1.3 Applications of Accumulators
There are five basic applications where accumulators are used in a hydraulic system:

1. **Accumulator as an auxiliary power source:** The purpose of accumulator in this application is to store the oil delivered by the pump during a portion of the work cycle. The accumulator then releases the stored oil on demand to complete the cycle, thereby serving as a secondary power source.

![Figure 1.8 Accumulator as an auxiliary power source.](image)

The schematic diagram is shown in Fig. 1.8. When the four-way valve is manually activated, oil flows from the accumulator to the blank end of the cylinder. This extends the piston until it reaches the end of the stroke. When the cylinder is in its fully extended position, the accumulator is being charged. The four-way valve is then deactivated for retraction of the cylinder oil flows from both the pump and accumulator to retract the cylinder rapidly.

2. **Accumulator as a leakage compensator:** An accumulator can be used as a compensator for internal and external leakage during an extended period in which the system is pressurized but not in operation. The pump charges the accumulator and the system until the maximum pressure sets the pressure switch ON. The schematic diagram is shown in Fig. 1.9. The contacts on the pressure switch then open to automatically stop the electric motor that drives the pump. The accumulator then supplies leakage oil to the system during a long period. Finally, when the system pressure drops to the minimum pressure setting of the pressure switch, it closes the electrical circuit of the motor until the system gets recharged. The check valve is placed between the pump and accumulator so that the pump does not reverse when the motor is stopped and does not permit all the accumulator charge to drain back into the power unit. With this circuit, the only time the power unit operates is when the pressure drops to an unsafe operating level. This saves electric power and reduces the heat in the system.
3. **Accumulator as an emergency power source**: In some hydraulic systems, safety dictates that a cylinder be retracted even though the normal supply of oil pressure is lost due to a pump or electrical power failures. The schematic diagram is shown in Fig. 1.10. In it, a solenoid activated three-way valve is used along with the accumulator. When the three-way valve is energized, oil flows to the blank end of the cylinder and also through the check valve into the accumulator and the rod end of the cylinder. The accumulator charges as the cylinder extends. If the pump fails due to an electric failure, the solenoid de-energizes, shifting the valve to its spring offset mode. Then the oil stored under pressure is forced from the accumulator to the end of the cylinder. This retracts the cylinder to its starting position.

4. **Accumulator as a hydraulic shock absorber**: One of the important applications of accumulators is the elimination of hydraulic shock. The schematic diagram is shown in Fig. 1.11. Hydraulic shock is
cause by the sudden stoppage or declaration of a hydraulic fluid flowing at relatively high velocity in a pipe line. Rapidly closing a valve creates a compression wave. This compression wave travels at the speed of sound upstream to the end of the pipe and back again to the closed valve, which causes an increase in pressure.

The resulting rapid pressure pulsations or high-pressure surges may cause damage to the hydraulic system components. If an accumulation is installed near the rapidly closing valve, the pressure pulsations or high-pressure surges are suppressed.

5. **Accumulator as a thermal expansion compensator:** When closed-loop hydraulic systems are subjected to heat conditions, both the pipe lines and the hydraulic fluid expand volumetrically. Because the coefficient of cubical expansion of most fluids is higher than that for pipe material, this expanded liquid volume increases the entire system pressure. This condition may cause pressures to exceed the limits of safety and may damage the system components. Under these conditions, an accumulator of proper capacity pre-charged to the normal system working pressure is installed. It takes up any increase in the system fluid volume, thus reducing the system pressure to its safe limits. The accumulator also feeds the required volume into the system as thermal contraction takes place. The schematic diagram of such an arrangement is shown in Fig. 1.12.
Example 1.1
A hydraulic cylinder has to move a certain load through a certain distance in 1 s at a pressure of 140 bar. An accumulator is integrated into the circuit to provide peak power. The accumulator is charged for the first 20 s and discharged in 2 s. The delivery expected from the accumulator is 0.6 L in 2 s as the pressure falls from 250 to 140 bar. Calculate the accumulator volume. The operating temperature is +25–70ºC. Also calculate the reduction in input power due to the accumulator.

