

## Lecture 3

### FLUIDS FOR HYDRAULIC SYSTEMS

#### Learning Objectives

Upon completion of this chapter, the student should be able to:

- List the various functions of hydraulic fluid.
- Explain the desirable properties of fluid.
- Differentiate between thick and boundary lubrication.
- Define neutralization number and demulsibility.
- Define fire point and flash point.
- Explain the various hydraulic fluids.
- Explain the various fire-resistant fluids.

#### 1.1 Introduction

Although mineral oils were readily available in the beginning of 20th century, they were not practically used in hydraulic system until the 1920. In 1940s, additives were first used to improve the physical and chemical properties of hydraulic mineral oils. The first additives were developed to counter rust and oxidation. However, mineral oils are highly flammable, and fire risk increases when operating at high temperatures. This led to the development of fire-resistant fluids that are mainly water based, with limitations on the operating conditions. The need for extremes of operating temperatures and pressures led to the development of synthetic fluids. Personnel who operate, service, or design fluid power should have knowledge of the individual characteristics of hydraulic fluid and this chapter deals with functions of hydraulic fluid and their effect on system's performance.

#### 1.2 Functions of Hydraulic Fluids

A hydraulic fluid is the transmitting medium of a hydraulic system. It is, therefore, an essential part of the system and we must know enough about it to ensure that the hydraulic system works efficiently. The most common liquid that is used as a medium in fluid power systems is petroleum-based mineral oil.

In fluid power systems, a hydraulic fluid has to perform various functions such as the following:

1. **Power transmission:** To transmit power, which is the primary function.
2. **Lubrication:** To lubricate various parts, so as to avoid metal-to-metal contact and reduce friction, wear and heat generation.
3. **Sealing:** To seal the moving elements to avoid leakage.
4. **Cooling:** To carry away the heat generated in the system and to dissipate the heat through a reservoir or a heat exchanger.
5. **Contaminant removal:** To carry along the contaminations to the tank, where they can be removed through filters.

For a fluid to perform efficiently, it must possess certain properties. The various properties required for an ideal hydraulic fluid are as follows:

1. Ideal viscosity.
2. Good lubrication capability.
3. Demulsibility.
4. Good chemical and environmental stability.
5. Incompressibility.
6. Fire resistance.
7. Low flammability.
8. Foam resistance.
9. Low volatility.
10. Good heat dissipation.
11. Low density.
12. System compatibility.

It is almost impossible to achieve all these properties in a hydraulic fluid. Although we can select a good fluid with desirable properties, some of the characteristics of a fluid change with usage. For example, it is common for the temperature of a fluid to rise due to friction in the system, which reduces the viscosity of the fluid, which in turn increases leakage and reduces lubrication ability. A fluid gets oxidized and becomes acidic with usage. Certain additives are added to preserve the desirable properties and to make the fluid more stable. Some of the desirable properties and their influence on a hydraulic fluid are discussed briefly in the following sub-sections.

### **1.2.1 Ideal Viscosity**

The most basic desirable property of a hydraulic fluid is optimum viscosity. It is a measure of a fluid's resistance to flow. When viscosity is low, the fluid flows easily. On the other hand, when viscosity is high, the fluid flows with difficulty. A low viscous fluid is thin and can flow easily, whereas a high viscous fluid is thick and cannot flow easily. The viscosity of a fluid should be high enough to seal the working gap between the parts and prevent leakage but should be low enough to cause easy flow throughout the system. A high-viscosity fluid requires high energy to overcome the internal friction, resulting in excess heat generation. On the other hand, a low-viscosity fluid flows easily but causes leakages and reduces the volumetric and overall efficiency. Therefore the hydraulic fluid should have an optimum viscosity.

#### **1. High viscosity:**

- High resistance to flow.
- Increased power consumption due to frictional loss.
- High temperature caused by friction.
- Increased pressure drop because of the resistance.
- Possibility of sluggish or slow operation.
- Difficulty in separating air from oil in a reservoir.
- Greater vacuum at the pump inlet, causing cavitation.
- Higher system noise level.

## 2. Low viscosity:

- Increased internal leakage.
- Excessive water.
- Possibility of decreased pump efficiency, causing slower operation of the actuator.
- Increased temperature resulting from leakage losses.

