Integral Accumulator

hidra[matic]

1. Instructions on Use

As per directive 97/23/EC, article 3, paragraph 3 without CE-marking

1.1 General

- the regulations for hydro accumulators applicable in the place installed are to be observed prior to commissioning and during operation
- the operating organisation is solely responsible for compliance with the existing regulations
- documents supplied are to be stored carefully, they will be required by the assessor during periodic inspections
- commissioning only by trained specialist personnel

1.1.1 Warning

⚠ do not solder or weld to the vessel or work by mechanical means
⚠ risk of explosion on welding or soldering
⚠ risk of bursting and loss of type approval if worked mechanically
⚠ do not charge hydro accumulators with oxygen or air: risk of explosion
⚠ prior to working on hydraulic systems, de-pressurise the system. Serious accidents can be caused in case of incorrect fitting

1.2 Safety devices

Equipping, installation and operation of hydro accumulators require the following safety equipment:

- device to prevent excess pressure (type approved)
- device for de-pressurising
- pressure measurement device
- test pressure gauge connection
- shut-off device

Option:

- electromagnetically operated device for de-pressurising
- safety device against exceeding temperature.

⚠ The safety devices must not perform any regulation function!

1.3 Commissioning

1.3.1 Notes

- **filling pressure**
  - hydro accumulators are in general supplied in a ready to use state. The filling pressure (p_0) is given on the accumulator housing.
  - prior to commissioning the accumulator must be filled to the filling pressure specified by the operator.
- **gas filling**
  - hydro accumulators are only allowed to be filled with nitrogen class 4.0 very pure, N_2 99,99 vol-%.
- **permissible operating temperature**
  - hydro accumulators from Integral Accumulator KG are suitable for operating temperatures from –10 to +80 °C. For different temperatures, please contact us.
- **installation position**
  - any, keep space of 200 mm clear for test and filling device.
- **fastening**
  - the accumulator is to be fastened such that reliable fastening is ensured during vibration in operation or on the fracture of the pipework or gas pipe.
    Integral Accumulator KG offers suitable mounting clips.
- **inspection prior to commissioning**
  - the inspection prior to commissioning and periodic inspections are to be performed in accordance with the EU directives (⟶ 5. European Directive on Pressure Equip. 97/23/EC (abridged information), from page 10.15).

1.3.2 Filling hydro accumulators that can be refilled

A filling and test device is to be used to fill the accumulators. Here the operating instructions for the filling device used are to be observed.

ℹ **Note:** the pre-filling pressure changes with the gas temperature. After filling or blowing off nitrogen, wait until the temperature has settled prior to checking the gas pressure.

1.4 Maintenance

⚠ **Warning:** prior to opening the hydro accumulator, the accumulator must be de-pressurised!

1.4.1 General

Hydro accumulators from Integral Accumulator KG are largely maintenance-free after filling with gas.
The following maintenance tasks are to be performed for malfunction free operation and long service life:

- check gas filling pressure
- check safety devices and valves
- check pipe connections
- check accumulator fastening

1.4.2 Checking the gas filling pressure

- **inspection interval**
  - the filling pressure is to be checked at least once in the week following commissioning of the accumulator. If no gas loss is found, the second check is to be performed after 3 months. If again no pressure change is found, it is possible to change to annual inspections
- **measuring on the fluid side**
  - connect pressure gauge with accumulator using pipe
  - alternatively the pressure gauge can be connected directly to the bleed connection
- **procedure:**
  - fill accumulator with hydraulic fluid
  - close shut-off device
  - allow hydraulic fluid to flow out slowly by opening the depressurising valve (temperature compensation)
  - during the emptying process, observe pressure gauge. As soon as the filling pressure in the accumulator is reached, the pointer falls suddenly to zero

  If differences are measured, it is first to be checked whether:
  - there are no leaks in pipes and valves
  - the changes are due to different ambient or gas temperatures

Only if a fault is not found here, is it necessary to check the hydro accumulator.

2. Guidelines for Selection, Installation and Operation

2.1 General

Hydro accumulators from Integral Accumulator have been in use in numerous branches of industry for many years and are proven components. Optimal function and long service life are however only achieved if specific selection criteria are observed and incorrect installations and incorrect operating conditions are avoided.

For improved understanding of the following sections, the most important expressions and terms are briefly explained here:

2.1.1 (Excess) operating pressure

The pressure in a hydro accumulator with fluid filling and in the hydraulic system.

$p_1 =$ lower operating pressure
$p_2 =$ upper operating pressure
$p_3 =$ max. permissible pressure in the hydro system (pressure adjustment, pressure limiting, $p_3 \leq 0{,}9 \times p_4$)
$p_m =$ mean operating pressure

2.1.2 Permissible excess operating pressure p_4

Max. pressure for which the hydro accumulator is designed and that can be found in the technical documentation and the marking (rating plate, lettering).

2.1.3 Gas filling pressure p_0

Pressure in the gas chamber in the hydro accumulator if the accumulator is not filled with fluid. The gas filling pressure is in general established at room temperature (20 °C).

2.1.4 Permissible pressure ratio p_2/p_0

Figure stipulated by the manufacturer in relation to the flexing motion of the diaphragm and thus its service life, e.g. 8:1; this figure should not be exceeded (use pressures as absolute figures).

2.1.5 Permissible pressure fluctuation range Δp_{perm}

Max. permissible pressure difference $p_2 - p_1$ for 2 million load changes and $p_2 \leq p_4$

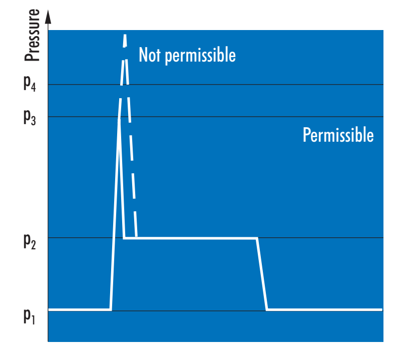


Fig. 10.1 Inadmissible pressure peaks

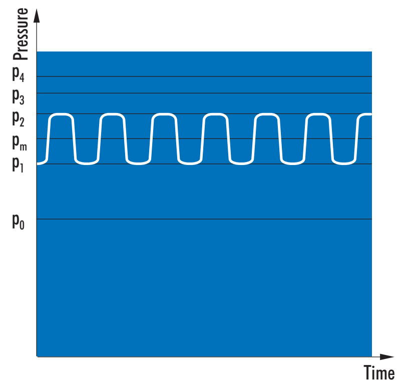


Fig. 10.2 Permissible operating behaviour

2.2 Aspects on the selection of a hydro accumulator

2.2.1 Selection in relation to the perm. excess operating pressure p_4

The hydro accumulator is to be selected such that the permissible excess operating pressure p_4 is in all circumstances above the upper operating pressure p_2 to be expected and also above any pressure peaks that may occur.
Pressure peaks or pressure increases occur, e.g., due the switching of multiway valves and the resulting retardation of oil masses, retardation of fast moving masses, pressure translation in differential circuits etc.
In this respect it is highlighted that pressure peaks may be so short that they can often not be measured with the aid of damped measuring instruments such as pressure gauges. Safety valves also do not always react to such short pressure peaks.

2.2.2 Correct selection of the gas filling pressure p_0

The magnitude of the gas filling pressure is dependent on the operating pressures to be expected and the type of application.

The following figures can be used as general guidance:

- with pulsation damping
  $p_0 = 0{,}6$ to $0{,}8 \times p_m$ (p_m = mean operating pressure)

- with surge damping or volume storage
  $p_0 = 0{,}6$ to $0{,}9 \times p_1$ (p_1 = lower working pressure)

It is to be ensured that the gas filling pressure does not exceed the value $0{,}9 \times p_1$ also at the operating temperature. The gas filling pressure established and specified at room temperature increases with increasing temperature in accordance with the gas laws.
As a rule of thumb, a pressure increase of 10% for a 30 °C temperature increase can be expected.
A gas filling pressure that is too low will result in high levels of filling of the hydro accumulator and thus to unnecessarily high flexing loads on the diaphragm; this can result in a reduction in the service life of the diaphragm.

2.2.3 Gas losses

Inadequate gas pressures can also be due to gas losses as a consequence of permeation processes. As elastic separating materials are not leak-proof in the absolute sense, gas filling molecules pass through the separating material, are dissolved in the operating fluid and transported to the reservoir where there can again separate from the fluid. The gas losses increase proportionally with the operating pressure and exponentially with the temperature. With conditions that are otherwise the same, gas losses will result in a faster reduction of the gas filling pressure on smaller hydro accumulators than on larger accumulators.

Estimates on possible gas losses or reductions in the gas filling pressure can be made by the manufacturer with detailed knowledge of the operating pressure and the operating temperature. From this information it is possible to estimate maintenance intervals (⟶ 2.5 Maintenance, page 10.6).
A gas filling pressure that is too low from the start will be further reduced by gas pressure losses, and, under operating conditions that otherwise remain the same, a hydro accumulator will not be able to store the same volume of fluid. Diaphragms or bladders as separating components are overloaded resulting in a reduction in the service life. The damping capacity of the hydro accumulator will be reduced, and any pressure peaks that occur can exceed the permissible excess operating pressure. For this reason the magnitude of the gas filling pressure is to be checked and increased at intervals to suit the application. The check can be performed very straightforwardly with the aid of a filling device DF... on the gas connection or by applying pressure to the fluid side using a method described briefly in ⟶ 2.5 Maintenance, page 10.6 and in more detail in ⟶ 4. Operating Instructions for Filling Device DFM, from page 9.55.

2.3 Correct installation

2.3.1 Safety-related equipment

At least for stationary hydraulic applications, it can be assumed that hydro accumulators are subject to the European directive on pressure equipment. The most important elements of the safety-related equipment are the pressure measuring device (pressure gauge), device for the preventing excess pressure (safety valves), non-return valves and shut-off valves and devices for de-pressurising (blow-off valves). The installation can be performed with individual components or integrated in the form of a safety block. This task can be made easier in that for entire groups of hydro accumulators, safety-related equipment is only required to be provided once (⟶ DIN 24 552).

2.3.2 Fastening

Hydro accumulators must be securely fastened such that movement cannot occur even on the facture of a pipe. Under no circumstances should hydro accumulators be fastened such that their mass is borne entirely by pipes. Special brackets, clips, mounts or female/feed through threads on the fluid connections can be used for secure fastening. If heavy vibration or shock loading is to be expected, please consult the manufacturer. The secure fastening of a hydro accumulator is be given the same importance as the checked and certified installation of a pressure vessel.

Pje. Sagristà, 12-14
08029 BARCELONA
T: (+34) 93 322 20 66
F: (+34) 93 439 25 05
hidramatic@hidramatic.com
www.hidramatic.com

2.4 Operating states to be avoided

2.4.1 Excessively high pressure ratio

An excessively high pressure ratio between the upper operating pressure p_2 and the gas filling pressure p_0 is to be avoided for various reasons. The max. permissible pressure ratio stated by the manufacturer takes into account a reasonable service life of diaphragms or bladders. If the ratio is exceeded, a significant reduction in the service life cannot be excluded. A further reason is that a hydro accumulator has a progressive characteristic curve, i.e. with increasing pressure the increase in the fluid volume stored per pressure unit becomes less and less. Expressed in a different way, the hydro accumulator becomes "harder and harder". In an application with volume storage, an increasing amount of (lost) energy must be expended to store less and less additional fluid.
It is to be noted that the pressure ratio on bladder and piston accumulators with additional gas volume (additional cylinders) is not definitive due to the increased overall volume and should be replaced by an adjusted pressure ratio or, even better, by a permissible amount of filling.

2.4.2 Insufficient spacing of the gas filling pressure p_0 from the lower operating pressure p_1

If the gas filling pressure is greater than the lower operating pressure, the hydro accumulator empties itself completely during each operating cycle. Particularly on diaphragm accumulators, the sealing elements on the diaphragms sit on or hit the inside of the housing in the area of the fluid connection. Continuous contact can cause flash to form or cause other material deformations that can in turn destroy the diaphragm.
It is important to note that a correct gas filling pressure can reach excessively high value due to increasing temperature.
Briefly passing the gas filling pressure during starting and shut down cannot be avoided and does not cause any damage.
If continuous transition of the gas filling pressure cannot be avoided for functional reasons, it is strongly recommended to consult the manufacturer, as special designs are available for difficult cases.

2.4.3 Sudden complete draining of a hydro accumulator

Applications in which a hydro accumulator can empty suddenly and without control are to be avoided. One of the possible disadvantages has already be described in → 2.4.2 Insufficient spacing of the gas filling pressure p_0 from the lower operating pressure p_1. It is clear that the deformation at a sealing component or by a sealing component are all the greater, the harder the impact of the sealing component. A further disadvantage is that on the rapid outflow of fluid, flow forces can be produced that accelerate the sealing components onto its seat before the fluid has flowed out completely. In such cases oil pockets are formed, i.e. the available useful volume could not be utilised. The fluid volume left in the accumulator also results in a fictional increase in the gas filling pressure that could also impair subsequent operating cycles. In extreme cases the separating material can also enter the fluid connection due to the flow forces before the sealing component has reached its seat.
This situation can be rectified by fixed regulators, regulator valves or pressure retention valves.

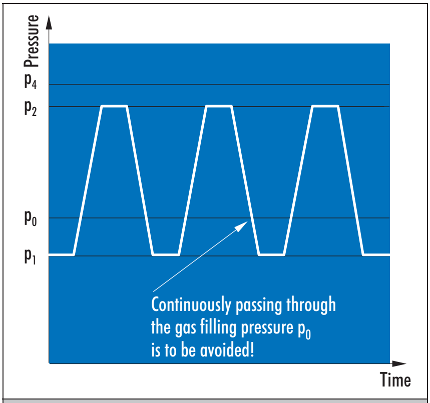


Fig. 10.3 Pressure curve on complete emptying

2.4.4 Sudden filling

Sudden filling can cause damage to a diaphragm due to the high inflow speeds. If the filling process, e.g., occurs during surge damping with complete emptying of the accumulator, a jet of fluid "shooting into the accumulator" can briefly over elongate the diaphragm "stuck" to the inside wall and sooner or later destroy it.
Fixed regulators and regulator valves can also be used to rectify this situation.

2.4.5 Raised temperatures

The usual operating conditions for hydro accumulators is between –10 °C and +80 °C. Higher temperatures are possible with separating components (bladders, diaphragms) made of special materials. However, here the progressively increasing gas losses (→ 2.2.3 Gas losses, page 10.4) with raised temperatures must be taken into account. In addition, a reduction in the permissible excess operating pressure is to be expected, as the strength figures for the housing material must also be reduced.

2.4.6 Low temperatures

At temperatures below –10 °C, the elasticity of the standard materials (NBR) for diaphragms and bladders reduces and there is a risk of fractures. If usage at such low temperatures cannot be avoided, special separating wall materials must be used. Please consult the manufacturer. It is also to be noted that not all housing materials are suitable or approved for low temperatures, as a drop in the notch impact strength can occur. In usage a differentiation is to be made between temperatures due to weather conditions and low temperatures of the medium stored. The manufacturer will be pleased to provide more information.

2.4.7 Incorrect operating medium

Hydro accumulators are designed as standard for use with mineral oil. If other fluids like water or even aggressive chemicals are to be used, hydro accumulators that meet these requirements in relation to the housing material, corrosion protection and the compatibility of their separating materials must be used. Along with housing damage (rust, pitting), swollen or shrunk and thus soon useless diaphragms or bladders are to be feared. It is imperative to consult the manufacturer.

2.5 Maintenance

Along with the external inspection for corrosion damage and correct fastening, the maintenance of a hydro accumulator is limited to the regular checking and correction if necessary of the gas filling pressure. While for volume storage, variations in the gas filling pressure is mostly to be noticed in the form of inadequate function, for pulsation damping or surge damping, incorrect gas filling pressure can remain undetected for long periods and cause damage to the hydro accumulators or the system.

For the check, filling devices should be used that are offered by the manufacturer for the various types of gas connections (M28x1,5 or filling valves with Vg8 filling connection) and at the same time can also be used for the connection to a pressure reducer connected to nitrogen cylinder for the correction or changing of the gas filling pressure.

If only the magnitude of the gas filling pressure is to be determined, this task can also be performed on the fluid side, if it is possible to slowly fill or drain the hydro accumulator.

During slow filling, the filling process will be seen to slow considerably when the gas filling pressure is reached. During draining, after a slowing in the pressure drop, a sudden pressure drop to zero occurs, which can be clearly seen on a pressure gauge. This process can be performed if necessary within a system without removing the accumulator. If the effective storage temperature during the test is different to room temperature RT, the result must be converted to RT = 20 °C.

The usage of filling devices with the accumulator installed, requires, of course, along with complete fluid side draining, good access to the gas connections and adequate clearance above them.

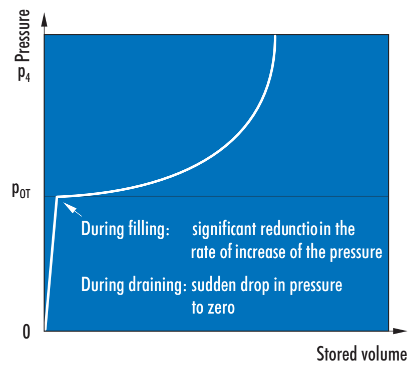


Fig. 10.4 Checking the gas filling pressure on the fluid side

2.6 Disposal

Hydro accumulators as sealed hollow bodies are not allowed to be included unopened in scrap for smelting, as per German accident prevention regulation VBG 111. It is therefore necessary to depressurise hydro accumulators on the gas side by carefully unscrewing gas filling screws or gas filling valves and opening the accumulator. Filling devices are also well suited to this task.

On special designs with a permanently sealed gas filling opening (disposable accumulators) only careful drilling ($\varnothing \geq 6$ mm) of the gas chamber in a suitable retaining jig can be used. As the gas flowing out can draw metal splinters or particles with it, safety glasses must be worn.

3. Calculation and Design

Almost all formulas for the calculation of hydro accumulators are based on the state changes or gas equations for ideal gases. Even though it is known that nitrogen, as the filling gas most frequently used, at high pressures and/or low temperatures has the behaviour of a real gas, which can be significantly different to the behaviour of an ideal gas, the formulas given below have proven surprisingly useful in practice for pressure ranges to around 200 bar for initial approximate calculations. Also other important effects such as the viscosity of the fluid, length and size of pipes or connections, valve closing times, moved masses etc. at times are not known at all, or at least their effect on the entire circuit is not known in detail and therefore more or less accurate assumptions must be made.
For the more detailed analysis of a problem and its optimal solution, today along with complex simulation calculations, trials are still to be recommended that should be performed at the operating organisation under practical conditions, as these are more realistic than any conditions set up in the laboratory. In general it can be assumed that the calculation of static applications produces more accurate results than the calculations of dynamic processes.

d	= inside diameter of a pipe
f_0	= natural frequency of an accumulator
k	= pump factor
l	= pipe length
n	= polytropic exponent
p	= pressure (as absolute value)
p_0	= gas filling pressure at room temperature
p_{0T}	= gas filling pressure at temperature T
p_1	= lowest operating pressure
p_2	= largest operating pressure
p_m	= mean pressure during pulses
p_{St}	= isothermal achieved steady state pressure
$(p_2/p_{0T})_{perm}$	= permissible pressure ratio
Δp	= pressure difference, range of fluctuations
Δp_{perm}	= perm. pressure difference p_4–p_1
Q	= flow rate
T	= absolute temperature in K
T_1	= temperature at p_1; V_1
T_2	= temperature at p_2; V_2
V_0	= gas volume without fluid filling
V_1	= gas volume at p_1
V_2	= gas volume at p_2
V_H	= stroke volume of an individual piston on a reciprocating pump
V_{St}	= gas volume at p_{St}
ΔV	= fluid volume stored between two pressures
Z	= calculated table value
δ	= residual pulse $(p_2–p_m)/p_m$
ε	= p_m/p_0
κ	= 1,4 (adiabatic exponent)
ρ	= density of a fluid

3.1 Isothermal state changes

Isothermal state changes reflect the state after very slow changes on full temperature compensation or an adequately long period of time after change.
The curves with the pressures on the abscissa and the volume stored on the ordinate appear in a double logarithmic scale as straight lines (→ Fig. 10.5), in a system with linear scales however lines with a curve to the right.

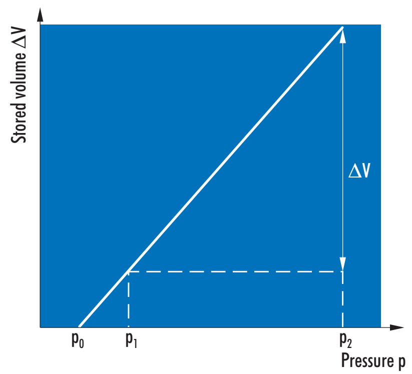


Fig. 10.5 Equation (2)

$$p \cdot V = \text{const.}$$

$$p_0 \cdot V_0 = p_1 \cdot V_1 = p_2 \cdot V_2 \quad (1)$$

$$\Delta V = p_0 \cdot V_0 \cdot \left(\frac{1}{p_1} - \frac{1}{p_2}\right) \quad (2)$$

3.2 Polytropic state changes

On polytropic state changes the heat exchange with the surrounding environment is at least partially suppressed. On the occurrence of pressure increases in the gas, a temperature increase therefore takes place. Conversely, on a reduction in pressure the temperature drops. If, during fast processes, temperature compensation does not occur, the change approaches the adiabatic in which the polytropic exponent *n* is replaced by the adiabatic exponent $\kappa = 1{,}4$ (for nitrogen N_2 as two atom gas). For real gases *n* can also be chosen larger than 1,4.

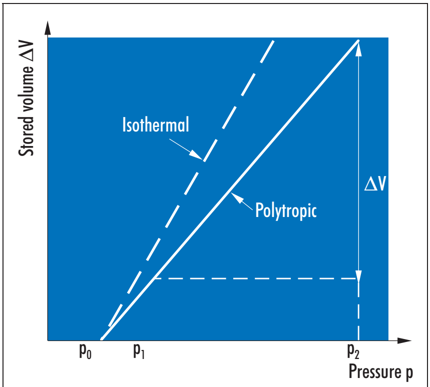


Fig. 10.6 Polytropic state change

Recommended: $p_0 = 0{,}6 \text{ x } p_1$ to $0{,}8 \text{ x } p_1$

$$p \cdot V^n = \text{const.}$$

$$p \cdot V^n = p_1 \cdot V_1^n = p_2 \cdot V_2^n \quad (3)$$

$$\Delta V = V_0 \cdot \left[\left(\frac{p_0}{p_1}\right)^{\frac{1}{n}} - \left(\frac{p_0}{p_2}\right)^{\frac{1}{n}}\right] \quad (4)$$

3.3 Isothermal charging with subsequent polytropic state change

Frequently practical applications are a mixture of isothermal and polytropic state changes. After a slow isothermal charging or starting from a steady state, e.g., on a surge or a sudden withdrawal of the stored pressure medium, a polytropic state change can occur. In the calculation, first the gas volume V_{St} is determined isothermally at the steady state pressure p_{St}, these two variables are then considered initial parameters in the context of V_0 and p_0 for the subsequent polytropic state change.

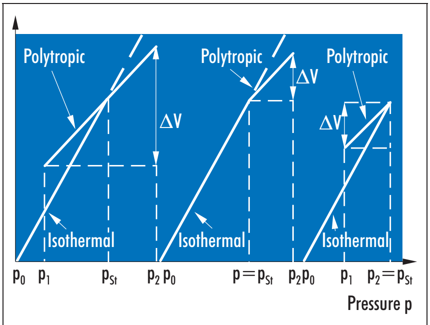


Fig. 10.7

Recommended: $p_0 = 0{,}6 \text{ x } p_1$ to $0{,}8 \text{ x } p_1$

$$V_{St} = V_0 \cdot \frac{p_0}{p_{St}} \quad (5)$$

$$\Delta V = V_0 \cdot \frac{p_0}{p_{St}} \cdot \left[\left(\frac{p_{St}}{p_1}\right)^{\frac{1}{n}} - \left(\frac{p_{St}}{p_2}\right)^{\frac{1}{n}}\right] \quad (6)$$

Special case: polytropic charging to p_2 starting from $p_1 = p_{St}$

$$\Delta V = V_0 \cdot \frac{p_0}{p_1} \cdot \left[1 - \left(\frac{p_1}{p_2}\right)^{\frac{1}{n}}\right] \quad (7)$$

Special case: polytropic discharging to p_1 starting from $p_2 = p_{St}$
ΔV is negative (withdrawal!)

$$\Delta V = V_0 \cdot \frac{p_0}{p_2} \cdot \left[1 - \left(\frac{p_2}{p_1}\right)^{\frac{1}{n}}\right] \quad (8)$$

3.4 Correction factors

At high pressures above 200 bar the gas equations based on ideal gases become increasingly inaccurate and it is recommended to use real gas equations or to apply correction factors *K* as per the equations 9 and 10. With $K_{1,2} > 1$ the real storage volume selected must be larger than the calculated volume. The ΔV_{real} to be used in the formula must be greater than that practically required. Correction factors increase with increasing pressures and reduce with increasing pressure ratios p_2/p_1.

$$V_{0real} = K_1 \cdot V_{0ideal} \qquad (9)$$

$$\Delta V_{ideal} = K_2 \cdot \Delta V_{real} \qquad (10)$$

3.5 Isochoric state changes

During an isochoric state change the gas volume stays constant and the pressure changes as a function of the absolute temperature. In hydro accumulators drained of fluid, this results in an increase or a drop in the gas filling pressure. In a sealed system the system pressure changes correspondingly.
Rule of thumb: a temperature change of 30 K or 30 °C results in a change to the gas filling pressure of approx. 10%, as 30 K is approx. 10% of RT=293 K.

$$\frac{p}{T} = \text{const.} \qquad (11)$$

$$\frac{p_{0T}}{T} = \frac{p_0}{293} \qquad p_{0T} = \frac{p_0 \cdot T}{293} \qquad (12)$$

293 K = room temperature RT

3.6 Pulsation damping

Surges in hydraulic systems in general stem from uneven pumping action in pumps, here particularly reciprocating pumps with only a few pistons are well known as pulse generators. The unevenness of the pumping action results from the number and arrangement of the pistons and the resulting overlap of the pumping curves for the individual pistons. A parameter for this action is the so-called pump factor *k*.
There follow a few examples:

k = 0,55	single-acting single piston pump
k = 0,21	double-acting single piston pump or single-acting two piston pump with 180° offset
k = 0,423	double-acting two piston pump with 180° offset
k = 0,009	single-acting three piston pump

With the aid of hydro accumulators, the pulsation can be reduced to a residual pulsation *d*. There are two possible ways of performing the calculation. From equation 15 p_1 and p_2 must be defined starting from a measurable pressure p_m. From equation 16 the selection of the residual pulsation *d* and the pressure ratio p_m/p_0 is sufficient. As all other values are constants, equation 16 can be rearranged to form equation 17 with a calculated value *Z* that can be taken from → Tbl. 10.1 for some cases.

Residual pulsation:

$$\delta = \frac{p_2 - p_m}{p_m} = \frac{p_m - p_1}{p_m} \qquad (13)$$

Pressure ratio:

$$\varepsilon = \frac{p_m}{p_0} \qquad (14)$$

$$V_0 = \frac{k \cdot V_H}{\left(\frac{p_0}{p_1}\right)^{\frac{1}{n}} - \left(\frac{p_0}{p_2}\right)^{\frac{1}{n}}} \qquad (15)$$

$$V_0 = \frac{k \cdot V_H \cdot \left(\frac{p_m}{p_0}\right)^{\frac{1}{n}}}{\frac{1}{(1-\delta)^{\frac{1}{n}}} - \frac{1}{(1-\delta)^{\frac{1}{n}}}} \qquad (16)$$

$$V_0 = V_H \cdot Z \qquad (17)$$

Please note that equations 16 and 17 can only be approximations as they contain no frequency information. As can be seen from → Fig. 10.8 Damping curve for a hydro accumulator with a single connection, the frequency is very important for the damping behaviour. In fact hydro accumulators, if they are not special designs, only provide their optimal damping behaviour in a narrow frequency band in the area of their natural frequency f_0. As to determine f_0 not only the features of a hydro accumulator itself but also the cross section and the length of the connection pipe are of importance, in case of doubt it is recommended to consult the manufacturer.

δ in %	Single piston pump single-acting		Two piston pump single-acting		Three piston pump single-acting	
	ε = 1,25	ε = 1,5	ε = 1,25	ε = 1,5	ε = 1,25	ε = 1,5
1,0	46	52	18	20	1,0	1,0
2,0	23	26	9	10	0,4	0,5
3,0	15	18	6	7	0,3	0,3
4,0	12	13	5	5	0,2	0,3
5,0	9	11	4	4	0,2	0,2
6,0	8	9	3	4	0,2	0,2
8,0	6	7	3	3	0,1	0,1
10,0	5	6	2	2	0,1	0,1

Tbl. 10.1 Table for reading Z (⟶ equation 17)

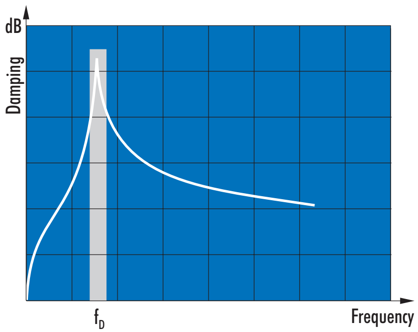


Fig. 10.8 Damping curve for a hydro accumulator with a single connection

Natural frequency is increased by:
- smaller nominal volume
- higher gas filling pressure
- larger connection cross section
- smaller connection length

Natural frequency is reduced by:
- larger nominal volume
- smaller gas filling pressure
- smaller connection cross section
- larger connection length

3.7 Surge damping

The most frequent cause of surges in hydraulic systems is fast closing valves. In the calculation the simplifying assumption is taken that the entire energy from the flowing fluid is converted into gas work within the hydro accumulator during a pressure increase. Starting from the pressure p_1 prior to the surge, the pressure increase must not exceed a stipulated value p_2. Valve closing times are not taken into account in the calculation, nor are connection resistances. The calculated value for the nominal volume on the hydro accumulator to be used is therefore to be taken as an initial estimate. It is recommended to perform trials.

A position as close as possible to the production of the surge is recommended for the installation. The surge should reach the hydro accumulator as directly as possible without many changes in direction.

$$p_0 = 0{,}8 \cdot p_1 \qquad (18)$$

$$V_0 = \frac{2 \cdot \rho \cdot 1 \cdot Q^2 \cdot (n-1)}{\pi \cdot d^2 \cdot 0{,}8 \cdot p_1 \cdot \left[\left(\frac{p_2}{p_1}\right)^{\frac{n-1}{n}} - 1\right]} \qquad (19)$$

Using the following values and dimensions

$\rho = 890$ kg/m
l in m
Q in l/min
p_1 and p_2 in bar

n = 1,4
d in mm
V_0 in l

the equation is:

$$V_0 = \frac{7{,}87 \cdot 10^{-4} \cdot l \cdot Q^2}{d^2 \cdot p_1 \cdot \left[\left(\frac{p_2}{p_1}\right)^{0{,}2857} - 1\right]} \qquad (20)$$

4. Recommended Oil Types

For normal operating conditions we recommend the usage of mineral oil based hydraulic oils HL and HLP as per the following list. For special conditions, it is also possible to use HLPD and HVLP oils with the same viscosity classes. Prior to the usage of HE fluids (HEPG, HETG and HEES biodegradable oils) or HFC (flame retardant water-glycol mixtures) we request you to contact us.
The order of the manufacturers listed is alphabetical and therefore not a ranking. The list also makes no claim to completeness. In general it is based on the information from the manufacturers and as such we cannot provide any guarantee in relation to the content. It is to be noted that some fluids cover a large viscosity range (e.g. 32–68) and are therefore only mentioned once.

	VG 46	VG 68
Mineral oil company/manufacturer		
a) HL[1] (mineral oil)	e) HEPG (polyglycol-based)	
b) HLP[2] (mineral oil)	f) HETG (vegetable oil)	
c) HVLP[3] (mineral oil)	g) HEES (synth. ester)	
d) HLPD[4] (mineral oil)	h) HFC (water/glycol)	
ARAL		
a)	Aral Vitam UF 46	Aral Vitam UF 68
b)	Aral Vitam GF 46	Aral Vitam GF 68
c)	Aral Vitam HF 46	Aral Vitam VF 68
	Aral Vitam VF 46	
d)	Aral Vitam DE 46	Aral Vitam DE 68
e)	Aral Vitam BAF 46	–
f)	–	–
g)	Aral Vitam EHF 46	–
h)	Aral Montral 44	–
BECHEM		
a)	–	–
b)	Staroil No. 46	Staroil No. 68
c)	Staroil HVI 46	Staroil HVI 68
d)	Staroil H-LPD 46	Staroil H-LPD 68
e)	Hydrostar UWF 46	Hydrostar UWF 68
f)	UWS Hydraulik 32	–
g)	Hydrostar HEP 46	Hydrostar HEP 68
h)	Hydrostar HY 46	–

	VG 46	VG 68
Mineral oil company/manufacturer		
a) HL[1] (mineral oil)	e) HEPG (polyglycol-based)	
b) HLP[2] (mineral oil)	f) HETG (vegetable oil)	
c) HVLP[3] (mineral oil)	g) HEES (synth. ester)	
d) HLPD[4] (mineral oil)	h) HFC (water/glycol)	
BP		
a)	BP Energol HL 46	–
b)	BP Energol HLP-HM 46	BP Energol HLP-HM 68
c)	Bartran HV 46	Bartran HV 68
d)	BP Energol HLP-D 46	BP Energol HLP-D 68
e)	–	–
f)	Carelube HTG 32	–
g)	Biohyd SE 46	Biohyd SE 68
h)	Enersyn SF-C 14	–
CASTROL		
a)	Magna 46	Magna 68
b)	Hyspin AWS 46	Hyspin AWS 68
	Hyspin SP 46	Hyspin SP 68
c)	Hyspin AWH-M 46	Hyspin AWH-M 68
d)	Vario HDX 46	Vario HDX 68
	hydraulic oil HLP-D 46 SF	hydraulic oil HLP-D 68 SF
e)	–	–
f)	Carelube HTG 32	Carelube HTG 68
g)	Castrol product 695/13	Castrol product 695/14
	Carelube HES 46	Carelube HES 68
h)	Anvol WG 46	–
DEA		
a)	Astron HL 46	Astron HL 68
b)	Astron HLP 46	Astron HLP 68
	Astron X HLP 46	Astron X HLP 68
c)	Astron HVLP 46	Astron HVLP 68
	Astron X HVLP 46	
d)	Actis HLPD 46	Actis HLPD 68
	Actis X HLPD 46	Actis X HLPD 68
	Trion EP 46	Trion EP 68
e)	Econa PG 46	–
f)	(Econa R 32)	–
g)	Econa E46	–
h)	Tectro HF-C 46 S	–

Integral Accumulator

	VG 46	VG 68
Mineral oil company/manufacturer		
a) HL[1] (mineral oil)	e) HEPG (polyglycol-based)	
b) HLP[2] (mineral oil)	f) HETG (vegetable oil)	
c) HVLP[3] (mineral oil)	g) HEES (synth. ester)	
d) HLPD[4] (mineral oil)	h) HFC (water/glycol)	
ELF		
a)	ELF POLYTELIS 46	ELF POLYTELIS 68
b)	ELFOLNA 46	ELFOLNA 68
	ELFOLNA DS 46	ELFOLNA DS 68
	ELFOLNA SP 46	ELFOLNA SP 68
c)	HYDRELF DS 46	HYDRELF DS 68
d)	ELFOLNA HLPD 46	ELFOLNA HLPD 68
	ELFOLNA HMD 46	ELFOLNA HMD 68
e)	–	–
f)	ELF XTD 93031	–
g)	HXDRELF BIO	–
h)	PYRELF HFC 46	–
ESSO		
a)	TERESSO 46	TERESSO 68
b)	NUTO H 46	NUTO H 6
	Hydraulic oil HLP 46	Hydraulic oil HLP 68
c)	UNIVIS N 46	UNIVIS N 68
d)	HLPD oil 46	HLPD oil 68
e)	Hydraulic oil PGK 46	–
f)	Hydraulic oil PFL	–
g)	Hydraulic oil HE 46	–
h)	–	–
FINA		
a)	CIRKAN 46	CIRKAN 68
b)	HYDRAN 46	HYDRAN 68
c)	HYDRAN HV 46	HYDRAN HV 68
d)	HYDRAN HLP-D 46	HYDRAN HLP-D 68
	Hydraulic oil D3033	
e)	Hydraulic oil D3031-46	–
f)	BIOHYDRAN RS 38	–
g)	BIOHYDRAN SE 38	BIOHYDRAN TMP 68
	BIOHYDRAN TMP 46	
h)	–	–
FRAGOL		
a)	–	–
b)	Hydraulic oil HLP 46	Hydraulic oil HLP 68
c)	Hydraulic oil HVLP 46	Hydraulic oil HVLP 68
d)	Hydraulic oil HLP-D 46	Hydraulic oil HLP-D 68
e)	Fragol Hydraulic TR 46	–
f)	Fragol Hydraulic V32	–
g)	Fragol Hydraulic HE 46	FRAGOL Hydraulic HE 68
h)	Fragol Hydrolub 125	FRAGOL Hydrolub 126
	Fragol Hydrolub NF 46-D	

	VG 46	VG 68
Mineral oil company/manufacturer		
a) HL[1] (mineral oil)	e) HEPG (polyglycol-based)	
b) HLP[2] (mineral oil)	f) HETG (vegetable oil)	
c) HVLP[3] (mineral oil)	g) HEES (synth. ester)	
d) HLPD[4] (mineral oil)	h) HFC (water/glycol)	
FUCHS		
a)	RENOLIN DTA 46	RENOLIN DTA 68
b)	RENOLIN B15VG 46	RENOLIN B15VG 68
	RENOLIN ZAF 46 B	RENOLIN ZAF 68 B
c)	RENOLIN MR 46 MC	RENOLIN MR 68 MC
	RENOLIN ZAF 46 MC	RENOLIN ZAF 68 MC
d)	RENOLIN MR 15 VG 46	RENOLIN MR 15 VG 68
	RENOLIN D 15 VG 46	RENOLIN D 15 VG 68
	RENOLIN ZAF 46 D	
e)	RENOLIN PG 46	RENOLIN PG 68
f)	PLANTOHYD 46 N	PLANTOHYD 68 N
	PLANTOHYD N	
g)	PLANTOHYD 46 S	PLANTOHYD 68 S
	PLANTOHYD 46 HVI	
	PLANTOHYD Super S	
h)	Hydrotherm 46 M	–
	Hydrotherm 46 NF 3	
MOBIL		
a)	Vactra Oil Medium	Vactra Oil Heavy Medium
	DTE Oil Medium	DTE Oil Heavy Medium
b)	Mobil DTE 25	Mobil DTE 26
c)	Mobil DTE 15 M	Mobil DTE 16 M
d)	Hydraulic oil HLPD 46	Hydraulic oil HLPD 68
e)	–	–
f)	Mobil EAL 224 H	–
g)	Mobil EAL Syndraulic 46	–
	Hydraulic Oil UF 46	
h)	Hydrofluid LT	–
	Nyvac FR 200 D Fluid	
OEST		
a)	Hydraulic oil H-L 46	Hydraulic oil H-L 68
b)	Hydraulic oil H-LP 46	Hydraulic oil H-LP 68
c)	Hydraulic oil HVI 46	Hydraulic oil HVI 68
d)	Hydraulic oil 46 DD	Hydraulic oil 68 DD
e)	–	–
f)	(BIO HY-FLUID HV 34)	(BIO HY-FLUID HV 68)
g)	Bio Synthetik HYD 46	Bio Synthetik HYD 68
h)	–	–
PANOLIN		
a)	Panolin Indol ISO 46	Panolin Indol ISO 68
b)	Panolin HLP ISO 46	Panolin HLP ISO 68
c)	Panolin HLP Universal 37	Panolin GP 55
d)	Panolin HLP-D ISO 46	Panolin HLP-D ISO 68
e)	–	–
f)	–	–
g)	Panolin HLP Synth 46	Panolin HLP Synth 68
h)	–	–

Pje. Sagristà, 12-14
08029 BARCELONA
T: (+34) 93 322 20 66
F: (+34) 93 439 25 05
hidramatic@hidramatic.com
www.hidramatic.com

	VG 46	VG 68
Mineral oil company/manufacturer		
a) HL[1] (mineral oil) b) HLP[2] (mineral oil) c) HVLP[3] (mineral oil) d) HLPD[4] (mineral oil)	e) HEPG (polyglycol-based) f) HETG (vegetable oil) g) HEES (synth. ester) h) HFC (water/glycol)	
PETROFER		
a)	Isolubric VG 46 L	Isolubric VG 68 L
b)	Isolubric VG 46	Isolubric VG 68
c)	Isolubric VG 46 HV	Isolubric VG 68 HV
d)	Isolubric VG 46 D	Isolubric VG 68 D
e)	Syntolubric 46	–
f)	Syntolubric 32	–
g)	Envolubric HE 46	Envolubric HE 68
h)	Ultra-Safe 620	Ultra-Safe 360
QUAKER		
a)	–	–
b)	–	–
c)	–	–
d)	–	–
e)	–	–
f)	GREENSAVE N 30	–
g)	GREENSAVE N 40	–
h)	QUINTOLUBRIC 730	–
SHELL		
a)	Morlina Oil 46	–
b)	Shell Tellus Oil 46	Shell Tellus Oil 68
c)	Shell Tellus Oil TD 46	–
d)	Shell Tellus Oil DO 46	Shell Tellus Oil DO 68
e)	Shell Fluid BD 46	–
f)	Shell Naturelle HF-R	–
g)	Shell Naturelle HF-E 46	Shell Naturelle HF-E 68
h)	–	–
STUART		
a)	–	–
b)	–	–
c)	–	–
d)	–	–
e)	ISOCOR E 46	–
f)	–	–
g)	ISOCOR HF 46	ISOCOR HF 68
h)	HYDROVOR CC 44	–
TEBIOL		
a)	–	–
b)	–	–
c)	–	–
d)	–	–
e)	–	–
f)	Florahyd HVI 46	Florahyd HVI 68
g)	Esterhyd HE 46	–
h)	–	–

	VG 46	VG 68
Mineral oil company/manufacturer		
a) HL[1] (mineral oil) b) HLP[2] (mineral oil) c) HVLP[3] (mineral oil) d) HLPD[4] (mineral oil)	e) HEPG (polyglycol-based) f) HETG (vegetable oil) g) HEES (synth. ester) h) HFC (water/glycol)	
TRIBOL		
a)	Tribol 772	Tribol 773
b)	Tribol 943 AW 46	Tribol 943 AW 68
c)	–	–
d)	–	–
e)	–	–
f)	–	–
g)	Tribol 1448/46	Tribol 1448/68
h)	–	–
WISURA		
a)	Dynex 46	Dynex 68
b)	Tempo 46	Tempo 68
c)	Hydroma 46	Hydroma 68
d)	HLPD 46	HLPD 68
e)	–	–
f)	Hydroma NAT 40	–
g)	Hydrofluid SE 46	–
h)	–	–

1) normally hydraulic oil in accordance with DIN 51524 part 1
2) normally hydraulic oil in accordance with DIN 51524 part 2
3) normally hydraulic oil in accordance with DIN 51524 part 3
4) like 2) or 3), however detergent action

5. European Directive on Pressure Equip. 97/23/EC (abridged information)

5.1 General

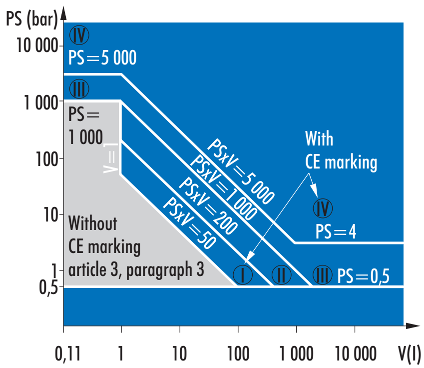
It is generally known that the free trade in hydro accumulators and other pressure vessels is made more difficult by different national regulations and the related different acceptance limits, calculation methods and acceptance methods. In Brussels efforts have therefore been underway for some time to create standard regulations. The

directive 97/23/EC of the European Parliament and of the Council of 29 May 1997 on the approximation of the laws of the Member States concerning pressure equipment

was published in the official journal of the European Union on 9.7.97 under No. L18. According to article 20 the member states must have adopted the necessary laws, regulations and administrative provisions by **29 May 1999**. From **29 November 1999** the new regulations can be applied. Up until **29 May 2002** pressure vessels are also allowed to be placed on the market in accordance with the previous regulations.

5.2 Important points in the directive in relation to hydro accumulators

- the directive applies to hydro accumulators (= pressure equipment) with more than 0,5 bar overpressure.
- exempt are hydro accumulators for the operation of vehicles that have been awarded type approval based on other European directives. Also exempt are hydro accumulators that would fall in the area of the Machinery directive 89/392 **and** correspond as a maximum with category I (see below). Also hydro accumulators fitted in ships, offshore plant and aircraft are exempt.
- hydro accumulators with nitrogen as the gas filling and mineral oil with a flame point above the perm. operating temperature (is actually always the case), are categorised in (hazard) group 2 both on the gas side and the fluid side; this group has increased exemption limits compared to the group 1 that applies to dangerous media (article 9).
- hydro accumulators are subject to a so-called declaration of conformity assessment as a function of the hazard groups, pressures, volumes and/or pressure-volume products to be applied. If certain limits are passed, they are classified in categories (I to IV) to which so-called modules are allocated; a detailed description of this aspect goes beyond the scope of this summary. As on the usage of nitrogen and mineral oil, the more severe conditions are produced in relation to nitrogen (gas), diagram 2 (→ Fig. 10.9) is to be used for hydro accumulators.
  It can be seen that all accumulators with $V \leq 1$ l or $V > 1$ l and $PS \times V \leq 50$ bar · l (→ Fig. 10.9, grey area) are below the categories, unless $PS > 1000$ bar (PS = max. perm. working pressure in bar).
- hydro accumulators that fall in the categories I to IV receive a CE marking. Hydro accumulators outside the categories (grey area) are not allowed to be given a CE marking. However they are permitted to participate in the free movement of goods when they comply with good engineering practice in a member state in relation to design and manufacture (article 3(3)).
- commissioning and periodic inspections:
  As no statements are made on this issue in the European directive for pressure equipment, we recommend maintaining previous practice.
  Previous practice requires that prior to initial commissioning, a hydro accumulator system must be subject to an acceptance test at the operating organisation; this test is to comprise a check on regulations, the installation and the equipment.
  On hydro accumulators up to category I, a specialist is allowed to perform and certify the acceptance test, while for hydro accumulators of category II an independent assessor (e.g. TÜV) must accept the test and certify it.
  Periodic inspections, e.g., every 2 years are allowed to be performed by a specialist up to and including category II.



I = module A
II = modules A1, D1, E1
III = modules B1+D, B1+F, B+E, B+C1, H
IV = modules B+D, B+F, G, H1

A = internal manufacturing checks (only manufacturer)
A1 = like A, with random sample monitoring of the final assessment
B = EC type examination
B1 = EC design examination
C1 = conformity of the type
D, D1, E, E1 = various quality assurance measures
F = testing of the products
G = EC unit verification
H = full quality assurance
H1 = like H, with design examination and final assessment surveillance

Fig. 10.9 Diagram 2 for gases (e.g. nitrogen) in hazard group 2

The modules allocated to the categories provide information on the responsibilities during the design, manufacture and examinations. Thus, e.g., on the application of module A the manufacturer is solely responsible. Module H is to have a particularly high value for certified companies.