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Information from AHP.

Since 1973 the name AHP Merkle stands for 100% quality, flexibility and innovations. All of our developments are proving our guideline: AHP Merkle is moving.

With “Information from AHP” we are taking one step forward, and complete our large cylinder range with basic knowledge, helpful advice, and valuable tips regarding the topic “Hydraulic cylinders”.

BZP 1/64

MBZ 1/80

ZHZ 6/2

VBZ 8/1

NEW

1



BZ, BZ 250,
BZN, BZN 250,
BZP, MBZ,
BZR, BZH, BRB,
BRBN, BVZ

Blockzylinder
Block cylinder
Vérin-bloc

2



STZ

Stanzzylinder
Stamping cylinder
Vérin d'estampage

3



RZ

Rundblockzylinder
Circular block cylinder
Vérin-bloc cylindrique

4



BSE, BSEP,
ZSE, ZSEP,
BZS

Schiebereinheiten
Push unit
Pousseur

5



UZ 100, UZN 100,
HZ 160, HZN 160,
HZ 250, HZH 250,
HZN 250, HZHN 250,
MHZ 160, HMZ

Standardzylinder
Standard cylinder
Vérin standard

NEW

6



DHZ,
ZHZ

Normzylinder
DIN standard cylinder
Vérin normalisé

7



HZF

Hydraulikzylinder mit äußerer Führung
Hydraulic cylinder with external guide
Vérin hydraulique avec guidage extérieur

NEW

8



VBZ

Verriegelungszyylinder
Locking cylinder
Vérin Autobloquant

9



WKHZ, KHZ

Kurzhubzylinder
Short-stroke cylinder
Vérin-cube à course réduite

10



EZ

Einschraubzylinder
Screw-in cylinder
Vérin fileté

11



KZE
KZEP

Kernzugeinheit
Core pull unit
Unité tire-noyau

12



FZ

Flanschzylinder
Flanged cylinder
Vérin à collet

13



DFZ

Doppelrohrzylinder
Double-lined cylinder
Vérin à double tube

14



BZF, BZK

Spannelemente
Clamping elements
Éléments de bridage

15



DA

Drehantrieb
Rotary drive unit
Servomoteur rotatif

16



ahp.solutions

17



Zubehör
Accessories
Accessoires

Information from AHP.

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5 Cylinder finder 94

A clear overview of the large product range from AHP Merkle. A fast selection giving the perfect product is possible through the required product properties.



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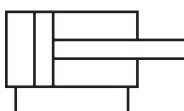
1 Basic information about hydraulic cylinders

1.1 Descriptions of the various types of cylinders

Differential cylinders

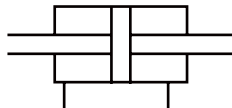
For hydraulic cylinders, a distinction is made between differential cylinders and double rod cylinders based on their methods of operation. Differential cylinders generally have only one piston rod. This means that there are differences in the size of the surfaces that determine the force generated and the speed of the piston. Under the same pressure and flow conditions both the force generation and the speed of the forwards and return stroke of the cylinder are distributed in accordance with the area ratio.

An additional distinction is made between single-acting and double-acting cylinders. While single-acting hydraulic cylinders have a pressure port on only one end, double-acting hydraulic cylinders have a port for both cylinder chambers in order to be able to perform forwards and backwards motions. With single-acting hydraulic cylinders, either the forward or return stroke has to be performed by an external force, such as spring force or gravity.



Double rod cylinder

Cylinders with a through style piston rod are called double rod cylinders. Unlike with differential cylinders, the pressurized surface is the same size for both the forwards and return stroke. This means that the work with the same conditions and in the same manner for both the forwards and return stroke. The amount of hydraulic fluid that should be introduced corresponds to the volume being displaced.



1.2 Types

Block cylinder (BZ)

A characteristic feature of block cylinders is their rectangular housing. This housing shape allows the implementation of various mounting options. They can be operated with an operating pressure of up to 500 bar (7250 PSI), and there are various options for sensing the piston position. For strokes greater than 200 mm (7.87 inches) the housing has a cuboid shape; larger strokes are implemented using a tube between the cuboid head and the bottom. The main area of application of block cylinders is mold construction.

Block cylinder with wedge clamp element / guide rod (BZK / BZF)

With these cylinders, a guide housing is flanged to a block cylinder. This housing guides a hardened rod that can be loaded with side forces. With the wedge clamp element (BZK), a bevel is created in the guide rod. This can be used, for example, to for the clamping of workpieces. With the BZF, the guide rod is used as a guide with the capability to absorb side forces, which with hydraulic cylinders normally has to be avoided.

Block cylinder with non rotating piston rod (BVZ)

These cylinders are available up to 250 bar (3625 PSI) and maximum permissible torques between 3 and 90 Nm (2.21 and 66.38 foot-pound force). This cylinder option is always advantageous when the piston rod – and any tools that it moves – are not allowed to rotate.

Circular block cylinder (RZ)

Circular block cylinders are a variant of the block cylinder product line. Their structural design is the same as that of the block cylinder. Their externally visible difference from them is their cylindrical housing, which has proven to be advantageous in some installation situations where little space is available.

Flanged cylinder (FZ)

Flanged cylinders are round hydraulic cylinders with flanges. Thanks to their small dimensions they are often used in fixture and mold construction. The pressure ports are located in the screw-on flange, and thus at one end of the cylinder. In practice, flanged cylinders are best suited for strokes up to 100 mm; in addition, the use of double-lined cylinders is advisable.

Cube cylinder (WKHZ)

Cube cylinders are cylinders with especially small external dimensions. They are thus used most often when there is not enough space for standard or block cylinders. Their maximum operating pressure is 400 bar (5800 PSI).

Short-stroke cylinder (KHZ)

Short-stroke cylinders have an external thread over their entire length. This means that they can be screwed into or flanged directly to a fixture, and can thus be adjusted optimally. Such cylinders can be fixed very easily using the supplied lock nut. Both hydraulic connections are arranged axially on the cylinder bottom.

Double-lined cylinder (DFZ)

Double lined cylinders are hydraulic cylinders with a very special design. Structurally they are designed with two cylinder tubes that are built one inside the other and sealed pressure-tight relative to each other. They can be ordered even for long strokes. The distinguishing feature of double lined cylinders is their round construction with a flange at one end. The flange is located either at the rod end or at the piston end. Attached to this flange are both ports for the forwards and return stroke, and the cylinder is also mounted on it. The use of double lined cylinders is always advisable when due to long strokes and installation in large molds one end of the cylinder is hard to access, and thus both ports have to be located on one end.

Standard cylinder (UZ, HZ, HZH)

AHP Merkle classifies its standard cylinders into three pressure ranges (100, 160 und 250 bar / 1450, 2320 and 3625 PSI) and four series (UZ 100, HZ 160, HZ 250 and HZH 250). These are all characterized by their round construction with a screwed head and bottom. Customers can choose between twelve different mounting options and the choice of integrated proximity switches or linear position transducer.

DIN standard cylinder (DHZ, ZHZ)

DIN standard cylinders are designed and manufactured according to the installation dimensions as per the standards DIN ISO 6020/2 / DIN ISO 6020/1 / ISO 6022, DIN 24333. A distinction is made between the pressure ranges 160 and 250 bar (2320 and 3625 PSI). Various mounting options are available.

Push units (BSE, ZSE)

Thanks to their additional external guides, push units can absorb high transverse forces and torques. This series contains options with 2, 3 or 4 guide columns. A front plate can be used to mount customer-specific tools.

Block pusher (BZS)

Block pusher units are modified block cylinders with integrated guides. This means that they are able to absorb certain side forces. Although these forces are smaller than with push units, on the other hand block pushers are very compact, and can be installed even in cramped spaces. This cylinder option provides an ideal combination of the advantages of block cylinders and push units.

Locking cylinder (VBZ)

Depending on the part geometry to be injected, it may be necessary to create a breakthrough or an undercut. The application requires keeping a core or a feeder in the cavity. This task is achieved through a Locking Cylinder. With its compact design, it withstands very high forces thanks to a mechanical locking mechanism (positive locking). This is mainly used in injection mold manufacturing.

Stamping cylinder (STZ)

The stamping cylinders are a further development of the block cylinder. A characteristic feature of stamping cylinders is that thanks to the special design and arrangement of their seals and guides they can absorb the large dynamic loads that are generated during stamping.

Screw-in cylinder (EZ)

The most space-saving option among AHP Merkle hydraulic cylinders are the screw in cylinders. Because these cylinders are screwed directly into the tool, the tool functions as a housing. The customer / user only has to create the mounting bore with the associated intake bores for forwards and return travel in the tool. There are both single-acting and double-acting options.

Core pull units (KZE)

Core pull units are primarily used in mold construction, but can also be used for other applications in which precise guiding is needed. By using these units, the user does not need to design an elaborate guide, such as those required with core pullers. The core pull unit is designed so that the entire piston surface is acted upon for „pulling“. Unlike with a pulling cylinder, this means that a smaller piston can be used with the same operating pressure. The space savings with this design can be up to 35% compared to conventional solutions. The precise guiding of the slide is ensured through the use of cross roller guides.

Hydraulic cylinder with external guide (HZF)

These hydraulic cylinders are available with external guides for max. pressures of up to 160 bar (2320 PSI). The cylinder liner is plasma nitrated and suitable for use as a guide. These cylinders are used very often in aluminum die casting systems.

Rotary drive units (DA)

There exist hydraulic rotary drives with angles of rotation from 0° to 720° and torques of up to 1,400 Nm (1,032.59 foot-pound force). Here the rotational motion is achieved via a hydraulically driven rack-and-pinion system. Thus this type of kinematic system is not comparable to those with hydraulic motors. The maximum torque is reached at the operating pressure of 50 bar.

1.3 General calculations



The design tool **ahp.calc** can be used to carry out a lot of complicated calculations in an easy and user-friendly way. The app also contains all calculations listed in chapter 1.3.

Conversions

$$1 \text{ Pa} = 1 \frac{\text{N}}{\text{m}^2} = 1 \frac{\text{kg}}{\text{m} \cdot \text{s}^2}$$

$$1 \text{ MPa} = 1 \frac{\text{N}}{\text{mm}^2} = 10 \text{ bar}$$

$$1 \text{ PSI} = 6.8948 \cdot 10^3 \text{ Pa} = 6.8948 \cdot 10^{-2} \text{ bar}$$

$$1 \text{ N} = \frac{\text{kg} \cdot \text{m}}{\text{s}^2}$$

$$1 \text{ W} = \frac{\text{kg} \cdot \text{m}^2}{\text{s}^3}$$

Force / piston diameter

- A: effective piston surface [mm²]
- F: force [N]
- p: pressure [bar]
- D: piston diameter [mm]
- d: rod diameter [mm]
- η: efficiency of the hydraulic cylinder

The efficiency [η], which is for the most part the result of the frictional losses (seals, guides), can be approximated as 0.8. The larger the cylinder, the smaller the effect of friction on the overall force. At speeds of less than 0.05 m/s (0.164 feet/s), the friction is practically independent of the pressure.

For piston diameters of 100 mm (3.94 inches) and larger the percentage loss is not more than 2%, even in the worst case. With even larger piston diameters it can even be regarded as insignificant.

Example:

For cylinders with a piston diameter of less than 20 mm (0.79 inches) and an operating pressure of approx. 140 bar (2030 PSI) the frictional losses can be about 20%. For a piston diameter of 100 mm (3.94 inches) this value is reduced to 2%.

It has been noted in practice that new seals have relatively high frictional values, which however become lower as the operating time increases, thus increasing the efficiency of the hydraulic cylinder. This should be taken into account above all when the cylinders are being operated at low speeds (stick-slip effect), or low operating pressures are present.

For hydraulic cylinders, the interrelationship between the force [F], the system pressure [p] and the piston area [A] is produced by the following formula:

$$F = 0.1 \cdot A \cdot p \cdot \eta$$



The force resulting from the system pressure is lower at the rod end than at the piston end. The effective surface is calculated as follows:

$$A = A_{\text{piston}} - A_{\text{rod}} = \frac{(D^2 - d^2) \cdot \pi}{4}$$

As a general rule, the circular area [A] is calculated from the diameter [D] using the following formula:

$$A = \frac{D^2 \cdot \pi}{4}$$

Alternatively from the force to be applied [F] and the pressure [p]:

$$A = \frac{F}{p \cdot \eta}$$

Determination of the piston diameter as a function of the system pressure and the required force:

$$D = \sqrt{\frac{4 \cdot F}{p \cdot \pi \cdot \eta}}$$

! Especially for pushing loads, in addition to the dimensioning of the hydraulic cylinder it is also necessary to calculate the buckling strength of the piston rod.

Tip For easy calculation of hydraulic cylinders you can use the cylinder calculator available on the Internet at www.ahp.de, which will recommend to you the suitable cylinder for your application.

Piston speed from flow rate / pump capacity

- v: piston speed [m/s]
- Q: flow rate [l/min]
- A: piston surface [mm²]
- P: required pump capacity [KW]
- p: system pressure [bar]
- η: efficiency of the hydraulic system

$$v = \frac{Q}{A \cdot 0.06}$$

$$v = \frac{P \cdot \eta \cdot 10^4}{A \cdot p}$$

$$P = \frac{Q \cdot p}{600 \cdot \eta}$$

Required oil quantity / flow rate

- Q: flow rate [l/min]
- A: piston surface [mm²]
- v: piston speed [m/s]
- η: efficiency of the hydraulic cylinder

$$Q = A \cdot 0.06 \cdot v$$

$$Q = \frac{P \cdot 600 \cdot \eta}{p}$$

Recommended flow speeds

The flow speeds in the pipes are limited.
The recommended flow speeds depend on pressure.

| | | |
|-----------------|-----------------------------------|-----------------------------------|
| Suction lines: | ≤ 1.5 m/s (4.92 feet/s) | |
| Return lines: | ≤ 3 m/s (9.84 feet/s) | |
| Pressure lines: | ≤ 25 bar (362.5 PSI) | ≤ 3 m/s (3.28 feet/s) |
| | 25 to 63 bar (362.5 to 913.5 PSI) | 3 – 5 m/s (10.76 to 16.40 feet/s) |
| | 63 to 160 bar (913.5 to 2320 PSI) | 4 – 6 m/s (13.12 to 19.68 feet/s) |
| | 160 to 250 bar (2320 to 3625 PSI) | 5 – 8 m/s (16.40 to 26.24 feet/s) |
| | > 250 bar (3625 PSI) | ≤ 10 m/s (32.8 feet/s) |

Buckling strength

Proper dimensioning of hydraulic cylinders with pushing load makes use of the four so-called Euler buckling modes. Because the following calculations already include a quintuple safety margin, the results can be used directly.

- d: Piston rod diameter [mm]
- F: Axial force [N]
- L: Mounting distance [mm]

First Euler buckling mode: piston rod is neither guided nor fastened – cylinder fixed

$$L = \sqrt{\frac{\pi^3 \cdot d^4 \cdot 164.06}{F}}$$



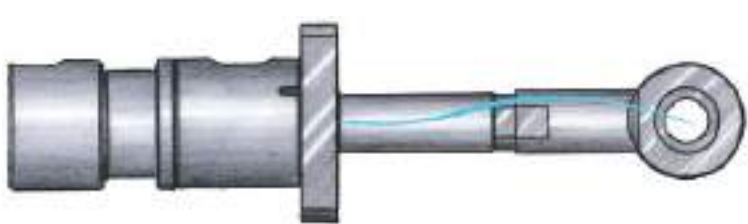
Second Euler buckling mode: piston rod and cylinder with rotating bearing

$$L = \sqrt{\frac{\pi^3 \cdot d^4 \cdot 656.25}{F}}$$



Third Euler buckling mode: piston rod with rotating bearing – cylinder fixed

$$L = \sqrt{\frac{\pi^3 \cdot d^4 \cdot 1312.5}{F}}$$



Fourth Euler buckling mode: piston rod guided and fastened – cylinder fixed

$$L = \sqrt{\frac{\pi^3 \cdot d^4 \cdot 2625}{F}}$$



1.4 Pressures in hydraulic cylinders

Pressure spikes

In the operation of hydraulic cylinders, it is a basic rule that the permitted pressure values must not be exceeded, even for a short time. It must be ensured that no pressure spikes occur in the system, either caused by the pump, nor due to external mechanical influences. Otherwise damage may result in the seals or the cylinder.