Solution: This is a case of isothermal compression and adiabatic expansion. The equation considered here is

\[ V_0 = \frac{\Delta V(p_2 / p_0)}{[(p_2 / p_1)^{0.7143} - 1]} \]

Because the maximum system pressure is above 200 bar, we consider a higher value of 1.6 for the adiabatic index \( n \). Therefore, \( 1/1.6 = 0.625 \). Inserting this value into the above equation, we have \( p_0 = 0.8 p_1 = 0.9 \times 140 = 126 \) bar (gauge) = 127 bar (absolute). So

\[ V_0 = \frac{\Delta V(p_2 / p_0)}{[(p_2 / p_1)^{0.7143} - 1]} = \frac{0.6(251/127)}{[(251/141)^{0.7143} - 1]} = 2.74 \text{ L} \]

If we apply the correction for temperature change because the pre-charge pressure \( p_0 \) was based on the maximum temperature indicated, we have the new corrected volume

\[ V_{0T} = 2.74 \times \frac{343}{298} = 3.15 \text{ L} \]

A 3.5 L accumulator would effectively serve the purpose. The delivery from the accumulator is 0.6 L in 2 s, 0.3 L/s or 18 L/min.
In the absence of an accumulator, the pump has to supply all of this delivery at a pressure of 140 bar. The HP required would be \((18 \times 140)/600 = 4.2\) k\(\text{W}\).

Here the efficiency of the pump is not considered. If the accumulator is included in the circuit, the pump has to deliver \(0.6/20 = 0.03\) L/s or \(1.8\) L/min sufficient to charge the accumulator to a pressure of 250 kgf/cm\(^2\) within the time interval of 20 s. Here again the flow required to retract the cylinder is not considered.

The power requirement in this case would be \((1.8 \times 250)/600 = 0.75\) k\(\text{W}\).

The power saved is \((4.2 – 0.75) = 3.45\) k\(\text{W}\).

**Example 1.2**

A hydraulic molding press is kept closed at a maximum system pressure of 200 kgf/cm\(^2\) for a duration of 60 min during the curing period. The maximum leakage permitted during this period is 2 cm\(^3\)/minute and minimum fall in pressure permitted is 198 kgf/cm\(^2\). Calculate the accumulator volume.

**Solution:** This is an application where the accumulator is used as a leakage compensator under isothermal conditions. Therefore, the equation used for this is

\[ V_0 = \frac{\Delta V}{[p_0 / p_1 - p_0 / p_2]} \]

Here \(\Delta V = (2\times60)/1000 = 0.12\) L, \(p_0 = (0.9\times198) = 178\) kgf/cm\(^2\). Inserting these values in the above equation, we have

\[ V_0 = \frac{0.12}{[199/199 \text{–} 179/201]} = 13.3\text{L} \]

A standard 15 L accumulator would meet the requirement.

**Example 1.3**

A three-piston single-acting pump of flow rate \(Q = 133\) LPM is operating at 20 bar and at 148 RPM. The working temperature is 400\(^\circ\)C. Calculate the accumulator volume needed to limit the remaining pulsation to –2.5%.

**Solution:** This is a typical condition of pulsation damping in adiabatic phase due to high-speed compression and expansion. For this condition,

\[ V_0 = \frac{\Delta V}{[(p_0 / p_1)^{0.7143} - (p_0 / p_2)^{0.7143}]} \]

Here \(–V = kq\) where \(k\) for a three-piston single-acting arrangement can be taken as 0.12. The pump displacement \(q\) is given by

\[ q = 133/3 \times 148 = 0.3\text{L} \]

Now

\[ a = \frac{2.5}{100} \times 100 = 0.5 \]
Now $p_1 = (p - a) = (20 - 0.5) = 1.5$ bar, $p_2 = (p + a) = (20 + 0.5) = 20.5$ bar, $p_0 = (0.7 \times 20) = 14$ bar. Substituting these values into the above equation, we have

$$V_0 = \frac{(0.12 \times 0.3)}{[0.0007]^{0.7143} - (15 / 20.5)^{0.7143}} = 1.5 \text{L}$$

A 2 L accumulator would be adequate. Because all calculations are based on the absolute temperature and pressure, the temperatures must be expressed in degree Kelvin ($^\circ K$) that is obtained by adding 273 to the operating temperatures recorded in °C. Similarly to obtain absolute pressure, 1 bar is added to the values of $P$ given.

**Example 1.4**

A dead-load accumulator has a cylinder bore of 500 mm and is to operate at a system pressure of 200 bar. What is the dead load required?

