HYDAC INTERNATIONAL

Diaphragm Accumulators

INDEX

1. DESCRIPTION

1.1. FUNCTION

Fluids are practically incompressible and cannot therefore store pressure energy.

In hydro-pneumatic accumulators the compressibility of a gas is utilised for storing fluids. HYDAC diaphragm accumulators are based on this principle using nitrogen as the compressible medium.

The diaphragm accumulator consists of a fluid section and a gas section with the diaphragm acting as a gas-proof screen.

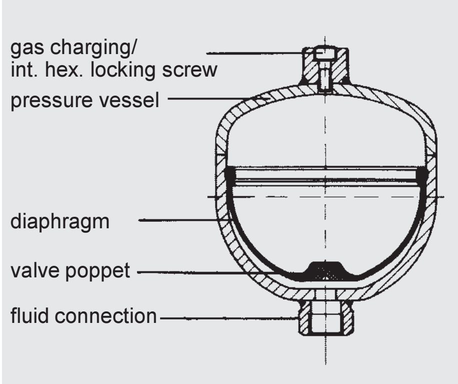
The fluid section is connected with the hydraulic circuit, so that the diaphragm accumulator draws in fluid when the pressure increases and the gas is compressed. When the pressure drops, the compressed gas expands and forces the stored fluid into the circuit.

At the base of the diaphragm is a prevulcanised valve poppet. This shuts off the hydraulic outlet when the accumulator is completely empty and thus prevents damage to the diaphragm.

1.2. CONSTRUCTION

HYDAC diaphragm accumulators are available in two versions.

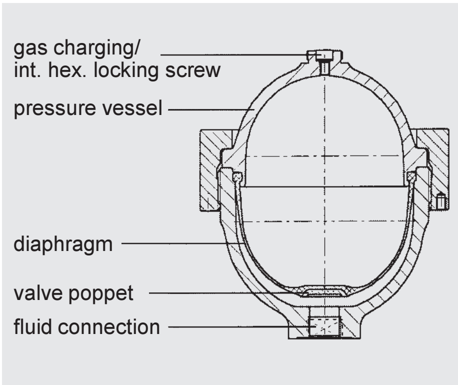
1.2.1 **Weld type**



This consists of:

- Welded pressure vessel, rechargeable on the gas side or, alternatively, completely sealed. Fluid connection available in various types.
- Flexible diaphragm to separate the fluid and gas sections.
- Valve poppet set into the base of the diaphragm

1.2.2 **Screw type**



This consists of:

- Forged upper section with gas pre-charge connection.
- Forged lower section with fluid connection.
- Exchangeable flexible diaphragm to separate the gas and fluid.
- Valve poppet set into the base of the diaphragm
- Lock nut, or direct screw-coupling, to hold the upper and lower sections of the accumulator together.

1.2.3 **Diaphragm material**

The diaphragms are available in the following elastomers:

- NBR (acrylonitrile butadiene rubber, PERBUNAN)
- IIR (butyl rubber)
- FKM (fluoro rubber, VITON)
- ECO (ethylene oxide epichlorohydrin rubber)

Material has to be selected according to the operating medium and temperature.

(see compatibility table 4.1.2 on page 8)

1.2.4 **Corrosion protection**

For use with chemically aggressive fluids the accumulator can be supplied with corrosion protection such as a synthetic protective coating or a galvanic or chemical surface protection. If this type of protection is not sufficient, nearly all types can be supplied in stainless steel.

The options detailed in points 1.2.3. and 1.2.4. allow these accumulators to be used with mineral oils, non-flam fluids and numerous chemically aggressive fluids.

1.3. MOUNTING POSITION

Optional; however, if there is a risk of contamination collecting, a vertical position is preferable, with the fluid connection at the bottom.

1.4. TYPE OF MOUNTING

Accumulators up to 2 l can be screwed directly inline.

– Where strong vibrations are expected, the accumulator must be secured to prevent it working loose. For weld type accumulators we recommend HYDAC support clamps; for screw types with lock nut, a suitable support console can be found in our brochure no. E 3.502../.., Supports for Hydraulic Accumulators

– Additional external thread on the hydraulic connection for screwing into mounting holes - see table 6.1.

