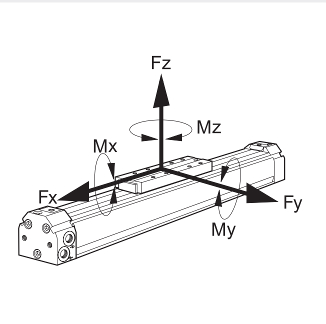
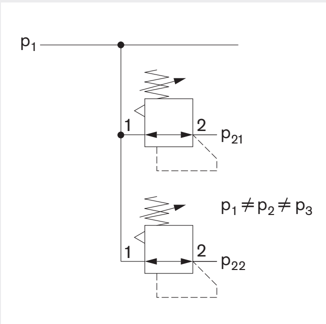
AVENTICS

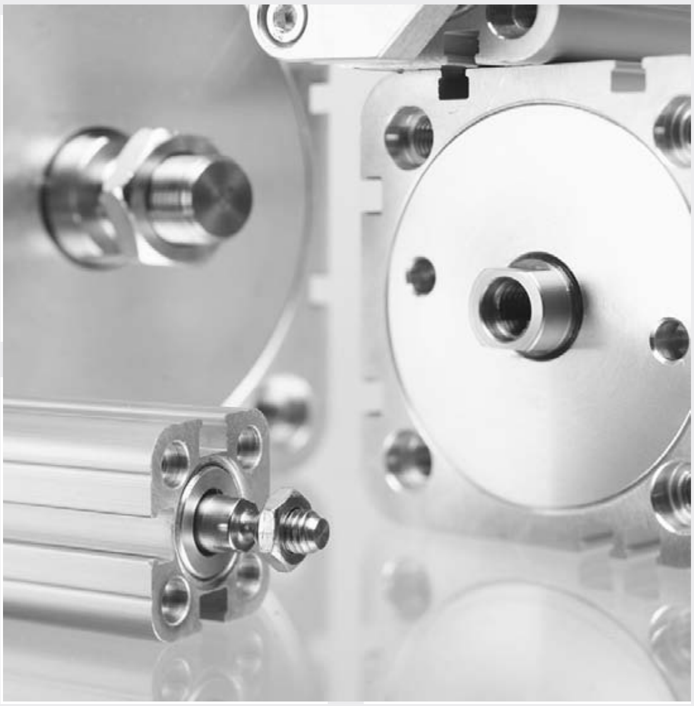
TECHNICAL INFORMATION

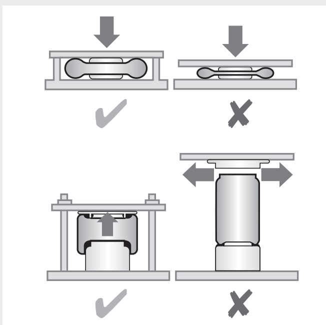
Supplement to the Pneumatics Catalog

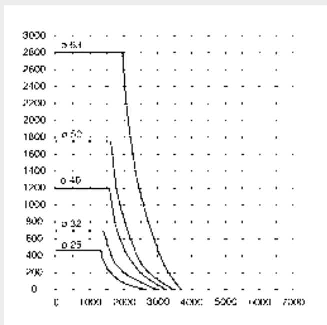
Rexroth Pneumatics











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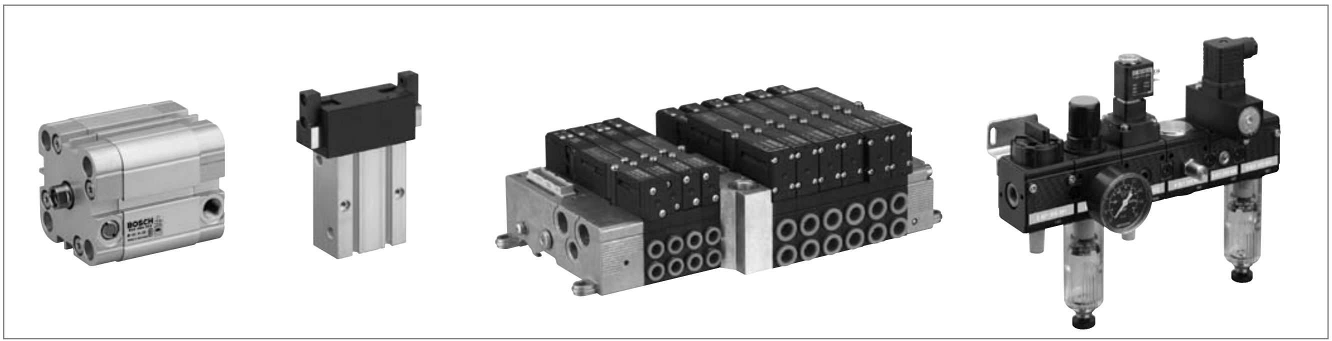


I General operating instructions

1 Storage and transportation

Pneumatic components typically have elastomer seals. These seals tend to age, i.e. devices stored for more than 2 years no longer have the expected service life.

The aging process can be accelerated by heat and light (UV rays).

2 Compressed air quality

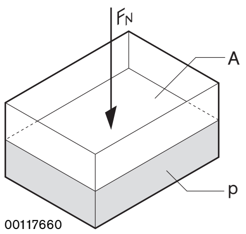
Various purity classes are described in ISO 8573-1.

With pneumatic components, ensure that the following impurities do not exceed the specified permissible values.

- Maximum particle size and density of solid impurities
- Water content
- Max. recommended values for the entire oil content for operation with lubricated and non-lubricated compressed air must be observed

3 Pressure and pressure ranges

$$p = \frac{F_N}{A}$$



The physical pressure p is the quotient of the force F_N acting perpendicularly on surface A and the area of A.

Various pressure classes are used in technology, primarily the difference between two pressures, which is also called “pressure” in everyday usage.

To avoid misunderstandings, DIN 1314 recommends the following designations:

- **Absolute pressure**
  Absolute pressure p_{abs}
  p_{abs} is the pressure compared with zero pressure in a total vacuum.

$$\Delta p = p_{1,2} = p_1 - p_2$$

- **Differential pressure Δp**
  Differential pressure $\Delta p_{1,2}$
  The difference between two pressures p_1 and p_2 is the differential pressure Δp

- Also called differential pressure $p_{1,2}$ if it is the measured value.

$$p_e = p_{abs} - p_{amb}$$

- Atmospheric differential pressure, overpressure p_e
  The difference between an absolute pressure p_{abs} and the corresponding (absolute) atmospheric pressure p_{amb} is the atmospheric differential pressure p_e, which is also called overpressure.

  Unless otherwise indicated, information in this catalog refers to overpressure p_e.

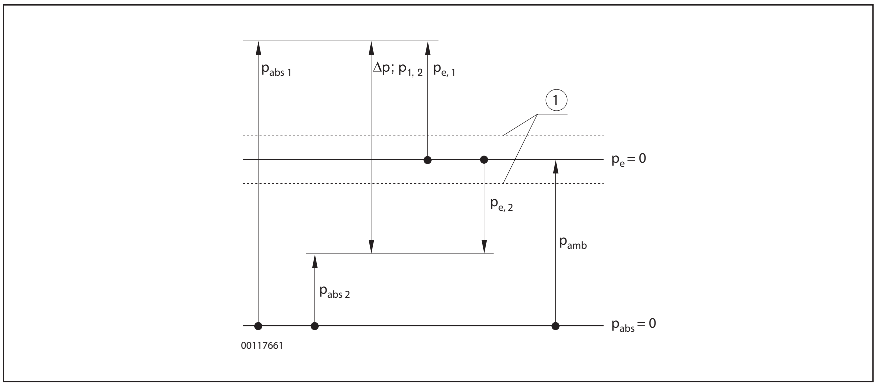


Fig. 1 Atmospheric differential pressure

1 Atmospheric pressure fluctuations

3.1 Working pressure range

Range between the pressure limit values in which a system or subsystem can be operated in an equilibrium condition.

3.2 Control pressure range

Range between the lowest required and highest permissible control pressure for a device or system to operate perfectly.

4 Connection thread

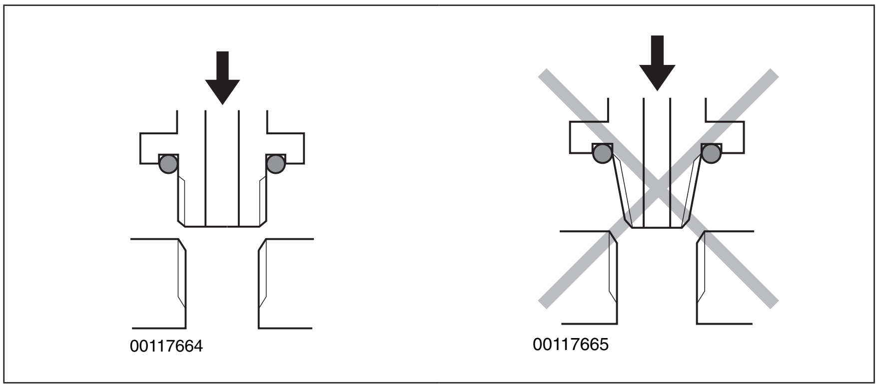


Fig. 2 Cylindrical connection thread

Only fittings with cylindrical threads and axial seals may be used as pipe fittings for connecting devices. Conical threads can cause device damage and premature failures.

Pneumatic devices from AVENTICS fulfill at least ISO 16030 in terms of thread depth and sealing surface.

5 IP protection classes

The indicated IP values from our pneumatics product catalog only refer to the plugs we have approved.

The division of protection classes according to enclosures for electrical equipment is described in DIN EN 60529 and IEC 60529.

Code					Description
IP	2	3	C	H	Code initials (International Protection)
IP	**2**	3	C	H	First code number (numbers 0 to 6, or letter X)*
IP	2	**3**	C	H	Second code number (numbers 0 to 8, or letter X)*
IP	2	3	**C**	H	Additional letter (optional; letters A, B, C, D)**
IP	2	3	C	**H**	Supplementary letter (optional; letters H, M, S, W)**

Table 1 IP code arrangement

*Must be replaced by the letter “X” (“XX” if both code numbers are omitted).
**Additional and/or supplementary letters may be omitted. Please follow alphabetical order if more than one supplementary letter is used.

Part	Code IP	Type of equipment protection Protection against penetration of solid foreign bodies	Type of worker protection Protection against access to dangerous parts
First code number	0	(No protection)	(No protection)
	1	≥ 50.0 mm Ø	Back of hand
	2	≥ 12.5 mm Ø	Fingers
	3	≥ 2.5 mm Ø	Tool
	4	≥ 1.0 mm Ø	Wire
	5	Protected against dust	Wire
	6	Dust proof	Wire
Second code number		**Protection against penetration of water with damaging effects**	
	0	(No protection)	
	1	Vertical drips	
	2	Drips (15° angle)	
	3	Water spray	
	4	Water splashes	
	5	Water jets	
	6	Strong water jets	
	7	Temporary immersion	
	8	Submersion	
Additional letter (optional)			**Protection against access to dangerous parts with**
	A		Back of hand
	B		Fingers
	C		Tool
	D		Wire
Supplementary letter (optional)		**Supplementary information specifically for**	
	H	High-voltage devices	
	M	Movement during water test	
	S	Standstill during water test	
	W	Weather conditions	

Table 2 IP protection class key

6 Service life of pneumatic products

To determine the service life of pneumatic products, service life figures are calculated in service life tests. The values serve for product quality assurance and can be used as a planning basis for configuring systems and machines, safety-relevant controllers, maintenance intervals, and preventive maintenance measures.

For valves, the service life is based on the number of switching cycles. For drives, the service life can be defined as the number of strokes or as the distance traveled by the piston (in kilometers).

Products with components made of plastic and sealing materials feature a long service life under standard application conditions for industrial use in pneumatic components. Additional loads on products, such as direct sunlight, disproportional changes in temperature, chemical attack caused by lubricants and anti-corrosion agents, paints, solvents, ozone, etc., can induce early aging and brittling processes that can impair the functionality of the products and possibly render them inoperative. For this reason, we recommend subjecting the product to an annual visual inspection and performing a leak test as needed. If you have any questions, please contact our technical consultants or call your local sales office.

Note: There is more than one service life figure, which is why the exact service life value as well as the applicable general conditions and operating conditions should be discussed in every customer discussion.

6.1 Service life tests and their evaluation

Failure frequency can be determined using statistical methods, such as Weibull statistics. A value calculated in a laboratory under defined operating conditions therefore supplies an expected value for the service life and functional life of the tested product under the selected conditions.

During evaluation of the results, it must be taken into consideration that the values are calculated under specific test conditions. A direct application to other operating conditions is generally not permitted.

Working pressure	Ambient temperature Compressed air quality	
p1 = 6.3 bar	Medium temperature	T = approx. 23°C
	Filtering	5 µ
	Pressure dew point	+3°C
	Oiling	None

Table 3 General test conditions

Endurance tests are performed with a defined minimum quantity of test objects to enable a solid statistical evaluation based on a Weibull distribution. Each object is tested until total failure or a previously defined limit is exceeded. In this case, basic function may still be guaranteed.

The resulting values allow for a statement regarding the reliability of the tested components.

6.2 Service life figures

6.2.1 B10 value

The key figure for assessing the reliability of a wear and tear component is the B10 value in accordance with ISO 19973. This value represents the service life up to which 10% of test objects exhibited failure. The B10 value for TC08 series 5/2 and 5/3 directional valves, for example, is 20 million switching cycles.

6.2.2 $B10_d$ value

EN ISO 13849 requires the $B10_d$ value as a special reliability value (d for dangerous). This value is the average number of cycles until which 10% of components have experienced failure representing a danger.

However, it is very difficult for manufacturers to estimate what type of failure has which hazard potential in unfamiliar applications.

To defuse this situation, EN ISO 13849 defines a pragmatic approach: only every second failure represents a dangerous failure. As a result, $B10_d$ can be estimated as $B10_d = 2 \times B10$ for the known B10 value.

6.2.3 Service life figure T according to ISO 19973

The service life figure T from a service life analysis according to ISO 19973 is the time period after which approximately 63.2% of the units have failed. This value is a figure from the Weibull distribution.

6.3 Standards

The following standards govern the reliability and safety of machines and components.

6.3.1 Standard: ISO 19973

This standard was developed especially for assessing the reliability of pneumatic components and describes the conditions and methods for performing service life testing.

Structure of ISO 19973

- Part 1 General procedures
- Part 2 Valves
- Part 3 Cylinders with piston rode
- Part 4 Pressure regulators

6.3.2 EN ISO 13849

The EN ISO 13849 standard focuses on the safety of machinery. It defines cross-technology (mechanics, pneumatics, hydraulics, electrical systems, electronics) principles for designing and integrating safety-relevant parts of controllers and their validation.

Structure of EN ISO 13849

- Part 1 General principles for design
- Part 2 Validation

Manufacturers of components that are to be used in safety-relevant parts of controllers are required to provide users with solid reliability values. With this data (B10, $B10_d$ values, etc.) and further information, the safety level (performance level, PL) of the controller can be calculated.

7 Symbols

Graphic symbols for pneumatic components should correspond to ISO 1219-1 and circuit diagrams should be drawn up according to ISO 1219-2. Identification of the connections and operating mechanisms for control valves and other components is described in ISO 11727.

8 Industry-specific requirements

8.1 Free of paint-wetting impairment substances (PWIS)

The acronym PWIS (paint-wetting impairment substances) has primarily been defined by the automotive industry. The objective is to avoid substances that have a negative impact on the adhesion and quality of paint applications. This is usually caused by the occurrence of substances with a low surface tension on drying paint. This includes silicones, polytetrafluoroethylene (Teflon®) and surfactants (tensides). Components of oils and greases can also impair paint wetting. This is noticeable in pits and cracking in the dried paint surface.

To meet the requirements for this sector, AVENTICS has created its own work instructions, which are fundamentally oriented toward various factory standards in the automotive industry (industry-specific requirements) as well as the company's experience in pneumatics.