Pressure spikes due to highly dynamic motions must always be absorbed by means of separate cushioning measures in the cylinder (cushioning) or outside of the cylinder (shock absorbers). It must always be ensured that the momentum of the motion process is NOT dissipated in the end positions of the cylinder.



In special applications such pressure spikes are unavoidable. Thus, for example, pressure spikes can occur during stamping whose level is many times that of the system pressure. Normal hydraulic cylinders are not suitable in this case; for such applications there are special stamping (block) cylinders that are designed for such extreme loads.

1.5 Drag flow pressure

AHP Merkle designs the cylinders in such a manner that under normal conditions there is no drag flow pressure. However, in unfavorable operating conditions it is possible for a drag pressure, which is higher than the pressure in the cylinder chamber, to build up on the rod end.

This can happen, for example, if external forces cause the piston rod to retract in such a way that the seal is not able to return the leak oil – e.g. due to vibrations or impacts. If the drag pressure increases excessively, damage to the primary seal and thus failure of the sealing system may result.

1.6 Seal systems

Modern sealing system are composed of various individual components (e.g. sealing ring, supporting ring, wiper, etc.), each of which has its corresponding purpose. Adapting them properly to the particular operational requirements has a decisive effect on how long hydraulic cylinders can operate without faults. Among other things, this means that seals that provide proper sealing under high pressures are not necessarily suitable for low pressures.



The compatibility of the hydraulic fluid with the seal material has to be tested.



AHP Merkle's years of experience in the development and production of hydraulic cylinders resulted in the selection of seals that cover the widest range of applications possible.

1.7 Operating temperature

For standard hydraulic cylinders, the upper limit for the operating temperature is 80 °C (176 °F). This is based on the selection of seals, which are composed of the elastomers polyurethane (PU), polytetrafluorethylene (PTFE) or nitrile butadiene rubber (NBR).

With temperature-resistant seals such as fluororubber (FKM) it is possible to achieve as a maximum operating temperature of up to 180 °C (392 °F) in special cases.



Short strokes lead to a very small oil exchange in the cylinder chambers and thus to heating of the pressure fluid, which also has a negative effect on the seals. The resulting lack of oil circulation results in increased oil contamination (e.g. due to wear) and reduction of the oil additivization.



With regard to the temperatures arising during operation of hydraulic cylinders it must be noted that all of the design elements have been dimensioned for this temperature. These include not just seals, guides, switches, etc., but also the hydraulic fluid itself. Furthermore, the compatibility of the hydraulic fluid with the seal materials has to be tested.

For certain applications, it may be helpful to use a hydraulic cylinder with integrated water cooling. In this way, the temperature of the cylinder can be reduced.

1.8 Air in the hydraulic system

It must always be ensured that there are no air trapped in the hydraulic fluid (oil change, maintenance work, etc.). Rapid compression can cause such air bubbles to heat up so much that spontaneous ignition (in the mineral oil) of the air-gas mixture can occur. The resulting increase in pressure and temperature contributes not only to oil aging, but can also damage the seals and the components in the hydraulic cylinder. This process is also known as the Diesel effect.

Up to ten percent air by volume can be dissolved in hydraulic fluid under atmospheric pressure. If the system pressure drops below the vapor pressure of the fluid, air bubbles are formed; these expand rapidly to form larger bubbles together with oil vapor. Compression processes can then result in the Diesel effect.

1.9 Piston speed

Like the maximum operating temperature, the maximum permissible piston speed is based on the selection of seals in the hydraulic cylinder. In practice, a maximum piston speed of 0.5 m/s (1.64 feet/s) is generally assumed. If this is exceeded, a cylinder solution should be specially adapted to the existing requirements. The corresponding cylinder selection options are available, among other places, at www.ahp.de.

In like manner it is necessary to adapt a cylinder to the corresponding application if the piston speeds are very low. This is because so-called stick-slip effects occur that allow the piston rod to „judder“ in the micro area.

This means that the piston rod moves in the narrow range between static and dynamic friction. At speeds of less than 0.05 m/s (0.164 feet/s), the friction is practically independent of the pressure.



Such an undesirable stick-slip effect is significantly amplified by yielding in the hydraulic system, such as air bubbles in the hydraulic fluid, and is generally connected with increased noise generation.

In the case of very dynamic applications, which also move large masses, heavy loads are made on the cylinders, the seals and the pressure fluid. The existing kinetic energy has to be deflected in a very short time. In such cases it is advisable to use hydraulic cylinders with integrated cushioning, and in the case of high loads also external shock absorbers. The cushioning of the stroke is available in adjustable and non-adjustable options – depending on the type of cylinder and the piston diameter.



Cushioning only makes sense starting with a stroke length that is longer than the cushioned path, because otherwise the piston would only move within the cushioned path. This would result in long cycle times and increased power requirements, and would have to be taken into account in the design.

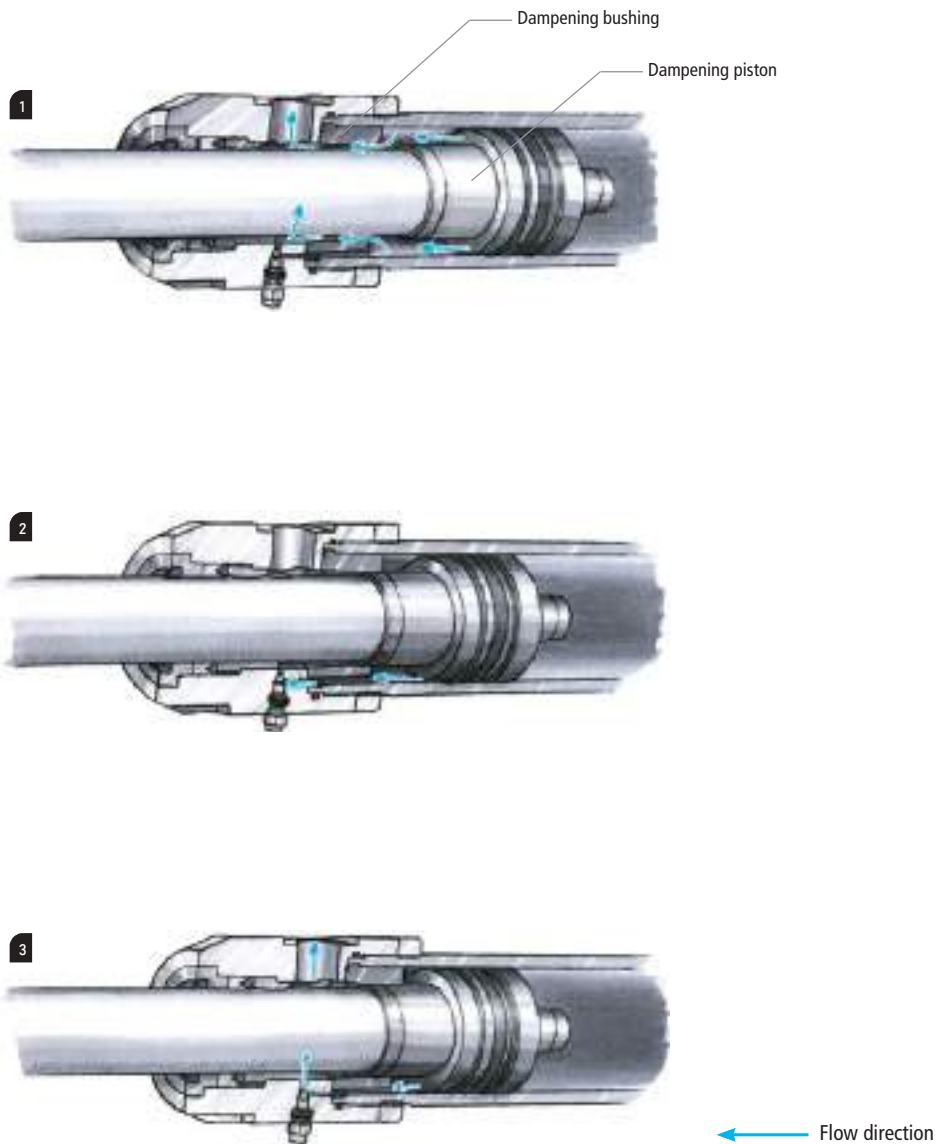
1.10 Cushioning of the stroke

Internal and external cushioning is advisable for high travel speeds with a fast approach to the end position – i.e. for also very dynamic drives. In this manner it is possible to prevent damage to the cylinder or to the piston rod, to reduce operating noises, and to reduce wear in the application. Integrated end position cushioning has an additional advantage that the kinematic/potential energy in the end position is reduced without causing the force loss of the cylinder. The cushioning of the stroke is also advisable, for example, when first programming a system, or during commissioning. The stroke should be cushioned where the piston moves against the stop with a speed greater than 0.1 m/s (0.328 feet/s)

The cushioning of the stroke in the hydraulic cylinders serves to absorb energy. At the end of the piston there is a so-called dampening piston (image 1). This moves in a dampening bushing, thus separating the piston chamber from the connection (image 2). The hydraulic fluid then flows through channels to the return flow connection (image 3). The cushioning characteristic curve is based on their dimensioning. The cushioning of the stroke has an adjusting screw that can be used to vary the flow cross-section. This means that the farther the piston moves in, the higher the cushioning effect. At a certain point the cushioning intensity becomes constant to the end of stroke.

Tip

An optimal solution for reducing the piston speed at the end of stroke without loss of force, is by cushioning the stroke of the AHP Merkle cylinder.



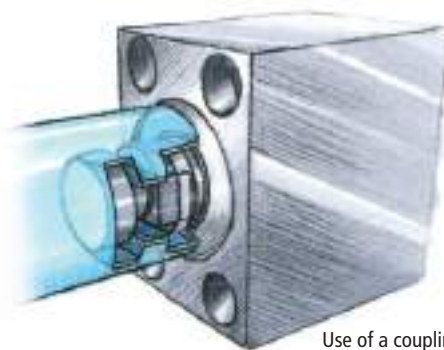
1.11 Effect of external forces

Hydraulic cylinders are extremely powerful, whose specific force generation is practically unique compared to other types of actuators. They provide their performance in the axial direction. This means that it is necessary to calculate the buckling strength and the basic system limits based on the pulling and pushing loads. At the same time, interaction with the specific application almost always results in side forces. These should be eliminated as much as possible, or should be absorbed using separate (mechanical) construction; this is also required by DIN EN ISO 4413. For example, one good possibility is to use appropriate couplings, like those offered by AHP Merkle. These allow side motions without transferring them to the piston rod. Alternatively, AHP Merkle has cylinder options that can absorb transverse forces and torques, such as the push units (BSE, ZSE) and core pull units (KZE).



Side forces or torques on hydraulic cylinders lead to:

- damaged guides
- damaged piston rods
- damaged running surfaces
- destroyed seals



Use of a coupling to avoid side loads.

1.12 Hydraulic fluids

Hydraulic fluids are subdivided into the following basic categories

- Mineral-oil based hydraulic fluids
- Flame retardant hydraulic fluids
- Quickly biodegradable hydraulic fluids

Mineral-oil based hydraulic fluids are designated in ISO 6743/4 as HL, HM, HV, and in DIN 51524 with HL, HLP, HVLP.

HL stands for hydraulic oils made of mineral oils with active ingredients that improve their corrosion protection and aging resistance. HLP oils improve the corrosion resistance, the aging resistance and the wear due to scoring in the mixed friction range. HVLPs additionally improve the viscosity/temperature behavior. There are also HLP-D hydraulic fluids that include cleaning additives (detergents).



There are certain additives in mineral oils that can accelerate the aging of elastomer seals at high temperatures. This results in subsequent vulcanization, which causes hardening and a loss of elasticity.



Use of zinc-free HLP oils in combination with certain sealing materials may result in increased wear of sealing elements and running surfaces.

Flame retardant hydraulic fluids are classified in VDMA 24317. They are available as HFAE, HFAS, HFB, HFC and HFD oils.

HFAEs are oil-in-water emulsions with a water content of greater than 80% and a mineral-oil or soluble polyglycol-based concentrate. In the mineral-oil based option it is necessary to watch out for decomposition and microbe growth. The fluid can be used at temperatures from +5 °C to +60 °C (+41 °F to +140 °F). For HFASs with synthetic concentrates there is no danger of decomposition. However, attention should be paid to the significantly increased tendency for corrosion.

HFBs are water-in-mineral oil emulsions with a water content greater than 40%. These hydraulic oils can also be used from +5 °C to +60 °C (+41 °F to +140 °F), but are not approved for use in Germany due to their inadequate fire safety characteristics.

HFCs are so-called aqueous glycols, quasi aqueous monomer or polymer solutions (frequently polyglycols). Their water content is generally between 35% and 65%. These flame resistant hydraulic fluids can be used at pressures of up to 250 bar (3625 PSI) and temperatures between -20 °C and +60 °C (between -4 °F and +140 °F).



When using HFC fluids, it must be clarified whether the seal materials being used are suitable. While fluororubber (FKM) is not suitable in every case, seals made of acrylnitrile-butadiene rubber (NBR) are unproblematic.

HFDs are water-free fluids that can be used in the temperature range from +20 °C to +150 °C (+68 °F to +302 °F). Their compositions differ greatly, which means that a further distinction is made among HFD-R, HFD-S, HFD-T, HFD-U. These fluids are flame retardant, but can cause problems in the suction performance of pumps, and they are corrosive to many seal materials.

Quickly biodegradable hydraulic fluids are created using vegetable-based materials. Their abbreviation HE stands for Hydraulic Environmental, and also appears in the following designations: HETG (based on triglycerides / vegetable oils), HEES (based on synthetic ester), HEPG (polyglycols), and HEPR (based on other fluids / primarily poly-alpha-olefins).

Pure water as a hydraulic fluid appears in very few applications, because its physical properties are hard to control.

1.13 Rod quality and selection of seals

Due to improvements in seal technology, today hydraulic systems can be designed so that they are completely leak-free. However, for seals which seal the piston rod relative to the pressure chamber, a minimal „lubricating film“ is desirable. This improves not only the gliding properties on the piston rod, but also reduces wear. For this purpose, the special seals have a recirculation function that conveys this microfilm back to the pressure chamber. This prevents the microfilm from forming drops, and thus ensures that no hydraulic fluid escapes into the environment.

In order to achieve as long a service life as possible, the seal, microfilm and rod characteristics have to be matched to each other optimally. Particular attention has to be paid to the rod surfaces; this can be achieved in the following ways:

- Piston rods hardened, polished and hard chrome plated
- Hardened and polished
- Hardened, polished and hard chrome plated



Even extremely fine scoring on the piston rod will inevitably lead to leakage, and will significantly reduce the service life of seals. Therefore it has to be ensured that piston rods are not subjected to any external mechanical stresses – either in operation or during maintenance.



The use of hardened, polished and hard chrome plated piston rods like those supplied by AHP Merkle significantly reduces the risk of damage.



Hardened piston rod (AHP Merkle standard)



Non-hardened piston rod

1.14 Application situations for hydraulic cylinders

The typical stroke ranges of AHP Merkle hydraulic cylinders extend from 1 mm to 2,000 mm (0.039 to 78.74 inches). Naturally there are also special designs with longer strokes. In the determination/dimensioning, particular attention should be paid to important operating conditions such as dynamics, piston speed, force ratios, etc.

Stamping

During stamping, for example, very high dynamic loads are generated (switching impacts, pressure spikes), and both the cylinder and the seals have to be designed for them. Thus the guides are reinforced, the seals are adapted and the overall design is dimensioned for the significantly higher loads. Another difference between stamping cylinders and block cylinders is the larger ports, which are used to achieve higher flow rates.

High piston speeds and / or large masses

With high piston speed and large moving masses, particular attention has to be paid to the approach to the end position. To avoid unnecessary impact loads, the use of hydraulic cylinders with end of stroke cushioning is recommended, or else the use of external shock absorbers – or even both. This is always applied when the piston moves to the end position at a speed greater than 0.1 m/s (0.328 feet/s).

