

## Lecture 30

### ACCESSORIES USED IN FLUID POWER SYSTEMS

#### Learning Objectives

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

- Differentiate between internal leakage and external leakage.
- Explain various types of seals used in fluid power.
- Explain the working of a durometer hardness tester.
- List various functions of a reservoir.
- Describe various types of reservoirs used in fluid power.
- Explain the design considerations for reservoirs used in fluid power.
- Carry out the heat transfer calculation of reservoirs.
- Differentiate between a strainer and a filter.
- Describe various types of filters used in fluid power applications.
- Define the beta ratio efficiency of a filter.
- Explain the importance of a heat exchanger.
- Size a heat exchanger.

#### 1.1 Introduction

Any hydraulic system is associated with a major problem, that is, leakage. This reduces efficiency and increases the power losses. Hence, sealing devices play a vital role in a hydraulic system by increasing the efficiency and decreasing the power losses. Leakage can be overcome by proper maintenance of the system and proper selection of seals and sealing at the design stage.

Leakage in a hydraulic system can be classified as follows:

**1. Internal leakage:** This occurs in hydraulic components built with operating clearances. Moving parts need to be lubricated and leakage path may be designed solely for this purpose. Internal leakage does not cause loss of fluid because the fluid returns to the reservoir. This leakage increases the clearances between mating parts due to wear. If the entire system leakage becomes large enough, the actuators do not operate properly.

**2. External leakage:** External leakage represents loss of fluid from the system. It also represents a safety hazard. Improper assembly of pipe fittings is the most common cause of external leakage. Over-tightened fittings may become damages or vibrations can cause properly tightened fittings to become loose. Failure to connect drain lines, excessive operating pressure and contamination might cause the fluid to externally leak.

#### 1.2 Functions of Seals

Seals are used in hydraulic systems to prevent excessive internal and external leakage and to keep out contamination. Various functions of seals include the following:

1. They prevent leakage – both internal and external.
2. They prevent dust and other particles from entering into the system.
3. They maintain pressure.
4. They enhance the service life and reliability of the hydraulic system.

### 1.2.1 Classification of Hydraulic Seals

Hydraulic seals can be classified as follows:

#### 1. According to the method of sealing:

- *Positive sealing:* A positive seal prevents even a minute amount of oil from getting past. A positive seal does not allow any leakage whatsoever (external or internal).
- *Non-positive sealing:* A non-positive seal allows a small amount of internal leakage, such as the clearance of the piston to provide a lubrication film.

#### 2. According to the relative motion existing between the seals and other parts:

- **Static seals:** These are used between mating parts that do not move relative to one another. Typical examples are flange gaskets and seals, o-rings, etc. These are relatively simple. They are essentially non-wearing and usually trouble-free if assembled properly.
- **Dynamic seals:** These are assembled between mating parts that move relative to each other. Hence, dynamic seals are subject to wear because one of the mating parts rubs against the seal.

#### 3. According to geometrical cross-section:

- **O-ring seal:** O-ring is the most widely used seal for hydraulic systems. It is a molded synthetic rubber seal that has a round cross-section in its free state (Fig. 1.1). O-ring can be used for the most static and dynamic conditions. It gives effective sealing through a wide range of pressures, temperatures and movements with the added advantages of sealing pressure in both directions and providing low running friction on moving parts.

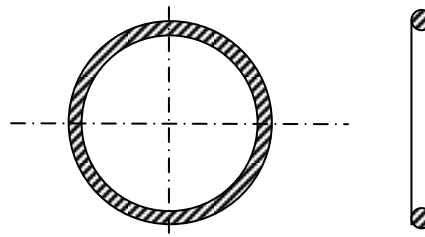
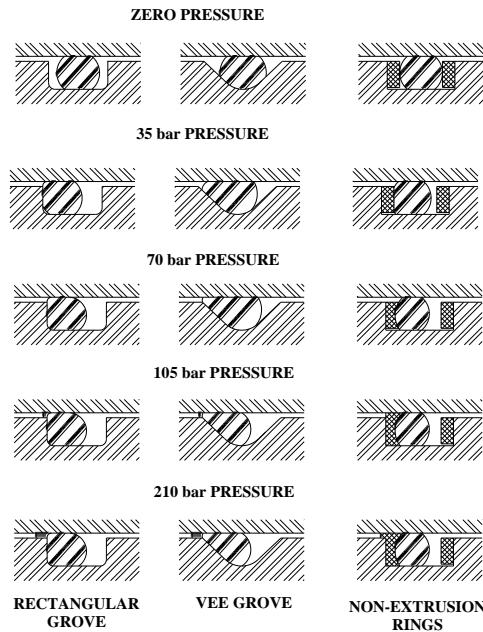


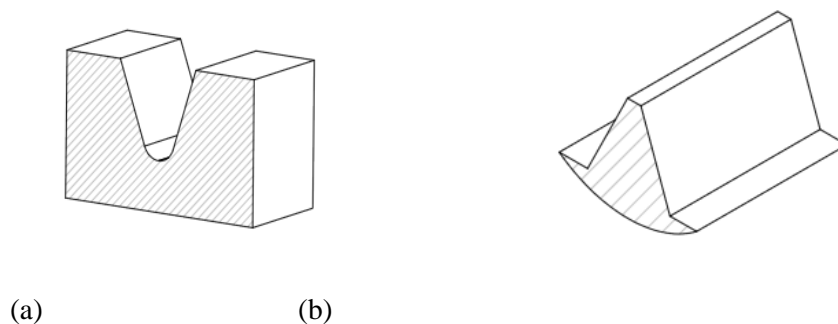
Figure 1.1 O-ring.