**Solution:** The dead load required will be the product of piston area times the pressure.

$$\text{Load} = \frac{\pi}{4} \times (500/1000)^2 \times 200 \times 10^5 \text{N}$$

$$= 3.93 \times 10^6 \text{N (approx. 400 Ton)}$$

**Example 1.5**

Calculate the increase in pressure if a cylinder 300 mm length × 500 mm stroke is locked in the extended condition and then subjected to a 20°C rise in temperature. What is the volume of fluid to be stored in an accumulator fitted to compensate for thermal expansion? (Take the bulk modulus to be 15000 bar).

**Solution:** Total volume of fluid contained in the cylinder is

$$\frac{\pi}{4} \times (0.3)^2 \times 0.5 \text{ m}^3 = 35.3 \text{ L}$$

Change in volume is

$$35.3 \times 0.0007 \times 20 = 0.49 \text{ L}$$

which is the additional volume to be stored. Without an accumulator, the change in pressure in the closed system is $\Delta p$, that is,

$$\Delta p = \beta (\Delta V / V)$$

$$= 15000 \times 0.49 / 35.3$$

$$= 210 \text{ bar}$$

**Example 1.7**

What size of accumulator is necessary to supply 500 cc of fluid in a hydraulic system of maximum pressure of 200 bar that drops to 100 bar minimum? Assuming N$_2$ gas pre-charged of 66 bar, find adiabatic and isothermal solution.

**Solution:** Stages of pre-charging, charging and delivery are shown in Fig. 1.13.
We shall assume the expansion and compressions as isothermal and adiabatic.

(a) Isothermal condition:

\[ V_3 - V_2 = \text{volume of oil that can be delivered} = 0.005 \text{m}^3 \]

\[ V_3 = V_2 + 0.005 \]

Using \( p_2V_2 = p_3V_3 \) we get

\[ V_2 = \frac{p_3}{p_2} \times V_3 \]

\[ = \left[ \frac{100 + 1.013}{200 + 1.013} \right] \times [V_2 + 0.005] \]

\[ = 0.5025 V_2 + 0.002512 \]

\[ = 0.00505 \text{ m}^3 \]

Using \( p_1V_1 = p_2V_2 \) we get

\[ V_1 = \frac{p_1}{p_2} \times V_2 \]

\[ = \left[ \frac{200 + 1.013}{60 + 1.013} \right] \times 0.00505 = 0.01663 \text{ m}^3 \]

(b) Adiabatic condition:

\[ p_2V_2^{1.4} = p_3V_3^{1.4} \]

\[ \Rightarrow V_2 = V_3 \times \left( \frac{p_1}{p_2} \right)^{\frac{1}{1.4}} \]

\[ = (V_2 + 0.005) \left( \frac{101.013}{201.013} \right)^{0.714} \]

\[ = 0.6118V_2 + 0.003059 \]

\[ = 0.00788 \text{ m}^3 \]

Using \( p_1V_1^{1.4} = p_2V_2^{1.4} \) we get

\[ V_1 = 0.00788 \left( \frac{201.013}{67.013} \right)^{0.714} = 0.01726 \text{ m}^3 \]

Example 1.8

What size of accumulator is necessary to supply 4917 cm$^3$ of fluid into a hydraulic system of maximum operating pressure of 207 bar that drops to minimum 103.5 bar? Assuming a nitrogen gas pre-charge of accumulator to be 67 bar, obtain both isothermal and adiabatic solutions.

Solution: Stages of pre-charging, charging and delivery are shown in Fig. 1.14.
We shall assume the expansion and compressions to be isothermal and adiabatic.

(a) Isothermal condition:

\[ V_3 - V_2 = \text{volume of oil that can be delivered} = 0.004917 \text{ m}^3 \]

\[ V_3 = V_2 + 0.004917 \]

Using \( p_2V_2 = p_3V_3 \) we get

\[ V_2 = \frac{p_3}{p_2} \times V_3 = \left[ \frac{103.5 + 1.013}{207 + 1.013} \right] \times [V_2 + 0.004917] \]

\[ = 0.5025 \times V_2 + 0.00247 \]

\[ = 0.00496 \text{ m}^3 \]

Using \( p_1V_1 = p_2V_2 \) we get

\[ V_1 = \frac{p_2}{p_1} \times V_2 = \left[ \frac{207 + 1.013}{67 + 1.013} \right] \times 0.00496 = 0.01518 \text{ m}^3 \]