There are two basic methods of specifying the viscosity of fluids: absolute and kinematic viscosity. Viscosity index is an arbitrary measure of a fluid resistance to viscosity change with temperature changes. Thus, viscosity is affected by temperature changes. As temperature increases, the viscosity of a fluid decreases. A fluid that has a relatively stable viscosity at temperature extremes has a high viscosity index. A fluid that is very thick while cold and very thin while hot has a low viscosity index.

### 1.2.1.1 Specification of Oil as Per ISO

Standardization of hydraulic oils has been done by the International Organization for Standardization. Table 1.1 lists ISO VG for engine oils and Table 1.2 lists ISO VG for industrial oil. Indian Oil Corporation markets oil as per ISO designation.

**Table 1.1** ISO VG for engine oils

ISO Viscosity Grade	Kinematic Viscosity (cS @ 40 °C)	
	Minimum	Maximum
ISO VG 2	1.98	2.42
ISO VG 3	2.88	3.52
ISO VG 5	4.14	5.06
ISO VG 7	6.12	7.48
ISO VG 10	9	11.0
ISO VG 15	13.5	16.5
ISO VG 22	19.8	24.2
ISO VG 32	28.8	35.2
ISO VG 46	41.4	50.6
ISO VG 68	61.2	74.8
ISO VG 100	90	110
ISO VG 150	135	165
ISO VG 220	198	242
ISO VG 320	288	352
ISO VG 460	414	506
ISO VG 680	612	748
ISO VG 1000	900	1100
ISO VG 1500	1350	1650

**Table 1.2** ISO VG for industrial oil

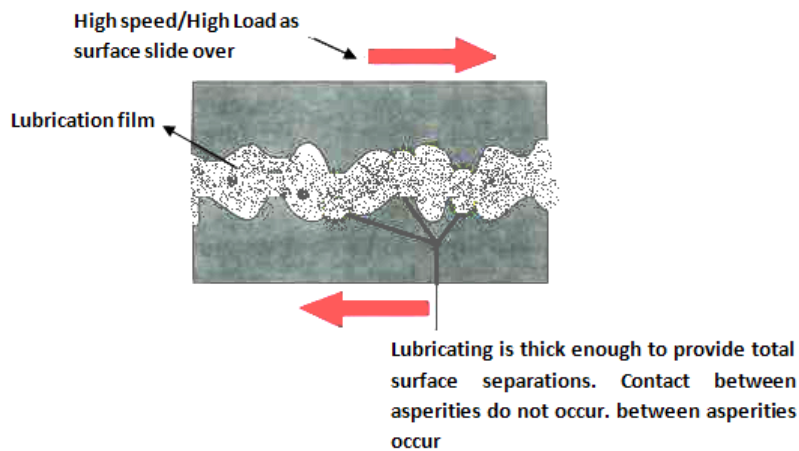
<b>Old Designation</b>	<b>New Designation</b>
Servo system 311	Servo system 32
Servo system 314	Servo system 46
Servo system 317	Servo system 57 <sup>a</sup>
	Servo system 68
Servo system 321	Servo system 81 <sup>a</sup>
	Servo system 100
Servo system 526	Servo system 121
	Servo system 150
Servo system 533	Servo system 176
	Servo system 220
Servo system 563	Servo system 320
	Servo system 460
Servo system 711	Servo system A 32
Servo system 733	Servo system A 176 <sup>a</sup>
Servocirol 11	Servocirol 32
Servocirol 14	Servocirol 46
Servocirol 17	Servocirol 57 <sup>a</sup>
	Servocirol 68
Servocirol 21	Servocirol 81 <sup>a</sup>
	Servocirol 100
Servocirol 26	Servocirol 121 <sup>a</sup>
	Servocirol 100
Servohydex 14	Servohydex 32
Servohydex 21	Servohydex 57 <sup>a</sup>

<sup>a</sup>Non-standard ISO VG.