An important factor in deciding on end of stroke cushioning or external shock absorbers is not just the moving mass, but also the stroke. If the stroke is very short, the cushioning can have a strong effect on the cylinder motion, thus making it „sluggish“. In this case it is advisable to use external cushioning.



The greater the piston speed or the mass moved by the cylinder, the more important cushioning is.

Transverse forces

Quite often in mechanical constructions transverse forces are generated; these must never be absorbed by the hydraulic cylinder (see also DIN EN ISO 4413). For one thing, this would damage the guides and seals, and secondly the piston rod can undergo plastic deformation if too much force is applied. For this reason it is necessary to use suitable guides to absorb the transverse forces that are generated; such guides are standard, for example, in the push units and core pull units from AHP Merkle.

Furthermore it is possible to prevent the undesirable application of force to hydraulic cylinders by means of suitable couplings and pivots.



If transverse forces are not absorbed completely by appropriate design elements, there is a risk of damage to the guides, running surfaces, seals and to the piston rod.

Synchronous application

In order to operate several cylinders (even identical ones) synchronously in an application, there are certain special considerations that must be kept in mind. This is because the synchronous running of several axes (and this also applied to hydraulic cylinders) can only be achieved with additional design measures, such as precise, stable guides. The reason for this is the large number of physical parameters affecting the system. For hydraulic cylinders this means that one of the cylinders always has the lowest resistance, and thus even units with identical designs do not always advance and retract completely identically. If synchronous applications are operated without the appropriate design measures for synchronization, damage to the cylinders can occur, and other elements in the system may also be damaged.

One effective way to achieve fault-free synchronous running is to use commercially-available flow dividers or flow splitters. These divide the available oil evenly among the cylinders. In addition, the pipes for the volume flow supply to the individual cylinders must have the same length (synchronous pipe system) and the cross-section of the pipes must be sufficiently large. In addition, external guides of an especially precise and stable construction are required. In most cases, a synchronous pipe system with a well thought out guidance of the molded parts to be moved is sufficient for many applications.

Another means of achieving synchronization is axis synchronization using a linear position transducer. Systems that are controlled in this manner offer the most accurate synchronization for its implementation of synchronous applications. Here proportional valves, control valves or servo valve perform precise control of the flow rate – and thus of the cylinder motion. However, the control electronics for this are much more complicated to implement.



Due to the complexity of synchronous applications and the resulting effects on the cylinder, overall construction and/or machine, AHP Merkle recommends performing a thorough investigation with regard to the force ratios, axis motions and other design details of the planned synchronous application.

Undesirable transmission of pressure

If hydraulic cylinders are combined with each other to optimize motion profiles or the development of force, the possible effects must be monitored carefully and taken into account in the design.

Example 1 (coupled cylinders):

If two hydraulic cylinders coupled on the piston rod have differing piston diameters, the pressure in the smaller one (p_1 , A_1) increases significantly when the larger one (p_2 , A_2) „pushes“. This situation follows the following relationship:

$$p_1 = \frac{p_2 \cdot A_2}{A_1}$$

With an output pressure of 250 bar (3625 PSI) and piston diameters of 50 mm (1.97 inches) (large cylinder) and 32 mm (1.26 inches) (small cylinder), the chamber pressure in the small cylinder increases to about 610 bar (8845 PSI). With an even smaller piston diameter of 25 mm (0.98 inches) (small cylinder) the value in the cylinder chamber even increases to 800 bar (11,600 PSI).

If in this arrangement the large hydraulic cylinder does not push on the piston surface, but rather on the ring surface of the smaller hydraulic cylinder, the increase in pressure becomes even more dramatic.

Example 2 (external forces):

One typical source of risks is when large external forces act on hydraulic cylinders. Such situations can occur, for example, when the valve for retracting the ejector does not open at the right time. The large force generated over the large surface of the main cylinder is then transmitted to the small surface of the ejector, creating a tremendous force that „blows up“ the hydraulic cylinder.

Pushing load / buckling strength

When designing hydraulic cylinders it is especially important whether the cylinder is pulling or pushing, or if they have to apply force in both directions. In the case of pushing loads, the buckling strength of the piston rod has to be taken into account. This is especially true for long strokes.

The buckling strength of the piston rod is influenced by the following factors:

- Diameter of the piston rod
- Length of the piston rod / of the cylinder
- Fastening of the piston rod and of the cylinder



At www.ahp.de there is an interactive calculation tool for the proper design, dimensioning and selection of hydraulic cylinders.



The design tool ahp.calc (app) can be used to carry out a lot of complicated calculations in an easy and user-friendly way.

Leakage oil

As a special design it is also possible to provide an additional leakage oil connection in the hydraulic cylinder. This is always required if no microfilm on the piston rod is permissible, such as in the food industry, for example. In this case there must be an additionally sealed annular chamber. The oil from the lubricating film can be deposited there, from which it is removed via an additional connection. This design measure has also proven useful to prevent hydraulic fluid from escaping into the environment even if the sealing capability of the rod seals is degraded due to normal wear.

Settling characteristics

Generally it is assumed that hydraulic fluids are non-compressible. In fact, however, in practice an appreciable „compression“ of the fluid is noted at high pressure loads. This type of „negative expansion“ is naturally also transmitted to the piston rod, which leads to undesirable changes in the positioning of the piston rod and in the stroke motion actually executed by the piston rod.

Example:

A cylinder with a piston diameter of 100 mm (3.94 inches) and a stroke of 100 mm (3.94 inches) can settle by about 1.5 mm (0.059 inches) when the load changes from 0 kN to 157 kN (0 to 17.65 ton-force) (corresponds to a pressure change of approx. 200 bar (2900 PSI)). At 500 bar (7250 PSI) such a „compression“ has already reached a value of 3.75 mm (0.15 inches).

This example does not take into consideration, however, either the seal effects or the feedback from the overall design of the hydraulic system, for example the use of hydraulic hoses.

1.15 Life of hydraulic cylinders

The life of hydraulic cylinders depends on a large number of variables. As a general rule hydraulic cylinders are very robust and durable actuators, that can also be repaired quickly and easily.

With proper design, dimensioning and operation, hydraulic cylinders last a long time. However, the following should always be taken into account in operation:

- Avoid pressure spikes (caused by the pump or the application of external forces).
- Avoid transverse forces, or absorb them using suitable guides
- Do not overheat seals
- Protect piston rod from mechanical damage/scoring (assembly, maintenance, environmental conditions)
- No contamination (from inside via abrasion and corrosion or from outside via worn seals, ambient dirt, metal chips or adding new unfiltered oil)
- No water in the oil
- No air in the hydraulic system
- Spark-over on piston rod

As soon as scoring appears or is visible on a piston rod, that is a sign that the operating conditions or the design are not-optimal. Furthermore the seals will also have sustained damage.

Contaminants in the hydraulic fluid will permanently accentuate the effects of scoring and damage to seals. Therefore hydraulic systems should have appropriate filter equipment that keeps solid contaminants to a minimum, and which also filters out any water in the oil. The corresponding reference values and system solutions can be obtained directly from the filter manufacturers.

The following basic rule applies: the higher the system pressures, the higher the oil purity should be. Therefore high-pressure systems should always satisfy purity level 14/10 according to ISO 4406.



Non-observance of these points may cause considerable damage to hydraulic cylinders already after a few working strokes, or even result in complete functional failure.



As a standard at AHP Merkle all piston rods are hardened for maximum life of the hydraulic cylinders.



Hardened piston rod (AHP Merkle standard)



Non-hardened piston rod

1.16 ATEX approval

The designation ATEX stands for the French abbreviation „Atmosphère explosible“. The term refers to two Directives of the European Union (EU), namely the ATEX Equipment Directive 94/9/EC and the ATEX Workplace Directive 1999/92/EG. In Germany, the European ATEX Equipment Directive 94/9/EC is implemented in national law by the Explosion Protection Ordinance (Explosionsschutzverordnung / 11. GPSGV).

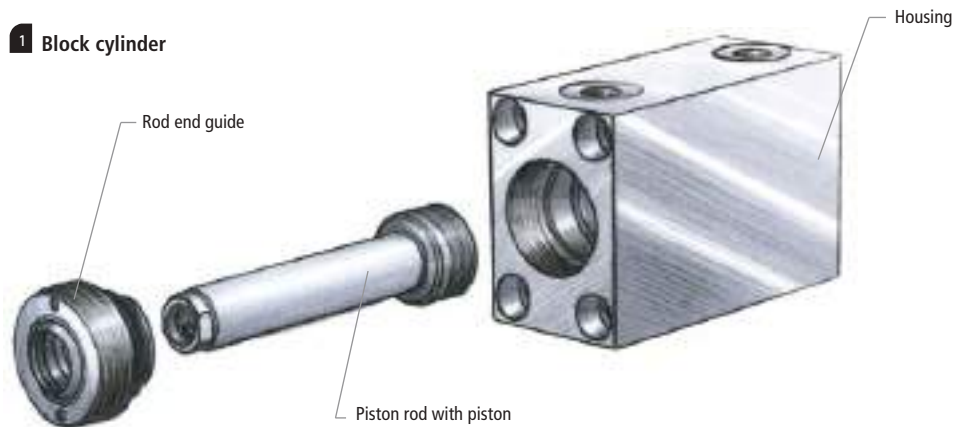
AHP Merkle can manufacture hydraulic cylinders according to the ATEX directive. However, the specific application must be considered in detail for this.

2 Cylinder parameters

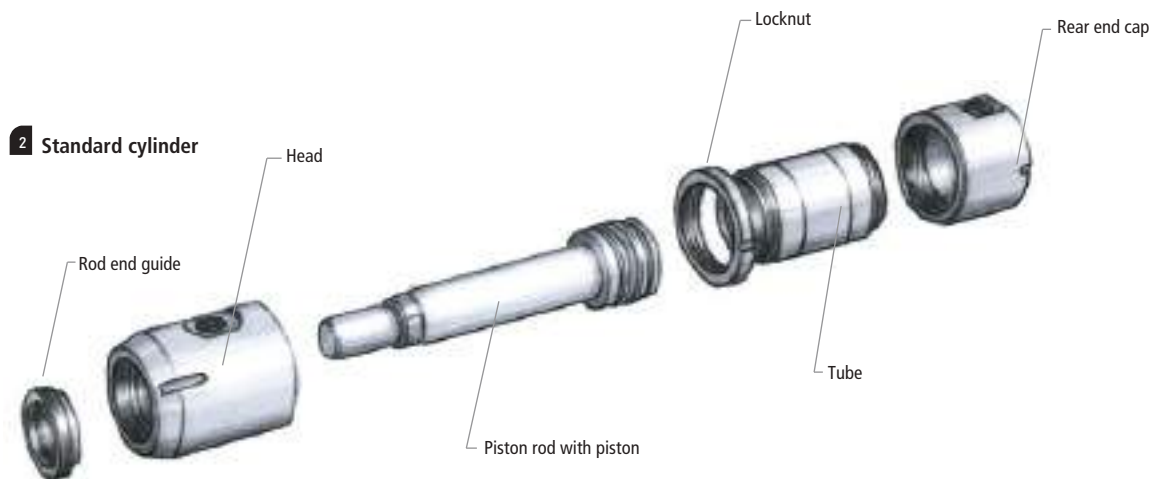
2.1 Component definitions

Unambiguous terminology prevents unnecessary loss of time in discussions and in finding the best solution. The same applies to manufacturing and configuring the ordered goods. For this reason, the individual components will be explained in more detail in the following chapter.

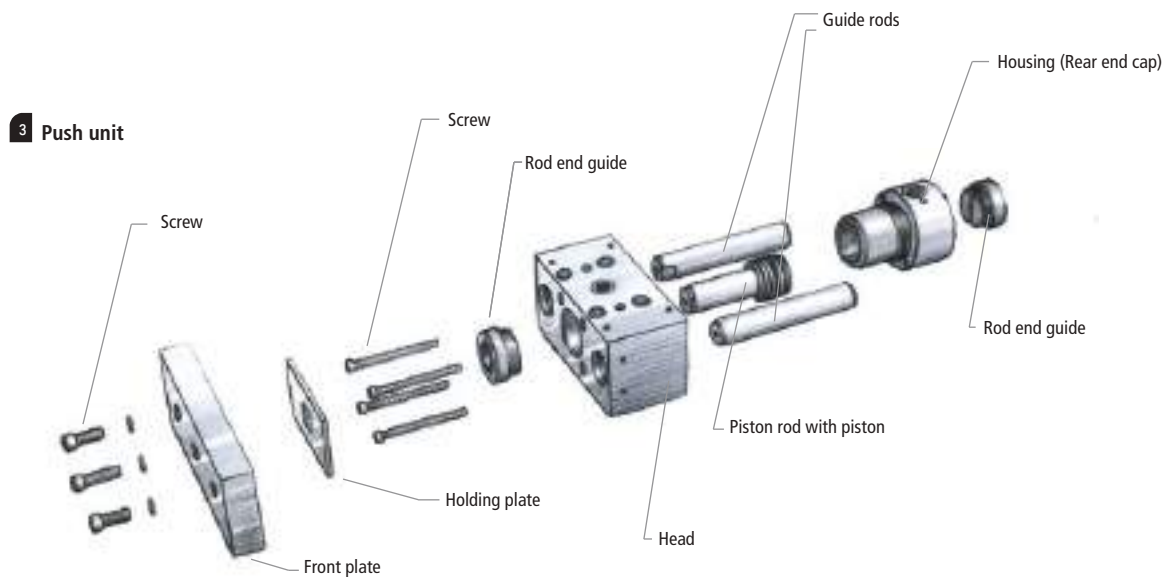
1 Block cylinder



2 Standard cylinder



3 Push unit



2.2 Surface quality of piston rods and cylinder running surfaces

Hardening, grinding, hard chrome plating

The service life of hydraulic cylinders depends on the quality of the piston rod, among other things. Hardened rods have a significantly thicker case depth, which significantly increases its resistance to wear – and especially to impact effects.

For optimal surface adjustment, the hardened rods are polished and if necessary also hard chrome plated.

At AHP Merkle, almost all piston rods are hardened and polished. For long-stroke cylinders the piston rods are additionally hard chrome plated.

The hardening process gives the piston rod material a case depth in the range from 0.5 to 2.5 mm (0.019 to 0.098 inches). This reaches a hardness value of up to 57 HRC. Hard chrome plating the surface increases the hardness value to up to 67 HRC, increasing the durability of the piston rod.

As a result, the hardened piston rods are much more resistant to impact, scratches and other wear. This increases their life, and also the life of the seals.

Roller burnishing

As an alternative to thermal, chemical and other processes for surface hardening, roller burnishing is also used for cylinder running surfaces. This burnishing process is a non-cutting surface treatment that creates a high-precision, high-strength cylinder running surface.

For example, at AHP Merkle the housings of the block cylinders are given a more „refined“ quality by the roller burnishing process. This increases the percentage contact area of the piston running surface, which provides optimal values in relation to wear and life of the cylinder.

2.3 Operation modes

Hydraulic cylinders differ both in their design and in their drive characteristics. Due to the wide variety of options, there is an optimal cylinder solution for almost any application. To make it easy to distinguish between the various solutions, at AHP they are assigned various number combinations. The most important of these are listed below.

Single acting:

- 101: single-acting – retraction via external force
- 102: single-acting – extension via external force
- 111: single-acting – retraction via an integrated spring
- 112: single-acting – extension via an integrated spring



When the cylinder is retracted via an integrated spring, only the force for the return stroke is applied. External masses are not taken into account.

In practice this type of piston return of single acting cylinders is generally only relevant for short strokes.