The action of the O-ring packing in the rectangular groove, in the V-groove and in the rectangular groove with backup washers at various pressures are shown in Fig. 1.2. It can readily be seen that without backup washers, as the pressure increases, the ring is forced or extruded into the clearance space. When the backup ring washers are used, however, this is prevented and packing life is thus extended.



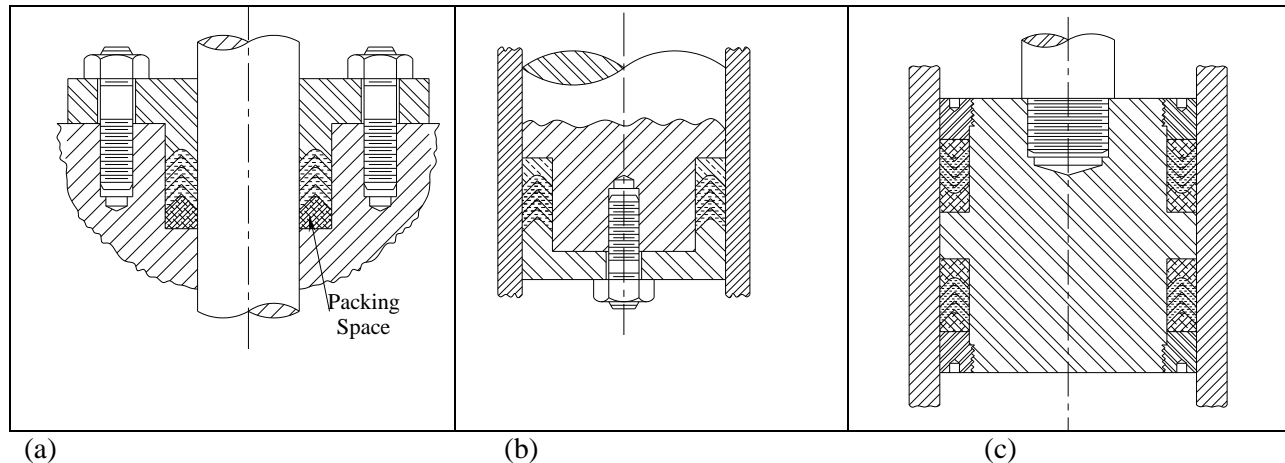
**Figure 1.2** Relative position of O-ring packings in different grooves at increasing pressure.

- V-ring seal and U-ring seal:** V- and U-ring seals are compression-type seals used in virtually in all types of reciprocating motion applications (Fig. 1.3). These include piston rods and piston seals in pneumatic and hydraulic cylinder, press rank, jacks and seals on plungers and piston in reciprocating pumps. They are also readily suited to certain slow rotary applications such as valve stems. These packings (which can be molded into U-shapes as well as V-shapes) are frequently installed in multiple quantities for more effective sealing.



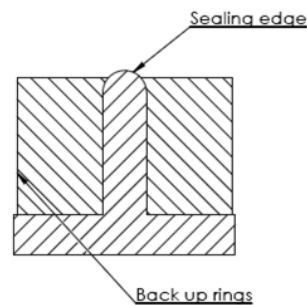
**Figure 1.3**(a)V-ring seal and (b) U-ring seal.

There are three important designs of V packings. They are shown in Fig. 1.4. Figure 1.4(a) shows an outward packed installation where the female support is an integral part of the nose on the gland ring. Figure 1.4(b) illustrates an installation of V packing on end of ram where a male ring is a part of the retaining gland ring. For inside-packed, double-acting cylinder, Fig. 1.4(c) illustrates a typical design. Here the gland rings are threaded and the male and female rings are separate units.



(a) (b) (c)  
Figure 1.4 V packings:(a) An outside packed V-ring installation;(b) installation of V packing on the end of the ram;(c) V packing for double-acting cylinder.

- **T-ring seal:** T-ring seal is a dynamic seal that is extensively used to seal cylinder-pistons, piston rods and other reciprocating parts (Fig. 1.5). It is made of synthetic rubber molded in the shape of the cross-section T and reinforced by backup rings on either side as shown in Fig. 1.5. The sealing edge is rounded and seals very much like an O-ring.



**Figure 1.5** T-ring seal.

- **Piston cup packings:** Piston cup packings are designed specifically for pistons in reciprocating pumps and pneumatic and hydraulic cylinders. They offer the best service life for this type of application, require a minimum recess space and minimum recess machining, and can be installed easily and quickly. In fastening the fabricated cup packing on the end of the piston, it is recommended that some provision be made to prevent the full pressure load from being taken on the bottom of the cup. The packing shown in Fig. 1.6 is single acting, while that shown in Fig. 1.7 is double acting. Piston shoulder K should be 0.127mm less than the nominal thickness of the packing. The tolerance on K is +0.00 to -0.0762mm. Figure 1.8 shows U cup packings installed in a piston assembly. Note other seals in cylinder.