### **1.2.2 Lubrication Capability**

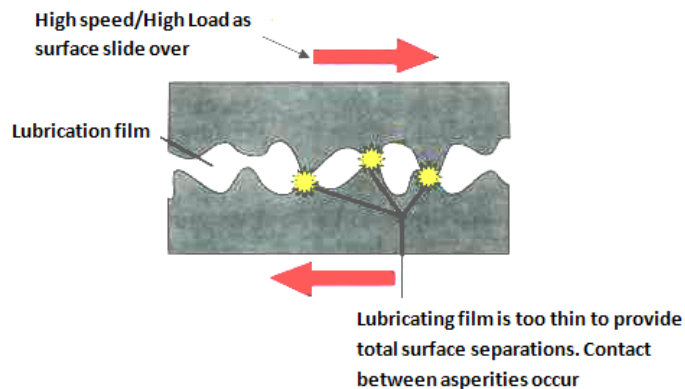
Hydraulic fluids must have *good* lubricity to prevent friction and wear between the closely fitted working parts such as vanes of pumps, valve spools, piston rings and bearings. Wear is the removal of surface material due to the frictional force between two metal-to-metal contact of surfaces. This can result in a change in dimensional tolerances, which can lead to improper functioning and failure of the components. Hydraulic oil should have a good lubricating property. That is, the film so formed should be strong enough that it is not wiped out by the moving parts.

There are two main kinds of lubrication mechanisms: thick film and boundary film. In low-pressure hydraulic systems such as hand-operated pumps and cylinders, a fluid providing thick-film lubrication is sufficient. A thick film is about 10 times the surface roughness. Under such conditions, there is no metal-to-metal contact as shown in Fig. 1.1, and therefore there is no wear (the coefficient of friction is as low as 0.01–0.02).



**Figure 1.2** Thick film lubrication

However as the speed of the moving part increases like in high speed motor, actuators, valves the film thickness reduces to about three to five times the surface roughness. This increases metal-to-metal contact as shown in Fig. 1.2 and also increases the coefficient friction and wear rate. In such situations, additives are added to the fluid to increase the load-carrying capacity of the film. In this case, the coefficient of friction is quite high and the wear rates are higher than the thick-film lubrication condition.



**Figure 1.2** Boundary film lubrication

The friction force ( $F$ ) is the force parallel to the two mating surfaces that slide relative to each other. This friction force actually opposes the sliding movement between the two surfaces. The greater the frictional force, the greater the wear and heat generated. This, in turn, results in power losses and reduced life, which, in turn, increases maintenance cost.

It has been determined that the frictional force ( $F$ ) is proportional to the normal force  $N$  that forces the two surfaces together. The proportionality constant is called the coefficient of

friction ( $\mu$ )

$$F = \mu N \quad (1.1)$$

Thus, the greater the values of the coefficient of friction and normal force, the greater the frictional force and hence wear. The magnitude of the normal force depends upon the amount of power and forces being transmitted and thus is independent of hydraulic fluid properties. However, the coefficient of friction depends on the ability of the fluid to prevent metal-metal contact of the closely fitting mating parts.

Equation (1.1) can be rewritten to solve for the coefficient of friction, which is a dimensionless parameter:

$$\mu = \frac{F}{N} \quad (1.2)$$

It can be seen now that  $\mu$  can be experimentally determined to give an indication of the anti-wear properties of a fluid  $F$  and  $N$  can be measured.

### 1.2.3 Demulsibility

The ability of a hydraulic fluid to separate rapidly from moisture and successfully resist emulsification is known as “demulsibility.” If an oil emulsifies with water, the emulsion promotes the destruction of lubricating and sealant properties. Highly refined oils are basically water resistant by nature.

### 1.2.4 Good Chemical and Environmental Stability (Oxidation and Corrosion Resistance)

For a good hydraulic fluid, a good chemical and environmental stability is desirable. Most fluids are vulnerable to oxidation, as they come in contact with oxygen in air. Mineral oils or petroleum-based oils (widely used in hydraulic systems) contain carbon and hydrogen molecules, which easily react with oxygen. The oxidation products are highly soluble in oil and being acidic in nature they can easily corrode metallic parts. The soluble acidic products cause corrosion, whereas insoluble products make the operation sluggish. Oxidation leads to deterioration in the chemical nature of fluid, which may form some chemical sledges, gum or varnish at low velocity or stagnation points in the system.

Many factors influence the rate of oxidation, such as temperature, pressure, moisture and so on. Temperature is the most affecting one, as the rate of oxidation increases severely with rise in temperature.

The moisture entering the hydraulic system with air causes the parts made of ferrous materials to rust. Rust is a chemical reaction between iron or steel and oxygen. Corrosion, on the other hand, is the chemical reaction between a metal and an acid. The result of rusting and corrosion is the “eating away” of the metal surfaces of the hydraulic components. Rust and corrosion cause excessive leakage between moving parts. Rust and corrosion can be prevented by incorporating additives that plate on the metal surface to prevent chemical reaction.