Double acting:

- 201: double-acting – non cushioned
- 204: double-acting – forward and return stroke cushioned
- 206: double-acting – cushioned forward stroke
- 208: double-acting – cushioned return stroke
- 244: double-acting – linear cushioning on both sides
- 246: double-acting – linear cushioning front side
- 248: double-acting – linear cushioning rear side

Special designs:

- 202: double acting for various media (consultation with AHP Merkle is necessary)



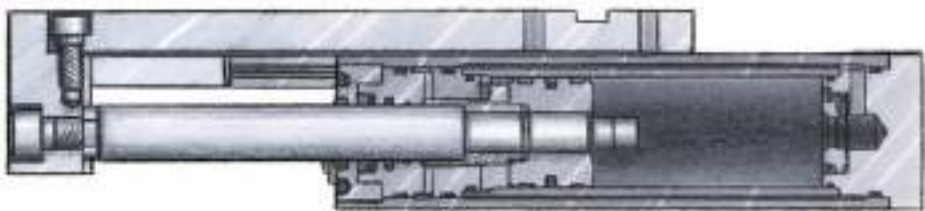
Not all operation modes are available for all cylinders. Additional options, and special design requirements are available upon request for each cylinder. Please contact us!

2.4 Hydraulic cylinders with special features

Core pull unit

Core pull units are hydraulic cylinder designed with a guide that can apply high linear forces and very precise motion. They are especially well suited for injection molding applications. In this arrangement of guide and cylinder, the unit „pulls“ out the core of an injection molding tool with great force. Because here the hydraulic cylinder „pushes“ with its entire piston surface – and not just with the ring surface, as is otherwise typical for pulling motions. In this manner it applies 1.6 times the force with the same pressure conditions. Thus, a smaller piston diameter can be selected.

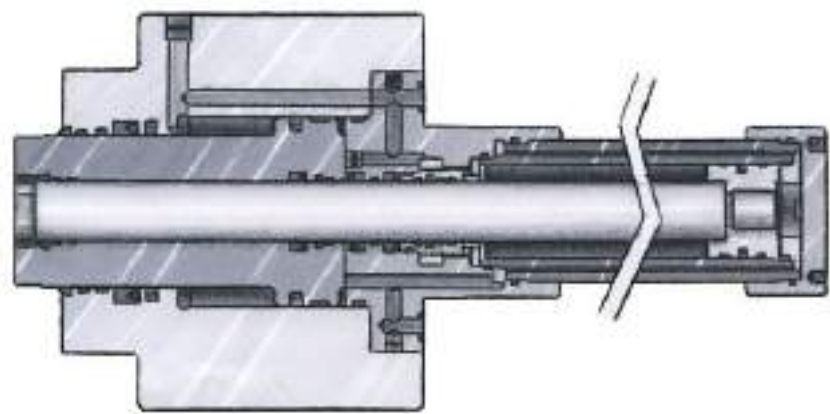
Core pull units also save space, and can absorb very strong side forces and torques. Both of these are important requirements for building optimal tooling solutions in injection molding.



Two-force cylinder – pushing

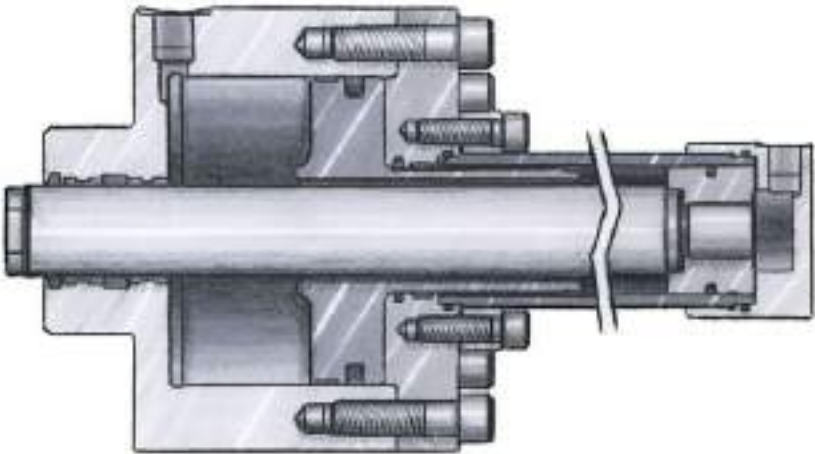
There are certain applications in which very different motion characteristics lead to an optimal manufacturing process. In practice it can be observed that in some applications high (breakaway) forces are required at the beginning of a motion, and then comparatively low forces are needed for the remaining motion. In such cases the cylinders are designed for the largest force that has to be applied.

As a more cost-effective alternative to this, AHP Merkle has developed two-force cylinders, which are designed so that they can execute various force and speed profiles. This is possible through the use of two concentric piston rods running one inside the other. Their advantage is the high force generated at the beginning of the motion, and the subsequent automatic switching to higher travelling speeds at the same flow rate.



Two-force cylinder – pulling

In this hydraulic cylinder option with stepwise force and motion characteristics the linear drive is designed for pulling. Here, too, two concentric piston rods run one inside the other. First a large piston with a correspondingly large ring surface receives pressure, which results in high force generation and low speed. Once the large piston is located at the housing wall and the pressure is only acting on the ring surface of the smaller piston, the force is reduced, and at the same time the travelling speed of the cylinder increases. In contrast to the „Two-Force Cylinder – pushing“, the option „Two-Force Cylinder – pulling“ develops the greatest force when the piston rod is extended.

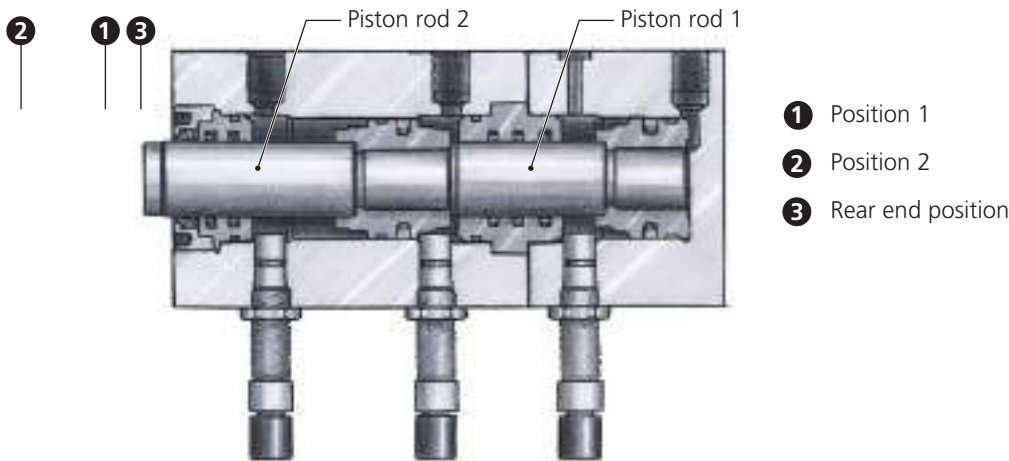


!

Two-force cylinders are for the most part always customer-specific solutions. This means that AHP Merkle adapts the changeover point from high force to high speed in accordance with individual customer requirements.

Multiposition cylinders

Multiposition cylinders are designed for moving to defined positions between the forward and return end positions. Multiposition cylinders are a simple, robust and especially economical alternative to complex servo or proportional cylinders with the associated control technology. From a design standpoint, these are compact cylinder units that are arranged one after the other. First piston rod 1 moves to the end position, at the same time also pushing forwards all of the piston rods located in front of it, and thus reaching position 1. To get to position 2, pressure is now applied to piston rod 2. The start and end positions of each individual stage can be detected via position switches.



Block cylinder with non rotating piston rod

In hydraulic cylinders, the piston rod can rotate. In order to prevent such rotation of the piston rod, the design has to be adapted. To do this, an element that is not visible from the outside is build into the piston rod; this element guides the piston rod and thus prevents it from rotating. In such solutions the hydraulic cylinder is somewhat longer.

However, when a component is mounted on the piston rod it has to be fixed in place. Please note that the non rotating piston rod is only dimensioned for the internal forces of the cylinder.

Other special design requirements (S)

AHP Merkle's extensive range of cylinders has grown consistently over the course of decades. Many cylinder options in the standard catalog have come about as a result of individual customer projects. Today, a high degree of flexibility in the development and construction of hydraulic cylinder solutions is still one of AHP Merkle's main areas of expertise.

If you have still not found a suitable cylinder solution despite the wide range of products in our catalog, your best option is to contact the specialists at AHP Merkle directly.

www.ahp.de

E-Mail: service@ahp.de

Tel.: +49 76 65 42 08-0

Fax: +49 76 65 42 08-88

With cylinder solutions which deviate from the standard, an „S“ is added to the type designation of the base cylinder in order to distinguish them more clearly from the standard cylinders:

Base cylinder: BZ 500.50/32.01.201.025

Special cylinder: BZ 500.50/32.01.201.025 S

The same base cylinder may have various modifications for each customer (e.g. additional holes/threads, modified dimensions compared with the standard, etc.).



This is why it is not sufficient to specify only the type designation to clearly identify a special cylinder solution in case of queries or when ordering spare or new parts.

Further information is required:

part number + order number

2.5 Venting the hydraulics

There are many reasons that it is necessary to vent the hydraulic system. Especially in the case of large pressure fluctuations, air inclusions in hydraulic oil can cause the so-called Diesel effect, in which extremely high temperatures lead to oil aging and seal wear.

Another negative effect is that air diffuses through the seal material towards the low-pressure side. The pressure decreases steeply at the surface of the seal, which causes the air bubbles to expand abruptly, which can damage or destroy the seal. Depending on the scale of such „micro explosions“, it is possible that in a very short time even the surfaces of the sealing and running surfaces could be affected so badly that they appear like they would when abrasive wear has occurred.

Compressed air inclusions – which under high pressure are no longer visible – can cut the sealing surface like tiny knives when they brush over the seal.

In short

Hydraulic cylinders – just like the hydraulic system as a whole – have to be vented carefully before they are put into operation. In order to make sure that there is no air remaining in any part of the hydraulic system, the application and the cylinders should be actuated a number of times with as low a pressure as possible; this will facilitate complete venting. For this reason AHP Merkle offers optional vents for almost all hydraulic cylinders.

The detailed procedure for venting hydraulic cylinders is provided in the chapter „Operating and maintenance instructions“



Because under certain circumstances air dissolved in the hydraulic fluid may be released, it is advisable to vent the system again when maintenance is performed.



To allow complete venting of hydraulic cylinders, the venting screws should be placed at the highest point.

2.6 Seals, guides

Together with the design of the installation spaces, the selection of seals is one of the most important factors in ensuring functional, long-lasting hydraulic cylinders. Therefore the following parameters must be taken into account very carefully in the dimensioning and selection of seal systems:

- temperature
- piston speed
- fluid
- operating pressure

Seals

The seals used in AHP Merkle cylinders are dimensioned for a maximum piston speed of 1 m/s (3.28 feet/s). Thanks to decades of experience and the systematic implementation of new technologies and innovative equipment, the range of applications for the seals used by AHP Merkle is correspondingly broad and diverse.

Standard seals

- Standard seals: -15 °C to 80 °C (5 °F to 176 °F)
- Viton®: -15 °C to 180 °C (5 °F to 356 °F)

In the AHP Merkle catalog range the seals are designed for HL or HLP oils; for HFC or other fluids the data sheet of the fluid manufacturer should be noted. The compatibility of the hydraulic fluid with the sealing materials must be checked.



Use of zinc-free HLP oils in combination with certain sealing materials may result in increased wear of sealing elements and running surfaces.



With very short strokes we recommend the use of special seal variants.



When selecting seals it is always essential to take into account the extent to which pressure spikes occur, or a particularly low pressure level is present. At particularly low pressures the danger of leaks is increased because due to the residual stress or the mode of action the seals only function „properly“ starting with a certain pressure.

Additional seal solutions for non-standard parameters are available on request.

Guide elements

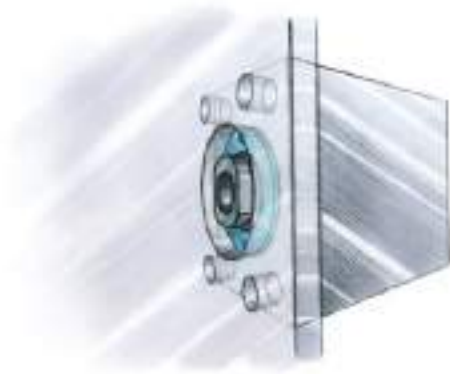
In hydraulic cylinders from AHP Merkle, the number, placement and design of the guide rings are adapted to the specific loads. Through the use of especially high-quality guides and optimized design, some product groups have been adapted for special high-load applications. These include, for example, the stamping cylinders (STZ).



Guides are dimensioned purely for the motions of the cylinder, not to absorb side forces.

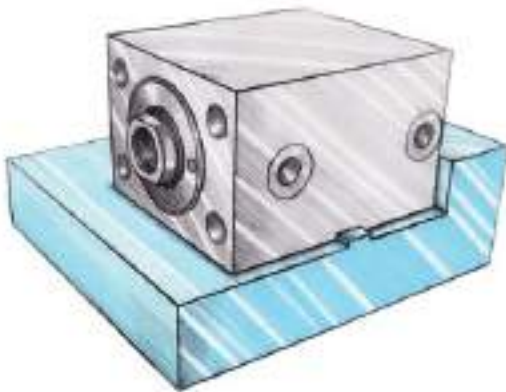
2.7 Centering collar

If the cylinder is mounted in the axial direction, the use of a centering collar may be expedient. This chamfer, which is centric to the piston rod, aligns the hydraulic cylinder precisely. The advantage of this option: It is easy to execute the design for an accurately-fitting alignment of the hydraulic cylinder.



2.8 Keyway

With a block cylinder, a side keyway can optionally be created in the housing. This keyway serves to absorb forces, and at the same time can be used for precise positioning. With higher forces the hydraulic cylinder must be provided with an additional rearwards support.



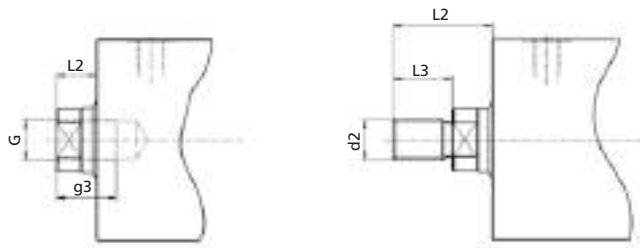
The bases of calculation for machine elements must also always be taken into account for the mounting of hydraulic cylinders. The tightening torques must be adapted appropriately depending on whether the screw connections are loaded axially or radially, for example. Thus when calculating the mounting it is necessary to consider not only the static forces, but also the possible high dynamic loads of hydraulic cylinders.

2.9 Non-standard piston rod end

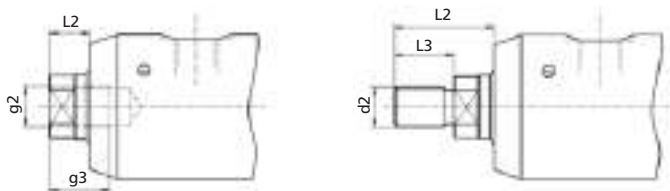
The piston rod end is always provided with a standard external / internal thread. AHP Merkle can also manufacture other thread dimensions to customer request.

When ordering a non-standard piston rod end, the option „M“ must be indicated in the order text together with the associated values. The desired thread data can be communicated by the customer in the form of a technical drawing. Alternatively it is sufficient to specify the corresponding numerical values for the thread as follows:

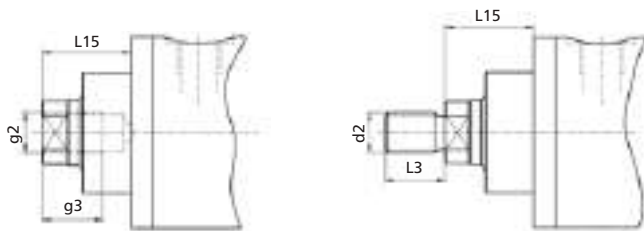
| Block cylinder | Internal thread | External thread |
|-----------------------|-----------------------|------------------------|
| Protrusion piston rod | L2 | L2 |
| Thread | G | d2 |
| Thread length / depth | g3 | L3 |
| Example | G=M20x2, g3=30, L2=15 | d2=M20x2, L3=30, L2=45 |



| Standard cylinders | Internal thread | External thread |
|-----------------------|------------------------|------------------------|
| Protrusion piston rod | L2 | L2 |
| Thread | g2 | d2 |
| Thread length / depth | g3 | L3 |
| Example | g2=M20x2, g3=30, L2=15 | d2=M20x2, L3=30, L2=45 |



| DIN standard cylinders | Internal thread | External thread |
|------------------------|-------------------------|-------------------------|
| Protrusion piston rod | L15 | L15 |
| Thread | g2 | d2 |
| Thread length / depth | g3 | L3 |
| Example | g2=M20x2, g3=30, L15=30 | d2=M20x2, L3=30, L15=60 |



If an accessory component from the AHP Merkle accessories range is selected, the thread of the piston rod may have to be adapted to the accessory component.