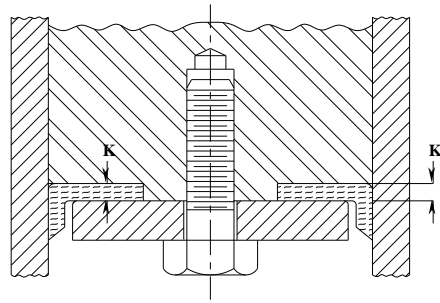


Figure 1.6 Correct method for supporting a cup packing – single acting.

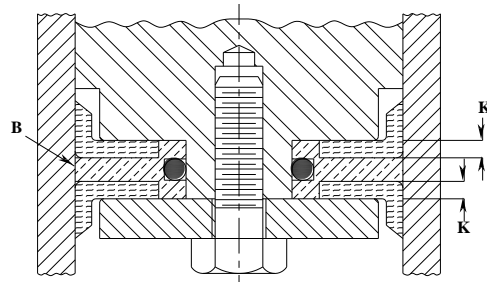


Figure 1.7 Correct method for supporting a cup packing –double acting.

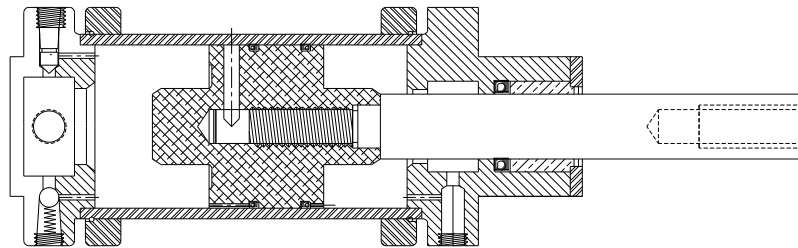


Figure 1.8 The use of U cup packings in piston assembly.

- Piston rings:** Piston rings are seals that are universally used for cylinder pistons. Metallic piston rings are made of cast iron or steel and are usually plated or given an outer coating of materials such as zinc phosphate or manganese phosphate to prevent rusting and corrosion. Piston rings offer substantially less opposition to motion than synthetic rubber (elastomer) seals. They have a number of non-metallic piston rings made out of tetrafluoroethylene, a chemically inert, tough, waxy solid. Their extremely low coefficient of friction (0.04) permits them to be run completely dry and at the same time prevents scoring of the cylinder walls. This type of piston ring is an ideal solution to many applications where the presence of lubrication can be detrimental or even dangerous. For instance, in an oxygen compressor, just a trace of oil is a fire or explosion hazard.
- Wiper rings and Scraper rings:** They are seals designed to prevent foreign abrasive or corrosive materials from entering a cylinder. They are not designed to seal against pressure. They provide assurance against rod scoring and add materiality to packing life. Figure 1.9 shows a number of ways in which wiper rings can be assembled into a cylinder. The wiper ring is molded from a synthetic rubber, which is stiff enough to wipe all dust or dirt from the rod yet pliable enough to maintain a snug fit. The rings are easily installed with a snap fit into a machined groove in the gland. This eliminates the need for and expense of a separate retainer ring. Figure

1.10 shows the application of synthetic scrapper rings. It has been found that wiper rings or scrapper rings made of TFE(Tetrafluorethylene) will not adhere to the piston rod even during extended inoperative periods, and will not score piston rods made of steel or chrome plated steel. TFE is unaffected by temperature from  $-75^{\circ}\text{C}$  to  $-250^{\circ}\text{C}$  and is not affected by grease, paint, or other coatings often used for protective packaging of cylinders and valves.

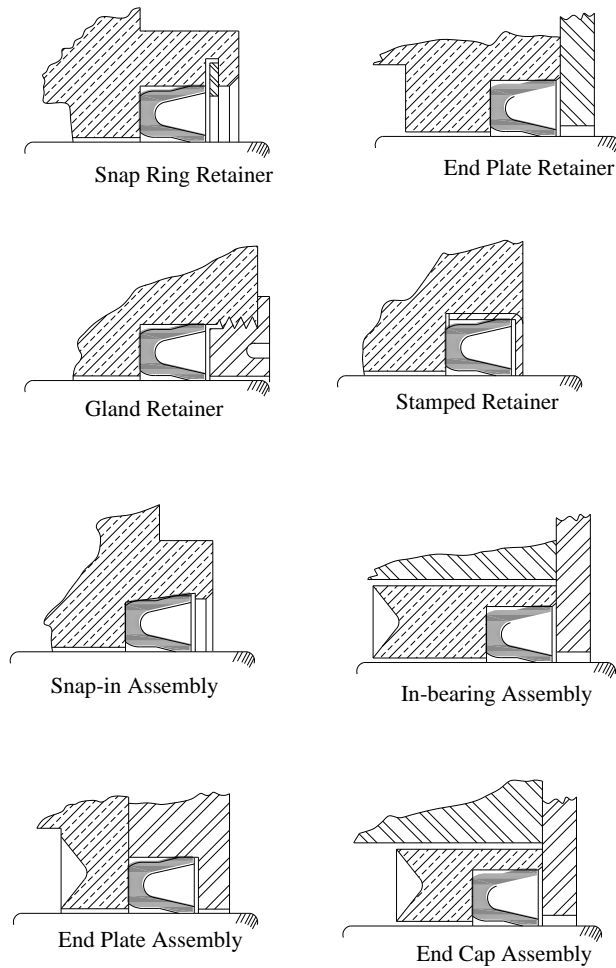


Figure 1.9 Assemblies for wiper rings.