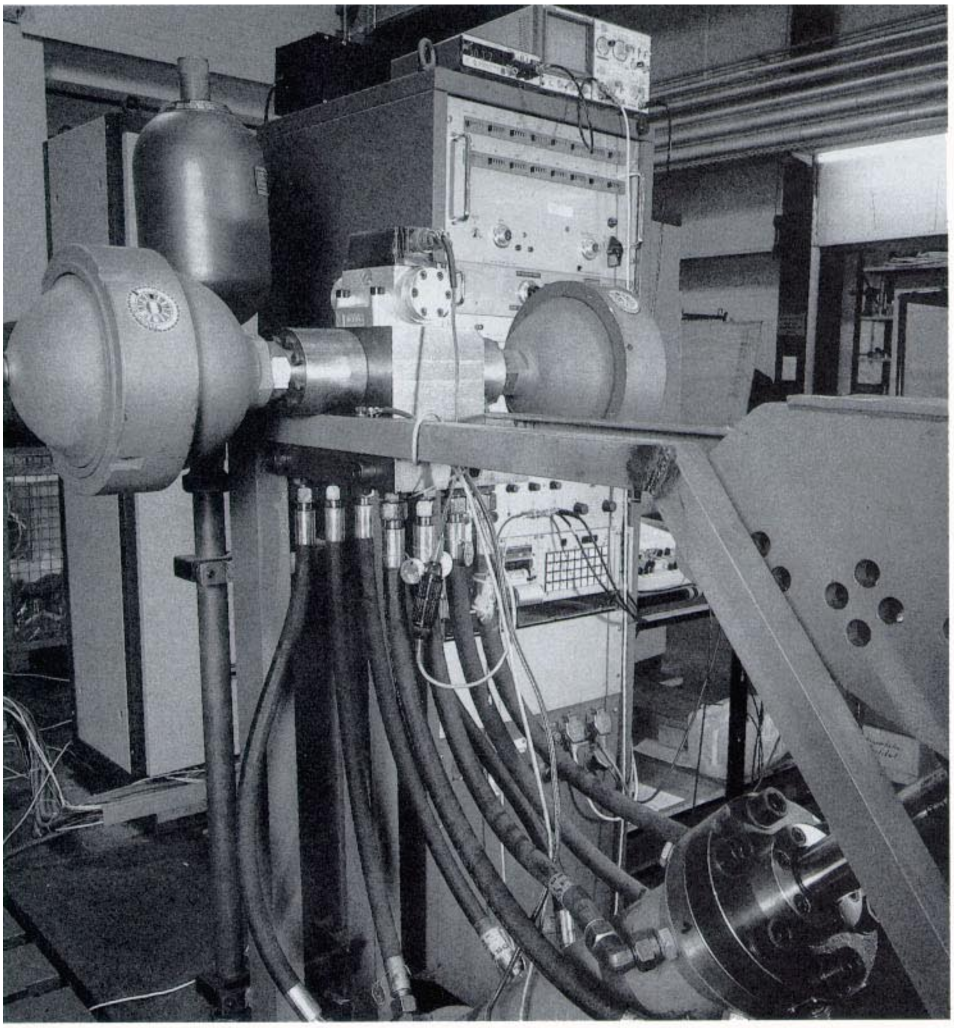
2. APPLICATIONS

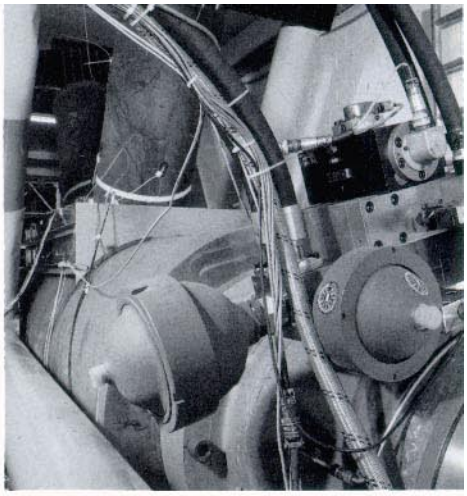
2.1. TYPICAL APPLICATIONS

HYDAC diaphragm accumulators, size 0.75 l, are used as pressure reservoirs for the hydraulic brake systems on all-wheel loaders. They are used for emergency operation of the brakes when the pump is not in operation and for reducing the pump output during normal operation.

For road transportation of extremely large or heavy components, special vehicles are used which have hydraulic axle compensation and HYDAC diaphragm accumulators as suspension elements.