### 1.2.5 Neutralization Numbers

Neutralization number is a measure of the acidity or alkalinity of hydraulic oil. This is referred to as the pH value of the oil. High acidity causes the oxidation rate in oil to increase rapidly.

### 1.2.6 Incompressibility

Though we consider hydraulic fluids as incompressible, in practice, they are relatively compressible. Most mineral oils undergo reduction in the volume of about 0.7% for every 100 bar rise in pressure. In fact, the compressibility of a fluid is greatly influenced by temperature and pressure.

The incompressibility of a fluid is a measure of its stiffness and is given by its bulk modulus. The bulk modulus ( $B$ ) of a fluid is the ratio of volumetric stress to volumetric strain and is given by the relation

$$B = \frac{\Delta P}{\Delta V / V}$$

where  $B$  is the bulk modulus (Pa),  $\Delta P$  is the change in pressure (Pa),  $\Delta V$  is the change in volume ( $\text{m}^3$ ) and  $V$  is the original volume. The compressibility of a fluid has an influence on the system response and makes it susceptible to shock waves. In normal hydraulic systems, its effect on system response is not considered, whereas decompression valves are used to avoid shock wave problems.

### 1.2.7 Fire Resistance

There are many hazardous applications where human safety requires the use of a fire-resistant fluid. Examples include coal mines, hot metal processing equipment, aircraft and marine fluid power systems. A fire-resisting fluid is one that can be ignited but does not support combustion when the ignition source is removed. Flammability is defined as the ease of ignition and ability to propagate the flame. The following are the usual characteristics tested in order to determine the flammability of hydraulic fluids:

1. **Flash point:** The temperature at which an oil surface gives off sufficient vapors to ignite when a flame is passed over the surface.
2. **Fire point:** The temperature at which an oil releases sufficient vapors to support combustion continuously for 5 s when a flame is passed over the surface.
3. **Autogenously ignition temperature:** The temperature at which ignition occurs spontaneously.

The fire-resistant fluids are designated as follows:

1. **HFA:** A high-water-content fluid or HWCF (80% or more), for example, water–oil emulsions.
2. **HFB:** This is water–oil emulsion containing petroleum oil and water.
3. **HFC:** This is a solution of water and glycol.
4. **HFD:** This is a synthetic fluid, for example, phosphates or phosphate–petroleum blends.

The commonly used hydraulic liquids are petroleum derivatives; consequently, they burn vigorously once they reach a fire point. For critical applications, artificial or synthetic hydraulic fluids are used that have fire resistance.

Fire-resistant fluids have been developed to reduce fire hazards. There are basically four different types of fire-resistant hydraulic fluids in common use:

1. **Water-glycol solution:** This type consists of an actual solution of 40% water and 60% glycol. These solutions have high-viscosity-index values, but as the viscosity rises, the water evaporates. The operating temperature ranges run from  $-20^{\circ}\text{C}$  to about  $85^{\circ}\text{C}$ .
2. **Water-in-oil emulsions:** This type consists of about 40% water completely dispersed in a special oil base. It is characterized by small droplets of water completely surrounded by oil. The operating temperature range runs from  $-30^{\circ}\text{C}$  to about  $80^{\circ}\text{C}$ . As is the case with water-glycol solutions, it is necessary to replenish evaporated water to maintain proper viscosity.
3. **Straight synthetics:** This type is chemically formulated to inhibit combustion and in general has the highest fire-resistant temperature. The disadvantages of straight synthetics include low viscosity index, incompatibility with most natural or synthetic rubber seals and high cost.
4. **High-water-content fluids (HWCFs):** This type consists of about 90% water and 10% concentrate (designated as 90/10). The concentrate consists of fluid additives that improve viscosity, lubrication, rust protection and protection against bacteria growth. The maximum operating temperature should be held to  $50^{\circ}\text{C}$  to minimize evaporation.

The advantages of HWCF are as follows:

1. Fire resistance due to a high flash point of about  $150^{\circ}\text{C}$ .
2. Lower system operating temperature due to good heat dissipation.
3. Biodegradable and environmental-friendly additives.
4. High viscosity index.
5. Cleaner operation of the system.
6. Low cost of concentrate and storage.