Products in the online catalog designated as "PWIS-free" have been designed and manufactured accordingly (without paint-wetting impairment substances).

9 Applicable directives

9.1 EC Machinery Directive (2006/42/EC)

In the view of the VDMA (Verband Deutscher Maschinen- und Anlagenbau e.V., Association of German Machinery and System Manufacturers), agents of the DGUV (Deutsche gesetzliche Unfallversicherung, German Statutory Accident Insurance Agency), and AVENTICS GmbH, the majority of our pneumatics components and assemblies do not fall within the scope of the EC Machinery Directive.

Safety components constitute an exception. These products are provided with a declaration of conformity.

Our pneumatic products are always designed in accordance with applicable standards for pneumatic systems (especially EN ISO 4414 “Pneumatic fluid power – General rules and safety requirements for systems and their components”).

9.2 EC Directive: “Electromagnetic Compatibility” (2004/108/EC)

This directive applies to our pneumatic products if they contain active electronic components. These products bear a CE marking and the associated declarations of conformity are available as required.

Solenoid coils for valves, for example, are not affected.

9.3 EC Directive: “Low Voltage” (2006/95/EC)

This directive applies to electrical and electronic products that are intended for use within certain voltage ranges (50-1000 V AC and 75-1500 V DC). These products must bear the CE marking. The associated declarations of conformity are available as required.

9.4 EC Directive: “Simple Pressure Vessels” (2009/105/EC)

The pressure reservoirs we offer comply with this directive. Depending on volumes and maximum permissible pressures, they are required to bear the CE marking. The declarations of conformity are enclosed with the products.

9.5 EC Directive: “Pressure Equipment” (97/23/EC)

Our pressure relief valves comply with this directive. These products bear the CE marking. The declarations of conformity are enclosed with the products.

9.6 EC Directive: “ATEX” (94/9/EC)

Our products intended for use in explosive areas (gas and/or dust) comply with this directive. Products with potential internal ignition sources are appropriately labeled (CE and ATEX markings). The declaration of conformity and the operating instructions are delivered with the product.

9.7 RoHS and WEEE

EC Directive 2002/95/EC (RoHS: Restriction of (the use of certain) Hazardous Substances), drafted to limit the use of certain dangerous substances in electrical and electronic devices, regulates the use of hazardous materials in devices and components, as well as specific implementation in national legislation.

The objective of the RoHS Directive is to prohibit the use of extremely problematic elements in products and to avoid and reduce electrical and electronic waste.

The following items play an important part in this context:

- Lead-free soldering of electronic components
- Prohibition of toxic flame retardants in cable production
- Intensified introduction of appropriate alternative products
- All parts and components must be free of the following substances:
  lead, mercury, cadmium, hexavalent chromium, polybrominated biphenyls (PBB), and polybrominated diphenyl ethers (PBDE)

RoHS does not prescribe the marking of RoHS-compliant parts or products.

In Germany, the Electrical and Electronic Equipment Act (ElektroG) came into effect on March 16, 2005, which, along with RoHS, also adopted EU Directive WEEE (Waste Electrical and Electronic Equipment) in German law.

The WEEE Directive corresponds with the EC Directive 2002/96/EC to reduce the increasing quantity of electronic waste from electrical and electronic devices that are no longer in use. The objective of the WEEE Directive is the avoidance and reduction of electrical and electronic waste, as well as the environmentally responsible disposal of the increasing quantities of electronic waste through extended producer responsibility.

The WEEE Directive defines the devices and device categories that fall under the RoHS and WEEE Directives.

10 REACH Regulation (EC) No. 1907/2006

REACH stands for **R**egistration, **E**valuation, **A**uthorization, and Restriction of **Ch**emicals. As an EU directive, REACH is equally and directly applicable in all EU member states.

The REACH system is based on the principle of voluntary producer responsibility. Within the scope of validity, chemical substances may only be put into circulation pending prior registration. Every manufacturer or importer that wants to place substances affected by REACH into circulation on the market must have a separate registration number for these substances.

The REACH Regulation holds manufacturers and importers of chemicals accountable for generating data that can be used to define the dangers and risks that can result from the use of certain substances.

11 General application and safety instructions

Only use the AVENTICS products shown in industrial applications.

Read the product documentation completely and carefully before using the product.

Observe the applicable regulations and laws of the respective country.

When integrating the product into applications, note the system manufacturer's specifications for safe use of the products.

The data specified above only serve to describe the product.

No statements concerning a certain condition or suitability for a certain application can be derived from our information.

The information given does not release the user from the obligation of own judgment and verification.

It must be remembered that the products are subject to a natural process of wear and aging.

II Pneumatic drives

1 Introduction

1.1 Cylinder drives

The spectrum of AVENTICS cylinders ranges from extremely compact cylinders for small handling applications to large-dimension standard cylinders for the most powerful tasks and rodless cylinders with guided slides for long strokes, to ISO cylinders with a clean design.

AVENTICS offers the following cylinder types:

- Mini and round cylinders
- Short-stroke and compact cylinders
- Profile and tie rod cylinders
- Rodless cylinders
- Special cylinders for handling technology
- Cylinder accessories and cylinder mountings

1.1.1 Conditions of use for cylinder drives: What must be observed?

- AVENTICS drives serve to transform the energy of the compressed air into motion and forces.
- They are not intended for use as springs or cushioning elements; should this occur, additional loads will accumulate.
- Intended use also includes compliance with the operating conditions specified by AVENTICS (e.g., pressure and temperature ranges, etc.).
- Unauthorized modifications of the drives constitute a safety risk and are therefore not permitted. AVENTICS does not assume any liability for damage arising from such procedures.

1.1.2 Medium

- When used as intended, AVENTICS drives are designed for oil-free operation with compressed air. Using oiled compressed air washes out the drive's initial lubrication. In this case, further use necessitates the constant use of lubricated air in order to guarantee the drive's basic lubrication.
- Information on compressed air quality, oil, and oil content can be found in Chapter VIII "Preparation of compressed air."

1.1.3 Speed

The maximum possible speed or achievable traversing time depends on application-specific parameters. Influencing factors include the cylinder size and stroke, cushioning, mounting orientation, and, if applicable, the mass to be moved, plus additional external forces, and the cylinder actuation (valves and tubing).

The traversing speed of a pneumatic cylinder is adjusted via the air flow. An important distinction is whether the throttling occurs at the inflowing air supply (inlet-side throttling) or the outflowing exhaust air (exhaust air throttling).

1.1.4 Kinetic energy

If the kinetic energy of the moved masses exceeds the maximum absorbable cushioning energy of the internal stop/cushioning system, either an additional external stop or a hydraulic shock absorber, which absorbs the remaining kinetic energy, is necessary.

1.1.5 Installation and mounting

AVENTICS drives should be mounted free of stress and distortion.

2 Technical principles

2.1 Air consumption of cylinder drives

Air consumption of cylinder drives depends upon:

- Operating pressure p
- Piston diameter Ø AL
- Piston rod diameter Ø MM (only during pressure application on piston rod connection)
- Stroke length S

$V_{AL} = V^*_{AL} \times S$

When applying pressure to the cylinder base side, as a function of piston air consumption V^*_{AL} per mm stroke and stroke length S

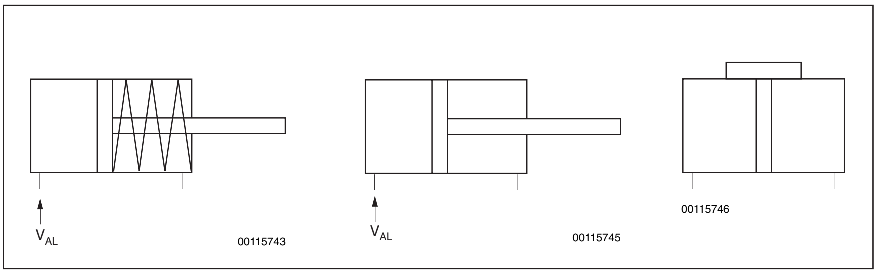


Fig. 1 Air consumption V_{AL} on the cylinder base side

$V_{AL-MM} = (V^*_{AL} - V^*_{MM}) \times S$

When applying pressure to the cylinder head side, as a function of piston and/or piston rod air consumption V^*_{AL}/V^*_{MM} per mm stroke and stroke length S

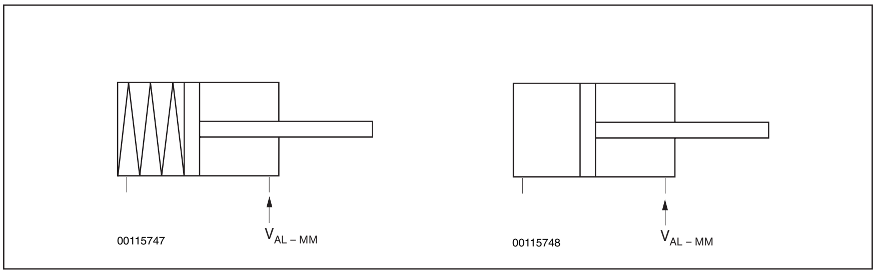
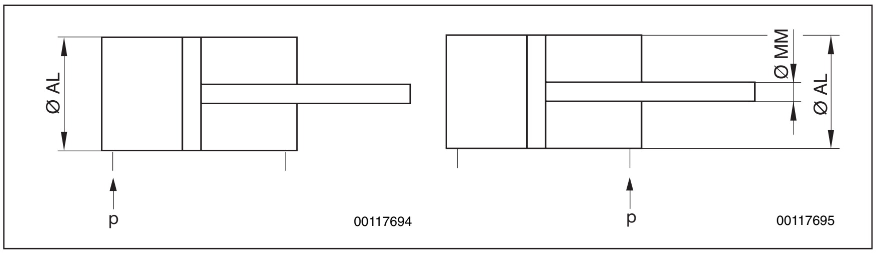


Fig. 2 Air consumption V_{AL} – MM on the cylinder head side

V_{AL} = Air consumption on the cylinder base side
V^*_{AL} = Air consumption on the cylinder base side per mm stroke
V_{AL-MM} = Air consumption on the cylinder head side
V^*_{MM} = Air consumption on the cylinder head side per mm stroke
s = Stroke length
Ø AL = Piston diameter AL
Ø MM = Piston rod diameter MM
p = Operating pressure

Air consumption table:

Air consumption L per mm stroke for piston diameter Ø AL and piston rod diameter Ø MM, as a function of operating pressure p [bar]



Ø AL / Ø MM	p [bar]									
[mm]	1	2	3	4	5	6	7	8	9	10
1	0,000016	0,000024	0,000031	0,000039	0,000047	0,000055	0,000063	0,000071	0,000079	0,000086
2	0,000063	0,000094	0,000126	0,000157	0,000188	0,000220	0,000251	0,000283	0,000314	0,000346
2,5	0,000098	0,000147	0,000196	0,000245	0,000295	0,000344	0,000393	0,000442	0,000491	0,000540
3	0,000141	0,000212	0,000283	0,000353	0,000424	0,000495	0,000565	0,000636	0,000707	0,000778
3,5	0,000192	0,000289	0,000385	0,000481	0,000577	0,000673	0,000770	0,000866	0,000962	0,001058
4	0,000251	0,000377	0,000503	0,000628	0,000754	0,000880	0,001005	0,001131	0,001257	0,001382
5	0,000393	0,000589	0,000785	0,000982	0,001178	0,001374	0,001571	0,001767	0,001963	0,002160
6	0,000565	0,000848	0,001131	0,001414	0,001696	0,001979	0,002262	0,002545	0,002827	0,003110
8	0,001005	0,001508	0,002011	0,002513	0,003016	0,003519	0,004021	0,004524	0,005027	0,005529
10	0,001571	0,002356	0,003142	0,003927	0,004712	0,005498	0,006283	0,007069	0,007854	0,008639
12	0,002262	0,003393	0,004524	0,005655	0,006786	0,007917	0,009048	0,010179	0,011310	0,012441
16	0,004021	0,006032	0,008042	0,010053	0,012064	0,014074	0,016085	0,018096	0,020106	0,022117
20	0,006283	0,009425	0,012566	0,015708	0,018850	0,021991	0,025133	0,028274	0,031416	0,034558
25	0,009817	0,014726	0,019635	0,024544	0,029452	0,034361	0,039270	0,044179	0,049087	0,053996
32	0,016085	0,024127	0,032170	0,040212	0,048255	0,056297	0,064340	0,072382	0,080425	0,088467
40	0,025133	0,037699	0,050265	0,062832	0,075398	0,087965	0,100531	0,113097	0,125664	0,138230
50	0,039270	0,058905	0,078540	0,098175	0,117810	0,137445	0,157080	0,176715	0,196350	0,215984
63	0,062345	0,093517	0,124690	0,155862	0,187035	0,218207	0,249380	0,280552	0,311725	0,342897
80	0,100531	0,150796	0,201062	0,251327	0,301593	0,351858	0,402124	0,452389	0,502655	0,552920
100	0,157080	0,235619	0,314159	0,392699	0,471239	0,549779	0,628319	0,706858	0,785398	0,863938
125	0,245437	0,368155	0,490874	0,613592	0,736311	0,859029	0,981748	1,104466	1,227185	1,349903
160	0,402124	0,603186	0,804248	1,005310	1,206372	1,407434	1,608495	1,809557	2,010619	2,211681
200	0,628319	0,942478	1,256637	1,570796	1,884956	2,199115	2,513274	2,827433	3,141593	3,455752
250	0,981748	1,472622	1,963495	2,454369	2,945243	3,436117	3,926991	4,417865	4,908739	5,399612
320	1,608495	2,412743	3,216991	4,021239	4,825486	5,629734	6,433892	7,238229	8,042477	8,846725

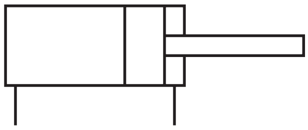
Table 1 Air consumption table

Notes

- The dead space of the cylinder base/head, inlets, and fittings has not been taken into account.
- The air consumption specifications refer to the “relaxed state” standard conditions according to ISO 8778.

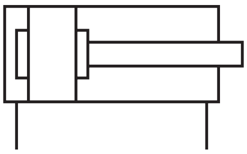
2.2 Dynamic energy

Several types of stop/cushioning systems are available for cylinders:



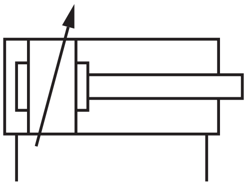
Fixed stop (shock load)

Cannot absorb any kinetic energy.



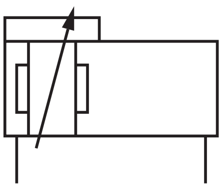
Elastic stop

Can absorb low amounts of kinetic energy.



Pneumatic cushioning (adjustable)

Can absorb moderate amounts of kinetic energy.



Use of external stop/cushioning systems

If the kinetic energy to be absorbed exceeds the cushioning capacity of the cylinder, the customer must provide an external fixed stop or a hydraulic shock absorber in order to take up the remaining energy.