(b) Adiabatic condition: Using \( p_2^{1.4}V_2^{1.4} = p_1V_3^{1.4} \) we get

\[ V_2 = V_3 \times \left( \frac{p_1}{p_2} \right)^{\frac{1}{1.4}} \]

\[ = (V_2 + 0.004917) \left( \frac{104.013}{208.013} \right)^{0.714} \]

\[ = 0.0117V_2 + 0.003007 \]

\[ = 0.007740 \text{ m}^3 \]

Using \( p_1^{1.4} = p_2^{1.4} \) we get

\[ V_1 = 0.007746 \left( \frac{208.013}{68.013} \right)^{0.714} \]

\[ = 0.0172 \text{ m}^3 \]

Example 1.9

A gas-charged accumulator supplies energy to a system with 15 L of oil within the pressure range of 125–175 bar. If the accumulator has pre-charged pressure of 90 bar, size the accumulator for (a) isothermal and (b) adiabatic pressures.

Solution: Stages of pre-charging, charging and delivery are shown in Fig. 1.15.

Let the pre-charging pressures be \( p_1 \) and \( V_1 \). Gas is compressed by incoming oil from pressure 90–175 bar. When the bladder is compressed to 175 bar, the volume of oil inside the accumulator is 15 L. Therefore, we can write
\[ V_3 - V_1 = 15 \]

(a) Isothermal condition:
\[ p_1 V_1 = p_3 V_3 \]
\[ \Rightarrow 90 \times V_1 = 175 \times (V_1 - 15) \]
\[ \Rightarrow 90 V_1 = 175V_1 - 2625 \]
\[ \Rightarrow V_1 = \frac{2625}{86} = 30.88 \text{ L} \]

(b) Adiabatic condition:
\[ p_1 V_1^\gamma = p_3 V_3^\gamma \]
\[ \Rightarrow 90(V_1)^\gamma = 175(V_1 - 15)^\gamma \]
since there will be some heat loss and perfect adiabatic condition is not possible. Take \( \gamma = 1.3 \). We get
\[ 90(V_1)^{1.3} = 175 \left(V_1 - 15\right)^{1.3} \]
\[ \Rightarrow \frac{90}{175} = \left(\frac{V_1 - 15}{V_1}\right)^{1.3} \]
\[ \Rightarrow \frac{V_1 - 15}{V_1} = \left(\frac{90}{175}\right)^{1/1.3} \]
\[ \Rightarrow V_1 - 15 = 0.6 V_1 \]
\[ \Rightarrow V_1 = 37.5 \text{ L} \]

Example 1.10
An accumulator has a ram diameter of 0.4 m and lift of 10 m. It is loaded with 1000 kN of total weight. The packing friction is 5\% of the load on the ram. Find the power delivered to the main if the RAM descends steadily through its full stroke in 5 min while the pump delivers 50 LPS through the accumulator.

Solution: The pressure developed in an accumulator due to weight is
\[ \text{Pressure} = \frac{\text{net load}}{\text{Area}} = \frac{1000 \times 0.95}{\pi/4 \times 0.4^2} = 7560 \text{kPa} \]
Pressure energy (head) supplied by the accumulator to water is
\[ \frac{p}{\rho \times g} = \frac{7560}{9810} = 770 \text{m of water} \]
Energy supplied by the accumulator (during ascend) is
\[ Q \times g \times h = 50 \times 9.81 \times 770 = 377685 \text{ W} \]
Energy supplied by the accumulator (during descend)
\[ \frac{\text{Net load} \times \text{Stroke}}{\text{Time of descent}} = \frac{1000 \times 1000 \times 0.95 \times 10}{300} = 31667 \text{ W} \]
Total power delivered is
\[ 377685 + 31667 = 409352 \text{ W} = 409.4 \text{ kW} \]
**Example 1.11**

A gas-charged accumulator supplies energy to a system with 6.7 L of oil within the pressure range of 150–110 bar. The accumulator has the pre-charge pressure of 85 bar. What should be the size of the accumulator if the oil is to be supplied (a) in about 5 s and (b) in about 5 min?

**Solution:** Stages of pre-charging, charging and delivery are shown in Fig. 1.16.

![Pressure Stages](image)

Figure 1.16

Let the pre-charging pressure be \( p_1 \) (85 bar). Gas is compressed by incoming oil from pressure 85 to 150 bar. When the bladder is compressed to 150 bar, the volume of oil inside the accumulator is 6.7 L. Therefore, we can write

\[ V_3 - V_1 = 6.7 \]

Consider the adiabatic condition with \( \gamma = 1.25 \).

