LUBRICANTS

SYLLABUS

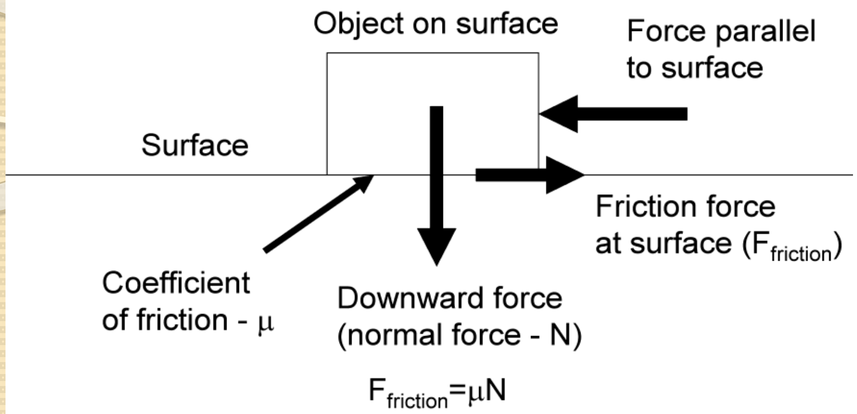
- Introduction, Role and Effects of Friction, Functions of Lubricants, Mechanism of Lubrication – Thick Layer, Thin layer and Extreme Pressure Lubrication.

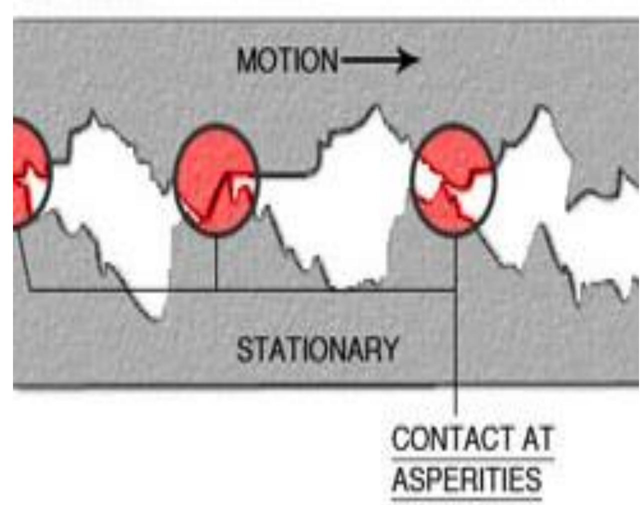
Liquid Lubricants: Detailed classification of Vegetable Oils, Animal Oils, Mineral Oils, Blended and Synthetic Oils, Physical and Chemical Properties, Their Importance and Testing;

Semi-solid Lubricants: Examples, Physical and Chemical Properties, Their Importance and Testing;

Solid Lubricants: Examples and Their Structures; Biodegradable Lubricants; Lubricating Emulsions; Cutting Fluids; Selection of Lubricants.

Friction





- The resistance that one surface or object encounters when moving over another.
- The coefficients of friction depend on the nature of the surface.
- The frictional force is nearly independent of the contact area between the objects.

Disadvantages of friction

- Wear and Tear of the machine parts - Wear is the gradual removal of material at solid surfaces occurring as a result of damage caused by friction and/or corrosion.
- It necessitates regular servicing OR replacement of parts OR whole of machines.
- Economic impact – a) Halt in production, b) Less work,
  c) Maintenance, d) replaced parts / machine
- Frictional heat – Moving objects generate kinetic energy. Friction causes this kinetic energy to change into thermal energy. Thus, work is converted into heat.
- Decreased efficiency of machines - Input would never be equal to output due to friction.

- Overheating of engines - This accelerates breakdown and decreases efficiency.
- Expansion of materials - This would lead to mechanical instabilities which impact the functioning of machines even more than normal wear and tear as this has a structural impact as well.
- Increase in fuel consumption – For performing same amount of work, more power is required
- Economic impact –More power consumption
- Noise generation – Loss of energy

Lubricants and Lubrication

Any substance introduced between two moving /sliding surfaces with a view to reduce the frictional resistance between them, is known as a lubricant.

The process of reducing frictional resistance between moving /sliding surfaces, by the introduction of lubricants in-between them, is called lubrication.

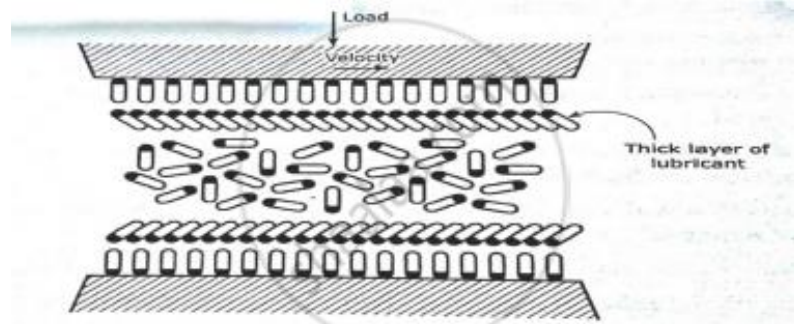
Functions of a Lubricant

- It reduces surface deformation, wear and tear, because the direct contact between the rubbing surfaces is avoided.
- It reduces the maintenance and running cost of the machine.
- It reduces waste of energy, so that efficiency of machine is enhanced.
- It reduces expansion of metal by local frictional heat.
- It avoids seizure of moving surfaces, since the use of lubricant minimizes the liberation of frictional heat.
- It also, sometimes, acts as a seal.

E.g. lubricant used between piston and the cylinder wall of an internal combustion engine.

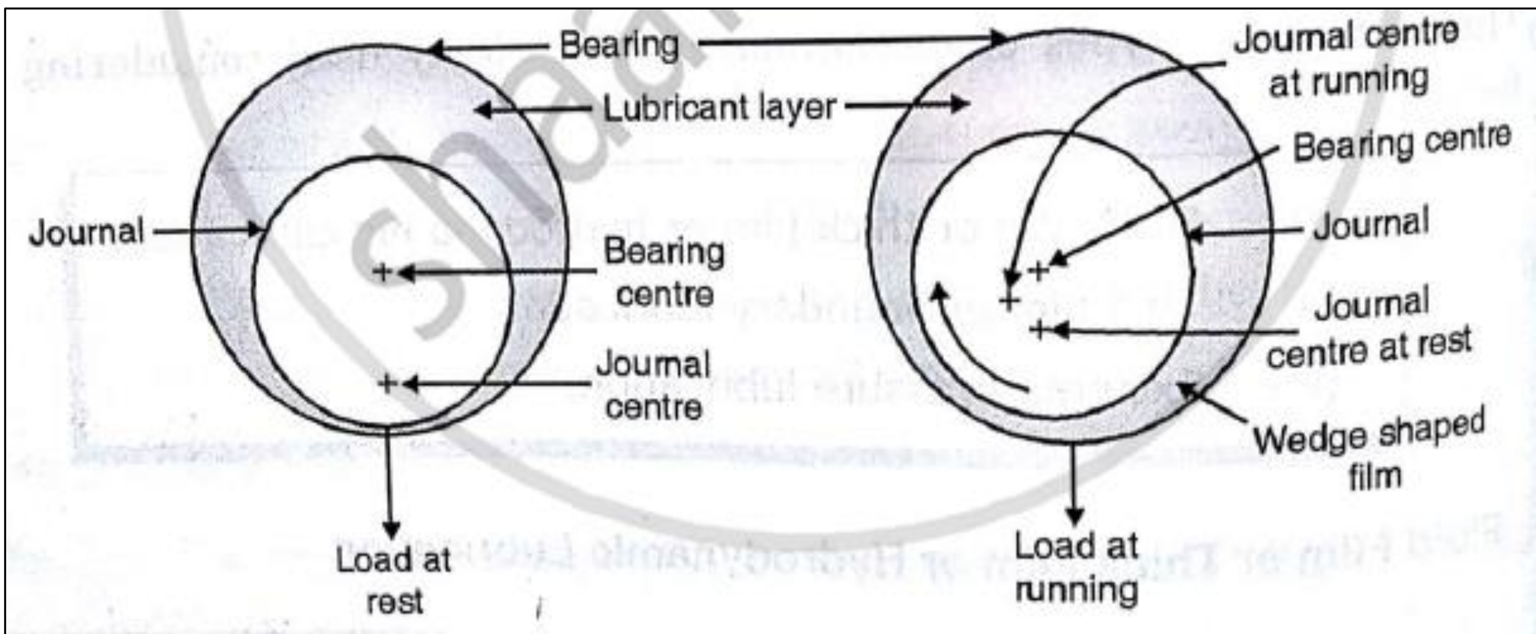
MECHANISM OF LUBRICATION

Thick-Film Lubrication

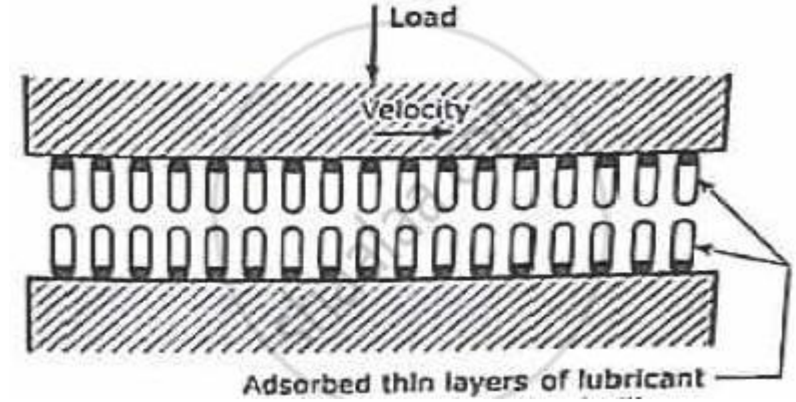


- Initial and most basic type of mechanism
- Lubricant layer is at least 1,000 Å thick, no contact between metal parts
- Conditions – Less speed, Less load (pressure), no jerks
- Result: Low Temperature
- Coefficient of friction = 0.001 to 0.03
- Satisfactory lubricants - Hydrocarbon oils (No semisolid or solid), thus also called Fluid film mechanism.
- Applied in: Delicate instruments, light machines like watches, clocks, guns, sewing machines, scientific instruments
- Not applicable for majority of machines

- Hydrodynamic Lubrication- A type of thick layer mechanism
- The basis of hydrodynamic lubrication is the formation of an oil wedge. When the journal rotates, it creates an oil taper or wedge between the two surfaces, and the pressure build up with the oil film supports the load.



