\text{F}(15^{\circ}\text{C})}{100}$$

**Flammability:** is defined as how easily something will burn or ignite, causing fire or combustion. The degree of difficulty required to cause the combustion of a substance is quantified through fire testing.

**Vapour pressure:** The volatility of petrol is also defined in terms of Reid vapour pressure. This is a measure of the vapour pressure of oil at 38°C expressed as millimetres of mercury pressure and indicates initial tendency of a fuel to vapour-lock.

**API gravity:** The American Petroleum Institute gravity, or API gravity is a measure of how heavy or light a petroleum liquid is compared to water.

Thus, the API gravity is an inverse measure of the relative density of a petroleum liquid and the density of the water, but it is used to compare the relative densities of petroleum liquids.

The specific gravity is the ratio of the weight of a unit volume of oil to the weight of the same volume of water at a standard temperature of 15°C (60°F).

$$\text{API gravity} = \frac{141.5}{\text{Specific gravity at } 15^{\circ}\text{C (60}^{\circ}\text{F)}} - 131.5$$

**Calorific value:** the heat evolved by the combustion of unit quantity of a fuel. (Weight for solid fuels; weight or volume for liquid fuels; volume for gaseous fuels.)

**Higher calorific value:** is the total amount of heat produced, when unit mass / volume of the fuel has been burnt completely and the products of combustion have been cooled to room temperature.

**Lower calorific value:** is the total amount of heat produced, when unit mass / volume of the fuel has been burnt completely and the products of combustion allowed to escape to atmosphere.

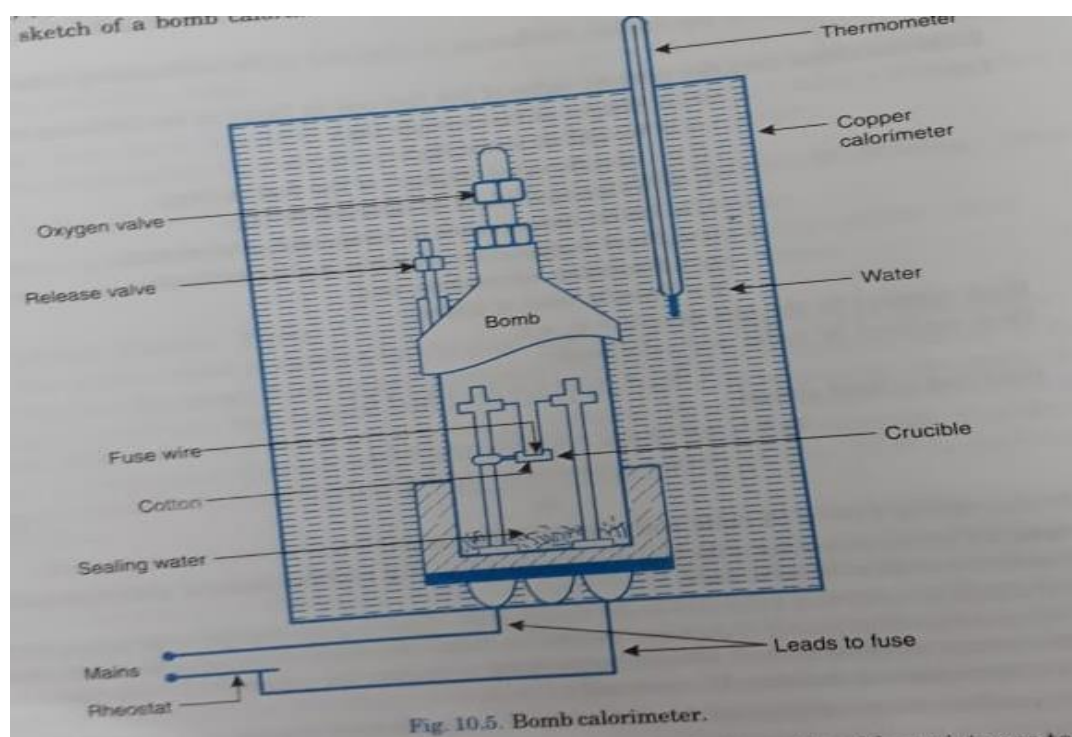
### **BOMB CALORIMETER:**

The calorific value of a solid or liquid fuel can be determined by using bomb calorimeter. The bomb calorimeter consists of a strong stainless steel bomb inside of which the fuel sample is burnt. The bomb is provided with an oxygen inlet valve and two stainless steel electrodes. The bomb is placed in a copper calorimeter containing a known weight of water. The copper calorimeter is provided with a Beckmann thermometer and a stirrer for stirring water.

One gm of fuel sample is accurately weighted into the crucible and a fuse wire is stretched between the electrodes. It should be ensured that the wire is in close contact with the fuel. To



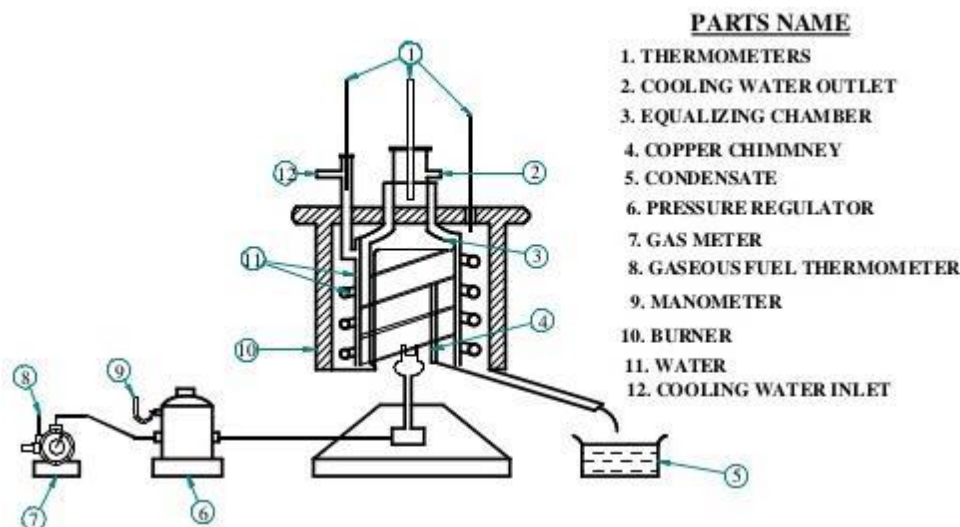
absorb the combustion products of sulphur and nitrogen 2 ml of water is poured in the bomb. Bomb is then supplied with pure oxygen through the valve to an amount of 25 atmosphere. The bomb is then placed in the weighted quantity of water, in the calorimeter. The stirring is started after making necessary electrical connections, when the thermometer indicates a steady temperature fuel is fired and temperature readings are recorded after  $\frac{1}{2}$  minutes intervals until maximum temperature is attained. Then the bomb is removed, the pressure slowly released through the exhaust valve and the contents of the bomb are carefully weighted for further analysis. The heat released by the fuel on combustion is absorbed by the surroundings water and the calorimeter.



- Let,  $X$  = mass in gm of the fuel sample
- $W$  = mass of water in calorimeter
- $w$  = water equivalent of calorimeter, stirrer, thermometer, bomb etc in gm
- $t_1$  = Initial temp of water in  $^{\circ}\text{C}$
- $t_2$  = Final temp of water in  $^{\circ}\text{C}$
- $C$  = calorific value of the fuel
- Now, Heat liberated by the fuel = Heat taken up by the calorimeter
- $X * C = (W + w) (t_2 - t_1)$
- $C = (W + w) (t_2 - t_1) / X$
- i. e, H.C. V =  $(W + w) (t_2 - t_1) / X$

## JUNKERS GAS CALORIMETER

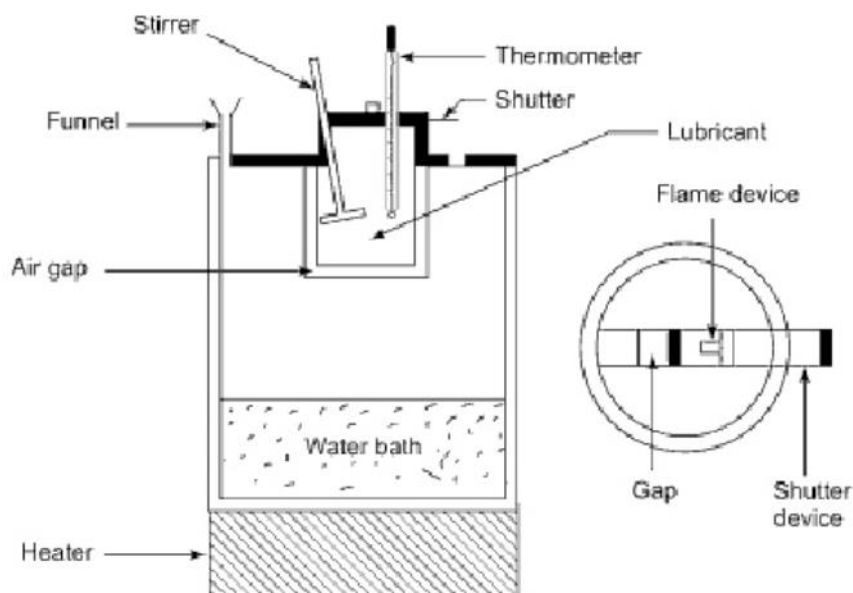
### JUNKERS GAS CALORIMETER



The apparatus consists of a cylinder shell with a copper coil arranged in two pass configuration. With water inlet and outlet to circulate through the copper coil. A pressure regulator, a wet type of gas flow meter and a gas burner, temperature sensor for measuring inlet and out let water temperatures and for flue gas temperature, a 2000 ml measuring jar, Determination of calorific value or heat value of combustible gasses is essential to assess the amount of heat given away by the gas while burning a known amount of gas to heat known amount of fluid (water) in a closed chamber.

Install the equipment on a flat rigid platform near an uninterrupted continuous water source of half inch size and drain pipe. Connect the gas sources to the pressure regulator, gas flow meter and the burner. Insert the thermometer / temperature sensor into their respective places to measure water inlet and outlet temperature and a thermometer to measure the flue gas temperature at the flue gas outlet. Start the water flow through the calorimeter at a study constant flow rate and allow it to drain through over flow. Start the gas flow slowly and light the burner outside the calorimeter. Regulate the flow of gas at a steady rate to any designed flow (Volume). Insert the burner into the calorimeter and allow the outlet water temperature to attain a steady state. Swing the outlet to a 1000ml jar and start the stop watch simultaneously. Record the initial gas flow meter reading at the same time. Note down the time taken to fill 1000ml and at the same time the final gas flow reading recorded by the gas flow meter. Tabulate all the readings and calculate the calorific value of the gas under test. Repeat the experiment by varying the water flow rate or gas flow for different conditions.

## FLASH POINT AND FIRE POINT APPARATUS



**Flash point** of the oil is the lowest temperature at which the oil gives sufficient amount of vapors resulting in a flash when a flame is brought near to it.

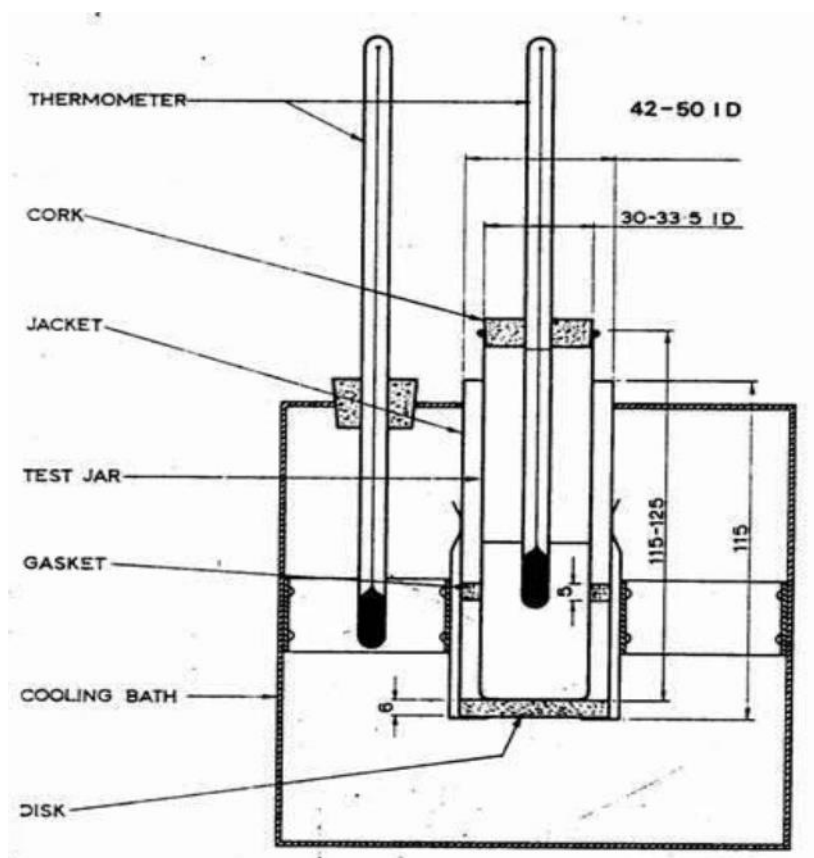
**Fire point** is the lowest temperature at which the oil gives sufficient amount of vapors resulting in a continuous burning of the oil when the flame is brought near to it.

### PROCEDURE:

Clean the cup and fill it with given sample of oil up to the filling mark. Insert the thermometer in the holder. Make sure that the thermometer should not touch the metallic cup. Heat the oil by means of electric heater so that the sample of oil gives out vapour at the rate of  $100^{\circ}\text{C}$  per minute. When the oil gives out vapour, introduce the test flame above the oil, without touching the surface of the oil and watch for flash with flickering sound.