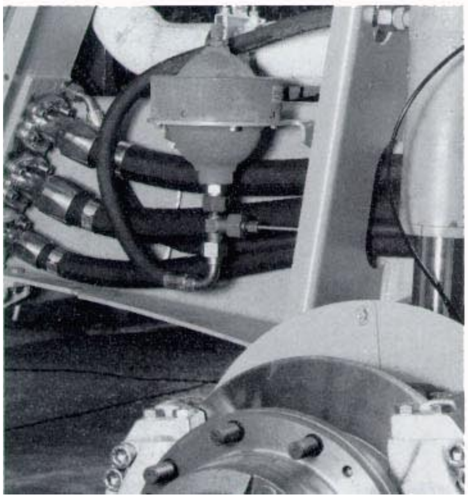
HYDAC diaphragm accumulators, size 0.75 l, were used to enable the hydraulically suspended arm of a hedge cutter to avoid uneven cutting or road surfaces.





Our diaphragm accumulators, 2.0 l and 4.0 l, screw type, are used on a test rig built by the Fraunhof Institute for Serviceability (IBF) in Darmstadt, Germany, for testing the fatigue limit of weld seams on a pipe line construction.

The Fraunhof Institute for Serviceability (IBF) in Darmstadt, Germany, has built a test rig for testing the fatigue limit of components under torsional stress. This test rig uses HYDAC diaphragm accumulators, screw type.

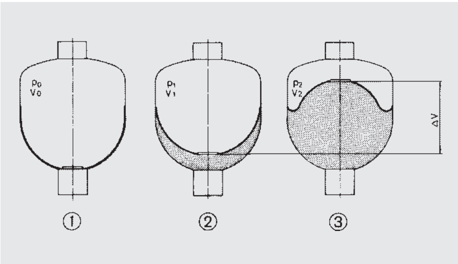


In order to absorb road surface shocks to the front wheels of O & K dumper trucks, HYDAC diaphragm accumulators, size 1.3 l, were used.

3. ACCUMULATOR SIZING

3.1. DEFINITION OF VARIABLES

p_0 = gas pre-charge pressure
p_1 = min. working pressure
p_2 = max. working pressure
V_0 = effective gas volume of accumulator
V_1 = gas volume at p_1
V_2 = gas volume at p_2
t_0 = pre-charge temperature (° C)
t_{min} = min. working temperature (° C)
t_{max} = max. working temperature (° C)



① The pre-charged diaphragm follows the inner contours of the accumulator. The valve poppet closes the fluid connection which prevents the diaphragm extruding from the shell.

② Position at minimum working pressure. A small quantity of fluid should remain in the accumulator so that the valve poppet does not hit the base each time the accumulator empties. p_0 should therefore always be lower than p_1.

③ Position at maximum working pressure. The difference in volume ΔV between the position at minimum and maximum working pressure represents the effective fluid volume:

$\Delta V = V_1 - V_2$

3.2. SELECTION OF GAS PRE-CHARGE PRESSURES

In order to obtain optimum efficiency from the accumulator the following gas pre-charge pressures are recommended:

3.2.1 Recommended values for energy storage

$p_{0\,t_{max}} = 0.9 \times p_1$

(p_1 = min. working pressure)

for pulsation damping:

$p_{0\,t_{max}} = 0.6 \times p_m$

(p_m = average working pressure)

or

$p_{0\,t_{max}} = 0.8 \times p_m$

(for several working pressures)

3.2.2 Critical values for the gas pre-charge pressure

a) **permissible pressure ratio $p_2 : p_0$**

Weld type:

2.8 and 3.5 litres	4 :1
other sizes:	8 :1

Screw type:

all sizes:	10 :1

Other pressure ratios on request.

b) **$p_{0,\,t_{max}} \leq 0.9 \times p_1$**

3.2.3 Temperature effect

In order that the recommended gas pre-charge pressures can be maintained, even at relatively high working temperatures, $p_{0,\,t_0}$ for filling and testing cold accumulators should be selected as follows:

$$p_{0,\,t_0} = p_{0,\,t_{max}} \times \frac{t_0 + 273}{t_{min} + 273}$$

To take into account the temperature effect when sizing accumulators, $p_{0,\,t_{min}}$ must be selected as follows:

$$p_{0,t_{min}} = p_{0,t_{max}} \times \frac{t_{min} + 273}{t_{max} + 273}$$

3.3. FORMULAE FOR SIZING ACCUMULATORS

The compression and expansion processes taking place in a diaphragm accumulator are governed by the polytropic changes of state.
The following applies for ideal gases:

$$p_0 \times V_0^n = p_1 \times V_1^n = p_2 \times V_2^n$$

where time is represented by the polytropic power "n".
For slow expansion and compression processes which occur almost isothermally, the polytropic power can be set at n = 1. For rapid processes, the adiabatic change of state can be calculated using $n = \chi = 1.4$ (for nitrogen as a diatomic gas)[1].

