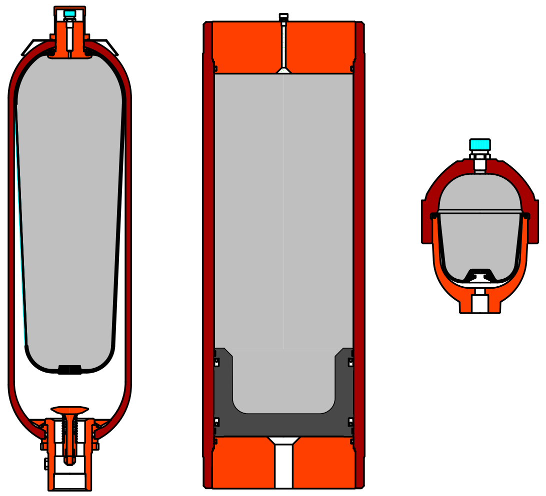
# GENERAL APPLICATIONS

## 1.1.1 GENERAL

The main task of the hydraulic accumulator is to accumulate fluid under pressure and return it when necessary.
Since the accumulator contains a fluid under pressure, it is treated as a pressure tank and must therefore be sized for the maximum operating pressure according to test regulations in force in the country where it is installed.
To achieve the volume compensation and get the accumulation of energy, the fluid is pre-loaded by a weight, a spring or a compressed gas.



1.1a

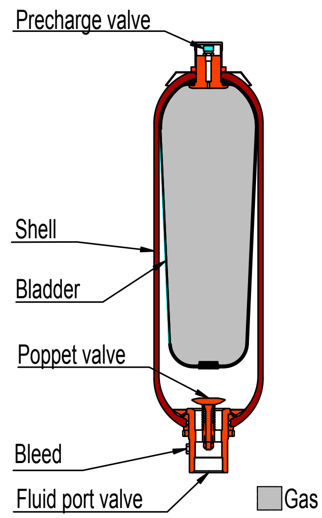
Between the pressure of fluid and the counter-pressure exerted by the weight, the spring or the compressed gas must be in a constant state of equilibrium. Weight and spring accumulators are used in industry only in special cases and thus have a relative importance.
Gas accumulators without a separating element are rarely used in hydraulics due to the absorption of gas by the fluid.
In most of the hydraulic systems are then used the gas accumulators provided with a separating element between gas and fluid.
Depending on the type of separating element, we can distinguish bladder, piston and diaphragm accumulators.

## 1.1.2 TYPES OF ACCUMULATORS WITH SEPARATING ELEMENT

These accumulators consist of a fluid zone, a gas zone and a separating gas-tight element.
The fluid area is in contact with the circuit. With the pressure increases, a certain volume of fluid enters into the accumulator and compresses the gases.
In the hydraulic systems, are used with the following accumulators with a separating element:
- bladder accumulators (Fig. 1.1b)
- piston accumulators (Fig. 1.1c)
- diaphragm accumulators (Fig. 1.1d)

### 1.1.2.1 BLADDER ACCUMULATORS

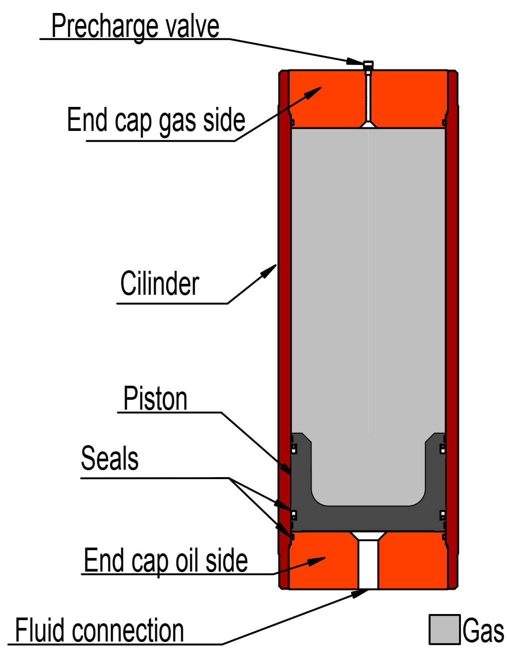
In the bladder accumulators, the fluid area is separated from the gas area by a flexible bladder. The fluid around the bladder is in contact with the circuit, so any increase in pressure causes the entry of the fluid into the accumulator and thereby compresses the gas. Vice versa, every drop of pressure in the circuit causes the expansion of the gas, resulting in delivery of the fluid from the accumulator to the circuit.
Bladder accumulators can be installed in vertical position (preferable), in horizontal one and, under certain operating conditions, also in an inclined one. In the inclined and vertical positions, the valve on the fluid side should face down. The bladder accumulators include a pressure welded or forged vessel, a flexible bladder and the fittings for gas and oil.




1.1b

### 1.1.2.2 PISTON ACCUMULATORS

In the piston accumulators, the fluid area is separated from the gas area from a metal piston fitted with gas tight seals. The gas area is filled with nitrogen.
The fluid zone is connected to the hydraulic system, so any increase

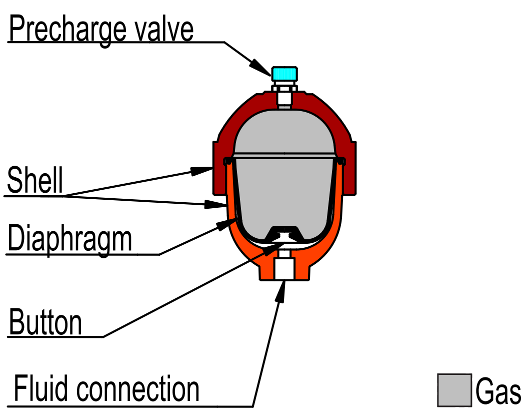



1.1c

in pressure in the circuit causes the entry of fluid in the accumulator resulting in compression of the gas.
Vice versa, at every drop of pressure in the circuit, the compressed gas contained in the accumulator expands and the accumulator delivers the fluid to circuit.
The piston accumulators can operate in any position, but it is preferable to mount them with the gas area upwards in order to prevent that solid contaminants contained in the fluid settle by gravity on the piston seals.
The typical structure of the piston accumulator, represented schematically in Figure 1.1c, includes a cylindrical pipe, a piston with seals, end caps in which there are the fluid side and gas side connections.
The pipe serves to resist to the internal pressure and to drive the piston.
To ensure that the pressures of the two chambers are as balanced as possible, during the movement, it's necessary that the friction between the piston and the pipe is minimized.
For this reason, the inner surface of the pipe must be honed. In practice, however, the friction between the piston seals and the pipe creates, between gas area and fluid one, a pressure difference that, however, can be limited to 1 bar with appropriate selection of seals.
The position of the piston can be shown continuously through a passing rod. By fixing a cam to the rod, you can also take advantage of the movement of the piston in order to control through limit switches the switching on or switching off of the pump.
For other types of monitoring of the piston position, see Section 4.1.

### 1.1.2.3 DIAPHRAGM ACCUMULATORS

Diaphragm accumulators are made of a steel pressure-resistant vessel, usually cylindrical or spherical in shape, inside which is mounted a flexible material diaphragm as separating element.
Diaphragm accumulators are manufactured in three versions:
- screwed execution (see Section 5.1.)
- forged execution (see Section 5.2.)
- welded execution (see Section 5.3.)




1.1d

In the screwed version, the diaphragm is blocked by a metal ring fitted between the lower shell and upper shell of the body.
In the welded accumulators, the diaphragm is pressed into the bottom before the welding of two steel shells.
Thanks to appropriate processes such as electron beam welding and also thanks to the special provision of the diaphragm, it's possible to prevent its damage and forging.

### 1.1.2.4 DERIVATION CONNECTION OF THE GAS BOTTLES

When for a given volume of fluid to provide/absorb the difference between the maximum and minimum pressure in the hydraulic circuit must be of limited size, the volume of the accumulator, obtainable with the calculation, may be very large. Under these conditions, it is preferable to connect the gas side of the accumulator with one or more additional gas bottles (Fig. 1.1l). For the sizing of the accumulator, you should take into account the following parameters:
- the useful volume to provide/absorb
- allowable ratios of pressures and volumes P2/Po = V0/V2
- the expansion of gas volume due to changes in operating temperature.

## 1.1.3 OPERATING CONDITIONS

**Stage A**
The accumulator is empty and neither gas nor hydraulic sides are pressurized Po = P = 0 bar

**Stage B**
The accumulator is pre-charged Po

**Stage C**
The hydraulic system is pressurized. System pressure exceeds the pre-charge one and the fluid flows into the accumulator Po→P1

**Stage D**
System pressure peaks. The accumulator is filled with fluid according to its design capacity.
Any further increase in hydraulic pressure would be prevented by a relief valve fitted on the system P1→P2

**Stage E**
System pressure falls. Pre-charge pressure forces the fluid from the accumulator into the system P2→P1

**Stage F**
Minimum system pressure is reached. The accumulator has discharged its maximum design volume of fluid back into the system min ΔP (P1min)


EPE ITALIANA s.r.l. - Viale Spagna,112 • 20093 Cologno Monzese (Mi) Italy
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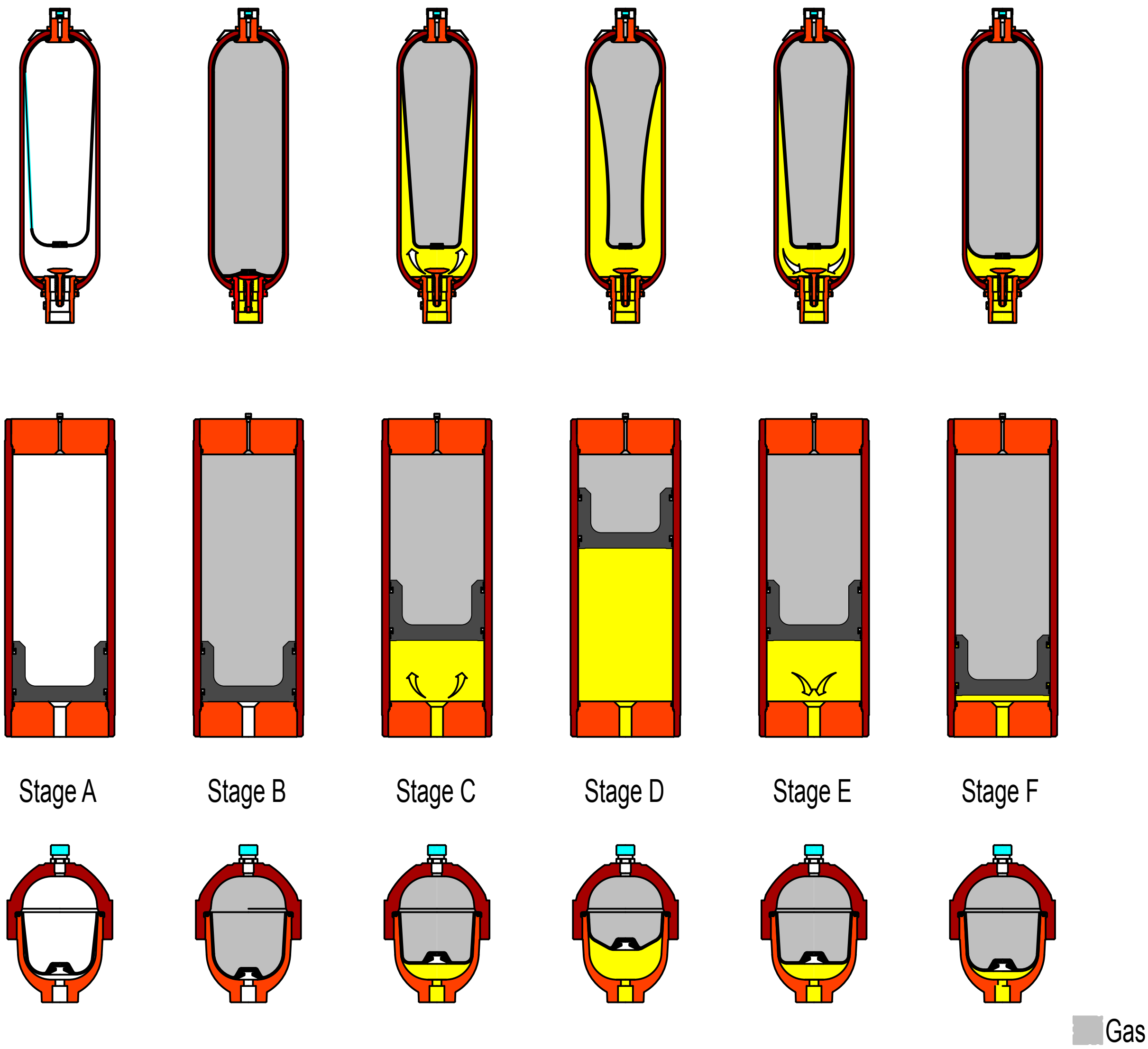