Introducing test flame should be continued at regular intervals until the first flash is observed with peak flickering sound. The temperature corresponding to this flickering sound is noticed and it is flash point temperature of the given sample of oil. Continue the process of heating and introducing the test flame until the oil will begin to burn continuously and observe the temperature. This is the fire point temperature of the given sample of oil. Repeat the test twice or thrice with fresh same sample of oil and observe the results.

## POUR POINT APPARATUS



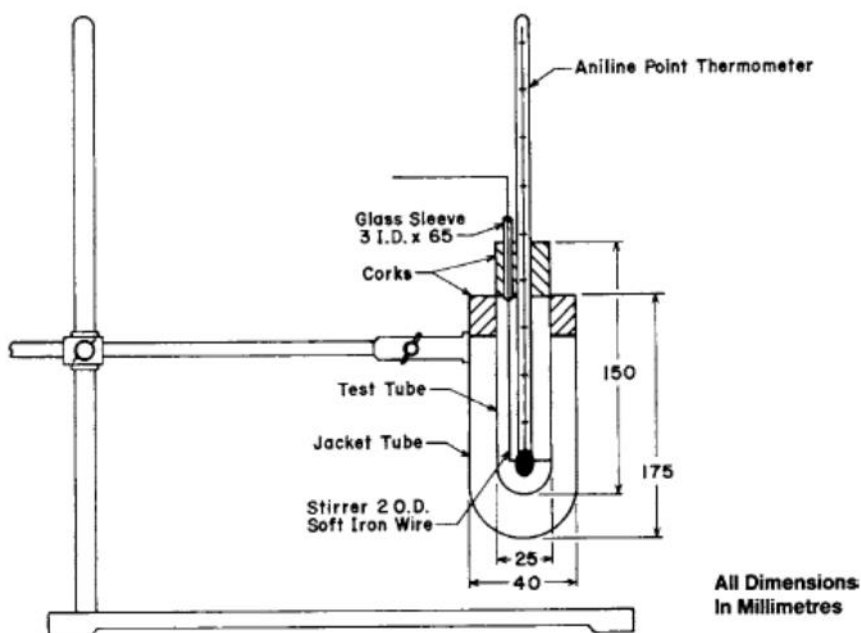
The **pour point** is that temperature just above which the oil sample will not flow under certain prescribed conditions.

### PROCEDURE:

The sample has cooled enough to allow the formation of the crystals. Maintain the bath temperature at  $-1^{\circ}\text{C}$  to  $2^{\circ}\text{C}$ . Support the jacket and jar in a vertical position in the bath so that not more than 25 mm projects from the cooling medium. Beginning at a temperature  $12^{\circ}\text{C}$  above the expected pour point, at each thermometer reading which is a multiple of  $3^{\circ}\text{C}$ , remove the jar from the jacket carefully, and tilt it just enough to see whether the oil will move and the replace it, this complete operation shall not take more than 3 sec. As soon as the sample ceases to flow when the jar is tilted, hold the jar in horizontal position for exactly 5 sec. If the sample shows any movement replace the jar in the jacket and cool down the sample for another  $3^{\circ}\text{C}$ . If the oil shows no movement during the 5 sec, record the reading of the thermometer. Add  $3^{\circ}\text{C}$  to the temperature recorded above and corrected for thermometer errors if necessary, and note down the result as the pour point.

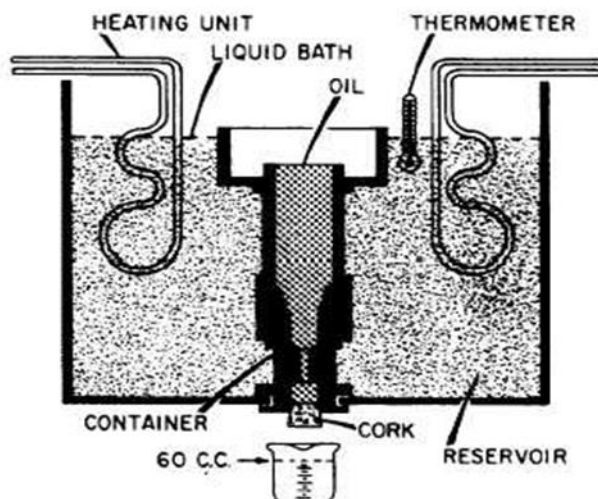
## ANILINE POINT APPARATUS

**Aniline point** is defined as the minimum equilibrium solution temperature for equal volume of aniline sample.



The apparatus consists of test tube, jacket tube, stirrer and thermometer. Equal amount of aniline and the dried sample is introduced in a test tube, placed in the center of a jacket tube. The mixture is stirred rapidly until it becomes homogeneous. If the mixture is not miscible at room temperature heat is applied to the jacket tube. The temperature is raised with a continuous stirring until the dried sample becomes miscible. Then the stirrer is stopped and the mixture is cooled. The point at which the mixture becomes cloudy is the aniline point.

## SAYBOLT VISCOMETER



It is used for determining viscosity of petroleum products. It is standardised with respect to the measurement of viscosity by time of flow from a standardised tube. Viscosity is defined as the time necessary for a quantity of fluid too pass through the orifice under the force of gravity.

Pour the oil in the oil tube until it ceases to overflow into gravity. Keep the oil well stirred with the oil tube thermometer. Adjust the bath temperature until the oil temperature is constant. Place the receiving flask under the outlet tube so that the stream oil will strike the neck of the flask. Time in seconds is so measured, is the saybolt viscosity of oil at the temperature at which the test is made.

## **VOLATILITY OF LIQUID FUELS**

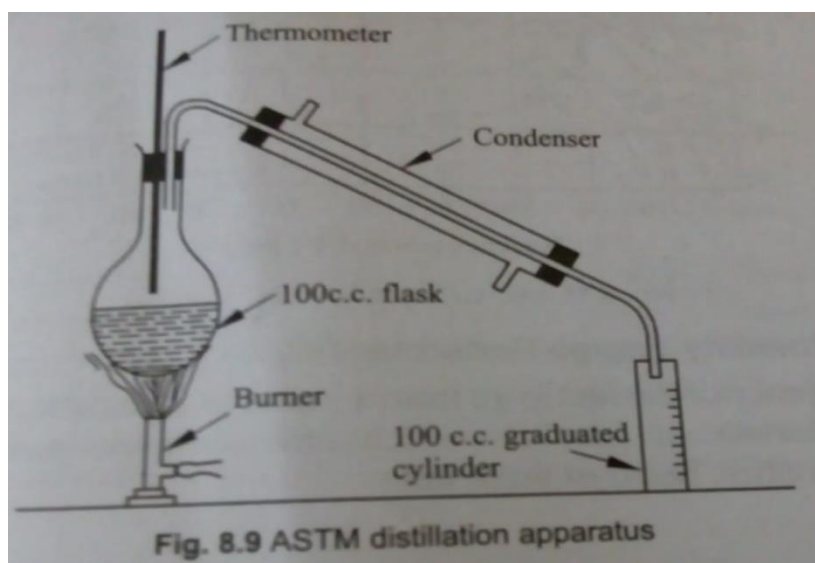
The volatility of a liquid is its tendency to evaporate under a given set of conditions. The constituents of gasoline, which is a mixture of many hydrocarbons, boil off at a wide range of temperature.

If a fuel is heated at a steadily increasing temperature and the percentage evaporated is plotted against temperature, we obtain a curve as shown in figure. This is called the **distillation curve**. A distillation curve is not a true boiling point curve but is commonly used to define and describe the volatility of fuels.

The volatility of gasoline is generally characterized by two laboratory tests.

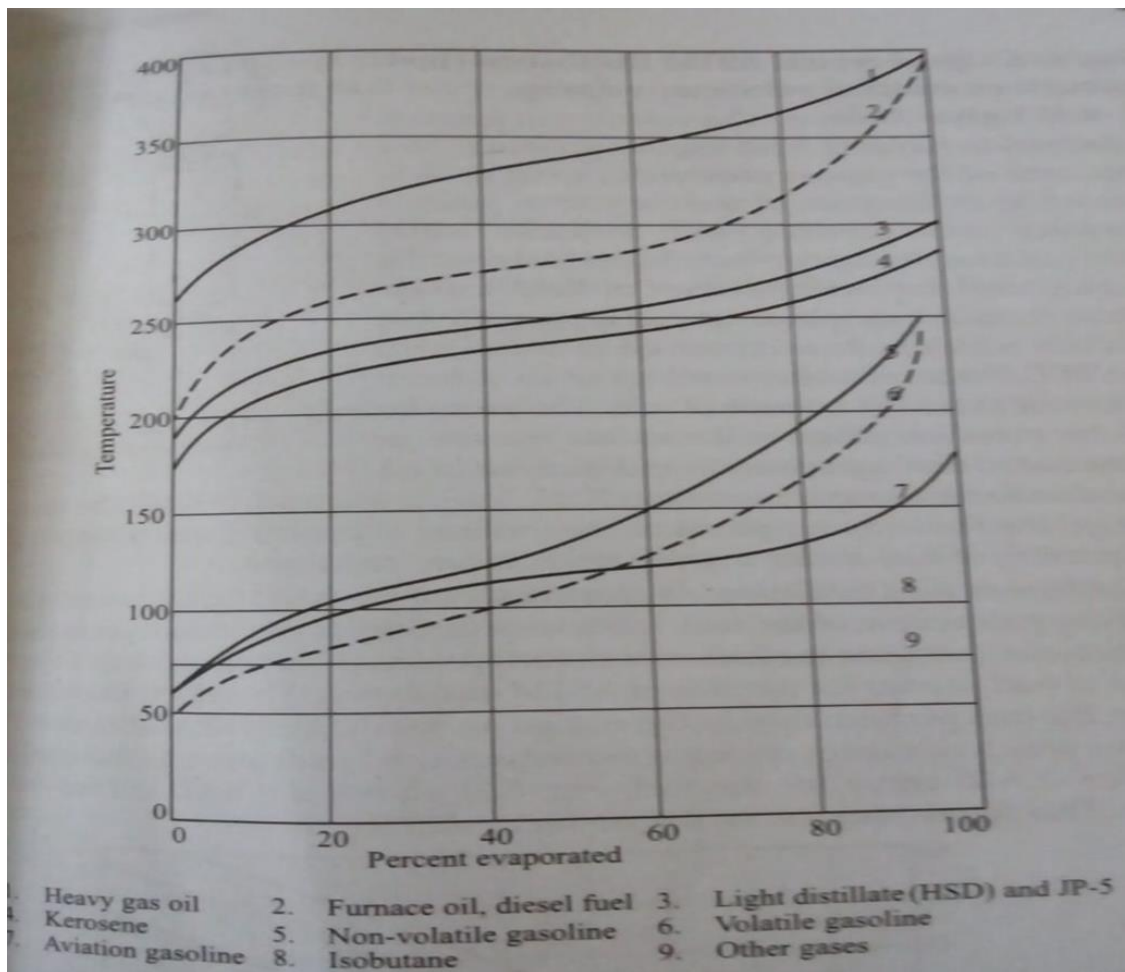
- ASTM Distillation Test
- Reid Vapour Test

## **ASTM DISTILLATION TEST**



One hundred cubic centimeters of fuel is distilled in that apparatus shown in figure. The temperature of the vapour when the first drop of condensate drop from the condenser is recorded as in '**initial boiling point**'. The vapour temperature is also recorded at each successive 10 % collected. When 95 % percent has been distilled the burner flame may need to be increased and the maximum temperature is recorded as the '**end point**'. The mass of the residue in the flask is also recorded.

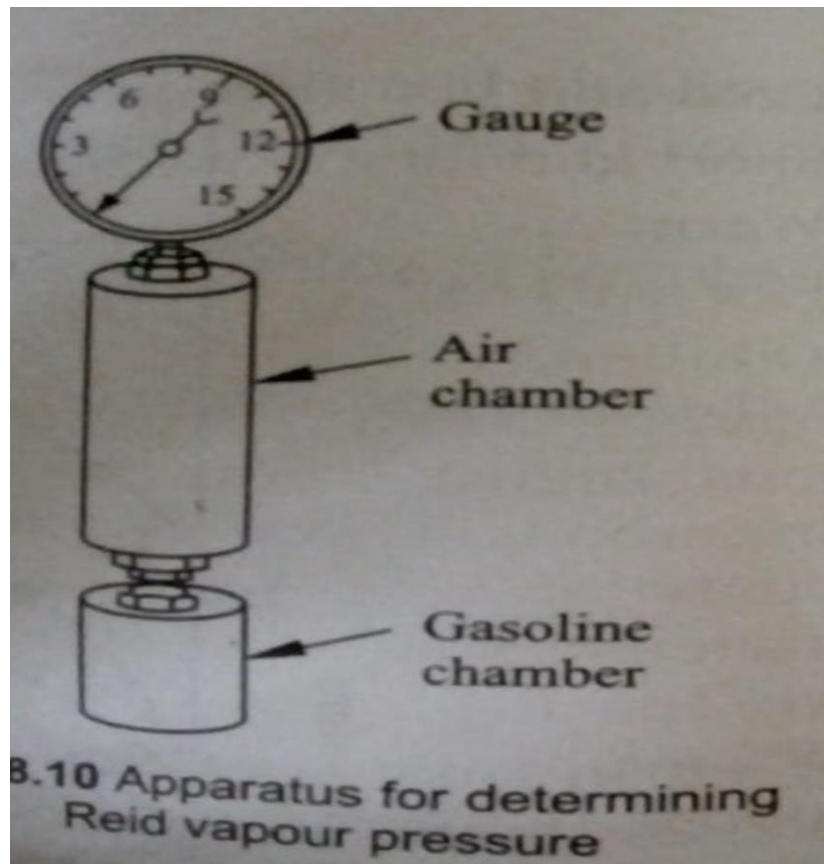
**TYPICAL ASTM DISTILLATION CURVE** for various products of petroleum refining is shown in figure.