2.3 Cylinders with piston rods

2.3.1 Forces

$F_{AL} = A_{AL} \times p - F_R$

$F_R \approx 5\% \times F_{AL}$

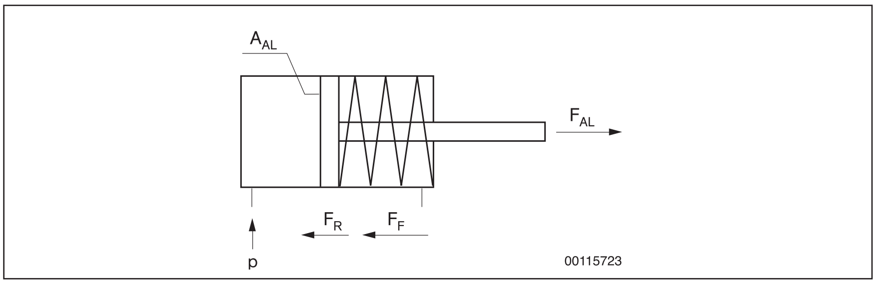


Fig. 3 Static forces in single-acting cylinders

Static forces in double-acting cylinders

$F_{AL} = A_{AL} \times p - F_R$

$F_R \approx 10\% \times F_{AL}$

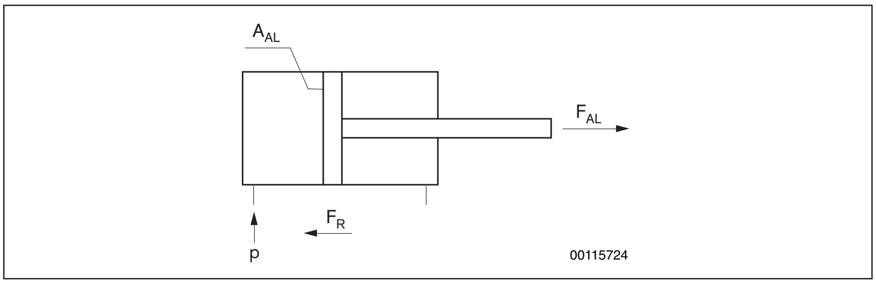


Fig. 4 Variant: Extending piston rod

Static forces in double-acting cylinders

$F_{AL-MM} = A_{AL-MM} \times p - F_R$

$F_R \approx 10\% \times F_{AL-MM}$

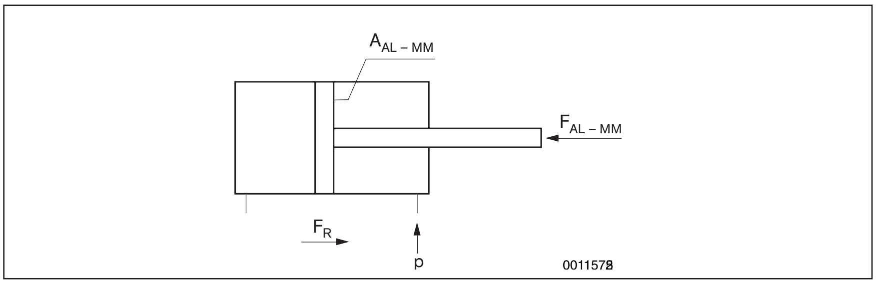


Fig. 5 Variant: Retracting piston rod

F_{AL} = Piston force (cylinder base side)
F_{AL-MM} = Piston force (cylinder head side)
F_F = Spring force
F_R = Friction force (approx. 10% of F)
A_{AL} = Piston surface area (cylinder base side)
A_{AL-MM} = Piston surface area (cylinder head side)
p = Operating pressure

2.3.2 Forces table

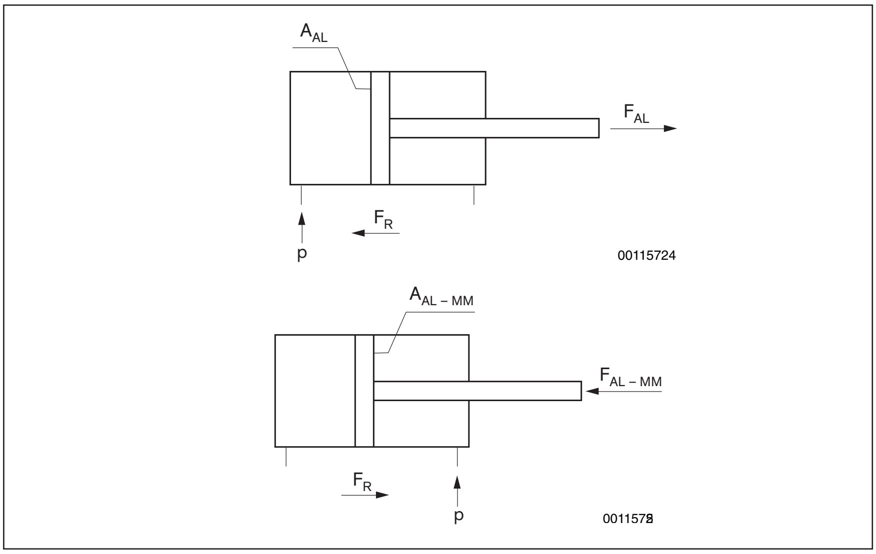


Fig. 6 Force parameters

The table below displays the effective position forces F_{AL} (cylinder base side)/ F_{AL-MM} (cylinder head side) as a function of the operating pressure p, piston diameter Ø AL, piston rod diameter Ø MM, and the piston surface areas A_{AL} (cylinder base side)/A_{AL-MM} (cylinder head side).

				p = 3 bar		p = 4 bar		p = 5 bar		p = 6 bar		p = 7 bar		p = 8 bar		p = 9 bar		p = 10 bar	
AL [mm]	MM [mm]	A_{AL} [cm²]	A_{AL-MM} [cm²]	F_{AL} [N]	F_{AL-MM} [N]	F_{AL} [N]	F_{AL-MM} [N]	F_{AL} [N]	F_{AL-MM} [N]	F_{AL} [N]	F_{AL-MM} [N]	F_{AL} [N]	F_{AL-MM} [N]	F_{AL} [N]	F_{AL-MM} [N]	F_{AL} [N]	F_{AL-MM} [N]	F_{AL} [N]	F_{AL-MM} [N]
8	4	0,50	0,38	13	10	17	13	2	17	26	20	31	23	35	27	40	30	44	33
10	4	0,78	0,66	21	17	28	21	35	29	42	35	49	41	56	46	63	52	70	58
12	6	1,1	0,85	29	22	39	30	48	37	58	45	68	52	77	60	87	67	97	75
16	6	2,0	1,73	53	46	70	61	88	76	106	91	123	107	141	122	158	137	176	152
20	8	3,1	2,6	82	69	109	92	136	114	164	137	191	160	218	183	246	206	273	229
25	10	4,9	4,1	129	108	172	144	216	180	259	216	302	253	345	289	388	325	431	361
32	12	8,0	6,9	212	182	282	243	352	304	422	364	493	425	563	486	634	546	704	607
40	16	12,6	10,5	333	280	444	373	554	466	665	560	776	653	887	746	998	840	1109	933
50	20	19,6	16,5	517	436	690	581	862	726	1035	871	1207	1016	1380	1162	1552	1307	1725	1452
63	20	31,1	28,0	824	739	1098	986	1373	1232	1647	1478	1923	1725	2196	1971	2471	2218	2746	2464
80	25	50,2	45,3	1328	1199	1771	1598	2213	1998	2656	2397	3098	2797	3541	3197	3984	3596	4426	3995
100	25	78,5	73,6	2072	1943	2763	2591	3454	3238	4145	3886	4836	4534	5526	5181	6217	5829	6908	6477
125	32	122,6	114,6	3239	3028	4319	4037	5399	5047	6479	6056	7558	7066	8638	8075	9718	9084	10798	10094
160	40	201,0	188,3	5309	4976	7079	6635	8848	8294	10618	9953	12388	11612	14157	13270	15927	14929	17697	16588
200	40	314,1	301,4	8295	7962	11060	10616	13825	13270	16590	15924	19355	18579	22120	21233	24885	23887	27650	26541
250	50	490,6	471,0	12960	12442	17280	16590	21600	20737	25920	24885	30239	29032	34559	33180	38879	37327	43199	41474
320	63	804,2	773,1	21230	20409	28307	27213	35384	34016	42461	40819	49538	47622	56615	54426	63692	61229	70769	68032

Table 2 Forces table

F_{AL} Piston force (cylinder base side)
F_{AL-MM} Piston force (cylinder head side)
A_{AL} Piston surface area (cylinder base side)
A_{AL-MM} Piston surface area (cylinder head side)
p Operating pressure
AL Piston diameter

2.3.3 Dynamic forces in double-acting cylinders

Piston diameter Ø AL calculation using the diagram

The diagram incorporates frictional losses and various applications of double-acting cylinders.

Operating pressure p is reflected in the cylinder curves (A/B/C).

- **A**: Clamping cylinders
- **B**: Cylinders that are to produce force during stroke movement. No requirements concerning the speed progression, e.g., during acceleration.
- **C**: Cylinders with cushioning and speed control (constant speed)

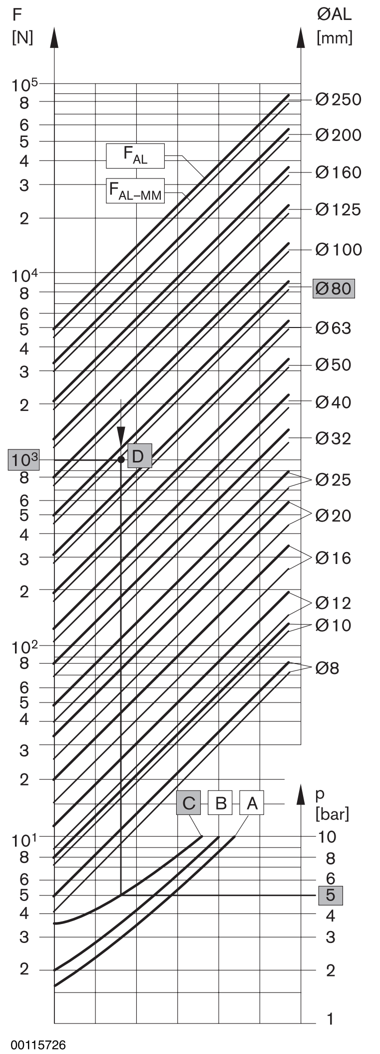


Fig. 7 Cylinder force diagram

The calculated cylinder force F and the reflected operating pressure p yield the point of intersection D in the diagram.

Each cylinder size (Ø AL) is represented by two piston force characteristic curves F_{AL}/ F_{AL-MM} in the diagram.

- F_{AL}: Piston force characteristic curve for extending piston rod
- F_{AL-MM}: Piston force characteristic curve for retracting piston rod

Please select the piston diameter Ø AL which lies above the determined point of intersection D.

2.3.4 Calculating the piston diameter Ø AL

Example: Given:

- Operating pressure p = 5 bar
- Cylinder force F = 1000 N
- Cylinder with cushioning and speed control = curve "C"

Find/calculate:

- Piston diameter Ø AL for extending piston rod = 80 mm

F Cylinder force

Ø AL Piston diameter AL

p Operating pressure

D Point of intersection: Force F/Operating pressure p

2.3.5 Permissible lateral forces

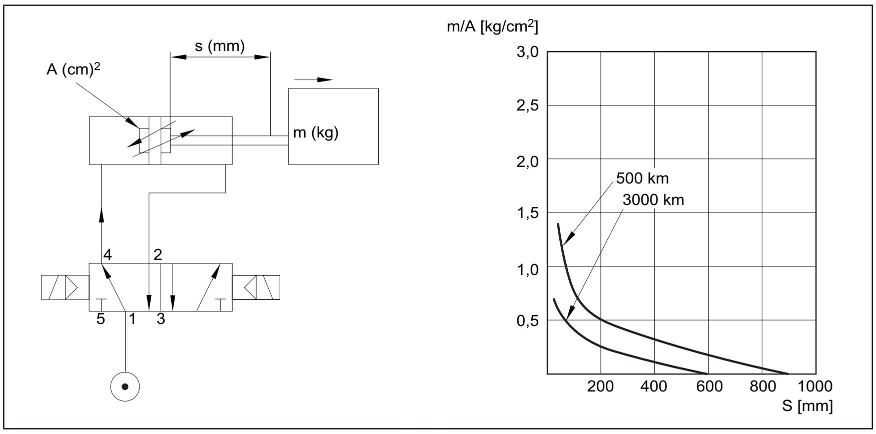


Fig. 8 Permissible forces

The selection of an unreasonably large cylinder due to lateral forces can be avoided by using an external guide.

Example: What maximum stroke S can a cylinder with Ø 50 mm have if the mass is m = 10 kg?

Neither an external nor an internal guide is present.

Solution: The piston surface area A is 20 cm^2.

The diagram shows that,
for the mass to surface area ratio m/A = 10/20 = 0.5, the stroke S must not exceed 200 mm.

2.4 Buckling loads

2.4.1 Buckling force F_K according to Euler

Pneumatics uses Euler cases 1 and 2 to calculate the buckling forces F_K.

Euler case 1: Application with cylinders with fixed mounting

$$F_K = \frac{\pi^2 \times E \times J}{4 \times l_K^2}$$

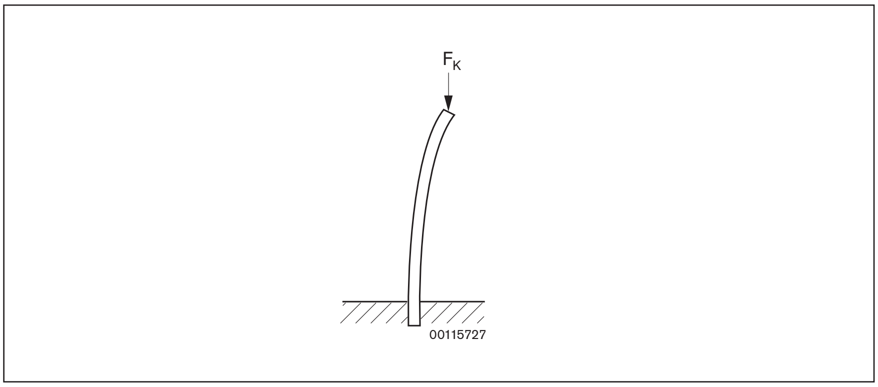


Fig. 9 Basic principle

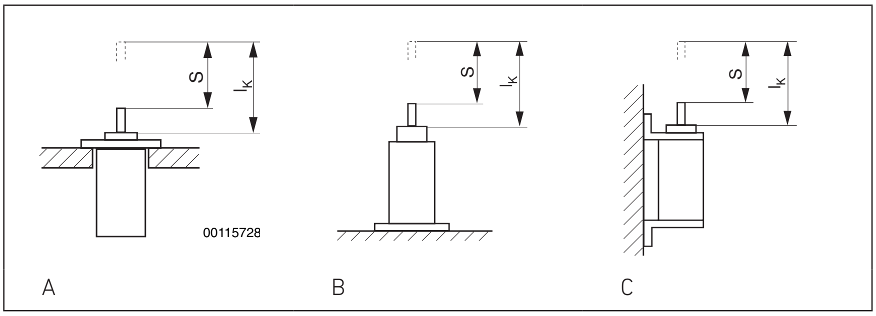


Fig. 10 Mounting application examples: (A) Front flange mounting; (B) Rear flange mounting; (C) Foot mounting

F_K = Buckling force

S = Stroke length

E = Elasticity modulus

J = Moment of inertia

l_K = Buckling length

Euler case 2: Application with cylinders with articulated mounting

$$F_K = \frac{\pi^2 \times E \times J}{4 \times l_K^2}$$

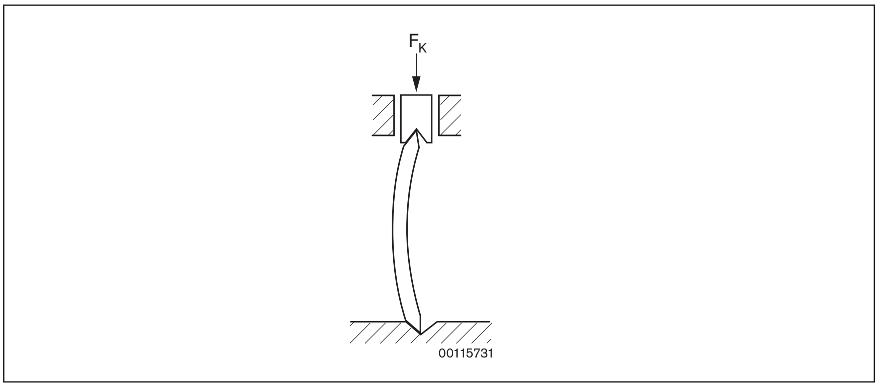


Fig. 11 Basic principle

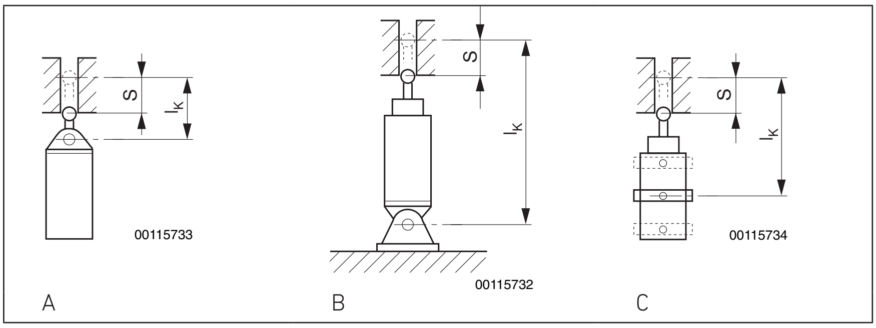


Fig. 12 Mounting application examples, (A) Front articulated mounting; (B) Rear articulated mounting; (C) Trunnion mounting

F_K = Buckling force
S = Stroke length
E = Elasticity modulus
J = Moment of inertia
l_K = Buckling length

2.4.2 Buckling force F_K as a function of the operating pressure p and piston diameter Ø AL

A safety factor ≥ 3 has been taken into account in the diagram.