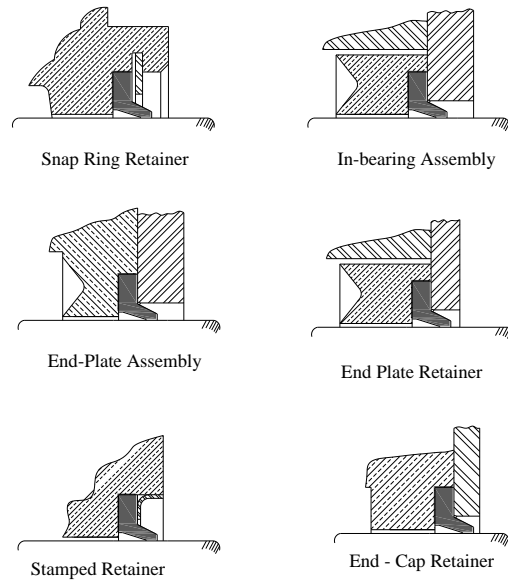


Figure 1.10 Assemblies for scraper rings.

4. **According to the type of seal material used:** Hydraulic seals may be classified according to the type of seal material used. Seals are manufactured from a variety of natural and synthetic materials. Earlier leather, cork and impregnated fibers were used in hydraulic systems. But nowadays, these are replaced by plastic and synthetic rubber materials. Synthetic rubbers (elastomers) are compatible with oil. Elastomers can be made in various compositions to meet various operating conditions:

- Neoprene (chloroprene).
- Buna-N.
- Silicone (Teflon).
- Tetrafluoroethylene.
- Viton.

Natural rubber is rarely used as a seal material because it swells and deteriorates with time in the presence of oil. In contrast, synthetic rubber materials are compatible with most oils. The most common types of materials used for seals are leather, Buna-N, silicone, neoprene, tetrafluoroethylene, viton and of course metals. Let us discuss them below:

- **Leather:** This material is rugged and inexpensive. However, it tends to squeeze when dry and cannot operate above  $90^{\circ}\text{C}$  which is inadequate for many hydraulic systems. Leather does not operate well at cold temperatures to about  $-50^{\circ}\text{C}$ .
- **Buna-N:** This material is rugged and inexpensive and wears well. It has a rather wide operating temperature range ( $-45$ – $110^{\circ}\text{C}$ ) during which it maintains its good sealing characteristics.
- **Silicone:** This elastomer has an extremely wide temperature range ( $-65$ – $232^{\circ}\text{C}$ ). Hence, it is widely used for rotating shaft seals and static seals where a wide operating temperature is expected. Silicone is not used for reciprocating seal applications because it has a low tear resistance.

- **Neoprene:** This material has a temperature range of 50–120°C. It is unsuitable above 120°C because it has a tendency to vulcanize.
- **Tetrafluoroethylene:** This material is the most widely used plastic for seals of hydraulic systems. It is a tough, chemically inert, waxy solid, which can be processed only by compacting and sintering. It has an excellent resistance to chemical breakdown up to temperatures of 370°C. It also has an extremely low coefficient of friction. One major drawback is its tendency to flow under pressure, forming thin, feathery films. This tendency to flow can be greatly reduced by the use of filler materials such as graphite, metal wires, glass fibers and asbestos.
- **Viton:** This material contains about 65% fluorine. It has become almost a standard material for elastomer-type seals for use at elevated temperatures up to 240°C. Its minimum operating temperature is 28°C.

### 1.3 Durometer Hardness Tester

The physical properties frequently used to describe the behavior of elastomers are as follows: hardness, coefficient of friction, volume change, compression set, tensile strength, elongation modulus, tear strength, squeeze stretch, coefficient of thermal expansion and permeability. Among these physical properties, hardness is the most important because it has a direct relationship to service performance.

A durometer is an instrument used to measure the indentation hardness of rubber and rubber-like materials. As shown, the hardness scale has a range from 0 to 100. The durometer measures 100 when pressed firmly on flat glass. High durometer readings indicate a great resistance to denting and thus a hard material. A durometer hardness of 70 is the most common value.

A hardness of 80 is usually specified for rotating motion to eliminate the tendency toward side motion and bunching in the groove. The values between 50 and 60 are used for static seals on rough surfaces. Hard seal materials (values between 80 and 90) have less breakaway friction than softer materials, which have a greater tendency to deform and flow into surface irregularities. As a result, harder materials are used for dynamic seals.

### 1.4 Reservoirs

The functions of a fluid reservoir in a power hydraulic system are as follows:

1. To provide a chamber in which any change in the volume of fluid in a hydraulic circuit can be accommodated. When the cylinder extends, there is an increased volume of fluid in the circuit and consequently there is a decrease in the reservoir level.
2. To provide a filling point for the system.
3. To serve as a storage space for the hydraulic fluid used in the system.
4. It is used as the location where the fluid is conditioned.
5. To provide a volume of fluid which is relatively stationary to allow entrained air to separate out and heavy contaminants to settle. The reservoir is where sludge, water and metal chips settle.
6. It is a place where the entrained air picked up by the oil is allowed to escape.
7. To accomplish the dissipation of heat by its proper design and to provide a radiating and convective surface to allow the fluid to cool.