### REID VAPOUR PRESSURE TEST

The volatility of petrol is defined in terms of Reid vapour pressure. This is a measured of the vapour pressure of an oil at 38°C expressed as millimeters of mercury and indicates initial tendency of a fuel to vapour-lock. Figure shows the apparatus used for determination of Reid vapour pressure.





A chilled sample of the fuel is placed in the Reid bomb which is then immersed in water bath held at  $38^{\circ}\text{C}$ , the air chamber contains an air volume equal to four times the volume of fuel. The pressure shown by pressure gauge will indicate the rise in pressure due to fuel vaporization and increase in air volume due to temperature increases. If later is subtracted from the total pressure rise we get the Reid vapour pressure, the increase in pressure due to vaporization of a given quantity of fuel under a given temperature condition.

### **SPONTANEOUS IGNITION TEMPERATURE**

It is the minimum temperature at which a fuel ignites in an oxidizing atmosphere without the help of any external source of fire. It is a characteristic property of the fuel and also depends upon other factors like the atmosphere, method of heating and nature of container.

The minimum temperature to which a combustible system is to be raised for bringing about rapid combustion or explosion is known as its spontaneous ignition temperature.



## **CARBON RESIDUE**

The carbon residue is an indication of the fuel to decompose and form carbonaceous material. The carbon residue of a fuel is the tendency to form carbon deposits under high temperature conditions in an inert atmosphere, and may be expressed commonly as Micro Carbon Residue (MCR) or alternatively Conradson Carbon Residue (CCR).

Assessing the carbon forming tendencies of a fuel is carried out using carbon residue test. The two common measures of carbon residue are Ramsbottom (RCR) - ASTM D 524 and Conradson carbon (CCR) - ASTM D 189.

The carbon residue provides information on the carbonaceous deposits which will result from combustion of the fuel. For fuels with a high carbon- high carbon/hydrogen ratio, it is proved more difficult to burn them fully, which results in increased deposits in the combustion and exhaust spaces.

Fuels with a high carbon residue value may cause problems in older engines when they are operating under part load conditions. The carbon residue value of a fuel depends on the refinery processes employed in its manufacture.

## **COPPER STRIP CORROSION**

The Copper Strip Tarnish Test assesses the relative degree of corrosivity of petroleum products, including aviation fuels, automotive gasoline, natural gasoline, solvents, kerosene, diesel fuel, distillate fuel oil, lubricating oil and other products.

A polished copper strip is immersed in 30mL of sample at elevated temperature. After the test period, the strip is examined for evidence of corrosion and a classification number from 1-4 is assigned based on a comparison with the ASTM Copper Strip Corrosion Standards (ASTM D 130). For aviation fuels and natural gasoline the sample tube is placed inside a stainless steel pressure vessel during testing.

This is a qualitative method that is used to determine the level of corrosion of petroleum products. In this test, a polished copper strip is suspended in the product and its effect observed.

The method is well suited for specification settings, internal quality control tools and development and research on aromatic industrial hydrocarbons. It also detects the presence of harmful corrosive substances, like acidic or sulfur compounds, which may corrode the equipment. The value of this test is reported in SI units. Copper strip corrosion is also known as the copper strip test.

## 20AU416 AUTOMOTIVE FUELS AND LUBRICANTS

### Unit – III

#### FUELS FOR I.C. ENGINES

**Types of fuels, liquid and gaseous fuels, desirable characteristics of SI engine fuels, knocking, octane rating, fuel requirements. CI engine fuels, desirable characteristics, diesel knock, cetane rating, fuel requirements. Additive - mechanism, requirements of additive, fuel additives – specifications of fuels.**

#### **FUELS:**

- ❖ Internal combustion engines can be operated on different types of fuels such as
  - Liquid
  - Gaseous and even solid fuels.
- ❖ Depending upon the type of fuel to be used the engine has to be designed accordingly.
- ❖ **Solid Fuels:**
- ❖ The solid fuels find little practical application at present because of the problems in handling the fuel as well as in disposing off, the solid residue after combustion.
- ❖ Compared to gaseous and liquid fuels, solid fuels are quite difficult to handle and storage and feeding are quite cumbersome.
- ❖ **Gaseous Fuels:** Gaseous fuels are ideal and pose very few problems in using them in IC engines.
- ❖ Being gaseous, they mix more homogeneously with air and eliminate the distribution and starting problems that are encountered with liquid fuels.
- ❖ Even though the gaseous fuels are the most ideal for IC engines, storage and handling problems restrict their use in automobiles.
- ❖ **Liquid Fuels:** In most of the modern IC engines, liquid fuels which are the derivatives of liquid petroleum are being used. The three principal commercial types of liquid fuels are benzyl, alcohol and petroleum products.

#### **FUELS FOR SI ENGINES**

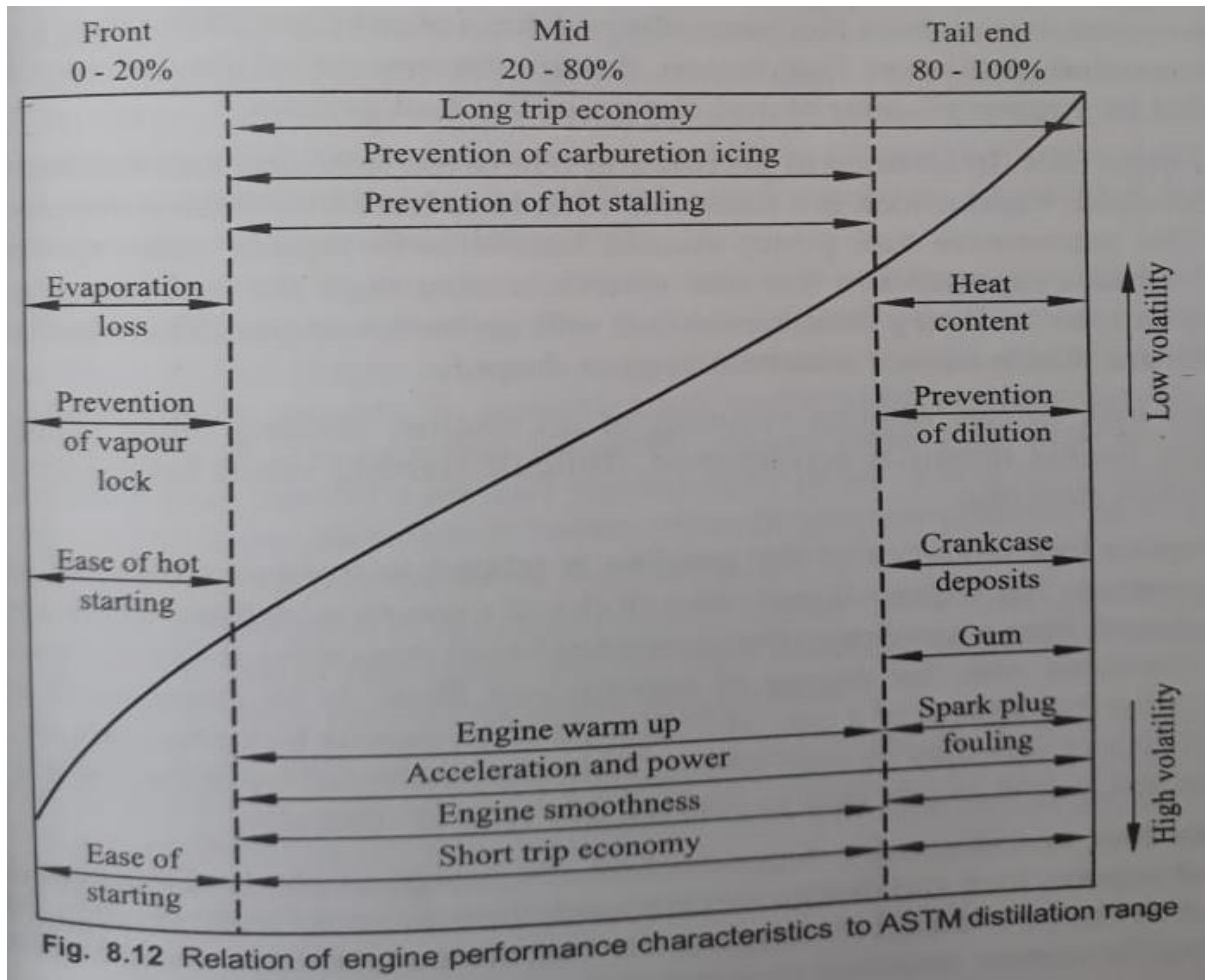
- ❖ **Gasoline:** It is the major product of the petroleum industry and forms most of the SI engine fuel.
- ❖ It is a mixture of various hydrocarbons such as paraffins, olefins, naphthenes, and aromatics.
- ❖ **Requirements of an Ideal Gasoline:**
- ❖ It should mix readily with air and afford uniform manifold distribution
- ❖ It must be knock resistant

- ❖ It should not pre-ignite easily
- ❖ It should be easy to handle.
- ❖ It must have a high calorific value
- ❖ It should not form gum and varnish.
- ❖ It must burn clean and produce no corrosion, etc., on engine parts.

#### **Important qualities (Desirable characteristics) of fuels for SI engine**

- ❖ **Volatility**: it is one of the main characteristics properties of gasoline which determines its suitability for use in an SI engine.
- ❖ Since gasoline is a mixture of different hydrocarbons, volatility depends on the fractional composition of the fuel.
- ❖ **Starting and Warm up**: A certain part of gasoline should vapourize at the room temperature for easy starting of the engine.
- ❖ As the engine warms up, the temperature will gradually increase to the operating temperature.
- ❖ **Operating range performance**: In order to obtain good vapourization of the gasoline, low distillation temperatures are preferable in the engine operating range.
- ❖ Better vapourization tends to produce both more uniform distribution of the fuel to the cylinders as well as better acceleration characteristics by reducing the quantity of liquid droplets in the intake manifold.
- ❖ **Crankcase dilution**: Liquid fuel in the cylinder causes loss of lubricating oil which deteriorates the quality of lubrication and tends to cause damage to the engine through increased friction.
- ❖ Sufficient low distillation temperature to insure that all gasoline in the cylinder is vapourized by the time the combustion starts.
- ❖ **Vapour lock characteristics**: High rate of vapourization of gasoline can upset the carburettor metering or even stop the fuel flow to the engine by setting up a vapour lock in the fuel passages.
- ❖ This characteristics demands the presence of relatively high boiling temperature hydrocarbons throughout the distillation range.
- ❖ **Antiknock quality**: Abnormal burning or detonation in an SI engine combustion chamber causes a very high rate of energy release, excessive temperature and pressure inside the cylinder adversely affects its thermal efficiency.

- ❖ The antiknock properties of a fuel depend on the self-ignition characteristics of its mixture and vary largely with the chemical composition and molecular structure of the fuel.
- ❖ **Gum deposits:** Reactive hydrocarbons and impurities in the fuel have a tendency to oxidize upon storage and form liquid and solid gummy substances.
- ❖ The amount of gum increases with increased concentration of oxygen, with rise in temperature, with exposure to sunlight and also on contact with metals.



### THE PHENOMENON OF KNOCK IN SI ENGINES:

In a spark-ignition engine combustion which is initiated between the spark plug electrodes spreads across the combustible mixture. A definite flame front which separates the fresh mixture from the products of combustion travels from the spark plug to the other end of the combustion chamber.

Heat-release due to combustion increases the temperature and consequently the pressure, of the burned part of the mixture above those of the unburned mixture. In order to effect

pressure equalization the burned part of the mixture will expand, and compress the unburned mixture adiabatically thereby increasing its pressure and temperature. This process continues as the flame front advances through the mixture and the temperature and pressure of the unburned mixture are increased further.

If the temperature of the unburnt mixture exceeds the self-ignition temperature of the fuel and remains at or above this temperature during the period of preflame reactions (ignition lag), spontaneous ignition or autoignition occurs at various pin – point locations. This phenomenon is called knocking. The process of autoignition leads towards engine knock.

### **EFFECT OF ENGINE VARIABLES ON KNOCK**

From the discussion on knock in the previous section, it may be seen that four major factors are involved in either producing or preventing knock. These are the temperature, pressure, density of the unburned charge and the time factors. Since, the effect of temperature, pressure and density are closely interrelated, these three are consolidated into one group and the time factors into another group.

### **EFFECT OF KNOCKING**

The effects of knocking are as follows:

1. **Noise and roughness:** Mild knock is seldom audible and is not harmful. When the intensity of the knock increases a loud pulsating noise is produced due to the development of a pressure wave which vibrates back and forth across the cylinder.
2. **Mechanical Damage**
3. **Carbon deposits**
4. **Increase in heat transfer**
5. **Decrease in power output and efficiency**
6. **Pre-ignition**

### **RATING OF SI ENGINE FUELS**

Resistance to knocking is an extremely important characteristics of fuel for SI engines. These fuels differ widely in their ability to resist knock depending on their chemical composition. A satisfactory rating method for comparing the antiknock qualities of the various fuels has been established.

In addition to the chemical characteristics of hydrocarbons in the fuel, other operating parameters such as fuel-air ratio, ignition timing, dilution, engine speed, shape of the combustion chamber, ambient conditions, compression ratio etc. affect the tendency to knock

in the engine cylinder. Therefore, in order to determine the knock resistance characteristic of the fuel, the engine and its operating variables must be fixed at standard values.

The antiknock value of an SI engine fuel is determined by comparing its antiknock property with a mixture of two reference fuels, iso-octane ( $C_8H_{18}$ ), and normal heptane ( $C_7H_{16}$ ). Iso-octane chemically being a very good antiknock fuel – rating of 100 ON. Normal heptane has very poor antiknock qualities and is given a rating of 0 ON.