Thin-Film Lubrication



- Based on the principle of adsorption (physical bonds)
- Only at the surface, 10-20 Å , Boundary Lubrication
- This happens when:
  - The speed is not uniform (varying)
  - The load is very high, resulting in high temp.
  - Viscosity of the oil is low
- Coefficient of friction = 0.05 to 0.15
- Satisfactory lubricants - Hydrocarbon oils with additives (liquid /solid) as well as semi-solid /solid lubricants

Additives should have following properties:

- Long hydrocarbon chains
- Polar groups to promote spreading
- Lateral attraction between the chains
- Active groups or atoms, which can form chemical linkages with the metals of other surfaces

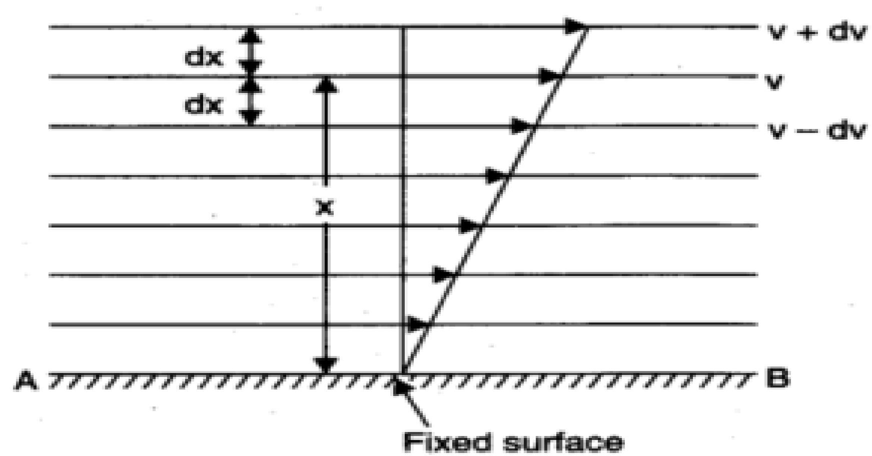
Additives typically make up about 0.1- 30 %.

Extreme Pressure Lubrication

- Extremely high pressure, resulting in extremely high temperature
- Breakage of physical bonds
- Formation of chemical covalent bonds
- Extreme pressure additives - organic compounds having active radicals or groups such as boron, chlorine, sulfur or phosphorus
- Examples: chlorinated esters, tricresyl phosphate, zinc dialkyldithiophosphates

Viscosity

- The property of a liquid or fluid by virtue of which it offers resistance to its own flow.
- Thickness

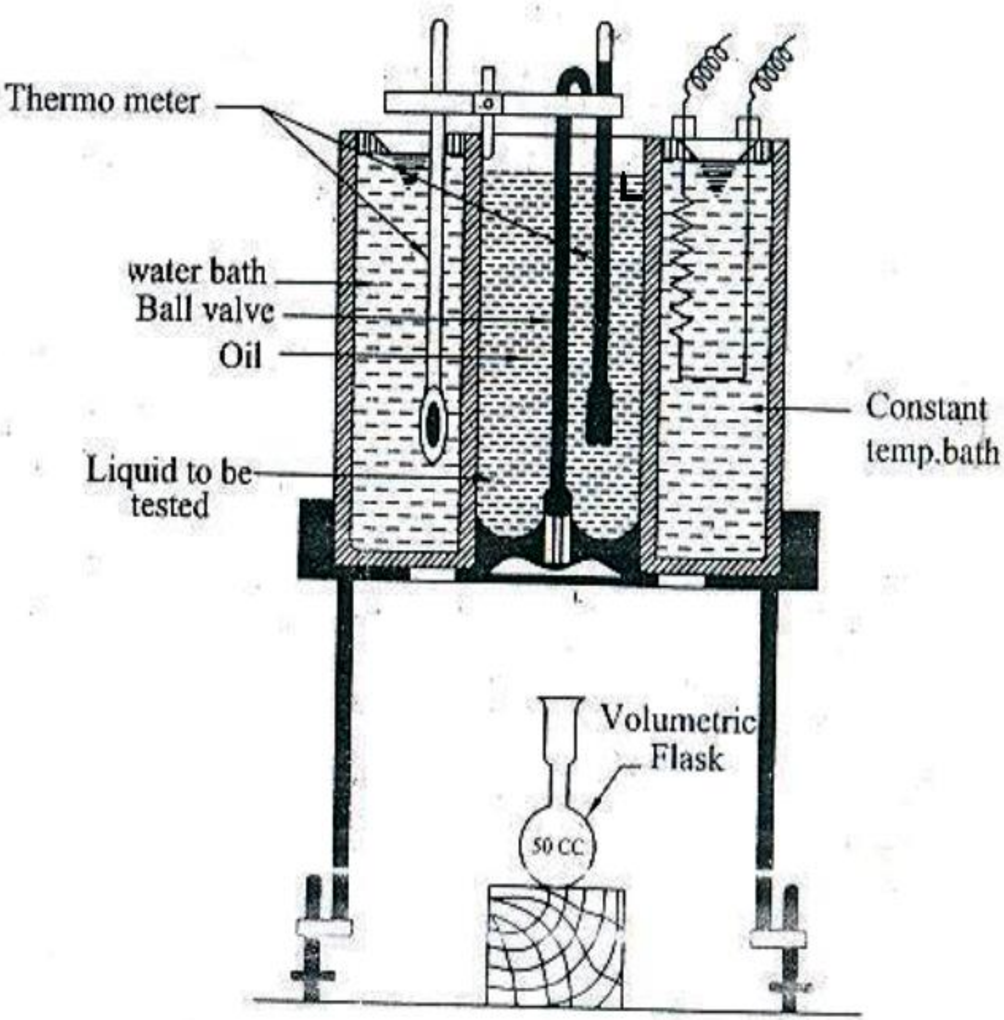


- Additives: Polymers having molecular weight ranging between 300-3000
- E.g. Polystyrene, polyesters

Viscometers

1. Brookfield Viscometer 2. Saybolt Viscometer 3. Redwood Viscometer

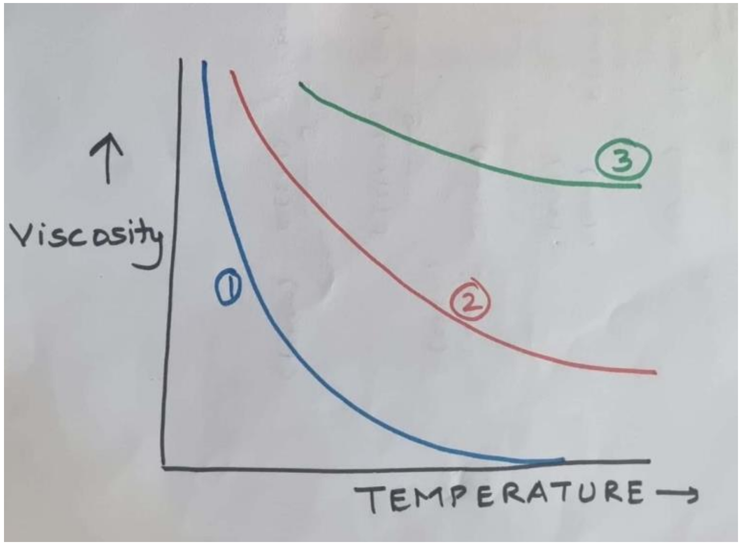
Redwood Viscometer



- Time of collection of 50 ml oil is noted.
- Capillary diameter is 1.62mm
- E.g. if time of collection of 50ml oil if 143sec at 25^0C, viscosity of the oil is said to be 143 Redwood seconds at 25^0C

Viscosity-Index (V.I.)

- An arbitrary scale to measure change of viscosity with changing temperature.
- If the viscosity of oil falls rapidly as the temperature is raised, it has a low viscosity-index.
- If viscosity of oil is only slightly affected on raising the temperature, its viscosity-index is high.



Viscosity index modifiers

- Polymeric molecules that are sensitive to temperature.
- At low temperatures, the molecule chain contracts and does not impact the fluid viscosity.
- At high temperatures, the chain relaxes and an increase in viscosity occurs.
- Polyalkylmethacrylates, Polyolefins

Standard oils

- **Texas Gulf Crude Oil** - takes its name for the Gulf of Texas, extracted in 1901.
  Naphthenic base oil
  It has low viscosity index, called as L-oil
  V.I. considered as 0.
- **Pennsylvania Grade Gulf Crude Oil** -takes its name for the state of Pennsylvania, where it was first extracted in 1859

  Paraffinic base oil

  It has superior qualities to act as lubricants.

  It has high viscosity index, called H-oil,

  V.I. considered as 100

Standard Tables

Viscosity of Pennsylvanian oils H-oils		Viscosity of Gulf oils L-oils	
100°F / 40°C	210°F / 100°C	100°F / 40°C	210°F / 100°C
A-1	B-1	C-1	D-1
A-2	B-2	C-2	D-2
A-3 (H)	B-3 (V)	C-3	D-3
A-4	B-4	C-4	D-4
A-5	B-5	C-5	D-5
A-6	B-6	C-6 (L)	D-6 (V)
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
A-n	B-n	C-n	D-n

A-1 to A-n, B-1 to B-n, C-1 to C-n and D-1 to D-n are all time of collection of oil in seconds at the specified temperatures.

Formula to calculate viscosity index

$$V.I. = \frac{L - U}{L - H} \times 100$$

Where

L→ viscosity of naphthenic base oil at 100^0F

H → viscosity of paraffinic base oil at 100^0 F

U→ viscosity of unknown oil sample at 100^0F

V → viscosity of unknown oil sample at 210^0F

V.I. < 35 (low grade),

V.I. = 35-80 (Medium grade),

V.I. = 80-110 (High grade),

V.I. >110 (Very high grade)

- An oil sample has viscosity of 64s at 210^{0}F and 564s at 100^{0}F. The low-viscosity standard oil possesses viscosity of 64s at 210^{0}F and 774s at 100^{0}F. The high-viscosity standard oil has viscosity 64s at 210^{0}F and 414s at 100^{0}F. Calculate the viscosity-index of the oil sample under test.
- Solution: U = 564s, V = 64s,

  H = 414s, L = 774s.

$$V.I. = \frac{L-U}{L-H} \times 100$$

= (774-564) / (774-414) x100

= (210 / 360) x 100

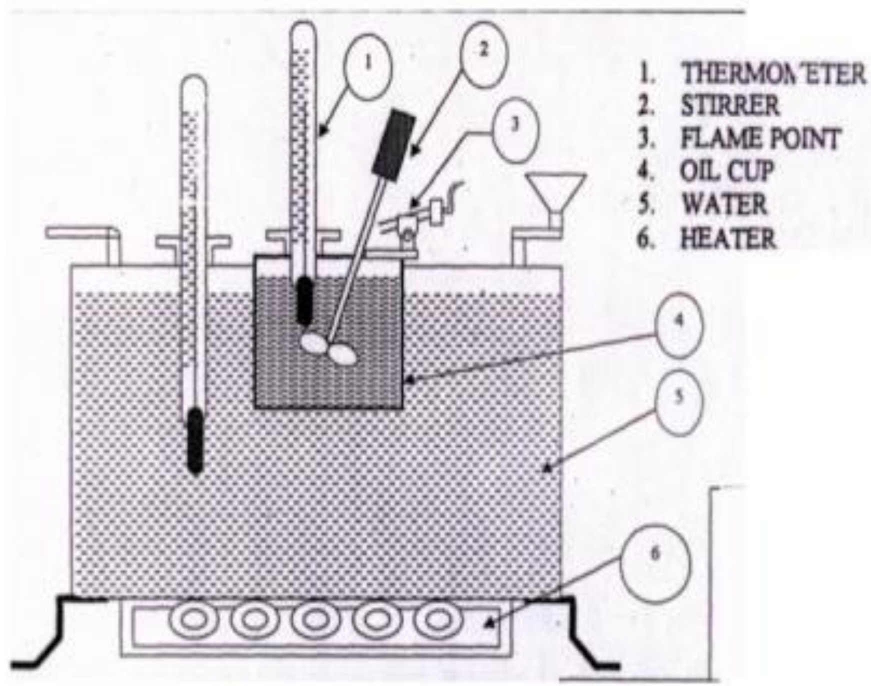
= 58.34 (moderate V.I.)