2.10 Corrosion-resistant designs

For certain applications AHP Merkle offers an optional corrosion-resistant design. A distinction is made here between chemical nickel-plating outside (corrosion-resistant) and inside (for water hydraulics). AHP Merkle makes the general distinction as follows:

- Order text BZW for water hydraulics (inside corrosion protection)
- Additional text W1 for special corrosion protection outside

Example of an order text:

BZW 500.50/32.03.201.50

BZ 500.50/32.03.201.50.W1




Most AHP cylinders can be supplied in a corrosion-resistant design through special treatment. In this case the seal elements are adapted to the specific application.

3 Switches and sensor systems

The possible switches for control and position monitoring of hydraulic cylinders differ fundamentally in their physical mode of action, their construction, their robustness and their operational limits.

Typical position detection systems are:

- | | |
|---|---|
| • Inductive switches integrated into the cylinder | up to 120 °C (248 °F) (standard 80 °C (176 °F)) |
| • Inductive, externally mounted switches | up to 120 °C (248 °F) (standard 80 °C (176 °F)) |
| • Mechanical switches | up to 180 °C (356 °F) (standard 80 °C (176 °F)) |
| • Magnetic field sensors | up to 130 °C (266 °F) (standard 80 °C (176 °F)) |
| • Linear position transducers | up to 75 °C (167 °F) |



When selecting a hydraulic cylinder, it should be clarified at an early stage whether a sensor is needed. Subsequent installation of switches is not possible.

Electronic position switches have a certain voltage drop in „idle“. This means that it is not possible to operate an unlimited number of electronic switches in series from a single voltage source. In contrast, mechanical position switches have no voltage drop.

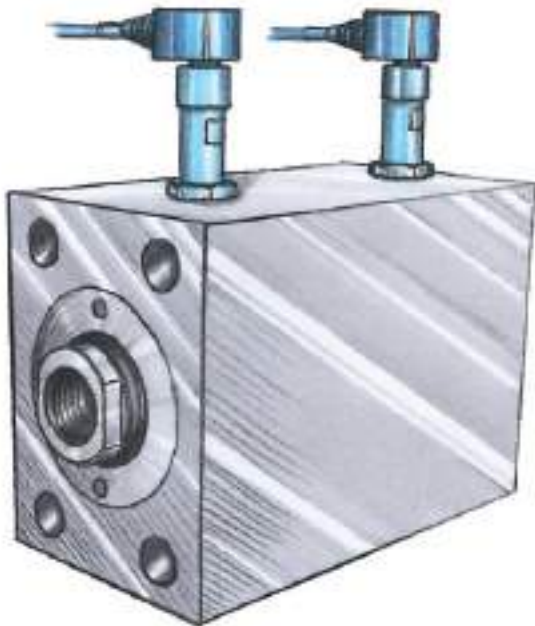
3.1 Inductive proximity switches


The mode of action of inductive sensors is based on a magnetic field generated by a coil (winding). When an electrically conductive material comes near the sensor, eddy currents are generated in the magnetic field. An oscillator detects the change in the magnetic field, and the sensor switches. This simple sensor principle can be used to detect positions in a non-contact, and thus wear-free, manner.

Inductive proximity switches have high switching accuracy (0.1 mm (0.0039 inches)), and can be used up to 80 °C (176 °F) (in special cases up to 120 °C (248 °F)). This means that they are ideal position sensors for hydraulic cylinders. They can be integrated into hydraulic cylinders in a pressure-tight manner, and are used for end position sensing.

If a cylinder with a high pressure inductive sensor is selected, the sensing point can be defined up to 5 mm (0.2 inches) before the stroke end position. Subsequent relocation of sensing point is not possible.

A special option for cylinders with inductive proximity switches is the fitting of an external sensor; this is implemented by means of an actuating rod opposite the piston rod. This allows easy adjustment of the sensing points.



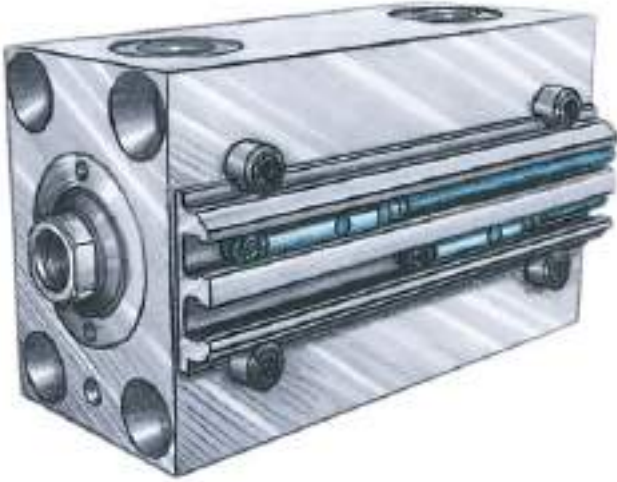


If the ripple in the electronic system is too high, malfunctions may occur in inductive sensors.

3.2 Magnetic field sensors

Magnetic field sensors have a current flowing through them, and can detect magnetic fields of a certain strength. If a magnet (magnetic field) is brought to the sensor, it delivers an output voltage. For this purpose, a magnet is integrated into the piston; this magnet can then be detected from outside. This allows unproblematic flexible, individual adjustment of the sensing points. However, when magnetic field sensors are used the cylinder housing has to be non-magnetic so as not to influence the magnetic field being detected.

The operational limits of these simple position sensors are at 105 °C (221 °F). AHP Merkle also offers a solution that goes up to 130 °C (266 °F); this is implemented through the use of switches with displaced electronics. Here the evaluation electronics are not located directly on the sensor element, but rather at a distance of up to 0.5 m (1.64 ft) via a cable connection.



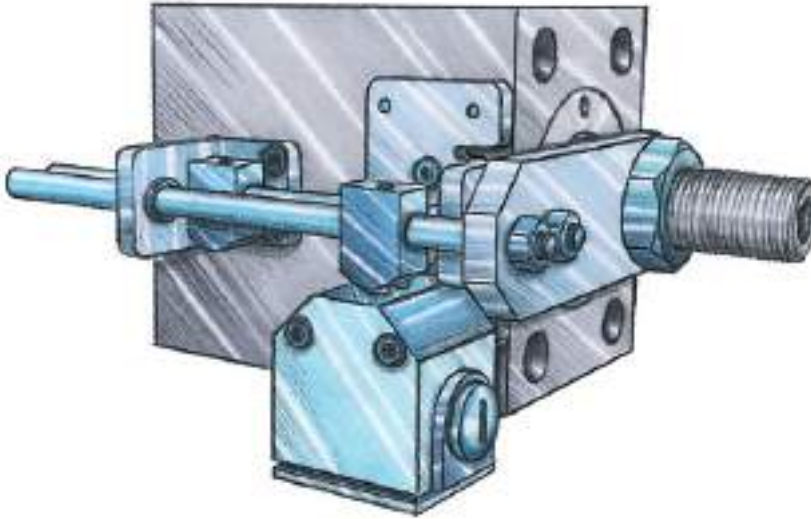
Due to their measurement principle, magnetic field sensors are especially vulnerable to electromagnetic interference pulses, such as those that may occur in industrial environments. Therefore it should be checked ahead of time whether this type of sensor is suitable for the specific application.

As a basic rule, ferromagnetic components have a negative influence on the functionality of magnetic field sensors, and should therefore not be placed closer than 30 mm (1.18 inches) from the sensor.

3.3 Mechanical switches

The greatest advantages of mechanical position switches are their robust design and their high switching current carrying capacity. They are generally switched via a cam or a switching lug, which actuates the sensor plunger, which then closes the electric circuit. Thanks to their high operational temperature limits of about 80 °C (176 °F) (in special cases even up to 180 °C (356 °F)), they are outstandingly suitable for particularly difficult environment conditions, for example foundries.

For high operating frequencies it is necessary to check whether the associated mechanical wear will have any effects on functionality over the entire period of operation.



3.4 Linear position transducers

Linear position transducers are superbly suited for closed-loop control processes. They are available in non-contact (magnetostrictive and inductive) and contact-type (potentiometer) options.

The linear position transducers most frequently used in hydraulic cylinders are based on the magnetostrictive principle. Magnetostriction is the deformation of ferromagnetic materials due to the application of a magnetic field. This causes the body to undergo an elastic change in length at a constant volume.

A significant advantage is that they can be connected directly to typical bus systems, such as CAN bus or Profibus. Their maximum precision of 1 µm (39.37×10^{-6} inches) is superbly suited for very precise control of hydraulic cylinders. Their maximum possible measurement length is 4,000 mm (1,574.8 inches).

4 Operating and maintenance instructions

4.1 General instructions for maintenance of hydraulic cylinders

As a general rule, the same general requirements concerning maintenance work apply for hydraulic cylinders as for other machine components. Maintenance work should be performed only by trained, qualified personnel. To prevent damage to the seals and cylinder parts, it is important to always pay attention to cleanliness.

When changing seals, there are some important points that must be observed. Scratches, scoring and notches damage seals and reduce their service life. Therefore is also important during maintenance work to make sure not to scratch surfaces or edges, and not to damage the cylinder or seals with impact effects. For safe installation of seals there are corresponding installation sets that can be purchased directly from AHP Merkle.



For some cylinders with inductive proximity switches, the switches have to be removed before dismantling.

Furthermore, there are some essential points that must be observed not only for maintenance work, but also for storage. These include the type of storage and the creation of certain storage conditions on the cylinder, seals and add-on parts, such as degreasing and protection against light, moisture, heat, etc.

It must also be ensured that seals are not stored in the vicinity of adhesives, solvents, fuels, chemicals, acids, disinfectants, or the like. See also DIN 7716 „Rubber products; requirements for storage, cleaning and maintenance“.



**Seals CANNOT be stored for indefinite periods.
Heat and light additionally speed up material changes.**



Complete installation sets for seals can be purchased directly from AHP Merkle

www.ahp.de

E-Mail: service@ahp.de

Tel.: +49 76 65 42 08-0

Fax: +49 76 65 42 08-88

4.2 Procedure for assembly and maintenance work

As a fundamental rule, only qualified personnel may perform work on hydraulic cylinders. At the beginning of maintenance work on hydraulic cylinders it must be ensured that no load motions are possible when the hydraulic system is depressurized. Suitable measures must be taken to ensure this, and the work safety rules must be observed. When installing or removing the hydraulic cylinder, the instructions of the machine manufacturer and/or systems integrator must be observed.

The use of system-based safety systems such as check valves or the like is not sufficient by itself.

Before the cylinder is opened or screw or hose connections are detached, it must be ensured that the entire hydraulic system has been depressurized – and also that it is not possible for pressure to build up unintentionally. All of the lines connected to the cylinder have to be removed before the fastening is released. It must be ensured that releasing the fastening will not endanger the maintenance personnel or any other persons.



It is advisable to ensure that no large quantities of oil can escape when the hydraulic system is opened at the cylinder. It may be possible to do this using shut off valves or quick disconnects within the hydraulic system, which can be used to cut off large volumes of oil from the rest of the system.

Once all of the preparatory work has been completed, the cylinder can be opened and the piston rod can be removed. This is best done from the rod end.

The removed parts should first be cleaned and then checked for damage such as scoring, scratches and the like. Cleaning should be performed using only lint-free cloths and suitable cleaning agents.

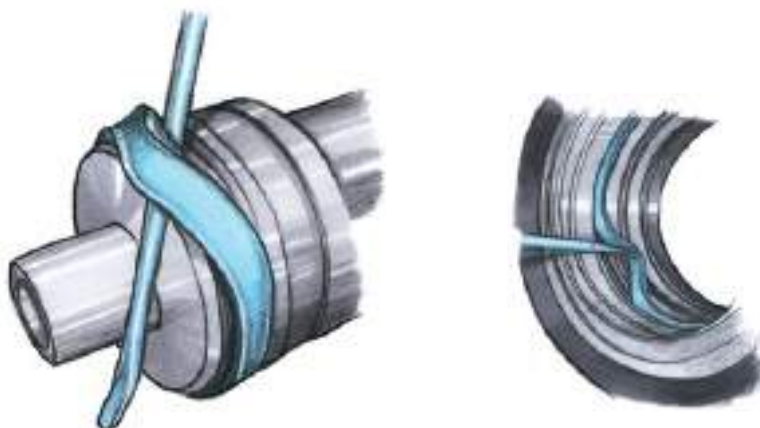


Even the smallest scratches and scoring cause damage to the seals, and lead to premature wear on the seals. More heavily damaged parts must be replaced.

In the case of normal signs of wear, maintenance at certain intervals is a necessary effort. In cases of premature damage, it is essential to find the cause so that the new seal can achieve a longer service life.

Removing seals

When removing the seals, be sure not to use sharp or hard tools. Improper removal can cause damage to the cylinder surfaces (edges, base of groove) that can later compromise the function of the seal and the hydraulic cylinder. The use of a rounded, polished screwdriver is recommended for proper removal of seals.



After the seals have been removed, clean everything carefully and prepare the new seals for installation. The installation spaces must be free of dirt and sharp edges.



When installing the new seals, ensure that they are installed in the right location and with the right orientation.

When installing rod seals it is necessary to work especially carefully and cautiously, because the recesses for the various seal types and seal sizes often appear very similar. As a fundamental rule, it is advisable to install new seal as soon as possible after the old seals are removed. Comparing the new seals to the old ones helps in finding the correct allocation.

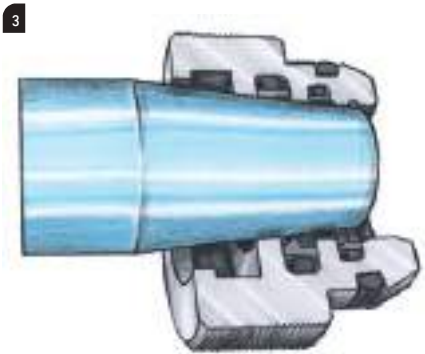
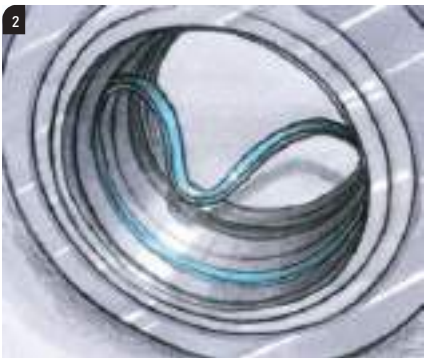
AHP Merkle can also provide information about the correct arrangement.



It has also proven very useful to use a digital camera to take a picture of the seal arrangement before removal, and possibly also pictures of other machine elements, so as to be able to verify them once assembly is complete.

Installing the rod seal

If the rod seal consists of two parts, the O-ring should be fitted first. Installation is always performed using the following pattern: The seal is held in a kidney shape and placed in the corresponding installation space (image 1), taking the mounting direction into account, and then carefully pressed into the groove (image 2). After insertion, the seal is brought to the correct shape and dimensions using a calibration gage (image 3).



In the case of a one-part shaft seal (e.g. groove ring), the seal is held in an oval shape and inserted in the groove. Here, too, it is important to note the correct mounting direction.