For pressures above 200 bar the real gas behaviour deviates considerably from the ideal one, which reduces the effective volume ΔV. In such cases a correction is made which takes into account a change of the χ value.

By using the following formulae, the required gas volume V_0 can be calculated for various applications.

Pressures of up to approx. 10 bar must always be used as absolute pressures in the formulae.

Calculation formulae:

poly-tropic:
$$V_0 = \frac{\Delta V}{\left(\frac{p_0}{p_1}\right)^{\frac{1}{n}} - \left(\frac{p_0}{p_2}\right)^{\frac{1}{n}}}$$

iso-thermal: (n=1)
$$V_0 = \frac{\Delta V}{\frac{p_0}{p_1} - \frac{p_0}{p_2}}$$

adiabatic: ($n=\chi=1.4$)
$$V_0 = \frac{\Delta V}{\left(\frac{p_0}{p_1}\right)^{0.714} - \left(\frac{p_0}{p_2}\right)^{0.714}}$$

Correction factors to take into account the real gas behaviour[2)]:

for an isothermal change of state:

$$C_i = \left(\frac{V_{0\,real}}{V_{0\,ideal}}\right)_{isothermal} \quad \text{or}$$

$$C_i = \left(\frac{\Delta V_{0\,ideal}}{\Delta V_{0\,real}}\right)_{isothermal}$$

for an adiabatic change of state:

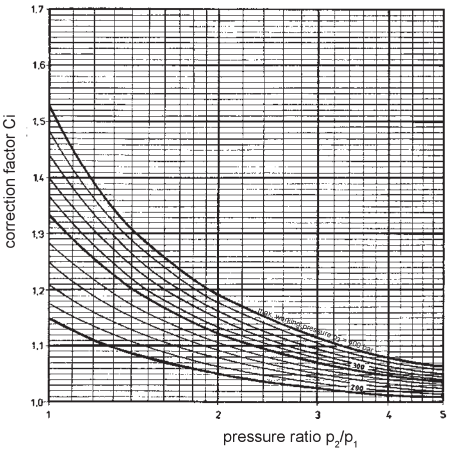
$$C_a = \left(\frac{V_{0\,real}}{V_{0\,ideal}}\right)_{adiabatic} \quad \text{or}$$

$$C_a = \left(\frac{\Delta V_{0\,ideal}}{\Delta V_{0\,real}}\right)_{adiabatic}$$

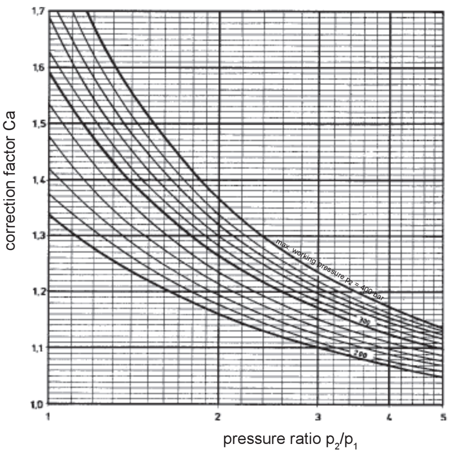
1) An estimate of accumulator size and a selection of pre-charge pressures can be made with the help of points 3.2 and 3.2.1. Accurate sizing, taking into account further limiting conditions, can be carried out by us; we have appropriate computer programs available.

2) The correction factors can be taken directly from the diagrams on page 7, depending on the pressure ratio p_2/p_1 and the maximum working pressure p_2, which is given as a parameter, for an isothermal or adiabatic change of state.

3.3.1 Correction factors for an isothermal change of state



3.3.2 Correction factors for an adiabatic change of state



3.4. CALCULATION EXAMPLE

A brake cylinder is to be operated on a cable winch by means of a HYDAC accumulator. Between a maximum working pressure of 210 bar and a minimum working pressure of 100 bar, an oil volume of 0.2 l must be made available. The maximum working temperature is 60 °C, the minimum temperature 25 °C.