Octane number of fuel is defined as the percentage, by volume, of iso-octane in a mixture of iso-octane and normal heptane, which exactly matches the knocking intensity of the fuel in a standard engine under a set of standard operating conditions.

The addition of certain compounds (e.g. tetraethyl lead) to iso-octane produces fuels of greater antiknock quality. The antiknock effectiveness of tetraethyl lead, for the same quantity of lead added, decreases as the total content of lead in the fuel increases.

### **Highest Useful Compression Ratio (HUCR)**

The highest useful compression ratio is the highest compression ratio at which a fuel can be used without detonation in a specified test engine under specified operating condition and the ignition and mixture strength being adjusted to give best efficiency.

#### **The advantages of high-octane fuel:**

1. The engine can be operated at high compression ratio and therefore, with high efficiency without detonation.
2. The engine can be supercharged to high output without detonation.
3. Optimum spark advance may be employed raising both power and efficiency.

### **Research Octane Number and Motor Octane Number**

The tendency of a fuel to knock varies in different engines and in the same engine under different operating conditions.

The Research test is carried out under relatively mild operating conditions (low engine speed and low mixture temperature). Octane number determined by Research test is termed as Research Octane Number (RON). The Research Octane Rating can be related to antiknock quality of the fuel when used in an engine which is highly loaded at low speeds.

The motor test is carried out under relatively more severe operating conditions (High engine speed and higher mixture temperature). Octane number determined by motor test is termed as Motor Octane Number (MON). The Motor Octane Rating is more indicative of antiknock performance at high speeds and part throttle.

## **Sensitivity**

The difference between Research Octane Number (RON) and Motor Octane Number (MON) is called sensitivity.

$$\text{Sensitivity} = \text{RON} - \text{MON}$$

## **Performance Number (PN)**

It is defined as the ratio of the knock-limited indicated mean effective pressure (klimep) of test fuel to knock-limited indicated mean effective pressure (klimep) of iso-octane.

## **CI Engine Fuels:**

Diesel fuels properties are influenced by the crude source and the method of refining. The properties important for a good diesel fuel can be discussed under the main headings:

- (i) Satisfactory handling and storage
- (ii) Smooth and efficient burning
- (iii) Continued cleanliness during user.

## **Important qualities (Desirable characteristics) of fuels for CI engine**

- ❖ **Knock characteristics**: Knock in the CI engine occurs because of an ignition lag in the combustion of the fuel between the time of injection and the time of actual burning.
- ❖ Hence, a good CI engine fuel should have a short ignition lag and will ignite more readily.
- ❖ Furthermore, ignition lag affects the starting, warm up, and leads to the production of exhaust smoke in CI engines.
- ❖ The fuel will have a cetane rating sufficiently high to avoid objectionable knock.
- ❖ **Volatility**: the fuel should be sufficiently volatile in the operating range of temperature to produce good mixing and combustion.
- ❖ **Starting characteristics**: The fuel should help in starting the engine easily.
- ❖ This requirement demands high enough volatility to form a combustible mixture readily and a high cetane rating in order that the self ignition temperature is low.
- ❖ **Smoke and odour**: The fuel should not promote either smoke or odour in the engine exhaust.
- ❖ Good volatility is the first prerequisite to ensure good mixing and therefore complete combustion.

- ❖ **Viscosity**: CI engine fuels should be able to flow through the fuel system and the strainers under the lowest operating temperatures to which the engine subjected to.
- ❖ **Corrosion and wear**: The fuel should not cause corrosion and wear of the engine components before or after combustion.
- ❖ These requirements are directly related to the presence of sulphur, ash and residue in the fuel.
- ❖ **Handling ease**: The fuel should be a liquid that will ready flow under all conditions that are encountered.
- ❖ This requirement is measured by the pour point and the viscosity of the fuel.
- ❖ The fuel should have high flash point and a high fire point.

## THE PHENOMENON OF KNOCK IN CI ENGINES

In CI engines the injection process takes place over a definite interval of time. Consequently, as the first few droplets to be injected are passing through the ignition delay period, additional droplets are being injected into the chamber. If the ignition delay of the fuel being injected is short, the first few droplets will commence the actual burning phase in a relatively short time after injection and a relatively small amount of fuel will be accumulated in the chamber when actual burning commences.

### Effect of Variables on the Delay Period

Increases in variable	Effect on Delay Period	Reason
Cetane number of fuel	Reduces	Reduces the self-ignition temperature
Injection pressure	Reduces	Reduces physical delay due to greater
Injection timing advance	Reduces	Reduced pressures and temperatures when the injection begins
Compression ratio	Reduces	Increases air temperature and pressure and reduces auto-ignition temperature
Intake temperature	Reduces	Increases air temperature
Jacket water temperature	Reduces	Increases wall and hence air temperature
Fuel temperature	Reduces	Increases chemical reaction due to better vaporization
Intake pressure	Reduces	Increases density and also reduces auto-ignition temperature
Speed	Increases in terms of crank angle. Reduce in terms of	Reduces loss of heat



	milliseconds	
Load (Fuel air ratio)	Decreases	Increase the operating temperature
Engine size	Decrease in terms of crank angle. Little effect in terms of milliseconds	Larger engines operator normally at low speeds
Type of combustion chamber	Lower for engines with pre-combustion	Due to compactness of the chamber.

## **RATING OF CI ENGINE FUELS**

In CI engines, the knock resistance depends on chemical characteristics as well as on the operating and design conditions of the engine. The knock rating of a diesel fuel is found by comparing the fuel under prescribed conditions of operation in a special engine with primary reference fuels.

The reference fuels are normal cetane,  $C_{16}H_{34}$ , which is arbitrarily assigned cetane number of 100 and alpha methyl naphthalene,  $C_{11}H_{10}$ , with an assigned a cetane number of 0.

Cetane number of a fuel is defined as the percentage by volume of normal cetane in a mixture of normal cetane and  $\alpha$  – methyl naphthalene which has the same ignition characteristics as the test fuel when combustion is carried out in a standard engine under specified conditions.

Since ignition delay is the primary factor in controlling the initial auto-ignition in the CI engine, it is reasonable to conclude that knock should be directly related to the ignition delay of the fuel. Knock resistance property of diesel oil can be improved by adding small quantities of compounds like amyl nitrate, ethyl nitrate or ether.

## **ADDITIVES**

Some compounds called additives or dopes are used to improve combustion performance of fuels. The main combustion problems that arise when operating conditions become severe or unfavourable are knock and surface ignition.

These combustion problems can be tackled by alternative means such as improvement of combustion chamber design, constructional materials, and fuel and oil quality, etc. Employment of additives, therefore, is only one of a number of measures that can be taken for solving the combustion problems.

## **REQUIREMENTS OF AN ADDITIVE:**

For an additive to be acceptable it must satisfy certain basic requirements, which are as follows:

- i) It must be effective in desired reaction, i.e., knock-resistant or surface ignition resistant or both.
- ii) It should be soluble in fuel under all conditions.
- iii) It should be stable in storage and have no adverse effect on fuel stability.
- iv) It should be in the liquid phase at normal temperature, and volatile to give rapid vaporization in manifold.
- v) It must not produce harmful deposits.
- vi) Its water solubility must be minimum to minimize handling losses.

### **Antiknock Additives**

Knocking is due to chain-branching reactions which product highly energized particles or radicals. These radicals generate more and more of free radicals increasing the reaction rate tremendously and causing knock.

The effectiveness of antiknock additives is measured by the increase in antiknock quality of the treated fuel, that is the increase in octane number. The mechanism by which additives decrease the tendency of the fuel to auto ignite is by no means very clear till now. The antiknock tendency of additives is believed to be the result of breaking of chain reactions thereby delaying the auto ignition of the end mixture and permitting the normal flame to pass through it without combustion knock.

**Tetraethyl Lead:** The principal antiknock agent is tetraethyl lead (TEL)  $(C_2H_5)_4Pb$ . TEL is a heavy liquid weighing about 1.7 kg per litre. It boils at  $200^\circ C$  and is soluble in gasoline. It was discovered in 1922 by Midgley and Boyd of General Motors Corporation of U.S.A. The average gasoline blends have octane number in the range 75 to 85 which is increased to 90 to 95 by addition of TEL. The addition of TEL does not change the reactions forming aldehydes and ketones. It does not affect the rate of energy liberation during a pre-combustion period.

**Tetra Methyl Lead:** The problem of maldistribution can be countered if boiling point of lead carrier can be decreased. So instead of TEL these days, tetra – methyl lead (TML),  $(CH_3)_4Pb$  is sometimes used. Since TML boils at  $110^\circ C$  that is within the medium fraction range, knock protection is provided, and improvements have been noted up to 6 road octane number than those obtained with TEL.

## **20AU416 AUTOMOTIVE FUELS AND LUBRICANTS**

### **Unit – IV**

#### **THEORY OF LUBRICATION**

**Engine friction: introduction, total engine friction, effect of engine variables on friction, hydrodynamic lubrication, elasto hydrodynamic lubrication, boundary lubrication, bearing lubrication, functions of the lubrication system, introduction to design of a lubricating system.**

#### **ENGINE FRICTION:**

- ❖ Friction generally refers to forces acting between surfaces in relative motion.
- ❖ In engines, frictional losses are mainly due to sliding as well as rotating parts.
- ❖ Engine friction is defined as the difference between the indicated horse-power and the brake horse power available at the output shaft.

$$\mathbf{F.P = I.P - B.P}$$

- ❖ Knowledge of engine friction is essential for calculating the efficiency of the engine.
- ❖ A good engine design should not allow the total frictional losses to be more than 30% of the energy input in reciprocating engines.
- ❖ It should be the aim of a good designer to reduce friction and wear of the parts subjected to relative motion.
- ❖ This is achieved by proper lubrication.

#### **FRICTIONAL LOSS IS MAINLY ATTRIBUTED TO THE FOLLOWING MECHANICAL LOSSES;**

- ❖ Direct frictional losses
- ❖ Pumping losses
- ❖ Power loss to drive the components to charge and scavenge
- ❖ Power loss to drive other auxiliary components.

#### **TOTAL ENGINE FRICTION**

Total engine friction, defined as the difference between indicated horse-power (IHP) and brake horse power (BHP), includes the power required to drive the compressor or a scavenging pump and the power required drive engine auxiliaries such as oil pump, coolant pump and fan, etc.

If the power to drive the compressor and auxiliaries is neglected, the total engine friction can be divided into five main components.

These are:

1. Crankcase mechanical friction;
2. Blowby losses
3. Exhaust and inlet system throttling losses
4. Combustion chamber pumping loop losses
5. Piston mechanical friction

### **CRANKCASE MECHANICAL FRICTION**

It can further be sub-divided into:

- (1) Bearing friction
- (2) Valve gear friction
- (3) Pumps and miscellaneous friction

- ❖ The bearing friction includes the friction due to main bearing, connecting rod bearing and other bearings. Bearing friction is viscous in nature and depends upon the oil viscosity, the speed, size and geometry of the journal.
- ❖ The valve gear friction losses vary with the engine design variables and no general equation is available for predicting them.
- ❖ Crankcase mechanical friction is about 15 to 20 per cent of total engine friction.

### **BLOWBY LOSSES**

- ❖ It is the phenomenon of leakage of combustion products past the piston and piston rings from the cylinder to the crankcase past the piston and piston rings.
- ❖ It depends on the compression ratio, inlet pressure and the condition of the piston rings.
- ❖ These losses vary as the **square root of inlet pressure**, and **increase as the compression ratio is increased**.
- ❖ These losses are reduced as the engine speed is increased.

### **EXHAUST AND INLET SYSTEM THROTTLING LOSSES**

- ❖ The standard practice for sizing the exhaust valve is to make them a certain percentage smaller than the inlet valves. This usually results in an insufficiently sized exhaust valve and results in exhaust pumping losses.
- ❖ The inlet throttling loss occurs due to the restrictions imposed by the air cleaner, carburettor venturi, throttle valve, inlet manifold and inlet valve. All these restrictions result in pressure loss.
- ❖ The work required to inhale fresh charge during the suction stroke and to exhaust the combustion products during the exhaust stroke is called the pumping friction work.

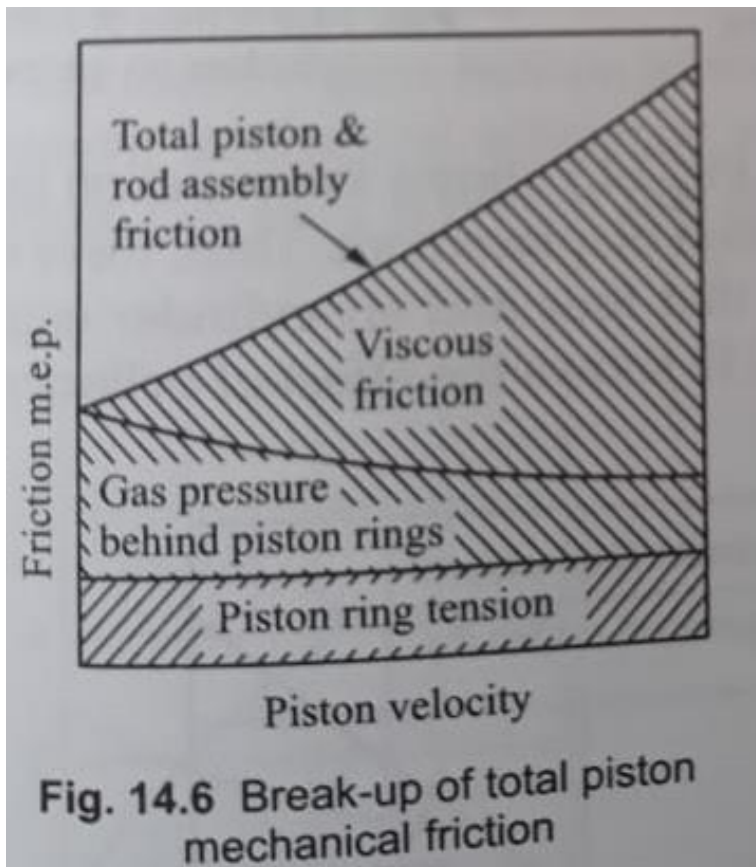
## COMBUSTION CHAMBER PUMPING LOOP LOSSES

- ❖ In case of pre-combustion chamber engines an additional loss occurs.
- ❖ This is the loss occurring due to the pumping work required to pump gases into and out of the pre-combustion chamber.
- ❖ The exact value of this would depend upon the orifice size connecting the pre-combustion chamber and the main chamber, and the speed.
- ❖ Higher the speed greater is the loss and smaller the orifice size greater is the loss.