(a) In about 5 s:

\[ p_1 V_1^\gamma = p_2 V_2^\gamma \]

\[ \Rightarrow 85(V_1)^\gamma = 150 \times \left( V_1 - \frac{6.7}{5} \right)^\gamma \]

\[ \Rightarrow 85(V_1)^{1.25} = 150 \times (V_1 - 1.34)^{1.25} \]

\[ \Rightarrow \frac{85}{150} = \left( \frac{V_1 - 1.34}{V_1} \right)^{1.25} \]

\[ \Rightarrow \left( \frac{V_1 - 1.34}{V_1} \right) = \left( \frac{85}{150} \right)^{1/1.25} \]

\[ \Rightarrow V_1 = 3.144 \text{ LPS} \]

Capacity of accumulator = \( 3.144 \times 5 = 15.72 \) L

(b) In about 5 min:

Capacity of accumulator = \( 3.144 \times 5 \times 60 = 943.2 \) L

**Example 1.12**

A circuit has been designed to crush a car body into bale using a 152 mm diameter hydraulic cylinder. The hydraulic is to extend 2.54 m during a period of 10 s. The time between crushing strokes is 5 min. The following accumulator gas absolute pressures are given: \( p_1 \) (gas pre-charge pressure) = 84 bar (abs), \( p_2 \) (gas charge pressure when the pump is turned ON) = 210 bar (abs) = pressure relief value setting, \( p_3 \) (minimum pressure required to actuate load) = 126 bar (abs).

(a) Calculate the required size of the accumulator.

(b) What are the pump hydraulic kW power and flow requirements with and without accumulator?
Solution: Stages of pre-charging, charging and delivery are shown in Fig. 1.17.

Let the pre-charging pressure be $p_1$ (85 bar). Gas is compressed by incoming oil from pressure 84 to 210 bar and accumulator is discharged till the pressure reaches 126 bar.

(a) Without accumulator: Let the compression and expansion of gas follow isothermal law:

$$p_1 V_1 = p_2 V_2 = p_3 V_3$$

Here $V_c$ is the volume of hydraulic cylinder. It can accommodate $(V_3 - V_2)$ amount of oil

$$V_c = (V_3 - V_2)$$

$$\Rightarrow p_3 V_3 = p_2 V_2$$

$$\Rightarrow V_3 = \frac{p_2 V_2}{p_3} = \frac{210 \times V_2}{126} = 1.67 V_2 \quad (1.13)$$

$$\Rightarrow V_c = \frac{\pi}{4} d^2 l = \frac{\pi}{4} (0.152)^2 \times 2.54 = 0.0461 m^3 = (V_3 - V_2) \quad (1.14)$$

Using Eq. (1.13) in Eq. (1.14) and solving, we get

$$V_2 = 0.0688 m^3$$

$$V_3 = 0.155 m^3$$

$$V_1 = \frac{p_1 V_2}{p_i} = \frac{210 \times 0.0688}{840} = 0.172 m^3 = 172 L$$

(b) With accumulator: The pump charges accumulator in every 2.5 min. In other words, two times in five minutes.

Flow supplied by the pump

$$Q_p = \frac{2(V_3 - V_2)}{30} = \frac{2(46.1)}{300} = 0.307 LPS$$

Neglecting all losses, power supplied to the pump is

$$P_pump = p_2 \times Q_p$$

$$= \frac{(210 \times 10^4)(0.307 \times 10^{-3})}{1000} = 6.45 kW$$

Without accumulator: The pump extends cylinder in 10 s. Flow supplied by the pump is

$$Q_p = \frac{46.1}{10} = 0.461 LPS$$

Neglecting all losses, power supplied to the pump is

$$P_pump = p_2 \times Q_p$$

$$= \frac{(126 \times 10^3)(461 \times 10^{-5})}{1000} = 58.1 kW$$

It can be seen that flow and power requirement by the pump is more without accumulator.
Example 1.13
What size of accumulator is necessary to supply 10000 cm$^3$ of fluid is a hydraulic system of maximum pressure of 200 bar to 100 bar minimum. Assuming $N_2$ gas per-charged pressure of 80 bar. Find adiabatic and isothermal solution.