The disadvantages of HWCF are as follows:

1. Greater contamination due to higher densities of fluids.
2. High evaporation loss.
3. Faster corrosion due to oxidation.
4. pH value to be maintained between 7.5 and 9.0.
5. Promotion of bacterial growth and filtration difficulties due to the acidic nature of fluids.

Performance of HWCFs can be improved using additives such as

1. Anti-wear additives.
2. Anti-foaming additives.
3. Corrosion inhibitors.
4. Biocides to kill water-borne bacteria.
5. Emulsifying agents.
6. Flocculation promoters.
7. Deionization agents.
8. Oxidation inhibitors.
9. Anti-vaporizing agents.

### **1.2.8 Low Flammability**

A fire-resistant fluid is one that can get ignited in the presence of an ignition source but does



not support combustion when the source is removed. This characteristic is defined as flammability. It refers to the ease with which a fluid gets ignited and propagates the flame. Hence, it is desirable to have a low flammability for a hydraulic fluid.

### **1.2.9 Foam Resistance**

Air can be present in a hydraulic fluid in two forms: dissolved and entrained. For example, if the return line to the reservoir is not submerged, the jet of oil entering the liquid surface will carry air with it. This causes air bubbles to form in the oil. If these bubbles rise to the surface too slowly, they will be drawn into the pump intake. This can cause pump damage due to cavitation. Another adverse effect of entrained and dissolved air is a great reduction in the bulk modulus of the hydraulic fluid.

### **1.2.10 Low Volatility**

A fluid should possess low vapor pressure or high boiling point. The vapor pressure of a fluid varies with temperature and hence the operating temperature range of the system is important in determining the stability of the fluid.

### **1.2.11 Good Heat Dissipation**

A hydraulic fluid should have a high heat dissipation capability. The temperature of a fluid shoots up if its heat dissipation characteristics are poor. Too high fluid temperature can cause a system to malfunction. If the fluid overheats, it may cause the following:

1. Give off vapor and cause cavitation of the pump.
2. Increase the rate of oxidation causing its rapid deterioration by producing sludges, varnishes, etc., thus shortening its useful life.
3. Reduce viscosity of the fluid resulting in increased leakage, both internal and external.
4. Cause thermal distortion in components.
5. Damage seals and packaging owing to embrittlement.

Hydraulic systems should be designed so that a heat balance occurs at a satisfactory operating temperature.

### **1.2.12 Low Density**

The relative density of a mineral oil is 0.9 (the exact value depends on the base oil and the additive used). Synthetic fluids can have a relative density greater than 1. The relative density is important when designing the layout of pumps and reservoir.

### **1.2.13 System Compatibility**

A hydraulic fluid should be inert to materials used in or near the hydraulic equipment. If the fluid in anyway attacks, destroys, dissolves or changes the parts of hydraulic system, the system may lose its functional efficiency and may start malfunction.

### 1.3 Additives in Hydraulic Fluids

Some of the commonly used additives and their purposes are as follows:

**1. Pour point depressant:** A pour point is the temperature at which a fluid ceases to flow. The minimum operating temperature in a hydraulic system should be at least 10°C above the pour point. Pour point depressants inhibit the formation of wax crystals in the mineral oils and hence enhance the pour points. There is a range of pour point depressant additives of different chemical species, important ones are polymethacrylates, polyacrylates and alkylated naphthalene.

**2. Viscosity index improvers:** These additives are long-chain polymers that stay in a coiled form in the hydraulic fluid. At a low operating temperature, they have no effect on viscosity. But when the temperature rises, these polymers uncoil and intermesh causing a thickness effect in the fluid, thereby not allowing the viscosity to drop down.

**3. Defoamers(anti-foam additives):** Certain additives, such as silicon polymer, act as defoamers. They cause a rapid breakdown of the foam by removing the entrained air bubbles. Foaming occurs in oil as a surface phenomenon. Bubbles of air are encircled by an oil film and cannot escape. These bubbles under pressure become very hot and can be the cause of system overheating. Foam usually forms in the reservoir and, if drawn into the pump suction, can cause noisy pump operation and may even damage pump parts. Control response is spongy and unreliable. Although all fluids are susceptible to foaming, the amount of foam in a system can be reduced to a minimum by the addition of chemical depressants.

**4. Oxidation inhibitors:** Oxidation causes the chemical reaction and formation of acidic products that leads to corrosion problems. The oxidation rate increases with temperature. Certain additives having greater affinity for oxygen are added so that they easily react with them than with oil.

