Parker
Hydraulics

Making the Choice

Selecting and Applying Piston and Bladder Accumulators

Catalogue 1243/1-GB

Hydro-pneumatic accumulators are the most widely used type of accumulator in industrial hydraulic systems. They use compressed gas to apply force to hydraulic fluid. Identical in their operating principle, Parker's piston and bladder accumulators use different mechanisms to separate the gas from the fluid. It is this difference – and the resulting performance characteristics – which determines their suitability for different applications. The correct selection and application of piston and bladder accumulators is examined in the following pages.

Adding an accumulator to a hydraulic system can:

- ***improve system efficiency***
- ***absorb shock***
- ***supplement pump delivery***
- ***provide emergency power***
- ***compensate for leakage***
- ***maintain pressure***
- ***dispense fluid***
- ***act as a fluid barrier***

Contents

Note: Failure or improper selection or improper use of accumulators or related items can cause death, personal injury and property damage. Parker Hannifin shall not be liable for any incidental, consequential or special damages that result from use of the information contained in this publication.

Introduction

Parker's hydro-pneumatic accumulators regulate the performance of a hydraulic system by providing an additional volume of system fluid, pressurised by an external gas supply. A correctly specified accumulator can:

- reduce shock effects in a system resulting from inertia or external mechanical forces
- maintain system pressure by compensating for pressure loss due to leakage
- provide a back-up supply of hydraulic energy to maintain a constant flow when system demand is greater than pump delivery.

In industrial applications, two types of hydro-pneumatic accumulator are widely used – the piston type and the bladder type. Each has particular advantages and limitations which should be considered when selecting an accumulator for a specific application.

Bladder accumulators are generally preferred for applications where very rapid cycling is expected, and high fluid tolerance and very low response times are required. They provide excellent gas/fluid separation.

Piston accumulators offer greater efficiency and flexibility in most applications, due to their wider range of sizes. Parker's piston accumulators feature a patented five-blade V-O-ring which maintains full contact between the piston and the bore, without rolling. Sealing remains effective even under rapid cycling at high operating pressures.

Design Features and Construction

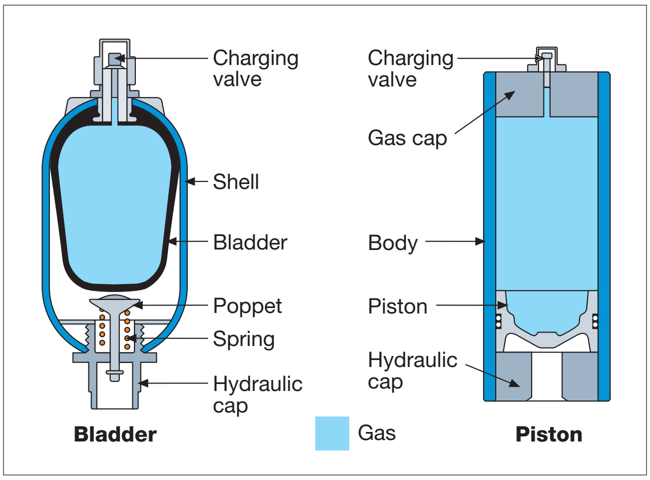
Bladder Accumulators

Parker's bladder accumulators feature a seamless, non-pleated, flexible rubber bladder housed within a steel shell. The open end of the bladder is attached to the precharging valve at the gas end of the shell. A poppet valve, normally held open by spring pressure, regulates fluid flow through the hydraulic port. Parker's bladder accumulators are available as either top or bottom repairable units, for optimum flexibility.

The bladder is charged with a dry inert gas, eg: nitrogen, to a set precharge pressure determined by the system requirements. As system pressure fluctuates, so the bladder expands and contracts to discharge fluid from, or allow fluid into, the accumulator shell.

