1.1 Definition and Functionality

The piston hydro pneumatic accumulator, is a component used to exchange energy using the hydraulic system to which it is connected. It escapes energy at determined moments, the accumulate in the form of pressure energy of gas, it readily and integrally replenishes the system on demand, returning to the conditions of receiving again.
The piston accumulator is particularly constructed with two chambers, one of which is filled with gas at opportune pressure, and the second one connected to the hydraulic circuit.
The gas pressure must be chosen in relation to the conditions of work of the accumulator, and constitutes the pre-loading pressure.

1.2 Constructive Characteristics

The piston accumulator consists of a steel cylinder, closed at both ends, in which slide an airtight aluminium piston.
This divides the internal of the cylinder in two chambers, one filled with pre-charge gas and the other with oil, or generally speaking, with fluid from the system (Fig 1).

- **The piston** is made from aluminium in order to have rapid response time and not to generate pressure peaks during rapid cycles. It also has a cavity in order to lighten it, visible in fig 1. facing the gas chamber, in order to increase the volume of accumulate. Even the surface in contact with the oil has a concave cavity. The purpose of this cavity is so that the oil pressure acts on almost the entire surface of the piston and not only in one spot when the piston is against the bottom end cover in the oil chamber

- **Seal between piston and cylinder** is guaranteed by a special multi ring seal, which constitutes the key characteristic elements to the efficiency of the accumulator. This type of seal has allowed the piston accumulator to have essential characteristics regarding air lightness, component longevity and stroking. In fact, the differential pressure necessary to move the piston, that relates directly on the speed of response of the accumulator, is contained in moderate values, contrary as occurs in most seals for standard pistons.
The maximum operating temperature with NBR seals is 80ºC.
It is possible to operate at temperatures up to 150ºC, using viton seals and reduced piston, as the expansion factors of aluminium and steel are different, it is therefore necessary to compensate the thermo effect.
In piston accumulators, the duration and number of operations effected without evidence of variation in pressure in excess of 5% in the value off the pre-charge surcomes without penetration, above a certain quantities of oil in the gas chamber.
It is usually preferable to assume the variation of pre-charge as a valuation of the longevity of the accumulator as long as this check is carried out fast and simply.
Through practical results, obtained from application experience, as well as laboratory test, it was proved that 1.000.000 operations can be achieved without maintenance or intervention of recharging.

- **The cylinder body of the accumulator** is made from low carbon steel, equivalent to mechanical characteristics of 97/23/CE.
The internal surface of the cylinder is honed to 0.2 micron of roughness.
For particular reasons, the cylinder and end covers can either be superficially treatment or made from stainless steel.

- **The gas side** end cover is screwed to the cylinder body, the seal is guaranteed by a toroidal gasket, complete with anti-extrusion ring.
In the standard version this end cap has a threaded seat in which the pre-charged valve is situated.

- **The oil side** end cover is also screwed to the cylinder body and is complete with relative seal.
This end cap has a coupling to connect it to the system, either threaded or flanged, in accordance to the clients requirements.

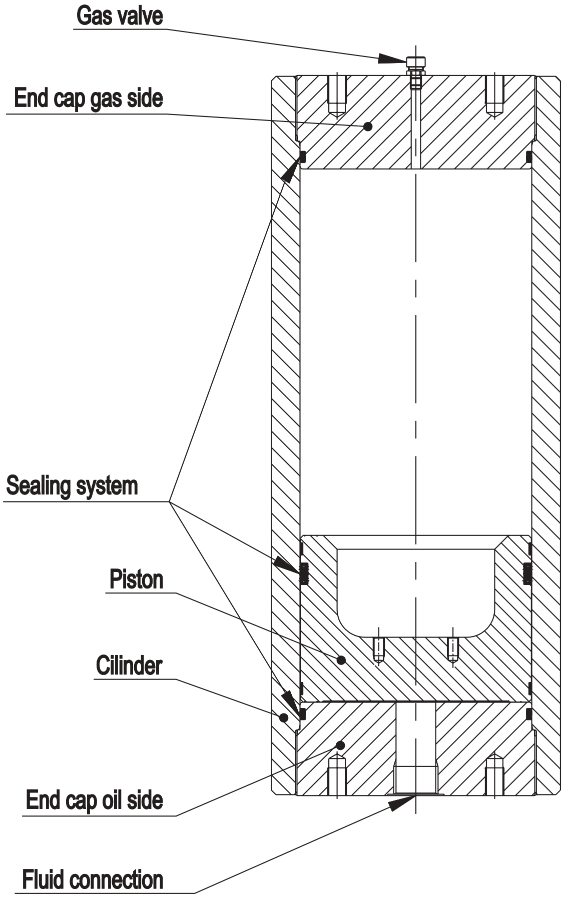


Fig. 1

- All the production of EPE accumulators is integrally tested to PED standards.
The accumulators are tested at PT pressure which is equal to maximum working pressure PS, multiplied by 1,43 which allows to verify the absence of defects, capable of causing flaws and deformities in the cylinder and piston, or gas or oil leak from the seals, threaded sections or valve.
The relieve pressure is in excess of 1 700 bar for model types, designed to work at a maximum pressure of 375 bar.

Advantages of the piston accumulator

2.1 Ratio of compression.

The volume of oil that can be stored by an accumulator also depends on the value of compression (Ratio between as and fluid) that the accumulator can endure. For example if we pre-charge a 35 litre accumulator with a pressure of 30 bar and we then full it with oil at a pressure of 210 bar we will at the end have 30 litres of oil in the accumulator, whilst the gas would result content in a volume of 5 litres. The compression ratio in this case 7:1 and be had available 30 liters of oil to the would discharge side of the accumulator. In the case of a bladder type accumulator, a compression ratio of 7:1 cannot be tolerated (in fact it is recommended not to exceed 4:1) this could cause premature failure of the rubber separation bladder.

2.2 Osmosis

Even if the piston accumulator has a part in motion, it must not be allowed that the gas filters through to the oil, since the pocket type is prone to the phenomenon of osmosis. In applications where the accumulator has to remain on pressure for long periods of time (In case of an emergency) oil can slowly leak through the bladder, up to 10% of the pre-charge gas. This would require periodic maintenance in the form of pre-charge or replacement of the bladder itself.

2.3 Storage

To keep a piston accumulator inoperative in storage will not have a harmful effect and does not implicate time problems, if from time to time it is given a pre-charge, to prevent air ingress which could contain moisture which could cause corrosion to the internal of the cylinder. As with the pocket type accumulator it is not advisable to keep it in storage for long periods of time as this could cause the rubber to deteriorate, even though it is synthetic.

2.4 Volumetric performance

If an accumulator is charged with a certain volume of oil, lets say that its volumetric performance is equal to the unity, if it should be in a position to entirely restore the volume in the system in a successive instant, in other words, to obtain unitary volumetric performance, an accumulator must not have dead spaces. In this condition it is similar (Volumetric performance approximately 0,99-0,995). In the piston accumulator nothing prevents the piston to reach the end of the stroke, against the oil exit orifice, which cannot be said for bladder type accumulators, since a strong charge could cause the membrane to obstruct the oil orifice or deform. It is in fact recommended by the manufacturers not to discharge a pocket type accumulator beyond 9/10 of the volume of accumulable oil.

2.5 Assembly position

There does not exist any limitations, assuming any inclinations between vertical and horizontal positions for the EPE Piston accumulator, always obtaining the same volumetric performance and functionality. The same cannot be said for a bladder type accumulator, which depends on flexible motion that is affected by gravity. This could prevent restitution of all the accumulated oil, which could cause damage to the rubber bladder as a result of uneven distribution of forces.

2.6 Operational Safety

The assurance that a component of a system offers during its operation is essentially based on the functionality of its project and on the simplicity of its execution, signifying to be able effectively a more precise and severe quality control. A piston accumulator consists of a lapped cylinder and a piston with a seal, therefore being the critical elements, only the condition of the one surface, which is mechanically obtained and the characteristics of a sealing ring, it is possible to achieve the most severe quality standards, with which it offers the maximum operational safety. Whilst with the pocket accumulator, apart from the mechanical components, the most critical point remains the rubber diaphragm. This is obtained by press fusion and when the dimensions exceed a certain limit, it becomes very difficult to control the quality in the point of view of composition, resistance, imperfections and thickness. The point of concern is that a breakdown in the pocket immediately puts the accumulator out of service with the consequence of blocking the all hydraulic system. There is in facet no pre-warning of the breakdown: this is always almost certain to cause failure of the pocket and damage the all surface.
It is important to observe, that is the piston accumulator is about to breakdown, it will start will gradual and progressive leaks, followed by a drop in response speed or efficiency of the unit, as well as a drop in pre-charge pressure. With this, there is ample warning to take necessary measures to prevent big consequences.