## PISTON MECHANICAL FRICTION

It can further be sub-divided into:

1. Viscous friction
    - (a) Friction due to ring tension
    - (b) Friction due to gas pressure forces behind the ring.
- ❖ Lower parts of the piston works more or less under viscous friction conditions.
  - ❖ The viscous friction depends upon the viscosity of the oil and the temperature of the various parts of the piston.



- ❖ The degree to which the upper part of the piston can be lubricated also affects the viscous friction.
- ❖ The oil film thickness between piston and cylinder is also affected by the piston side-thrust and the resulting vibrations.
- ❖ Because of ring tension the ring presses against the cylinder wall and results in frictional losses.
- ❖ In addition to the ring tension, the gas pressure behind the ring also causes friction losses.
- ❖ The pressure behind the top piston ring is as high as the pressure of the combustion chamber.
- ❖ For other piston rings it is much lower. For the oil scraper ring, due to its unique construction, no gas pressure can act behind it.

### **EFFECT OF ENGINE VARIABLES ON ENGINE FRICTION**

- ❖ Engine Design
  - Stroke-bore Ratio
  - Effect of Engine Size
  - Piston Rings
  - Compression Ratio
  - Journal Bearings
- ❖ Engine Speed
- ❖ Engine load
- ❖ Cooling Water Temperature
- ❖ Oil Viscosity

#### **Effect of stroke/bore ratio:**

- ❖ The effect of stroke/bore ratio on engine friction and economy is very small.
- ❖ High stroke/bore ratio engines have equally good friction MEP as that for low stroke/bore ratio.
- ❖ Indications are that at high speeds the higher stroke/bore ratio engine may be at some disadvantages.

#### **Effect of cylinder size and number of cylinders:**

- ❖ The friction and economy improves as a smaller number of larger cylinders are used.
- ❖ This is because the proportion between the working piston area and its friction producing area, i.e. circumference, is reduced.

#### **Effect of number of piston rings:**

- ❖ The effect of number of piston ring is not very critical and this number is usually chosen on the basis of cost, size and other requirements rather than on the basis of their effect on friction.
- ❖ Reducing the number of piston rings and reducing the contacting surface of the ring with cylinder wall reduces the friction.

#### **Effect of compression ratio:**

- ❖ The friction mean effective pressure increases with increase in compression ratio.
- ❖ But the mechanical efficiency either remains constant or may improves as the compression ratio is increased.

#### **Effect of Journal Bearings:**

- ❖ Reducing journal diameter/diametrical clearance ratio in journal bearing reduces the FMEP.

#### **Effect of engine speed:**

- ❖ Engine friction increases rapidly with increasing speed. At higher speeds mechanical efficiency starts deteriorating considerably.
- ❖ The best way to improve mechanical efficiency as the speed increases the number of cylinders.

#### **Effect of oil viscosity:**

- ❖ Higher the oil viscosity greater is the friction loss. The temperature of the oil in the crankcase significantly affects the friction losses, wear and service life of an engine.
- ❖ Viscosity and friction loss are proportional to each other.

#### **Effect of cooling water temperature:**

- ❖ A rise in cooling water temperature reduces engine friction through its effect on oil viscosity.
- ❖ Friction losses are high during starting since temperature of water and oil are low and viscosity is high.

#### **Effect of engine load:**

- ❖ As the load increases the maximum pressure in the cylinder has a tendency to increase slightly. This results in slightly higher friction values.
- ❖ For diesel engines the frictional losses are more or less independent of engine load.
- ❖ For petrol engines the throttling losses reduces as the throttle is opened more and more to supply more fuel for allowing an increase in engine load.

## **LUBRICATION**

- ❖ Lubrication is an art of admitting a lubricant between two surfaces that are in contact and in relative motion.
- ❖ The energy loss from the friction between different components of the engine can be minimized by providing proper lubrication.

### **Purpose of Lubrication:**

- ❖ To reduce friction between the moving parts.
- ❖ To reduce wear of the moving parts.
- ❖ To act as a seal and prevent leakage between the parts such as pistons, rings and cylinders.
- ❖ To carry away much of the heat generated by friction, by flowing between the moving parts.
- ❖ To keep down the temperature of the moving parts and thus prevent seizure.

## **MECHANISM OF LUBRICATION**

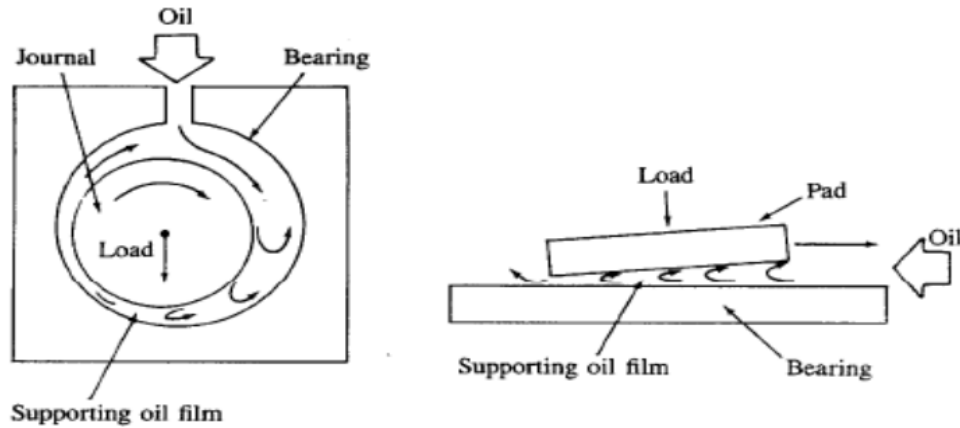
- ❖ Consider two solid blocks which are in contact with each other. In order to move the upper block over the surface of the lower block, a constant tangential force must be applied.
- ❖ The force due to the weight of the upper block acting perpendicular to the surface is called the normal force.
- ❖ The ratio of the tangential force to the normal force is known as the **dynamic coefficient of friction** or the **coefficient of friction,  $f$** .
- ❖ **Hydrodynamic Lubrication**
- ❖ **Elasto-hydrodynamic Lubrication**
- ❖ **Boundary Lubrication**
- ❖ **Bearing Lubrication**

## **HYDRODYNAMIC LUBRICATION**

- ❖ When the block is moved over the surface, a wedge-shaped oil film is built-up between the moving block and the surface.
- ❖ This wedge-shaped film is thicker at the leading edge than the rear. This generates appreciable oil film pressure which carries the load.
- ❖ This type of lubrication where a wedge-shaped oil film is formed between two moving surfaces is called hydrodynamic lubrication.

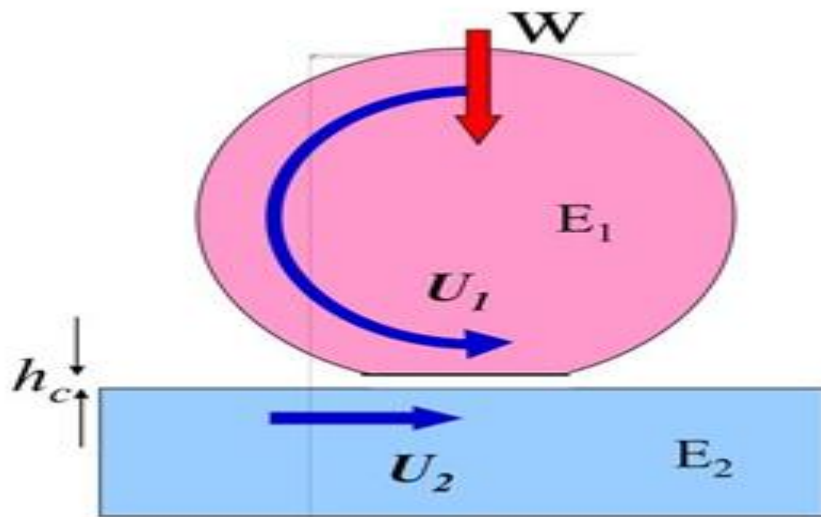


- ❖ The important feature of this type of lubrication is that the load carrying capacity of the bearing increases with increase in relative speed of the moving surfaces.
- ❖ Many surfaces which use hydrodynamic lubrication are cylinder wall, valve guide, main bearings, connecting rod bearings, and camshaft bearings.



### ELASTOHYDRODYNAMIC LUBRICATION

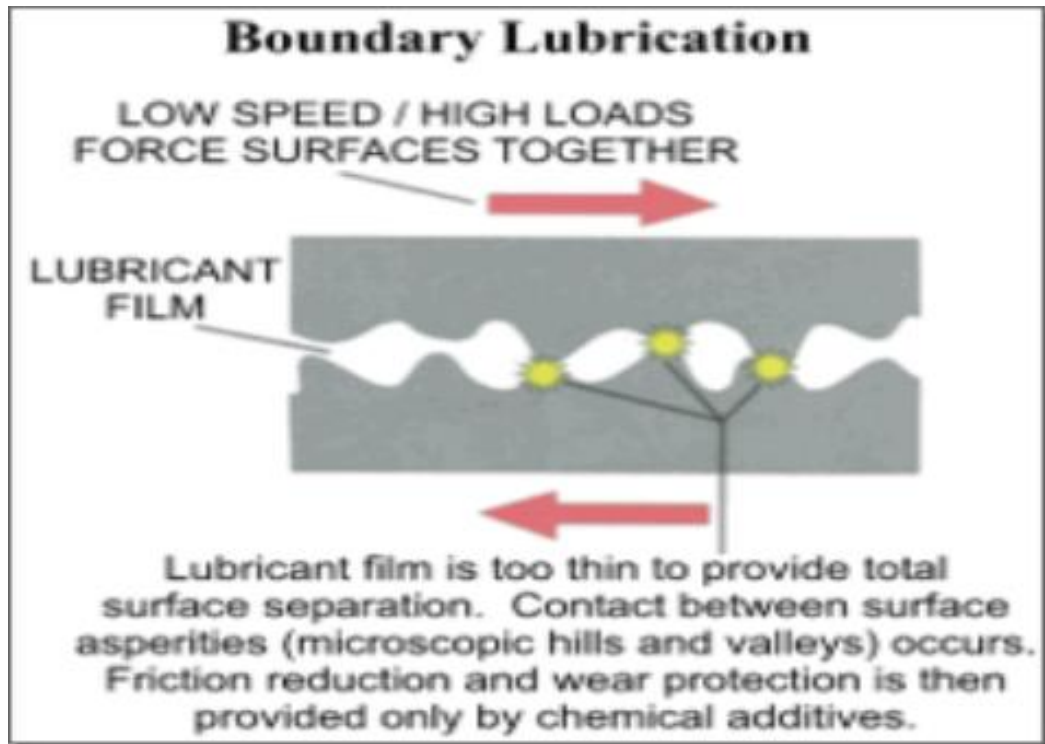
- ❖ It is the phenomenon that occurs when the bearing material itself deforms elastically against the pressure built up of the oil film.
- ❖ This type of lubrication occurs between cams and followers, gear teeth and roller bearings where the contact pressures are extremely high.



### BOUNDARY LUBRICATION

- ❖ If the film thickness between the two surfaces in relative motion becomes so thin that formation of hydrodynamic oil film is not possible and the surface high spots or asperities penetrate this thin film to make metal – to – metal contact then such a lubrication is called boundary lubrication.

- ❖ Such a situation may arise due to too high a load, too thin an oil or insufficient supply of oil due to low speed movement.
- ❖ Most of the wear associated with friction occurs during boundary lubrication due to metal – to – metal contact.
- ❖ A condition of boundary lubrication always exists when the engine is first started.



- ❖ Boundary lubrication may also occur when the engine is under very high loads or when the oil supply to the bearing is insufficient.