Parameters:

max. working pressure
p_2 = 210 bar

min. working pressure
p_1 = 100 bar

effective volume ΔV = 0.2 l

max. working temperature
t_{max} = 60 °C

min. working temperature
t_{min} = 25 °C

Required:

a) necessary accumulator size, taking into account the real gas behaviour

b) gas pre-charge pressure p_0 at 20 ° C

Solution:

Since it is a rapid process, the change of state of the gas can be assumed to be adiabatic.

a) Determination of gas pre-charge pressure

$$p_{0\text{ at }t_{max}} = 0.9 \text{ x } p_1$$
$$= 0.9 \text{ x } 101 \text{ bar}$$
$$= 91 \text{ bar}$$

In order that the minimum required working pressure is not exceeded even at minimum working temperature, p_o must be calculated at t_{min}.

$$p_{0,t_{min}} = p_{0,t_{max}} \times \frac{t_{min} + 273}{t_{max} + 273}$$
$$= 91 \text{ bar} \times \frac{25+273}{60+273}$$
$$= 81.4 \text{ bar} \approx 81 \text{ bar}$$

Determination of the required gas volume:

$$V_{0\text{ ideal}} = \frac{\Delta V}{\left(\frac{p_{0(t_{min})}}{p_1}\right)^{0.714} - \left(\frac{p_{0(t_{min})}}{p_2}\right)^{0.714}}$$
$$= \frac{0.2}{\left(\frac{81}{101}\right)^{0.714} - \left(\frac{81}{211}\right)^{0.714}}$$
$$= 0.57 \text{ l}$$

Taking into account the real gas behaviour:

$$\frac{p_2}{p_1} = 2.09 \rightarrow C_a \approx 1.16$$
$$V_{0\text{ real}} = C_a \text{ x } V_{0\text{ ideal}}$$
$$= 0.66 \text{ l}$$

Selected:

Diaphragm accumulator
SBO 210 - 0.75

b) Determination of the gas pre-charge pressure p_0 at 20 °C:

$$p_{0,t_{min}} = p_{0,t_{max}} \times \frac{t_{min} + 273}{t_{max} + 273}$$
$$p_{0,20°C} = 91 \text{ bar} \times \frac{20+273}{60+273} = 80 \text{ bar}$$

Selected:

Gas pre-charge pressure at 20 °C
p_0 = 80 bar

4. RECOMMENDATIONS

4.1. GENERAL

On no account must any welding, soldering or mechanical work be carried out on the accumulator shell. After the hydraulic line has been connected it must be completely vented. Work on systems with accumulators (repairs, connecting pressure gauges etc) must only be carried out once the pressure and fluid have been released.

HYDAC diaphragm accumulators fitted with a HYDAC safety and shut-off block comply with the safety regulations to TRB. Please also see our brochure "Safety and Shut-off Block SAF/DSV" no. E 3.551.

4.2. EXTRACT FROM THE APPROVAL SPECIFICATIONS

4.2.1 Federal Republic of Germany

As pressure vessels, hydraulic accumulators are subject to the Pressure Vessel Regulations (DruckbehV). The design, manufacture and testing is in accordance with AD notices. Installation, equipment and operation are controlled by the "Technical Regulations - Pressure Vessels (TRB)". The pressure vessels of hydraulic accumulators are divided into groups, according to the permissible working pressure p in bar, the capacity I in litres and the pressure capacity p x l.
The Pressure Vessel Regulations (DruckBehV) remain in force until 29.05.2002 in parallel with the Pressure Equipment Directive 97/23/EC (transitional regulation), see point 4.2.3.
The following tests are prescribed for each group:

Group	Tests before commissioning at manufacturer´s	at user´s	Recurrent testing
II p > 25 bar and p x l ≤ 200	Manufacturer confirms satisfactory manufacture and testing by stamping 'HP' or by certificate	Inspection certificate (accuracy test, test of equipment and installation) by authorities	Test periods must be set by user according to experience of operating method and operating fluid
III p > 1 bar, p x l > 200 and p x l ≤ 1000	Preliminary inspection by authorities Construction and pressure testing and certification through manufacturer (registration of design), or through authorities (individual certificate)	Inspection certificate from authorities	As for group II
IV p > 1 bar and p x l > 1000	As for group III	As for group III	Internal test: every 10 years for non-corrosive fluids otherwise every 5 years. Pressure test: every 10 years Testing to be carried out by authorities

Elastomer compatibility table

In order to maximize system performance it is important to match your system fluid and its temperature range with the appropriate elastomer compound. The table below illustrates the most common ones. For special requirements, please consult HYDAC.