2.7 Capacity

With the difficulties mentioned above to obtain a perfectly homogenized bladder, without imperfection when the dimensions exceed a certain limit, the bladder accumulators have rather low volumetric values: usually 50 litres is the maximum limit. There is no limit for piston accumulators, manufactured by EPE with a standard limit of 300 litres.

2.8 Monitoring

With a piston accumulator, it is easy to monitor the position of the piston for the entire or part of its stroke, with the result knowing how much oil has accumulated, indicated by on-off signals, amalogical or digital, on the control system. This monitoring system, serves to utilize the maximum stroke with the result of obtaining maximum quantity of fluid accumulated, to action the start and stop of the pump, to indicate anomalies and to visualize the quantity of fluid available.

2.9 Maintenance

The lifespan of a piston accumulator is conditioned according to the condition of the seal, which is necessary to replace only once the efficiency drops, to regain an efficient component at a modest cost. This cannot be said for a bladder type, not only for the high cost of the replacement, also the difficulty in replacing and the need to remove the accumulator from the installation to carry out maintenance.

3.1 Auxiliary Pressure Source

In a system that operates with a certain amount of intermittence, the pump is required to intervene for short intervals with significant volume and pressure values. The use of an accumulator as a means of auxiliary feed, reasonably reduces the size of the required pump, in as much as it is solely used to charge the accumulator during stopped periods of the system, whist it is the accumulator that provides the higher capacity of oil required by the system during the functional period. In this type of application, it can also happen that the system requires a quicker response, than an effective availability of oil pressure must be available when required. In similar circumstances, the time lapse between the start up of the pump (Simultaneous to the requirement of pressure) and the instant that the system itself reaches the required conditions.

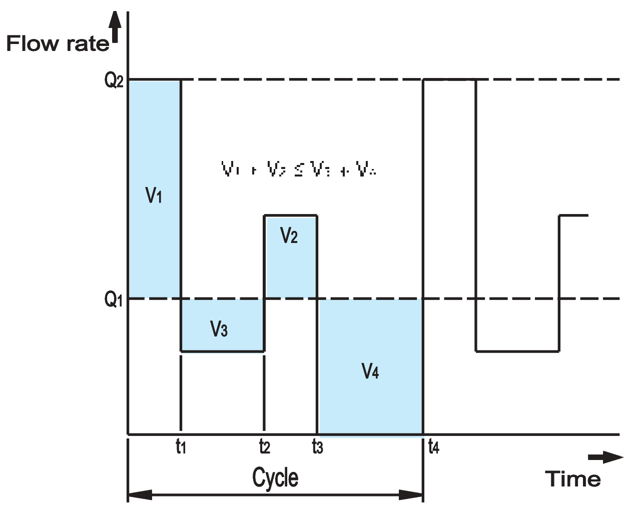


Fig. 2

3.2 Pressure drop Compensator

In a closed system, where it is absolutely necessary to maintain a determined pressure value for an indefinite period of time, independent from any fluid feed to any other utility, the presence of an accumulator guarantees the required results, eliminating any fluctuation in pressure.

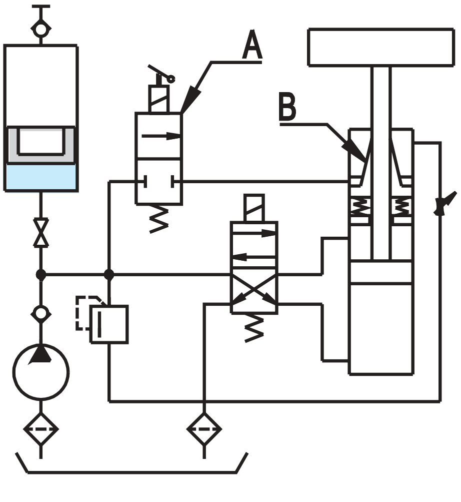


Fig. 3

3.3 Leakage Compensator

During the in operational periods of the pump, the accumulator replenishes part of the oil in the system, compensating for any leakages. This greatly reduces the frequency of interventions to the pump, which is only required to re-charge the accumulator in the event that the pressure drops below the minimum required value.

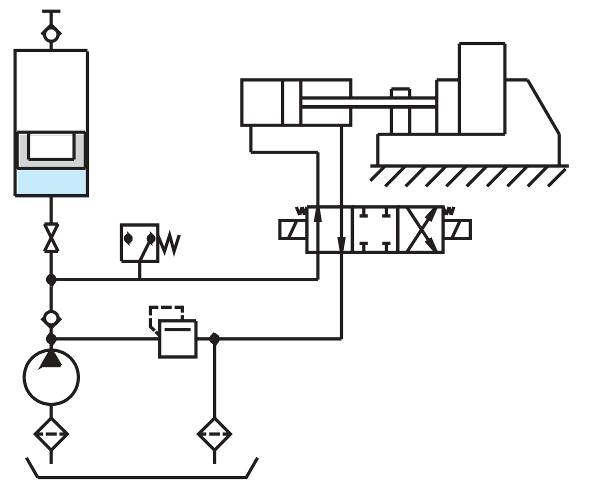


Fig. 4

3.4 Circuits with two pressure values

This is typical case in presses used for rubber and plastic where there is a need for increased speed and moderate pressure during the first phase of the stroke, and a slow motion but with high pressure in the final stage of the stroke. Whilst the arm of the press is activated by the high pressure pump, the same motor also activates the low pressure pump, which re-charges the accumulator. The discharge of this last motion supplies oil for the faster movement at a lower pressure, without any assistance from the pump. This decreases the size of the installation.

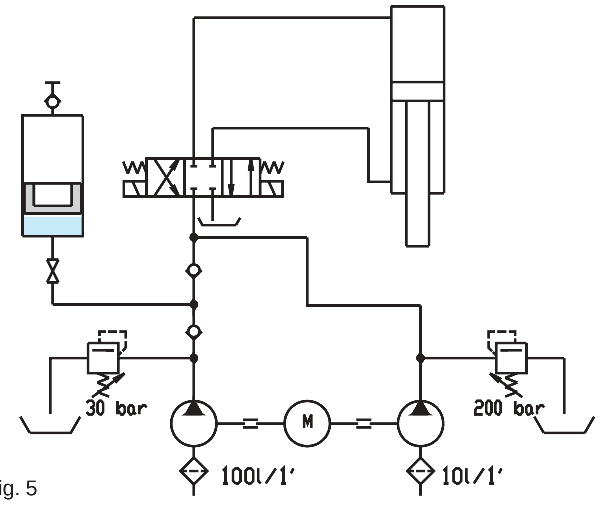


Fig. 5

3.5 Compensation Elements Pressure – Volume

The presence of an accumulator tends to eliminate any danger derived from uneventful increase in pressure in the system, be it through thermal effect, as a consequence of piston movement or any other possible cause. In the case of an hydraulic control system of a roll mill for example, the instant that the ingot is fed into the rolls, a super-pressure in the hydraulic system is created. This has to be absorbed by a battery of accumulators if it is to avoid any variation in the force of the cylinder or any other harmful consequence, be it to the system or the product.

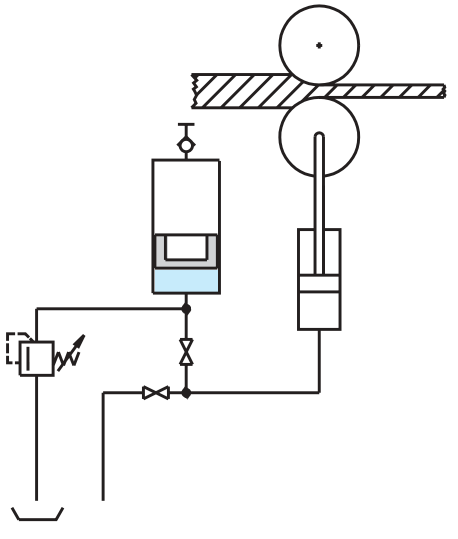


Fig. 6

3.6 Emergency Source

A sudden breakdown in the system could incapacitate the hydraulic circuit to any intervention, as a result of a pressure drop. Only using one or more accumulators, or even better, a battery (accumulators + additional bottles could at least guarantee one emergency operation) consenting for example the intervention of protection and security devices. This is very important in the case of the control of the regulation rods in nuclear reactors or the directional system or braking system in heavy vehicles. In these cases the dimensioning of the accumulator or battery, should be made by valuating the volume of liquid necessary in relation to the number of emergency manoeuvres required.

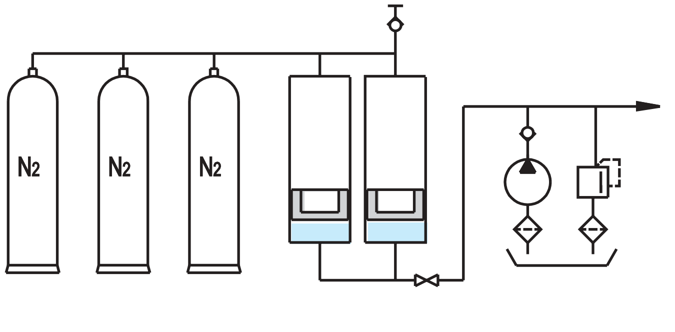


Fig. 7

3.7 Separator of two different fluids

This is the case where it would be required to transfer the pressure from one fluid to another absolutely avoiding direct contact of the two fluids.

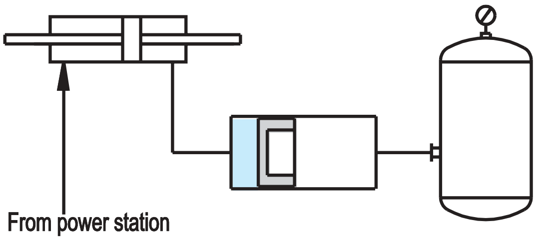


Fig. 8

3.8 Hydraulic line shock damper

Each time a liquid mass has to vary its velocity an energy equal to the variation of the quantity of movement of the fluid: Can only be eliminated, without consequence, by absorbing it with hydraulic accumulators. An important application is used on pipe lines used for refuelling aircraft at major airports or on piping systems at refineries.

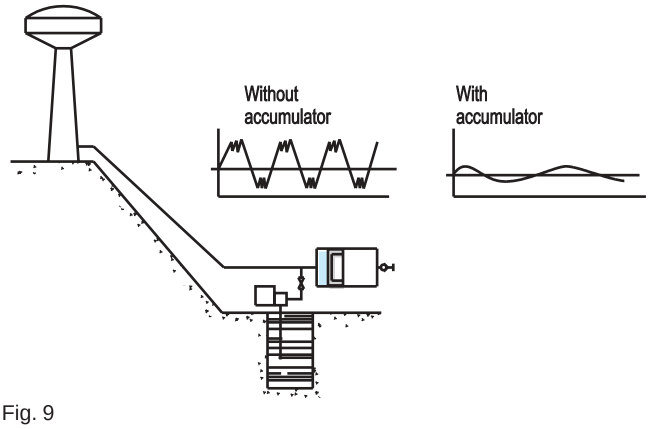


Fig. 9

3.9 Pulsation Attenuator and shock absorber

This is a typical application in reciprocating pumps to regulate the stream of liquid in the system. In fact, piston, diaphragm, pneumatic and dosage pumps, produce a pulsating pressure in the hydraulic circuit, which in the long term, can effect the good operation and longevity of the components. The installation of a piston accumulator on the suction line and in close proximity to the pump, will reduce ox illations to within acceptable values.

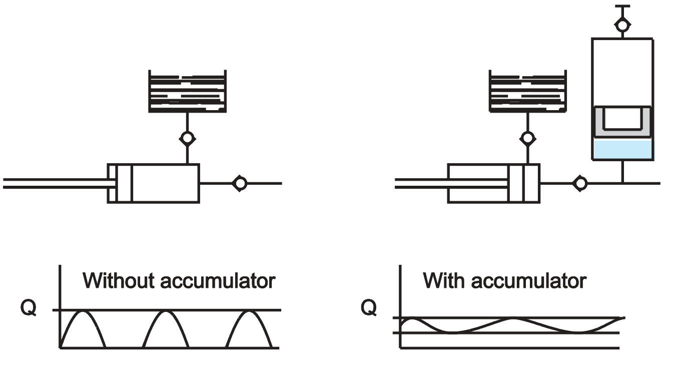


Fig. 10

4 Accumulator Sizing

4.1 Project Data

When sizing a piston accumulator, independently from the application, it is necessary to precisely define the following operational parameters.

- Minimum working pressure P_1
  In the minimum pressure at which the system will still function.

- Maximum working pressure P_2
  To the maximum pressure at which the system will function. The value of P_2 must always be less than or equal to the maximum working pressure of the accumulator.

- Volume ΔV

Is the volume accumulate or restored

$\Delta V = V_1 - V_2$

where

V_1 (Volume of gas at P_1)

V_2 (Volume of gas at P_2)

- Minimum temperature of gas T_1
  Is the minimum working temperature the gas.

- Maximum temperature of gas T_2
  Is the maximum temperature the gas.

- Mode and /or field of implementation **ADIABATIC** or **ISOTHERMIC** transformation

The compression and decompression of nitrogen contained in the accumulator is regulated by the prefect gas laws. If the compression or the decompression is slow (in excess of 3 minutes) such to allow the gas to maintain the temperature close to constant, you will have **ISOTHERMIC** transformation (Pressure stabilizer, forces balancer, volume compensator, feed in the lubrication circuits) in as much as the change of gas volume follows the law of Bayle Mariotte.

$$V_1 \times P_1 = V_2 \times P_2$$

In other cases (energy reserve, pulsation compensator, water hammer absorbers etc.) the heat exchange with the ambient is negligible given the speed with which it operates. You therefore have contemporary pressure and temperature variations of the gas, with which you have **ADIABATIC** transformation, governed by the law:

$$V_1^n \times P_1 = V_2^n \times P_2$$

Where the coefficient *n* takes on values from 1 to 1.4 during the process of compression or decompression (See fig. 11 and fig. 13).

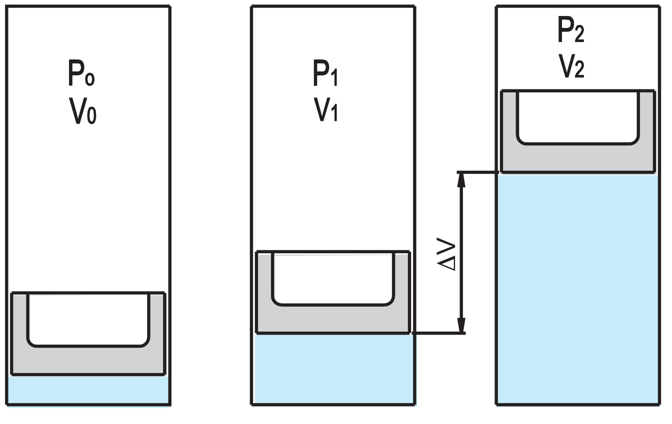


Fig. 11

4.2 Pre-charge pressure Po

The definition of the pre-charge pressure of the accumulator has a fundamental importance in order to obtain maximum efficiency in conditions that do not prejudice the longevity of its components. The maximum accumulate or replenishment of liquid we have in theory, with a pre-charge Po equal to the minimum pressure of exertion P_1. In practice the pre-charge pressure (at the maximum exertion pressure T_2) should be at least less than 3 ÷ 5 bar of the minimum pressure of exertion, to avoid that the piston strike, the oil side flange and damage the components during replenishment of fluid.
It is advisable that the minimum pre-charge pressure (At the minimum exertion pressure T_1) be in excess of friction force and also the weight of the piston itself in a case of horizontal installation or the fluid side in the upright position.
For specific requirements consult our Technical Service Dept. For particular applications, and in the following cases, the recommended pre-charge values are:

$$\mathbf{P_o = 0{,}95 \div 0{,}97\ P_1}$$

The value of $\mathbf{P_o}$ is referred to the **maximum working temperature of the gas, foreseen by the <u>user.</u>**

The pre-charge and the control are usually affected at a different temperature that the maximum working temperature $\mathbf{T_2}$, in which the pre-charge pressure P_o at a pre-charge or control **Tc** becomes:

$$\textbf{Po pre-charge/control} = P_o \times \frac{293 + TC\ (°C)}{273 + 12\ (°C)}$$

Example for a pre-charge effectuated at 20° C:

$$P_o \text{ at } 20°C = P_o \times \frac{293}{273 + T_2\ (°C)}$$

N.B. *The pre-charge pressure of EPE accumulators supplied directly from the factory, are referred to a temperature of 20° C.*

Pulsation compensator and shock absorber:

$\mathbf{P_o = 0{,}6 \div 0{,}75\ Pm}$ or $\mathbf{P_o = 0{,}8\ P_1}$

Where:

Pm = medium working pressure

Hydraulic line shock damper:

$\mathbf{P_o = 0{,}6 \div 0{,}9\ Pm}$

Where:

Pm = medium working pressure of free flow.

4.3 Calculation principles

Compression and expansion of gas inside the accumulator takes place according to the Boyle-Mariotte law regarding the status change in the perfect gases:

$$P_o \cdot V_o^n = P_1 \cdot V_1^n = P_2 \cdot V_2^n$$

The PV diagram Fig. 12 shows the "pressure-volume" relationship inside the accumulator.

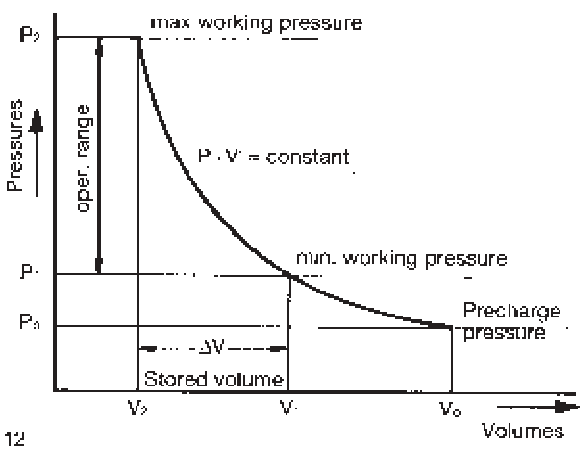


fig. 12

where:

V_o = Nitrogen pre-charge volume at pressure P_o (litres). It is the maximum volume of gas which can be stored in the accumulator.

V_1 = Nitrogen volume at pressure P_1 (litres).

V_2 = Nitrogen volume at pressure P_2 (litres).

ΔV = Volume of discharged or stored liquid (litres).

P_o = Precharge pressure (bar).

P_1 = Minimum operating pressure (bar).

P_2 = Maximum operating pressure (bar).

n = Polytropic exponent.

The curve of volume variation as a function of pressure is dependant on the exponent **n**, which for nitrogen is contained between the limit values:

n = 1 In case compression or expansion of nitrogen takes place so slowly that a complete interchange of heat is allowed between gas and enviroment, that is at constant temperature, **the condition is isothermal.**

n = 1,4 When operation is so quick that no interchange of heat can take place, **the condition is adiabatic.**

In fact, these are theoretical and not practical conditions.
It is however possible to state, with reasonable accuracy, that when an accumulator is used as a volume compensator, leakage compensator, the condition is isothermal. In the remaining applications, such as energy accumulator, pulsation damper, emergency power source, dynamic pressure compensator, water hammer absorber, shock absorber, hydraulic spring, etc., it is possible to state, with reasonable accuracy, that the condition is adiabatic.

When is required a more accurate calculation, is possible to use intermediate values of **n** as function of **t**, that is of expansion or compression time, according to diagram (fig. 13):

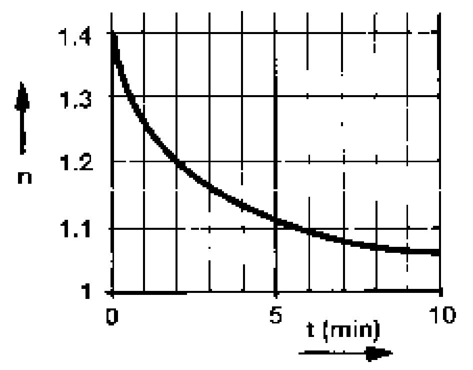


fig. 13

Note: *In all calculations, pressures are expressed as* ***absolute bar (pressure of a fluid or a gas refer to the void)*** *and* ***Temperature as Kelvin degrees (°K=273 + °C).***

4.4 Volume calculation (isothermal condition)

When **n = 1**, the Boyle-Mariotte law becomes

$$P_o \cdot V_o = P_1 \cdot V_1 = P_2 \cdot V_2$$

so that.

$$V_1 = V_o \cdot \frac{P_o}{P_1} \quad \text{and} \quad V_2 = V_o \cdot \frac{P_o}{P_2}$$

The difference between volume V_1 (at minimum operating pressure) and V_2 (at maximum operating pressure) gives the amount of stored liquid (See Section 1.1):

$$\Delta V = V_1 - V_2 = V_o \frac{P_o}{P_1} - V_o \frac{P_o}{P_2}$$

so that;

$$\Delta V = V_o \left(\frac{P_o}{P_1} - \frac{P_o}{P_2} \right)$$

Accumulator volume V_o will be:

$$V_o = \frac{\Delta V}{\left(\frac{P_o}{P_1} \right) - \left(\frac{P_o}{P_2} \right)}$$

which could be also written:

$$V_o = \frac{\Delta V}{P_o \left(\frac{1}{P_1} - \frac{1}{P_2} \right)}$$

which shows that accumulator volume increases when ΔV is increasing, when P_o is decreasing and when the difference between the two operation pressures P_1 and P_2 is decreasing.
The values of ΔV and V_o could be deduced more quickly from the diagrams on pages 12 and 13.

4.4.1 Volume compensator (isothermal)

A typical example of calculation in the isothermal condition is when the accumulator is used as a volume compensator.

Assume a tube with ØI.D.=77,7 mm, 120 m long and inside which some oil is flowing at a pressure of 30 bar and a temperature of T_1 = 10°C and T_2 = 45°C.
Permissible change of pressure ± 8%.

The volume variaton will be:

$$\Delta V = V_T\,(T_2 - T_1)\,(\beta - 3\alpha)$$
$$= 596\,(45 - 10)\,(0.00095 - 3 \cdot 0.000012) = 18{,}2 \text{ lt.}$$

where:

V_T = piping volume (litres).

T_2 = max. temperature (°C).

T_1 = min. temperature (°C).

β = cubic expansion coefficient of fluid $(\frac{1}{°C})$.

α = linear expansion coefficient of piping $(\frac{1}{°C})$.

P_1 = min. permissible operating pressure (bar).

P_2 = max. permissible operating pressure (bar).

where:

P_1 = 8% of 30 = 27.6 bar 28.6 (absolute pressure)
P_2 = 8% of 30 = 32.4 bar 33.4 (absolute pressure)
P_o = 0.95 · 27.6 = 26.2 bar 27.2 (absolute pressure)

and necessary volume will be:

$$V_o = \frac{\Delta V}{\frac{P_o}{P_1} - \frac{P_o}{P_2}} = \frac{18.2}{\frac{27}{28.6} - \frac{27}{33.4}} = 132.8 \text{ lt.}$$

Problem solution requires the use of an accumulator station with 3 accumulators type **AP50P250**...

or: 1 accumulator and 2 additional bottles 50 litres.
2 accumulators from 80 litres
1 accumalator from 150 litres

4.4.2 Leakage compensator (isothermal)

a) Assume a molding press working at 200 bar which has to be kept closed during the curing time and at constant pressure. Min. permissible pressure 198 bar.
After the mold has been closed, the pump is stopped.
The oil leakages are in the order of 2 cm³/minute.
Curing time is 60 minutes.

$\Delta V = Q_l \cdot t$ = 0.002 x 60 = 0.12 lt.

P_1 = 198 bar 199 (absolute bar)

P_2 = 200 bar 201 (absolute bar)

P_o = 0.95 · 198 = 188 bar 189 (absolute bar)

$$V_o = \frac{\Delta V}{\frac{P_o}{P_1} - \frac{P_o}{P_2}} = \frac{0.12}{\frac{189}{199} - \frac{189}{201}} = 12.8 \text{ litres}$$

The capacity of the standard accumulator closest to the calculated value is **15 litres.** So the chosen accumulator is **AP15P375...**

b) If it is required to know when the pump must operate again to reload an accumulator of 15 litres to maintain the condition stated on a), we will have:

$$t = \frac{\Delta V}{Q_l}$$

$$\Delta V = V_o \left[\frac{P_o}{P_1} - \frac{P_o}{P_2} \right]$$

V_o = 16.1 litres of nitrogen for accumulator AP15P375 (see section 6)

$$\Delta V = 16.1 \left[\frac{189}{199} - \frac{189}{201} \right] = 0.16 \text{ l}$$

where:

$$t = \frac{0.16}{0.002} = 80 \text{ min.}$$

4.5 Volume calculation (adiabatic condition)

Starting from the basic formula:

$$P_o \cdot V_o^n = P_1 \cdot V_1^n = P_2 \cdot V_2^n$$

and following what is shown for isothermical calculation, we have:

$$\Delta V = V_o \left[\left(\frac{P_o}{P_1}\right)^{\frac{1}{n}} - \left(\frac{P_o}{P_2}\right)^{\frac{1}{n}} \right] \quad \text{where} \quad \frac{1}{n} = 0.7143$$

$$V_o = \frac{\Delta V}{\left(\frac{P_o}{P_1}\right)^{\frac{1}{n}} - \left(\frac{P_o}{P_2}\right)^{\frac{1}{n}}}$$

Formulas are valid when operation is taking place in adiabatic conditions both in the expansion as well as the compression phases.