1.1e

## 1.1.4 ACCUMULATOR SELECTIONS

When selecting an accumulator for a particular application, both system and performance criteria should be taken into account.
To ensure long and satisfactory service life, the following factors should be taken into account.

- failure modes
- flow rate
- response time
- high frequency cycling
- external forces
- output volume
- fluid type
- shock suppression
- sizing information
- temperature effect
- safety
- certification

### 1.1.4.1 FAILURE MODES

In certain applications, a sudden failure may be preferable than a gradual failure. A high-speed machine, for example, where product quality is a function of hydraulic system pressure.
As sudden failure is detected immediately, scrap is minimized, whereas a gradual failure might mean that production of a large quantity of sub-standard product could occur before the failure becomes apparent.
A bladder/diaphragm accumulator would be most suitable to this application. Vice versa, where continuous operation is paramount and sudden failure could be detrimental as, for example, in a braking or steering circuit on mobile equipment, a progressive failure mode is desirable. In this application, a piston accumulator would be appropriate.

### 1.1.4.2 FLOW RATE

Fig. 1.1.n shows typical maximum flow rates for Epe’s accumulator styles in a range of sizes.
The larger standard bladder designs are limited to 1000 LPM, although this may be increased to 2000 LPM using a high-flow port.
The poppet valve controls the flow rate, with excessive flow causing the

poppet to close prematurely.
Flow rates greater than 2000 LPM may be achieved by mounting several accumulators on a common manifold - see Accumulators station, Section 10.
For a given system pressure, flow rates for piston accumulators generally exceed those of the bladder designs.
Flow is limited by piston velocity, which should not exceed 3 m/sec. to avoid piston seal damage.
In high-speed applications, high seal contact temperatures and rapid decompression of nitrogen, which has permeated the seal itself, can cause blisters, cracks and pits in the seal surface. In this type of application, a bladder style accumulator would be better suited.

### 1.1.4.3 RESPONSE TIME

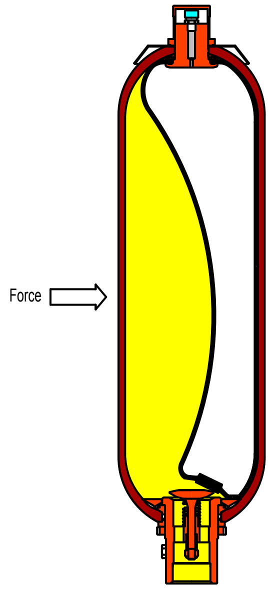
In theory, bladder and diaphragm accumulators should respond more quickly to system pressure variations than piston types.
There is no static friction to be overcome as occurs with a piston seal, and there is no piston mass to be accelerated and decelerated.
In practice, however, the difference in response is not great, and is probably insignificant in most applications.
This applies equally in servo applications, as only a small percentage of servos requires response times of 25 ms or less.
This is the point where the difference in response between piston and bladder accumulators becomes significant.
Generally, a bladder accumulator should be used for applications requiring less than 25 ms response time, and either accumulator type for a response of 25 ms or greater.

### 1.1.4.4 HIGH FREQUENCY CYCLING

High-frequency system pressure cycling can cause a piston accumulator to "dither", with the piston cycling rapidly back and forth so covering a distance less than its seal width.
Over an extended period, this condition may cause heat build-up under the seal due to lack of lubrication, resulting in seal and bore wear.
For high frequency dampening applications, therefore, a bladder/diaphragm accumulator is generally more suitable.

### 1.1.4.5 EXTERNAL FORCES

Any application subjecting an accumulator to acceleration, deceleration or centrifugal force may have a detrimental effect on its operation, and could cause damage to the bladder.
Forces along the axis of the pipe or shell normally have little effect on a bladder accumulator but may cause a variation in gas pressure in a piston type accumulator because of the mass of the piston.
Forces perpendicular to an accumulator's axis should not affect a piston model, but fluid in a bladder accumulator may be thrown to one side of the shell (Fig. 1.1f), displacing the bladder and flattening and lengthening it. In this condition, fluid discharge could cause the poppet valve to pinch and cut the bladder.




1.1f

*Fig. 1.1f: Perpendicular force causes the mass of the fluid to displace the bladder. Higher pre-charge pressures increase the resistance of the bladder according to the effects of the perpendicular forces.*

### 1.1.4.6 OUTPUT VOLUME

The maximum sizes available of each type of accumulator determine the limits of suitability where large output volumes are required. There are, however, several methods to achieve higher output volumes than standard accumulator capacities suggest - see Accumulators station, Section 10.

| Compression ratio | System pressure bar | | Recommended Precharge bar | | Fluid Output LPM | |
|---|---|---|---|---|---|---|
| | max | min | Bladder | Piston | Bladder | Piston |
| 1,5 | 210 | 140 | 125 | 130 | 10,5 | 11,5 |
| 2 | 210 | 105 | 95 | 98 | 16 | 16,5 |
| 3 | 210 | 70 | 60 | 60 | 21,5 | 21,5 |
| 6 | 210 | 35 | * | 28 | * | 24 |

* *Below required minimum operating ratio of 4:1*

1.1g

*Fig. 1.1g compares typical fluid outputs for Epe's 35 litres piston and bladder accumulators operating isothermally as auxiliary power sources over a range of minimum system pressures.*
The higher pre-charge pressures recommended for piston accumulators result in higher outputs than as occurred in comparable bladder accumulators.


EPE ITALIANA s.r.l. - Viale Spagna,112 • 20093 Cologno Monzese (Mi) Italy
Tel.: +39 02 25459028 • Fax: +39 02 25 25459773 • E-mail: epeitaliana@epeitaliana.it • Internet: www.epeitaliana.it

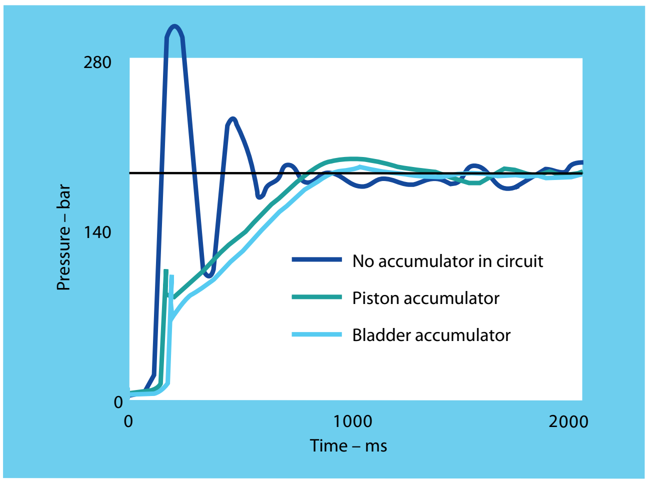
In addition, bladder accumulators are not generally suitable for compression ratios greater than 1:4, as these could result in excessive bladder deformation.
Piston accumulators have an inherently higher output relative to their overall dimensions, which may be critical in locations where space is limited.
Piston accumulators are available in a choice of diameters and lengths for a given capacity, whereas bladder and diaphragm accumulators are frequently offered in only one size per capacity, and fewer sizes are available.
Piston accumulators can also be built to custom lengths for applications in which the available space is critical

## 1.1.4.7 FLUID TYPE

Bladder/Diaphragm accumulators are more resistant to damage caused by contamination of the hydraulic fluid than piston types.
While some risks exist from contaminants trapped between the bladder and the shell, a higher risk of failure exists from the same contaminants acting on the piston seal.
Bladder accumulators are usually preferred to piston type accumulators for water service applications.
Water systems tend to carry more solid contaminants and lubrication is poor.
Both the piston and bladder type units require some type of preparation to resist to corrosion on the wetted surfaces (example nickel coated) Piston accumulators are preferred for systems using special fluids or where extreme temperatures are experienced as compared to bladders.
Piston seals are more easily moulded in the required special compounds and may be less expensive.

## 1.1.4.8 SHOCK SUPPRESSION

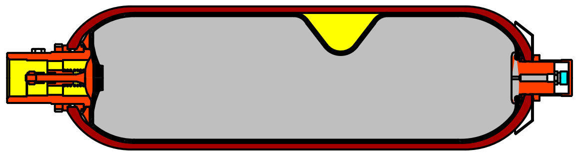
Shock control does not necessarily demand a bladder/diaphragm accumulator, it is possible to use also a piston accumulator, see example Fig. 1.1h




1.1h

## 1.1.4.9 MOUNTING POSITION

The optimum mounting position for any accumulator is vertical, with the hydraulic port downwards. Piston models can be mounted horizontally if the fluid is kept clean but, if solid contaminants are present or expected in significant amount; horizontal mounting can result in uneven or accelerated seal wear.
A bladder accumulator may also be mounted horizontally, but uneven wear on the top of the bladder as it rubs against the shell while floating one the fluid can reduce its service life and even cause permanent distortion.
The extent of the damage will depend on the fluid cleanliness, cycle rate, and compression ratio. In extreme cases, fluid can be trapped away from the hydraulic port ( Fig. 1.1i),



1.1i

Fig. 1.1i *A horizontally-mounted bladder accumulator can trap fluid away from the hydraulic valve reducing output, or the bladder may become elongated, forcing the poppet valve to close prematurely.*

## 1.1.4.10 SIZING INFORMATION

Accurate sizing of an accumulator is critical if it has to deliver a long and reliable service life. Information and worked examples are shown in Section 2 or accumulator size can be calculated automatically by entering application details into Epe's Sizing software selection program.
Please contact your local Epe distributor for details or contact us at **www.epeitaliana.it**

## 1.1.4.11 TEMPERATURE EFFECT

Temperature variation can seriously affect the pre-charge pressure of an accumulator. As the temperature increases, the pre-charge pressure increases; Vice versa, decreasing temperature will decrease the precharge pressure. In order to assure the accuracy of your accumulator pre-charge pressure, you need to factor in the temperature variation.
The temperature variation is determined by the temperature encountered during the pre-charge versus the operating temperature expected in the system, (see Section 2.2.)