Flash and Fire-Points

- Flash point - Flammability characteristic to assess the hazardous nature of a material.
- It does not have any bearing with the lubricating property of the oil.
- Important when oil is exposed to high-temperature.
- Flash point is "the lowest temperature at which the oil lubricant gives off enough vapors that ignite for a moment, when a tiny flame is brought near it"
- Fire point is "the lowest temperature at which the vapors of the oil burn continuously for at least five seconds, when a tiny flame is brought near it".
- In most cases, the fire-points are 5 to 40° higher than the flash-points.

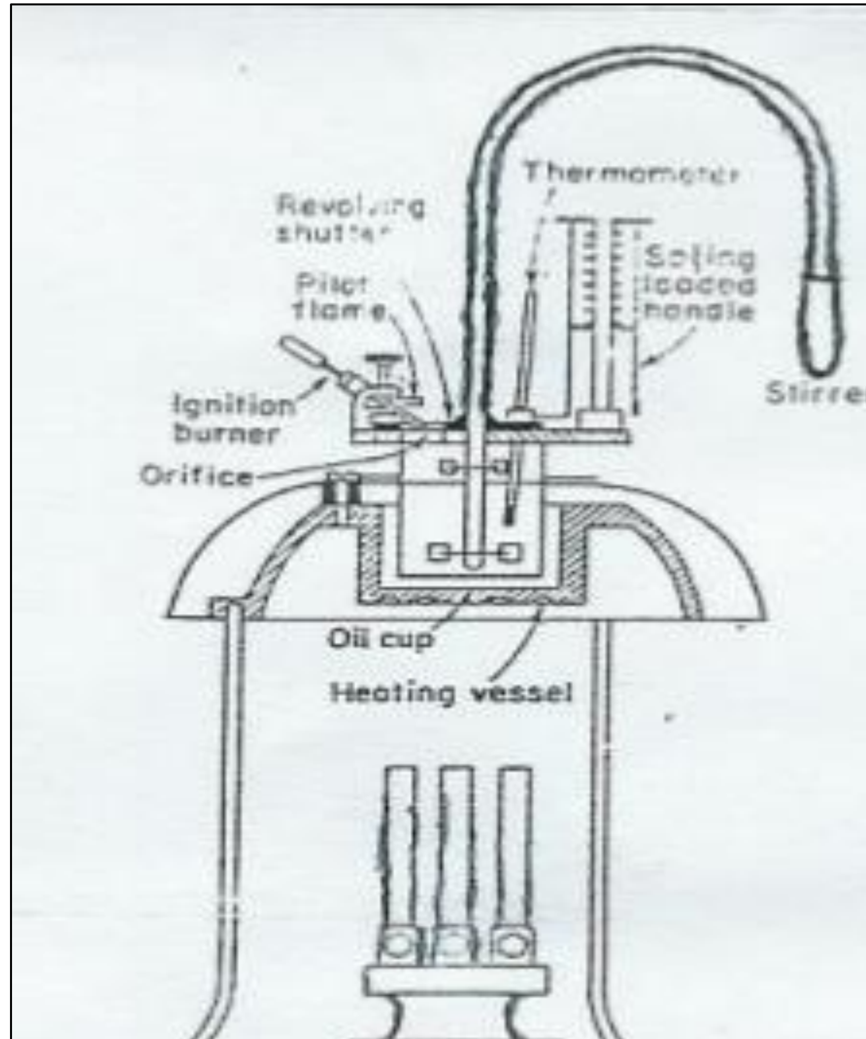
Apparatus Used

Abel close cup apparatus – It is a close cup apparatus and can be used only for oils whose fire point is below 100^{0}C.



ABEL'S APPARATUS

Pensky Marten apparatus: It is also a close cup apparatus and can be used for all type of oils.



Clevelands open cup apparatus: It is an open cup apparatus and can be used for all the oils.

Oiliness

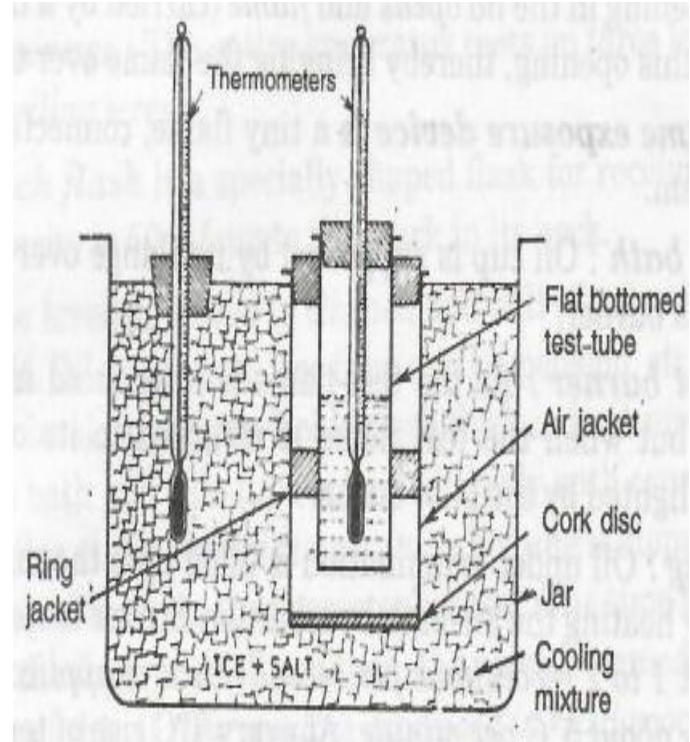
- It is a measure of its capacity to stick on to the surfaces of machine parts, under conditions of heavy pressure or load.
- Important for extreme-pressure lubrication.
- Mineral oils have got very poor oiliness; while vegetable oils have good oiliness.
- Additives -Vegetable oils and higher fatty acids containing strong polar groups
- Examples: Oleic acid, Stearic acid, Dibenzyl disulphide, Tricresyl phosphate.
- There is no perfect method for the determination of absolute oiliness, only be the feel on fingers.

Cloud and Pour Points

- They indicate the suitability of lubricants in cold conditions.
- Cloud point: The temperature at which oil becomes cloudy or hazy in appearance.
- Pour point : The temperature at which the oil ceases to flow or pour.
- Paraffin wax begins to separate out.
- Pour-point Depressants _ They reduce the size and cohesiveness of the crystals of wax, like, Phenolic polymers, Alkylated napthalene, Polymethacrylates.

Cloud point - pour point apparatus

- Flat-bottomed tube (about 3 cm in diameter and 12 cm high) enclosed in an air-jacket.
- The jacket is surrounded by freezing mixture placed in a jar.
- The tube is half-filled with oil.
- A thermometer is dipped in the oil.
- With every degree fall of temperature of the oil, the tube is withdrawn from the air-jacket for a moment and examined.
- It is then replaced immediately.
- The temperature at which cloudiness is noticed is recorded as the cloud-point.



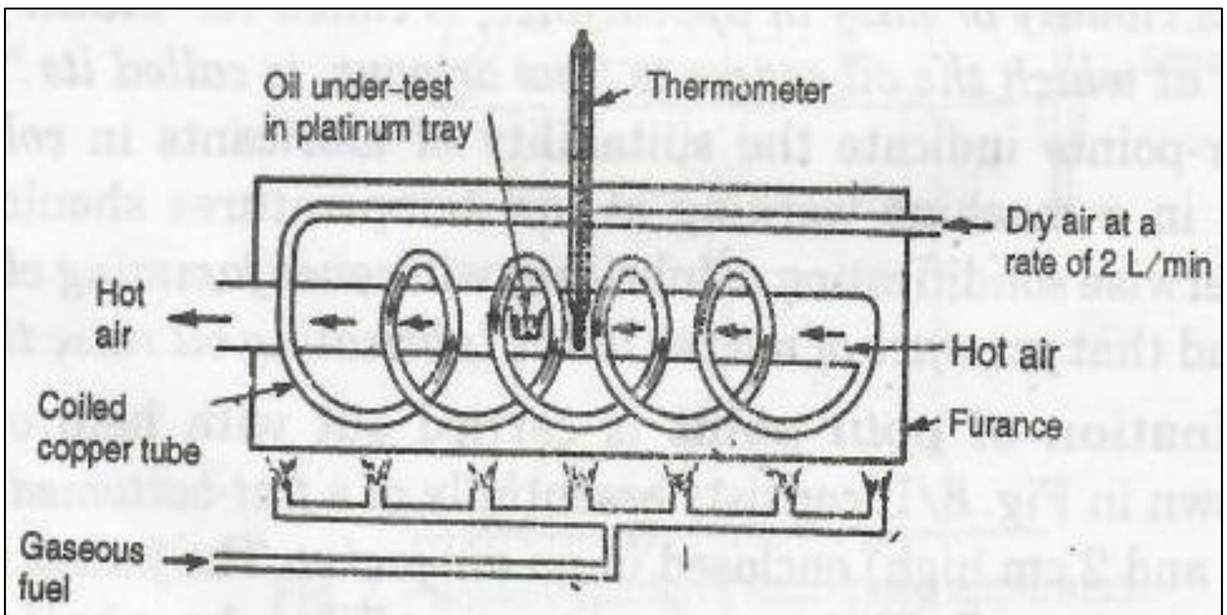
- After this, cooling is continued and the test-tube is withdrawn after every degree fall of temperature and tilted to observe the flow or pour of oil.
- The temperature at which oil does not flow even when kept horizontal for 5 seconds, is recorded as the pour-point.
- Freezing mixture
- Upto 10°C → ice + water
- Upto -12°C → crushed ice and salt
- Upto -26°C → ice + $CaCl_2$
- Upto -57°C → solid CO_2 and petrol

Emulsification

- It is the property of oils to get intimately mixed with water, forming a mixture, called emulsion.
- Emulsions have a tendency to collect dirt, grit, foreign matter, etc., thereby causing abrasion and wearing out of the lubricated parts of the machinery.
- 20 ml of oil is taken in a test-tube and steam at 100°C is bubbled through it, till the temperature is raised to 90°C.
- The tube is then placed in a bath maintained at 90°C and the time in seconds is noted, when the oil and water separate out in distinct layers.
- The time in second in which oil and water emulsion separates out in distinct layers, is called "steam emulsion number (S.E.N.).
- A good lubricant should possess a low steam emulsion number or demulsification number.
- Additives/Demulsifiers: Derivatives of ethylene oxide, phenolic aldehyde/amine.