**5. Corrosion inhibitors:** These additives form a thin film on the metal surface and shield it from coming in direct contact with the chemicals/acids in the fluid, thereby preventing corrosion problems.

**6. Anti-wear additives:** These are either long-chain polymer or extreme pressure (EP) additives. The long-chain polymers are adsorbed on the metal surfaces, causing a high local temperature and polish the surface. This helps in reducing the surface roughness, hence the wear problem.

**7. Load-carrying capacity:** The load-carrying capacity of a hydraulic fluid is a measure of the oil's capability to maintain a film of lubricant between two metal surfaces under extremes of load or pressure. All hydraulic oils have a natural load-carrying capacity that can be enhanced by special additives known as EP additives. These additives help reduce wear especially in hydraulic pumps and motors by providing lubrication when almost all the oil film has been squeezed out under heavy load conditions.

### 1.4 Types of Hydraulic Fluids

There are different types of hydraulic fluids that have the required properties. In general, while selecting a suitable oil, a few important factors are considered. First, its compatibility with seals, bearing and components is seen; second, its viscosity and other parameters such as fire resistance and environmental stability are also considered. There are five major types of hydraulic flow fluids which meet various needs of the system. These are briefly discussed as follows:

**1. Petroleum-based fluids:** Mineral oils are the petroleum-based oils that are the most commonly used hydraulic fluids. Basically, they possess most of the desirable characteristics: they are easily available and are economical. In addition, they offer the best lubrication

ability, least corrosion problems and are compatible with most seal materials. The only major disadvantage of these fluids is their flammability. They pose fire hazards, mainly from the leakages, in high-temperature environments such as steel industries, etc.

Mineral oils are good for operating temperatures below 50°C, At higher temperatures, these oils lose their chemical stability and form acids, varnishes, etc. All these lead to the loss of lubrication characteristics, increased wear and tear, corrosion and related problems. Fortunately, additives are available that improve chemical stability, reduce oxidation, foam formation and other problems.

A petroleum oil is still by far the most highly used base for hydraulic fluids. In general, petroleum oil has the following properties:

- Excellent lubricity.
- Higher demulsibility.
- More oxidation resistance.
- Higher viscosity index.
- Protection against rust.
- Good sealing characteristics.
- Easy dissipation of heat.
- Easy cleaning by filtration.
- Most of the desirable properties of the fluid, if not already present in the crude oil, can be incorporated through refining or adding additives.

A principal disadvantage of petroleum oil is that it burns easily. For applications where fire could be a hazard, such as heat treating, hydroelectric welding, die casting, forging and many others, there are several types of fire-resistant fluids available.

**2. Emulsions:** Emulsions are a mixture of two fluids that do not chemically react with others. Emulsions of petroleum-based oil and water are commonly used. An emulsifier is normally added to the emulsion, which keeps liquid as small droplets and remains suspended in the other liquid. Two types of emulsions are in use:

- Oil-in-water emulsions:** This emulsion has water as the main phase, while small droplets of oil are dispersed in it. Generally, the oil dilution is limited, about 5%; hence, it exhibits the characteristics of water. Its limitations are poor viscosity, leading to leakage problems, loss in volumetric efficiency and poor lubrication properties. These problems can be overcome to a greater extent by using certain additives. Such emulsions are used in high-displacement, low-speed pumps (such as in mining applications).
- Water-in-oil emulsions:** Water-in-oil emulsions, also called inverse emulsions, are basically oil based in which small droplets of water are dispersed throughout the oil phase. They are most popular fire-resistant hydraulic fluids. They exhibit more of an oil-like characteristic; hence, they have good viscosity and lubrication properties. The commonly used emulsion has a dilution of 60% oil and 40% water. These emulsions are good for operations at 25°C, as at a higher temperature, water evaporates and leads to the loss of fire-resistant properties.

**3. Water glycol:** Water glycol is another nonflammable fluid commonly used in aircraft hydraulic systems. It generally has a low lubrication ability as compared to mineral oils and is not suitable for high-temperature applications. It has water and glycol in the ratio of 1:1. Because of its aqueous nature and presence of air, it is prone to oxidation and related problems. It needs to be added with oxidation inhibitors. Enough care is essential in using this fluid as it is toxic and corrosive toward certain metals such as zinc, magnesium and

aluminum. Again, it is not suitable for high-temperature operations as the water may evaporate. However, it is very good for low-temperature applications as it possesses high antifreeze characteristics.