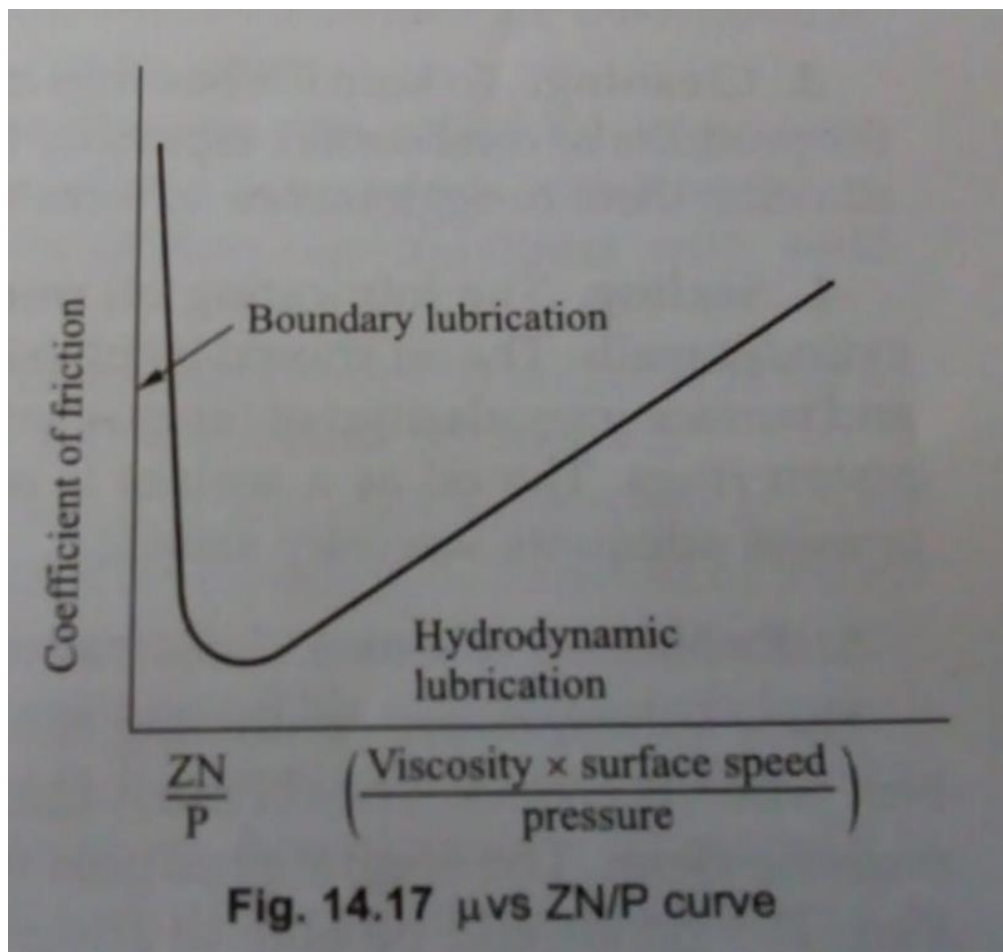
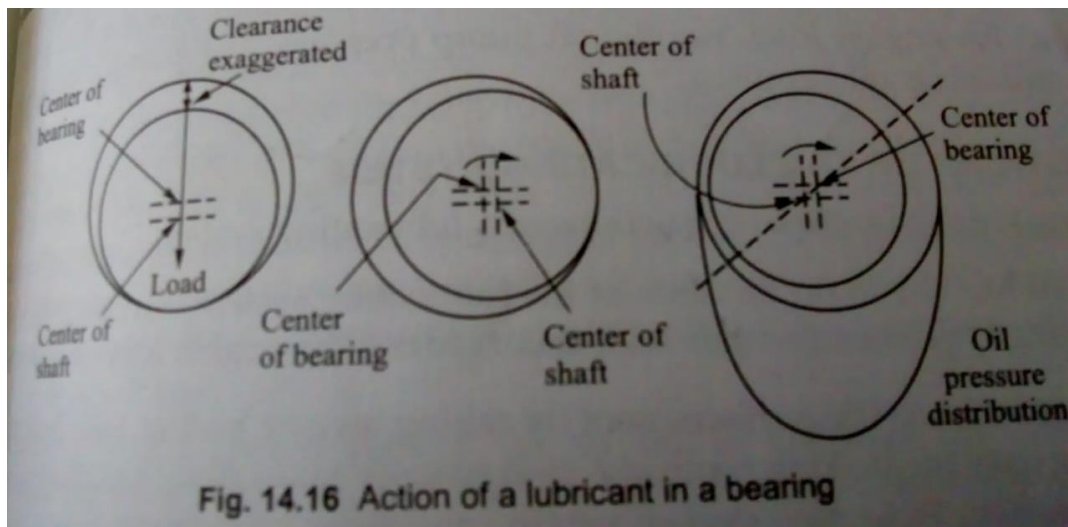
### **HYDROSTATIC LUBRICATION**

- ❖ In hydrostatic lubrication a thin oil film resists its instantaneous squeezing-out under reversal of loads with relatively slow motion. The oil film acts as a cushion.
- ❖ If oil supply is sufficient the oil film thickness is restored before next reversal of load

### **BEARING LUBRICATION**

- ❖ When the shaft is not rotating, there is metal-to-metal contact between the shaft and bearing due to squeezing out of oil from under the journal because of shaft weight.
- ❖ As the shaft starts to rotate, due to high starting friction, the journal momentarily rolls slightly up the side wall.
- ❖ If some surface oil remains on the bearing the shaft will slide back to the bearing bottom when it hits the oil.

- ❖ This climbing and sliding back continues till sufficient oil is supplied by the pump so that the climbing shaft grabs the oil instead of the bearing wall and a curved wedge-shaped oil film is formed.



- ❖ This phenomenon of shift from boundary lubrication to hydrodynamics lubrication is shown in figure with help of the relation between coefficient of friction  $\mu$  and dimensionless number  $ZN / P$  where  $Z$  is the oil viscosity,  $P$  is the pressure and  $N$  is the speed.
- ❖ The coefficient of friction  $\mu$  is minimum only at one value of  $ZN / P$ .
- ❖ To the left side of the point the hydrodynamic pressure developed by the film is too low to lift the shaft and metal-to-metal contact ensues. This is the zone of boundary lubrication.
- ❖ Reduction in viscosity or speed or increase in load( $P$ ), all move the operating point to left.
- ❖ The operation of bearing in this zone is unstable because under boundary lubrication the coefficient of friction is high which results in more heat generation.
- ❖ This decreases the viscosity of the oil which leads to higher value of coefficient of friction through lower values of  $ZN / P$ .
- ❖ This ultimately leads to seizure of metallic surfaces.
- ❖ The bearing operation to the right of this minimum  $ZN / P$  point is stable. An increase in bearing temperature reduces the oil viscosity and hence, results in lower friction coefficient which gives rise to lower bearing temperature due to reduced heat generation, thereby, stabilizing the bearing temperature.

## FUNCTIONS OF LUBRICATION SYSTEM

- ❖ **Lubrication:** Main function is to keep the moving parts sliding freely past each other. Thus, reduce the engine friction and wear.
- ❖ **Cooling:** To keep the surfaces cool by taking away a part of their heat through the oil passing over them. This cooling action usually takes place simultaneous to the lubrication function.
- ❖ **Cleaning:** To keep the bearings and piston rings clean of the products of wear and the products of combustion, especially the carbon, by washing them away.
- ❖ **Reduction of noise:** Lubrication reduces the noise of the engine.
- ❖ **Sealing:** The lubrication oil must form a good seal between piston rings and cylindrical walls.
- ❖ The oil should be physically capable of filing the minute leakage paths and surface irregularities of the mechanical sealing elements, i.e., cylinders, pistons and piston rings.

- ❖ The oil as a sealant is subjected to high temperatures and hence must possess adequate viscosity stability.

## **LUBRICATION SYSTEM**

The function of a lubrication system is to provide sufficient quantity of cool, filtered oil to give positive and adequate lubrication to all the moving parts of an engine. The various lubrication systems used for internal combustion engines may be classified as

1. Mist lubrication system
2. Wet sump lubrication system
3. Dry sump lubrication system

### **Mist lubrication system**

This system is used where crankcase lubrication is not suitable. In two-stroke engine, as the charge is compressed in the crankcase, it is not possible to have the lubricating oil in the sump. Hence, mist lubrication is adopted in practice.

In such engines, the lubricating oil is mixed with the fuel, the usual ratio being 3% to 6%. The oil and the fuel mixture are induced through the carburetor. The fuel is vaporized and the oil in the form of mist goes via the crankcase into the cylinder.

The oil which strikes the crankcase walls lubricates the main and connecting rod bearings, and the rest of the oil lubricates the piston, piston rings and the cylinder.

The **advantages** of this system are its simplicity and low cost as it does not require an oil pump, filter etc.

There are certain **disadvantages**:

1. It causes heavy exhaust smoke due to burning of lubricating oil partially or fully and also forms deposits on piston crown and exhaust ports which affects engine efficiency.
2. Since the oil comes in close contact with acidic vapours produced during the combustion process gets contaminated and may result in the corrosion of bearing surface.
3. This system calls for a thorough mixing for effective lubrication. This requires either separate mixing prior to use or use of some additive to give the oil good mixing characteristics.

In some of the modern engines, the lubricating oil is directly injected into the carburetor and the quantity of oil is regulated. Thus the problem of oil deficiency is eliminated to a very great extent. In this system the main bearings also receive oil from a separate pump. For this

purpose, they will be located outside the crankcase. With this system, formation of deposits and corrosion of bearings are also eliminated.

### **Wet Sump Lubrication System**

In the wet sump system, the bottom of the crankcase contains an oil path or sump from which the lubricating oil is pumped to various engine components by a pump. After lubricating these parts, the oil flows back to the sump by gravity. Again it is picked up by a pump and recirculated through the engine lubricating system.

There are three varieties in the wet sump lubrication system. They are

1. Splash system
2. Splash and pressure system
3. Pressure feed system

### **Dry Sump Lubrication System**

In this system, the supply of oil is carried in an external tank. An oil pump draws oil from the supply tank and circulates it under pressure to the various bearings of the engine. Oil dripping from the cylinders and bearings into sump is removed by a scavenging pump which in turn the oil is passed through a filter, and is fed back to the supply tank.

Thus, oil is prevented from accumulating in the base of the engine. The capacity of the scavenging pump is always greater than the oil pump. In this system, a filter with a bypass valve is placed in between the scavenging pump and the supply tank.

If the filter is clogged, the pressure relief valve opens permitting oil to by-pass the filter and reaches the supply tank. A separate oil cooler with either water or air as the cooling medium, is usually provided in the dry sump system to remove heat from the oil.

## **20AU416 AUTOMOTIVE FUELS AND LUBRICANTS**

### **UNIT – V**

#### **LUBRICANTS**

**Specific requirements for automotive lubricants, oxidation deterioration and degradation of lubricants, additives and additive mechanism, synthetic lubricants, classification of lubricating oils, properties of lubricating oils, tests on lubricants. Grease, classification, properties, test used in grease.**

#### **1. Specific requirements for automotive lubricants**

- ✓ Suitable viscosity
- ✓ Oiliness to ensure adherence to the bearings, and for less friction and wear when the lubrication is in the boundary region, and as a protective covering against corrosion
- ✓ High strength to prevent the metal to metal contact and seizure under heavy load
- ✓ Should not react with the lubricating surfaces
- ✓ A low pour point to allow flow of the lubricant at low temperatures to the oil pump
- ✓ No tendency to form deposits by reacting with air, water, fuel or the products of combustion.
- ✓ Cleaning ability, non-toxic, non-flammability, non-foaming characteristics
- ✓ Low cost.

#### **2. PROPERTIES OF LUBRICATING OILS (Lubricants)**

##### **Viscosity:**

Viscosity of an oil is measure of its resistance to flow and is usually measured in terms of Saybolt Universal Seconds (SUS) which is the time required, in seconds, for a given quantity of the oil to flow through a capillary tube under specified test conditions. Viscosity is usually expressed a two temperatures-18°C (0°F) and 99°C (210°F).

In general, large clearances and high loads require high-viscosity oils whereas high speeds require low viscosity oils. Hence, the oil supplied must be in a position to meet the variable viscosity requirements.

##### **Viscosity Index:**

The viscosity index is a measure of change in viscosity of an oil with temperature as compared to two reference oils having same viscosity at 100°C. It is an empirical number wherein typical Pennsylvania (paraffinic base) oil is assigned an index of 100 and Gulf Coast (naphthenic base) oil is assigned an index of zero.

In general, the high viscosity index number indicates relatively a smaller change in viscosity with temperature. A low index number for a given oil indicates relatively large change of viscosity with temperature.

Thus, the viscosity index of a lubricating oil is an important factor where extreme range of temperature is encountered. The oil must necessarily maintain sufficiently viscosity at operating temperatures. Normally, a high viscosity index is preferred for engine lubrication, because of relatively smaller changes in viscosity of the oil with temperature.

#### **Cloud Point and Pour Point:**

If an oil is cooled, it will start solidifying at some temperature. This temperature is called cloud point.

The pour point is that temperature just above which the oil sample will not flow under certain prescribed conditions. The pour point indicates the lowest temperature at which an oil stops flowing to the pump, bearings or cylinder walls. It is particularly important for immediate oil circulation in respect of starting of engines in very cold climates with gravity lubricating systems.

The fluidity is a factor of pour point and viscosity of the cold oil. Pour point depressants may be added to wax containing oils to lower the pour points instead of dewaxing the oil.

#### **Flash Point and Fire Point:**

The temperature at which the vapours of oil flash when subject to a naked flame is known as the flash point of the oil. If the container is closed at the time of the test it is called closed flash point, and if open it is called open flash point.

Fire point is the temperature at which the oil, if once lit with flame, will burn steadily at least for 5 seconds. This is usually 11°C higher than open flash point and varies from 190°C to 290°C for the lubricants used for the internal combustion engines.

Fire and flash points are good indication of relative flammability of the oil and except for the safety from fire hazards, they do not have any significance for engine operation. However, fire and flash points of used lube oil are very good indication of the crankcase dilution.

#### **Carbon Residue:**

Carbon residue is the quantity of the known mass sample of the oil, which on evaporation under specific conditions remains as carbeneous residue. This is a very rough pointer to the deposit characteristics of the oil. Paraffinic-base oils have higher carbon residue than the asphaltic base oils.



**Oiliness:**

The property of an oil to cling to the metal surfaces by molecular action and then to provide a very thin layer of lubricant under boundary lubrication conditions is called the oiliness or lubricity or film strength. Oiliness or film strength of a lubricant is a measure of the protective film between shaft and bearing.

Film strength refers to the ability of the lubricant to resist welding and scuffing. The lubricating oil used must be of enough film strength to take care of welding and scuffing.

**Colour:**

This has no practical significance except that it is an indication of the degree of refining of the oil.

**Detergency:**

An oil has the property of detergency if it acts to clean the engine deposits. A separate property is the dispersing ability which enables the oil to carry small particles uniformly distributed without agglomeration.