Volatility

- Vaporisation of lower components when heated
- Apparatus -Vaporimeter
- A furnace heated by some fuel gas.
- A coiled-form of copper tube, through which air can be passed.
- A known weight of oil under-examination is taken in a platinum crucible, which is then introduced into the copper tube.
- Dry air at a rate of 2 litres/minute is passed through the copper tube.
- After one hour of heating, the tray is taken out, cooled and weighed.



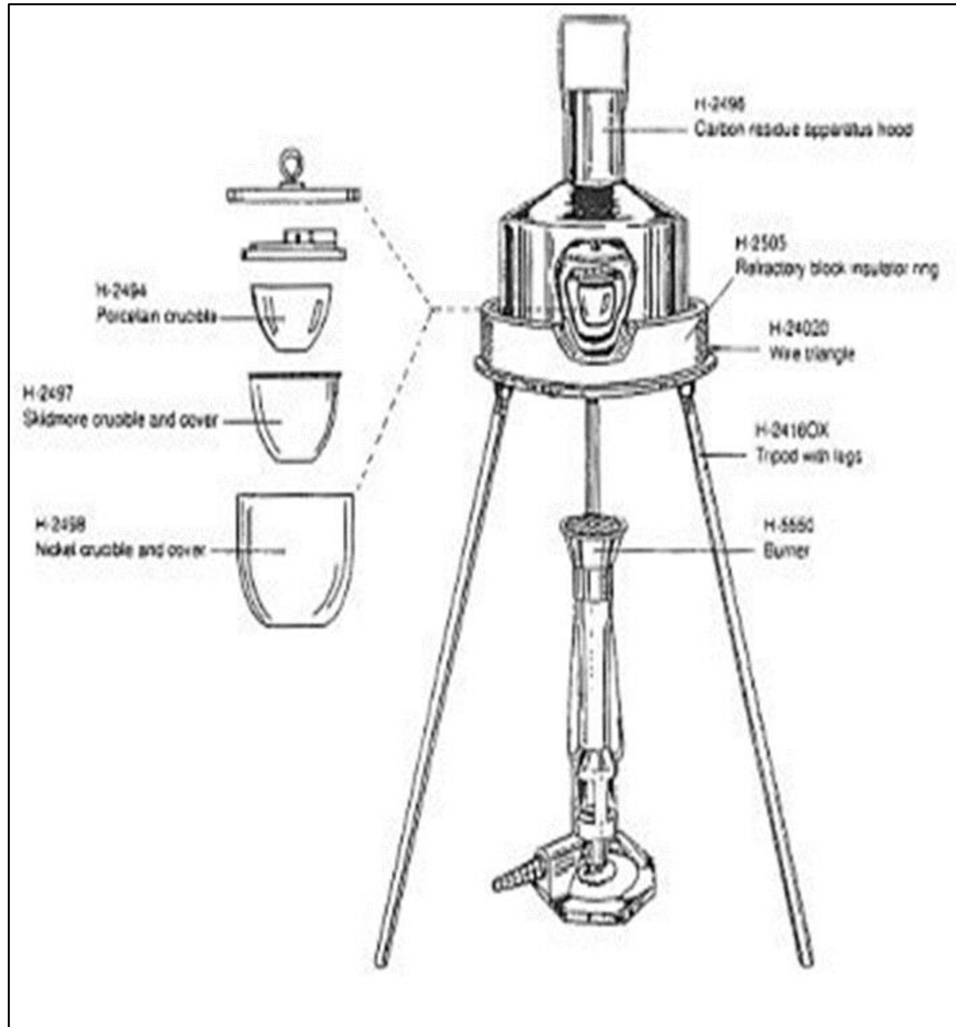
- Weight of empty crucible = w_1 gm
- Initial weight of crucible and oil = w_2 gm
- Initial weight of oil = $(w_2 – w_1)$ gm
- Weight of crucible and oil after heating = w_3 gm
- Weight of oil left after heating = $(w_3 – w_1)$ gm
- Weight of oil vaporised off during heating =

$$(w_2 – w_1) - (w_3 – w_1) \text{ gm}$$

- Percentage volatility =

$$[(w_2 – w_1) - (w_3 – w_1) \text{ gm} / (w_2 – w_1) \text{ gm}] \times 100$$

Carbon Residue: Conradson Apparatus



- A weighed quantity of oil is taken in a silica crucible (of about 65-85 ml capacity).
- This skidmore crucible is provided with a lid, having a small tube-type opening for the escape of volatile matter.
- The combination is then placed in a wrought iron crucible (about 8 cm in diameter and 6 mm high) covered with chimney-shaped iron hood (of about 10 cm diameter).

- The wrought iron crucible is heated slowly for 10 minutes, till flame appears.
- Slow heating is continued for 5 minutes more.
- Finally, strong heating is done for about 15 minutes, till vapors of all volatile matter are burnt completely.
- Apparatus is then allowed to cool and weight of residue left is determined.
- The result is expressed as percentage of the original weight of oil taken.

- Weight of empty crucible = w_1 gm
- Initial weight of crucible and oil = w_2 gm
- Initial weight of oil = $(w_2 - w_1)$ gm
- Weight of crucible and oil after heating = w_3 gm
- Weight of carbon left after heating = $(w_3 - w_1)$ gm
- Percentage carbon residue =

$$[(w_3 - w_1) \text{ gm} / (w_2 - w_1) \text{ gm}] \times 100$$

Corrosion Stability

- Corrosion – A natural process which converts a refined metal into a more chemically-stable form like oxide, hydroxide or sulfide.
- Due to corrosive substance present in oil like sulfur, hydrogen sulfide and polysulfides.
- Copper corrosion test/ Brass corrosion test.
- A polished copper strip is placed in the lubricating oil for a specified time at a particular temperature.
- After the stipulated time, the strip is taken out and examined for corrosion effects.
- Inhibitors -Organic compounds containing phosphorus, arsenic, antimony, chromium, bismuth or lead. Their function is to prevent contact between metal and substances.

Decomposition Stability

Oxidation - The main destructive influence.

It produces acids, sludges and varnish.

At low temperature reaction is slow, but above 80°C, oxidation doubles at every 8°C.

Antioxidants – phenols, amines, organic phosphides and their derivatives.

Hydrolysis - Esters get hydrolysed releasing alcohols and destructive fatty acids.

Pyrolysis - The cracking of petroleum chains due to the high temperatures.

Effect: The deposition of gummy and carbon sediments within the lubricant.

Sligh oxidation number - 10 g of oil sample is taken in a special flask and air in it is displaced by oxygen.

The flask is then kept in an oil-bath, maintained at 200°C.

After 2 hours of heating, the flask is removed, cooled and contents are diluted with petroleum naphtha and then, allowed to stand undisturbed for an hour.

Any precipitate formed is filtered, washed, dried and weighed. It is expressed as the percentage of the original weight of oil taken.

A good lubricant should possess a low Sligh oxidation number.

Aniline Point

- Aromatic hydrocarbons have a tendency to dissolve natural rubber and certain types of synthetic rubbers.
- Low aromatic content in the lubricants is desirable.

{Aniline is partially soluble in all hydrocarbons. When completely soluble, transparent at that temperature. Paraffin has least solvency whereas aromatic has maximum in aniline.}

- Definition: The minimum equilibrium solution temperature for equal volumes of aniline and oil sample.
- A higher aniline-point means lower percentage of aromatic hydrocarbons and thus desirable.

- It is determined by mixing mechanically equal volumes of the oil sample and aniline in a test-tube.
- The mixture is heated, till homogeneous solution is obtained.
- The tube is allowed to cool at a controlled rate.
- The temperature at which the two phases (oil and aniline) separate out is recorded as the aniline point.

Typically, an aniline point higher than 93°C indicates paraffinicity, and an aniline point lower than 65°C indicates aromaticity.

Neutralization Number

- The acidity or alkalinity of lubricating oil is determined in terms of neutralization number.
- Determination of acidic constituents is more common and it is referred to as "Acid number or value".
- Definition: The number of milligrams of KOH required to neutralize the free acids in 1g of the oil.
- Lubricating oil should possess acid value less than 0.1
- Value greater than 0.1 indicates

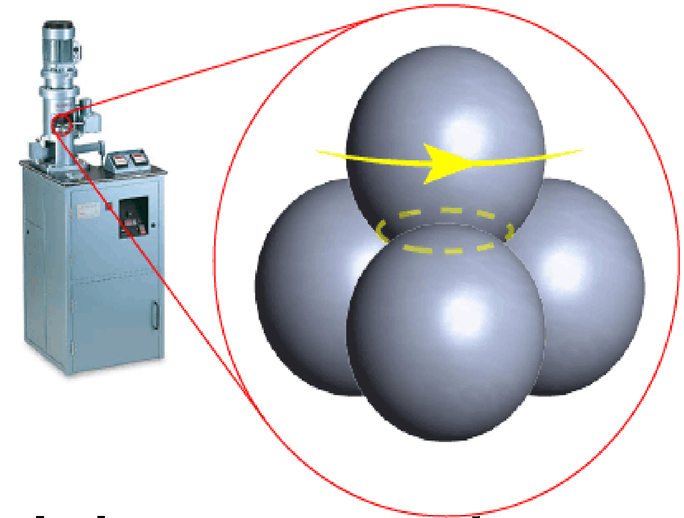
Used oil -oil has been oxidized, need to be changed

Fresh oil – faulty refining

Saponification Number

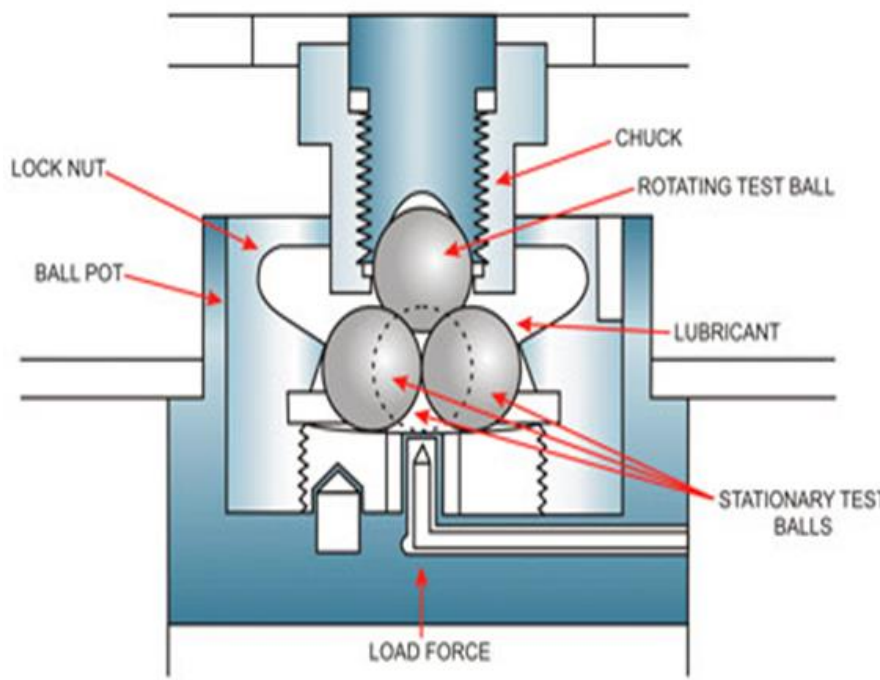
- Definition: The number of milligrams of KOH required to saponify one gram of oil.
- Mineral oils do not saponify at all, but vegetable and animal oils do.
- This test helps us to ascertain whether the oil under reference is animal and vegetable oil or mineral or a compounded oil containing mineral and vegetable oils.