## 1.1.4.12 SAFETY

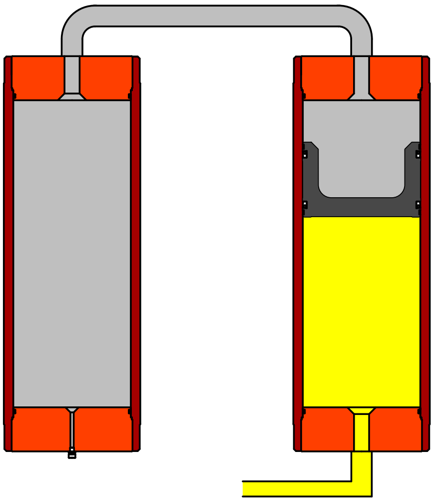
Hydro-pneumatic accumulators should always be used in conjunction with a safety block, to enable the accumulator to be isolated from the circuit in an emergency or for maintenance purposes, (see Section8 e 9).

## 1.1.4.13 CERTIFICATION

Accumulators are frequently required to conform to national or international certification. These requirements range from simple design factors to elaborate materials testing and inspection procedures carried out by an external agency. Most of the accumulators within Epe's piston, bladder or diaphragm ranges are available with certification PED97/23EC or other on request (see Section 1.4)

### 1.1.5 GAS BOTTLES INSTALLATION

Remote gas storage offers installation flexibility where the available space or position cannot accommodate an accumulator of the required size. A smaller accumulator may be used in conjunction with an Epe additional gas bottle, which can be located elsewhere (Fig. 1.1l)



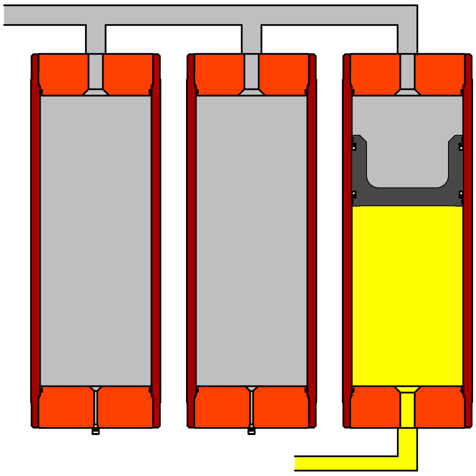
1.1l

*Fig. 1.1l Piston accumulator with additional bottles type AB.*

The gas cylinder and the accumulator must be sized by Section 2:
Gas bottle installations may use either bladder or piston accumulators, subject to the following considerations.

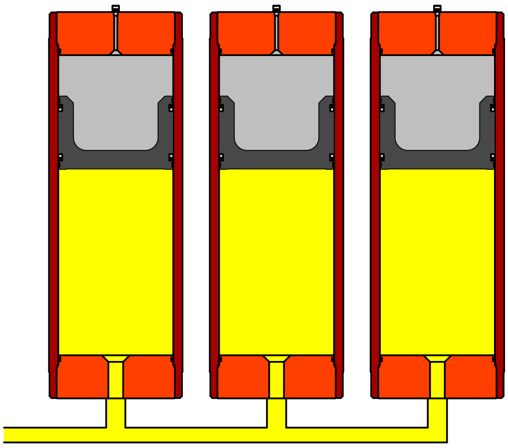
- Any accumulator used with remote gas storage should generally have the same size port of the gas end as at the hydraulic end, to allow an unimpeded flow of gas to and from the gas bottle. The gas bottle will have an equivalent port in one end and a gas charging valve at the other.
- A piston accumulator should be carefully sized to prevent the piston bottoming at the end of the cycle. Bladder designs should be sized to prevent filling of more than 75% full.
- Bladder installations require a special device called transfer barrier at the gas end, to prevent extrusion of the bladder into the gas bottle piping. The flow rate between the bladder transfer barrier and its gas bottle will be restricted by the neck of the transfer barrier tube.
- Because of the above limitations, piston accumulators are generally preferred to bladder types for use in gas bottle installations.
- Diaphragm style accumulators are normally not used in conjunction with gas bottles.

The requirement for an accumulator with an output of more than 200 litres cannot usually be met by a single accumulator, because larger piston designs are relatively rare and expensive, and bladder designs are not generally available in these sizes. The requirement can, however, be met using one of the multiple-component installations shown in Figs. 1.1m and 1.1n.



1.1m

*Fig. 1.1m (above) Several gas bottles can supply pre-charge pressure to a single accumulator*



1.1n

*Fig. 1.1n (above) Multiple accumulators connected together offer high system flow rates*

The installation in Fig. 1.1m consists of several gas bottles serving a single piston accumulator through a gas manifold. The accumulator portion may be sized outside of the limitations of the sizing formula on Section 2.2, but should not allow the piston to strike the caps repeatedly while cycling. The larger gas volume available with this configuration allows a relatively greater piston movement – and hence fluid output – than with a conventionally sized single accumulator. A further advantage is that, because of the large pre-charge “reservoir”, gas pressure is relatively constant over the full discharge cycle of the accumulator. The major disadvantage of this arrangement is that a single seal failure could drain the whole gas system.
The installation in Fig. 1.1n uses several accumulators, of piston or bladder design, mounted on a hydraulic manifold. Two advantages of multiple accumulators over multiple gas bottles are that higher unit fluid flow rates are permissible, and a single leak will not drain pre-charge pressure from the entire system.
A potential disadvantage is that, where piston accumulators are used, the piston with the least friction will move first and could occasionally bottom on the hydraulic end cap. However, in a slow ore infrequently used system, this would be of little significance.


**EPE ITALIANA s.r.l.** - Viale Spagna,112 • 20093 Cologno Monzese (Mi) Italy
Tel.: +39 02 25459028 • Fax: +39 02 25 25459773 • E-mail: epeitaliana@epeitaliana.it • Internet: www.epeitaliana.it

## 1.1.6 FAILURE PREVENTION

Accumulator failure is generally defined as inability to accept and exhaust a specified amount of fluid when operating over a specific system pressure range.
Failure often results from an unwanted loss or gain of pre-charge pressure.
It cannot be too highly stressed that the correct pre-charge pressure is the most important factor in prolonging accumulator life.
If maintenance of the pre-charge pressure and relief valve settings are neglected, and if system pressures are adjusted without making corresponding adjustments to pre-charge pressures, shortened service life will result.

### 1.1.6.1 FAILURE

Bladder/diaphragm accumulator failure occurs rapidly due to bladder/diaphragm rupture (Fig. 1.1o). Rupture cannot be predicted because the intact bladder or diaphragm is essentially impervious to gas of fluid seepage; no measurable gas or fluid leakage through the bladder or diaphragm precedes failure.

### 1.1.6.2 PISTON ACCUMULATOR FAILURE

Piston Accumulator failure generally occurs in one of the following gradual modes.

- FLUID LEAKS TO THE GAS SIDE

This failure, sometimes called dynamic transfer, normally takes place during rapid cycling operations after considerable time in service. The worn piston seal carries a small amount of fluid into the gas side during each stroke.
As the gas side slowly fills with fluid, pre-charge pressure rises and the accumulator stores and exhausts decreasing the amounts of fluid. The accumulator will totally fail when pre-charge pressure equals the maximum hydraulic system pressure. At that point, the accumulator will accept no further fluid. As the increase in pre-charge pressure can be measured (Fig. 1.1oa), failure can be predicted and repairs can be carried out before total failure occurs.

- GAS LEAKAGE

Pre-charge may be lost as gas slowly bypasses the damaged piston seals. Seal deterioration occurs due to excessively long service, fluid contamination or a combination of the two. Gas can also vent directly through a defective gas core or an end cap O-ring.
The reducing pre-charge pressure then forces progressively less fluid into the system. As this gradual decrease in pre-charge pressure can be measured (Fig. 1.1ob), repairs can again be carried out before total failure occurs.

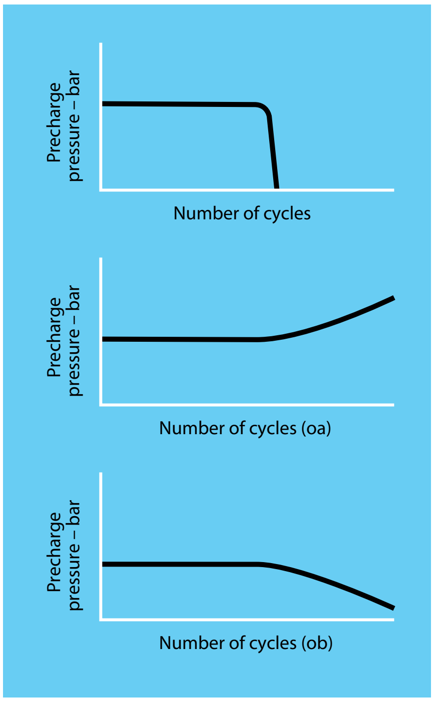



*Fig.1.1.o When an accumulator bladder ruptures, precharge pressure immediately falls to zero*

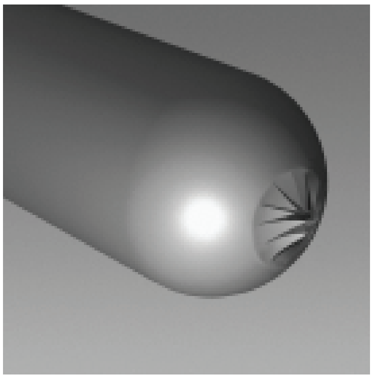
*As fluid leaks past an accumulator piston, precharge pressure rises (oa).*

*Gas leaking past the piston or valve causes precharge pressure to fall (ob)*

1.1o

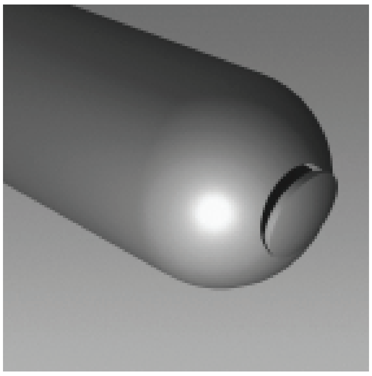
## 1.1.7 PRE-CHARGING PROCESS

Correct pre-charging involves accurately filling of the gas side of an accumulator with a dry, inert gas such as nitrogen, before admitting fluid to the hydraulic side.
It is important to pre-charge an accumulator under the correct specified pressure. Pre-charge pressure determines the volume of fluid retained in the accumulator at minimum system pressure. In an energy storage application, a bladder/ diaphragm accumulator is typically pre-charged to 90% of the minimum system pressure, and a piston accumulator to 97% of the minimum system pressure at the system operating temperature.
The ability to correctly carry out and maintain pre-charging is an important factor when choosing the type of accumulator for an application.
Bladder accumulators are more susceptible to damage during pre-charging than piston types. Before pre-charging and entering in service, the inside of the shell should be lubricated with system fluid.
This fluid acts as a cushion and lubricates and protects the bladder as it expands. When pre-charging, the first 10 bar of nitrogen should be introduced slowly. Failure to follow this precaution could result in immediate bladder failure: high pressure nitrogen, expanding rapidly and thus cold, could form a channel in the folded bladder, concentrating at the bottom. The chilled expanding rapidly brittle rubber would then inevitably cause the rupture (Fig. 1.1p).
The bladder could also be forced under the poppet, resulting in a cut. (Fig. 1.1q).
Close attention should be paid to operating temperature during pre-charging, as an increase in temperature will cause a corresponding increase in pressure which could then exceed the pre-charge limit.
Little damage can occur when pre-charging or checking the pre-charge on a piston accumulator, but care should be taken to make sure the accumulator is void of all fluid to prevent getting an incorrect reading on the pre-charge.



