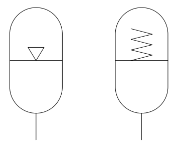
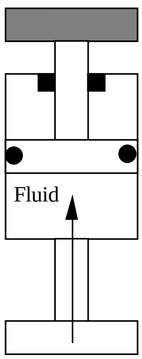
# Chapter 7 Accumulators

Accumulators are used to store fluid under pressure, cushion shock waves, and to perform a combination of both.



## 7.1 Weight Loaded or Gravity Type




- constant pressure source depending on the weight of the load
- can supply large quantities of fluid at a constant pressure

- heavy and large - unsuitable for mobile equipment

- Very expensive
- When in operation, these accumulators are pressure sources because they dictate the system pressure.

Figure 7.1 Weight accumulator

## 7.2 Spring Loaded Accumulator

- As fluid enters at a pressure P, the piston moves up. Hence, the spring compresses and P increases
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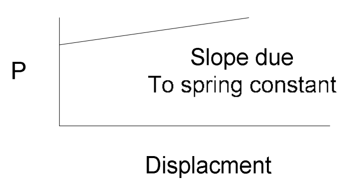



- It is not a constant pressure accumulator
- These units are good only at small flows and pressures.
- High cycle rates are not recommended.

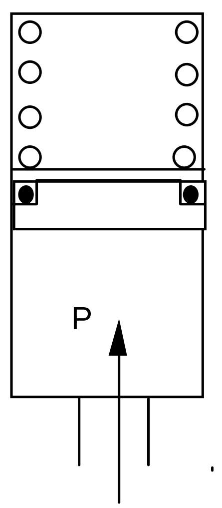



Figure 7.2 Spring loaded accumulator

## 7.3 Gas Loaded Accumulators

- used more than above two
- operates on Boyles law PV = const / T=const $PV^\gamma$ = const / adiabatic

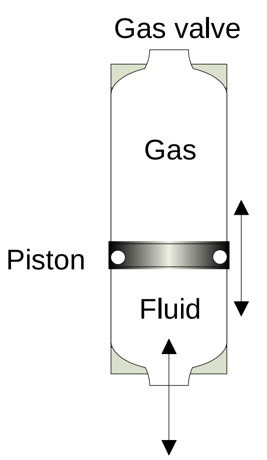
### 7.3.1 Non-Separator Type

- gas acts directly on the fluid
- problems arise when gas is absorbed into the fluid itself causing cavitation, etc

### 7.3.2 Separator Types

- a physical barrier exists between the fluid and gas

### 7.3.3(a) Piston Type




- Units are expensive and have practical limitations in size.
- Leakage is a problem.
- Friction effects becomes predominate at low pressures.
- Cannot be used as pulsation dampers due to inertia of pistons and friction of seals.
- Can be used at high or low temps.

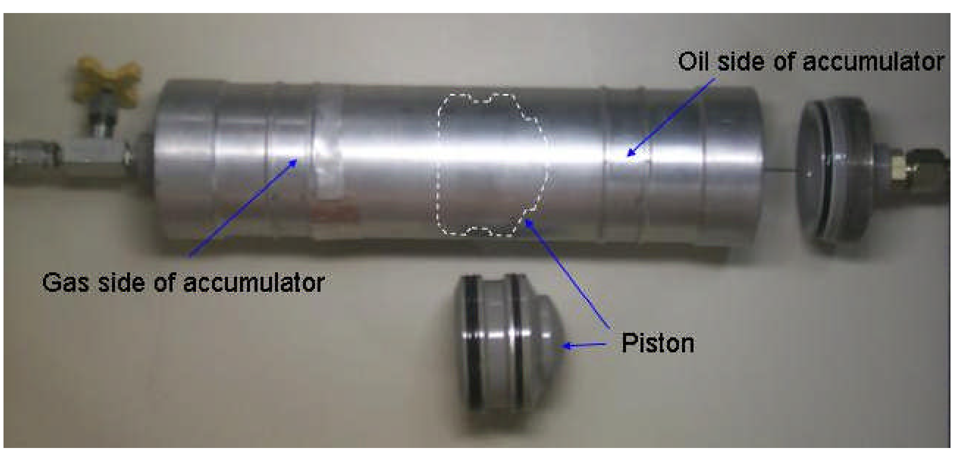
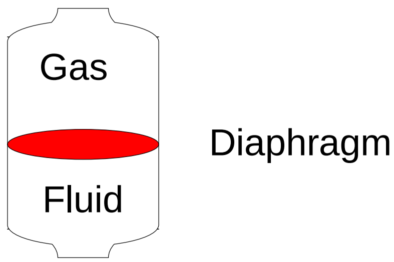