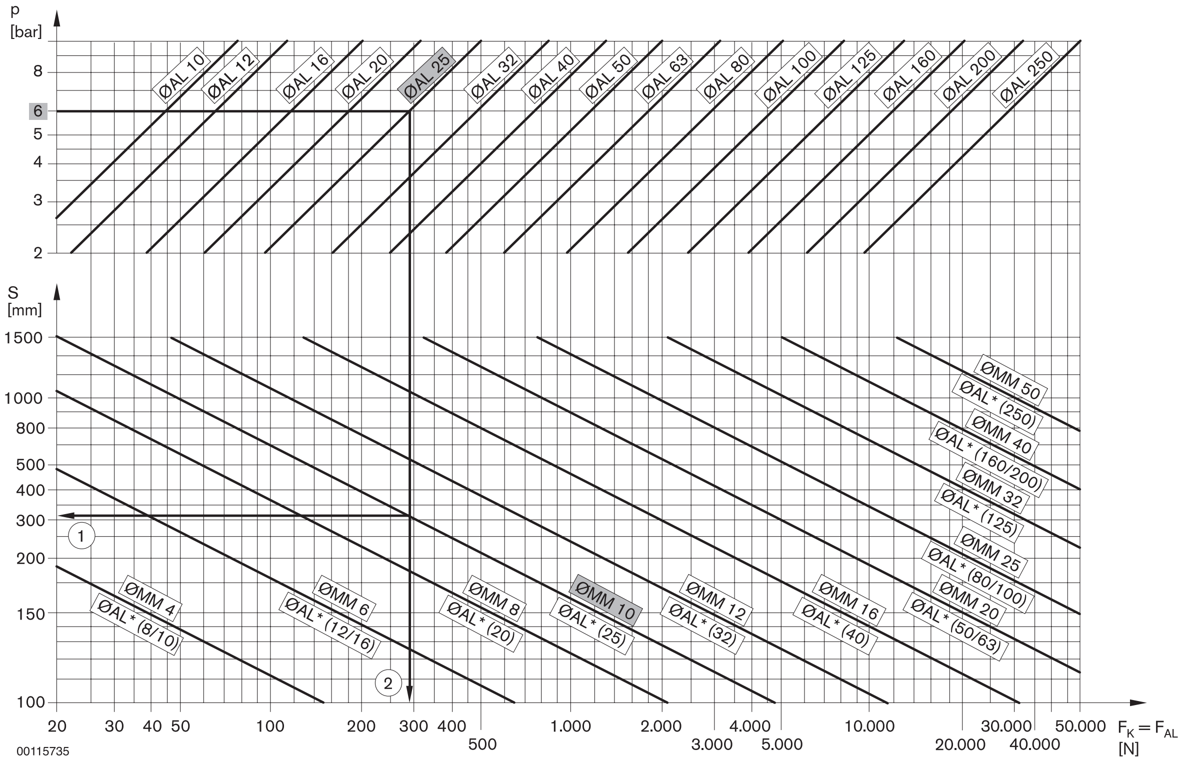


Fig. 13 Buckling force F_K as a function of the operating pressure p and piston diameter AL

p	Operating pressure
F_{AL}	Piston force (cylinder base side), extending piston rod
S	Maximum permissible stroke (cylinder/piston rod stroke)
Ø AL	Piston diameter AL
Ø AL*	Piston diameter AL for cylinders in accordance with ISO 15552 or DIN ISO 6432
Ø MM	Piston rod diameter MM

Example Given:

- Operating pressure p = 6 bar
- Cylinder in accordance with DIN ISO 6432
- Piston diameter AL = 25 mm

Find/calculate:

1 Maximum stroke length S ≈ 310 mm

2 Buckling force F_K ≈ 290 N

3 Products

3.1 Product-specific information: Mini cylinders

With piston rod diameters ranging from 2.5 mm to 25 mm, mini cylinders provide the right components in an extensive range of configurations for every conceivable application. The MNI, OCT, 131, and ICM series from AVENTICS, with their specific characteristics, strengths, and properties, are designed for special applications and industry solutions.

3.1.1 MNI series (ISO 6432)

The MNI is a standard cylinder according to DIN ISO 6432, with optional ATEX certification. The MNI is available in a variety of single-acting and double-acting versions (also with through piston rod).

3.1.2 ICM series

The ICM is available with piston diameters Ø from 8 to 32 mm; the magnetic piston variant with piston diameters Ø from 8 to 25 mm complies with DIN ISO 6432. The 32 mm piston diameter Ø is not covered by the standard.

3.1.3 OCT series

The OCT profile cylinder also complies with DIN ISO 6432 and provides push-in connections and slots on all sides for sensor mounting as additional functions. The OCT (octagon) is equipped with an octagonal piston, which includes optional steel pins for anti-torsion protection of the piston rod. Single-acting and double-acting profile cylinders (also with through piston rod) are available. The OCT offers increased corrosion protection compared to the MNI thanks to plastic covers and an anodized cylinder barrel.

Options:

Magnetic piston, torsion protection, pneumatic cushioning (12 – 25 mm), piston rod extension, holding unit, accessories

3.1.4 131 series

The 131 cylinder series is available in single-acting and double-acting variants.

Options:

Magnetic piston

3.1.5 Cushioning diagram for MNI and OCT

Double-acting cylinder during extension. The pressure at the connections is 6.3 bar. The curves display the maximum values.

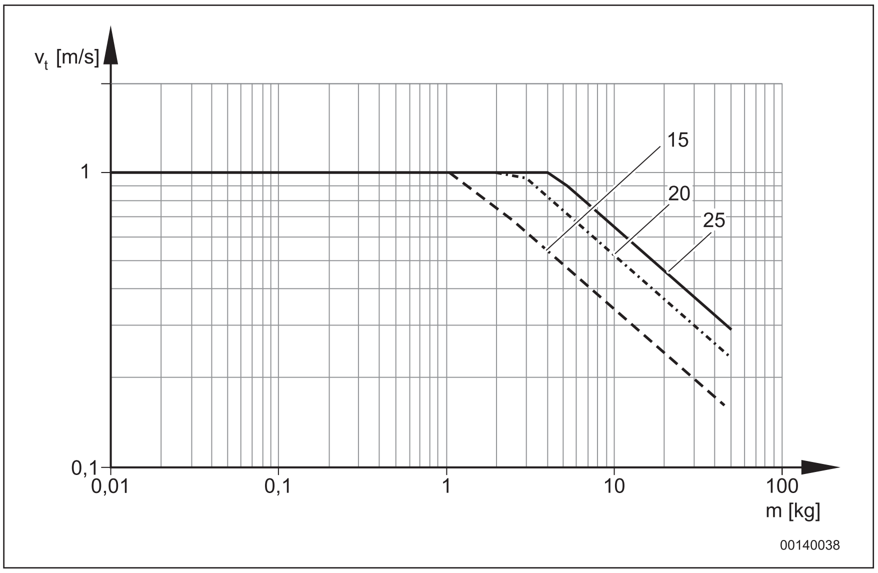


Fig. 14 Cushioning diagram for MNI and OCT

The diagram applies to horizontal and descending movements.

As a general rule for ascending movements:

- Mass to surface area ratio m/A (kg/cm^2) < 2
- Speed v_t < 0.7 m/s

The ideal level of pneumatic cushioning is achieved along the diagonal line.
This zone also yields the optimal cycle time.

To avoid impact as the piston meets the cover or base, cylinders without cushioning should either be operated with lower piston speeds or externally arranged stops or shock absorbers should be used.

3.2 Product-specific information: PRA/TRB series standard cylinders

3.2.1 PRA series

The PRA is a standardized profile cylinder in accordance with DIN ISO 15552 with a magnetic piston, as well as sensor slots in the aluminum profile. The PRA is available as a double-acting cylinder with a single or through piston rod and optional ATEX certification.

Options:

ATEX, heat-resistant variant with magnetic piston (-10°C to 120°C), heat-resistant variant without magnetic piston (to 150°C), pneumatic cushioning, piston rod extension, holding unit, accessories

3.2.2 TRB series

The TRB is a standardized tie rod cylinder in accordance with ISO 15552. It differs from the PRA only in its smooth barrel and tie rods. The performance of the TRB is the same as the PRA. An additional low-friction version is also available.

3.2.3 Cushioning diagram for PRA/TRB

Double-acting cylinder during extension. The pressure at the connections is 6.3 bar. The curves display the maximum values.

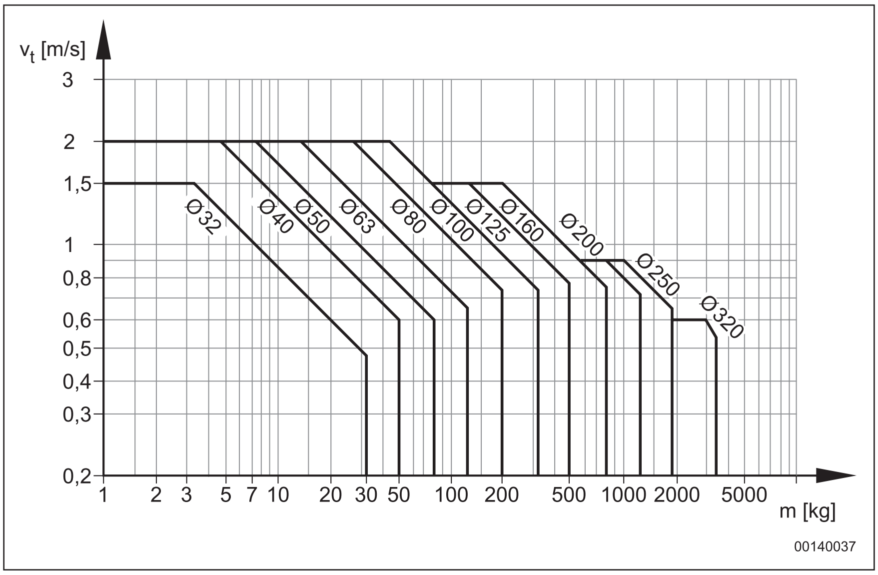


Fig. 15 Cushioning diagram

The diagram applies to horizontal and descending movements.

As a general rule for ascending movements:

- Mass to surface area ratio m/A (kg/cm^2) < 2
- Speed v_t < 0.7 m/s

The ideal level of pneumatic cushioning is achieved along the diagonal line. This zone also yields the optimal cycle time.

To avoid impact as the piston meets the cover or base, cylinders without cushioning should either be operated with lower piston speeds or externally arranged stops or shock absorbers should be used.

3.3 Product-specific information: Rodless cylinders, grinding cylinders

3.3.1 Cylinder configurator

All cylinders can be individually configured with the AVENTICS product configurator. An individual order number is created during configuration with the product configurator.

3.3.2 RTC series

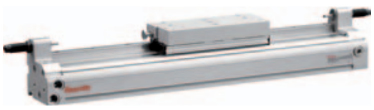
Compared with a round piston, the oval piston of the RTC cylinder can withstand higher loads and moments.

On the RTC cylinder, the shuttle and piston are a unit.

The RTC series program is based on three variants with different key strengths: for large loads, very precise movement and positioning and a wide range of speeds.

Overview of RTC variants:

- **RTC-BV (Basic Version) with internal guide**
  Used at low and medium torque.
  Piston size: 16 – 80 mm.



- **RTC-CG (Compact Guide) with ball rail guide**
  Used at low loads and torque, where extra high precision is required.
  Piston size: 16 – 40 mm

- **RTC-HD (Heavy Duty) with reinforced ball rail guide**
  Used with high loads and torque where extra high precision is required.
  Piston size: 16 – 63 mm.

Application

The RTC cylinder is used in industrial manufacturing to achieve uniform linear motion of products and workpieces. The RTC cylinder can be mounted horizontally or vertically. Its installation dimensions are minimal and it can provide a stroke of up to 10 meters.

Other characteristics:

- Several versions with different fixing possibilities and guiding rails for slides make it possible to move and control heavy loads with great accuracy and precision.
- For increased flexibility, compressed air can be connected at both ends of the cylinder.
- Integral controllable pneumatic cushioning and the option of an extra mechanical shock absorber.
- Electromagnetic sensors can be installed where required for flexible position sensing.

RTC sensor installation

- RTC-BV and RTC-SV have sensor slots on both sides of the cylinder body.
- RTC-CG and RTC-HD have one sensor slot on the side with compressed air ports.
- No more than two sensors in either direction can be placed in each slot.

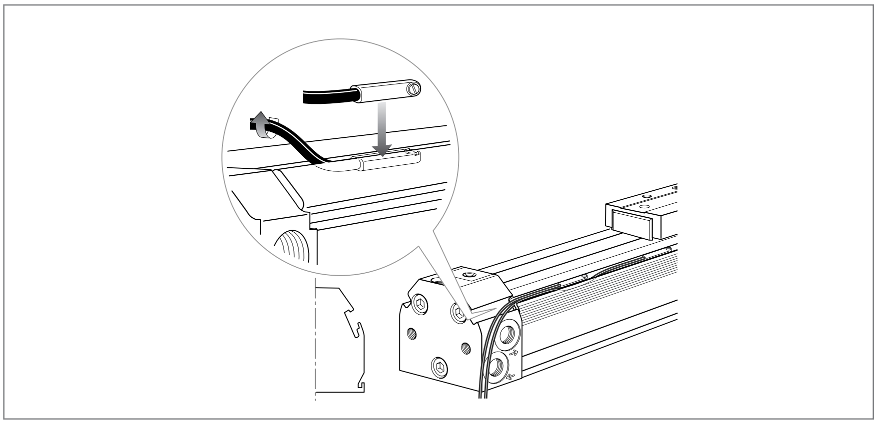


Fig. 16 Fitting sensors, RTC

RTC load mounting

There are many ways of attaching a load to the RTC cylinder slide.

Note: Make sure that the load is properly attached for the specific application, and that the attachment can handle the load for which the cylinder is dimensioned.

RTC-BV (Basic Version)

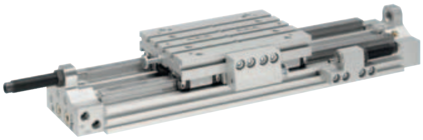
The load is generally attached with one of the mountings available as accessories.

RTC-CG (Compact Guide)

The load is attached to the carriage with or without centering rings.

RTC-HD (Heavy Duty)

The load is attached to the carriage with or without centering rings. Either the load is attached with screws to some of the threaded holes, or with nuts placed in the nut slots. Place the nuts symmetrically in the slots of the carriage. See the product catalog for product numbers.