1.1p

*Fig. 1.1p Starburst rupture caused by loss of bladder elasticity*



1.1q

*Fig. 1.1q C-shaped cut shows that bladder has been trapped under poppet*

EXCESSIVELY HIGH PRE-CHARGE

Excessive pre-charge pressure or a decrease in the minimum system pressure without a corresponding reduction in pre-charge pressure may cause operating problems or damage to accumulators.

With excessive pre-charge pressure, a piston accumulator will cycle between stages (e) and (b) of Fig. 1.1e), and the piston will travel too close to the hydraulic end cap. The piston could bottom at minimum system pressure, thus reducing the output and eventually damaging the piston and the piston seal. The piston can often be heard bottoming, warning of impending problems.

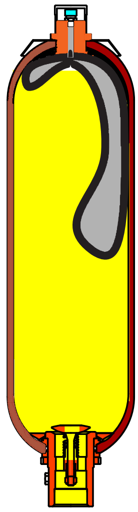
An excessive pre-charge in a bladder accumulator can drive the bladder into the poppet assembly when cycling between stages (e) and (b).This could cause fatigue failure of the poppet spring assembly, or even a pinched and cut bladder, should it become trapped beneath the poppet as it is forced closed (Fig. 1.1q). Excessive pre-charge pressure is the most common cause of bladder failure.

EXCESSIVELY LOW PRE-CHARGE

Excessively low pre-charge pressure or an increase in system pressure without a corresponding increase in pre-charge pressure can also cause operating problems and subsequent accumulator damage. With no pre-charge in a piston accumulator, the piston will be driven into the gas end cap and will often remain there. Usually, a single contact will not cause any damage, but repeated impacts will eventually damage the piston and seal.

Vice versa, for a bladder accumulator, too low or no pre-charge can have rapid and severe consequences. The bladder will be crushed into the top of the shell and can extrude into the gas stem and be punctured (Fig 1.1r). This condition is known as “pick out”. One cycle as the one mentioned above is sufficient to destroy a bladder.

Overall, piston accumulators are generally more tolerant with respect to careless pre-charging.



1.1r

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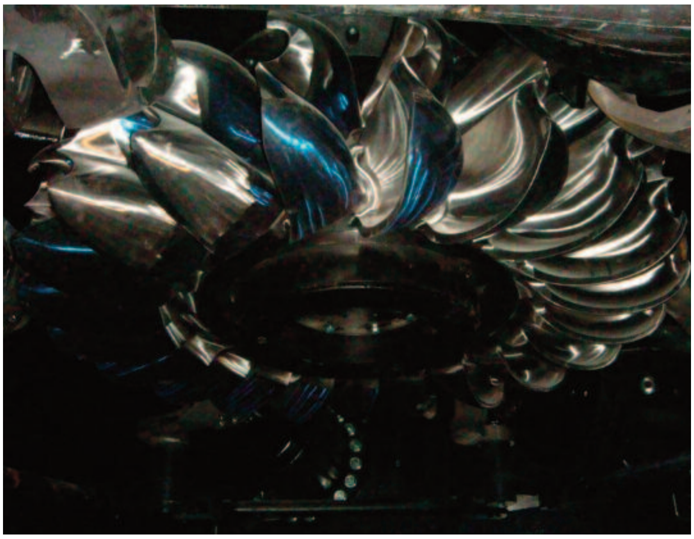
## 1.2.1 DESCRIPTION
The main sectors and areas of application are industrial hydraulics, process technology and mobile sistems

## 1.2.2 ENERGY POWER PLANTS
Energy is the topic of the future. Global energy demand is rapidly rising. Oil supply for lubrication and/or emergency.



1.2a

1.2b

## 1.2.3 DIE CASTING MACHINERY
High pressure and flows in a short time period.

1.2c

## 1.2.4 PLASTIC MACHINERY
Quick response.

1.2d

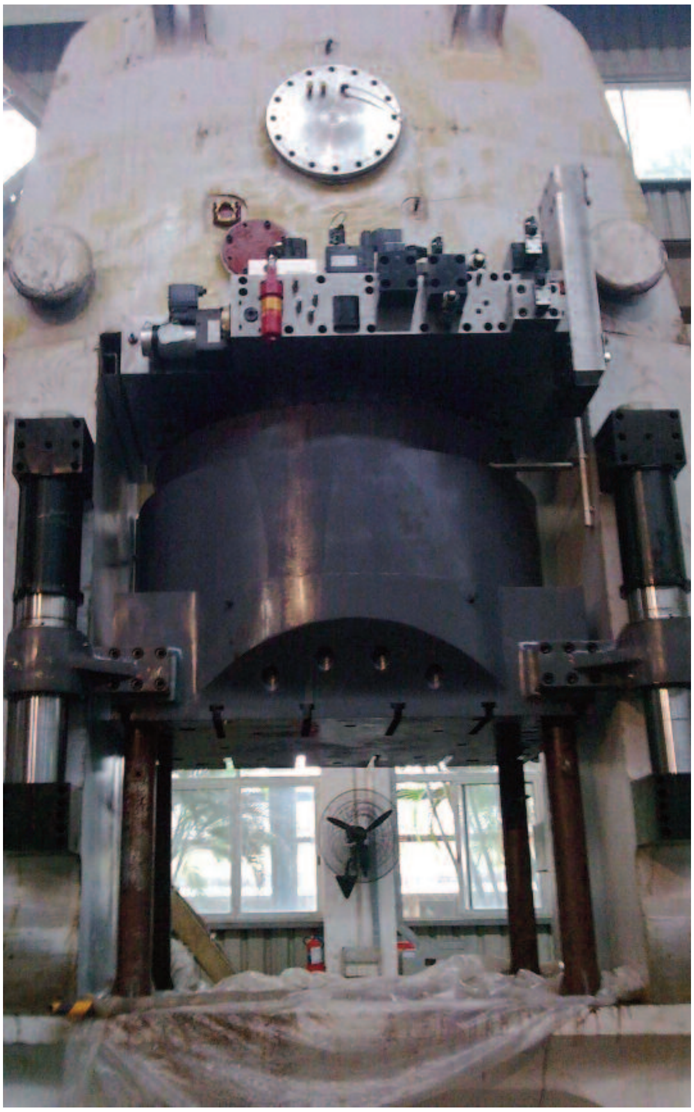
1.2e

## 1.2.5 STEEL INDUSTRY
High pressure and fast movements.

1.2f

## 1.2.6 MACHINE TOOLS

Maintains pressure, reduces pump size.



1.2g

## 1.2.8 CHEMICAL INDUSTRY

Reduce pump pulsations.

1.2i

## 1.2.7 CRANES VEHICLES

High demands and load stabilizer.

1.2h

## 1.2.9 CONSTRUCTION MOBILE MACHINERY

Constant power.


1.2l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## 1.2.10 OIL & GAS / OFFSHORE

Emergency and shock damper.

1.2m

## 1.2.11 INDUSTRIAL APPLICATIONS

Energy reserve.

1.2o

1.2n

## 1.2.12 AUTOMOTIVE

Braking system.

1.2p

### 1.2.13 LOADING STATION
Shock absorber.

1.2q

### 1.2.14 AGRICULTURY MACHINERY
Stabilizer system.

1.2r

### 1.2.15 COMPENSATOR
Liquid separator and pressure compensator for subsea applications.

1.2s




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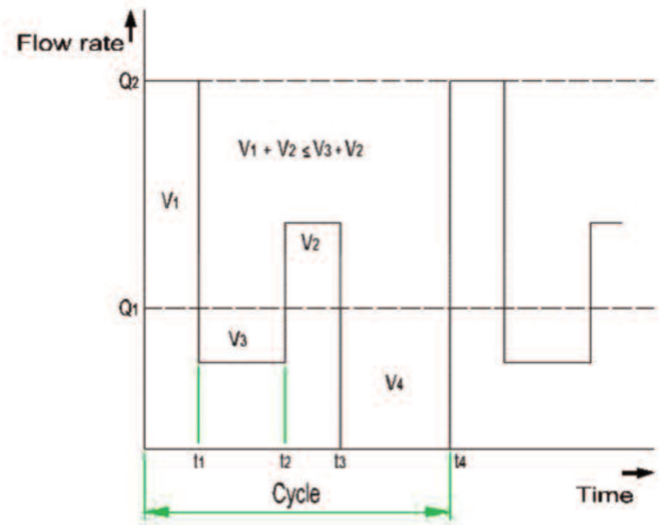
## 1.3.1 GENERAL

It is not possible to design an optimum hydraulic system in economic and technical point of view that does not involve the use of hydropneumatic accumulators. From an economic point of view, the use of hydropneumatic accumulators usually leads to a reduction in equipment and operating costs (energy savings) and dimensions of the plant. From a technical point of view, the use of an accumulator may become relevant or appropriate to carry out certain functions, such as increase reliability, improve overall efficiency, extend the lives of the plant components and eliminate secondary phenomena (noise, development of heat).
The hydropneumatic accumulators used in order to: save on the pump power to be installed in the case of variable demand for oil, supply power in emergency situations or during working stages requiring a high power even for short periods, shorter the working cycles, drive the secondary circuits as volume compensators when there are variations of pressure and temperature, maintain the pressure in the closed circuits, compensate for the losses, recover the braking energy, as a tank of fluid under pressure, separate the fluids, such as replacement of springs and damper for shocks and pulsations absorbing. Here below, we describe some applications in more detail.

## 1.3.2 ACCUMULATION OF ENERGY

The graph (cyclograph) of the power required by a plastic injection machine shown in Chart 1.3a shows that, with a high rate of injection into the mould, the maximum power is required only for a short time. Without a compensation system, the pump should be sized for peak power, even if requested for a few moments.
Once used an accumulator, the power (and thus the flow rate) of the pump can be instead fixed according to the average absorption.
In the early stages of the working cycle when the needs of system flow rate is less than the pump one, this fills the accumulator. When you need the maximum flow rate, the difference in comparison with the pump supply is taken from the accumulator.