**4. Synthetic fluids:** Synthetic fluid, based on phosphate ester, is another popular fire-resistant fluid. It is suitable for high-temperature applications, since it exhibits good viscosity and lubrication characteristics. It is not suitable for low-temperature applications. It is not compatible with common sealing materials such as nitrile. Basically being expensive, it requires expensive sealing materials (viton). In addition, phosphate ester is not an environmental-friendly fluid. It also attacks aluminum and paints.

**5. Vegetable oils:** The increase in the global pollution has led to the use of more environmental-friendly fluids. Vegetable-based oils are biodegradable and are environmental safe. They have good lubrication properties, moderate viscosity and are less expensive. They can be formulated to have good fire resistance characteristics with certain additives. Vegetable oils have a tendency to easily oxidize and absorb moisture. The acidity, sludge formation and corrosion problems are more severe in vegetable oils than in mineral oils. Hence, vegetable oils need good inhibitors to minimize oxidation problems.

**6. Biodegradable hydraulic fluids:** As more and more organizations are understanding their social responsibility and are turning toward eco-friendly machinery and work regime, a biodegradable hydraulic fluid is too becoming a sought after product in the dawn of an environmentalist era. Biodegradable hydraulic fluids, alternatively known as bio-based hydraulic fluids, Bio-based hydraulic fluids use sunflower, rapeseed, soybean, etc., as the base oil and hence cause less pollution in the case of oil leaks or hydraulic hose failures. These fluids carry similar properties as that of a mineral oil-based anti-wear hydraulic fluid,

Hypothetically, if a company plans to introduce bio-based fluids into the hydraulic components of the machinery and the permissible operating pressure of hydraulic components is reduced to 80%, then it would inversely lead to a 20% reduction in breaking-out force owing to the 20% reduction in excavator's operating pressure. It is so because a reduction in the operating pressure of a system leads to a reduction in actuator force.

Besides, the transformation would not only include the cost of fluid and flushing of machinery to transcend from a mineral oil to vegetable oil repeatedly but also include the derating costs of machinery.

### **1.5 Factors Influencing the Selection of a Fluid**

The selection of a hydraulic fluid for a given system is governed by the following factors:

1. Operating pressure of the system.
2. Operating temperature of the system and its variation.
3. Material of the system and its compatibility with oil used.
4. Speed of operation.
5. Availability of replacement fluid.
6. Cost of transmission lines.
7. Contamination possibilities.
8. Environmental condition (fire proneness, extreme atmosphere like in mining, etc.).
9. Lubricity.
10. Safety to operator.
11. Expected service life.

### **Objective-Type Questions**

#### **Fill in the Blanks**

1. The ability of a hydraulic fluid to separate rapidly from moisture and successfully resist emulsification is known as \_\_\_\_\_.
2. The neutralization number is a measure of the \_\_\_\_\_ of hydraulic oil.
3. Emulsions are a mixture of two fluids which \_\_\_\_\_ chemically react with others.
4. Rust is a chemical reaction between iron or steel and \_\_\_\_\_.
5. The incompressibility of a fluid is a measure of its \_\_\_\_\_.

#### **State True or False**

1. Synthetic fluids can have a relative density greater than 1.
2. Viscosity index improvers are short-chain polymers.
3. Viscosity index is the arbitrary measure of a fluid resistance to viscosity change with temperature changes.
4. Mineral oils or petroleum-based oils easily react with oxygen.
5. Rust is a chemical reaction between a metal and an acid.

### **Review Questions**

1. What is a fluid? What are the functions and characteristics of hydraulic fluids?
2. List 10 properties that a hydraulic oil should possess.
3. Discuss the role of additives used in fluid power systems.
4. Differentiate between absolute and kinematic viscosities. Also write their units in CGS and SI systems of units.
5. List some fire-resistant fluids used in hydraulic industry.
6. Why is water not used as a medium in fluid power systems?
7. What are the advantages of high-water-based fluids?
8. How are fire-resistant fluids designated?
9. What is the neutralization number of a hydraulic fluid? Give its importance.
10. What are the functions of a hydraulic fluid?
11. What are the types of liquids used in a hydraulic system?
12. List the types of additives used in a hydraulic fluid.
13. Give the specification of two typical mineral-based hydraulic oils as per ISO.
14. What are the main disadvantages of biodegradable oils?