**Stability:**

The ability of the oil to resist oxidation that would yield acids, lacquers and sludge is called stability. Oil stability demands low-temperature (under 90°C) operation and the removal of all hot areas from contact with the oil.

**Foaming:**

Foaming describes the condition where minute bubbles of the air held in the oil. This action accelerates oxidation and reduces the mass flow of oil to the bearings thus reducing the hydrodynamic pressure in the bearing and hence the load bearing capacity of the bearing.

**3. Additives mechanism**

Simple mineral oil has most of the characteristics needed for a good lubricant. However, varying operating conditions require some specific properties it cannot meet.

The examples are the ability of oil to give good viscosity over a range of temperatures, i.e.

High viscosity index,

Resistance to oxidation

The property to dissolve and cleanse the deposits,

The detergency properties, corrosive resistiveness, etc.

In order to confer upon the oil all or some of the required attributes different types of compounds, called additives, are added. The compounds may give one or more of characteristics, or different compounds can be used to give distinct properties and accordingly they are called V.I. improvers, anti-oxidants, detergent-dispersants etc.

### **Major class of engine oil additives and their primary function**

<b>Additive Class</b>	<b>Function</b>
Detergent	Control of high temperature deposits. If overbased also acts as effective acid neutralizer
Dispersant	Control of low- temperature sludge and varnish deposits.
Anti-wear	Reduce wear and prevent scoring, galling and seizure.
V.I. Improver	Increase V.I. of oil, thereby reducing sensitivity of oil viscosity to temperature
Pour point depressant	Reduce pour point of oil by interfering with wax crystallization
Anti-oxidant	Reduce oil oxidation to protect alloy bearings against corrosive attack.

### **3.1. ADDITIVES IN LUBRICATING OILS**

Additives are substances formulated for improvement of the anti-friction, chemical and physical properties of base oils (mineral, synthetic, vegetable or animal), which results in enhancing the lubricant performance and extending the equipment life.

Combination of different additives and their quantities are determined by the lubricant type (Engine oils, Gear oils, Hydraulic oils, cutting fluids, Way lubricants, compressor oils etc.) and the specific operating conditions (temperature, loads, machine parts materials, environment). Amount of additives may reach 30%.

- ✓ Friction modifiers
- ✓ Anti-wear additives
- ✓ Extreme pressure (EP) additives
- ✓ Rust and corrosion inhibitors
- ✓ Anti-oxidants
- ✓ Detergents
- ✓ Dispersants
- ✓ Pour point depressants
- ✓ Viscosity index improvers
- ✓ Anti-foaming agents

#### **Friction modifiers**

Friction modifiers reduce coefficient of friction, resulting in less fuel consumption. Crystal structure of most of friction modifiers consists of molecular platelets (layers), which may easily slide over each other.

The following Solid lubricants are used as friction modifiers:

- ✓ Graphite;

- ✓ Molybdenum disulfide;
- ✓ Boron nitride (BN);
- ✓ Tungsten disulfide (WS<sub>2</sub>);
- ✓ Polytetrafluoroethylene (PTFE).

### **Anti-wear additives**

Anti-wear additives prevent direct metal-to-metal contact between the machine parts when the oil film is broken down. Use of anti-wear additives results in longer machine life due to higher wear and score resistance of the components. The mechanism of anti-wear additives: the additive reacts with the metal on the part surface and forms a film, which may slide over the friction surface.

The following materials are used as anti-wear additives:

- ✓ Zinc dithiophosphate (ZDP);
- ✓ Zinc dialkyldithiophosphate (ZDDP);
- ✓ Tricresylphosphate (TCP).

### **Extreme pressure (EP) additives**

Extreme pressure (EP) additives prevent seizure conditions caused by direct metal-to-metal contact between the parts under high loads.

The mechanism of EP additives is similar to that of anti-wear additive: the additive substance form a coating on the part surface. This coating protects the part surface from a direct contact with other part, decreasing wear and scoring.

**The following materials are used as extra pressure (EP) additives:**

- ✓ Chlorinated paraffins;
- ✓ Sulphurized fats;
- ✓ Esters;
- ✓ Zinc dialkyldithiophosphate (ZDDP);
- ✓ Molybdenum disulfide;

### **Rust and corrosion inhibitors**

Rust and Corrosion inhibitors, which form a barrier film on the substrate surface reducing the corrosion rate. The inhibitors also absorb on the metal surface forming a film protecting the part from the attack of oxygen, water and other chemically active substances.

**The following materials are used as rust and corrosion inhibitors:**

- ✓ Alkaline compounds;
- ✓ Organic acids;
- ✓ Esters;
- ✓ Amino-acid derivatives.

## **Anti-oxidants**

Mineral oils react with oxygen of air forming organic acids. The oxidation reaction products cause increase of the oil viscosity, formation of sludge and varnish, corrosion of metallic parts and foaming.

Anti-oxidants inhibit the oxidation process of oils.

Most of lubricants contain anti-oxidants

**The following materials are used as anti-oxidants:**

- ✓ Zinc dithiophosphate (ZDP);
- ✓ Alkyl sulfides;
- ✓ Aromatic sulfides;
- ✓ Aromatic amines;
- ✓ Hindered phenols

## **Detergents**

Detergents neutralize strong acids present in the lubricant (for example sulfuric and nitric acid produced in internal combustion engines as a result of combustion process) and remove the neutralization products from the metal surface. Detergents also form a film on the part surface preventing high temperature deposition of sludge and varnish.

Detergents are commonly added to Engine oils.

Phenolates, sulphonates and phosphonates of alkaline and alkaline-earth elements, such as calcium (Ca), magnesium (Mg), sodium (Na) or Ba (barium), are used as detergents in lubricants.

## **Dispersants**

Dispersants keep the foreign particles present in a lubricant in a dispersed form (finely divided and uniformly dispersed throughout the oil).

The foreign particles are sludge and varnish, dirt, products of oxidation, water etc.

Long chain hydrocarbons succinimides, such as polyisobutylene succinimides are used as dispersants in lubricants

## **Pour point depressants**

Pour point is the lowest temperature, at which the oil may flow. Wax crystals formed in mineral oils at low temperatures reduce their fluidity. Pour point depressant inhibits formation and agglomeration of wax particles keeping the lubricant fluid at low temperatures. Co-polymers of polyalkyl methacrylates are used as pour point depressant in lubricants.

## **Viscosity index improvers**

Viscosity of oils sharply decreases at high temperatures. Low viscosity causes decrease of the oil lubrication ability.

Viscosity index improvers keep the viscosity at acceptable levels, which provide stable oil film even at increased temperatures.

Viscosity improvers are widely used in multi-grade oils, viscosity of which is specified at both high and low temperature.

Acrylate polymers are used as viscosity index improvers in lubricants.

#### **Anti-foaming agents**

Agitation and aeration of a lubricating oil occurring at certain applications (Engine oils, Gear oils, Compressor oils) may result in formation of air bubbles in the oil - foaming. Foaming not only enhances oil oxidation but also decreases lubrication effect causing oil starvation.

Dimethylsilicones (dimethylsiloxanes) is commonly used as anti-foaming agent in lubricants.

### **4. Synthetic lubricants**

Synthetic lubricants are usually manufactured using chemically modified petroleum components rather than whole crude oil, but they can also be synthesized from other raw materials. Synthetic oil is used as a substitute for lubricant refined from petroleum when operating in extreme temperatures because, generally speaking, it provides superior mechanical and chemical properties to those found in traditional mineral oils.

#### **Advantages of synthetic lubricants**

There are five main advantages synthetic oils have over conventional oils:

**Superior temperature resistance** – Synthetic oils can safely handle higher operating temperatures without breaking down. Synthetic oils are thus recommended for hot climates as well as heavy-duty, turbocharged or hard-use applications.

**Better low-temperature performance** – With easier engine starts in cold weather, synthetic oils are ideal for cold climates. Synthetics flow freely at extremely low temperatures (-30 to -40 degrees Celsius) unlike synthetic oil, which tends to thicken in cold weather.

**Better engine protection** – High-speed engine parts can shear additives as motor oil travels through the engine, thinning the oil. Full synthetic motor oils resist shear under heavy loads better than conventional oils. This helps synthetic motor oil maintain its viscosity grade, enabling it to withstand more extreme engine conditions and offering better engine protection.

**Lower oil consumption** – Synthetic oils experience less “boil-off” than conventional motor oils. A good synthetic will lose only about 4% of its weight when run at 400 degrees for six hours, compared to a 30% loss for conventional petroleum-based oil. The lower evaporation rate translates to less oil consumption and higher oil-drain intervals of up to 30,000km.

**Cleaner engines** – Synthetics don't break down or sludge up as fast as ordinary mineral-based oils. This maintains lubrication efficiency during short city trips in winter.

## 5. CLASSIFICATION OF LUBRICATING OILS

Lubricants can be broadly classified, on the basis of their physical state, as follows:

- (1) Liquid lubricants or lubricating oils;
- (2) Semi-solid lubricants or greases,
- (3) Solid lubricants.

### 5.1. Lubricating oils

Lubricating oils reduce friction and wear between two moving/sliding metallic surfaces by providing a continuous fluid film in-between them. They also act as: (a) cooling medium; (b) sealing agent, and (c) corrosion preventer. Good lubricating oil must possess: (a) low pressure (or high boiling point), (b) adequate viscosity for particular service conditions, (c) low freezing point, (d) high oxidation resistance. (e) Heat stability, (f) non-corrosive properties, (g) stability to decomposition at the operating temperatures. Lubricating oils are further classified as:

**(1) Animal and vegetable oils:** Before the advent of the petroleum industry, oils of the vegetable and animal origins were the most commonly used lubricants. They possess good oiliness (a property by virtue of which the oil sticks to the surface of machine parts, even under high temperatures and heavy loads). However, they: (i) are costly, (ii) undergo oxidation easily forming gummy and acidic products and get thickened on coming in contact with air, (iii) have some tendency to hydrolyze, when allowed to remain in contact with moist-air or aqueous medium. So at present, they are rarely used as such. Actually, they are used as "blending agent" with other ' lubricating oils (like mineral oils) to produce desired effects in the latter.

**(2) Mineral or petroleum oils** are obtained by distillation of petroleum. The length of the hydrocarbon chain in petroleum oils varies between about 12 to 50 carbon atoms. The shorter-chain oils have lower viscosity than the longer-chain hydrocarbons. These are the most widely used lubricants, because they are; (i) cheap, (ii) available in abundance, and (iii) quite stable under service conditions. However, they possess poor oiliness as compared to that of animal and vegetable oils. The oiliness of petroleum oils can be increased by the addition of high molecular weight compounds like oleic acid, stearic acid, etc.

**(3) Blended oils:** No single oil serves as the most satisfactory lubricant for many of the modern machineries. Typical properties of petroleum oils are improved by incorporating specific additives. These so-called 'blended oils' give desired lubricating properties, required for particular machinery. The following additives are employed

(i) Oiliness-carriers: Oiliness of a lubricant can be increased by addition of an oiliness-carrier like vegetable oils (e.g., coconut oil, castor oil) and fatty acids (like palmitic acid, stearic acid, oleic acid. etc.).

(ii) Extreme-pressure additives: Under extreme-pressure, a thick film of oil is difficult to maintain, and the oil need to have a high oiliness. Besides improving oiliness directly, high-pressure additives are used. These additives contain certain materials which are absorbed on the metal surface or react chemically with metal, producing a surface layer of low shear-strength on the metal surface, thereby preventing the tearing up of the metal. Another property of high-pressure additives is that they react, at high temperature on metal surfaces, forming surface alloys so as to prevent the welding together of the rubbing parts under severe operating conditions.

The main substances added for high-pressure lubrication are : (a) fatty ester, acids, etc., which form oxide film with the metal surface ; (i) organic materials, which contain sulphur ; (c) organic chlorine compounds ; (d) organic phosphorus compounds. High-pressure lubricants also contain some lead in order to produce thin film of lead sulphide and other lead compounds on the surfaces of machines like gear teeth.

(iii) Pour-point depressing additives used are phenol and certain condensation products of chlorinated wax with naphthalene. These prevent the separation of wax from the oil.

(iv) Viscosity-index improvers are certain high molecular weight compounds like hexanol.

(v) Thickeners such as polystyrene are materials usually of molecular weight between 300 and 3,000. They are added in order to give the lubricating oil a higher viscosity.

(vi) Antioxidants or inhibitors, when added to oil, retard oxidation of oil by getting themselves preferentially oxidized. They are particularly added in lubricants used in internal combustion engines, turbines, etc., where oxidation of oil is a serious problem. The antioxidants are aromatic, phenolic or amino compounds.

(vii) Corrosion preventers are organic compounds of phosphorus or antimony. They protect the metal from corrosion by preventing contact between the metal surfaces and the corrosive substances.

(viii) Abrasion inhibitors like tricresyl phosphate.

(ix) Antifoaming agents (like glycols and glycerol) help in decreasing foam formation.

(x) Emulsifiers such as sodium salts of sulphonic acid.

(xi) Deposit inhibitors are detergents such as the salts of phenol and carboxylic acids. Deposits are formed in internal combustion engine, due to imperfect combustion. Such additive disperses and cleans the deposits.

## 5.2. GREASES OR SEMI-SOLID LUBRICANTS

Lubricating grease is a semi - solid, consisting of a soap dispersed throughout liquid lubricating oil. The liquid lubricant may be petroleum oil or even synthetic oil and it may contain any of the additives for specific requirements.

Greases are prepared by saponification of fat (such as tallow or fatty acid) with alkali (like lime, caustic soda, etc.), followed by adding hot lubricating oil while under agitation. The total amount of mineral oil added determines the consistency of the finished grease.

The structure of lubricating greases is that of a gel. Soaps are gelling agents, which give an interconnected structure (held together by intermolecular forces) containing the added oil.

At high temperatures, the soap dissolves in the oil, whereupon the interconnected structures cease to exist and the grease liquefies.