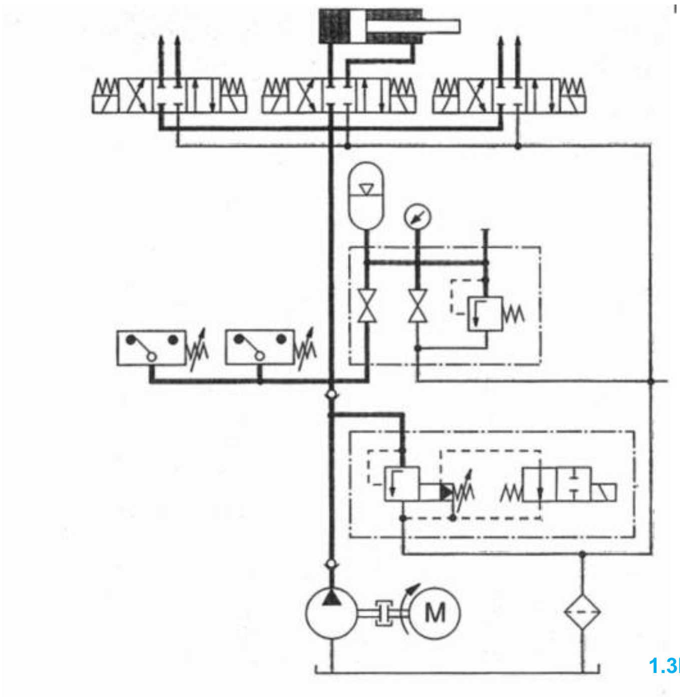

1.3a

Advantages:
- use of lower capacity pumps
- lower installed power
- less heat generation
- easy maintenance and installation

- for certain applications: damping the peaks and pressure pulses, with consequent longer life time of the components.

The installation of hydropneumatic accumulators allows substantially saving energy.
For the systems with very strong instantaneous or short-term absorptions or short operating cycles, the only economic solution is represented by the hydropneumatic accumulators.

### 1.3.2.1 MORE USERS WITH DIFFERENT ABSORPTION

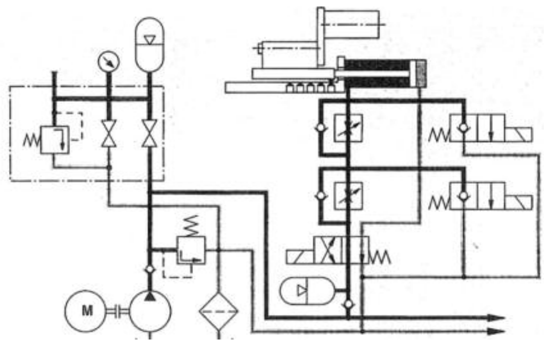



1.3b

*Fig. 1.3b: circuit diagram for the accumulation of energy of a plastic injection machine*

### 1.3.2.2 REDUCTION OF THE TIMES OF THE WORKING CYCLES (EXAMPLE, TOOL MACHINES)

Thanks to the hydropneumatic mounting directly next to the user, the inertia of the fluid column is exceeded more quickly than if all the fluid must be set in motion by the pump.
So you get a faster start-up and also the accumulators compensate the instantaneous differential absorptions of the single users.

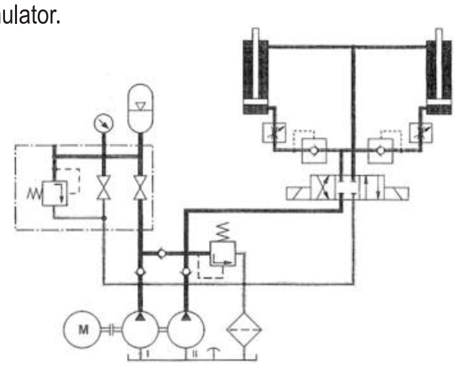



1.3c

*Fig. 1.3c: circuit diagram for the accumulation of energy of a tool machine.*

### 1.3.2.3 REDUCTION OF THE APPROACH TIMES

The rational performance of the pressing and printing cycles demands for rapid empty strokes in order to make more time available for the phase of work under high pressure.
During progressing under empty, the fluid is simultaneously delivered by the low pressure pump, the high pressure pump and the accumulator, so as to achieve high speed.
At the end of the approach stroke, the pressure increases, the check valve closes and only the high pressure pump delivers to the activator a reduced flow rate but at high pressure, while the low pressure pump charges the accumulator.



1.3d

*Fig. 1.3d: circuit diagram for the reduction of the approach time of a press.*

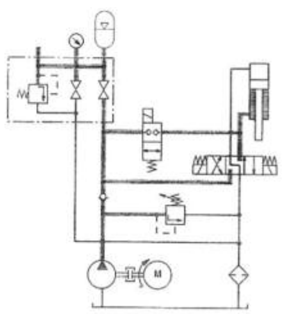
### 1.3.3 RESERVE OF FLUID (SAFETY)

Using the accumulator as a safety device in normal operation of the system, it does not act as an energy source, although it is always connected to the pump.
If the accumulator is equipped with a high quality separating element, the accumulated energy can be stored almost indefinitely and is always available when needed.
Safety devices on the accumulators are used for emergency operation on the hydraulic plants, to ensure the performance of certain functions in the event of failure, such as:

- closure of bulkheads, valves, exchanges
- switching on of gate valves
- switching on of power switches
- start-up of rapid switching off systems

### 1.3.3.1 EMERGENCY DRIVE

In an emergency, for example due to power failure, the presence of an accumulator allows carrying out one or more output and/or return strokes. Fig. 1.3e shows the circuit diagram of an emergency drive: in case of power failure, the spring returns the valve to its resting position, making the connection between the accumulator and rod side chamber with a consequent return of the cylinder.



1.3e

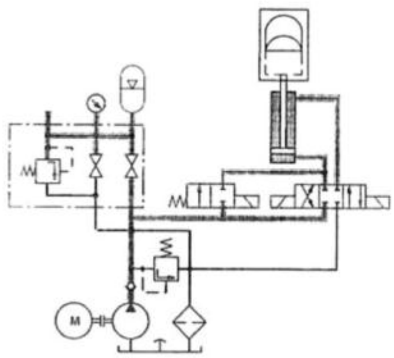
*Fig. 1.3e: circuit diagram of an emergency drive.*

Another case of emergency drive based on the accumulator is the completion of a working cycle already begun, despite the failure of a pump or a valve.
Advantages of the emergency drive with accumulator:

- immediate availability of stored energy
- indefinite energy conservation
- no operator fatigue
- immediate response
- maximum security with low maintenance.

High short-term oil absorption during failure

With the circuit of Figure 1.3f, the output of the cylinder, in case of pump failure, is guaranteed by the accumulator.

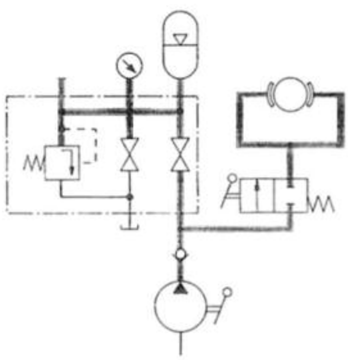


1.3f

*Fig 1.3f: output of the cylinder in case of damage to the pump.*

### 1.3.3.2 EMERGENCY BRAKING

The hydraulic accumulator is used to operate the emergency drive of the brake and the doors of funicular railways, cableways, special vehicles etc. The accumulators charge (closed circuit) is performed with a motor pump in proper workshop or with a pump.
Often the emergency brake circuit is passive: in case of failure, the braking is automatic by effect of a spring, while in normal conditions the brake cylinders are kept open by the pressure of the accumulator that operates contrary to the spring.



1.3g

*Fig.1.3g: emergency brake for cableway*

### 1.3.3.3 EMERGENCY LUBRICATION

To maintain intact the lubricating film in the bearings, they must be constantly fed with oil, so the lubrication points should always be under pressure. In case of failure of the lubricant pump, the presence of an accumulator keeps the pressure up until the stop of the machine or until any auxiliary lubrication pump restore the required pressure.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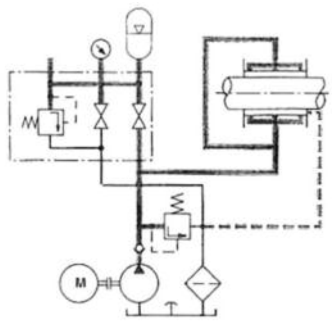
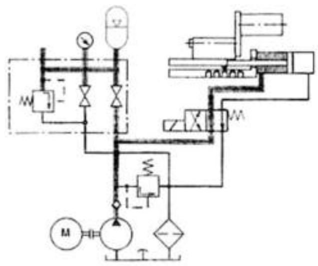


1.3h

*Fig. 1.3h: emergency lubrication for bearings.*

## 1.3.3.4 OPERATING SECURITY

The lack of voltage during the operation of a machine may cause costly business interruptions. The accumulators allow the completing of the production cycle started.



1.3i

*Fig. 1.3i: operational safety circuit.*

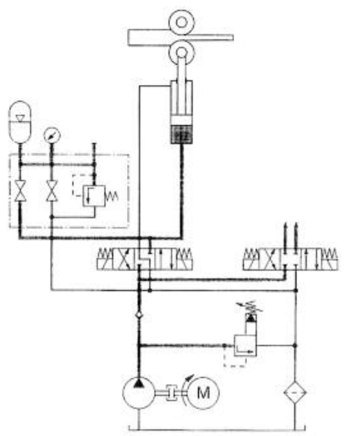
## 1.3.4 FORCES COMPENSATOR

With the accumulators forces or movements can be compensated. This need arises when, during a continuous working process, i.e. rolling, may occur obliquely positioning of the forming rolls as a result of variables resistances by the material to be laminated. Thanks to the balance of the rolls, you get a uniform thickness.

Fig. 1.3l shows the circuit diagram for the balance of the rolls of a rolling mill, comprising an accumulator with its safety block.

Advantages:

- mild compensation of the forces and, therefore, less load on the foundation and frame
- savings of counter weights and thus reduction in weight and dimensions of the plant



1.3l

*Fig. 1.3l: balance of the rollers of a rolls mill*

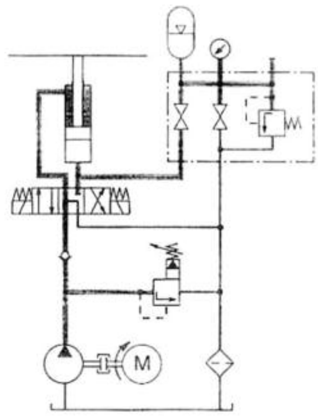
## 1.3.5 COMPENSATION OF LEAKAGES

The compression force exerted by a hydraulic cylinder can only be maintained by compensating the inevitable losses due to system leakage.

The accumulators are particularly suitable for this purpose. Fig. 1.3m shows a scheme of a system of compensation for a leak, through which, when the pump is stopped, the leakage losses are replenished by dispensing oil from the accumulator to the piston side chamber of the cylinder. The pump starts only when the pressure falls below a predetermined value and charges the accumulator.

Advantages:

- intermittent pump operation
- less heat generation, resulting in lower operating costs
- longer life of the plant.