A reservoir is constructed with steel plates. The inside surface is painted with a sealer to prevent rust due to condensed moisture. At the bottom, it contains a drain plug to allow the complete drainage of the tank when required. A removable head can be provided for easy access during cleaning. A vented breather cap is also included that contains an air filtering screen. This allows the tank to breathe as the oil level changes due to system demand requirements.



A baffle plate extends lengthwise across the center of the tank. The purpose of the baffle plate is to separate the pump inlet line from the return line to prevent the same fluid from recirculating continuously within the tank. The functions of a baffle plate are as follows:

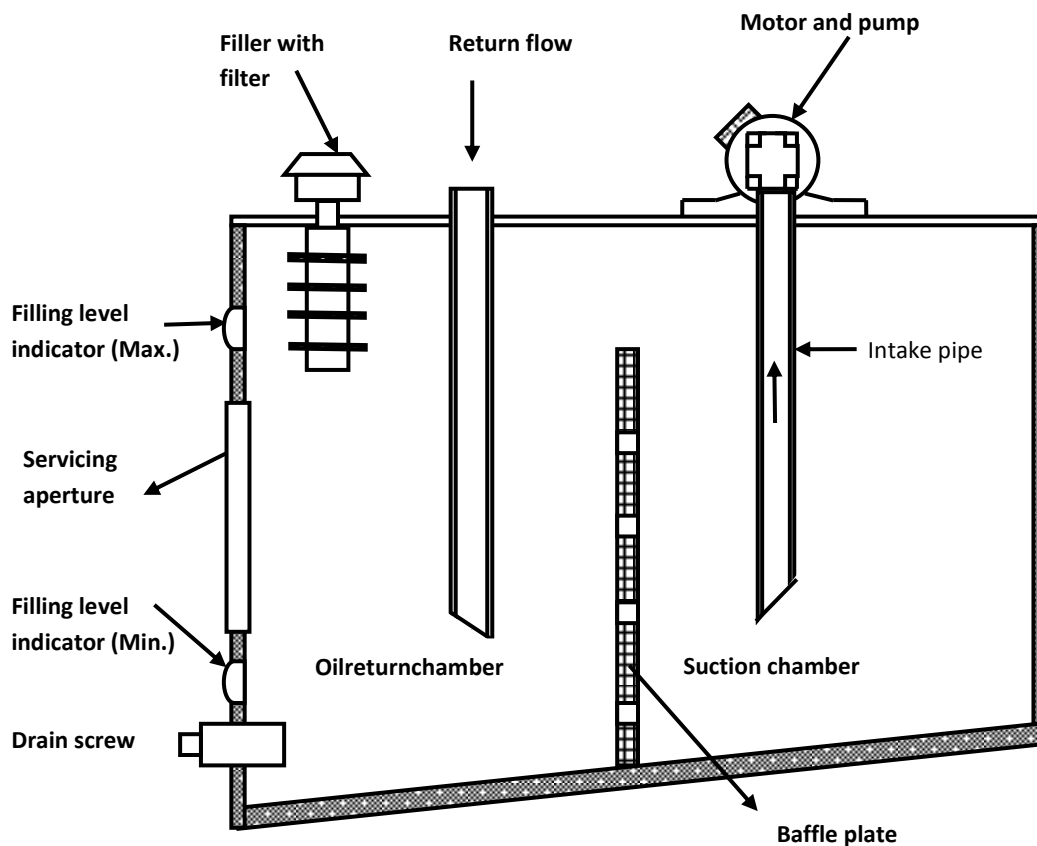
1. To permit foreign substances to settle to bottom.
2. To allow entrained air to escape from oil.
3. To prevent localized turbulence in the reservoir.
4. To promote heat dissipation through reservoir walls.

The return line should enter the reservoir on the side of the baffle plate that is opposite to the pump suction line.

#### 1.4.1 Features of a Hydraulic Reservoir

Schematic diagram of hydraulic reservoir is shown in Fig.1.11. There are many components mounted on reservoir and each one of them having specific features. Following are the features of a hydraulic reservoir:

1. **Filler cap (breather cap):** It should be airtight when closed but may contain the air vent that filters air entering the reservoir to provide a gravity push for proper oil flow.
2. **Oil level gauge:** It shows the level of oil in the reservoir without having to open the reservoir.



**Figure 1.11** Hydraulic reservoir.

**3. Baffle plate:** It is located lengthwise through the center of the tank and is two-third the height of the oil

level. It is used to separate the outlet to the pump from the return line. This ensures a circuitous flow instead of the same fluid being recirculated. The baffle prevents local turbulence in the tank and allows foreign material to settle, get rid of entrapped air and increase heat dissipation.

**4. Suction and return lines:** They are designed to enter the reservoir at points where air turbulence is the least. They can enter the reservoir at the top or at the sides, but their ends should be near the bottom of the tank. If the return line is above the oil level, the returning oil can foam and draw in air.

**5. Intake filter:** It is usually a screen that is attached to the suction pipe to filter the hydraulic oil.

**6. Drain plug:** It allows oil to be drained from the reservoir. Some drain plugs are magnetic to help remove metal chips from the oil.