Figure 7.3 Piston accumulator

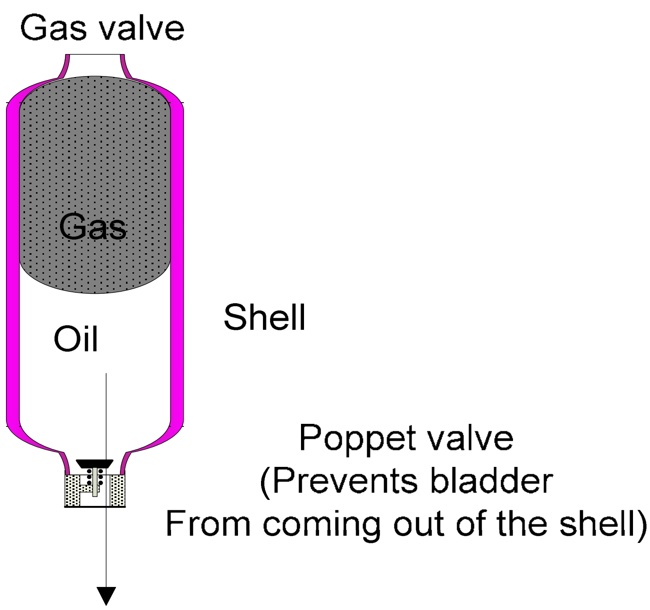
**7.3.3(b)** Diaphragm Type




- It has a small weight to vol. ratio.
- Limited size
- Excellent dynamic characteristics

Figure 7.4 Diaphragm accumulator

**7.3.3(c)** Bladder Type




- Has a high vol. eff.

- Positive sealing between gas & oil.

- Has a quick pressure response for pressure regulating pulse dampening, etc.

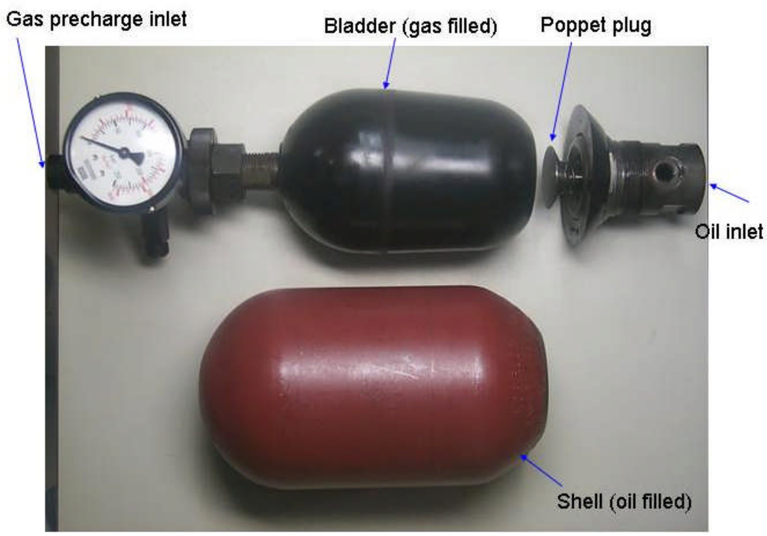



Figure 7.5 Bladder accumulator

## 7.4 Accumulator Size Selection

The formulas given here will be derived as homework (first two classes).

### 7.4.1 Auxiliary Power Source

In many applications, accumulators are used as an auxiliary power source. Therefore, for a given set of conditions, the capacity of an accumulator can be found from

(a) Isothermal (T = const PV = const)

$$V_1 = \frac{V_x (P_3 / P_1)}{1 - (P_3 / P_2)}$$

(b) Adiabatic (no heat transfer) n = 1.4

$$V_1 = \frac{V_x (P_3 / P_1)^{1/n}}{1 - (P_3 / P_2)^{1/n}}$$

where:

$V_1$ = Size of accumulator $cm^3$ ($in^3$) (Maximum volume occupied by gas at the precharge pressure).

$V_x$ = Volume of fluid discharged from accumulator (additional fluid required by the system) $cm^3$ ($in^3$)

$P_1$ = Gas precharge of accumulator Pa (psia). This pressure may be less than or equal to min. system pressure $P_3$

$P_2$ = Maximum system design operating pressure Pa (psia)

$V_2$ = Compressed vol. of gas at max. system pressure $cm^3(in^3)$
$P_3$ = Minimum system pressure Pa (psia) at which the additional fluid is needed.
$V_3$ = Expanded volume of gas at minimum system pressure
$V_x$ = $V_3 - V_2$ which is the amount of fluid required for the application.

Note: The precharge pressure must be less than the normal operating pressure of the system.