1.3m

*Fig. 1.3m: leak compensation*

## 1.3.6 CUSHIONING

In the hydraulic systems, pressure oscillations can occur when the flow conditions vary for reasons related to the operation of the system; i.e.

- uneven distribution of the pump
- presence of systems including masses and resilience (i.e. valves pressure balancing device) or instantaneous connection of circuit branches at different pressures
- switching on of regulation and interception valves with short opening and closing
- switching on or off of pumps.

These phenomena can cause variations in flow rate or pressure, which may have adverse effects on the life of components.

According to the conditions of formation, the pressure oscillations can be divided into impulsive (pressure peaks) and periodic (pulses).

To prevent that the functioning of the system is compromised, you should evaluate, already during the design phase, the amplitude of these oscillations and provide appropriate measures of damping.

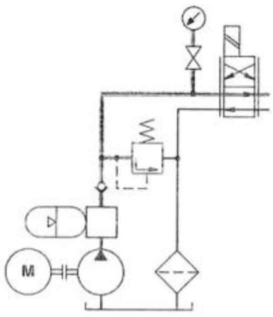
While there are several options to reduce the pressure fluctuations, in hydraulic systems are particularly suitable certain types of accumulators.

To meet the requirements of the machines in terms of performance and speed of the cycles, while ensuring a limited noise, it is advisable to install an accumulator with appropriate features as ahock absorber in order to:

- reduce the flow rate fluctuations caused by the operation of the machine and their transmission to the mechanical structures that act as resonant bodies and convert them to noise
- extend the life of the machine.

### 1.3.6.1 FLOW RATE FLUCTUATIONS OF PUMPS

The volumetric pumps produce more or less pronounced flow rate pulsations, causing noise and vibrations, with danger of damage to the plant. An accumulator mounted near the pump reduces this phenomenon.

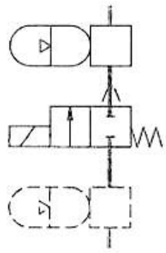



1.3n

*Fig 1.3n Damping pulsations caused by the volumetric pumps.*

### 1.3.6.2 DAMPING OF PRESSURE WAVES

In most of the hydraulic plants, pressure waves are generated by various components or by the effect of load changes in the system, for example when using the bucket of an excavator.
The installation of an accumulator protects the sensitive components from pressure waves and, in particular, the pumps.

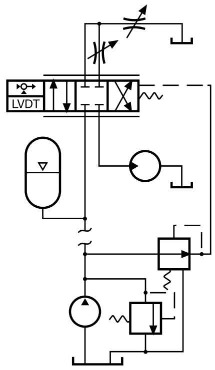


1.3o

*Fig. 1.3o: dampening the pulsations downwards the pump*

### 1.3.6.3 FAST OPENING AND CLOSING OF THE VALVES

By discharging instantly a strong flow rate in the return line generate water hammer, which can damage the heat exchangers and the filters on the return lines.
But even when the fluid in motion is stopped suddenly (i.e. due to an emergency stop), the water hammer can damage the valves, pipes and fittings.



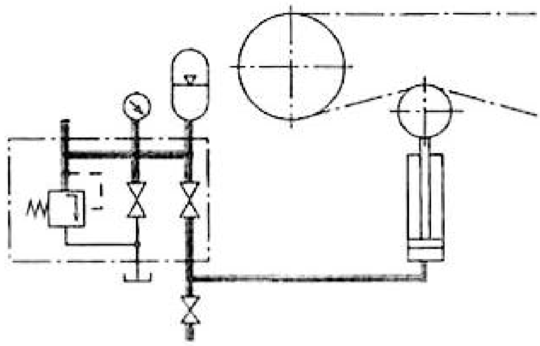

1.3p

*Fig. 1.3p: damping the water hammer.*

### 1.3.6.4 HYDRAULIC SPRING

For the damping of shock waves and pressure fluctuations, the accumulator acts as a hydraulic spring thanks to the compressible gas it contains.

The first example below for the application of the "hydraulic spring" is the hydraulic tensioning device of a chain (Fig. 1.3q).

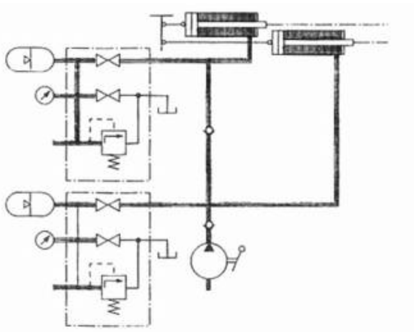


1.3q

*Fig. 1.3q: tensioning of a chain for a tool machine.*

By installing an accumulator to stretch the chain of a tool machine or a vehicle, you avoid tearing chain transmission to the system.

The second application example of the "hydraulic spring" is the tensioning of the hauling cables and main ones (Fig. 1.3r).



1.3r

*Fig. 1.3r: tensioning of the supporting cables of a cableway.*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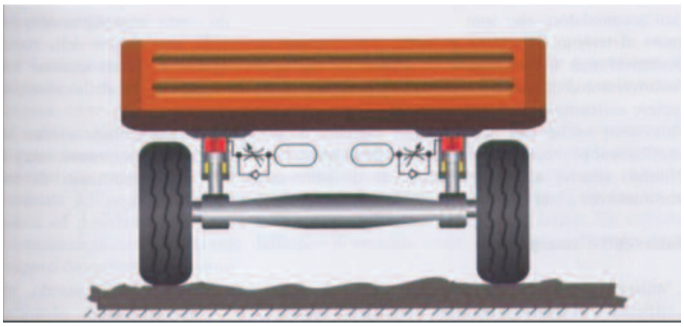
*The third application example of the "hydraulic spring" is the cushioning system for vehicles (fig. 1.3s).*

It's known that for the smooth operation of the cableways and elevators, small tolerances are required on cable lengths.

The differences in length of the cables caused, in case of cableways, by the strokes up and down and in the case of elevators by the temperature variations or by the inequalities of the loads are compensated by inserting one or more accumulators in the hydraulic circuit.



1.3s

*Fig. 1.3s: suspension system for vehicles*

Marching on irregular road surfaces, a vehicle is affected by mechanical stresses, potentially harmful for the body and the chassis.

By installing a hydropneumatic suspension system comprising some cylinders connected to an accumulator, the mechanical stresses are first converted into hydraulic stresses in the cylinders and then are absorbed by the accumulator.

The use of in-vehicle hydropneumatic suspensions:

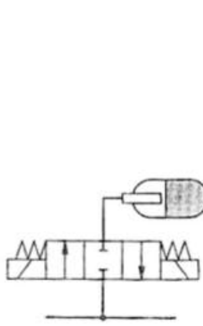
- reduces the risk of accidents
- extends the life of the vehicle
- allows faster cornering
- keeps the load in the desired position
- reduces stress on material
- reduces the operating costs

## 1.3.7 SEPARATION OF FLUIDS

In fluid power systems in which there are two fluids that must interact while remaining strictly separated, as separating element, it is used a bladder or a diaphragm accumulator.

### 1.3.7.1 SEPARATION BETWEEN AIR AND OIL

In some pneumatic systems, it can be useful to add a hydraulic component when it is required the generation of a high force.
The separation between the pneumatic circuit and hydraulic one is obtained with an accumulator. As in this application the fluid power comes from the pneumatic circuit, the hydraulic circuit does not require a power unit.

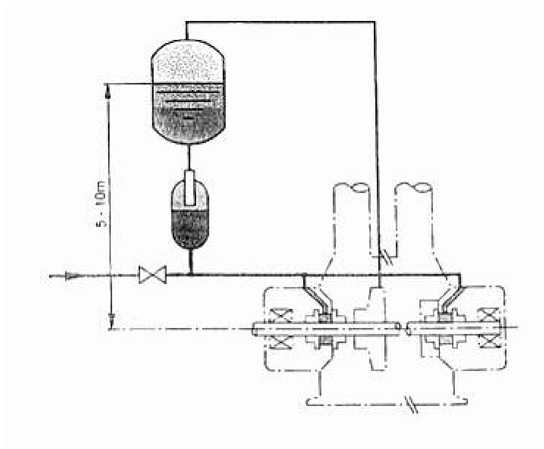


1.3t

*Fig. 1.3t: accumulator used for the separation of a pneumatic circuit from a hydraulic one.*

### 1.3.7.2 SEPARATION OF TWO FLUIDS

In compressors for petrochemical use with floating ring seals, for operational and pollution reasons, the process gas pumped by the compressor should not come into contact with the flushing fluid of the seals.
On the other hand, the operation of this type of seal requires a flushing pressure greater than 0.5 – 1.0 bar with respect to the process gas.
To ensure the overpressure, a tank containing a liquid is installed in an elevated position with respect to the compressor (Fig. 1.3u,) on the surface of which acts the same process gas supplied by the compressor.
To avoid contamination of the process gas, the fluid should have a neutral behaviour with regard to the gas. But, as normally it does not have the lubricity that the floating seals and shaft bearings require, to the seals must be sent a different fluid than the one contained in the tank. The separation between the two fluids is achieved with an accumulator.

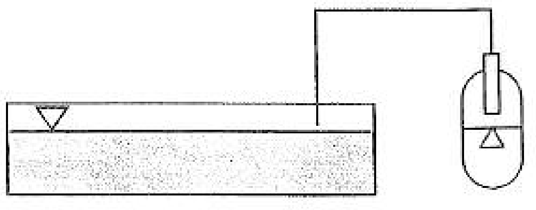



1.3u

*Fig. 1.3u: accumulator for the separation of the fluids.*

### 1.3.7.2 SEPARATION OF TWO GASES

In systems that can be damaged by the infiltration of moisture through the tank breather filter, or in the case of pressurized tanks with nitrogen to prevent condensation due to temperature changes, compensation in volume changes is provided by an accumulator (Fig. 1.3v).



1.3v

*Fig. 1.3v: accumulator for the volume compensation.*

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## 1.4 DESCRIPTION

Accumulators are pressure vessels subjected to the specific current regulations or accepted ones of the Countries where they will be installed.
For all the European Countries, design, construction and accumulator testing must be carried out according to the Directive 97/23/EC on Pressure Equipment.
EPE ITALIANA, also in virtue of the quality system using EN ISO 9001:2000, works according to forms H and H1 of total quality guarantee and design control issued by the Notify Body.
The above mentioned Directive includes the pressure equipment that exceeds 0.5 bar. So all the accumulators are involved in this Directive even if it provides different procedures of testing and certification.
Please keep in mind that accumulators up to 1 litre of volume, even if manufactured according to the Directive 97/23/EC, are not marked EC and are not provided with the conformity declaration.
For volumes higher than 1 litre, after the testing, each accumulator is stamped with the mark CE followed by the number that identifies the Notify Body.
For these high pressure and low pressure accumulators, the documentation necessary includes the conformity declaration and the operator's manual.
It is also possible to supply accumulators in accordance with Directive ATEX 94/9/EC (enclosure VIII) and with harmonized regulations EN 13463-1 related to non-electrical equipment to be used in environment with potentially explosive atmosphere and to be included into the classification ATEX EC II2GcT4.
EPE ITALIANA provides also other tests and certifications for those Countries in which EC regulations are not accepted:
- ASME-U.S. for USA, Canada, South Africa, etc..
- ML (ex SQL) for China.
- Australian Pressure Vessel Standard AS1210-1997 for Australia.
- GOST for Russia.
- RTN - Rostechnadzorfor Ukraine
- DDP passport for Algeria
- RINA and in some cases BS-L Lloyd's Register and Germanischer Lloyd for naval construction.
- For other Countries, which require a specific test, accumulators are in any case manufactured according to the European Directive but are supplied without EC marking and with factory test only.