Consistency of greases may vary from a heavy viscous liquid to the stiff solid mass. To improve the heat-resistance of grease, inorganic solid thickening agents (like finely divided clay, bentonite, colloidal silica, carbon black, etc.) are added.

Greases have higher shear or frictional resistance than oils and, therefore, can support much heavier loads at lower speeds. They also do not require as much attention unlike the lubricating liquids. But greases have a tendency to separate into oils and soaps.

### **Grease are used :**

- (i) in situations where oil cannot remain in place, due to high load, low speed, intermittent operation, sudden jerks, etc. e.g. rail axle boxes,
- (ii) in bearing and gears that work at high temperatures ;
- (iii) in situations where bearing needs to be sealed against entry of dust, dirt, grit or moisture, because greases are less liable to contamination by these ;
- (iv) in situations where dripping or spurting of oil is undesirable, because unlike oils, greases if used do not splash or drip over articles being prepared by the machine.

For example, in machines preparing paper, textiles, edible articles, etc.

The main function of soap is thickening agent so that grease sticks firmly to the metal surfaces. However, the nature of the soap decides: (a) the temperature up to which the grease can be used; (b) its consistency; (c) Its water and oxidation resistance. So, greases are classified after the soap used in their manufacture.

### **Important greases are:**

- (i) **Calcium-based greases** or cup-greases are emulsions of petroleum oils with calcium soaps. They are, generally, prepared by adding requisite amount of calcium hydroxide to hot oil (like tallow) while under agitation. These greases are the cheapest and most commonly



used. They are insoluble in water, so water resistant. However, they are satisfactory for use at low temperatures, because above  $80^{\circ}\text{C}$ , oil and soap begins to separate out.

(ii) **Soda-base greases** are petroleum oils, thickened by mixing sodium soaps. They are not water resistant, because the sodium soap content is soluble in water. However, they can be used up to  $175^{\circ}\text{C}$ . They are suitable for use in ball bearings, where the lubricant gets heated due to friction.

(iii) **Lithium-based greases** are petroleum oils, thickened by mixing lithium soaps. They are water-resistant and suitable for use at low temperatures [up to  $15^{\circ}\text{C}$ ] only.

(iv) **Axle greases** are very cheap resin greases, prepared by adding lime (or any heavy metal hydroxide) to resin and fatty oils. The mixture is thoroughly mixed and allowed to stand, when grease floats as stiff mass. Filters (like talc and mica) are also added to them. They are water-resistant and suitable for less delicate equipments working under high loads and at low speeds. Besides the above, there are greases prepared by dispersing solids (like graphite, soapstone) in mineral oil. These are mostly used in rail axle boxes, machine bearings, tractors rollers, wires ropes etc.

### 5.3. SOLID LUBRICANTS

Solid lubricants are used where: (i) operating conditions are such that a lubricating film cannot be secured by use of lubricating oils or greases; (ii) contamination (by the entry of dust or grit particles) of lubricating oil or grease is unacceptable, (iii) the operating temperatures or load is too high even for a semi-solid lubricant to remain in position; and (iv) combustible lubricants must be avoided.

The two most usual solid lubricants employed are graphite and molybdenum disulphide. Graphite consists of a multitude of flat plates, one atom thick, which are held together by only weak bonds, so that the force to shear the crystals parallel to the layers is low. Consequently, the parallel layers slide over one another easily. Usually, some organic substances are mixed solid lubricants so that they may stick firmly to the metal surface.

On the other hand, molybdenum disulphide has a sandwich like structure in which a layer of a Mo atoms lies between two layers of S atoms.

Poor interlaminar attraction is responsible for low shear strength in a direction parallel to the layers. Solids lubricants are used either in the dry powder or mixed with water or oil. The solids fill up the low spots in the surfaces of moving parts and form solid films, which have low frictional resistance. The usual coefficient of friction between solid lubricants is between 0.005 and 0.01.

- (a) **Graphite** is the most widely used of all solid lubricants. It is very soapy to touch, non-inflammable and not oxidized in air below 375°C. In the absence of air, it can be used upto very much higher temperatures.

Graphite is used either in powdered form or as suspension. Suspension of graphite in oil or water is brought about with the help of an emulsifying agent like tannin. When graphite is dispersed in oil, it is called 'oildag' and when it is dispersed in water; it is called 'aquadag'. Oildag is found particularly useful in internal combustion engines, because it forms a film between the piston rings and the cylinder and gives a tight-fit contact, thereby increasing compression. On the other hand, oil dag is useful where a lubricant free from oil is needed. e.g., foodstuffs industry.

Graphite is also mixed with greases to form graphite-greases, which are used at still higher temperatures.

**Uses:** As lubricant in air-compressors, lathes, general machine-shop works, foodstuffs industry, railway track-joints, open gears, chains, cast iron bearings, internal combustion engine, etc.

- (b) **Molybdenum disulphide** possesses very low coefficient of friction and is stable in air up to 400°C. Its fine powder may be sprinkled on surfaces sliding at high velocities, when it fills low spots in metal surfaces, forming its film. It is also used along with solvents and in greases. Besides the more important graphite and molybdenum disulphide, other substances like soapstone, talc, mica, etc., are also used as solid lubricants.

## 6. CLASSIFICATION OF GREASES

**Calcium greases:** are emulsion of petroleum oil with calcium soap. they are generally prepared by adding requisite amount of calcium hydroxide to a hot oil, like allow while under agitation. These greases are cheapest and most commonly used. They are insoluble in water, so water resistant.

**Soda based greases:** are petroleum oil, thickened by mixing sodium soap, they are not water resistant, because the sodium soap content is soluble in water. They can be used up to 175°C. They are suitable for use in ball bearing, where the lubricant gets heated due to friction.

**Lithium based greases:** are petroleum oils are thickened by mixing lithium soap. They are water resistant and suitable for use at lower temperature.

**Axle greases** are very cheap resin greases, prepared by adding lime (or any heavy metal hydroxide) to resin and fatty oils. The mixture is thoroughly mixed and allowed to stand, when grease floats as stiff mass. Filters (like talc and mica) are also added to them. They are water-resistant and suitable for less delicate equipments working under high loads and at low speeds.

Besides the above, there are greases prepared by dispersing solids (like graphite, soapstone) in mineral oil. These are mostly used in rail axle boxes, machine bearings, tractors rollers, wires ropes etc.

## **7. Properties of Greases**

**Pumpability:** is the ability of a grease to be pumped or pushed through a system. It is the ease with which a pressurized grease can flow through lines, nozzles.

**Water resistance:** This is the ability of a grease to withstand the effects of water with no change in its ability to lubricate.

**Consistency:** Grease consistency depends on the type and amount of thickener used and the viscosity of its base oil. A grease consistency is its resistance to deformation by an applied force. The measure of consistency is called penetration. It is the degree of hardness of a grease and may vary considerably with temperature.

**Dropping point:** it is an indicator of the heat resistance of grease. As grease temperature increases, penetration increases until the grease liquefies and the desired consistency is lost. The dropping point is the temperature at which a grease becomes fluid enough to drip.

### **High temperature effects:**

Grease, by its nature, cannot dissipate heat by convection like a circulating oil. Consequently, without the ability to transfer away heat excessive temperature result in accelerated oxidation or even carbonization where grease hardness.

## **8. TESTING OF LUBRICANTS**

### **Physical tests**

1. Viscosity test
2. Flash point and fire point test
3. Loss due to evaporation
4. Cold or pour point test
5. Specific gravity test

### **Chemical Tests**

1. Acid value test
2. Saponification value test
3. Insoluble residue test
4. Moisture and emulsification test

### **Viscosity Tests**

1. Redwood viscometer
2. Saybolt viscometer
3. Engler viscometer

# Analysis of Lubricating Greases and Petroleum Products

## A. Lubricating Greases

Greases are defined as lubricating oils bodied by soaps. Sometimes fillers are also added. For stiff greases, sodium stearate soap is commonly used. Aluminium, lead, potassium, zinc, barium, lithium, iron and strontium are employed, giving particular characteristics to the greases. Lead soaps give greases with little body and are used for added film strength. Sometimes beeswax, rosin oil, candle pitch and other asphaltic materials are added with the lubricating oil.

Fillers most commonly used are asbestos, chalk, talc, gypsum, wood flour etc. Graphite is also used.

### Analysis

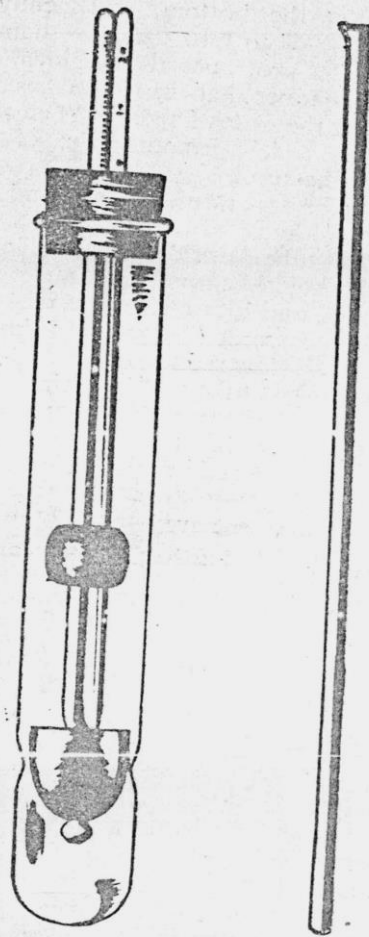
#### 1. Dropping point of lubricating greases.

The dropping point is the temperature at which the grease passes from a semisolid to a liquid state under the conditions of test. The dropping points of some greases, particularly those containing aluminium soaps, are known to decrease upon ageing, the change being much greater than the deviation permitted in results obtained by different laboratories.

For this test an apparatus as shown in the sketch (page 169) is used. This special equipment is chromium-plated brass cup. A pyrex test tube with rim, 4 inches in length by 15/32 inch inside diameter and provided with three indentations equally spaced, about 3/4 inch from the bottom, is also needed. Two ASTM partial immersion thermometers reading  $-5$  to  $+300^{\circ}$  are required.

### **Drop point tests on grease using grease drop point apparatus with a neat sketch.**

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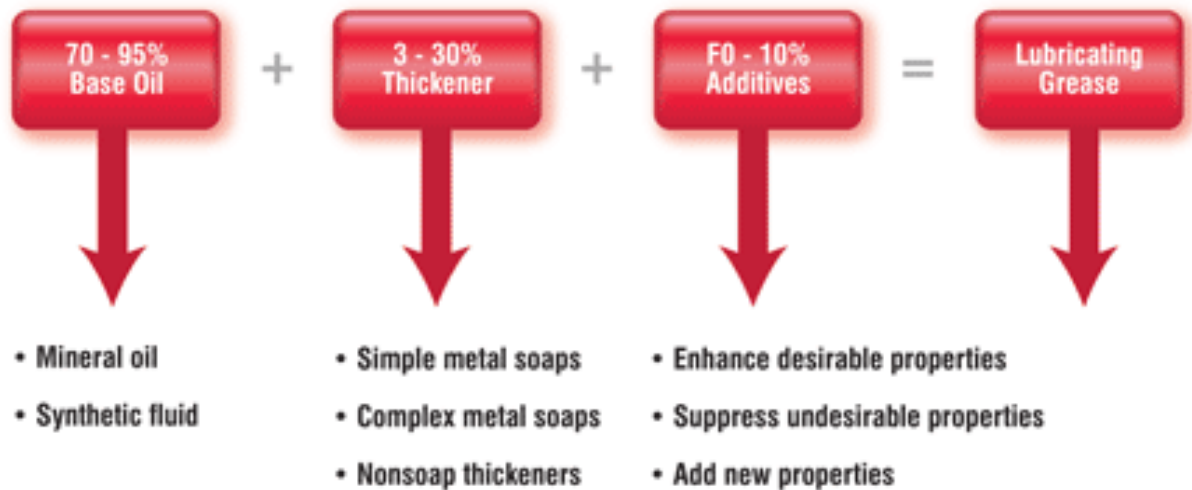
APPARATUS FOR DROPPING  
POINT OF LUBRICATING GREASES

Fig. 1

#### Process

Adjust the thermometer in the pyrex tube so that the tip of the bulb is about 3 mm. above the bottom of the grease cup. Suspend the assembled apparatus by means of a clamp in an oil bath consisting of a 400 mls. beaker and suitable oil. Suspend the second thermometer in the oil bath so that its bulb is app. at the same level as the bulb of the thermometer in the test tube.

Remove the grease cup, and fill by pressing the larger opening into the grease to be tested until the cup is filled. Remove excess grease with a spatula. Hold the cup in a vertical position with the



## CLASSIFICATION OF LUBRICATING OILS

- The lubricating oils are normally classified according to **their viscosity**.
- The SAE (Society of Automotive Engineers) method of assigning number to different oils is in universal use.
- SAE has assigned a number to an oil whose viscosity at given temperatures falls in certain range.
- There are two temperatures used as reference in assigning the numbers to oils -18°C (0°F) and 99°C (210°F).
- SAE 5W, 10W and 20W grades are defined in terms of viscosity at -18°C and are oils which render starting in cold climates easy, while SAE 20, 30, 40 and 50 grades defined in terms of viscosity of 99°C (210°F), are the oils which work satisfactorily in normal and hot climates.
- These numbers are merely for classification of oils according to viscosity and do not indicate quality of the oil since these do not consider factors like stability, oiliness, etc.
- With the advent of additives such as V.I. Improvers it is possible to develop oil with more than one viscosity at different temperatures. Thus, SAE 20W/50 oil has a viscosity equal to that at SAE 20W oil at -18°C (0°F) and a viscosity equal to that of SAE 50 at 99°C (210°F). Such oils are called **multi-grade oils**.