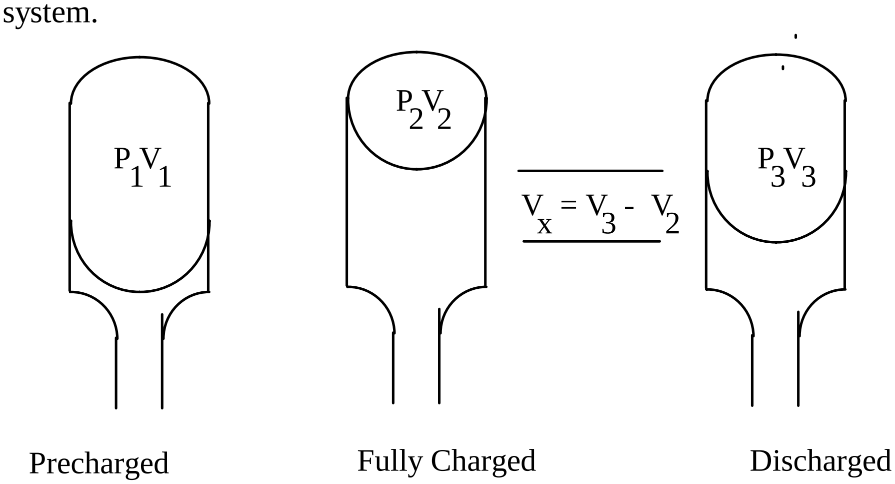



Figure 7.6 Sizing up an accumulator

### 7.4.2 Example:

What size of accumulator is necessary to supply 300 $in^3$ of fluid in a hydraulic system of maximum operating pressure 3000 psiA which drops to a minimum of 1500 psia. The accumulator is precharged with nitrogen @ 1000 psiA.

ISOTHERMAL

$$V_1 = \frac{300(\frac{1500}{1000})}{1-\frac{1500}{3000}} = 3.9 \text{ Gals.}$$

ADIABATIC

$$V_1 = \frac{300(\frac{1500}{1000})^{.714}}{1-(\frac{1500}{3000})^{.714}} = 4.45 \text{ Gals.}$$

### 7.4.3 Thermal Expansion Compensator

In closed systems, T variations can result in expansion of fluid and, hence, increased pressure.

$$V_1 = \frac{V_a (T_2 - T_1)(\beta - 3\alpha)(P_2/P_1)^{1/n}}{1 - (P_2/P_3)^{1/n}}$$

$V_1$ = Size of accumulator required $cm^3(in^3)$ (Max volume at precharge pressure)

$P_1$ = Gas precharge pressure Pa (psiA) (Must be less than the minimun pressure $P_2$)
$V_a$ = Total vol. of fluid in the pipe $cm^3$ $(in^3)$.

$T_1$ = Initial temp. °C (°F)
$T_2$ = Final temp. . °C (°F)
$P_2$ = Pressure Pa (psiA) at $T_1$ - Min system pressure
$P_3$ = Pressure Pa (psiA) at $T_2$ - Max system pressure
$\alpha$ = Coefficient of linear expansion of pipe material (1/°C) (1/°F)
$\beta$ = Coefficient of cubical expansion of fluid (1/°C) (1/°F)
n = 1.4 (nitrogen)

**7.4.4** Pump Pulsations

Used to damp pressure pulsations caused by the reciprocating action of piston-type pumps which produce periodic flow and pressure variations at their discharge ports.

$$V_1 = \frac{AKL\left(\frac{P_2}{P_1}\right)^{1/n}}{1-\left(\frac{P_2}{P_3}\right)^{1/n}}$$

$V_1$ = Size of accumulator $cm^3$ ($in^3$)
$P_2$ = System operating pressure Pa (psiA) = mean line pressure.
= Bore of one cylinder cm (in)
$P_1$ = Min system pressure Pa (psiA) = precharge pressure of acc.
$P_3$ = Max system pressure Pa (psiA)

| | | | | K |
|---|---|---|---|---|
| A | = | Area of bore $cm^2$($in^2$) | simplex single acting | .60 |
| | | | simplex double acting | .25 |
| K | = | Const. depending on the pump | duplex single acting | .25 |
| | | | duplex double acting | .15 |
| L | = | Length of stroke cm (in) | triplex single acting | .13 |
| n | = | 1.4 | triplex double acting | .06 |

**7.4.5** Line Shock Dampener (Bladder Types)

- Used to dampen pressure shock waves due to rapid deceleration of fluid at a valve closure.
- Should be installed as close to valve as possible

$$V = \frac{w}{2g} V^2 \left(\frac{n-1}{P_1}\right) \left[\frac{12}{\left(\frac{P_2}{P_1}\right)^{(n-1)/n} - 1}\right]$$

V = required acc. capacity
$P_2$ = Max. allow. press. shock Pa (psiA)
W = Total weight of fluid in line kg ($lb_f$)
g = 9.8 m/sec$^2$ (32.2 ft/sec$^2$)

n = 1.4
$\bar{V}$ = average flow velocity m/sec (ft/sec)
$P_1$ = system pressure at normal flow rate Pa(psia)
- also the accumulator precharge pressure

## 7.5 Accumulator Application - Example

An accumulator circuit can be used to save energy. In many instances, a certain amount of fluid is required to supplement an existing situation but only occasionally. Rather than having a pump over-rated to supply this extra flow, an accumulator can be used. If just a pump is used (fixed displ.), then most of the time, fluid is dumped past a relief valve wasting energy.