Compound	Operating temp. range	Some typical fluids
NBR (BUNA N)	-15 °C to + 80 °C	mineral oils
	0 °C to + 80 °C	water and water-glycols
LT-NBR (LOW TEMP. BUNA)	-40 °C to + 80 °C	mineral oils
ECO (HYDRIN)	-30 °C to +120 °C	mineral oils
IIR (BUTYL)	-30 °C to + 90 °C	phosphate esters brake fluids
FKM (VITON)	-15 °C to +150 °C	chlorinated hydrocarbons

Notes:

1. The operating temperature range does vary with fluid types, please consult HYDAC for more specific fluid data.
2. The above typical fluids are some examples of the most common fluids, please consult HYDAC for more specific data.
3. For other applications not listed, please consult HYDAC.

4.2.2 Other countries

Pressure accumulators which are installed in other countries are supplied with the test certificates required in that country. The user country must be stated when ordering. The German certificate is not generally accepted in all countries.

HYDAC pressure vessels can be supplied with virtually any test certificate.

The permissible working pressure can differ from the nominal pressure.

The following table contains the codes used in the model codefor different countries:

Australia	F
Austria	D
Belgium	H
Brazil	A1
Canada	S1
China	A9
CIS	A6
Czech. Rep.	A3
Denmark	A5
EU member states	U
Finland	L
France	B
Germany	A
Great Britain	K
India	N
Italy	M
Japan	P
Luxembourg	A1
Netherlands	C
New Zealand	T
Norway	A1
Poland	A4
Portugal	A1
Rep. of Ireland	A1
Romania	K
Slovakia	A8
South Africa	A1
Spain	A2
Sweden	R
Switzerland	G
USA	S
others on request	

4.2.3 European pressure equipment directive PED (DGRL/DEP)

On 29 November 1999 the directive 97/23/EC (pressure equipment directive) came into force. This directive applies to the design, manufacture and conformity assessment of pressure equipment and assemblies with a maximum permissible pressure of over 0.5 bar. It guarantees the free movement of goods within the European Community. EU member states must not prohibit, restrict or obstruct the circulation and commissioning of pressure equipment on account of pressure related hazards, if the equipment complies with the requirements of the pressure equipment directive and has the CE mark, and is subject to a conformity assessment.

According to Article 3, Paragraph 3, hydraulic accumulators with a capacity V ≤ 1 l, a maximum permissible pressure PS ≤ 1000 bar and a pressure capacity PS x V ≤ 50 bar x l do not receive a CE mark.
Operational safety and repeat testing are controlled as before by national laws.

5. TECHNICAL SPECIFICATIONS

5.1. MODEL CODE

(also order example)

SBO 210 – 2 E1 / 112 A – 210 AK 50

Series

Nominal volume (l)

Type code[2)]
E1 = weld type, standard model, rechargeable (M 28 x 1.5)
E2 = weld type, sealed gas connection
with gas pre-charge pressure as requested
E3 = weld type, gas valve M 16 x 1.5, rechargeable
A6 = screw type, standard model, rechargeable (M 28 x 1.5)
A3 = screw type, gas valve M 16 x 1.5, rechargeable

Material code[2)]
depending on operating fluid
standard model = 112 for mineral oil

Fluid connection
1 = carbon steel
3 = stainless steel (316)
4 = carbon steel with surface protection[1)]
6 = low temp. carbon steel (-40 °C)

Accumulator body
0 = plastic coating
1 = carbon steel
2 = carbon steel with surface protection[1) 3)]
4 = stainless steel (316)
6 = low temp. carbon steel (-40 °C)

Diaphragm
2 = NBR (acrylonitrile butadiene)
3 = ECO (ethylene oxide epichlorohydrin)
4 = IIR (butyl)
5 = low temperature - NBR
6 = FKM (fluoro rubber)
7 = others (on request)

User country[2)]
A = Germany
(for other countries see table under 4.2.2.)

Permissible working pressure (bar)

Fluid connection[2)]
AK = standard
AB = standard

for other connections, see point 6.1.,
or contact our sales/technical department
e.g. form AK = G ¾
for SBO 210-2 see table on page 10

Pre-charge pressure p_0 at 20 °C (bar) to be advised when ordering[4)]

1) only for screw type
2) not all combinations are possible
3) only parts in contact with the medium
4) only for type E1 or E2, for scheduled orders

5.2. GENERAL

5.2.1 **Permissible working pressure**
See tables 6.1 and 6.2.

In other countries the permissible working pressure can be different to the nominal pressure.

5.2.2 **Nominal volume**
See tables 6.1. and 6.2.