The documentation related to each regulation is normally provided in a proper envelope along with the goods. If it's not available, it will be sent by post or in another way as soon as possible.
In order to define correctly both the price and the availability, it is necessary that in the inquiry it is mentioned the required certification.

## 1.4.0 REPORT TEST

All EPE components are completely tested and, upon request, you can receive the certificate of inspection by the factory.

## 1.4.1 TR CERTIFICATE

In most of cases, for importing products into the Russian Federation and former Soviet republics (Belarus, Ukraine, Kazakhstan), you must have various product certificates. The most common one is the TR certificate. This certificate confirms to the end user that the product complies with certain regulations on safety of the Country. Without the certification, the goods cannot be cleared and the end user (importer) cannot start-up or use the product because it is classified not safe.

1.4a

## 1.4.2 AUSTRALIAN PRESSURE VESSEL STANDARD

In Australia, it is necessary to define the level of risk that a vessel under pressure represents.
The level of risk is a ok of: volume to pressure, type of contente fickle/unstable, its compressibility, operating conditions (static, movable, proximity to public, etc.).
The degree of risk level is expressed in the Australian Standard with some letters according to "AS4343-1999 - Equipment under pressure - Level of risk".
Any pressure vessel that has a level of risk higher than the level "E" should belong to a registered drawing.
The registration of the drawings is issued by a Government agency in every State of Australia called "Work Safe Australia".
The "Work Safe" will issue the registrations only for vessels under pressure showing to be in accordance with Australian standards: AS1210-1997 - pressure vessels - and, normally, this registration is accepted by the other Australian States.

## 1.4.3 ML (EX SQL) - CHINA

With the entry of China into the WTO (World Trade Organization), the Chinese State Council has officially issued (02/19/2003) the new regulations on safety supervision of special equipment to be entered in the Chinese market.
The organization "General Administration of Quality Supervision Inspection and Quarantine" (AQSIQ) was authorized to take care of the direct control and management of this special equipment used in China.
To this control system must therefore be subject even the special equipment that are imported into China from all over the world.
In place of Safety Quality License Office (SQLO), the offices of SELO (Special Equipment Licensing Office) directly under AQSIQ, become the new operational reference.
SELO is solely responsible for the management of documentation and for the evaluation of the manufacturer in order to obtain of the license (Manufacture License ML).
EPE ITALIANA was authorized by SELO to export its products in China with License ML No. TS2200710-2012.

## 1.4.4 RINA

**RINA certification for the marine industry.** RINA is a third party that, in accordance with its rules, tests and certifies various pressure equipment that will be used in the marine industry.
RINA is an associate member of IACS and is authorized to act on behalf of the Italian administration in accordance with EU Directive 94/57 and about 70 other flag administrations.

## 1.4.7 ASME-U.S.

ASME (American Society of Mechanical Engineers) is an organization that regulates the design and manufacture of pressure vessels. Accumulators are categorized as unfired pressure vessels and fall under the jurisdiction of ASME Code when required by State law.
Accumulators specifically fall under the section of the code referred to Section VIII, Division 1. This section requires certification on vessels with internal diameters of 6" or greater and with the "U" symbol as evidence that they were designed and manufactured in accordance with the Code. The "U" symbol is an internationally recognized symbol of design and quality manufacturing.
The essential criteria of ASME Certification is a requirement of strength and material traceability. Accumulators must be manufactured with materials that meet ASME specifications and require a design factor of 4:1 in the ratio of burst pressure to rated pressure.
This 4:1 requirement is mandatory for all accumulators with ASME Certification with the exception of those that comply with a specific rule within the Code called "Appendix 22".
Appendix 22 permits that accumulators manufactured with "forged" shells, with connections of a specified maximum size, may be certified with a design factor of 3:1 in the ratio of burst pressure to rated pressure.
ASME requires that each vessel is marked with the design pressure at the Minimum Design Metal Temperature (MDMT) for the vessel.
ASME Certification requires third party surveillance of an approved quality system and requires witness by a third party of all hydrostatic testing.
Currently, unlike many other standards around the world, there is no ASME national requirement for periodic inspection of accumulators after installation. However, local laws would dictate such inspections.

## 1.4.8 97/23/EC EUROPE

The Pressure Equipment Directive is one of the series of technical harmonization directives covering subjects such as machinery, simple pressure vessels, gas appliances, etc., which were identified by the European Community's program for the elimination of technical barriers to trade.
The purpose of the PED is to harmonize national laws of Member States regarding the design, manufacture, testing and conformity assessment of pressure equipment and assemblies of pressure equipment.
The program aims to ensure the free placing on the market and putting into service of relevant equipment within the European Union and the European Economic Area.
The Directive requires that all pressure equipment and assemblies within its scope must be safe when placed on the market and put into service.
The Pressure Equipment Directive applies to the design, manufacture and conformity assessment of pressure equipment and assemblies of pressure equipment with maximum allowable pressure greater than 0.5 bar above atmospheric pressure (i.e.:1.5 bar of absolute pressure).
The PED Conformity Assessment Forms apply to all accumulators using fluids of Group 2 (i.e.: non-hazardous), with a volume greater than 1 litre and a product of service pressure (PS) and volume (V) greater than 50 bar x litre or for any pressure vessel where PS exceeds 1000 bar.
PED applies in the member States of the European Union (EU) and the European Economic Area (EEA). Similar requirements to PED have been adopted by many other countries, which joined the European Union.
The EU member States are: Austria, Belgium, Bulgaria, Cyprus, Denmark, Estonia, Finland, France, Germany, Greece, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Czech Republic, Romania, Slovakia, Slovenia, Spain, Sweden, Hungary, and United Kingdom.
The European Economic Area (EEA) includes the 27 EU countries listed above, plus Iceland, Liechtenstein, Norway and Switzerland.

## 1.4.9 ATEX (94/9/EC)

Fall within the scope of the Directive 94/9/EC also non-electrical equipment that have to be used in potentially explosive atmospheres so they must be certified Atex according to the customer's risk area. See section 0.8.
As required by the regulation 94/9/EC, in addition to the deposit of the technical dossier, EPE ITALIANA monitors its internal production and constantly checks that the production cycle is consistent with the risk analysis performed on the equipment and it carries out a self-certification.

## 1.4.10 DNV

«Det Norske Veritas» (DNV) Certification, section «Maritime».
DNV certifies all materials, components and systems that are relevant to the operation of ships in terms of safety and quality. The Classification is a particular type of certification, which is used to confirm that the ships and all structures that exist within it conform to the requirements.
These requirements are specified in the regulations of DNV. The classification, in fact, provides that the same company that performs the classification, namely the institution of the third party, establishes the requirements.

## 1.4.11 RTN - ROSTECHNADZOR

RTN Rostekhnadzor Certification
The FSETAN RTN ROSTECHNADZOR certificate (former Gosgorteknadzor).
The FSETAN and RTN RosTechNadzor permissions for the use of technological systems (production lines) are required in dangerous industrial areas during flammable and explosive processes and for the use of the related equipment as well as in any other field that may cause danger to the ecology and the human being. The Permissions are granted by the Federal Ecological, Technological and Atomic Monitoring Service according to expert conclusions on the industrial safety carried out by specialists of the Organization. Therefore, all components used on these plants are accompanied by its passport RTN.

## 1.4.12 ALGERIAN PASSPORT

EPE Italiana is able to supply its components with the Algerian passport for all applications that it's required.
After the approval of the preliminary dossier from the Algerian Ministry of Energy and Certification with endorsement by the Algerian Consulate in Italy and the Italian Chamber of Commerce, will be issued the final dossier in French language and carried out, by third party, the pressure test on the equipment subjected to this certification.




**EPE ITALIANA s.r.l.** - Viale Spagna,112 • 20093 Cologno Monzese (Mi) Italy
Tel.: +39 02 25459028 • Fax: +39 02 25 25459773 • E-mail: epeitaliana@epeitaliana.it • Internet: www.epeitaliana.it

## 1.5.1 DETAILS OF THE BLADDERS AND/OR SEALS MATERIAL

The bladders can be made of various types of elastomers. To obtain the thermal and chemical compatibility with the fluid used, you must select the proper elastomer, depending on the fluid used and the working temperature. For more precise information than the specifications outlined below, please contact our technical service.

## 1.5.2 "P" NITRILE RUBBER (NBR)

Nitrile rubber NBR is the generic name of the acryl-nitrile butadiene compound. The content of nitrile-acrylate is greater than 33%, so you have the right balance between a good compatibility with oils and fuels, while maintaining good flexibility at low temperatures. The NBR rubber is highly resistant to ozone and weathering. Heat resistance up to 80°C and for short periods up to 90°C (at higher temperatures, the aging is accelerated). Resistance to low temperatures down to -20°C, for short periods up to -25° C.

**Chemical compatibility:**
- aliphatic hydrocarbons (propane, butane, gasoline, oils, mineral greases, diesel fuel, fuel oil, kerosene)
- mineral greases and oils
- HFA, HFB, HFC fluids
- many dilute acids, alkalis, salt solutions
- water
- water glycol

**Not compatible with:**
- fuels with high aromatic content (i.e. premium gasoline)
- aromatic hydrocarbons (benzene)
- chlorinated hydrocarbons (trichloroethylene)
- polar solvents (ketone, acetone, ethylene esters of acetic acid)
- strong acids
- brake fluids based on glycol
- water glycol
- poor resistance to ozone, weathering and aging.

## 1.5.3 "F" NITRILE RUBBER FOR LOW TEMPERATURES

The same as with standard nitrile and most types of freon. It has lower content of acrylic nitrile with respect to the standard, so it is best suitable to work at low temperatures but the chemical resistance to various liquids is slightly lower. Working temperature –40°C +70°C.

## 1.5.4 "H" NITRILE RUBBER FOR HYDROCARBONS

Compatible with normal gasoline, super low-aromatic ones, combined heavy oil and all fluids of standard nitrile. Working temperature –10°C +90°C

## 1.5.5 "K" HYDROGENATED NITRILE (HNBR)

The hydrogenated nitrile rubber is obtained by adding hydrogen to the compound of the NBR rubber, which imparts superior mechanical properties, outstanding abrasion resistance, high tensile strength, excellent resistance to high temperatures, low gas permeability. Heat resistance up to 130°C, with higher peaks for short periods of up to 150°C. Resistance to low temperatures up to -30°C.
Chemical compatibility greater than the NBR rubber.

## 1.5.6 "B" BUTYL (IIR)

The butyl rubber has low gas permeability and good electric insulation capacity. Heat resistance up to 100°C, with higher peaks for short periods of up to 120°C. Resistance to low temperatures up to -30°C.