3.3.3 CKP series

- **CKP (compact module with ball rail guide, pneumatic drive)**
  Rodless cylinder with double ball rail guides.
  Used with high loads and torque. The CKP has the same mounting dimensions as the electrically driven compact modules CKK (ball screw drive) and CKR (toothed belt drive).
  Piston size: 16, 25, and 32 mm.
- **CKP-CL (camoLINE)**
  Compatibe with cartesian motion building system.
  Based on CKP, but with holes for centering rings underneath for positioning.
  Piston size: 16, 25, and 32 mm.

CKP sensor installation

- CKP and CKP-CL have sensor slots on both sides of the cylinder body.
- To fit the sensor in the slot a special sensor holder is required.
- Sensors may be positioned anywhere along the length of the cylinder.
- No more than three sensors can be placed in each slot. If more than three sensors are required there is no room for the cables in the slot.
  In that case you must make sure that the cables are attached properly to avoid being damaged by shuttle movements.

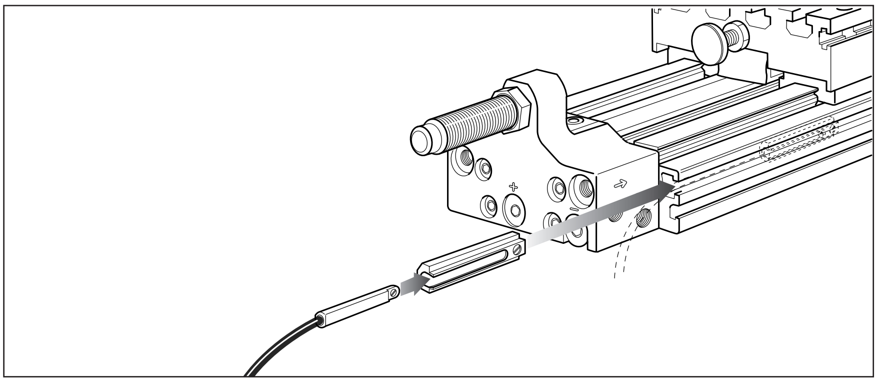


Fig. 17 Fitting sensors, CKP

CKP and CKP-CL load mounting

The load is attached to the carriage with or without centering rings.

3.3.4 Loads on the cylinder

- The mass leads to moments on the shuttle due to acceleration, cushioning, and weight during the movement.
- The guide leads to moments on the shuttles due to friction.
- The force leads to moments on the shuttle.
- An attached mass which does not act on the middle of the shuttle piston exerts a moment on it.
- Mechanical load is produced on the cylinder and guide when the piston stops.

Piston Ø	α	β	Lx	Ly	Lz
16	<0.1°	<0.2°	260	260	260
25	<0.1°	<0.2°	344	344	344
32	<0.1°	<0.2°	404	404	404
40	<0.1°	<0.2°	440	440	440
50	<0.1°	<0.2°	532	532	532
63	<0.1°	<0.2°	644	644	644

Table 3 Moments, RTC-HD (Heavy Duty) with reinforced ball rail guide

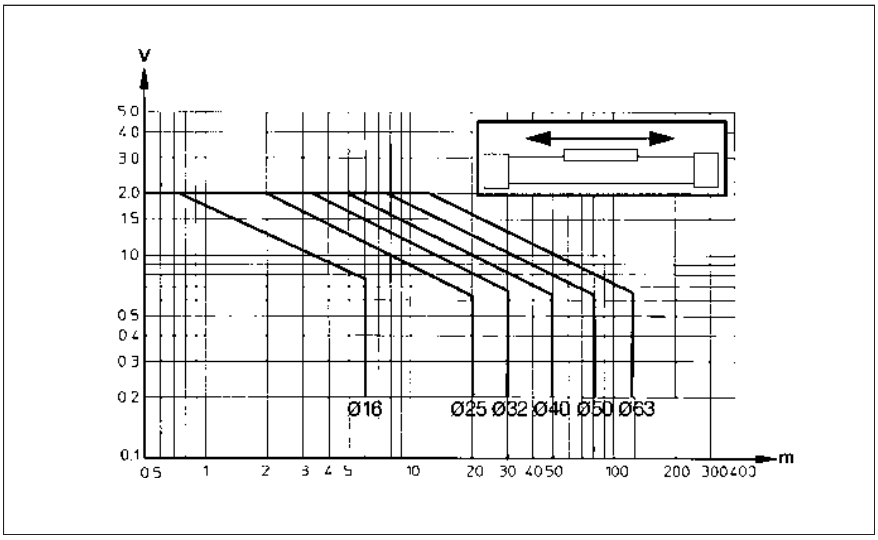


Fig. 18 Limit diagram for pneumatic cushioning with horizontal mounting

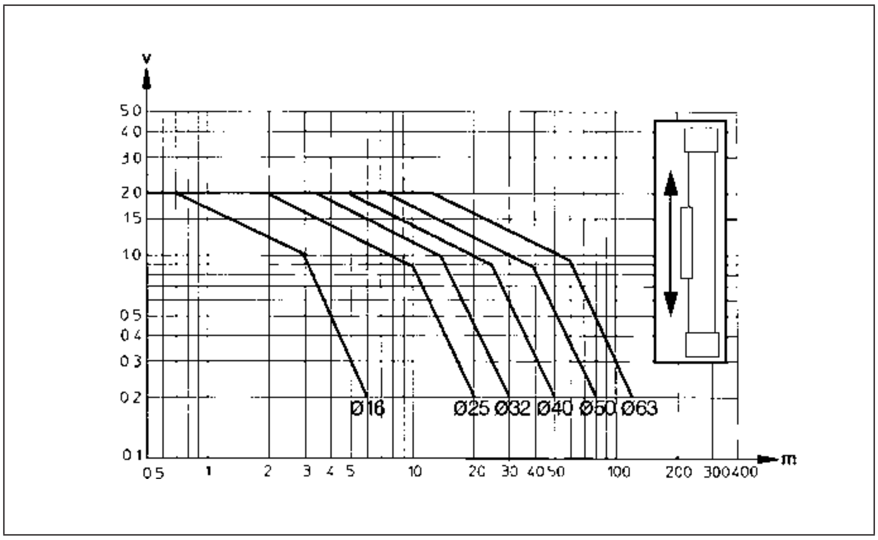


Fig. 19 Limit diagram for pneumatic cushioning with vertical mounting

v Piston velocity [m/s]

m Cushionable mass [kg]

The values for the cushionable mass m and piston velocity v must be on or below the curve for the selected piston diameter Ø.

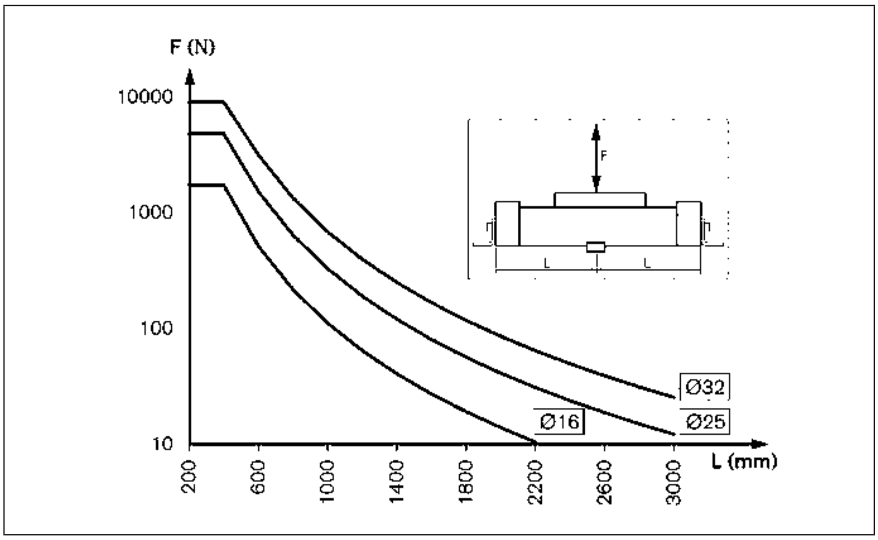


Fig. 20 **Max. support span L [mm] as a function of F [N] at a deflection of 0.5 mm, part 1**

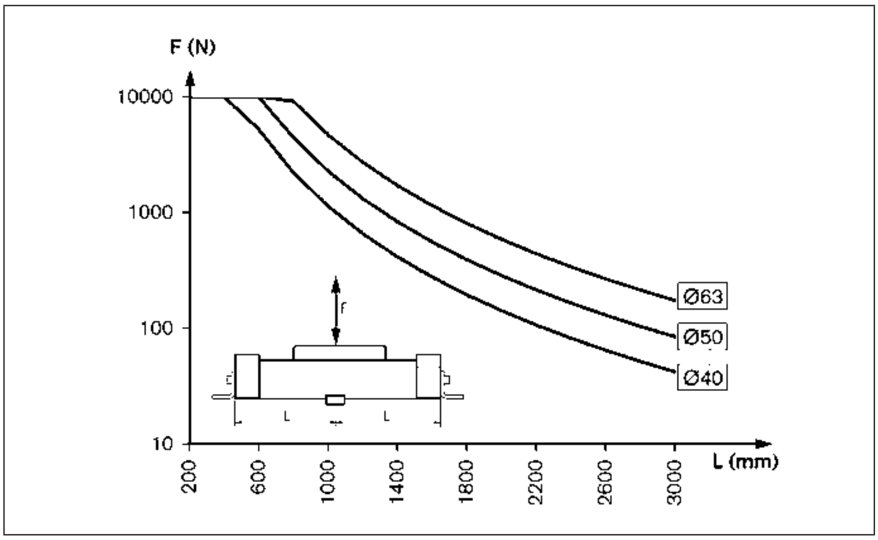


Fig. 21 **Max. support span L [mm] as a function of F [N] at a deflection of 0.5 mm, part 2**

3.4 Additional cylinder series Guide cylinders/double piston cylinders

3.4.1 GPC and TWC series

The GPC is a guided cylinder, with the cylinder and guide integrated in one the housing. GPC cylinders are robust double-acting cylinders with an integrated magnetic ring in the piston. These cylinders can be mounted directly to other cylinders. The GPC series features a high lateral load capacity and anti-torsion protection.

TWC double piston cylinders are equipped with a long slide bearing guide bushings for minimum piston rod play. The TWC double piston cylinder permits piston rod locking in both retracted and extended states.

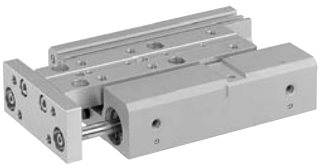
3.4.2 MSC, MSN, and ZSC series

Mini slides from AVENTICS enable precise short-stroke movements and feature Easy-2-Combine interfaces.

MSC mini slides feature an integrated precision guide as well as a standardized Easy-2-Combine interface. MSC cylinders are equipped with an integrated guide and integrated sensor slots (on both sides); a compressed air connection is also possible on three sides.

Mini slides from the MSC series have an optimized guide and cushioning system and ensure maximum rigidity for the highest torque and load capacities.

The narrow, double-acting MSN mini slide has an integrated magnetic ring in the piston, elastic cushioning and an integrated, ball-bearing rail guide. With a variety of attachment and ventilation options, the MSN mini slide can be installed in nearly every position and orientation.



The double-acting ZSC mini slide with magnetic piston andEasy-2-Combine interface is ideal for vertical applications. It has a very smooth running double piston system with a ball-bearing circulating guide as well as a flat design.

3.4.3 RCM, GSP series rack-and-pinion gears and grippers

The RCM series of rotary compact modules can be configured for all standardized rotary and swivel movements. The modules feature an Easy-2-Combine interface and can be installed directly on mini slides. They can also be equipped with mechanical GSP grippers.

3.4.4 CVI cylinder valve unit

Typical areas of application for the CVI series include open/close functions such as flap control, and spool applications in remote and often hard-to-reach areas. Two ISO cylinder series (PRA, TRB) and five freely combinable valve series (TC08, TC15, CD07, CD12, 740) are at the core of the modular concept.

All individual components are technically compatible and can be configured for specific applications:

- Energy-saving valve, reduced pressure on return stroke
- Stop valve, movement comes to a halt
- Modular sealing concept, custom version with special scrapers
- Valve flow rate dimensioning according to the precise need
- Short, direct tubing connections
- Stop valves to bring movements to a halt and prevent the unintended activation of systems

3.5 Bellow actuators

With their varying designs, features, and materials, all bellow actuator series are configured for specific tasks. Bellow actuators require minimal installation space and are nearly wear- and maintenance-free.

BCC series (standard version)

The BCC series is the standard version of the latest generation. The cover is removable. Connection pieces are available in steel or aluminum.

BCP series (standard version)

The BCP series is the basic version of the family of bellow actuators, with standard bellow material NR/BR and a flanged galvanized steel cover with air connections. They are used as single, double, and triple bellows.

BCS series (corrosion-resistant version)

The BCS series bellow actuators are equipped with stainless steel flanged plates (flanged cover). Resistant to corrosion and acids, they are especially suitable for use in the food industry as well as in offshore applications and the pharmaceutical and process industries.

BCE series (heat-resistant version)

The bellow material in the BCE series consists of the new epichlorohydrin rubber mix. It ensures excellent temperature resistance and remains insensitive to aggressive media, oils, and lubricating greases. The main application area is the paper industry.

BCR series (bead ring version)

Bellow actuators from the BCR series are equipped with high-strength aluminum mounting rings without cover plates. They are ideal for press technology applications. Bead rings are removable and do not require seals.

BRB series (flexible rolling bellow)

Bellow actuators in the BRB series are extremely light and designed for small forces and strokes. Flexible rolling bellows (BRP) are designed for force transmission or as pneumatic springs for vibration isolation in heavy machinery and foundations. The mounting parts are low-friction; version made of plastic.

3.5.1 What are bellow actuators for?

Bellow actuators are implemented in various technological areas:

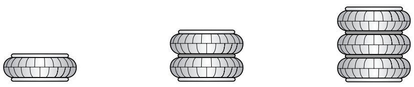
- Force transmission
- Storage
- Vibration isolation (pneumatic spring)

The classic fields of application for bellow actuators include:

- Presses
- Roller tensioners
- Tilt devices
- Tensioning devices
- Actuation of scissors-type lifting tables
- Use in vibration isolation as air springs

BCP/BCE/BCS/BCR series

Use in various areas for force transmission or vibration isolation



- Single-convolution bellow actuator:

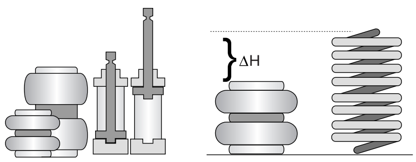
  Universal application, low block height, ideal for vibration isolation
- Double-convolution bellow actuator:

  Low block height, large stroke, low natural frequency
- Triple-convolution bellow actuator:

  Low block height, largest possible stroke, high tilting capacity

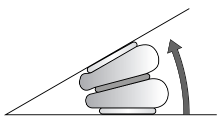
3.5.2 Advantages of bellow actuators

Low height



Unlike conventional pneumatic cylinders, bellow actuators have no piston rod. Bellow actuators have a low installation height and thus save on design height. The static spring deflection is eliminated.

Angular movements without adapters



Depending on the type, bellow actuators can be used for tilt angles of up to 30°. As a result, costly connection elements and hinged constructions are unnecessary.

Low procurement costs

The procurement costs are generally far lower than for conventional pneumatic cylinders. In addition, bellow actuators have a long service life and are maintenance-free, thus cutting operating costs further.

Wear- and maintenance-free

Bellow actuators function even under harsh operating conditions. The bellow actuator has no mechanical friction points (seals) moving against one another. The product operates wear-free even under adverse ambient conditions involving dirt, dust, granules, and mud.

Long service life

Bellow actuators are dynamically robust products. They are resistant to weather, as well as many environmental influences and chemicals. Their materials are proven in commercial vehicle, car, and railbound vehicle construction. A long service life is achieved even under high loads.