Piston Accumulators

Parker's piston accumulators consist of a cylindrical body, sealed by a gas cap and charging valve at the gas end, and by a hydraulic cap at the hydraulic end. A lightweight piston separates the gas side of the accumulator from the hydraulic side.



As with the bladder accumulator, the gas side is charged to a pre-determined pressure. Changes in system pressure cause the piston to rise and fall, allowing fluid to enter or forcing it to be discharged from the accumulator body.

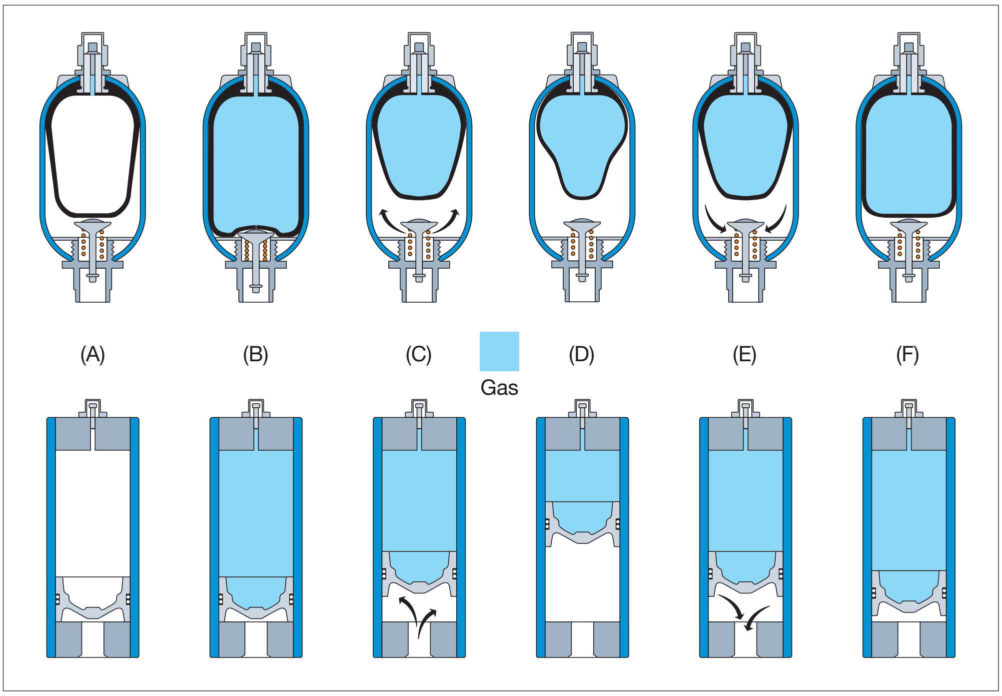
Fig.1 Typical bladder and piston accumulators

Stage A The accumulator is empty, and neither gas nor hydraulic sides are pressurised.

Stage B The accumulator is precharged.

Stage C The hydraulic system is pressurised. System pressure exceeds precharge pressure, and fluid flows into the accumulator.

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



Stage E System pressure falls. Precharge pressure forces fluid from the accumulator into the system.

Stage F Minimum system pressure is reached. The accumulator has discharged its design maximum volume of fluid back into the system.

Fig.2 Operating conditions of bladder and piston accumulators

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

- Failure mode
- Output volume
- Flow rate
- Fluid type
- Response time
- Shock suppression
- High frequency cycling
- Mounting position
- External forces
- Sizing information
- Certification
- Safety

Failure Modes

In certain applications, a sudden failure may be preferable to a gradual failure: a high-speed machine, for example, where product quality is a function of hydraulic system pressure. Because sudden failure is detected immediately, scrap is minimised, whereas a gradual failure might mean that production of a large quantity of sub-standard product could occur before the failure became apparent. A bladder accumulator would be most suitable for this application.

Conversely, where safety is paramount and sudden failure could be catastrophic 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.

Output Volume

The maximum sizes available of each type of accumulator determine the limits of their suitability where large output volumes are required. There are, however, several methods of achieving higher output volumes than standard accumulator capacities suggest – see Large/ Multiple Accumulators, page 8.

Table 1 compares typical fluid outputs for Parker's 40 litres piston and bladder accumulators operating isothermally as auxiliary power sources over a range of minimum system pressures. The higher precharge pressures recommended for piston accumulators result in substantially higher outputs than from comparable bladder accumulators. Also, bladder accumulators are not generally suitable for compression ratios greater than 4:1, as these could result in excessive bladder deformation and high bladder temperatures.

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 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 available space is critical.

Table 1: Relative Outputs of a 40 litre Accumulator

Compression Ratio	System Pressure bar		Recommended Precharge bar		Fluid Output litres	
	max	min	Bladder	Piston	Bladder	Piston
1.5	210	140	119	137	11.3	13
2	210	105	105	102	16.9	19.3
3	210	70	59	63	22.6	24
6	210	35	*	28	*	26.7

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

Flow Rate

Table 2 shows typical maximum flow rates for Parker's piston and bladder accumulators in a range of sizes.

The larger standard bladder designs are limited to 825 litres/min, although this may be increased to 2250 litres/min using a high-flow port. The poppet valve controls flow rate, with excessive flow causing the poppet to close prematurely. Flow rates greater than 2250 litres/min may be achieved by mounting several accumulators on a common manifold – see Large/Multiple Accumulators, page 8.

For a given system pressure, flow rates for piston accumulators generally exceed those for bladder designs. Flow is limited by piston velocity, which should not exceed 3m/s to avoid piston seal damage. In high-speed applications, high seal contact temperatures and rapid decompression of nitrogen that has permeated the seal itself, can cause blisters, cracks and pits in the surface of the seal.

Table 2: Max. Recommended Accumulator Flow Rates

Piston			Bladder		
Capacity litres	Bore mm	Flow, lpm at 210 bar	Capacity litres	Flow, lpm at 210bar Standard	Hi-Flow
1	51	375	1	225	-
4	102	1500	4	560	-
10	146	3000	10	825	2250
57	178	4500	Over 10 litres	825	2250
75	229	7500		825	2250
190	302	12750		825	2250

Fluid Type

Bladder accumulators are more resistant than piston types to damage caused by contamination of the hydraulic fluid. While some risk exists 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 also preferred to piston types for water service, because water systems tend to carry more solid contaminants, lubrication is poorer, and the piston and bore require plating to resist corrosion.

Piston accumulators are preferred for systems using exotic fluids or where extremes of temperature are experienced as, compared to bladders, piston seals are more easily moulded in the special compounds required, and may be less expensive.

Response Time

In theory, bladder accumulators should respond more quickly to system pressure variations than piston types. There is no static friction to be overcome as 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 require response times of 25ms or less, the region where the difference in response between piston and bladder accumulators becomes significant. Generally, a bladder accumulator should be used for applications requiring less than 25ms response time, and either accumulator type for a response of 25ms or greater.

Shock Suppression

Shock control does not necessarily demand a bladder accumulator.

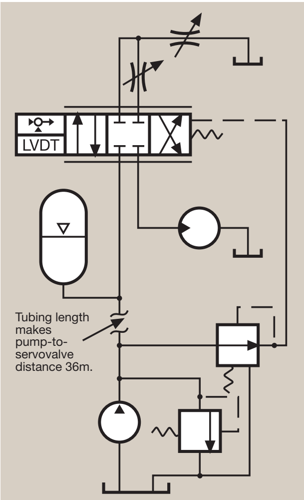


Fig.3 Test circuit to generate and measure shock waves in a hydraulic system

Example 1

A test circuit (Fig.3) includes a control valve situated 36m from a pump supplying fluid at 113 litres/min. The circuit uses 30mm tubing and the relief valve is set to open at 190 bar. Shutting the control valve (Fig.4) produces a pressure spike of 27 bar over relief valve setting (blue trace).

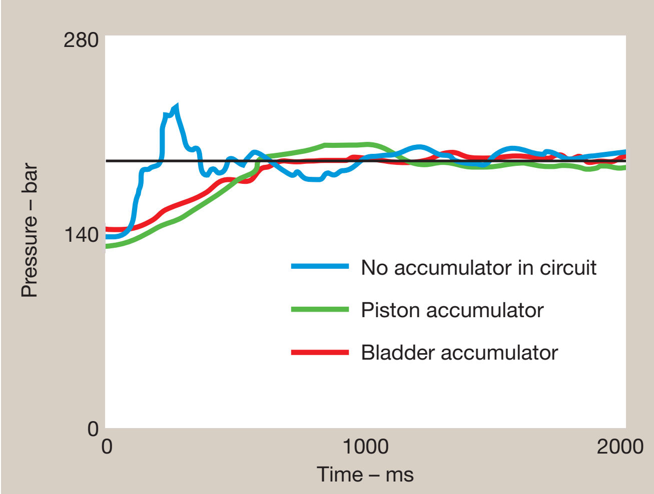


Fig.4 Shock wave test results – Example 1

Installing a Parker 4 litre piston accumulator at the valve reduces the transient to 6.9 bar over relief valve setting (green trace). Substituting a 4 litre bladder accumulator further reduces the transient to 5.4 bar over relief valve setting (red trace), an improvement of only 1.5 bar and of little practical significance.

Example 2

A second, similar test using 15mm tubing and a relief valve setting of 180 bar (Fig.5) results in a pressure spike of 139 bar over relief valve setting without an accumulator (blue trace). A Parker piston accumulator reduces the transient to 7.4 bar over relief valve setting (green trace), while a bladder accumulator achieves a transient of 6.0 bar over relief valve setting (red trace). The difference between accumulator types in shock suppression is again negligible.

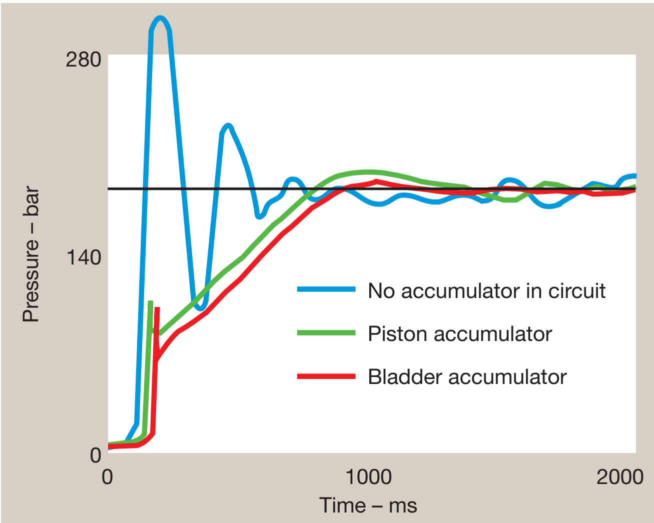


Fig.5 Shock wave test results – Example 2

Accumulator Selection (continued)

High Frequency Cycling

High-frequency system pressure cycling can cause a piston accumulator to ‘dither’, with the piston cycling rapidly back and forth in 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 damping applications, therefore, a bladder accumulator is generally more suitable.

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 amounts, 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 on the fluid can reduce its service life and even cause permanent distortion. The extent of the damage will depend upon fluid cleanliness, cycle rate, and compression ratio (i.e. maximum system pressure divided by minimum system pressure). In extreme cases, fluid can be trapped away from the hydraulic port (Fig.6), reducing output, or the bladder may become elongated, forcing the poppet valve to close prematurely.

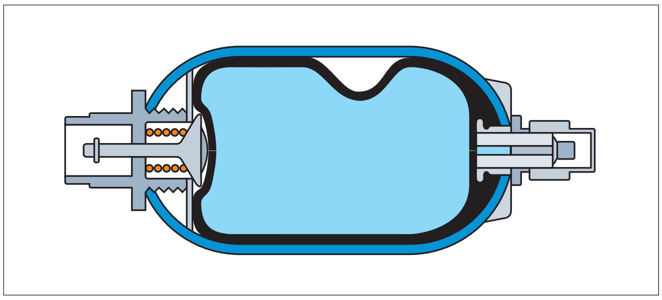


Fig.6 A horizontally-mounted bladder accumulator can trap fluid away from the hydraulic valve

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 a bladder accumulator.

Forces along the axis of the tube or shell normally have little effect on a bladder accumulator but may cause a variation in gas pressure in a piston type 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.7), displacing the bladder and flattening and lengthening it. In this condition, fluid discharge could cause the poppet valve to pinch and cut the bladder. Higher precharge pressures increase the resistance of the bladder to the effects of perpendicular forces.

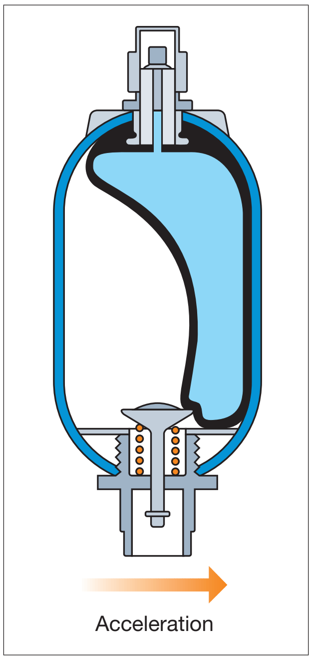


Fig.7 Perpendicular force causes the mass of the fluid to displace the bladder

Sizing Information

Accurate sizing of an accumulator is critical if it is to deliver a long and reliable service life. Information and worked examples are shown in Parker’s accumulator catalogues, or accumulator size can be calculated automatically by entering application details into Parker’s inPHorm software selection programme – please contact your Parker Sales Office for details.

Certification

Accumulators are frequently required to conform to domestic or international certification. These requirements range from simple safety factors to elaborate materials testing and inspection procedures carried out by an external agency. Most of the accumulators in Parker’s piston and bladder ranges are available with certification to the major European standards.

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.

Gas Bottle Installations

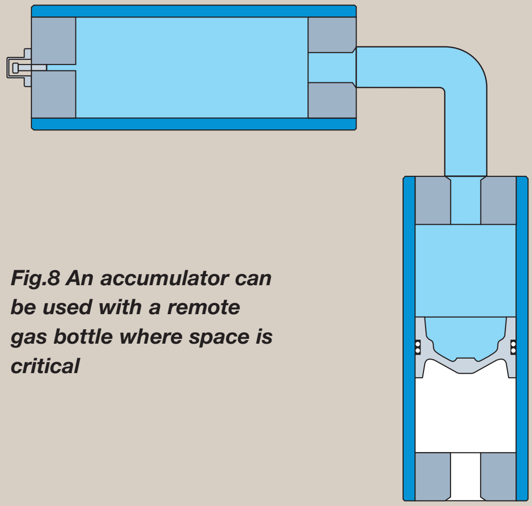


Fig.8 An accumulator can be used with a remote gas bottle where space is critical

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 a Parker auxiliary gas bottle, which can be located elsewhere (Fig.8).

The gas bottle is sized by the formula:

accumulator size – required fluid output = gas bottle size

For example, an application that calls for a 115 litre accumulator may only actually require 30-40 litres of fluid output. This application could therefore be satisfied with a 40 litre accumulator and a 75 litre gas bottle.

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 at 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 to more than 75% full.
- Bladder installations require a special device called a 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.

Multiple accumulator/ storage bottle assembly

Large/Multiple Accumulators

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. 9 and 10.

The installation in Fig.9 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 page 7, 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, without causing an excessive increase in gas pressure. A further advantage is that, because of the large precharge '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.10 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 precharge 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 or infrequently used system, this would be of little significance.

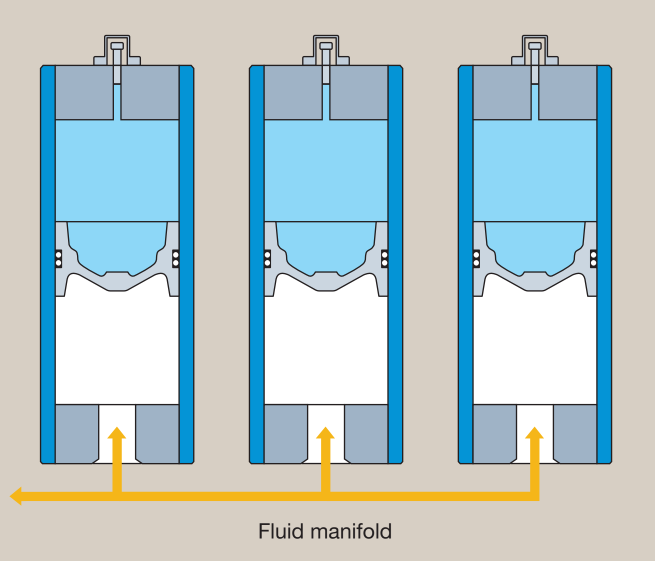
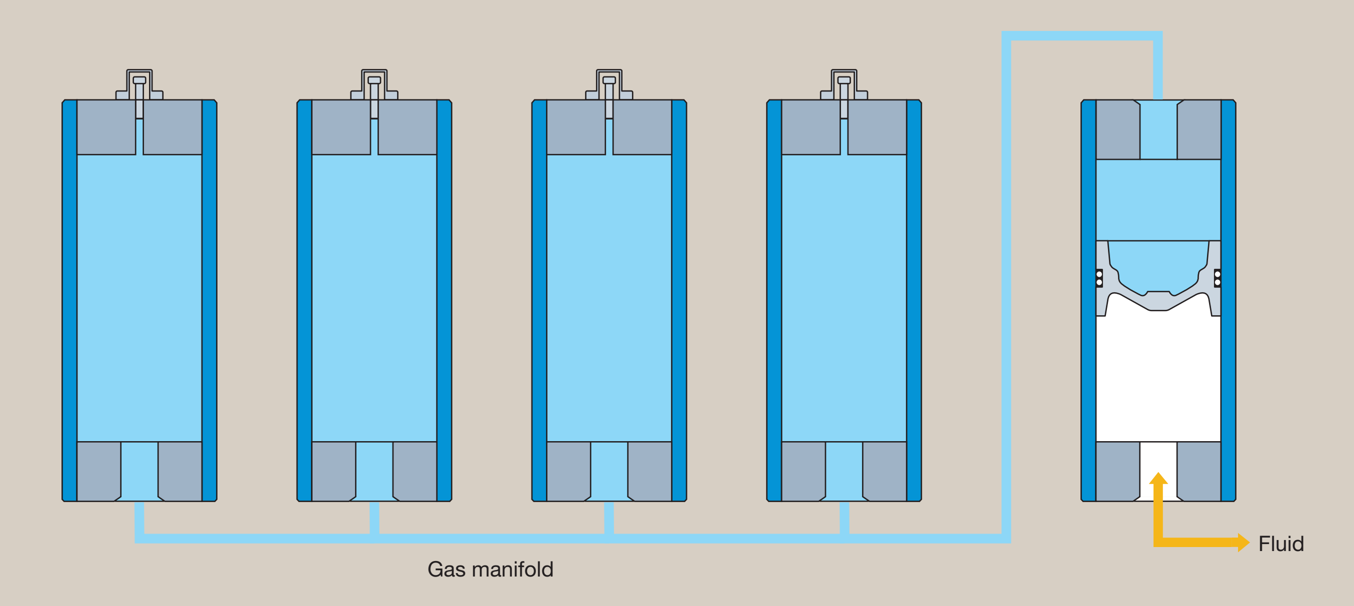


Fig.9 (below) Several gas bottles can supply precharge pressure to a single accumulator

Fig.10 (above) Multiple accumulators manifolded together offer high system flow rates



Precharging Process

Correct precharging involves accurately filling 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 precharge an accumulator to the correct specified pressure. Precharge pressure determines the volume of fluid retained in the accumulator at minimum system pressure. In an energy storage application, a bladder accumulator is typically precharged to 80% of minimum system pressure, and a piston accumulator to 7 bar below, or 90% of, minimum system pressure.

The ability to correctly carry out and maintain precharging is an important factor when choosing the type of accumulator for an application.

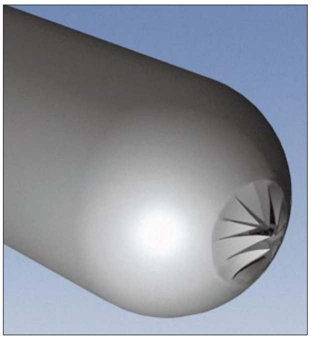


Fig.11 Starburst rupture caused by loss of bladder elasticity

Bladder accumulators are far more susceptible to damage during precharging than piston types. Before precharging and entering 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 unwinds and unfurls. When precharging, the first 5 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, brittle rubber, expanding rapidly would then inevitably rupture (Fig.11). The bladder could also be forced under the poppet and torn (Fig.12).

Fig.12 C-shaped cut shows that bladder has been trapped under poppet

Close attention should be paid to operating temperature during precharging, as a rise in temperature will cause a corresponding increase in pressure which could then exceed the precharge limit.

Little damage can occur when precharging a piston accumulator, but the fluid side should be empty so that the gas volume is maximised.

Excessively High Precharge

Excessive precharge pressure or a reduction in the minimum system pressure without a corresponding reduction in precharge pressure may cause operating problems or damage to accumulators.

With excessive precharge pressure, a piston accumulator will cycle between stages (e) and (b) of Fig.2, see page 3, and the piston will travel too close to the hydraulic end cap. The piston could bottom at minimum system pressure, reducing output and eventually damaging the piston and piston seal. The piston can often be heard bottoming, warning of impending problems.

An excessive precharge 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.12). Excessive precharge pressure is the most common cause of bladder failure.

Excessively Low Precharge

Excessively low precharge pressure or an increase in system pressure without a corresponding increase in precharge pressure can also cause operating problems and subsequent accumulator damage. With no precharge 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.

Conversely, for a bladder accumulator, too low or no precharge can have rapid and severe consequences. The bladder will be crushed into the top of the shell and may extrude into the gas valve and be punctured (Fig.13). One such cycle is sufficient to destroy a bladder. Overall, piston accumulators are generally more tolerant of careless precharging.

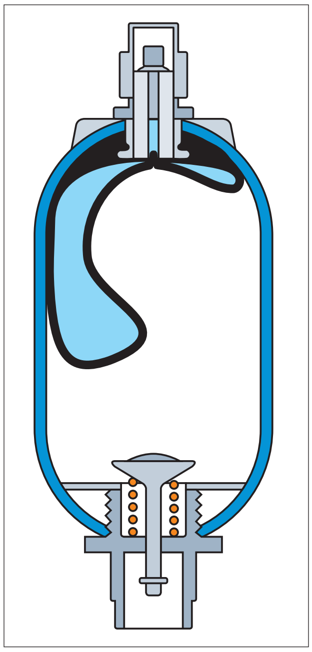


Fig.13 Fluid entering an unprecharged bladder accumulator has forced the bladder into the gas valve

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