Mechanical Stability



- To judge the suitability of a lubricant under conditions of very high pressure.
- "Four-balls extreme pressure lubricant test"
- The lubricant under-test is poured in a machine containing four balls.
- The lower three balls are stationary, while the upper ball is rotated.

- Load is gradually increased and the balls withdrawn and examined at specific intervals for scale formation, etc., on them.
- If the lubricant is satisfactory under the given load, the ball bearings after the test comes out clean.
- This test enables us to determine the maximum load that can be carried safely by a lubricant.



CLASSIFICATION OF LUBRICANTS

Liquid lubricants or lubricating oils

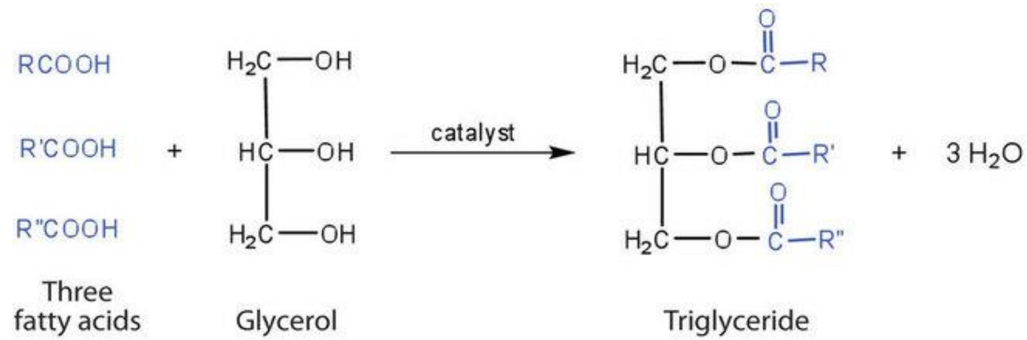
- Vegetable and Animal-Based oils
- Mineral/hydrocarbon Oils
- Blended Oils
- Synthetic Oils

Vegetable and Animal-Based oils

- Rapeseed (Canola), Castor oil, coconut oil, palm oil etc
- Animal origin oils
- Lard (from pigs)
- Tallow (from farm animals)
- Neatsfoot oil (from hooves of farm animals)
- Cod-liver oil (from cod fish)
- Sperm oil (from Sperm Whale)

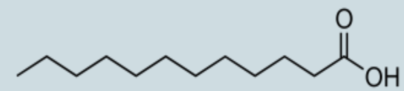
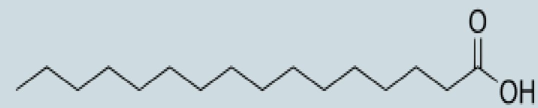
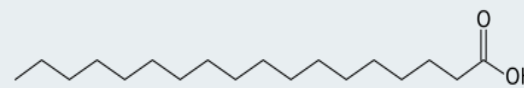
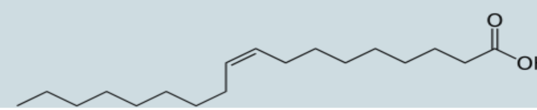
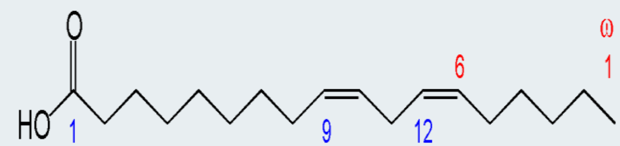
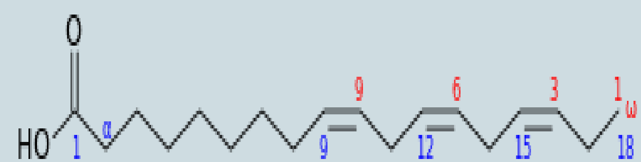
Triglycerides

- Esters composed of three fatty acid units joined to *glycerol*, a trihydroxy alcohol



- If all three OH groups on the glycerol molecule are esterified with the same fatty acid, the resulting ester is called a *simple triglyceride* .
- Different fatty acid components then *mixed triglyceride*.
- A triglyceride is called a fat if it is a solid or semisolid at 25°C; it is called oil if it is a liquid at that temperature.
- These differences in melting points reflect differences in the degree of unsaturation and number of carbon atoms in the constituent fatty acids.
- Triglycerides obtained from animal sources are usually solids, while those of plant origin are generally oils (exception : fish oil).

Commonly found Triglycerides

Name of Acid	Saturated/Unsaturated	No. of Carbon atoms	Structure
Lauric Acid	Saturated	12	
Myristic Acid	Saturated	14	
Palmitic Acid	Saturated	16	
Stearic Acid	Saturated	18	
Oleic Acid	Mono-Unsaturated	18	
Linoleic Acid	Poly-Unsaturated (2 double bonds in cis-configuraion)	18	
Linolenic Acid	Poly-Unsaturated (3 double bonds in cis-configuraion)	18	

Comparison of Average fatty acid composition

	Lauric	Myristic	Palmitic	Stearic	Oleic	Linoleic	Linolenic
Lard oil		1	27	15	48	6	1
Coconut oil	50	18	8	2	6	1	
Olive oil			13	3	85	5	
Palm oil		2	41	5	43	7	

Advantages

- High oiliness
- High viscosity
- High viscosity-index
- Low emulsifying characteristics
- Low volatilities
- Non toxic
- Biodegradable
- Better solvency for additives
- Fully mixable with mineral oils
- Do not react with seal materials, varnish and paints

Disadvantages

- Cannot be produced in enormous amounts.
- Comparatively costly
- Unsaturated components at high temperature promotes a series of destructive chemical reactions
- Oxidation → primary oxidation products (hydroperoxides) → secondary oxidation products (volatiles, non-volatiles, high molecular weight and free fatty acids)
- Poor Corrosion protection
- Solidify at low temperatures

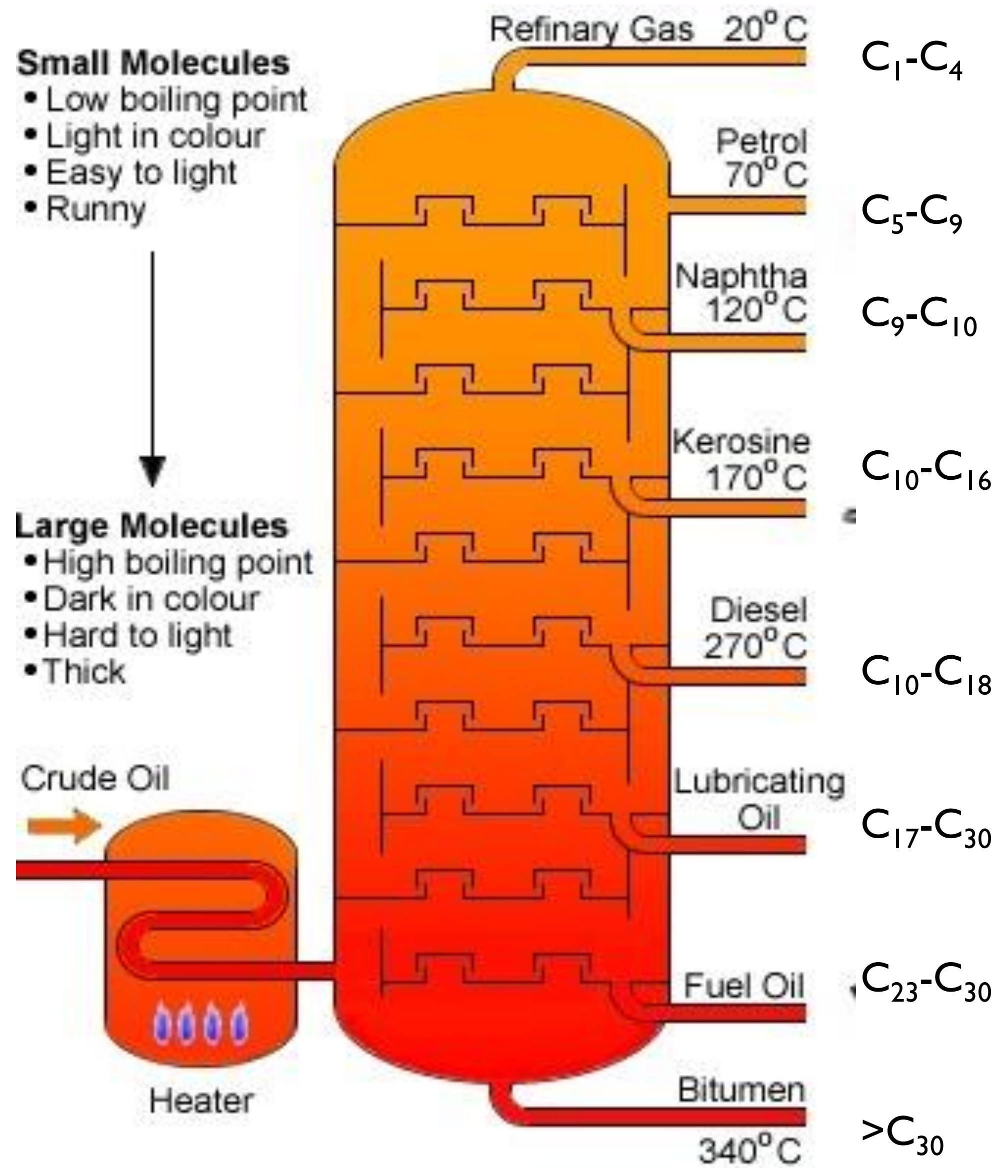
Mineral oils/Hydrocarbon oils

Component	Content by weight (%)
Carbon	83-87
Hydrogen	11-14
Sulphur	0-8
Nitrogen	0-1
Oxygen	0.5
Metals	0.02

- Dead organic matter fell to the ocean floor and was mixed with inorganic material.
- Bacteria decomposed the organic material in the absence of oxygen and the temperature of the material increased with the increased pressure on it from sediment above.
- As pressure and temperature increased, the organic material slowly turned into crude oil and natural gas.
- Crude oil is a complex mixture of many compounds (mainly hydrocarbon).
- It consists of over 100,000 compounds, with the exact composition of the sample varying based on the field it was extracted at.
- There are four main types of hydrocarbons found in crude oil.
- paraffins (15-60%)
- naphthenes (30-60%)
- aromatics (3-30%)
- asphaltics (remainder)

The Fractionating Column

- Height of tower = 60m
- Diameter at top and bottom around 1.2 and 2 m
- Continuous process
- The most volatile fraction/the molecules with the lowest boiling points /shortest hydrocarbon molecules, boil or evaporate off first
- They go higher up the column and condense out at the higher levels in the fractionating column at the lowest temperature.