5.2.3 **Effective gas volume**
Corresponds to the nominal volume of the diaphragm accumulator.

5.2.4 **Effective fluid volume**
Volume of fluid available between the working pressure p_2 and p_1.

5.2.5 **Fluids**
Mineral oils, hydraulic oils.
Other fluids on request.

5.2.6 **Gas charging**
Only use nitrogen when charging diaphragm accumulators, never oxygen (risk of explosion).
All accumulators are supplied with a protective pre-charge.

Higher gas pre-charge pressures are available on request.

5.2.7 **Permissible operating temperature**
-10 °C to + 80 °C
(263 K to 353 K) for material code 112.
Others on request.

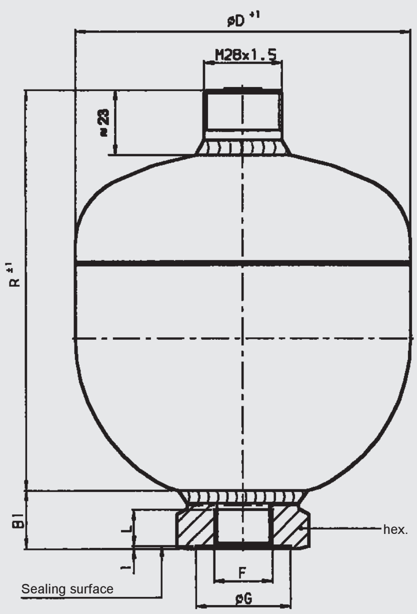
5.2.8 **Permissible pressure ratio**
Ratio of max. working pressure p_2 to gas pre-charge pressure p_0 (see 3.2.2).

5.2.9 **Maximum flow rate**
It is necessary to ensure that a residual fluid volume of approx. 10 % of the effective gas volume remains in the accumulator if the maximum flow rate given in the tables is to be achieved.

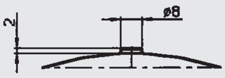
6. DIMENSIONS

6.1. WELD TYPE - non-exchangeable diaphragm -

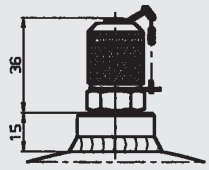
Type E1
Form AK



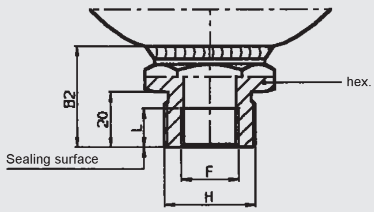
Type E2



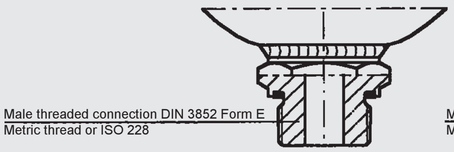
Type E3

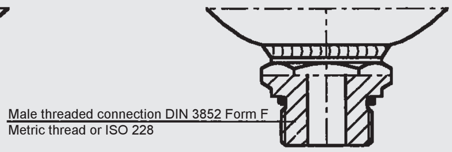


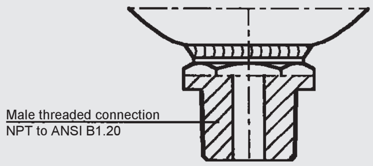
Form AB



Alternative fluid connection on request
Examples:







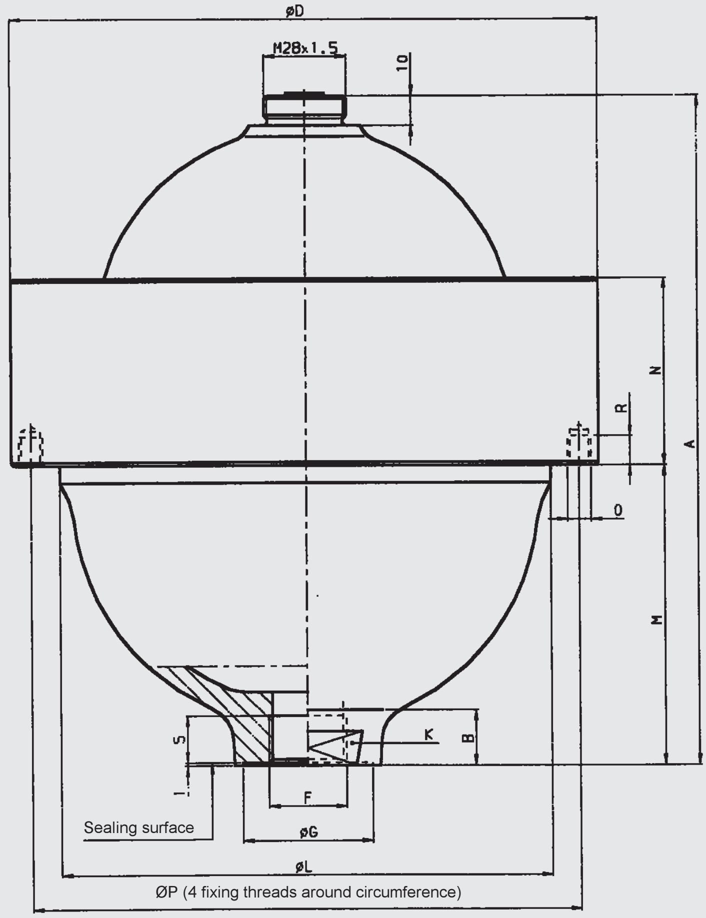
Nominal volume[1] (l)	Per-missible pressure ratio $p_2 : p_0$	Series	User country A – Perm. working pressure (bar) – Carbon steel	Stainl. steel	R (mm)	ØD (mm)	Weight (kg)	Q[2] (l/min)	Standard - Fluid connection – Form AK – F (ISO 228)	ØG (mm)	L (mm)	B[1] (mm)	hex. SW	Form AB – F (ISO 228)	H (DIN 13)	L (mm)	B[2] (mm)	hex. SW
0.075	8 : 1	250	250		91	64	0.7	38	G 1/2	-	14	21	30	not available				
0.16		210	210	180	103	74	0.8											
0.32		210	210	160	116	93	1.3	95										
0.5		210	210		133	105	1.7											
0.6		330	330		151	115	3.3			34			41	G 1/2	M33 x 1.5	14	36	41
0.7		100	100		151	106	1.8											
0.75		210	210	140	147	121	2.8											
		330	330		140	126	4.0					26				15	42	
1		200	200		160	136	3.6											
1.4		140	140		173	145	3.9					21				14	36	
		210	210		179	150	5.4											
		330	330		174	155	7.6					31				15	42	
2		100	100	100	190	160	4.0	150	G 3/4	44	16	28	46	G 3/4	M45 x 1.5	16	33	46
		210	210		196	167	6.6											
		330	330		183	172	8.7					42					42	
2.8	4 : 1	210	210		250	167	8.2					28					33	
		330	330		238	172	11.0					42					42	
3.5		250	210		306	170	11.2					28					33	
		330	330		276	172	13.8					42					42	

1) others on request
2) max. flow rate

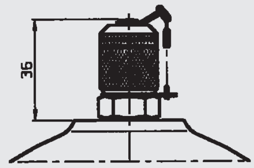
6.2. SCREW TYPE - exchangeable diaphragm -

6.2.1. **Standard Model**

Type A6 (Standard)



Type A3



Nom. vol.[1] (l)	Per-missible pressure ratio $p_2 : p_0$	Series	User country A Perm. working pressure (bar) Carbon steel	Stainl. steel	Weight (kg)	A (mm)	B (mm)	ØD (mm)	ØL (mm)	M (mm)	N (mm)	O	ØP (mm)	R (mm)	Q[2] (l/min)	Standard - Fluid connection Form AK F ISO 228	S (mm)	ØG (mm)	K SW
0.1	10 : 1	500	500		1.9	110	30	95	68	53	35	-	-	-	95	G ½	14	-	32
0.25		500	500	350	3.9	128	20	115	92	55	55							-	36
		750	750	600	9.0	136	11	153	114	58	63							27	36
0.6		450	330	250	5.7	170	19	140	115	68	57							34	41
1.3		210	210		8.5	190	8	170	145	78	55	M8	160	10				-	32
		400	400		11.2	197	28	199	160	97	65		180		150	G ¾	16	44	50
2		100	100		10.7	227	17	201	168	101	64		188						
		250	250	180	11.4														
2.8		210	210		15.5	242	6	216	185	103	70		204					-	41
		400	400		22.0	257	30	252	207	106	80		230					44	50
4		210	210		23.0	280		250	214	129	74		235						65
		400	400		34.0	262		287	236	106	90		265						50

1) others on request
2) max. flow rate

7. PLEASE NOTE

For supports, see brochure no. E 3.502../..
All details in this brochure are subject to technical modifications.