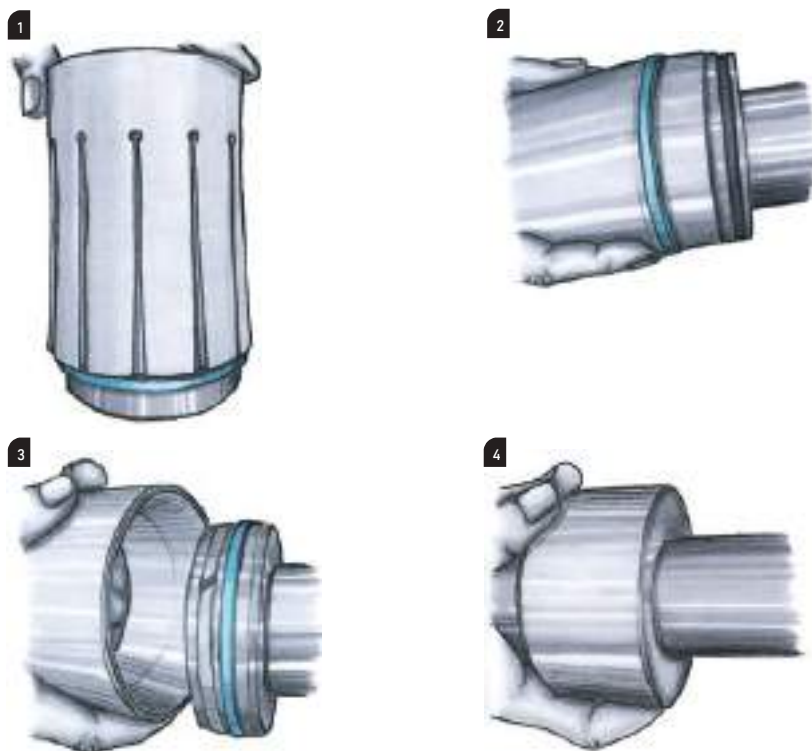


Shaft seals should be installed quickly so that they can be returned more or less to their original dimensions.

Installing the piston seal

The piston seal is relatively easy to install using a suitable tool (mounting taper, mounting sleeve). If the piston seal consists of two parts, the O-ring should be fitted first. The seal is placed in the designated groove using a mounting sleeve (image 1) and a mounting taper (image 2). For sets with O-rings, it must be ensured that the O-ring is not twisted in the process. For seals that do not return to their original shape by themselves, a calibrating sleeve has to be used (image 3 and 4). After the seal has been installed, this sleeve is slid over the piston and seal so as to press the seal radially into the groove.

Two piece sealing system:



One piece sealing system:



Tip

If the necessary tools are not available, the seal can be made more flexible in the hydraulic fluid heated up to about 60 °C (140 °F). This allows it to stretch more easily, so that it can be slipped carefully over the piston.

!

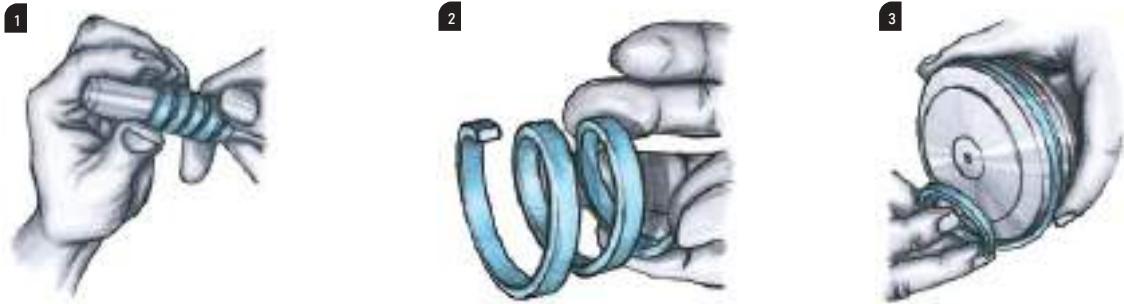
Piston seals should be installed quickly so that they can to their original dimensions.

Installing the guide rings

The installation of the guide rings varies depending on whether they are being installed as piston guides or rod guides.

In the case of guide rings for the rod, the guide ring is placed in the corresponding groove and pressed in lightly. It may be necessary to use a calibration gage to give it the right shape.

In the case of guide rings for the piston, the guide ring is rolled into a spiral (image 1 and 2) in order to give it a pretension that is useful for installation. The guide ring can then be placed in the groove (image 3).



The ends of the guide rings should never be installed flush with the port holes. Otherwise there is a danger of shearing off in the port holes. In the case of two or more guide rings the ends of the guide rings should never be lined up with each other.

The guide rings should be installed with the aid of suitable lubricants.



Because seal sets often contain more seals and guide rings than are needed, all of the parts being exchanged should be checked again before assembly.

Assembling the cylinder

Before assembly, all seals and guides should be coated with a suitable lubricant or with the hydraulic fluid being used. When assembling the cylinder components, it must be ensured that they are assembled in alignment with each other. Particular care should be taken during the entire assembly processes to ensure that the seals are not damaged through the use of excessive force or by sharp edges.



Any damage to seal interfaces (e.g. wrench surfaces) have to be rounded or polished before assembly.

Damaged or defective hydraulic cylinders may no longer be used.

When maintenance work is completed, the hydraulic cylinder and the hydraulic system must be put into operation using the proper procedure. Please see the procedure described under „Assembly and commissioning“.

4.3 Disposal

Used parts and any hydraulic fluid that has been collected or discharged must be disposed of properly.

4.4 Obtaining spare parts quickly and reliably

AHP Merkle has been producing hydraulic cylinders for more than 35 years, and can supply spare parts for them even today. This illustrates just how secure an investment these products are, and how long they last. A smoothly-functioning spare parts service is made possible by a clear strategy of building up hydraulic cylinders from modular components, thus using as many similar standard parts as possible.

The simple way in which spare parts are supplied is expressed, for example, when new seals are ordered: most of the spare parts are in stock, and the seal sets can be used for a wide variety of AHP cylinders. That naturally also simplifies stock-keeping at the end customer's location, and increases the process reliability of machines and systems.

But other parts for every hydraulic cylinder supplied to date are also available in a very short time.

Before placing a spare parts order, however, there are a few important points that should be clarified in order to obtain exactly the right part. Because one of AHP Merkle's specialties is the implementation of individual customer requirements. Thus many standard products are modified by means of individual adaptations.

In short:

The cylinder designation as shown on the delivery note, invoice and rating plate only provides information about the type and size of a cylinder.

Only the part number provides an unambiguous classification of the product. Each part number is used only once, and thus constitutes an unambiguous identifier for the product in question. Therefore the part number should be communicated as a part of the spare parts order – ideally together with the original order, delivery note or invoice. The part number can be found on the rating plate. If it is no longer legible, the part number also appears as an embossed number on every product supplied by AHP Merkle.



Each part number is unique, and thus constitutes the only unambiguous identifier of a product when purchasing spare parts. It can be found on the rating plate and as an embossed number on the product, as well as on the order, delivery note and invoice.

The order number, and is also noted in the embossed number.

Quickest way to order spare parts = part number + order number



Tip

The fastest and simplest ways to order spare parts are

per

Internet: www.ahp.de

or per

fax: +49 76 65 42 08-88

or per

telephone: +49 76 65 42 08-0

or per

E-Mail: service@ahp.de

using the

Part number + order, invoice or delivery note!

4.5 Assembly and commissioning of hydraulic cylinders

Mounting screws for cylinders and add-on parts have to be designed and mounted in such a way that they can absorb all foreseeable forces. As much as possible the screws should be free of shear forces. (see also „General safety instructions“)

When installing cylinders it must be ensured that no distortion of the cylinder occurs. This can always happen when the machine or system does not meet the mounting specifications due to improper mechanical construction or excessive manufacturing tolerances. The result of this is that mounting points are not properly aligned or undesirable side forces occur.

Before commissioning of hydraulic cylinders hydraulic systems, the technical personnel must make sure that there is no contamination or residue from manufacture or assembly of the component parts (e.g. chips) remaining in the system. To do this, it is advisable to clean the hydraulic system several times with rinsing fluid, while also using filter equipment. Once all of the hydraulic supply lines have been cleaned and fitted pressure-tight, the actual commissioning can begin.

The subsequent filling of the hydraulics with the specified pressure fluid should be performed using separate filling units that clean the new hydraulic fluid already. This is because practice has shown that new oil is in no way clean enough to meet the requirements of certain hydraulic systems. The same also applies, naturally, whenever hydraulic fluid is added later.



Before the hydraulic system is brought up to the system pressure, the entire system has to be vented.

Venting of the hydraulic system is performed via suitable ports. The hydraulic cylinders have optional dedicated venting screws. At idle pressure, simply loosen the venting screw and the fittings at the bottom and rod ends. This is done by unscrewing the screw by not more than a half turn (image 1). Close them again only when the escaping oil is free of bubbles (image 2). After that, move the system only with significantly reduced operating pressure. This process has to be repeated several times in order to guarantee that the hydraulic system is completely free of air and gases. Finally, re-seal all venting screws and fittings so that they are pressure-tight. The function of the cylinder can be checked by moving it in and out several times under low pressure.

Tip

Because under certain circumstances the air dissolved in the hydraulic fluid can be desorbed, it is advisable to vent the system again when maintenance is performed at the latest.



Before the hydraulic system is brought to operating pressure, all components should be checked again for proper installation.

1



2



4.6 Adjusting the cushioning

For cylinders with non-adjustable cushioning, the cushioning characteristics are determined by the design. In the case of adjustable cushioning, the cross sections of flow in the hydraulic cylinder can be adjusted for the specific requirements. To do this, turn the adjusting screw as far as it will go, and then back again until the desired cushioning intensity is reached.



The adjusting screw of the cushioning in the cylinder should not be screwed out too far (maximum of 1.5 turns), so as to prevent free travel to the end position. The minimum cushioning intensity is reached at this point.

4.7. Proper handling of switches and linear position transducers

High pressure inductive proximity switches:

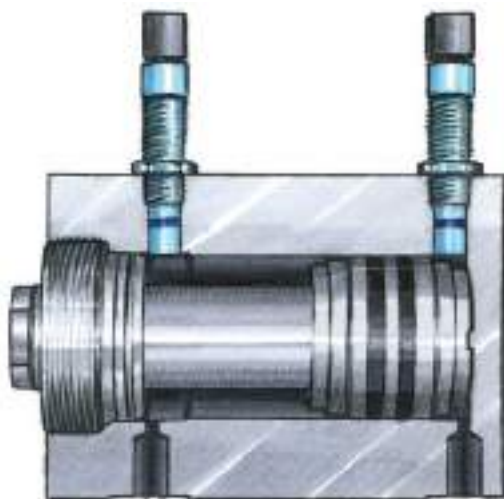
If required, hydraulic cylinders from AHP Merkle are equipped with inductive proximity switches that are pressure-tight up to 500 bar (7250 PSI). The switches are protected against polarity reversal and short-circuit as standard.

If hydraulic cylinders are ordered with inductive proximity switches, the sensors are mounted and adjusted ready for operation. It is not permitted to tamper with the proximity switches, otherwise all warranties will become void.

If such a proximity switch has to be exchanged in the course of maintenance work, it is essential to ensure that it is adjusted properly. To do this, move the piston to the position to be monitored, turn the new proximity switch with its front side carefully to the stop, and then turn it back again 360°. This achieves the required switching distance of 1 mm (0.039 inches) Then lock it using the lock nut.



With hydraulic cylinders from AHP Merkle, the standard sensing point is the cylinder end position. It is possible to shift the sensing point up to 5 mm (0.2 inches) before the piston end position. The customer has to specify such special requirements clearly already when the hydraulic cylinder is ordered, because no subsequent adaptations are possible.



Adjustable inductive proximity switches

As an alternative to the high pressure inductive proximity switches there is also the option of adjustable inductive proximity switches. These are not pressure-tight, and detect the cylinder stroke via a rod that extends out of the pressure chamber to the rear.

These sensors are protected against polarity reversal, but NOT protected against short-circuit.

Magnetic field sensors

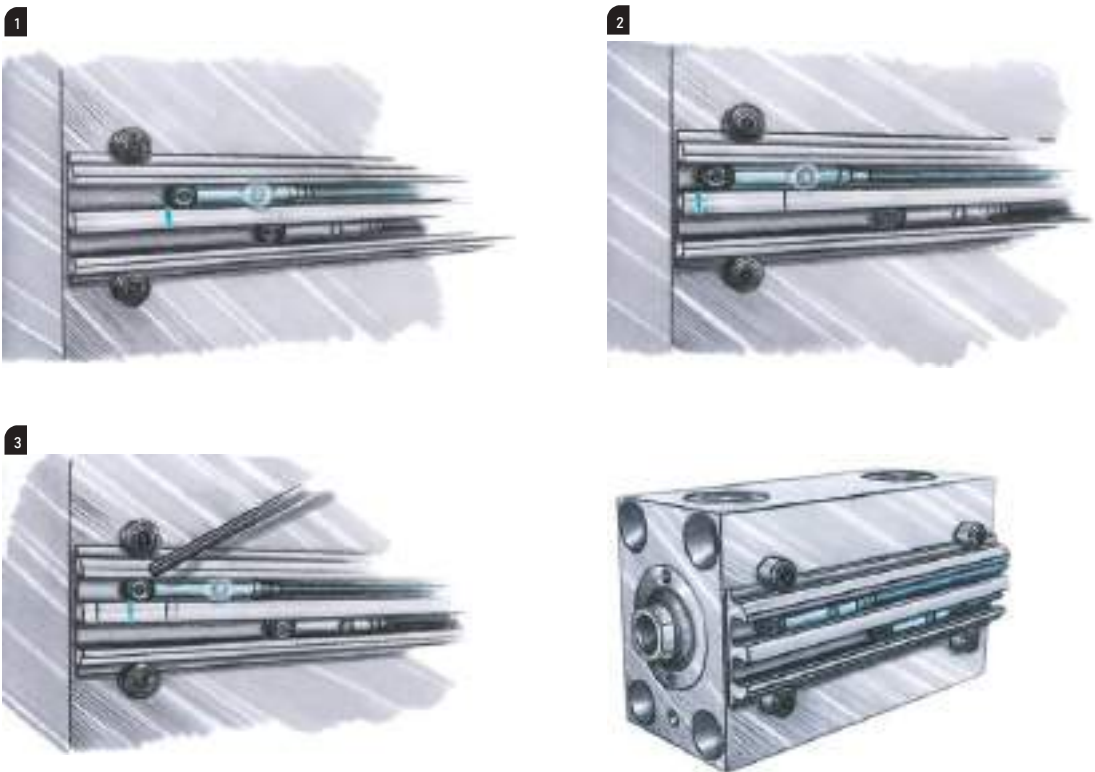
The magnetic field switches are very easy to adjust using the slot mounting.

For exact positioning the switch is slid towards the permanent magnetic field generated by the piston until it switches (image 1). Mark this position.

Repeat the same procedure at the end of the magnetic field and conclude it with a corresponding mark (image 2).

Finally, position the switch in the middle between the two marks and fix it in place (image 3).

Because of their mode of operation, magnetic field sensors have a relatively wide switching range.



Mechanical limit switch

Mechanical limit switches are actuated via an external stop or a switch cam. If the switch is actuated via a switch cam, the switching position can be changed subsequently. The switches are notable for their high switching current carrying capacity.

Linear position transducer

When installing a linear position transducer, pay very close attention to ensuring that after assembly the linear position transducer and the hole in the piston and piston rod are optimally aligned; this prevents crushing or other damage. The simplest way to do this is to move the piston to the piston end as far as it will go and only then push the linear position transducer through the hole.

4.8 General safety instructions

As a fundamental rule, only qualified personnel may perform work on hydraulic cylinders.

Never open hydraulic systems that are pressurized.

Hydraulic systems must be vented completely before being put into operation again or after maintenance work.

Dismantled parts and any hydraulic fluid that has been collected or discharged must be disposed of properly.

When there is interaction between different hydraulic cylinders, it must be ensured that no forces or pressures are added together unintentionally, which would lead to dangerous situations within the hydraulic system.

Hydraulic cylinders may never be subjected to transverse forces. Such forces can be absorbed by means of special cylinder designs with additional external guides.