Refining of Lubricating Oils

Dewaxing

- Principal solvents used are methyl ethyl ketone (MEK) and toluene.

Solvent Refining

- Separates aromatics, napthenes and other impurities from the product stream by dissolving or precipitation.
- Principal solvents used are phenol, furfural, and cresylic acid

Acid Refining

- Fuming sulphuric acid
- Oil purified by neutralizing, washing and treatment with clay

Positives

- Available in bulk
- Cost effective
- Does not get hydrolysed or oxidized easily
- Good solubility of additives

Negatives

- Non biodegradable
- High toxicity level, also releases compounds which are harmful to ecology
- Cannot be replenished

Blended oils

- Developed in 1930s–1940s
- Due to inability of mineral lubricating oils to meet all the criteria of machinery.
- Mix of Base oil and additives
- Additives are organic or inorganic compounds dissolved or suspended as solids in oil.
- 0.1%- 30 % of the oil volume.
- Additives have three basic roles:
- 1) **Enhance existing base oil properties** with antioxidants, corrosion inhibitors, anti-foam agents and demulsifying agents.
- 2) **Suppress undesirable base oil properties** with pour-point depressants and viscosity index improvers .
- 3) **Impart new properties to base oils** with extreme pressure (EP) additives, detergents, metal deactivators and tackiness agents.

Synthetic oils

- Man-made / Tailored
- Made by combining low molecular weight materials via chemical reaction into higher molecular weight materials.
- Higher price justified by improved performance

ADVANTAGES:

1. Predictable Properties and Performance
2. Longer Oil Life – Enhanced Thermal and Oxidation Stability
3. Reduced Oil Consumption – Lower Volatility
4. Satisfies Specific Requirements – Military Specifications – Severe Operating Conditions
5. Safer Operation – High Flash Points, Fire Points, Spontaneous Ignition Temperatures
6. Easier Disposal – Lower Toxicity and Better Biodegradability

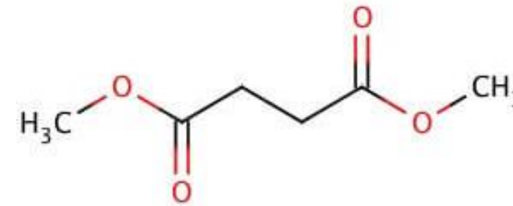
Disadvantages:

1. High synthesis cost
2. Toxicity
3. Highly specific
4. High disposal cost

Commonly used synthetic oils

- Synthetic Hydrocarbons – Polyalphaolefins, alkylated aromatics, polybutenes
- Organic Esters – Diesters, Polyol Esters
- Polyglycol Ethers
- Phosphate Esters
- Silicones
- Silicate Esters
- Halogenated Hydrocarbons
- Polyphenyl Ethers

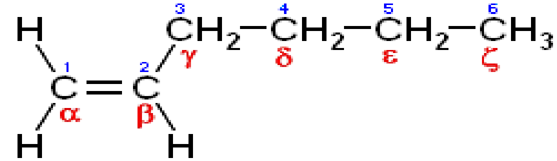
Dibasic acid esters



- Developed in Germany during World War II
- Dibasic ester or DBE is an ester of a dicarboxylic acid.
- Produced by Dibasic acid + Mono-functional alcohol
- Polarity of ester molecule responsible for its properties

Strengths	Weaknesses	Applications
• Very low volatility, • high thermal stability, • excellent viscosity temperature characteristics, • non-corrosive, • non-toxic, • stable to hydrolysis, • Temp. range around -50°C to 230°C.	• Low hydrolytic stability • Incompatible with sealing materials, causes swelling • Limited biodegradability	• Engine oils, specially jet engines • Gear oils • Bearing oils • Compressor oils

Polyalphaolefins

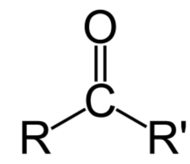


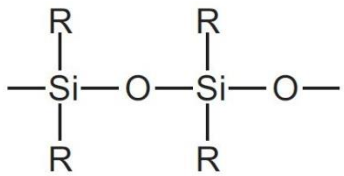
- most common major synthetic base oil, developed in the 1930s
- Alpha-olefin :- Alkene where the carbon-carbon double bond starts at the α-carbon atom, i.e. the double bond is between the #1 and #2 carbons in the molecule.
- Costs four times more than mineral oil, less than other synthetics

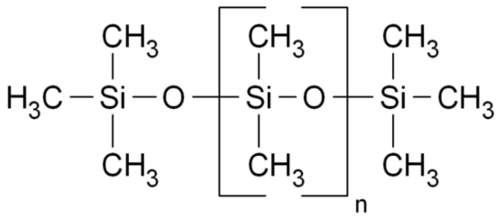
Strengths	Weaknesses	Applications
• High viscosity index (VI) (130 approx.) • High thermal oxidative stability • Low volatility • Good flow properties at low temperatures • Non-toxic • Compatible with mineral oils • High flash point	• Limited biodegradability • Limited additive solubility • Seal shrinkage risk	• Engine oils • Gear oil • Bearing oils • Compressor oils • High temperature greases

Silicones (Polysiloxanes)

- They are polymers that include any synthetic compound made up of repeating units of siloxane, which is a chain of alternating silicon atoms and oxygen atoms, combined with carbon, hydrogen and sometimes other elements.
- They are typically heat-resistant and either liquid or rubber-like.
- Are used in sealants, adhesives, lubricants, medicine, cooking utensils, and thermal and electrical insulation.
- Si-O bond is longer, more polar and has higher energy than C-C bond.
- Si-O-Si bond angle larger than C-C-C
- Thus free rotation of side groups possible and backbone chain also more flexible.







Polydimethyl siloxane

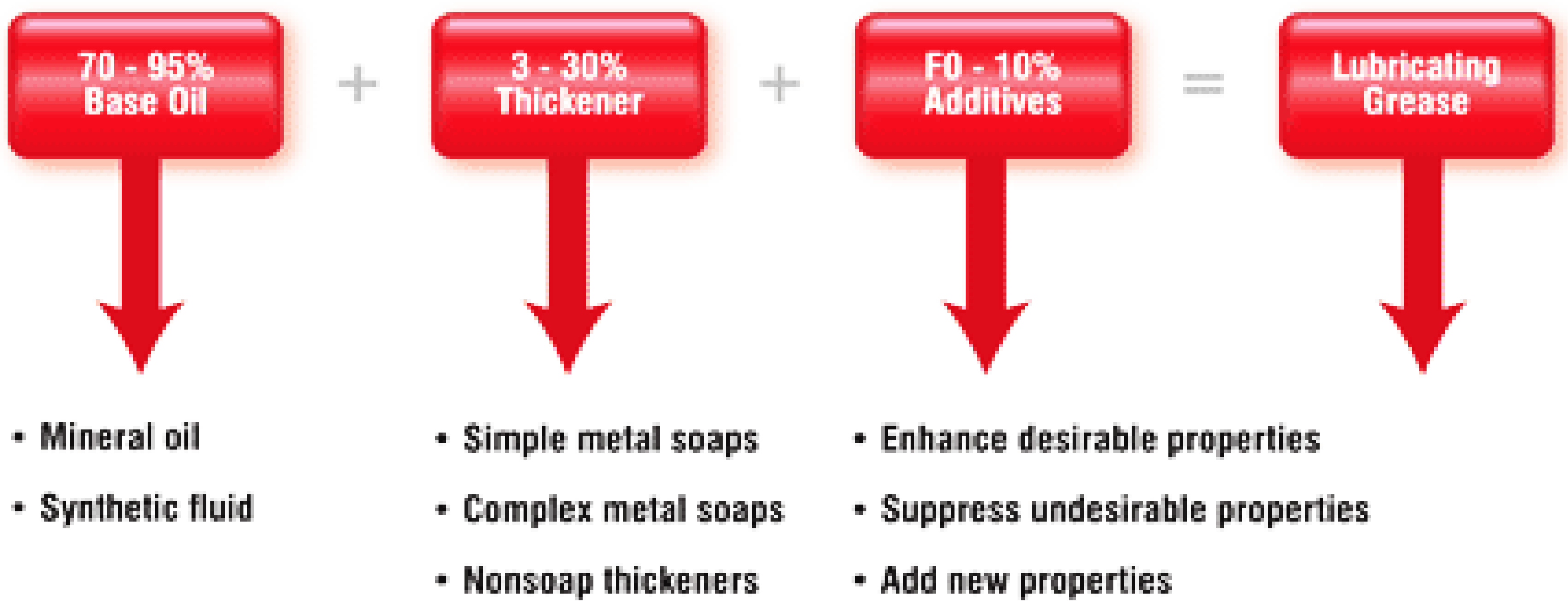
Properties of silicones

- Very High VI
- Superior Thermal Stability - Oxidation Resistance
- Wide Operating Temperature Range
- Low Volatility
- Seal Compatibility
- Resistance to Water, Solvents, Chemicals

Drawbacks-

- At very high temperatures, SiO_2 is obtained, which is an abrasive.
- They do not get adsorbed on steel.
- Poor Load Carrying Ability
- Poor Additive Response
- High Price (13-20 times to Mineral Oil)

Lubricating Greases



Conditions under which they are Used:

- When Pressure and/or temperature is so high that even blended oils do not stick.
- Infrequent usage of machine
- Dripping of the oil cannot be tolerated, e.g. textile, paper, edibles
- Too many jerks during movement.
- When parts to be lubricated are not easily accessible.
- Easier to contain than oil.
- It can also act as seal.

Drawbacks:

- Higher coefficient of friction.
- Difficulty in cleaning for renewal.
- Heat conduction is not as effective as oils, so localized heating will break it.
- Does not cool uniformly, quickly and properly.