**7. Strainers and filters:** Strainers and filters are designed to remove foreign particles from the hydraulic fluid. Strainers and filters are discussed in detail in Section 1.6.

### 1.4.2 Types of Reservoirs

Industrial reservoirs come in a variety of styles. Some of them are the following:

**1. Non-pressurized:** The reservoir may be vented to atmosphere using an air filter or a separating diaphragm. The type most commonly used in industry, normally, has an air breather filter, although in very dirty environments, diaphragms or air bags are used.

**2. Pressurized:** A pressurized reservoir usually operates between 0.35 and 1.4 bar and has to be provided with some method of pressure control; this may be a small air compressor maintaining a set charge pressure. In motor circuits where there is a little change in fluid volume in the reservoir, a simple relief valve may be used to limit the air pressure that alters with changes in temperature. The advantages of a pressurized reservoir are that it provides boost pressure to the main pump and prevents the ingress of atmospheric dirt.

### 1.4.3 Sizing of the Reservoir

The reservoir capacity should be adequate to cater for changes in fluid volume within the system, and with sufficient surface area to provide system cooling. An oversize reservoir can present some disadvantages such as increased cost, size and longer warming-up periods when starting from cold. There are many empirical rules for sizing reservoirs.

The sizing of a reservoir is based on the following criteria:

- 1.** The minimum reservoir capacity should be twice the pump delivery per minute. This must be regarded as an absolute minimum and may not be sufficient to allow for the volume changes in the system.
- 2.** The reservoir capacity should be three to four times the pump delivery per minute. This may well be too high a volume for mobile application.
- 3.** The reservoir capacity should be 2–15 L per installed horse power. This may result in very large reservoirs when high-pressure systems are used.
- 4.** It must make allowance for dirt and chips to settle and for air to escape.
- 5.** It must be able to hold all the oil.

6. It must maintain the oil level high enough to prevent the whirlpool effect.
7. It should have a large surface area to dissipate heat generated in the system.
8. It should have an adequate air space to allow for the thermal expansion of oil.

All the above rules are based on conventional-shaped reservoirs. Special shapes require special considerations. When heat dissipation from the reservoir is a critical factor, it can be calculated by the following basic formula:

$$H = h A \Delta T \times 3.6 \quad (1.1)$$

where  $H$  is the heat transfer (W),  $h$  is the heat transfer coefficient,  $A$  is the surface area in  $m^2$  and  $\Delta T$  is the temperature differential ( $^{\circ}C$ ). For a vertical plate of height  $L$ ,

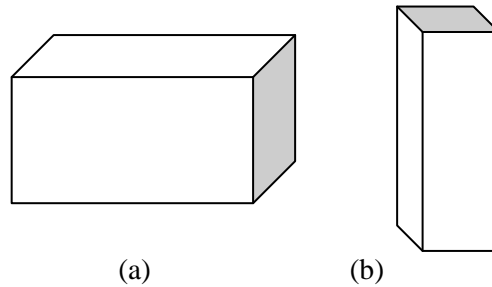
$$h = 1.42 \left( \frac{\Delta T}{L} \right)^{1/4} \quad (1.2)$$

For a horizontal plate of width  $W$ ,

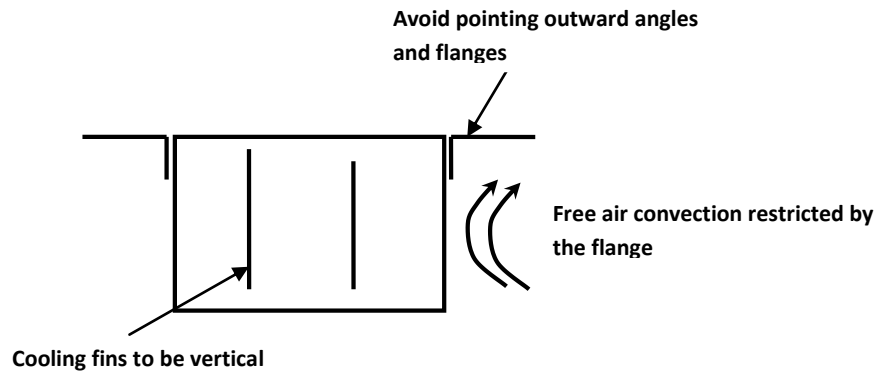
$$h = 1.32 \left( \frac{\Delta T}{W} \right)^{1/4} \quad (1.3)$$

These formulas apply to natural radiations. Normal air circulation round the reservoir increases the cooling considerably. For maximum heat radiations, the reservoir should be of minimum height and maximum length (see Fig. 1.12). Figure 1.12(a) shows minimum height and is best design from heat transfer point of view and figure shown in Fig. 1.12(b) has poor heat transfer. The equations neglect the cooling effect of the pipe work valves and actuators which may have a surface area comparable with that of the fluid reservoir.

The reservoir should not have any horizontal lips or angles on the vertical face as this interferes with the natural air convection. The cooling efficiency can be increased by using a finned design (Fig. 1.13); the fins should be vertical not horizontal. To assist the free circulation of external air and hence cooling, the reservoir should be mounted clear of the ground.



**Figure 1.12**(a)Best design for heat transfer; (b) design for poor heat transfer.



**Figure 1.13**Effect of fins and flanges.

The operating temperature of a fluid greatly affects its life. Table 1.1 gives an indication of operating temperatures for various types of fluids. These are typical values only and the exact value for a specific hydraulic fluid should be ascertained from the fluid supplier.