Any mechanical modifications to hydraulic cylinders require consultation with the manufacturer to ensure that they do not cause any changes to the characteristics or operational limits of the cylinder.

Selected standards

DIN 24343: List for attendance and inspection of hydraulic equipments

DIN 24346: Hydraulic systems; general rules for application

DIN EN ISO 4413: Safety requirements for fluid power systems and their components

5 Cylinder finder

| | | | | Forces in N at working pressure | | | | | | | |
|------------------------|----------------------|------------|--------------------|---------------------------------|----------|----------|----------|-----------|-----------|-----------|-----------|
| Piston Ø (mm) | Piston area A1 (mm²) | Rod Ø (mm) | Ring area A2 (mm²) | 5 bar | | 10 bar | | 50 bar | | 80 bar | |
| | | | | pushing | pulling | pushing | pulling | pushing | pulling | pushing | pulling |
| Table of piston forces | | | | | | | | | | | |
| 16 | 201,06 | 8 | 150,80 | 100,53 | 75,40 | 201,06 | 150,80 | 1005,31 | 753,98 | 1608,50 | 1206,37 |
| | | 10 | 122,52 | | 61,26 | | 122,52 | | 612,61 | | 980,18 |
| 20 | 314,16 | 10 | 235,62 | 157,08 | 117,81 | 314,16 | 235,62 | 1570,80 | 1178,10 | 2513,27 | 1884,96 |
| | | 12 | 201,06 | | 100,53 | | 201,06 | | 1005,31 | | 1608,50 |
| 25 | 490,87 | 12 | 377,78 | 245,44 | 188,89 | 490,87 | 377,78 | 2454,37 | 1888,88 | 3926,99 | 3022,21 |
| | | 14 | 336,94 | | 168,47 | | 336,94 | | 1684,68 | | 2695,49 |
| | | 16 | 289,81 | | 144,91 | | 289,81 | | 1449,06 | | 2318,50 |
| | | 18 | 236,40 | | 118,20 | | 236,40 | | 1182,02 | | 1891,24 |
| 32 | 804,25 | 14 | 650,31 | 402,12 | 325,15 | 804,25 | 650,31 | 4021,24 | 3251,55 | 6433,98 | 5202,48 |
| | | 16 | 603,19 | | 301,59 | | 603,19 | | 3015,93 | | 4825,49 |
| | | 18 | 549,78 | | 274,89 | | 549,78 | | 2748,89 | | 4398,23 |
| | | 20 | 490,09 | | 245,04 | | 490,09 | | 2450,44 | | 3920,71 |
| 40 | 1256,64 | 22 | 424,12 | 628,32 | 212,06 | 1256,64 | 424,12 | 6283,19 | 2120,58 | 10053,10 | 3392,92 |
| | | 18 | 1002,17 | | 501,08 | | 1002,17 | | 5010,84 | | 8017,34 |
| | | 20 | 942,48 | | 471,24 | | 942,48 | | 4712,39 | | 7539,82 |
| | | 22 | 876,50 | | 438,25 | | 876,50 | | 4382,52 | | 7012,03 |
| 50 | 1963,50 | 25 | 765,76 | 981,75 | 382,88 | 1963,50 | 765,76 | 9817,48 | 3828,82 | 15707,96 | 6126,11 |
| | | 28 | 640,88 | | 320,44 | | 640,88 | | 3204,42 | | 5127,08 |
| | | 22 | 1583,36 | | 791,68 | | 1583,36 | | 7916,81 | | 12666,90 |
| | | 25 | 1472,62 | | 736,31 | | 1472,62 | | 7363,11 | | 11780,97 |
| 63 | 3117,25 | 28 | 1347,74 | 1558,62 | 673,87 | 3117,25 | 1347,74 | 15586,23 | 6738,72 | 24937,96 | 10781,95 |
| | | 32 | 1159,25 | | 579,62 | | 1159,25 | | 5796,24 | | 9273,98 |
| | | 36 | 945,62 | | 472,81 | | 945,62 | | 4728,10 | | 7564,96 |
| | | 28 | 2501,49 | | 1250,75 | | 2501,49 | | 12507,47 | | 20011,95 |
| 80 | 5026,55 | 32 | 2313,00 | 2513,27 | 1156,50 | 5026,55 | 2313,00 | 25132,74 | 11564,99 | 40212,39 | 18503,98 |
| | | 36 | 2099,37 | | 1049,68 | | 2099,37 | | 10496,85 | | 16794,95 |
| | | 40 | 1860,61 | | 930,30 | | 1860,61 | | 9303,04 | | 14884,87 |
| | | 45 | 1526,81 | | 763,41 | | 1526,81 | | 7634,07 | | 12214,51 |
| 100 | 7853,98 | 36 | 4008,67 | 3926,99 | 2004,34 | 7853,98 | 4008,67 | 39269,91 | 20043,36 | 62831,85 | 32069,38 |
| | | 40 | 3769,91 | | 1884,96 | | 3769,91 | | 18849,56 | | 30159,29 |
| | | 45 | 3436,12 | | 1718,06 | | 3436,12 | | 17180,58 | | 27488,94 |
| | | 50 | 3063,05 | | 1531,53 | | 3063,05 | | 15315,26 | | 24504,42 |
| 125 | 12271,85 | 56 | 2563,54 | 6135,92 | 1281,77 | 12271,85 | 2563,54 | 61359,23 | 12817,70 | 98174,77 | 20508,32 |
| | | 45 | 6263,55 | | 3131,78 | | 6263,55 | | 31317,75 | | 50108,40 |
| | | 50 | 5890,49 | | 2945,24 | | 5890,49 | | 29452,43 | | 47123,89 |
| | | 56 | 5390,97 | | 2695,49 | | 5390,97 | | 26954,86 | | 43127,78 |
| 140 | 15393,80 | 60 | 5026,55 | 7696,90 | 2513,27 | 15393,80 | 5026,55 | 76969,02 | 25132,74 | 123150,43 | 40212,39 |
| | | 70 | 4005,53 | | 2002,77 | | 4005,53 | | 20027,65 | | 32044,25 |
| | | 56 | 9808,84 | | 4904,42 | | 9808,84 | | 49044,19 | | 78470,70 |
| | | 70 | 8423,40 | | 4211,70 | | 8423,40 | | 42116,98 | | 67387,16 |
| 160 | 20106,19 | 80 | 7245,30 | 10053,10 | 3622,65 | 20106,19 | 7245,30 | 100530,96 | 36226,49 | 160849,54 | 57962,38 |
| | | 90 | 5910,12 | | 2955,06 | | 5910,12 | | 29550,61 | | 47280,97 |
| | | 80 | 10367,26 | | 5183,63 | | 10367,26 | | 51836,28 | | 82938,05 |
| | | 90 | 9032,08 | | 4516,04 | | 9032,08 | | 45160,39 | | 72256,63 |
| 180 | 25446,90 | 100 | 7539,82 | 12723,45 | 3769,91 | 25446,90 | 7539,82 | 127234,50 | 37699,11 | 203575,20 | 60318,58 |
| | | 70 | 16257,74 | | 8128,87 | | 16257,74 | | 81288,71 | | 130061,94 |
| | | 90 | 13744,47 | | 6872,23 | | 13744,47 | | 68722,34 | | 109955,74 |
| | | 100 | 12252,21 | | 6126,11 | | 12252,21 | | 61261,06 | | 98017,69 |
| 200 | 31415,93 | 110 | 10602,88 | 15707,96 | 5301,44 | 31415,93 | 10602,88 | 157079,63 | 53014,38 | 251327,41 | 84823,00 |
| | | 100 | 17592,92 | | 8796,46 | | 17592,92 | | 87964,59 | | 140743,35 |
| | | 110 | 15943,58 | | 7971,79 | | 15943,58 | | 79717,91 | | 127548,66 |
| | | 125 | 13175,05 | | 6587,53 | | 13175,05 | | 65875,27 | | 105400,43 |
| 200 | 31415,93 | 90 | 25054,20 | 15707,96 | 12527,10 | 31415,93 | 25054,20 | 157079,63 | 125271,01 | 251327,41 | 200433,61 |
| | | 110 | 21912,61 | | 10956,30 | | 21912,61 | | 109563,04 | | 175300,87 |
| | | 125 | 19144,08 | | 9572,04 | | 19144,08 | | 95720,40 | | 153152,64 |
| | | 140 | 16022,12 | | 8011,06 | | 16022,12 | | 80110,61 | | 128176,98 |



Attention: The values in this table do NOT take friction loss into account.
For further information see Chapter 1.3.

| Forces in N at working pressure | | | | | | | | | | | |
|---------------------------------|-----------|-----------|-----------|-----------|-----------|------------|------------|--------------------|------------|----------------------|---------------|
| 100 bar | | 160 bar | | 250 bar | | 500 bar | | Ring area A2 (mm²) | Rod Ø (mm) | Piston area A1 (mm²) | Piston Ø (mm) |
| pushing | pulling | pushing | pulling | pushing | pulling | pushing | pulling | | | | |
| Table of piston forces | | | | | | | | | | | |
| 2010,62 | 1507,96 | 3216,99 | 2412,74 | 5026,55 | 3769,91 | 10053,10 | 7539,82 | 150,80 | 8 | 201,06 | 16 |
| | 1225,22 | | 1960,35 | | 3063,05 | | 6126,11 | 122,52 | 10 | | |
| 3141,59 | 2356,19 | 5026,55 | 3769,91 | 7853,98 | 5890,49 | 15707,96 | 11780,97 | 235,62 | 10 | 314,16 | 20 |
| | 2010,62 | | 3216,99 | | 5026,55 | | 10053,10 | 201,06 | 12 | | |
| 4908,74 | 3777,77 | 7853,98 | 6044,42 | 12271,85 | 9444,41 | 24543,69 | 18888,83 | 377,78 | 12 | 490,87 | 25 |
| | 3369,36 | | 5390,97 | | 8423,40 | | 16846,79 | 336,94 | 14 | | |
| | 2898,12 | | 4636,99 | | 7245,30 | | 14490,60 | 289,81 | 16 | | |
| | 2364,05 | | 3782,48 | | 5910,12 | | 11820,24 | 236,40 | 18 | | |
| 8042,48 | 6503,10 | 12867,96 | 10404,95 | 20106,19 | 16257,74 | 40212,39 | 32515,48 | 650,31 | 14 | 804,25 | 32 |
| | 6031,86 | | 9650,97 | | 15079,64 | | 30159,29 | 603,19 | 16 | | |
| | 5497,79 | | 8796,46 | | 13744,47 | | 27488,94 | 549,78 | 18 | | |
| | 4900,88 | | 7841,42 | | 12252,21 | | 24504,42 | 490,09 | 20 | | |
| 12566,37 | 4241,15 | 20106,19 | 6785,84 | 31415,93 | 10602,88 | 62831,85 | 21205,75 | 424,12 | 22 | 1256,64 | 40 |
| | 10021,68 | | 16034,69 | | 25054,20 | | 50108,40 | 1002,17 | 18 | | |
| | 9424,78 | | 15079,64 | | 23561,94 | | 47123,89 | 942,48 | 20 | | |
| | 8765,04 | | 14024,07 | | 21912,61 | | 43825,22 | 876,50 | 22 | | |
| 19634,95 | 7657,63 | 31415,93 | 12252,21 | 49087,39 | 19144,08 | 98174,77 | 38288,16 | 765,76 | 25 | 1963,50 | 50 |
| | 6408,85 | | 10254,16 | | 16022,12 | | 32044,25 | 640,88 | 28 | | |
| | 15833,63 | | 25333,80 | | 39584,07 | | 79168,13 | 1583,36 | 22 | | |
| | 14726,22 | | 23561,94 | | 36815,54 | | 73631,08 | 1472,62 | 25 | | |
| 31172,45 | 13477,43 | 49875,92 | 21563,89 | 77931,13 | 33693,58 | 155862,27 | 67387,16 | 1347,74 | 28 | 3117,25 | 63 |
| | 11592,48 | | 18547,96 | | 28981,19 | | 57962,38 | 1159,25 | 32 | | |
| | 9456,19 | | 15129,91 | | 23640,48 | | 47280,97 | 945,62 | 36 | | |
| | 25014,93 | | 40023,89 | | 62537,33 | 251327,41 | 125074,66 | 2501,49 | 28 | | |
| 50265,48 | 23129,98 | 80424,77 | 37007,96 | 125663,71 | 57824,94 | | 115649,88 | 2313,00 | 32 | 5026,55 | 80 |
| | 20993,69 | | 33589,91 | | 52484,23 | | 104968,46 | 2099,37 | 36 | | |
| | 18606,08 | | 29769,73 | | 46515,21 | | 93030,41 | 1860,61 | 40 | | |
| | 15268,14 | | 24429,02 | | 38170,35 | | 76340,70 | 1526,81 | 45 | | |
| 78539,82 | 40086,72 | 125663,71 | 64138,76 | 196349,54 | 100216,81 | 392699,08 | 200433,61 | 4008,67 | 36 | 7853,98 | 100 |
| | 37699,11 | | 60318,58 | | 94247,78 | | 188495,56 | 3769,91 | 40 | | |
| | 34361,17 | | 54977,87 | | 85902,92 | | 171805,85 | 3436,12 | 45 | | |
| | 30630,53 | | 49008,85 | | 76576,32 | | 153152,64 | 3063,05 | 50 | | |
| 122718,46 | 25635,40 | 196349,54 | 41016,63 | 306796,16 | 64088,49 | 613592,32 | 128176,98 | 2563,54 | 56 | 12271,85 | 125 |
| | 62635,50 | | 100216,81 | | 156588,76 | | 313177,52 | 6263,55 | 45 | | |
| | 58904,86 | | 94247,78 | | 147262,16 | | 294524,31 | 5890,49 | 50 | | |
| | 53909,73 | | 86255,57 | | 134774,32 | | 269548,65 | 5390,97 | 56 | | |
| 153938,04 | 50265,48 | 246300,86 | 80424,77 | 384845,10 | 125663,71 | 769690,20 | 251327,41 | 5026,55 | 60 | 15393,80 | 140 |
| | 40055,31 | | 64088,49 | | 100138,27 | | 200276,53 | 4005,53 | 70 | | |
| | 98088,38 | | 156941,40 | | 245220,94 | | 490441,88 | 9808,84 | 56 | | |
| | 84233,95 | | 134774,32 | | 210584,88 | | 421169,77 | 8423,40 | 70 | | |
| 201061,93 | 72452,98 | 321699,09 | 115924,77 | 502654,82 | 181132,45 | 1005309,65 | 362264,90 | 7245,30 | 80 | 20106,19 | 160 |
| | 59101,21 | | 94561,94 | | 147753,03 | | 295506,06 | 5910,12 | 90 | | |
| | 103672,56 | | 165876,09 | | 259181,39 | | 518362,79 | 10367,26 | 80 | | |
| | 90320,79 | | 144513,26 | | 225801,97 | | 451603,94 | 9032,08 | 90 | | |
| 254469,00 | 75398,22 | 407150,41 | 120637,16 | 636172,51 | 188495,56 | 1272345,02 | 376991,12 | 7539,82 | 100 | 25446,90 | 180 |
| | 162577,42 | | 260123,87 | | 406443,55 | | 812887,10 | 16257,74 | 70 | | |
| | 137444,68 | | 219911,49 | | 343611,70 | | 687223,39 | 13744,47 | 90 | | |
| | 122522,11 | | 196035,38 | | 306305,28 | | 612610,57 | 12252,21 | 100 | | |
| 314159,27 | 106028,75 | 502654,82 | 169646,00 | 785398,16 | 265071,88 | 1570796,33 | 530143,76 | 10602,88 | 110 | 31415,93 | 200 |
| | 175929,19 | | 281486,70 | | 439822,97 | | 879645,94 | 17592,92 | 100 | | |
| | 159435,83 | | 255097,32 | | 398589,57 | | 797179,14 | 15943,58 | 110 | | |
| | 131750,54 | | 210800,87 | | 329376,35 | | 658752,71 | 13175,05 | 125 | | |
| | 250542,01 | | 400867,22 | | 626355,04 | | 1252710,07 | 25054,20 | 90 | | |
| | 219126,09 | | 350601,74 | | 547815,22 | | 1095630,44 | 21912,61 | 110 | | |
| | 191440,80 | | 306305,28 | | 478602,01 | | 957204,01 | 19144,08 | 125 | | |
| | 160221,23 | | 256353,96 | | 400553,06 | | 801106,13 | 16022,12 | 140 | | |