Extensive product range

Bellow actuators can cover a large number of applications normally handled by pneumatic cylinders. They are available with effective diameters Ø from 60 to 950 mm. Strokes of up to 455 mm are possible. Forces from 0.5 – 440 kN can be achieved with the AVENTICS product range.

Friction-free = jerk-free movement

Bellow actuators have no parts or seals that move against each another. There is therefore no stick-slip effect. The bellow actuators thus respond immediately and uniformly, even with minor changes in pressure.

Lateral flexibility

Bellow actuators can operate reliably with a lateral offset of up to 30 mm. They do not contain seals that can wear or jam. Sophisticated precision guides that are not susceptible to dust or dirt are no longer required.

Simple, inexpensive installation

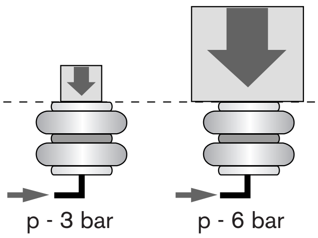
Thanks to their minimal height when pressure-free, BCP and BCR bellow actuators can be installed very easily. That saves assembly time and expenses. The flexible bellow actuator can compensate for assembly inaccuracies.

High operational reliability

Bellow actuators can be operated with oil-free compressed air. They are therefore also suitable for use in special applications, e.g. in the food industry. Thanks to the corresponding safety standards, the bellow actuators are protected against failure, even at several times the maximum permissible operating pressure.

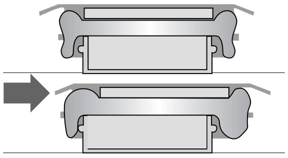
Resistance to various media

Bellow actuators can be operated in pneumatic applications both with compressed air and with other gaseous media, such as nitrogen. For low-pressure applications, the use of hydraulic media, such as water and glycol, is also permitted.



Constant operating height

The operating height of the bellow actuators can be set via the air pressure, independent of the load to be supported. There is no static spring deflection as with other spring elements. A user-friendly automatic control system guarantees a constant operating height even with varying loads to be supported.



Lateral stability

Bellow actuators have outstanding lateral stability and can achieve a transverse rigidity of up to 100% of the vertical rigidity, depending on the type.

Load-independent insulating properties

The spring rigidity is proportional to the load capacity. The vibration isolation is practically independent of the load capacity, i.e. natural frequencies remain constant even with varying loads. Bellow actuators can thus be standardized for equipment assembly families, thanks to a wide bearing load range.

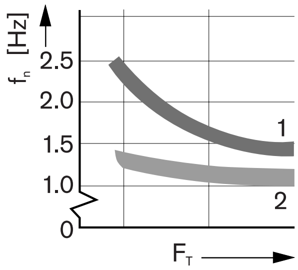
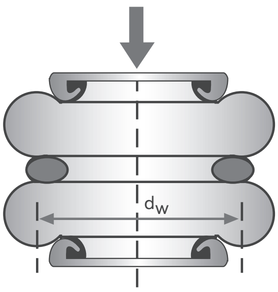


Fig. 22 Diagram: Spring rigidity, load capacity

f_n	Natural frequency [Hz]	1	Steel spring
F_T	Load capacity	2	Pneumatic spring

3.5.3 Installation and operation



Load capacity

In bellow actuators, the working diameter Ø d_W and the associated effective surface area A_W do not correspond to the piston diameter Ø in conventional pneumatic cylinders. The working diameter Ø can also change with the operating height. Bellow actuators therefore have a decreasing load capacity with increasing stroke, depending on their type and size. During configuration, the force/stroke diagram must be consulted as to whether the planned bellow actuator will achieve the required force at both end points of the stroke to be performed, and what pressure is necessary for this.

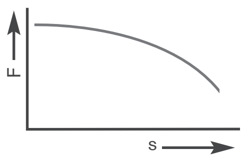


Fig. 23 Force-displacement diagram for the load capacity

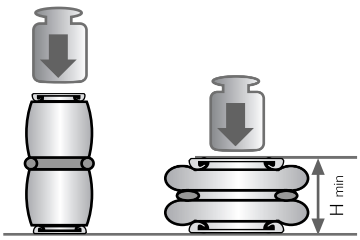
F	Force	s	Stroke

Stroke

Bellow actuators have a minimum height H_{min} (in compressed state) and a maximum permissible height H_{max}. The maximum permissible stroke of bellow actuators is calculated from the difference between the maximum permissible height and the minimum height. This stroke or any section of the stroke can be used. Larger stroke heights can be achieved using a scissors-type construction or by connecting two or more bellow actuators in series. When bellow actuators are connected in series, the mounting plates required between pairs of bellow actuators must be guided laterally.

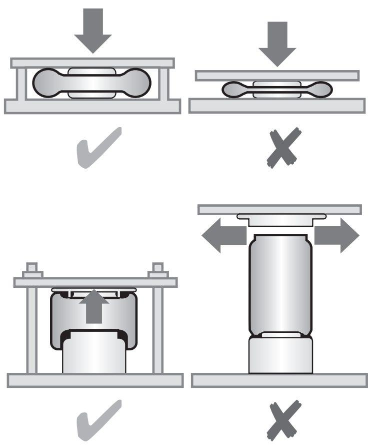
Offset assembly

Thanks to their flexibility, the top and bottom of bellow actuators can be assembled slightly offset.
The offset may not exceed 10 mm for single bellows, 20 mm for double bellows, and 30 mm for triple bellows.



Return force

Bellow actuators are single-acting cylinders. A return force is required to compress the flexible bellow to the minimum height. The return force value can be found in the table in the appropriate data sheet. With bellows, a deformation is possible without internal pressure. Rolling bellows and flexible rolling bellows require a minimum pressure in order to be able to roll out along the piston. The level of this minimum pressure in indicated in the data sheet.



Stroke stops

Bellow actuators must be provided with stroke limitation at the end points of the stroke. The bellow actuators are not designed for forces that can occur under pressure load without load or stroke stops. Air pressure filling without load can cause damage to the product and a risk of injury for personnel.

Tilt angle

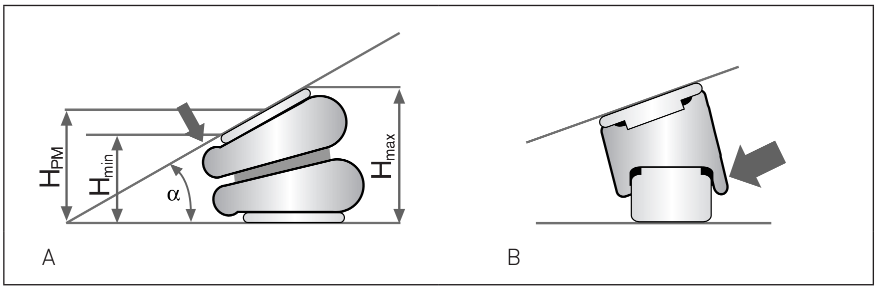


Fig. 24 Tilt angle: A: abrasion points; B: There should be no abrasion between the walls of the bellows

H_{min} Min. height

H_{max} Max. height

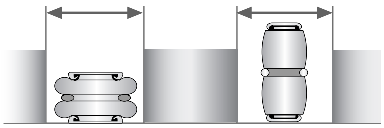
H_{PM} Plate center

Bellow actuators can perform their stroke at an angle. The maximum permissible angle of tilt depends on the type of bellow and kinematics.

The following angles can be considered as reference values:

Bellows type	Angle
Single bellows	10 – 20°
Double bellows	15 – 25°
Triple bellows	15 – 30°
Rolling bellows	15°

During configuration note that the bellow actuator must never be compressed to less than its minimum height, nor may the maximum height be exceeded. The height in the center of the plate is the reference value for determining the necessary force. If in doubt, contact AVENTICS in advance or carry out kinematics tests.



Required installation space

The installation location must provide adequate space to accommodate the change in bellows diameter over the entire stroke.

Avoid side contact points (abrasion points).

3.5.4 Diagrams and selection parameters

Main dimensions and connection dimensions

Details of the height can be found in the force-displacement diagram. It contains all the major connection dimensions. The thread dimensions can be found in the data sheets.

Force-displacement and volume characteristic curves

All of the important function values are shown in the force-displacement diagram:

- The isobars, i.e. the force progression as a function of height at a constant operating pressure.
- The volume curve, which describes the "spatial capacity" of the pneumatic spring at the respective height. The relevant operating heights are plotted on the x-axis: the minimum height H_{min}, the recommended height for vibration isolation, the maximum recommended height $H_{max\ r}$, up to which the pneumatic spring can be used without limitation, and the maximum permissible height H_{max}.
  In some cases, operation in the dotted range between $H_{max\ r}$ and H_{max} may put considerable stress on the pneumatic spring. We recommend having the operating parameters thoroughly checked by the Application Technology department before use in this operating range.

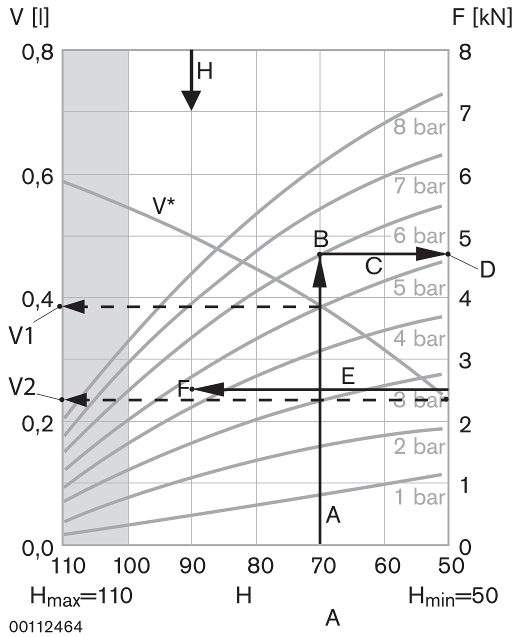


Fig. 25 Force-displacement diagram

H	Height [mm]
H_{min}	Min. operating height [mm]
H_{max}	Max. height [mm]
H	Recommended operating height for vibration isolation 90 mm
V*	Volume characteristic
V	Volume [l]

Note: Please always consult your AVENTICS contact person for configurations in the gray zone.

Example of pneumatic application

What is the stroke force of a bellow actuator with a 20 mm stroke and an operating pressure of 6 bar?

Solution: Min. operating height = 50 mm
Stroke = 20 mm
50 mm + 20 mm = 70 mm

1. Draw a vertical line (**A**) through 70 mm height. This line intersects the 6-bar line at point (**B**).
2. Draw a horizontal line (**C**) through (**B**). The point where (**C**) intersects the force axis (**D**) is the desired value: approx. 4.7 kN.

What is the required volume?

Note: Use the force-displacement diagram as an aid.

Solution: Intersection point of the volume characteristic and minimum height (50 mm) > V_2 = 0.24 l

- Intersection point of the volume characteristic and operating height (70 mm) > V_1 = 0.38 l
- Operating pressure at minimum height P_2 = 0 bar
- Operating pressure at operating height P_1 = 6 bar

$$L = \frac{V_1 \cdot (p_1 + p_a)}{p_a} - \frac{V_2 \cdot (p_2 + p_a)}{p_a}$$

Using the adjacent formula, an air consumption of 2.42 l is required to lift a load of 4.7 kN from H = 50 mm (without pressure) to 70 mm (at 6 bar).

Read-off example for vibration isolation

What operating pressure does a bellow actuator require at 2.5 kN load capacity?

Solution:

- Draw a horizontal line (**E**) through the force axis at 2.5 kN. (**E**) intersects the line for the recommended height for vibration isolation (**H***) at point (**F**). This lies between the 4 bar and 5 bar isobars. The value is estimated at roughly 4.5 bar.

An exact value can be determined by linear interpolation using the “Isolation diagram” table with the next closest operating parameter.

3.5.5 Selection parameters for bellow actuators as pneumatic springs

The following main criteria have to be taken into consideration to select the right bellow actuators:

- Load capacity or total weight and number of bearing points
- Recommended operating height
- Degree of isolation
- Operating pressure

The following descriptions and explanations are based on a simplified spring mass system and the following assumptions:

- The springs are damping-free.
- The machine mass is small relative to the base.
- The machine is a compact, rigid body.
- The exciting force has a harmonious curve.

Notes for configuration

Note: For questions on the configuration, please contact your regional center.

The following aspects are relevant for the vibration isolation.

Configuration of a pneumatic spring

Pneumatic springs are very low-frequency bearing elements that build up their spring force through the compression of the gas contained in them. As machine bearings they reduce the transmission of vibrations, structure-borne noise in the environment (active isolation) or the effects of vibrations from the environment on sensitive systems (passive isolation).

Vibration damping is always necessary when a vibration source or vibration interference causes problems. The interference can come from the environment. This can be caused, for example, by floor vibrations that interfere with a coordinate measuring device to such an extent that precise measurements are not possible. The interference can, however, also be caused by a device, e.g. a vibratory screen or a generator. Although these situations appear to be very different at first sight, they are both attributable to the same problem.

Complete systems

The vibration isolation with pneumatic springs can be purchased from AVENTICS as a complete system consisting of pneumatic springs, level control, and all relevant accessories.

Load capacity

When selecting the bellow actuators, a load capacity reserve should be planned in order to compensate for asymmetric load distribution or deviating weights. The pneumatic springs are designed so that they can absorb additional dynamic load increases from operational vibrations.

Recommended operating height

Bellow actuators develop their load capacity from variable internal pressure. Unlike steel or elastomer springs, bellow actuators have no static spring deflection. There is no direct relationship between the applied load and the height. Changes in the spring deflection due to varying loads can be compensated for by adapting the operating pressure.

$f_2 > \sqrt{2} \times f_n$

Degree of isolation

The degree of isolation describes the level of isolation against vibration excitation. Vibration isolation exists only when the excitation frequency is at least 1.4 times the respective natural frequency.

The degree of isolation can be read from the following diagram with the parameters “natural frequency” and “excitation frequency”.

A degree of isolation of 98%, for example, means that only 2% of the excitation forces are transmitted by the bellow actuators; 98% of the excitations are insulated.

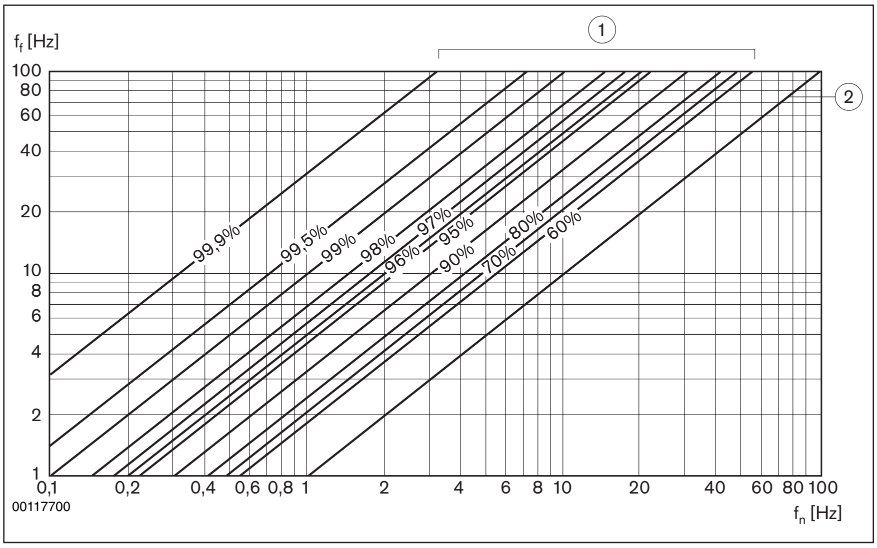


Fig. 26 Isolation diagram

f_n	Natural frequency	1	Isolation [%]
f_f	Interference frequency	2	Resonance

Operating pressure

The necessary operating pressure in relation to the load capacity and operating height can be taken from the data sheet. As a rule, the bellow actuator is correctly dimensioned when the operating pressure lies between 4 and 6 bar.