Consider the circuit shown as follows:

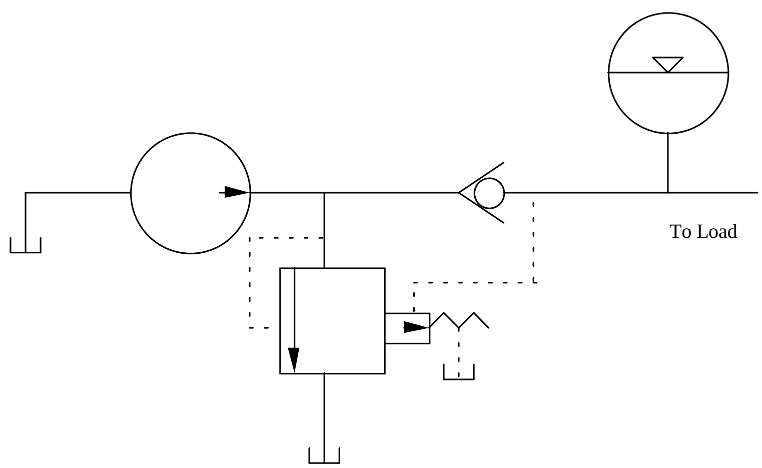



Figure 7.7 Accumulator example

This example was considered earlier when we looked at unloading valves. When the load pressure increases as it charges up the accumulator, it will reach the setting of the unloading valve. The unloading valve opens fully and is held there by the combined effects of the accumulator and the check valve which prevents reverse back flow. The pump is unloaded. As the accumulator discharges fluid for its particular application, the load pressure drops but because of the design of the unloading valve, the valve does not close. When the load pressure reaches the lower closing pressure of the valve, the unloading valve closes and provides flow to the load and the cycle is repeated. The effect is illustrated graphically in Figure 7.8.

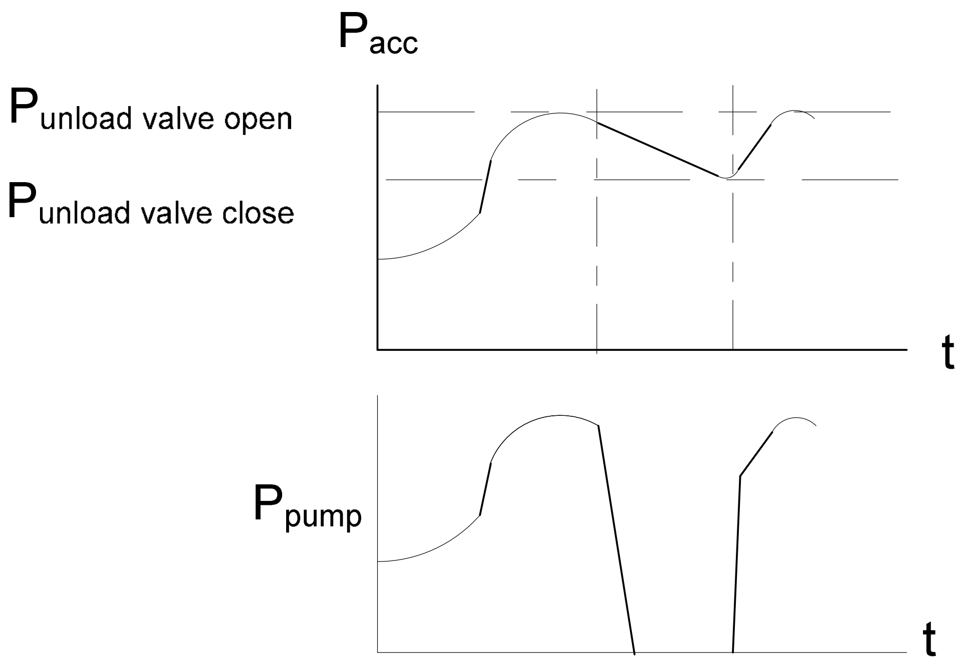



Figure 7.8 Unloading accumulator profile

1. Unloading Valve opens all the way
2. Closing pressure << opening pressure to allow the pressure in the main circuit to drop to a preset value. Reseating and cracking pressures are designed to be different