Types of Greases

- **Calcium-based greases** – yellow or reddish in color, smooth buttery texture, cheapest, most commonly used, insoluble in water, used below 65° C.
- **Sodium-base greases** - yellow or green in color, spongy or fibrous texture, not water resistant, can be used up to 175°C.
- **Lithium based greases** - brownish-red color, buttery texture, good high temperature (150°C) and good water resistant properties , have high mechanical stability, low oxidation, stable in storage, non-corrosive, high cost.

- **Aluminum-soap** greases - contain 5% more oil than other greases, thus water-proof, can-not be used above 90°C.

- **Silicone grease** - translucent white viscous paste, water-proof ,
- made by combining a silicone oil with a thickener,
- Mostly polydimethylsilicone used as oil with amorphous fumed silica,
- commonly used for lubricating and preserving rubber parts ,
- also used widely by the plumbing industry in faucets and seals, as well as dental equipment ,
- generally have a temperature range of -40°C to 400°C.

Solid Lubricants

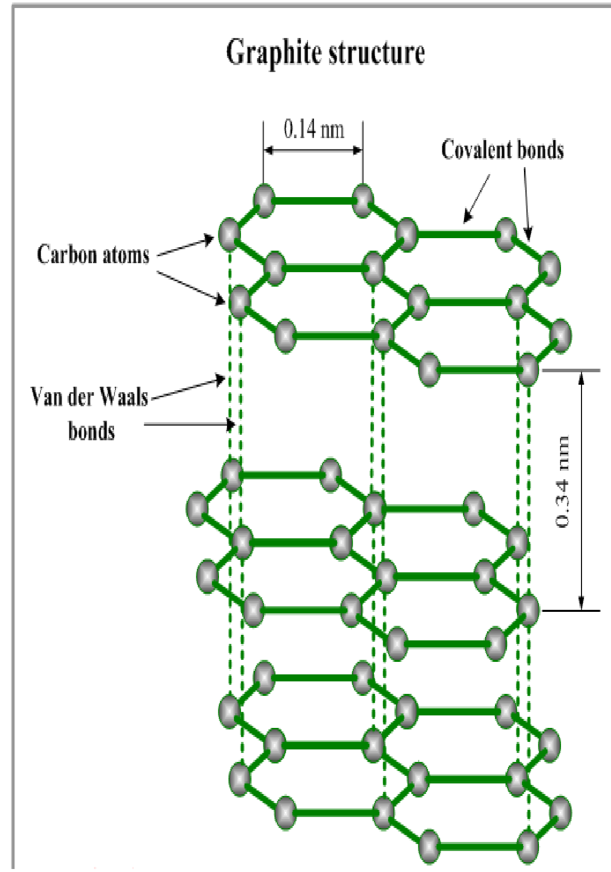
Important property- lamellar/layered structure

Solid lubrication is done where:

- Operating conditions are such that a lubricating film cannot be secured by use of lubricating oils or greases.
- Contamination (by the entry of dust or grit particles) of lubricating oil or grease is unacceptable.
- The operating temperatures or load is too high, even for a semi-solid lubricant to remain in position.
- Combustible lubricants must be avoided.
- Examples: Graphite, Molybdenum disulphide, Tungsten disulfide, Mica, Boron nitride, Borax, Silver sulfate and lead iodide, White lead, Lime, Talc, Bentonite, Silver iodide.

Graphite

- Graphite is structurally composed of planes of polycyclic carbon atoms that are hexagonal in orientation.
- The distance of carbon atoms between planes is longer and, therefore, the bonding is weaker.
- Water vapor is a necessary component for graphite lubrication. The adsorption of water reduces the bonding energy between the hexagonal planes of the graphite to a lower level than the adhesion energy between a substrate and the graphite.



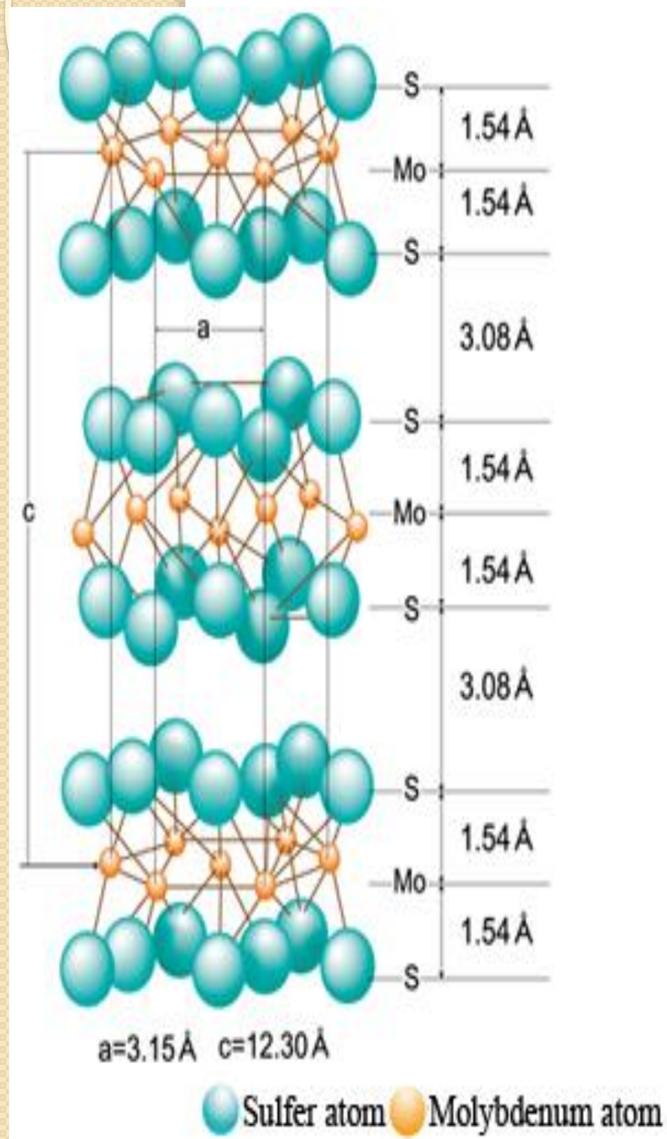
Properties

- Graphite is not effective in vacuum.
- In an oxidative atmosphere, graphite is effective at high temperatures up to 450 °C.
- Coefficient of friction = 0.07 (in moist atmosphere). Coefficient of friction = 0.5 (in dry atmosphere / vacuum)

Graphite is characterized by two main groups:

- Natural graphite -carbon 96−98%, sulfur, SiO_2, and ash.
- Synthetic graphite - carbon (99.5−99.9%).

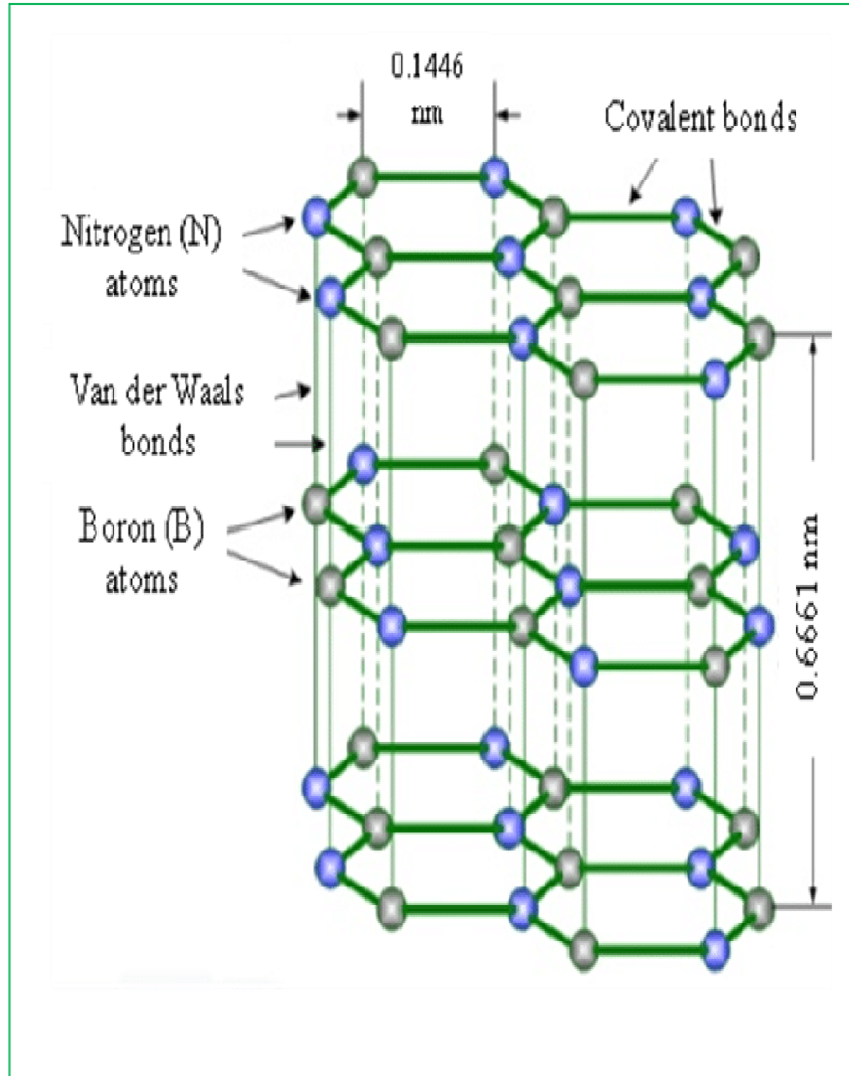
Molybdenum disulphide



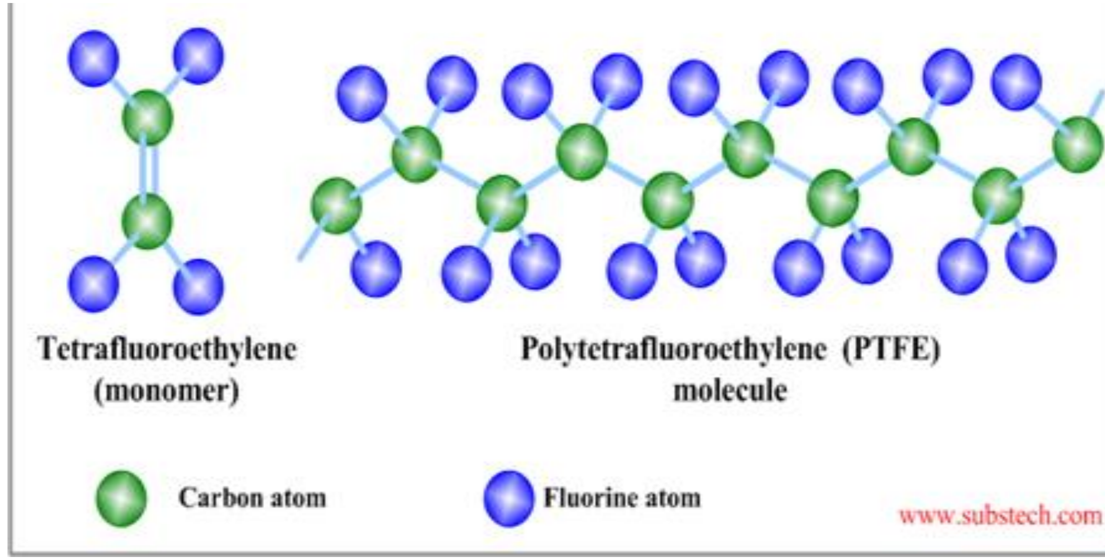
- MoS_2 is a mined material found in the thin veins within granite and highly refined in order to achieve purity suitable for lubricants.
- hexagonal crystal structure
- A layer of molybdenum atoms is sandwiched between two layers of sulfur atoms.
- effective in vacuum as well
- temperature limitation of MoS_2 at 400 °C
- low coefficient of friction (0.03-0.06)

Boron nitride

- Boron Nitride is a ceramic powder lubricant.
- high temperature resistance of 1200°C
- Only hexagonal structure is the lubricating version.