It is necessary to check whether the line pressure available on site – allowing for pressure fluctuations and losses in the fittings – is sufficient.

Unless otherwise indicated, all indicated pressure values are understood as overpressure.

3.5.6 Bellow actuator formulas

$$p \times V^K = con$$

Thermodynamic change of state:

For dynamic spring operation: K = 1.4 (for air)

$$p_2 = (p_1 + p_a) \times \left(\frac{V_1}{V_2}\right)^K$$

Pressure change from p_1 to p_2:

Pressure change as a result of adiabatic spring operations from height 1 to height 2 at volumes V_1 and V_2: see catalog.

$$L = \frac{V_1 \times (p_1 + p_a)}{p_a} - \frac{V_2 \times (p_2 + p_a)}{p_a}$$

Air consumption:

Air consumption for spring operations from height 1 to height 2 at volumes V_1 and V_2: see data sheet.

Formula symbol [unit]	Parameter
L [l]	Air consumption per stroke
p_a [bar]	Atmospheric pressure ~ 1 bar
p [bar]	Operating overpressure
p_1 [bar]	Overpressure at operating point 1
p_2 [bar]	Overpressure at operating point 2
V [l]	Volume at operating point
V_1 [l]	Volume at operating point 1
V_2 [l]	Volume at operating point 2
K	Polytropic index

3.6 Rotary actuators

3.6.1 Rack-and-pinion gears

RCM series rotary compact modules

The RCM series of rotary compact modules can be configured for all standardized rotary and swivel movements.

TRR series rotary cylinders

The double-acting rotary cylinders with cushioning can be used as pneumatic drives for straight-line movements. Drive rotary movement and force generation are performed via the pressure means transferred to the pressure chambers through the port openings.

3.6.2 Rotary wing drives

RAN series rotary wing drives

Rotary actuator series RAN with vane cell technology and fixed stop

The versatile RAN rotary actuator provides a high torque while maintaining a low weight and leakage. The product series also includes units with pre-mounted, compact sensor housings.

3.6.3 Indexing tables

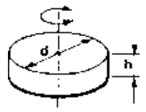
RWT series indexing table

RWT indexing tables convert the energy of the compressed air into a rotating movement and force.

The RWT indexing table from AVENTICS combines high-quality mechanical and pneumatic drive elements with a reliable, precise gear mechanism. It enables continuous rotation exceeding 360°, which saves time by eliminating resynchronization.

3.6.4 Rotary drive formulas

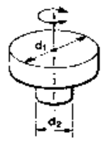
Moment of inertia J for various objects



Disk

$$J = \frac{m \times d^2}{8}$$

d	Diameter [m]
m	Mass [kg]

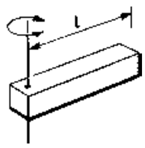


Stepped disk

$$J = \frac{m_1 \times d_1^{\,2} + m_2 \times d_2^{\,2}}{8}$$

d_1, d_2	Diameter [m]
m_1, m_2	Proportional mass [kg]

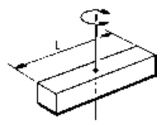
If d_2 is much smaller than d_1, then the value of d_2 is negligible.



Shaft, pivoted at one end

$$J = \frac{m \times l^2}{3}$$

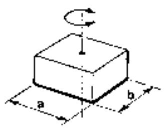
l	Bar length [m]
m	Mass [kg]



Shaft, centrally pivoted

$$J = \frac{m \times l^2}{12}$$

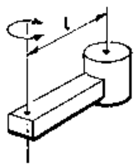
l	Bar length [m]
m	Mass [kg]



Rectangular block

$$J = \frac{m \times (a^2 + b^2)}{12}$$

a, b	Side lengths [m]
m	Mass [kg]



Shaft with load

$$J = m_1 \times l^2 + \frac{m_2 \times l^2}{3}$$

l	Arm length [m]
m_1	Mass of concentrated load [kg]
m_2	Mass of arm in [kg]

If m_2 is significantly smaller than m_1, then assume m_2 to be 0 for calculation purposes.

Stroke time t

Calculation of the torque s required for the specified time. The maximum frequency is 0.4 Hz for a double stroke of 2 × 270°.

General formula:

$$M_t = M_\alpha + M_{TP} + M_E$$

Where:

Torque Mα related to inertia:

$$M_\alpha = K \times J \times \frac{\varphi \times 2\pi}{306 \times t^2}$$

K = Constant = 2

J = Moment of inertia [kg × m^2]

φ = Rotational angle [°]

T = Time [s]

Torque M_{TP}, if load is off-center:

$$M_{TP} = K \times m_{TP} \times 9.81 \times L_T$$

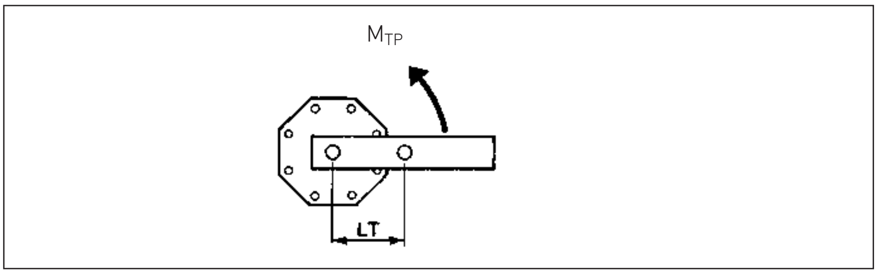


Fig. 27 Torque M_{TP}

K = Constant = 5

m_{TP} = Mass [kg]

L_T = Torque on arm [Nm]

External torque M_E, if present:

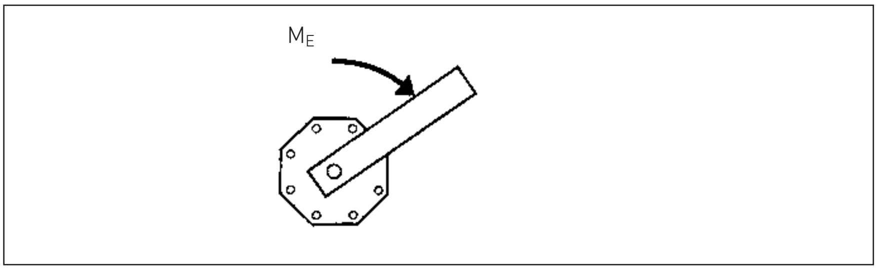


Fig. 28 Torque M_E

M_E = Actual value [Nm]

4 Applications

4.1 Dimensioning of a cylinder drive without piston rod using the RTC rodless cylinder as an example

Dimensioning steps for the RTC

1. Determine the area of application.
2. Determine lever arms Lx, Ly, Lz [m], as well as masses m [kg] and velocity v [m/s] for the applications.
3. Select appropriate cylinders (www.aventics.com/pneumatics-catalog).

Dimensioning fundamentals

- **Operating pressure p:**
  A pressure of 6 bar is always taken as a basis.
- **Velocity v:**
  If a movement velocity value v ≤ 0.7 m/s is exceeded, the actual mass must be multiplied by a correction factor of 2 × v^2. The calculations must be continued with the corrected mass.
- **Cycle time t:**
  To ensure proper pneumatic control of piston movement and reduce the risk of failure, e.g. during startup, the mass to surface area ratio m/A (m = mass in kg and A = area in cm^2) should be ≤ 4 kg/cm^2 for horizontal applications and ≤ 2 kg/cm2 for vertical applications.

Dimensioning example:

An RTC with Ø 63 mm and a 200 mm stroke length (S) is to move a mass (m) of 45 kg vertically upwards. Estimate the time for a single stroke if the max. velocity of the cylinder is to be 0.7 m/s.

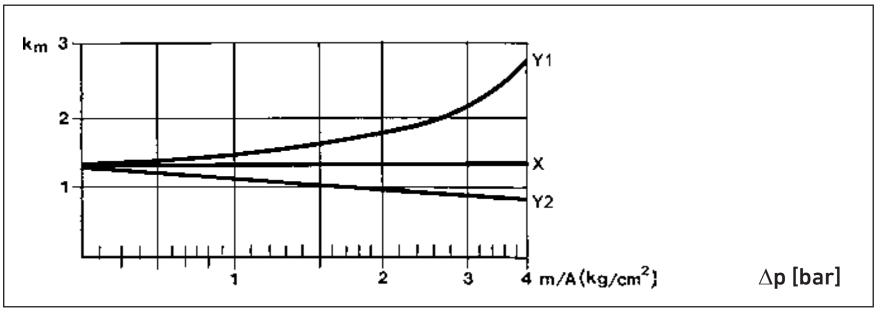


Fig. 29 Diagram: Correction factor k_m, mass to surface area ratio m/A

1. Calculate mass to surface area ratio m/A:

$$m/A = \frac{m}{d^2 \times \pi} \times 4 = \frac{45\ kg}{(6.3\ cm)^2 \times \pi} \times 4 = 1.5\ kg/cm^2$$

2. Calculate correction factor k_m:

X Horizontal movement

Y1 Vertical movement “up”

Y2 Vertical movement “down”

Δp Pressure drop (scale: Δp = m/A)

It can also be seen from the diagram that a pressure drop of approx. 1.5 bar over the cylinder piston is required to overcome the mass load.

3. Calculate cycle time t:

$$t = \frac{k_m \times S}{1000 \times v} = \frac{1.575 \times 200\ \text{mm}}{1000 \times 0.7\ \text{m/s}} = 0.45\ \text{s}$$

t [s] = Cycle time

S [mm] = Stroke

v [m/s] = Speed

k_m = Correction factor

Note: Limitation: Accuracy is reduced for short-stroke cylinders.

- In many cases, only the cycle time t is known, not the cylinder velocity v. A conversion can be made by means of the diagram "Correction factor k_m".
- In the diagrams for dimensioning the cushioning, calculations must be based on the actual mass m. If the cushioning capacity of a cylinder is insufficient, either a larger cylinder must be used or external shock absorbers must be mounted in the center of the mass to be cushioned.
- The values for the AVENTICS guide include cases with large shock loads.
- The play, stiffness, and maximum efficiency of the cylinders should also be considered when selecting the cylinder.

Control of rodless cylinders

The control of the rodless cylinder must be realized in such a way that the pneumatic cushioning works reliably even after a pressure breakdown or when starting the system again. However, this is possible only if the secondary chamber of the cylinder is under pressure.

Setting the speed and cushioning

The cushioning, i.e. the impact of the piston at the end covers of the cylinder, is set with the cylinder cushioning screw.

When the cushioning is being set, the cylinder must be loaded as in normal service and the speed must be increased gradually to the desired operating speed.

Normally the speed is controlled by throttling the exhaust air from the cylinder chambers with a check-choke valve.

To set the correct/desired speed, use of VTM (Velocity Time Meter) is recommended. This is an optional accessory available from AVENTICS (at www.aventics.com/pneumatics-catalog).

Note: If the cushioning is correctly set, the piston will reach its end position without rebounding from or hitting the end cover. AVENTICS will gladly provide assistance with the optimization of cushioning settings.

Guide overview: RTC

- **RTC-BV**: Basic Version with integrated guide
- **RTC-CG**: Compact Guide with compact ball rail guide
- **RTC-HD**: Heavy Duty with reinforced ball rail guide
- **CKP**: Compact module K (ball rail guide), Pneumatic drive, rodless cylinder with double ball rail guides
- **CKP-CL**: Compact module K (ball rail guide), Pneumatic drive – camoLINE, compatible with cartesian motion building system

$$\frac{Mx}{Mx_{max.}} + \frac{My}{My_{max.}} + \frac{Mz}{Mz_{max.}} \leq 1$$

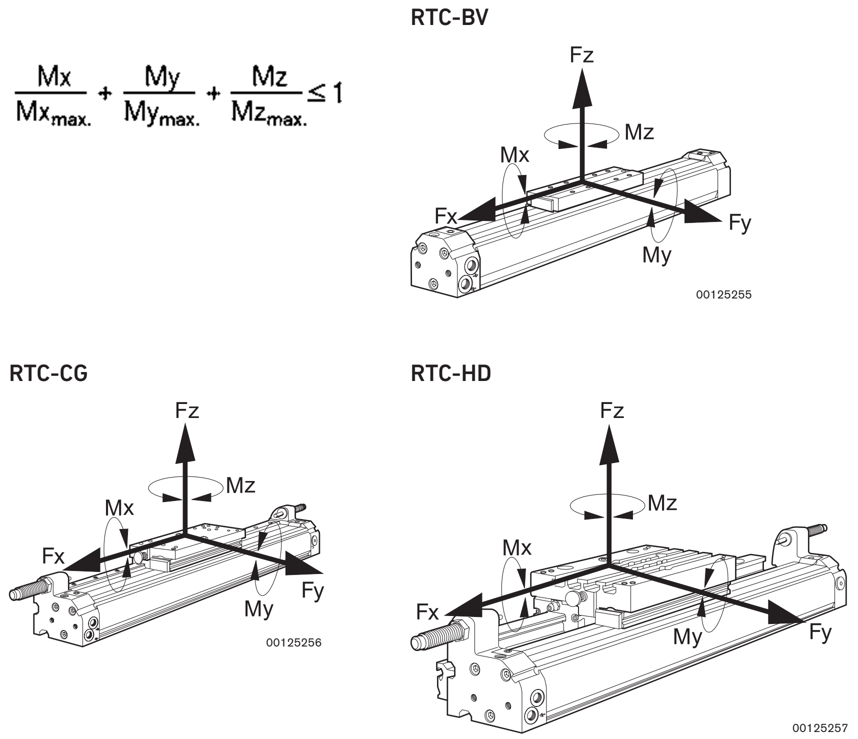


Fig. 30 Permissible forces Fx, Fy, Fz and moments Mx, My, Mz

Static							Dynamic		
Piston Ø	Fx [N]	Fy [N]	Fz [N]	Mx [Nm]	My [Nm]	Mz [Nm]	Mx [Nm]	My [Nm]	Mz [Nm]
16	800	150	1100	2	25	8	0.42	10	2
25	1800	210	3800	6	50	12	1	24	3
32	2200	550	6600	18	80	43	3.8	42	12
40	3500	650	8000	28	140	55	6	75	15
50	5000	750	9000	35	230	70	9.1	128	20
63	6800	850	13000	45	340	90	14.5	195	24
80	9500	1000	13000	55	500	110	20	300	28

Table 4 RTC-BV

Static				Static and dynamic		
Piston Ø	Fx [N]	Fy [N]	Fz [N]	Mx [Nm]	My [Nm]	Mz [Nm]
16	744	744	744	4	30	30
25	1456	1456	1456	10	78	78
32	1840	1840	2646	22	158	110
40	1640	1640	4284	36	284	109

Table 5 RTC-CG

Static				Static and dynamic		
Piston Ø	Fx [N]	Fy [N]	Fz [N]	Mx [Nm]	My [Nm]	Mz [Nm]
16	1640	1640	4284	34	138	53
25	2640	2640	7810	100	336	114
32	3760	3760	9952	154	502	190
40	6840	6840	13922	254	764	376
50	6840	6840	13922	254	924	455
63	6840	6840	13922	254	1120	551

Table 6 RTC-HD

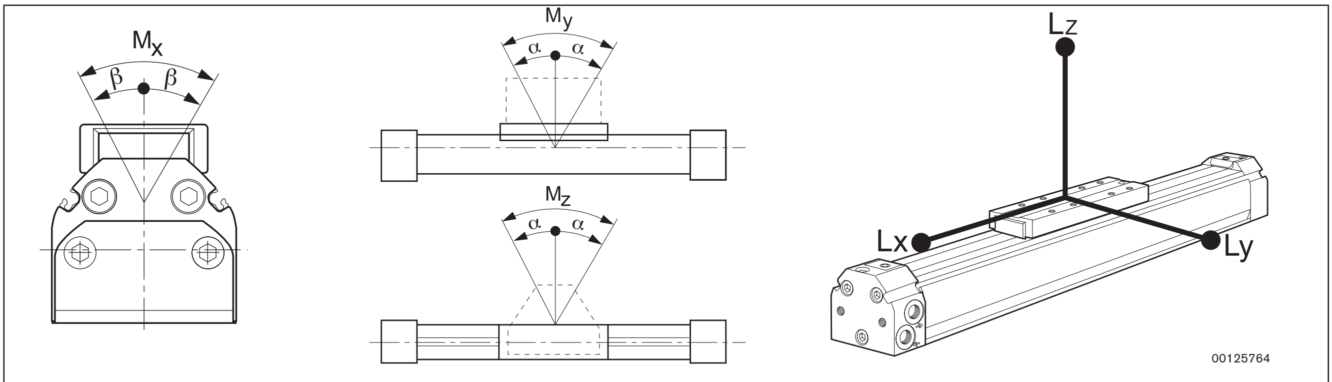


Fig. 31 Max. play and recommended max. lever arm length

Torque dimensioning

The diagrams on the following pages show the permissible mass m as a function of the lever arms Lx, Ly, Lz. For applications outside permissible limits, please contact your AVENTICS regional sales office.