5 Cylinder finder

| | | | | Options | | | | | | Characteristics | | | | | | | | Application | | | | | |
|-------------------|---------|---------------|-------------------------|-------------|------------------|--------|-------------|--------|------------|----------------------------|-------------|---------------------------------|-------------------------------|--|--------------|-------------------------|---------------------------------|-------------------|----------------------------------|--------------------------|--|--|--|
| | Index | Piston Ø (mm) | Max. pressure (bar/PSI) | Stroke (mm) | Centering collar | Keyway | Viton® seal | Vented | Cushioning | Possibility of O-ring port | System port | Temperature with standard seals | Temperature with viton® seals | Switch | dipp® system | Non-rotating piston rod | Guide rods / integrated guiding | Rotation possible | Cylindertube suitable as a guide | For stamping application | Direct installation of cylinder possible | | |
| Block cylinder | | | | | | | | | | | | | | | | | | | | | | | |
| BZ 500 | 1 | 16 | 500/7200 | 0...100 | | | | | | | | -15 ... 80°C 5 ... 176°F | -15 ... 180°C 5 ... 356°F | without | | | | | | | | | |
| | | 25-63 | | 0...130 | | | | | | ■ | | | | | | | | | | | | | |
| | | 80-100 | | 0...160 | | | | | | | ■ | | | | | | | | | | | | |
| | | 125-200 | | 0...200 | | | | | | | ■ | | | | | | | | | | | | |
| BZ 320 | | 25-63 | 320/4600 | 101... 200 | | | | | | | ■ | | | | | | | | | | | | |
| | 80-100 | 131... 200 | | | | | | | | | ■ | | | | | | | | | | | | |
| | 125 | ≥161 | | | | | | | | | | | | | | | | | | | | | |
| BRB 250 | | 25-100 | 250/3600 | 201... 500 | | | | | | ■ | | | | | | | | | | | | | |
| BZN 500 | 1 | 16 | 320/4600 | 0...100 | | | | | | | | -15 ... 80°C 5 ... 176°F | -15 ... 120°C 5 ... 248°F | inductive, high-pressure resistant | | | | | | | | | |
| | | 25-63 | | 0...130 | | | | | | | ■ | | | | | | | | | | | | |
| | | 80-100 | | 0...160 | | | | | | | | | | | ■ | | | | | | | | |
| | | 125-200 | | 0...200 | | | | | | | | | | | ■ | | | | | | | | |
| BZN 320 | | 25-63 | 320/4600 | 101... 200 | | | | | | | ■ | | | | | | | | | | | | |
| | 80-100 | 131... 200 | | | | | | | | | ■ | | | | | | | | | | | | |
| | 125 | ≥161 | | | | | | | | | | | | | | | | | | | | | |
| BRBN 250 | | 25-100 | 250/3600 | 201... 500 | | | | | | ■ | | | | | | | | | | | | | |
| MBZ160 | 1 | 25-63 | 250/3600 | 0...100 | | | | | | | | -15 ... 80°C 5 ... 176°F | -15 ... 130°C 5 ... 266°F | magnetic field | | | | | | | | | |
| MBZ160L | | 25-63 | | 101... 200 | | | | | | | | | | | | | | | | | | | |
| BZR 500 | 1 | 25-63 | 500/7200 | 0...100 | | | | | | ■ | | -15 ... 80°C 5 ... 176°F | -15 ... 180°C 5 ... 356°F | mechanical | | | | | | | | | |
| | | 80-100 | | 0...130 | | | | | | | ■ | | | | | | | | | | | | |
| | | 125-200 | | 0...160 | | | | | | | | | | | ■ | | | | | | | | |
| | | 125-200 | | 0...200 | | | | | | | | | | | ■ | | | | | | | | |
| BZR 320 | | 25-63 | 320/4600 | 101... 200 | | | | | | | ■ | | | | | | | | | | | | |
| | 80-100 | 131... 200 | | | | | | | | | ■ | | | | | | | | | | | | |
| | 125-200 | ≥161 | | | | | | | | | | | | | | | | | | | | | |
| BZH 500 | 1 | 25-125 | 500/7200 | 0...100 | | | | | | | | -15 ... 80°C 5 ... 176°F | -15 ... 120°C 5 ... 248°F | inductive, external | | | | | | | | | |
| BZP 501 | 1 | 25-63 | 500/7200 | 0... 50 | | | | | | ■ | | -15 ... 80°C 5 ... 176°F | -15 ... 140°C 5 ... 284°F | inductive, external | | | | | | | | | |
| | | 80-100 | | 0...130 | | | | | | | ■ | | | | | | | | | | | | |
| | | 125-200 | | 0...160 | | | | | | | | | | | ■ | | | | | | | | |
| | | 125-200 | | 0...200 | | | | | | | | | | | ■ | | | | | | | | |
| BZP 321 | | 25-63 | 320/4600 | 101... 200 | | | | | | | ■ | | | | | | | | | | | | |
| | 80-100 | 131... 200 | | | | | | | | | ■ | | | | | | | | | | | | |
| | 125-200 | ≥161 | | | | | | | | | | | | | | | | | | | | | |
| BZ 250 | 1 | 25-125 | 250/3600 | 0... 200 | | | | | | ■ | | -15 ... 80°C 5 ... 176°F | -15 ... 180°C 5 ... 356°F | without | | | | | | | | | |
| BVZ 250 | 1 | 40-100 | 250/3600 | 0...100 | | | | | | | | -15 ... 80°C 5 ... 176°F | -15 ... 100°C 5 ... 212°F | without | | | | | | | | | |
| Stamping cylinder | | | | | | | | | | | | | | | | | | | | | | | |
| STZ 250 | 2 | 40-63 | 250/3600 | 0...100 | | | | | | ■ | | -15 ... 80°C 5 ... 176°F | -15 ... 180°C 5 ... 356°F | without | | | | | | | | | |
| | | 80-100 | | 0...130 | | | | | | | | | | | ■ | | | | | | | | |
| | | 125-200 | | 0...160 | | | | | | | | | | | | | | | | | | | |

| | | | | Options | | | | | | Characteristics | | | | | | Application | | | | | | | |
|-------------------------|--------|---------------|-------------------------|-------------|------------------|--------|-------------|--------|------------|----------------------------|-------------|---------------------------------|-------------------------------|--|--------------|-------------------------|---------------------------------|-------------------|----------------------------------|--------------------------|--|--|--|
| | Index | Piston Ø (mm) | Max. pressure (bar/PSI) | Stroke (mm) | Centering collar | Keyway | Viton® seal | Vented | Cushioning | Possibility of O-ring port | System port | Temperature with standard seals | Temperature with viton® seals | Switch | dipp® system | Non-rotating piston rod | Guide rods / integrated guiding | Rotation possible | Cylindertube suitable as a guide | For stamping application | Direct installation of cylinder possible | | |
| Circular block cylinder | | | | | | | | | | | | | | | | | | | | | | | |
| RZ 500 | 3 | 16 | 500/7200 | 0...100 | | | | | | | | -15...80°C 5...176°F | -15...180°C 5...356°F | without | | | | | | | | | |
| | | 20-63 | | 0...130 | | | | | | | | | | | | | | | | | | | |
| | | 80-100 | | | | | | | | | | | | | | | | | | | | | |
| RZ 320 | | 16 | 320/4600 | 101...200 | | | | | | | | | | | | | | | | | | | |
| | | 20-63 | | 131...200 | | | | | | | | | | | | | | | | | | | |
| | | 80-100 | | | | | | | | | | | | | | | | | | | | | |
| Push unit | | | | | | | | | | | | | | | | | | | | | | | |
| BSE 250 | 4 | 20 | 250/3600 | 0...500 | | | | | ■ | | | -15...80°C 5...176°F | -15...80°C 5...176°F | mechanical | | | 2,4 | | | | | | |
| | | 25-40 | | | | | | | ■ | | | | | | | | 2,3,4 | | | | | | |
| | | 50-100 | | | | | | | ■ | | | | | | | | 2,4 | | | | | | |
| ZSE | 4 | 40 | 250/3600 | 0...500 | | | | | ■ | | | -15...65°C 5...149°F | -15...65°C 5...149°F | mechanical | | | 4 | | | | | | |
| | | 50 | | | | | | ■ | | | | | | | | 2,4 | | | | | | | |
| | | 63-80 | | | | | | ■ | | | | | | | | 4 | | | | | | | |
| BZS | 4 | | | | | | | | | | | -15...80°C 5...176°F | -15...180°C 5...356°F | without | | | 4 | | | | | | |
| Standard cylinder | | | | | | | | | | | | | | | | | | | | | | | |
| UZ 100 | 5 | 16-25 | 100/1400 | 20...2000 | | | | | ■ | | | -15...80°C 5...176°F | -15...180°C 5...356°F | without | | | | | | | | | |
| | | 32-100 | | | | | | | ↗ | | | | | | | | | | | | | | |
| HZ 160 | | 16-25 | 160/2300 | 20...2000 | | | | | ■ | | | | | | | | | | | | | | |
| | | 32-100 | | | | | | | | | ↗ | | | | | | | | | | | | |
| HZ 250 | | 20 | 250/3600 | 20...2000 | | | | | ■ | | | | | | | | | | | | | | |
| | 25-100 | | | | | | | | | ↗ | | | | | | | | | | | | | |
| HZH 250 | | 20 | 250/3600 | 20...2000 | | | | | ■ | | | | | | | | | | | | | | |
| | | 25-100 | | | | | | | | | ↗ | | | | | | | | | | | | |
| UZN 100 | 5 | 16-25 | 100/1400 | 20...2000 | | | | | ■ | | | -15...80°C 5...176°F | -15...120°C 5...248°F | inductive, high-pressure resistant | | | | | | | | | |
| | | 32-100 | | | | | | | | | ↗ | | | | | | | | | | | | |
| HZN 160 | | 16-25 | 160/2300 | 20...2000 | | | | | ■ | | | | | | | | | | | | | | |
| | | 32-100 | | | | | | | | | ↗ | | | | | | | | | | | | |
| HZN 250 | | 20 | 250/3600 | 20...2000 | | | | | ■ | | | | | | | | | | | | | | |
| | 25-100 | | | | | | | | | ↗ | | | | | | | | | | | | | |
| HZHN 250 | | 20 | 250/3600 | 20...2000 | | | | | ■ | | | | | | | | | | | | | | |
| | | 25-100 | | | | | | | | | ↗ | | | | | | | | | | | | |
| HMZ 250 | 5 | 40-100 | 250/3600 | 20...2000 | | | | | ↗ | | | -15...80°C 5...176°F | -15...80°C 5...176°F | magnetostrictive position measuring Balluff/MRS/TR | | | | | | | | | |
| DIN standard cylinder | | | | | | | | | | | | | | | | | | | | | | | |
| ZHZ 160 | 6 | 25-200 | 160/2300 | 0...500 | | | | | | | | -15...80°C 5...176°F | -15...180°C 5...356°F | without | | | | | | | | | |
| DHZ 160 | | 25-200 | 160/2300 | 0...1000 | | | | | ↗ | | | -15...80°C 5...176°F | -15...180°C 5...356°F | | | | | | | | | | |
| DHZ 250 | | 50-200 | 250/3600 | 0...1000 | | | | | ↗ | | | -15...80°C 5...176°F | -15...180°C 5...356°F | | | | | | | | | | |

| | | | | | Options | | | | | | Characteristics | | | | | | Application | | | | | | | |
|--|-------|---------------|-------------------------|-------------|------------------|--------|-------------|--------|------------|----------------------------|-----------------|---------------------------------|-------------------------------|--|--------------|-------------------------|---------------------------------|-------------------|----------------------------------|--------------------------|--|--|--|--|
| | Index | Piston Ø (mm) | Max. pressure (bar/PSI) | Stroke (mm) | Centering collar | Keyway | Viton® seal | Vented | Cushioning | Possibility of O-ring port | System port | Temperature with standard seals | Temperature with viton® seals | Switch | dipp® system | Non-rotating piston rod | Guide rods / integrated guiding | Rotation possible | Cylindertube suitable as a guide | For stamping application | Direct installation of cylinder possible | | | |
| Hydraulic cylinder with external guide | | | | | | | | | | | | | | | | | | | | | | | | |
| HZF 160 | 7 | 63–140 | 160/2300 | | | | | | | | | –15 ... 80°C 5 ... 176°F | –15 ... 180°C 5 ... 356°F | without | | | | | | | | | | |
| Locking cylinder | | | | | | | | | | | | | | | | | | | | | | | | |
| VBZ 160 | 8 | 32–40 | 160/2300 | 0 ... 110 | | | | | | | | –15 ... 80°C 5 ... 176°F | –15 ... 80°C 5 ... 176°F | inductive, high-pressure resistant | | | | | | | | | | |
| Short-stroke cylinder | | | | | | | | | | | | | | | | | | | | | | | | |
| WKHZ 400 | 9 | 25 | 400/5800 | 10 | | | | | | | | –15 ... 80°C 5 ... 176°F | –15 ... 180°C 5 ... 356°F | without | | | | | | | | | | |
| | | 32–50 | | 15 | | | | | | | | | | | | | | | | | | | | |
| KHZ 160 | | 25 | 160/2300 | 10 | | | | | | | | | | | | | | | | | | | | |
| | | 32 | | 15 | | | | | | | | | | | | | | | | | | | | |
| Screw-in cylinder | | | | | | | | | | | | | | | | | | | | | | | | |
| EZ 251 | 10 | 25 | 250/3600 | 10 | | | | | | | | –15 ... 80°C 5 ... 176°F | –15 ... 180°C 5 ... 356°F | without | | | | | | | | | | |
| | | 25 | | 25 | | | | | | | | | | | | | | | | | | | | |
| | | 32 | | 32 | | | | | | | | | | | | | | | | | | | | |
| | | 40 | | 40 | | | | | | | | | | | | | | | | | | | | |
| Core pull unit | | | | | | | | | | | | | | | | | | | | | | | | |
| KZE 251 | 11 | 32–50 | 250/3600 | 50 ... 250 | | | | | | | | –15 ... 80°C 5 ... 176°F | –15 ... 100°C 5 ... 212°F | mechanical | | | | | | | | | | |
| Flanged cylinder | | | | | | | | | | | | | | | | | | | | | | | | |
| FZ 250 | 12 | 25–80 | 250/3600 | 0 ... 96 | | | | | | | | –15 ... 80°C 5 ... 176°F | –15 ... 180°C 5 ... 356°F | without | | | | | | | | | | |
| Double-lined cylinder | | | | | | | | | | | | | | | | | | | | | | | | |
| DFZ 250 | 13 | 32–80 | 250/3600 | 0 ... 500 | | | | | | | | –15 ... 80°C 5 ... 176°F | –15 ... 180°C 5 ... 356°F | without | | | | | | | | | | |
| Clamping elements | | | | | | | | | | | | | | | | | | | | | | | | |
| BZK 250 | 14 | 25–125 | 250/3600 | 20–40 | | | | | | | | –15 ... 80°C 5 ... 176°F | –15 ... 180°C 5 ... 356°F | inductive, high-pressure resistant inductive, external magnetic field | | | | | | | | | | |
| BZF 500 | | 25–63 | 500/7200 | 20–63 | | | | | | | | –15 ... 80°C 5 ... 176°F | –15 ... 180°C 5 ... 356°F | inductive, high-pressure resistant inductive, external magnetic field | | | | | | | | | | |
| Rotary drive unit | | | | | | | | | | | | | | | | | | | | | | | | |
| DA 100 | 15 | 25–100 | 50/725 | 0 ... 720° | | | | | | | | –15 ... 80°C 5 ... 176°F | –15 ... 180°C 5 ... 356°F | without | | | | | | | | | | |