PTFE



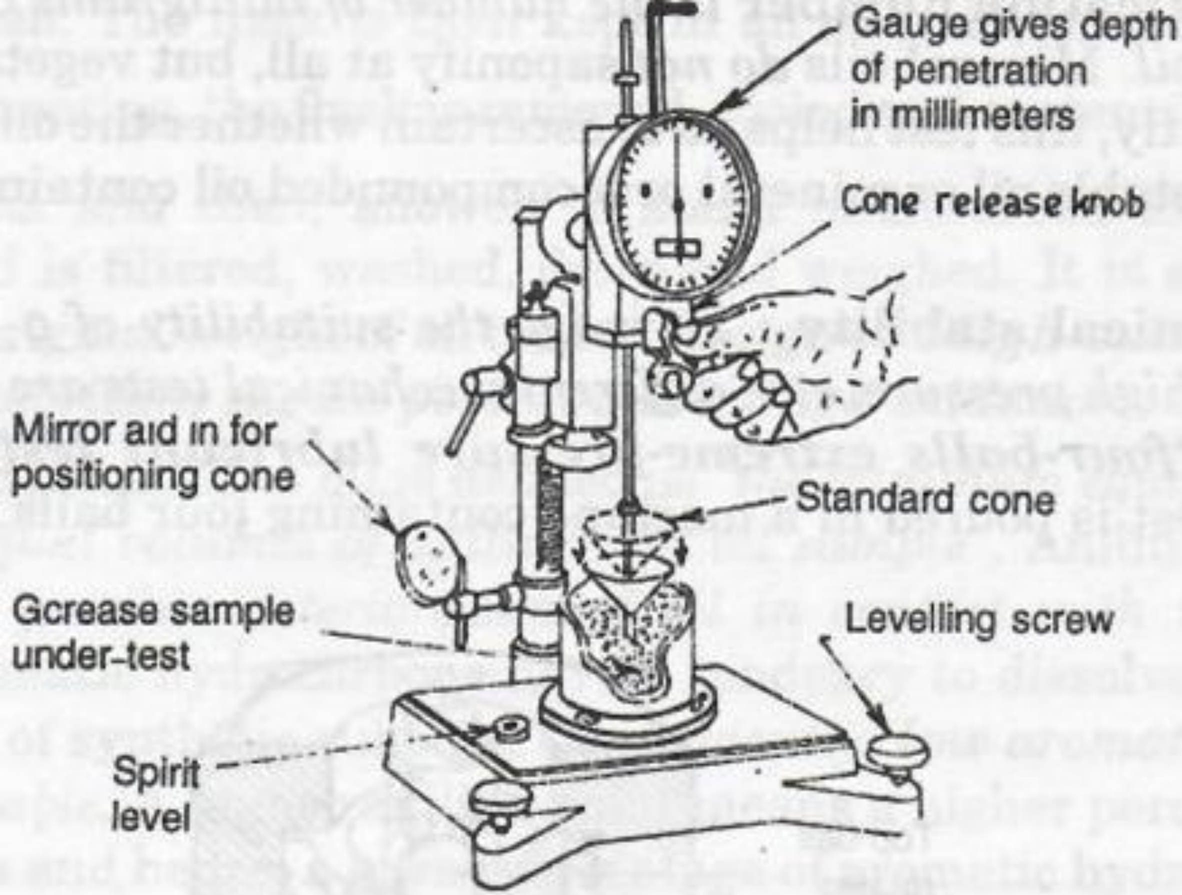
- Polytetrafluoroethylene
- Due to the low surface energy of PTFE, stable unflocculated dispersions of PTFE in oil or water can be produced.
- PTFE does not have a layered structure.
- The macro molecules of PTFE slip easily along each other, similar to lamellar structures.
- coefficients of friction= 0.04.
- Operating temperatures 260°C.

Properties of Grease

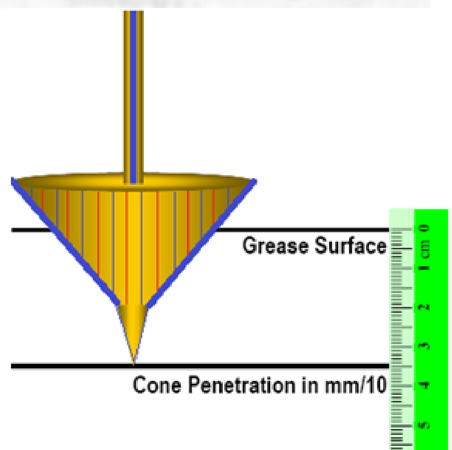
1. Consistency
2. Drop-point
3. Base oil viscosity
4. Ash content
5. Water stability
6. Neutralization number

Consistency or yield value

- Expressed in terms of penetration.
- Determined by using Penetrometer.
- The distance in tenth of millimeter that a standard cone penetrates vertically into the sample, under the standard conditions of load, temperature and time.
- The value of load, temperature and time are taken respectively as 150 g, 25°C, and 5 seconds.
- Consistency of grease depends on the structure and interaction of the gelling elements in it and to some extent on the viscosity of oil used.

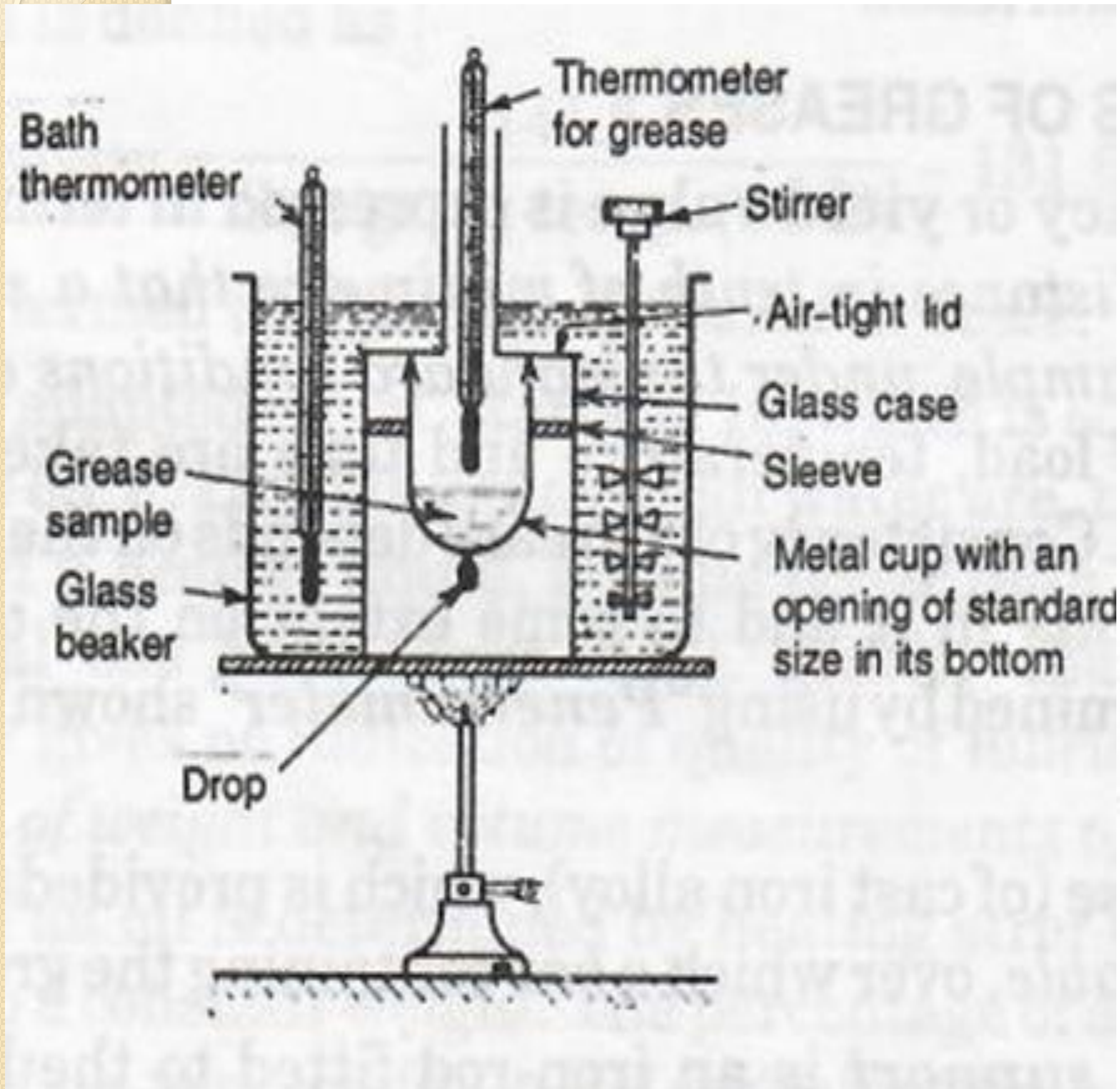

Gauge gives depth of penetration in millimeters
Cone release knob
Mirror aid in for positioning cone
Standard cone
Gcrease sample under-test
Levelling screw
Spirit level


ELE


Grease Surface
Cone Penetration in mm/10

Drop-point

- It is a measure of the heat resistance of a grease.
- The temperature at which the grease passes from semi-solid state to liquid state.
- The grease sample is taken in a metal cup having an opening of a standard dimension at the bottom.
- The cup is fitted in the glass case with a tightly fitting lid.
- A thermometer is inserted in to the cup.
- The entire assembly is then kept in a glass beaker containing water.
- The beaker is slowly heated at the rate of 1°C per minute.
- At a particular temperature, the first drop emerging out of the opening of the metal cup falls down.
- This temperature is recorded as drop-point of the grease sample.


Thermometer for grease
Bath thermometer
Stirrer
Air-tight lid
Glass case
Sleeve
Grease sample
Metal cup with an opening of standard size in its bottom
Glass beaker
Drop