**Table 1.1** Operating temperatures for various types of fluids

Temperature	Mineral Oil (°C)	Water in Oil (60/40) (°C)	Water Glycol (°C)	Phosphate Ester (°C)
Maximum local temperature	100	65	65	150
Maximum temperature for continuous operation	65	40	40	95
Maximum temperature for optimum fluid life	40	25	25	65

#### 1.4.4 Reservoir Design and Construction

The reservoir must be equipped with a filling point and an air vent point. These are often combined as filler breather unit complete with a filling mesh. Combined units of this nature tend to have a slow filling rate and the filling mesh is often deliberately punctured to speed up the inflow. This defeats its purpose and allows large dirt into the reservoir. It is also very easy to leave the air-filter cap off after filling thereby permitting contaminants to enter. It is better to have a separate filling point complete with a quick release coupling and integral filler unit, in which case all the fluid is pumped into the reservoir through the filter, spin-on air breather are available with a fine filter range: 25  $\mu\text{m}$  absolute is typical ( $\beta_{25} = 75$ ).

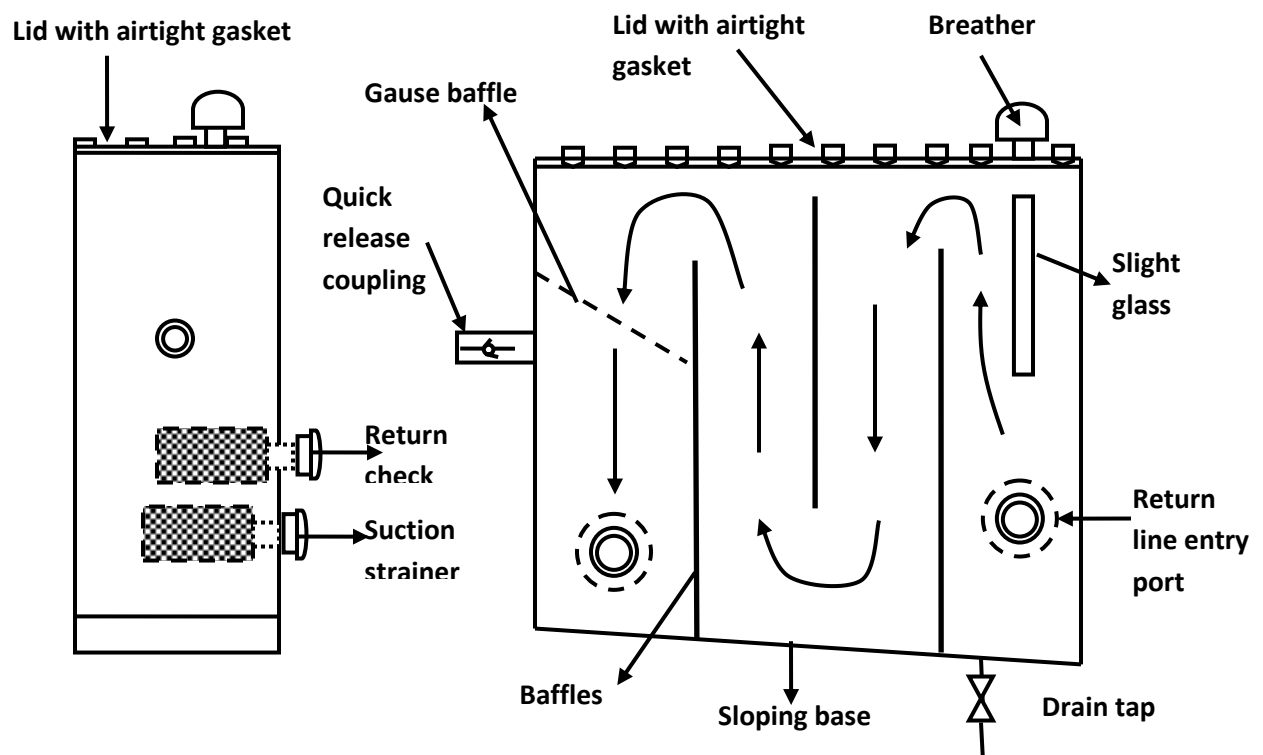
The pump suction line should be fitted with an adequately sized strainer. The strainer should be located so that there is a well distributed flow and its lowest point should be at least 75 mm above the bottom of the reservoir (to prevent any debris on the bottom of the tank being pulled into the suction line). The top of the strainer should be at least 150 mm below the lowest fluid level to prevent a vortex being formed and air drawn into the suction line.

System return lines and drain lines should terminate below the minimum fluid level to prevent aeration of the fluid. The main returns should be fitted with diffusers that reduce the return oil velocity and prevent turbulence. Where diffusers are not used, the end of return lines should be cut at 45°. Return outlets

should be carefully positioned to minimize interaction between the return flow and the reservoir boundaries. If the return pipes have an anti-syphon hole, aeration may be caused by the jet of fluid emanating from them during normal operation. This can be reduced by fitting deflector plates.

The reservoir must be fitted with some form of level indicator, generally a sight glass that should have the minimum and maximum levels clearly marked. A float switch can be incorporated to give an alarm or shut the pump down if the oil level falls below a certain value. This is very important in large systems where there is a possibility of a pipe failure or other sudden leak. Shutting the pump down protects the pump from cavitation and reduces the spillage of fluid.