Piston Ø	α	β	Lx	Ly	Lz
16	0.5°	2.0° ±1°	162	94	162
25	0.5°	2.0° ±1°	217	123	217
32	0.6°	1.5° ±0.5°	240	139	240
40	0.4°	1.0° ±0.3°	275	158	275
50	0.4°	1.0° ±0.3°	317	181	317
63	0.3°	1.0° ±0.3°	368	209	368
80	0.3°	1.0° ±0.3°	435	245	435

Table 7 Moments, RTC-BV (Basic Version) with integrated guide

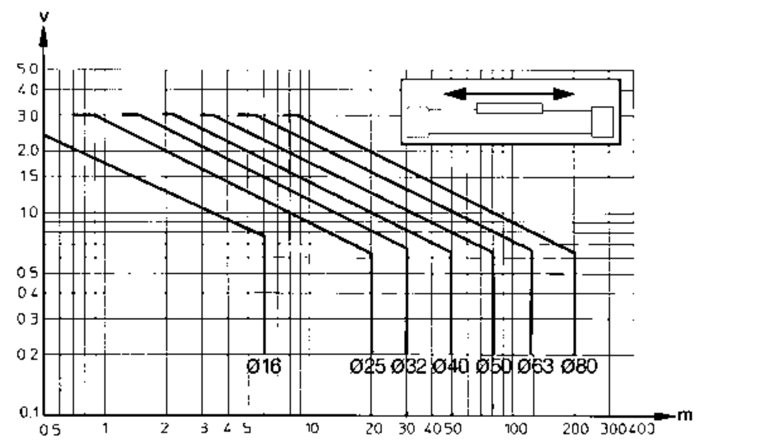


Fig. 32 Limit diagram for pneumatic cushioning with horizontal mounting

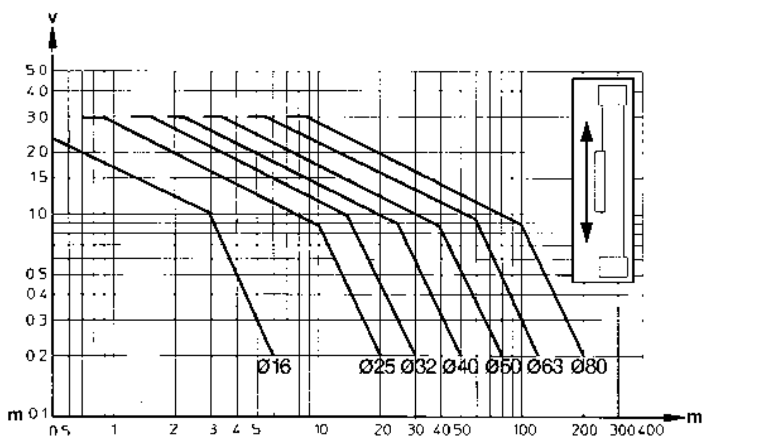


Fig. 33 Limit diagram for pneumatic cushioning with vertical mounting

v Piston velocity [m/s]

m Cushionable mass [kg]

The values for the cushionable mass m and piston velocity v must be on or below the curve for the selected piston diameter.

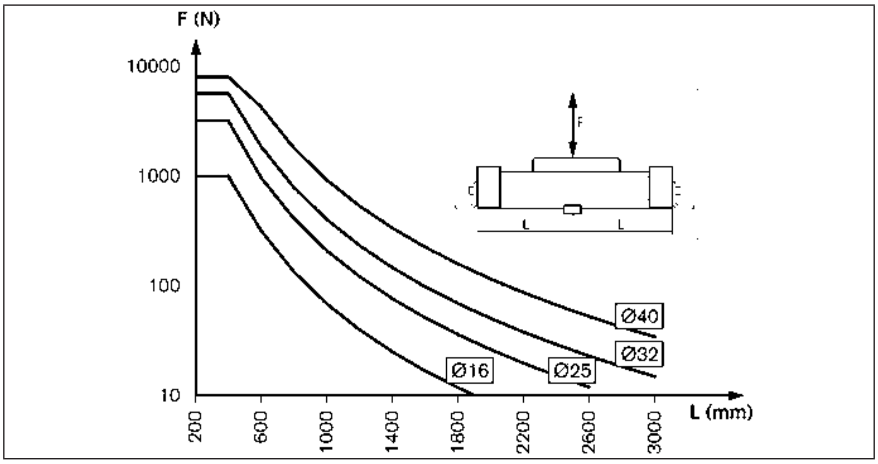


Fig. 34 Support span L [mm] as a function of F [N] at a deflection of 0.5 mm, part 1

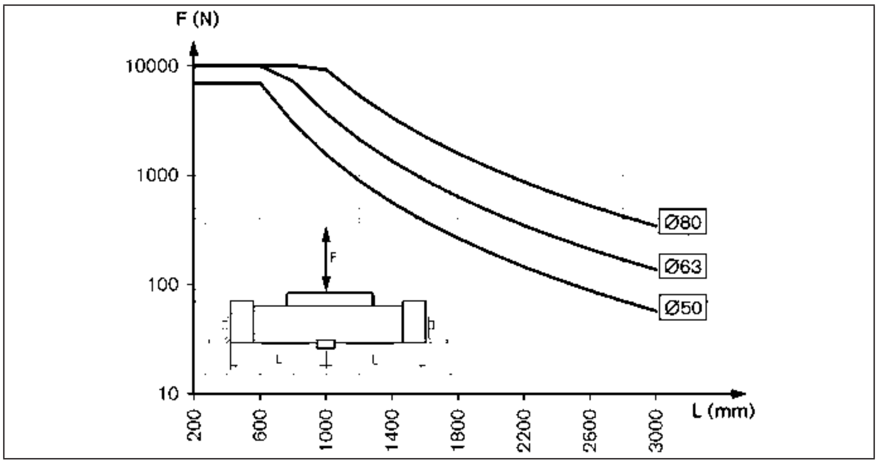


Fig. 35 Support span L [mm] as a function of F [N] at a deflection of 0.5 mm, part 2

Piston Ø	α	β	Lx	Ly	Lz
16	<0.1°	<0.2°	328	328	328
25	<0.1°	<0.2°	424	424	424
32	<0.1°	<0.2°	480	480	480
40	<0.1°	<0.2°	532	532	532

Table 8 Moments, RTC-CG (Compact Guide) with compact ball rail guide

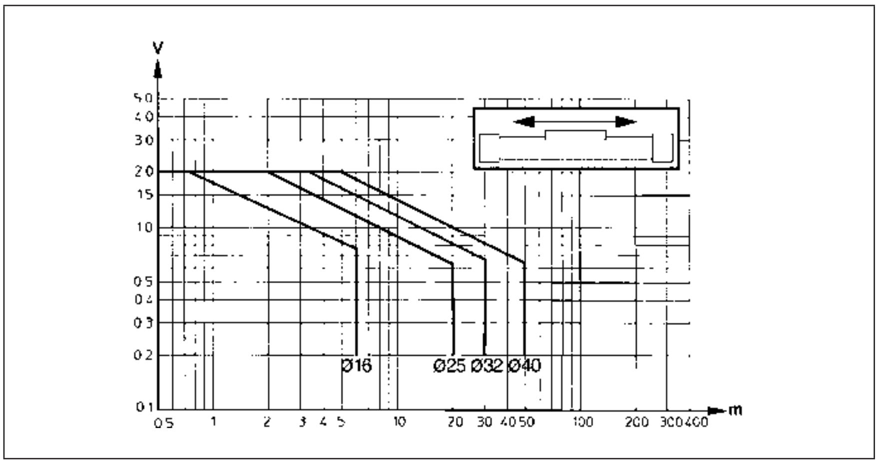


Fig. 36 Limit diagram for pneumatic cushioning with horizontal mounting

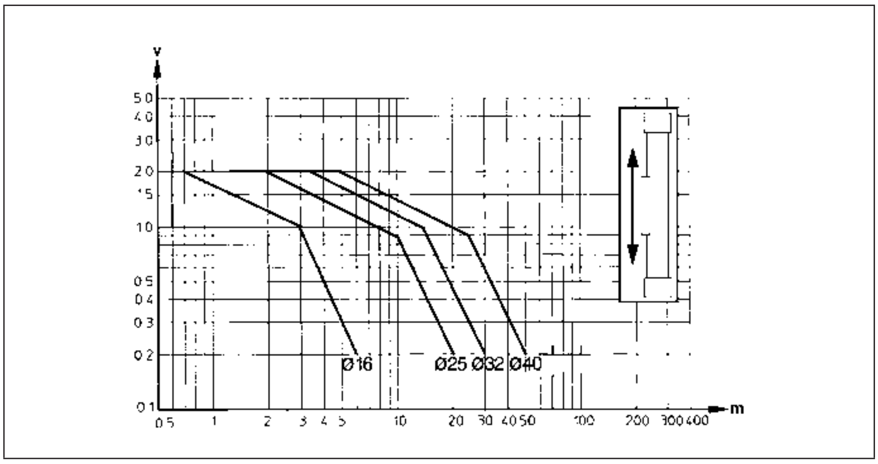


Fig. 37 Limit diagram for pneumatic cushioning with vertical mounting

v Piston velocity [m/s]

m Cushionable mass [kg]

The values for the cushionable mass m and piston velocity v must be on or below the curve for the selected piston diameter.

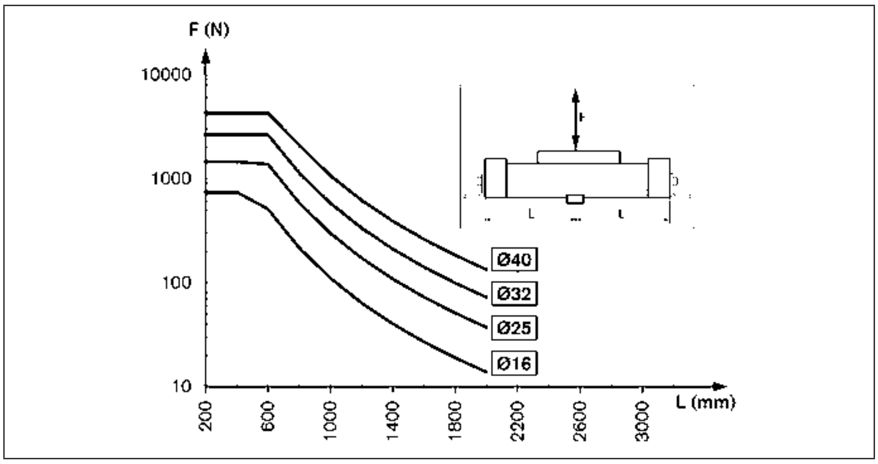


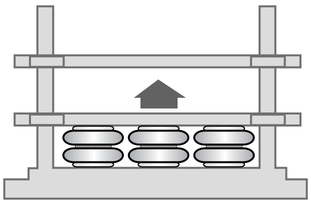
Fig. 38 Max. support span L [mm] as a function of F [N] at a deflection of 0.5 mm

4.2 Bellow actuators: Application areas for pneumatics

Bellow actuators are particularly suited for use in the following industries:

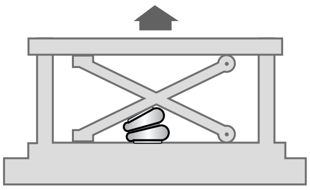
- Conveying systems
- Agricultural machinery
- Food industry
- Paper and textile machines
- Sawmill machinery
- Punching and forming presses

Examples



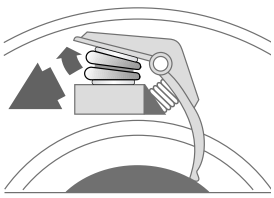
Veneering press

Simple multiplication of the stroke force through parallel connection of multiple bellow actuators.



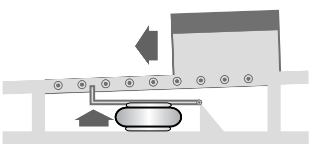
Scissor lift table

Tilt angles up to 30° are possible



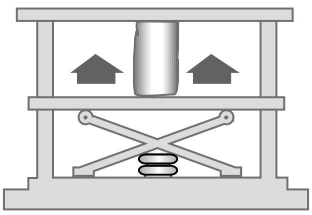
Bark peeling machine

High contact force and flexibility; long service life despite harsh ambient conditions.



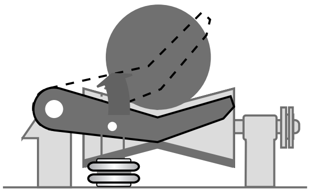
Stopper

Low minimum height; fast stroke movement.



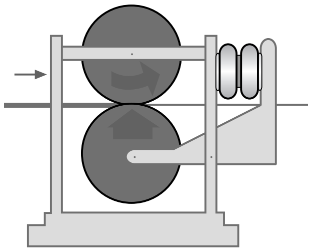
Press

Easily regulated contact pressure over a wide stroke range.



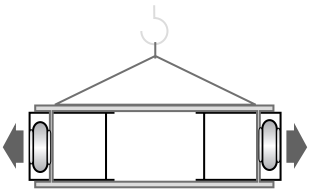
Transport transfer device

Large stroke; long service life despite harsh ambient conditions.



Roller tensioners

Contact pressure of the rollers; irregularities in the processed material are compensated for by the spring properties of the bellow actuators



Clamping device

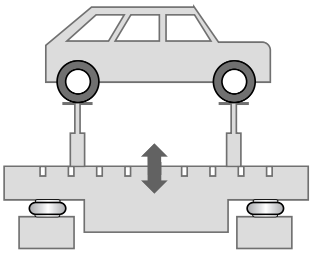
No escape of environmentally harmful media if the bellow actuator is damaged

4.3 Bellow actuators: Application areas for vibration isolation

Bellow actuators are particularly suited for the following applications:

- Diesel engines, generators
- Vehicle test stands
- Foundation bearings
- Measuring instruments
- Heavy-duty machinery
- Washing machines
- Weaving looms

Example



Test stand support

Vertical natural frequency of approx. 1.5 Hz, down to approx. 0.5 Hz if required. Avoidance of resonances through detuning of spring values. Level control for horizontal alignment.

III Shock absorbers

1 Introduction

The shock absorbers are intended to stop a mass quickly, gently, and without any damage.

The load will push the piston rod into the shock absorber and displace hydraulic oil in the pressure pipe through throttle openings and into the accumulator.

The number of effective throttle openings decreases proportionally to the displacement. Dynamic pressure and counterforce remain almost the same throughout the entire stroke. For this reason, the entry speed decreases constantly. The spring pushes the piston rod back when the load is relieved. The oil flows back into the pressure pipe. The piston rod extends. The throttle bore surface area can be changed by turning the adjusting screw on adjustable shock absorbers (e.g. SA1-MA series).

2 Technical principles

2.1 Impact force of shock absorbers on adjacent machine parts

The impact force F_d transferred to other machine components is obtained using the adjacent formula:

$$F_d = F + \frac{W_k}{s_d}$$

F_d = