

### Nomenclature

P0	Nitrogen pressure	Bar
P1	Minimum pressure of fluid	Bar
P2	Maximum pressure of fluid	Bar
V0	Accumulator volume	Litre
ΔV	Volume of accumulated fluid	Litre
T1	Minimum temperature of fluid	°C
T2	Maximum temperature of fluid	°C
Y	Specific nitrogen temperature ratio = 1,4	

## Application and Sizing

### Energy accumulator:

It is improbable that an hydraulic system use all of its capacity without interruptions. An hydropneumatic accumulator can store a certain amount of fluid that normally would be simply discharged in the tank and therefore help the pump when maximum capacity is requested.

It is therefore possible to measure the same system with reduced pump capacity and consequently save installed capacity.

Moreover, fluids tend to heat less, less system noise together with a flattening out of pressure and water hammer absorption variations due to rapid valve operation.

The following formulas are the basis for measuring the exact FOX accumulator either for this application or for all other applications in which its use is requested. In all applications the following isothermal formula is used when charge and discharge times are prolonged at constant temperature (~3 minutes) and the adiabatic formula in the presence of frequent cycles. To get the maximum output of the accumulator the pressure of the nitrogen owes to be 0.9xP1

**Isothermal Conditions** a)  $V_0 = \frac{\Delta V \cdot P_1 \cdot P_2}{P_0 \cdot (P_2 - P_1)}$

b)  $\Delta V = \frac{P_0 \cdot V_0 \cdot (P_2 - P_1)}{P_1 \cdot P_2}$

**Abiatic Conditions** a<sub>1</sub>)  $V_0 = \frac{\Delta V}{\left(\frac{P_0}{P_1}\right)^{\frac{1}{Y}} - \left(\frac{P_0}{P_2}\right)^{\frac{1}{Y}}}$

b<sub>1</sub>)  $\Delta V_0 = V_0 \left[ \left(\frac{P_0}{P_1}\right)^{\frac{1}{Y}} - \left(\frac{P_0}{P_2}\right)^{\frac{1}{Y}} \right]$

Where  $\frac{1}{Y} = 0.7143$

To get the maximum output of the accumulator the pressure of the nitrogen owes to be 0.9xP1

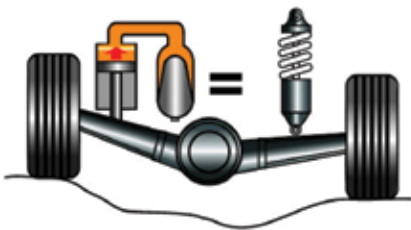
### Temperature Influence:

In order to obtain maximum yield from the accumulator the nitrogen pressure must be: P0 = 0,9 · P1 When a temperature change takes place in the system (T2) it is necessary to regulate the accumulator taking into consideration this variable. Consequently the values obtained from the previous formulas will be varied in the following manner:

c)  $V_{0t} = V_0 \cdot \frac{273 + T_2}{273 + T_1}$  **V<sub>0t</sub>** = Accumulator volume in consideration of temperature variation.

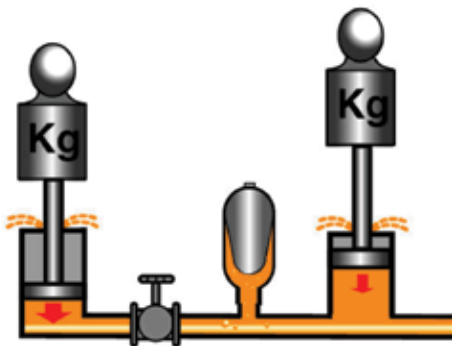
An other factor influenced by temperature is the nitrogen pre-loading phase also subject to pressure variations in function of temperature change. Considering that pre-loading pressure is carried out at an environmental temperature of 20° C, the formula to apply is the following:

d)  $P_0 \text{ a } 20^\circ\text{C} = 0.9 \cdot P_1 \cdot \frac{293}{273 + T_2}$  **P0 a 20° C** = Value of the nitrogen pre-loading pressure at 20° C in consideration of pressure increase when temperature rises to value T2



### Hydraulic Spring Balancing of Forces Hydropneumatic Suspension

In these applications the accumulator volume is obviously in function of the fluid volume to be absorbed and the pressure variation within which a certain stroke is desired from one or more cylinders (formula). It's also necessary to consider indispensable to insert an unidirectional flow regulator inline to permit rapid accumulation and controlled return. As far as the closed circuits are concerned, it is also obligatory to insert a safety valve set at 95% of the maximum accumulator pressure.



### Leakage Compensator

A FOX hydropneumatic accumulator can be used to maintain the pressure in a closed hydraulic circuit compensating the losses due to gasket blow-by and valve leakage. To regulate, it is necessary to quantify the volume of fluid to be stored also in relation to the amount of time under pressure, in addition to establishing minimum and maximum system pressures and applying formula (a) for sizing.

The value of P0= 0.9 · P1

## Application and Sizing

### Thermal Expansion Compensator

In a closed hydraulic circuit subject to temperature variations, a variation of pressure takes place due to fluid expansion.

A FOX hydropneumatic accumulator is able to absorb the expanded quantity of fluid and limit pressure increases within the values desired.

To determine these values it is necessary to calculate the volume of fluid to be absorbed with the following formula:

$\Delta V = V_0 (T_2 - T_1) \alpha \beta$  where  $V_0$  = Volume of tank fluid (lt) and  $\beta$  = coefficient of cubic expansion of fluid.

Applying formula (a), the volume of the accumulator is selected in relation to the desired pressure at maximum temperature.

Consider as well the formulas that take into consideration the measurement of temperature influence (c,d)

### Water Hammer/Shock Absorber

As in the preceding example it is necessary to calculate the volume of fluid that generates water hammer and apply formula (a) for setting a value indicating  $P_2$  as maximum desired pressure.

It is evident that the difficulty consists in quantifying the volume of fluid that generates water hammer subject to innumerable variables such as: tube diameter and length, pump capacity and pressure, valve closure time, temperature, type and viscosity of fluids etc...

Our technical office, due to its vast acquired experience can help to resolve such application problems.

### Pulsation Dampener

It is well known that pumps, in particular plunger pumps, have a more or less fixed capacity determined

by their displacement and revolutions per minute. It is possible to improve pump flow uniformity by installing a FOX hydropneumatic accumulator. For proper selection use the formula: (a1) considering:  $\Delta V = C \times K$  where:

**C** = plunger displacement in litres

**K** = pump type coefficient

Pompa	K
Simplex	0.6
Duplex	0.25
Triplex	0.12
Quintuplex	0.06

As far as the pressure values to be inserted in formula (a1) are concerned, they are a function of desired residual pulsation.

For example, if a pulsation of 5% above average delivery pressure is desired ( $P_m$ ) the values will be  $P_2 = P_m + 5$  and  $P_1 = P_m - 5$ .

The value  $P_0$  relative to the precharge pressure must be:

$P_0 = 0.6 \cdot P_1$  for simplex and duplex pumps

$P_0 = 0.7 \cdot P_1$  for triplex pumps

$P_0 = 0.8 \cdot P_1$  for quintuplex pumps and beyond.

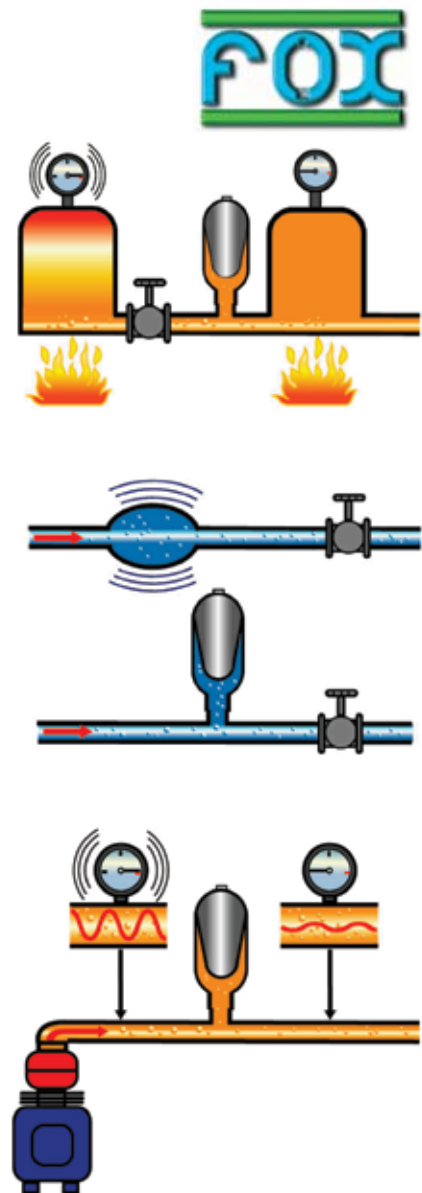
For the precharge phase consider formula (d) which takes into consideration eventual temperature variations during the work phase.

In practical use, an easier way to calculate this volume has been developed experimentally and has been proven to be very useful:

$$V_0 = C \times Z$$

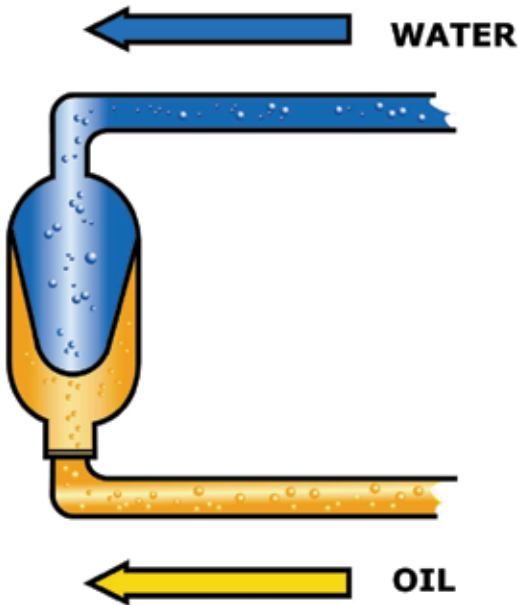
where  $Z$  is the coefficient of the displacement of delivery in one revolution ( $c$ ) of the pump (in litres), to obtain the volume of desired residual pulsation.

For this specific application it should be noted that in addition to different types of elastomers, various alternative body constructions can also be supplied which are not provided in this catalogue, such as the following: dampeners with larger inlets with improved yield according to pressure or accumulators constructed without poppet valve, with direct flow passages or antiextrusion screen and versions with welded, stainless steel bodies for low pressure. Dampeners with inline flow passages, etc.



Pump (S.E.)	Z	Residual pulsation
Simplex	12	± 5%
	30	± 2.5%
	60	± 1.5%
Duplex	5	± 5%
	13	± 2.5%
	25	± 1.5%
Triplex	2	± 5%
	4	± 2.5%
	6	± 1.5%
Quintuplex	1	± 5%
	2	± 2.5%
	3	± 1.5%

Example		
Pump:	Triplex	$V_0 = (190 \times 4) / 270 = 2.8$ Litres $P_0 = 150 \times 0.7 = 105$ bar
Flow:	190 litri/min	If the working temperature increases to 50°C we shall have:
N° cycles:	270	$V_{0t} = 4.2 \times (273+50) / (273+20) = 4.6$ litri
Pressure:	150 bar	$P_0$ nitrogen at 20°C = $105 \times 293 / (273+50) = 94.5$ bar
Residual pulsation:	± 2.5%	94.5 bar represents the value of preload to effect to 20°C to have to 50°C a pressure of exercise equal to 105 bar



## Application, Sizing & Instructions

### Fluid Separator

An hydropneumatic accumulator can be used to transfer pressure on two different fluids that must not come in contact with each other. For this application in addition to requesting elastomers compatible with the fluids utilized it is necessary that the nominal value of the accumulator be 25% greater than the maximum quantity of fluid to be transferred in order to avoid excessive stretching of the elastomers.

Accumulators With Additional Gas Cylinders When in an hydraulic circuit the difference between maximum and minimum pressure is minimal and requires a considerable accumulation of fluid it is possible to connect additional cylinders of nitrogen to the accumulators in order to receive the total requested volume ( $V$ ) reducing the number of installed accumulators and exploiting even more the single capacity of accumulation. For regulation consider formula (a) bearing in mind that in addition to the formulas of temperature influence (c, d) we must also consider the quantity of gas divided in two parts: one in the accumulator and the other in the additional cylinder. In the first case, it is indispensable that at least 25% of nominal accumulator volume remain when maximum value pressure is reached ( $P_2$ ), therefore  $V = 0,75 \cdot V_0$  where  $V_0$  is the accumulator volume not considering the volume of the additional cylinders. The pre-loading nitrogen pressure must be  $P_0 = P_1 \cdot 0,97$ .

### Other Applications

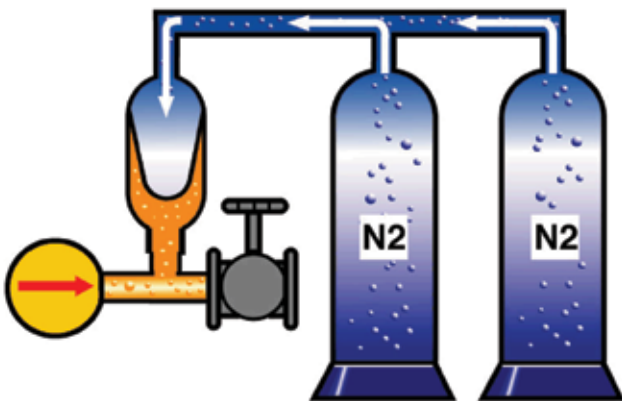
- Protection of pressure control and measuring instruments.
- Noise reduction of system.
- Timer for pressure rise.

### General note for assembly and maintenance

Before effecting assembly check and compare data stamped on body or data plate of FOX accumulator with respective system, in particular maximum permissible pressure and pre-loading pressure. An incorrect pre-loading pressure selection often negatively influences accumulator life time.

### Installation

When the possibility exists, in order to achieve maximum yield, it is preferable to mount the accumulator as close as possible to the operator. The ideal position for the bag accumulators is from the vertical (with the nitrogen valve towards the top) to the horizontal position. Diaphragm accumulators can be mounted in any position. It is advisable to leave accumulator data plate visible as well as 15 cm space around the nitrogen valve permitting easy access for controls and pre-loading regeneration.



## Instructions

### Fastening in Position

For small volumes installed on fixed machinery a standard screw thread attachment is sufficient, for larger volumes fixing brackets or clamps are necessary which protect the accumulator against vibrations or eventual impacts. At any rate it is absolutely prohibited to carry out welding on the bodies of the accumulators.

### Start Up

Before beginning the work cycle make sure that the circuit pressure limiting valve is connected directly to the accumulator. Bleed the air out of the fluid side utilizing the

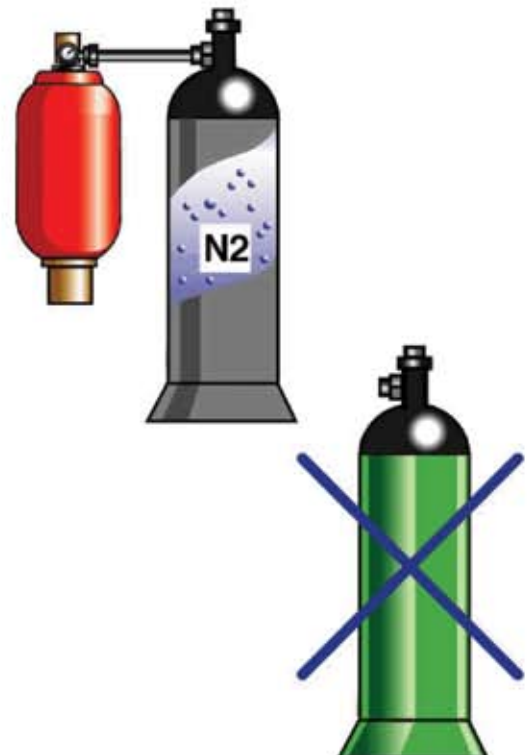
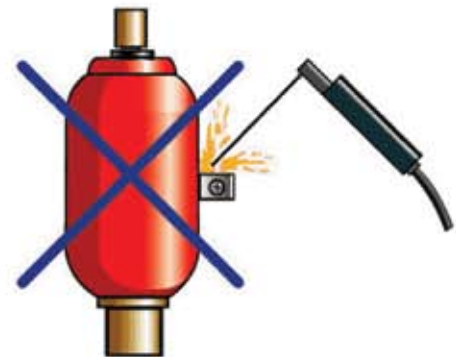
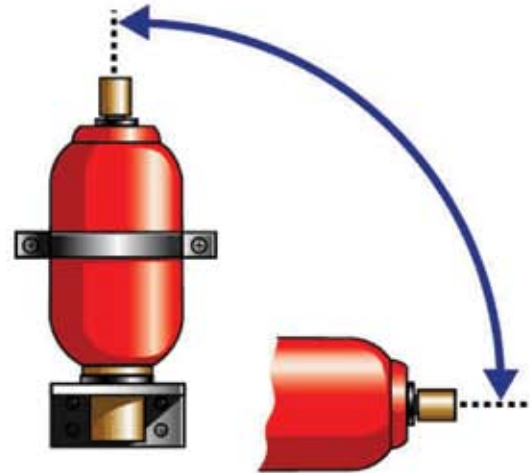
special screws provided on poppet valve type and furnish and fit a retaining valve at pump outlet that protects it from backflow. We also recommend a cut-off and drain valve that permits maintenance during the working phase of the system as well as a unidirectional on line rate of flow regulator in order to regulate accumulator discharge flow.

### Pre-Loading Gas

FOX hydropneumatic accumulators are usually already loaded direct from the factory with the quantity of gas stipulated during the order phase and indicated on the data plate or stamped on accumulator body. This operation takes place at room temperature (~20° C); different working temperatures require different pre-loading procedures (see formula d).

### Control of Gas Pre-Loading

It is advisable to control pre-loading pressure within 10 days after system start up and subsequently every 6 months. Controls can be carried out easily from the fluid side with the accumulator mounted on system. This test method is based on the fact that, during the slow drainage phase of an accumulator full of fluid, the pressure on the accumulator side initially diminishes slowly according to laws regarding the physical properties of gas, but then suddenly drops off when the relative pre-loading gas value is reached. Such a phenomenon can be noticed with the aid of a manometer measuring accumulator fluid pressure directly. It is however also possible to control gas preloading from the gas side with the aid of the pre-loading device (AR), which also permits regeneration or pressure increase through bottled dry nitrogen(N2). It is absolutely prohibited to utilize compressed air, gas cylinders or other types of gas. It is indispensable that the control or preloading pressure variation be carried out in the absence of pressure on the fluid side no matter whatever accumulator is mounted on the system. The space above the nitrogen valve in order to be able to reach the pre-loading equipment must be at least 15 cm.





## Maintenance and Repair

### How to disassembly bladders:

1. Discharge the nitrogen value contained in the bladder using our "AR" charging and gauging assembly.
2. Make sure that the nitrogen pressure is nil and then disassembling all the components of the nitrogen valve.
3. Set the accumulator into a vice, remove the vent (bladder) screw, then unscrew the threaded sleeve which retains the fluid valve, then push the complete valve assembly inside the accumulator and remove the internal seal.
4. Remove, by folding, the rubber-metal seal put inside the accumulator, through the exit of the poppet valve.
5. Unscrew the nut which retains the bladder, remove the identification plate and extract the bladder.

### How to assembly bladders:

6. After having replaced all defective parts and checked that the accumulator body is internally clean repeat all previous operation inversely.  
May attention there is no air inside the bladder by folding it before reintroduce into the accumulator body.
7. For an easy introduction of the bladder inside the accumulator body we suggest the use of a rod having one end threaded M11x1 which can be screwed on to the bladder threaded port. We strongly recommend to fill the accumulator with oil in a quantity of 5% of total volume capacity, this will allow the bladder to get the right position when filled with nitrogen.

We also recommend to fill nitrogen very slowly specially when the bladder is initially expanding.

### How to disassembly diaphragms:

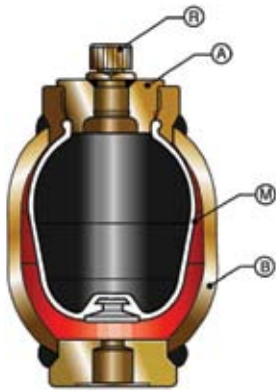
1. Before any repair work, discharge totally the nitrogen inside the accumulator by using our "AR" charging and gauging assembly.
2. After making sure that the internal pressure is 0, remove the gas valve "R" from the accumulator.
3. Firmly fasten the lower part (B) of accumulator in a vice.
4. Unscrew the top cap (A) using a band or chain pipe wrench Dis.3° or an open ended wrench for Dis.1° and 2°.
5. Extract the diaphragms (M) and the seals.

### How to reassembly diaphragms:

6. After careful cleaning, replace any damaged parts. Wet the outer surface of the bag and seals with the operating fluid. Reassemble the cap (or ring nut) and tighten it firmly.
7. Reassemble the nitrogen valve and start filling the gas with the "AR". Slowly introduce nitrogen into the accumulator until it reaches a pressure 5% higher than the value required.  
Disconnect the charging hose from the equipment and wait some minutes for the stabilization of the temperature and the set the pressure by venting off excess gas.

### Note:

Prohibited the use of oxygen or air. We recommend an initial check within the first week and then every 6 months.



Dis. n° 1



Dis. n° 2



Dis. n° 3