Solution: Let

- $V_1 =$ Volume of accumulator (cm$^3$)
- $V_2 =$ Volume of gas at high pressure (cm$^3$)
- $p_2 =$ Maximum pressure, bar = 200 bar
- $p =$ Minimum pressure, bar = 100 bar
- $p_1 =$ Per-charged pressure, bar = 80 bar

Let $V_1$ be the volume of gas in the accumulator at pre-charged 80 bar and $V_2$ be the volume of gas in the accumulator at 200 bar. Now

$$V_1 = V_2 + 10000 \text{ cm}^3$$

$\Rightarrow V_2 = V_1 - 10000$

(a) Adiabatic process: We have

$$p_1 V_1' = p_2 V_2'$$

Now $\gamma = 1.25$. So

$$(80)V_1' = (200)(V_1 - 10000)^\gamma$$

$\Rightarrow \frac{80}{200} = \left(\frac{V_1 - 10000}{V_1}\right)^\gamma$

$\Rightarrow 0.4 = \left(\frac{V_1 - 10000}{V_1}\right)^{1.25}$

$\Rightarrow \frac{V_1 - 10000}{V_1} = (0.4)^{1/1.25} = (0.4)^{0.8} = 0.4804$

$\Rightarrow V_1 - 10000 = 0.4804V_1$

$\Rightarrow V_1 - 0.4804V_1 = 10000$

$\Rightarrow 0.5195 V_1 = 10000$

$\Rightarrow V_1 = 19249.3 \text{ cm}^3$

Size of accumulator = 19249.3 cm$^3$

(b) Isothermal process: We have
\[ p_1V_1 = p_2V_2 \]
\[ \Rightarrow 80 \times V_1 = 200 \times (V_1 - 10000) \]
\[ \Rightarrow \frac{80}{200} = \frac{V_1 - 10000}{V_1} \]
\[ \Rightarrow 0.4 = \frac{V_1 - 10000}{V_1} \]
\[ \Rightarrow V_1 - 10000 = 0.4V_1 \]
\[ \Rightarrow V_1 - 0.4V_1 = 10000 \]
\[ \Rightarrow 0.6V_1 = 10000 \]
\[ \Rightarrow V_1 = 16666.7 \text{ cm}^3 \]

Size of accumulator = 16666.7 cm³
Objective-Type Questions

Fill in the Blanks

1. A hydraulic accumulator is a device that stores the potential energy of an ______ held under pressure by an external source against some dynamic force.
2. The main disadvantage of a weight-loaded or gravity accumulator is its extremely ______ size and ______ weight.
3. A spring-loaded accumulator stores energy in the form of a ______ spring.
4. Pulsation damping is typically an ______ condition because both storage and discharge have to be accomplished in a very short time.
5. The nitrogen pre-charge pressure in an accumulator is based on the expected maximum rise in the circulating hydraulic oil ______.
6. An accumulator permits ______ to be absorbed and stored in a hydraulic system.
7. Air or ______ should never be used in gas-charged accumulators.

State True or False

1. A gas-loaded accumulator is popularly used in industries.
2. In a bladder accumulator, the bladder is filled with oxygen until the designed pre-charge pressure is achieved.
3. An accumulator can be used as a compensator for both internal and external leakages.
4. One of the important applications of accumulators is the elimination of hydraulic shock.
5. An accumulator can be used as a fail–safe device.

Review Questions

1. Define an accumulator and explain its function.
2. What are the different types of accumulators?
3. Mention some of the industrial applications of an accumulator. Explain any one of them with an example.
4. Why are accumulators used?
5. Define and derive an expression for the volumetric capacity of bladder-type accumulators.
6. Explain the construction and operation of piston-type accumulators.
7. Explain the construction and operation of bladder-type accumulators.
8. Explain the construction and operation of diaphragm-type accumulators.
9. Discuss in detail the application of hydraulic accumulators as energy storage elements. Draw a hydraulic circuit for this application.
10. Discuss in detail the application of hydraulic accumulators for protection against shocks.
11. Discuss in detail the application of hydraulic accumulators in protecting against thermal expansion.
12. Discuss in detail the application of hydraulic accumulators for internal leakage compensation and the application of constant pressure.
13. What is the difference between separator and non-separator types of accumulators.
14. Name three different types of separator-type accumulators.
15. What are the advantages of bladder accumulators over piston accumulators?
Answers

Fill in the Blanks

1. Incompressible fluid
2. Large, heavy
3. Compressed
4. Adiabatic
5. Temperature
6. Energy
7. Pure oxygen

State True or False

1. True
2. False
3. True
4. True
5. True