**Chemical Compatibility:**
- hot water up to 100°C
- brake fluids based on glycol
- many acids and bases
- salt solutions
- polar solvents such as alcohols, ketones and esters
- polyglycol-based hydraulic fluids (HFC fluids) and bases of phosphoric acid esters (HFD-R fluids)
- silicone oils and greases
- Skydrol 500 e 7000
- resistance to ozone, weathering and aging

**Not compatible with:**
- mineral oils and greases
- fuels
- chlorinated hydrocarbons

## 1.5.7 "E" ETHYLENE-PROPYLENE (EPDM)

EPDM is a rubber derived from the copolymerization of ethylene with propylene and diene, so it has features particularly suitable to contact with hydraulic fluids based on phosphate esters; it can be also used with fluids of the glycol-based brake systems. Heat resistance up to 100°, with higher peaks for short periods of up to 120°C . Resistance to low temperatures up to -30°C.

**Chemical Compatibility:**
- hot water up to 100°C
- brake fluids based on glycol
- many organic and inorganic acids
- detergents, sodium and potassium solutions
- hydraulic fluids based on phosphate esters (HFD-R)
- silicone oils and greases
- many polar solvents (alcohol, ketones, esters)
- Skydrol 500 and 7000
- resistance to ozone, weathering and aging

**Not compatible with:**
- mineral oils and greases
- fuels

## 1.5.8 "N" CHLOROPRENE (CR)

Trade name NEOPRENE.
Chloroprene rubber is one of the first rubbers created synthetically. Given the high content of chlorine, vulcanizing items have good flammability. They burn under direct action of the flame, but go out when it goes away. The compatibility to the oil is medium, good mechanical properties in the wide temperature range of use. Heat resistance up to 100°C , with higher peaks for short periods of up to 110°C . Resistance to low temperatures up to -30°C.

**Chemical Compatibility:**
- mineral paraffin oils

- silicone oils and greases
- water and aqueous solutions
- refrigerants (ammonia, carbon dioxide, Freon)
- naphthenic mineral oils
- low molecular aliphatic hydrocarbons (propane, butane, gasoline)
- brake fluids based on glycol
- better resistance to ozone, weathering and aging than in NBR rubber.

**Not compatible with:**
- aromatic hydrocarbons (benzene)
- chlorinated hydrocarbons (trichloroethylene)
- polar solvents (ketones, esters, ethers, acetone).

## 1.5.9 "Y" EPICHLOROHYDIN (ECO)
The epichlorohydrin rubber is a copolymer which has good compatibility with mineral oils, fuels and ozone. The high temperature resistance is good; it still has a good elasticity at low temperature, while the gas permeability is not excellent. Heat resistance up to 110°C, with higher peaks for short periods of up to 120°C. Resistance to low temperatures up to -30°C.

**Chemical Compatibility:**
- mineral oils and greases
- aliphatic hydrocarbons (propane, butane and gasoline)
- silicone oils and greases
- water at ambient temperature
- resistance to ozone, weathering and aging

**Not compatible with:**
- aromatic hydrocarbons and chlorinated solutions
- ketones and esters
- non-flammable hydraulic fluids of HFD-R and HFD-S groups
- brake fluids based on glycol

## 1.5.10 "V" FLUOROCARBON (FPM)
The trade name ("DuPont") is VITON®. The fluorocarbon rubber has excellent resistance to high temperatures, ozone, oxygen, mineral oils, synthetic hydraulic fluids, fuels and many chemicals and organic solutions. In the field of low temperatures, its behaviour is not optimal. The permeability to gases is very low, similar to that of butyl. Heat resistance up to 180?, for short periods of up to 200?. Resistance to low temperatures up to - 10?.

**Chemical Compatibility:**
- mineral oils and greases
- non-flammable fluids of HFD group
- silicone oils and greases
- animal and vegetable oils and greases
- aliphatic hydrocarbons (gasoline, butane, propane, natural gas)
- aromatic hydrocarbons (benzene, toluene)
- chlorinated hydrocarbons (tetrachloroethylene, carbon tetrachloride)
- fuels (normal, premium and containing methanol)
- good resistance to ozone, weathering and aging.

**Not compatible:**
- polar solvents (acetone, methyl ethyl ketone, ethyl acetate, diethyl ether, dioxane)
- Skydrol 500 and 7000
- brake fluids based on glycol
- ammonia gas, amines, alkali
- superheated steam
- low molecular organic acids (formic and acetic acid).

## 1.5.11 POLYURETHANE (HPU)
The H-PU polyurethane is a copolymer, based on aromatic isocynate and diols.
Compared to all other elastomers, it has excellent wear resistance, excellent resistance to extrusion and high elasticity. The gas permeability is good compared to that of IIR. Heat resistance: up to approx. +80°C; resistance to low temperatures: up to approx. –20°C.

**Chemical Compatibility:**
- pure hydrocarbons
- natural oils and greases
- silicone oils and greases
- water up to +50°C
- resistance to ozone and aging

**Not compatible with:**
- ketones, esters, ethers, alcohols, glycols
- hot water, steam, alkalis, amines, acids

**Resistant to:**
- oil, petrol, hot water, hot air, ozone, synthetic and native esters

**Not resistant to:**
- conc. Acids, conc. lyes, conc. alcohols and aromatic solvents.

## 1.5.12 SILICON-FLUORINE (MFQ)
The rubber MFQ contains in its molecule, as well as methyl groups, even trifluoropropyl groups. The physical and mechanical properties are comparable to those of silicone rubber (MVQ). In comparison to silicone (MVQ), the silicon fluoride (MQF) shows a significantly higher compatibility to fuels and mineral oils, while resistance to the hot air is slightly lower.
Heat resistance: up to approx. 150?. (max. 180°C)
Resistance to low temperatures: up to approx. +50°C

**Chemical Compatibility:**
- mineral aromatic oils (i.e. ASTM Oil No. 3)
- fuels
- aromatic low molecular hydrocarbons (i.e. benzene, toluene)
- engine oils and aliphatic type transmissions
- animal and vegetable oils and greases
- brake fluids based on glycol
- non-flammable hydraulic fluids, HFD-R and HFD-S fluids
- chlorinated aromatic hydrocarbons with high molecular content (i.e. Chlophen), chlorinated diphenyl
- water up to +70?
- dilute salt solutions
- resistance to ozone, aging and weathering

**Not compatible with:**
- superheated steam over 100°C
- acids and alkalis


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- silicone oils and greases
- low molecular chlorinated hydrocarbons (i.e. trichloroethylene)

## 1.5.12 TEFLON (PTFE)

Normally it is better known by its trade name Teflon®, in which other stabilizers and plasticizers are added to the polymer to improve the characteristics depending on the application. It's a plastic smoother to the touch and resistant to high temperatures (up to 200°C).
The main features are:

- the complete chemical inertia, so it's not attacked by almost all chemical compounds (with the exception of molten alkali metals, fluorine at high pressure and some fluorine compounds under particular conditions of temperature) and especially it does not change the fluids with which is placed in contact, such as high purity fluids for the electronics industry
- the complete insolubility in water and in any organic solvent
- good electric quality (65 kV / mm of dielectric strength)
- excellent resistance to fire: it does not propagate the flame
- Excellent flow properties on the surface: the coefficient of friction is the lowest among the industrial sealing products
- Non-stick: the surface cannot be glued (contact angle is of 127°)

These characteristics take on added importance when you take into account that remain virtually unchanged in a range of temperatures from -50°C and 150°C (max. 200°C).

**Chemical Compatibility:**

- Teflon has a high chemical compatibility with most fluids and chemicals used.

**Not compatible with:**

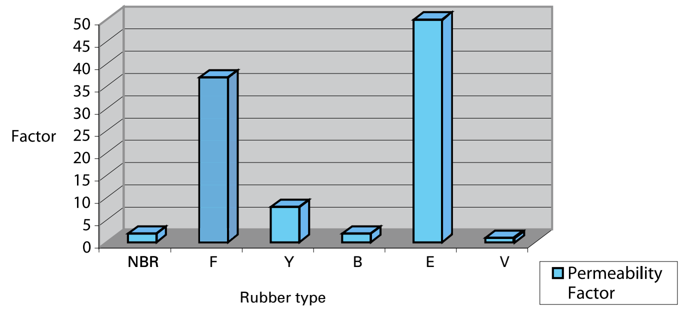
- hardly compatible with fuel oils in general

## 1.5.13 THE GAS PERMEABILITY ISSUE SIMPLIFIED

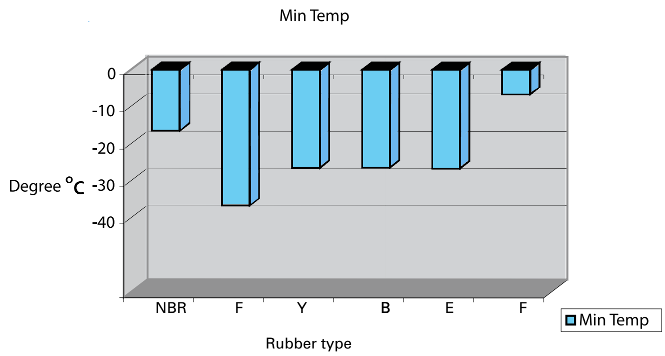
As you gain low temperature capability in a bladder compound, permeability of the bladder increases, and hence greater pre-charge loss due to gas permeation at working temperature.
To show the direct correlation, the potential permeability of each bladder compound was tested to define the relationship between the bladder compound permeability and temperature.
The Gas Permeability Factor was determined by rating the permeability (potential loss of gas pre-charge through the bladder or through the seal) of each compound on a scale of 0 to 50 at 70°F. The higher the Permeability Factor of the faster gas pre-charge would be lost in a low-temperature application using that bladder compound.
Specifically:

| Rubber type | TSmin °C | Permeability Factor |
|---|---|---|
| "**P**" Nitrile (NBR) | - 20 | 3 |
| "**F**" Nitrile (NBR–LT) | - 40 | 30 |
| "**Y**" Epichlorohydrin ECO) | - 30 | 8 |
| "**B**" Butyl (IIR) | - 30 | 2 |
| "**E**" Ethylene-propylene(EPDM) | - 30 | 50 |
| "**V**" Fluorocarbon (FPM) | - 10 | 1 |

The Permeability Factor increases or decreases with temperature, setting up a trade-off situation for having to use a low temperature bladder compound. If the application requires a – 40°C bladder material because the equipment needs to be left out the cold overnight, the upside is that the bladder won't shatter at low temperature.
The downside is that the pre-charge in the bladder will have to be checked more often because of the higher working temperature when the oil warms up.
The following charts will assist bladder accumulator users when they have a low temperature application. Figure 1.5a Permeability Factor & Bladder Compounds shows the permeability of each compound within a 0 to 50 Permeability Factor scale.




1.5a




1.5b

*Figure 1.5b– Minimum Use Temperature & Bladder Compounds shows the lowest temperature at which each bladder compound can be used. With reference to both charts, it is graphically easy to see that the nitrile low temperature compound, for example, has excellent low temperature capability at – 40°C, but the trade-off for that low temperature performance is a relatively high Permeability Factor of 30. This is a solid confirmation that using this bladder compound will require more frequent maintenance checks for the loss of pre-charge due to gas permeation.*