Bear in mind however that accumulator yield, and therefore the accumulator calculation, is influenced by both operating temperature and pressure (see section 4.6 and 4.7).

4.6 Temperature influence

It should be anticipated that the operating temperature will change considerably during the cycle and this variation should be taken into account when the volume is calculated.

If an accumulator is sized to a maximum temperature, then the precharge pressure will be referenced to that temperature. When the temperature drops there will be a comparable reduction of the precharge pressure according to the **Gay Lussac law** on the relationship between pressures and volumes, as a result, you will get a **lower accumulator capacity.**

Therefore it will be necessary to have a higher V_o to accumulate or to yield the same amount of liquid ΔV (see section 4.4).

The relationship between pressures and volumes is:

$$V_{oT} = V_o \frac{T_2}{T_1}$$

where:

T_2 = (°C)+273 = max. working temperature (°K).

T_1 = (°C)+273 = min. working temperature (°K).

V_o = volume calculated neglecting thermal variation (litres)

V_{oT} = increased volume for thermal variation (litres)

Example:
Assume the accumulator volume has to be calculated with the following data:

Stored volume ΔV = 1.7 Lt. in 2 s

Min. pressure P_1 = 50 bar 51 absolute bar

Max. pressure P_2 = 115 bar 116 absolute bar

Operating temperature = +25°C ÷ +70°C

The precharge pressure referred to maximal temperature is:

$P_o = 0.95\, P_1$ = 47 bar 48 absolute bar

Volume, calculated in adiabatic conditions, will be:

$$V_o = \frac{\Delta V}{\left(\frac{P_o}{P_1}\right)^{\frac{1}{n}} - \left(\frac{P_o}{P_2}\right)^{\frac{1}{n}}} = \frac{1.7}{\left(\frac{48}{51}\right)^{1/1.4} - \left(\frac{48}{116}\right)^{1/1.4}} = 3.99 \text{ litres}$$

Keeping in mind the temperature, we have:

$$V_{oT} = V_o \frac{T_2}{T_1} = 3.99 \frac{343}{298} = 4.59 \text{ litres}$$

The precharge pressure at 20°C will be:

$$P_{o20°C} = 48 \times \frac{293}{343} = 41 \text{ abs. bar} = 40 \text{ relative bar}$$

The accumulator type is **AP5P375...**

4.7 Correction coefficent for high pressure

The formulas refer to ideal gases, but industrial nitrogen used in accumulators does not behave according to ideal gas laws when pressures increase.
It is convenient to keep in mind this characteristic for pressure P2 > 200 bar, both for adiabatic as well as for isothermal conditions.

Isothermal correction coefficent C_i

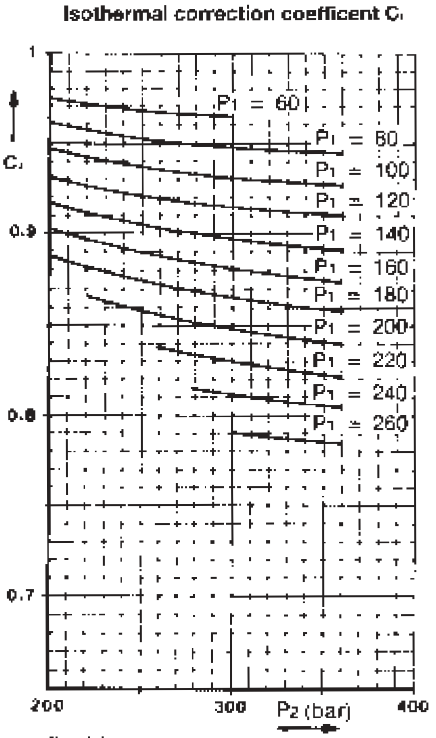


fig. 14

Adiabatic correction coefficient C_a

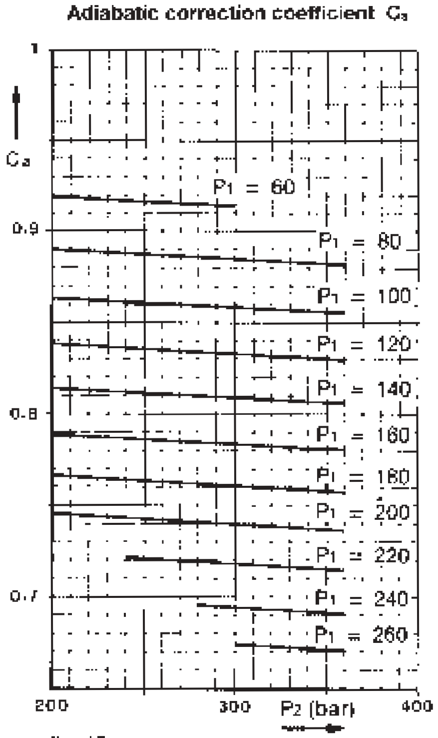


fig. 15

Value of V_o becomes:

$$V_{or} = \frac{V_o}{C_i} \text{ (isothermal)}$$

$$V_{or} = \frac{V_o}{C_a} \text{ (adiabatic)}$$

Yielded volume ΔV becomes:

$$\Delta V_r = \Delta V \cdot C_i \text{ (isothermal)}$$

$$\Delta V_r = \Delta V \cdot C_a \text{ (adiabatic)}$$

where:

V_{or} = real volume of accumulator to be used for operating pressures P_1 and P_2.

ΔV_r = real yield obtained from accumulator for the same pressures.

C_i, C_a = Coefficients to be deduced from diagrams of Figures 14 and 15.

4.8 Emergency energy reserve

Typical occasion when storage is slow (isothermal) and discharge is quick (adiabatic).

Volume will be given by:

$$V_0 = \frac{\Delta V}{\left(\frac{P_0}{P_2}\right)^{\frac{1}{n}} \cdot \left[\left(\frac{P_2}{P_1}\right)^{\frac{1}{n}} - 1\right]}$$

and stored volume by:

$$\Delta V = V_0 \left(\frac{P_0}{P_2}\right)^{\frac{1}{n}} \cdot \left[\left(\frac{P_2}{P_1}\right)^{\frac{1}{n}} - 1\right]$$

where:

n = 1.4 adiabatic coefficient (quick discharge phase)

n = 1 ÷ 1.4 polytropic coefficient (slow storage phase)

Value is a function of time and it will be deduced from the diagram in Fig. 13.

In the majority of cases it is possible to suppose $n_c = 1$ so that calculation is simplified and result is not affected:

$$V_0 = \frac{\Delta V \frac{P_2}{P_0}}{\left(\frac{P_2}{P_1}\right)^{0.7143} - 1} \quad ; \quad \Delta V = V_0 P_0 \frac{\left(\frac{P_2}{P_0}\right)^{0.7143} - 1}{P_2}$$

Example:

An accumulator must discharge 4.6 litres of oil in 3 seconds with a change of pressure from P_2 = 280 bar to P_1 = 208 bar.
The loading time is 4 minutes. Define the capacity keeping in mind that ambient temperature will change from 20°C to 50°C.

$$V_0 = \frac{\Delta V}{\left(\frac{P_0}{P_2}\right)^{\frac{1}{n}} \cdot \left[\left(\frac{P_2}{P_1}\right)^{\frac{1}{n}} - 1\right]}$$

$$= \frac{4.6}{\left(\frac{199}{281}\right)^{0.909} \cdot \left[\left(\frac{281}{209}\right)^{0.7143} - 1\right]} = 27.5 \text{ litres}$$

P_1 = 209 abs. bar — n_c = 1.1 (from Figure 13)

P_2 = 281 abs. bar — T_1 = (273 + 20) = 293 °K

P_0 = 0.95x208 = 198 ≈ 199 bar abs. — T_2 = (273 + 50) = 323 °K

Considering the correction coefficient for high pressure and the temperature change, we have:

$$V_{CT} = \frac{V_0}{C_m} \times \frac{T_2}{T_1} = \frac{27.5}{0.777} \times \frac{323}{293} = 39 \text{ lt.}$$

where:

C_a = 0.72

C_i = 0.834

$$C_m = \frac{C_a + C_i}{2} = 0.777$$

The precharge pressure at 20°C will be:

$$P_{0\,(20°C)} = 199 \times \frac{293}{323} = 180.5 \text{ bar} = 179.5 \text{ rel. bar}$$

The accumulator type is **AP40P375...**

4.9 Pulsation compensator Q

A typical calculation in adiabatic conditions due to high speed storage and discharge.
The liquid amount ΔV to be considered in the calculation is a function of type and capacity of pump:

$$\Delta V = K \cdot q$$

Volume becomes:

$$V_0 = \frac{K \cdot q}{\left(\frac{P_0}{P_1}\right)^{0.7143} - \left(\frac{P_0}{P_2}\right)^{0.7143}}$$

where:

q = pump displacement (litres)

= A x C (piston surface x stroke)

$= \frac{Q}{n} = \frac{\text{flow rate (l/min)}}{\text{strokes/min.}}$

P = average working pressure (bar)

P_1 = P-X (bar)

P_2 = P+X (bar)

$X = \frac{\alpha \cdot P}{100}$ (bar) deviation from average pressure

α = remaining pulsation ± (%)

K = coefficient taking into account the number of piston and if pump is single or double acting.

Pump type	K
1 piston, single acting	0.69
1 piston, double acting	0.29
2 pistons, single acting	0.29
2 pistons, double acting	0.17
3 pistons, single acting	0.12
3 pistons, double acting	0.07
4 pistons, single acting	0.13
4 pistons, double acting	0.07
5 pistons, single acting	0.07
5 pistons, double acting	0.023
6 pistons, double acting	0.07
7 pistons, double acting	0.023

Example:
Assume a 3-piston pump, single acting, with a flow rate Q = 8 m³/h and operating pressure of 20 bar. Calculate the volume necessary to limit the remaining pulsation to α = ± 0,25%. Pump R.P.M. 1480 Working temperature 40°C.

P = 200 bar

$$q = \frac{8000}{60 \times 1480 \times 3} = 0.03 \text{ lt.}$$

P_1 = (200 − 0.5) = 199.5 bar

P_2 = (200 + 0.5) = 200.5 bar

K = 0.12

P_0 = (0.7 · 200) = 140 bar

$$X = \frac{0.25 \times 200}{100} = 0.5 \text{ bar}$$

$$V_0 = \frac{0.12 \times 0.03}{\left(\frac{141}{200.5}\right)^{0.7143} - \left(\frac{141}{201.5}\right)^{0.7143}} = 1.28 \text{ lt.}$$

$$P_{0\,(20°C)} = 141 \times \frac{293}{313} = 132 \text{ abs. bar} = 131 \text{ bar rel.}$$

The most suitable accumulators is the low pressure type: **AP1,5P375...**

4.10 Hydraulic line shock damper

A rapid increase in pressure caused by a high acceleration or deceleration in flow is commonly known as water hammer.
The overpressure, **ΔP max**, that takes place in piping when a valve is closed is influenced by the lenght of the piping, the flow rate, the density of the liquid and the valve shut down time.
This is given by:

$$\Delta P \text{ max (bar)} = \frac{2\,\gamma\,L\,v}{t \times 10^5}$$

The volume of the accumulator required to reduce shock pressure within predetermined limits AP, is obtained with:

$$V_0 = \frac{\dfrac{Q}{7.2}\left(\dfrac{2\,\gamma\,L\,v}{\Delta P_0 \times 10^5} - t\right)}{\left(\dfrac{P_0}{P_1}\right)^{0.7143} - \left(\dfrac{P_0}{P_2}\right)^{0.7143}}$$

where:

- V_0 = accumulator gas capacity (litres)
- Q = flow rate in the piping (m^3/h)
- L = total lenght of piping (m)
- γ = specific gravity of liquid (kg/m^3)
- $V = \frac{Q}{S} \times \frac{10^6}{3.6}$ = flow velocity (m/s)
- $S = \frac{\pi d^2}{4}$ = internal pipe section (mm^2)
- d = internal pipe diameter (mm^2)
- ΔP = allowable overpressure (bar)
- P_1 = operating pressure by free flow (absolute bar)
- $P_2 = P_1 + \Delta P$ = max allowable pressure (absolute bar)
- t = deceleration time (s) (valve shut down, etc.)

Example:

Assume a water pipe (γ = 1000 Kg/m³) with internal diameter d = 80 mm, lenght L = 450 m, flow rate Q = 17 m³/h, operating pressure P_1 = 15 bar, allowable overpressure ΔP = 2 bar, valve closure time t = 0.8 s.

$$\Delta P \text{ max} = \frac{2 \times 1000 \times 450 \times 0.94}{0.8 \cdot 10^5} = 10.57 \text{ bar}$$

The accumulator volume necessary to reduce the ΔP max to 2 bar is:

$$V_0 = \frac{\dfrac{17}{7.2}\left(\dfrac{2 \times 1000 \times 450 \times 0.94}{2 \times 10^5} - 0.8\right)}{\left(\dfrac{5.5}{16}\right)^{0.7143} - \left(\dfrac{5.5}{18}\right)^{0.7143}} = 116.5 \text{ litres}$$

where: $S = \frac{\pi \times 80^2}{4} = 5026.5 \text{ mm}^2$

$$V = \frac{17 \times 10^6}{5026.5 \times 3.6} = 0.94 \text{ m/s}$$

$P_0 = 15 \times 0.9 = 12 = 13$ abs. bar

P_1 = 16 abs. bar

P_2 = 15 + 2 = 17 bar = 18 abs. bar

An accumulator of 120 litres, type **AP120P250....**

4.11 Accumulator + additional gas bottles (transfer)

In all cases where a considerable amount of liquid must be obtained with a small difference between P_1 and P_2, the resultant volume V_0 is large compared to ΔV.
In these cases it could be convenient to get the required nitrogen volume by additional bottles.
Volume calculation is performed, in function of the application, both in isothermal as well as in adiabatic conditions using the formulas given before always taking temperaure into account.
To get the maximum of efficiency it is convenient to fix for precharge quite a high value. In cases of **energy reserve, volume compensator, hydraulic line shock damper,** etc. it is possible to use:

$P_0 = 0.97\ P_1$

Once the required gas volume is calculated, the volume must be allocated between the minimum indispensable portion V_A, which will be contained in the accumulator, and the remaing portion V_B, which represents the volume of additional bottles.

$$V_{0T} = V_{0A} + V_{0B}$$

where:

$$V_{0A} \geq \frac{\Delta V + (V_{0T} - V_0)}{0.75}$$

That means that the sum of volume of required liquid plus volume change due to temperature must be **lower than 3/4 of accumulator capacity.**
The bottle volume is given by the difference

$$V_{0B} = V_{0T} - V_{0A}$$

Example:

Suppose a ΔV = 30 lts. must be obtained in 2 seconds going from a pressure P_2 = 180 bar to P_1 = 160 bar.
Temperatures: θ_1 = 20°C; θ_2 = 45°C

P_0 = 0.97 x 160 = 155 bar

$$V_0 = \frac{\Delta V}{\left(\dfrac{P_0}{P_1}\right)^{0.7143} - \left(\dfrac{P_2}{P_1}\right)^{0.7143}}$$

$$= \frac{30}{\left(\dfrac{156}{161}\right)^{0.7143} - \left(\dfrac{156}{181}\right)^{0.7143}} = 382.4 \text{ lt.}$$

$$V_{0T} = 382.4 \times \frac{318}{293} = 415 \text{ lt.}$$

$$V_{0A} = \frac{30 + (415 - 382.4)}{0.75} = 83.5 \text{ lt.}$$

One accumulators **AP100P250....** are used with total V_0 = 100 lts. plus **6 bottles of 50 lts.** type **BB52P360...**

5.1 Technical Characteristics

Working pressures PS:	**up to 375 bar (others on request)**
Test pressures PT:	**1,43 x PS**
Minimum working temperature:	**-20 °C**
Maximum working temperature:	**+120 °C (150 °C on request)**
Nominal capacity:	**up to 300 litres**
Bores:	**60,100,180,250,350**

5.2 Materials

Accumulator Body: Low carbon steel, EN 10216-3TC type P335N, seamless tube, internally lapped with a maximum roughness of Ra 0,2. Stainless steel AISI 316L on request.
Gas side end cap: Low carbon steel. Stainless steel on request.
Oil side end cap: Low carbon steel. Stainless steel on request.
Piston: Aluminum EN AW-2011
For protective coating consult our Technical Service.
Gasket: Standard P (Perbunan- NBR)
On request V (Viton or other compounds)
Anti-extrusion and guide rings: PTFE
Gas Valve: Low carbon steel with 5/8 UNF fitting and coated in white zinc chromate.

5.3 Tests and Certification

– CE (PED) the accumulators serried AP are designed and homologated to use group 2 fluids (Not hazardous) in conformance with EUROPEAN DIRECTIVE 97/23/EC.
To use group 1 fluids consult our technical service.
The accumulators are pressure vessels and as such are subject to national government regulations in ever country they are installed.
For all the **European Countries,** design, construction and accumulator test must be done according to the Directive of pressure equipment 97/23/EC.
EPE ITALIANA, also in virtue of quality system used EN ISO 9001:2000, works according to **modules H and H1** of total quality guarantee and design control issued by the Notify Body. The above mentioned directive includes the pressure equipment that exceed 0,5 bar. So all the accumulators are involved in this directive even though it provides different procedures of test and certification.
Concerning this, keep in mind that accumulators **up to 1 litre volume included,** even if it is 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** each accumulator after the test is marked with the mark **CE** followed by the number that identify the Notify Body.
For these accumulators, both high pressure and low pressure, the documentation necessary includes the conformity declaration and the manual's operator.

– **ATEX**. EPE ITALIANA can supply the series of accumulators in accordance to directive **ATEX 94/9/CE** (attachment VIII) and to the harmonized norm EN, 13463-1, relative to not electric equipment for uses in environment with atmosphere potentially explosive that are included into the classification **ATEX CE** Ex **12GcT4**.

As well EPE ITALIANA provides other tests and certification for countries in which the CE norm is not accepted:

– **GOST -R** for Russia
– **ML (ex SQL)** for China
– **RINA** for use on ships
– **BS-L Lloyds register** for construction of ships
– **ASME** for the United States, Canada, South Africa etc.

– For other countries in which specific test are not required, the accumulator are however always manufactured according to the European norm, but supplied without CE markings and with a factory test certificate.

Relative documentation is supplied in an envelope attached to the goods.

The strict EPE quality standard and relative test, guarantee a safe operation of these accumulators (the operator must thoroughly familiarize himself with the operational and maintenance manual). The accumulators are pressure vessels and must be tested to the national government regulations in every country they are installed.

5.4 Velocity

The range of EPE accumulators allows to choose 2 diameter bores for the same capacity, the choice, as well as being economic, it is influenced by available installation space and the amount of oil required in operation of the time cycle. In fact, it is necessary to ensure that the piston **velocity does not exceed 2 meters for second**. For higher speeds consult our Technical Service.
Even the fluid flow must be chosen in relation to the acceptable loses, however the **velocity of the fluid is not to exceed 10m for second**. In the case where piston accumulator is connected to additional bottles, the tubing and connectors are to be chosen so as not to allow **the gas flow at a velocity in excess of 30m for second.**

5.5 Filtration

As with al oleodynamic components, even the accumulators, to guarantee a longer working life, it is necessary that the fluid under pressure does not contain contaminants such as metal particles, water etc. As much as the fluid may be pure it must conform to ISO4406 norm and the quality of the filters must conform to appropriate ISO standard. The grade of filtration is dependent on the components of the system and the application. The minimum grade request for hydraulic systems is equivalent to class 19/15, ISO 4406 which is 25 micron with B≥75 ISO 4572.

5.6 Pre-charge

The EPE accumulators with the gas side connectors complete with pre-charge valve (V), if not otherwise requested during ordering, are supplied with a pre-charge of nitrogen at 30 bar.

CAUTION: Use only nitrogen NOT oxygen or compressed air (Danger of explosion)

5.7 Order code

AP | 10 | P | 375 | C | 100 | G | 4 | V | ... _ 8 _ ...

Series
Piston accumulator = **AP**

Capacity
Nominal capacity in litres fluid side:
diam. 60 = **0.1 - 0.25 - 0.8 - 1**
diam. 100 = **1-1.5-2-2.5-3-4-5-6-8-10**
diam. 180 = **6-8-10-15-20-25-30-40-50-60-80**
diam. 250 = **30-40-50-60-80-100-120-150-180**
diam. 350 = **100-120-150-180-200-250-300**
Other capacity on request.

Gasket material
Gasket materials: Perbunan = **P**
Viton = **V**
Perbunan, elastomer in nitryl rubber nitrilica suitable for working temperatures of –20÷+80 °C and petroleum based fluid, mineral oil, lubrificants, diesel oil, etc.
Viton, eleasometer suitable for temperatures –20÷ +120 °C and fluidsat high temperatures or synthetic.
Other compounds and temperature on request.

Maximum working pressure
Maximum working pressure in bar:
diam. 60 = **375**
diam. 100 = **375**
diam. 180 = **250 – 375**
diam. 250 = **250 – 350**
diam. 350 = **220 – 350**
The pressure is limited to **210** bar in cases where connction type L is chosen (flange SAE 3000).
Other pressures on request.

Body and flange materials
Carbon steel whit a coat of rust inhibitor = **C**
Carbon steel chemicallynickel pladed th. 25µ = **N**
Stainless stell AISI 316–L = **X**
Other materials and treatment on request.

Nominal internal diameter
Internal diameter in mm = **60 – 100 – 180 – 250 – 350**

Type of connection side
Without connection = **O**
Female thread ISO 228 = **G (standard)**
Female thread NPT F = **P**
Female thread ISO 228 whit chamfer for or = **A**
Holes for flange SAE 3000, metric screew = **L**
Holes for flange SAE 6000, metric screew = **H**
Holes for flange ANSI, metric screew = **B**
Holes for flange UNI = **U**
Holes for flange for special flange = **F**
Female thread metric = **M**
Female thread SAE = **S**
Other connections on request.

Dimension of connection side
For the type of connection: 0 = **0**

G – P – A – L – H : 1/8" = **1**
1/4" = **2**
3/8 = **3**
1/2" = **4 (*)**
3/4" = **5**
1" = **6 (**)**
1"1/4 = **7**
1"1/2 = **8 (***)**
2" = **9**
2"1/2 = **10**

* (standard for int. diam. 60)
** (standard for int. diam. 100)
*** (standard for int. diam. 180–250–350)

B = To be specify **DIMENSION / RATING**
Es. 1" ANSI300 = **1/300**
U = To be specify the **DN / PV**
Es. DN50 PN16 = **50/16**
F = – **To be specify diameter cental hole, number, dimension and depth of fixing holes, wheel center and reces of or**
M = To be specify the **DIAMETER / PITCH**
Es. M18x1,5 = **18/1,5**
S = To be specify the **DIAMETER in"-PITCH in"**
Es. (SAE6) 9/16–18 = **9/16-18**

Variant and/or accessories
Electric control of position of piston
(last 300 mm gas side = **C.....add n° of magnetic switch.**
Es. n° 2 magnetic switch = **C2**
Electric control of position of piston
(last 700 mm gas side = **D.....add n° of magnetic switch.**
Es. n° 2 magnetic switch = **D2**
Transducer of position potentiometric = **TP**
Transducer of position whit out 0–10 V = **T10**
Transducer of position whit out 4–20 mA = **T20**
Exit roadwhit indicator = **U ....add of n° of micro switch.**
Es. n° 3 micro switch = **U3**
Piston in alluminium anodized = **P1**
Piston in carbon steel = **P2**
Piston in stainless steel = **PX**
Piston iwhit seal low friction = **PB**
Special accumulator by design = **A .....add of n° of design.**

Test and certification
Factory testing = **0**
GOST– R = **1**
ML (ex SQL) = **3**
RINA = **4**
BS–LLOYS'S REGISTERR = **5**
GERMANISCHER LLOYYD = **6**
ASME = **7**
PED (97/23/CE) = **8**
ATEX (94/9/CE) = **9**
Other to be specified = **10**

In the case of more certification to be indicate the request type spacing of /
Es. certification PED + ATEX = 8/9

Dimension of connections gas side
V = **–** (Standard pre–charge valve whit 5/8 UNF tread)
VX = **–**
For the type of connection: □ = **0**

G – P – A – L – H : 1/8" = **1**
1/4" = **2** (standard for diam. int. 60)
3/8" = **3**
1/2" = **4**
3/4" = **5**
1" = **6** (standard for diam. int. 100)
1"1/4 = **7**
1"1/2 = **8** (standard for diam. int. 180–250–350)
2" = **9**
2"1/2 = **10**

B = To be specify **DIMENSION / RATING**
Es. 1" ANSI 300 = **1/300**

U = To be specify the **DN / PN**
Es. DN50 PN16 = **50/16**

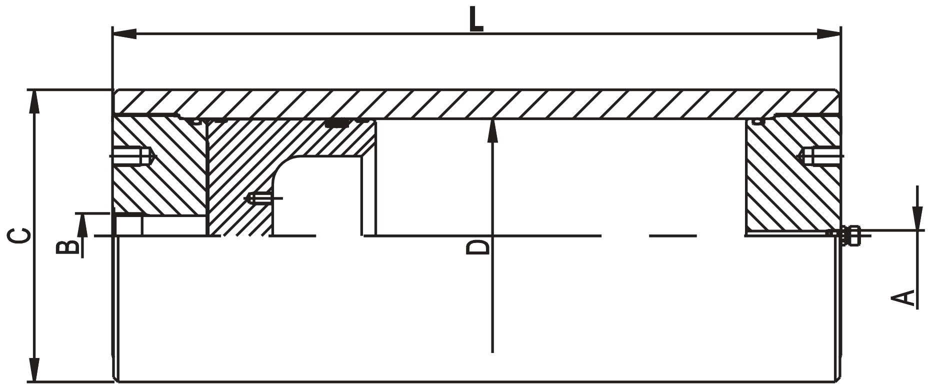
F = – **To be specify diameter cental hole, number, dimension and depth of fixing holes, wheel center and reces of OR**

M = To be specify the **DIAMATER/PITCH**
Es. M18x1,5 = **18/1,5**

S = To be specify the **DIAMETER "inch"/PITCH "inch"**
Es. (SAE6) 9/16–18 = **9/16–18**

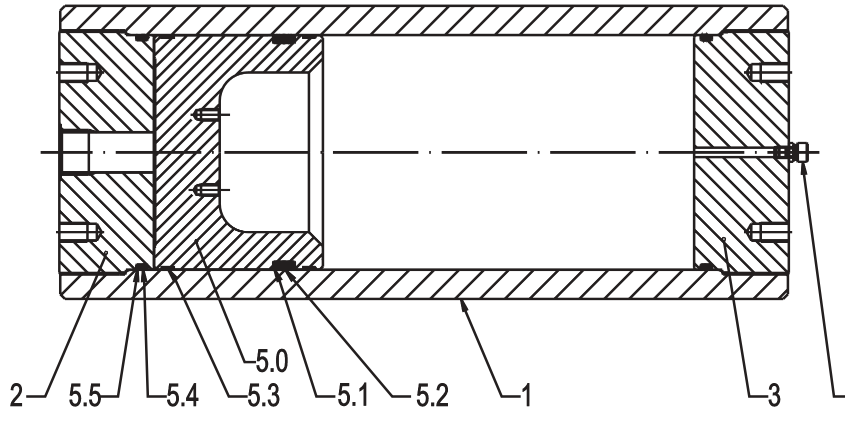
Type of connection gas side
Standard pre–charge valve whit 5/8 UNF tread = **V (standard)**
Standard pre–charge valve whit 5/8 UNF tread in stainless steel = **VX**
Without connection = **O**
Female thread ISO 228 = **G**
Female thread NPT F = **P**
Female thread ISO 2228 whit camfer for OR = **A**
Holes for flange SAE 3000, metric screew = **L**
Holes for flange SAE 6000, metric screew = **H**
Holes for flange ANSI, metric screew = **B**
Holes for flange UNI = **U**
Holes fby design for special flange = **F**
Female thread metric = **M**
Female thread SAE = **S**
Other connections or pre–charge valves on request.

6.1 Dimension



Nominal internal diameter	Maximum pressure bar	Capacity fluid litres	Capacity gas litres	External diameter mm	Lenght mm	Standard connection fluid side	Standard connection gas side
D	-	-	-	C	L	B	A
60	375	0,1	0,12	80	156	1/2" BSP	Pre-carge valve 5/8 UNF
		0.25	0,27		210		
		0,5	0,52		298		
		1	1,02		475		
100	375	1	1,15	130	308	1" BSP	Pre-carge valve 5/8 UNF
		1,5	1,65		372		
		2	2,15		435		
		2.5	2,65		500		
		3	3,15		562		
		4	4,15		690		
		5	5,15		818		
		6	8,15		945		
		8	9,15		1200		
		10	10,15		1455		
180		6	7,1		542	1 1/2" BSP	Pre-carge valve 5/8 UNF
		8	9,1		620		
		10	11,1		698		
		15	16,1		895		
	250	20	21,1	210	1092		
		25	26,1		1288		
	375	30	31,1	220	1485		
		40	41,1		1878		
		50	51,1		2270		
		60	61,1		2665		
		80	80,1		3450		
250		30	32,5		983	1 1/2" BSP	Pre-carge valve 5/8 UNF
		40	42,5		1188		
		50	52,5		1388		
	250	60	62,5	292	1593		
		80	82,5		1998		
	350	100	102,5	312	2408		
		120	122.5		2818		
		150	152,5		3428		
		180	182,5		4038		
350	220	100	105	406	1552	1 1/2" BSP	Pre-carge valve 5/8 UNF
		120	125		1762		
		150	155		2072		
		180	185		2382		
		200	205		2592		
		250	255		3112		
		300	305		3632		
350	350	100	105	419	1592	1 1/2" BSP	Pre-carge valve 5/8 UNF
		120	125		1802		
		150	155		2112		
		180	185		2422		
		200	205		2632		
		250	255		3152		
		300	305		3672		

6.2 Spare parts



6.3 Order code

Pos.	Spare parts	Internal diameter	Order code	Quantity	Component	Type
1		-	Not supplied as spare part		Accomulator shell	
2		-			Cap oil side	
3		-			Cap fluid side	
4		-	2072	1	Gas-fill valve	5/8" UNF
5.1	Seal kit	60	2405	2	Anti-extruder ring	11563
5.2				1	Gasked	11564
5.3				1	Wear ring	11565
5.4				2	"O" Ring	OR 156
5.5				2	Supporting ring	8-227
5.0	Kit piston whit seal		2400	1	Piston	11495
5.1				2	Anti-extruder ring	11563
5.2				1	Gasked	11564
5.3				1	Wear ring	11565
5.1	Seal kit	100	2406	2	Anti-extruder ring	11522
5.2				1	Gasked	11518
5.3				1	Wear ring	11523
5.4				2	"O" Ring	OR 185
5.5				2	Supporting ring	8-341
5.0	Kit piston whit seal		2401	1	Piston	11496
5.1				2	Anti-extruder ring	11522
5.2				1	Gasked	11518
5.3				1	Wear ring	11523
5.1	Seal kit	180	2407	2	Anti-extruder ring	11528
5.2				1	Gasked	11524
5.3				1	Wear ring	11526
5.4				2	"O" Ring	OR 228
5.5				2	Supporting ring	8-439
5.0	Kit piston whit seal		2402	1	Piston	11496
5.1				2	Anti-extruder ring	11528
5.2				1	Gasked	11524
5.3				1	Wear ring	11526
5.1	Seal kit	250	2408	2	Anti-extruder ring	11525
5.2				1	Gasked	11527
5.3				1	Wear ring	11529
5.4				2	"O" Ring	OR 825
5.5				2	Supporting ring	8-448
5.0	Kit piston whit seal		2403	1	Piston	11498
5.1				2	Anti-extruder ring	11525
5.2				1	Gasked	11527
5.3				1	Wear ring	11529
5.1	Seal kit	350	2409	2	Anti-extruder ring	11560
5.2				1	Gasked	11561
5.3				1	Wear ring	11562
5.4				2	"O" Ring	OR 81300
5.5				2	Supporting ring	8-455
5.0	Kit piston whit seal		2404	1	Piston	11499
5.1				2	Anti-extruder ring	11560
5.2				1	Gasked	11561
5.3				1	Wear ring	11562