Baffles are fitted in the reservoir to separate the return lines from the suction lines. They create a long flow path, which reduces surging effects, encourages dirt separation and improves cooling. A fine wire mesh baffle between 60 and 200 mesh size ( $250\text{--}75\text{ }\mu\text{m}$  aperture), set at an angle of  $20\text{--}40^\circ$  to horizontal, with the top edge terminating below the fluid surface will considerably aid the separation of entrained air. Wherever the hydraulic fluid is an oil and water emulsion, baffles should not be used as they tend to separate emulsion. With these fluids, good circulation in the reservoir is important to maintain emulsion. Figure 1.14 shows a reservoir designed to include most of these features. Although it is not the best shape for heat dissipation, it has other merits. If the fluid temperature inside the reservoir varies outside specified limits, temperature switches can be used to give a warning, switch in coolers or heaters, shut down pumps, prevent startup, etc. Wherever systems operate outdoors in cold temperatures or, for example, servo systems, which in order to preserve accuracy need to work at a constant temperature, heaters may be incorporated. These are a special type of immersion heaters having a low wattage relative to the surface area (maximum  $6\text{ W/m}^2$ ).



**Figure 1.14** Reservoir design and construction.

### 1.5 Fluid Conditioners

In the case of large reservoirs and systems where online filtration is impossible, separate clean-up filtration loops should be fitted. These may include an oil cooler. There are two types of oil coolers in use:

**1. Water tube coolers:** Water tube oil coolers consist of a series of interconnected copper tubes through which the cooling water passes surrounded by a jacket through which the hydraulic fluid passes. It is quiet in operation and can be arranged so that the oil pressure is higher than the water pressure; consequently, any leakage is more likely to be of oil into the water that is less serious than the contamination of the hydraulic fluid. When a water tube cooler is used, there is considerable flow of water involved and a separate water cooling tower and a circulating water supply may be necessary. Usually, the water supply is thermostatically controlled so that it is only switched ON when required.

**2. Air blast coolers:** An air blast cooler is similar in construction to a vehicle radiator with a powered air fan. It should be situated in a cool area so that cold air is blown over the radiator. An air blast cooler tends to be noisy but on small installations is preferable to water coolers owing to running and installation costs. Air blast coolers are now available to fit between the pump and the electric motor as part of the bell housing and coupling. Such coolers do not need a separate electric motor drive, but it is necessary to take into account the extra power needed when sizing the pump drive.

### **1.5.1 Centralized Hydraulic System**

The forerunner of modern gas, electricity and water authorities were a large number of local and municipal undertakings meeting the demands of large towns and industrially customers. In the late 19th and early 20th century, there existed several public hydraulic power companies providing water power in a similar manner.

The earliest system was in dockyards driving machinery of cranes, dock gates and sluices, commencing with an installation at hull docks in 1876. During that time, there were sizable undertakings in most parts of the world.

The change to hydraulic oil as a working medium fluid made such large installation impractical, but there has recently been a renaissance of centralized systems operating on a smaller scale. The idea of a hydraulic ring main running around a factory in a manner similar to the pneumatic ring mains which are in everyday use has many attractions. The principal difference, apart from the higher pressures involved and the obvious seriousness of leaks, is that a return pipe has to be provided as well as supply. Their most frequent use is in a factory or process plant where a group of related machines is powered from a central source.

### **1.5.2 Individual versus Centralized Systems**

There is still much controversy over the use of centralized hydraulic systems as opposed to individual power packs. The features of both are being compared. In general, what is an advantage for one is a disadvantage for the other. Both have their merits and every application must be assessed on its own particular requirement.

#### **1.5.2.1 Individual Power-Pack Systems**

Individual power packs are provided for each machine and components mounted are specific to the operation. They are usually supplied as modular units.

The advantages of individual power-pack systems are as follows:

- 1.** They are completely independent of each other.
- 2.** Different grades or types of fluids can be used as appropriate to each system.
- 3.** Each can operate at different pressures.
- 4.** If one circuit fails, others are still operative.
- 5.** Power packs can be adjacent to the machine.

The disadvantages of individual power-pack systems are as follows:

1. More power packs and components to maintain.
2. Increased cost.
3. More floor space required.
4. Greater total power.

#### ***1.5.2.2 Centralized Hydraulic Systems***

In centralized hydraulic system, reservoir will cater to many machines. This is like a hydraulic ring which runs around a factory in a manner similar to pneumatic ring.

The advantages of centralized hydraulic systems are as follows:

- Single oil reservoir.
- Standby pumps can be designed into the power pack.
- Reduced cost.
- Single unit to be maintained.
- Less space required.
- Fluid conditioning can be incorporated either offline or in the return line at much lower cost than when individual power packs are used.
- Total power-pack capacity may be less than that for individual power packs.

The disadvantages of centralized hydraulic systems are as follows:

- If there is a failure in the power pack, all the systems fail (unless standby facility included).
- Longer pipe runs are involved than with individual power packs.
- If more than one operating pressure is involved, pressure-reducing valves have to be fitted to the appropriate circuits.
- A large volume of fluid in the reservoir can be a considerable fire hazard.
- There may be interaction between the circuits.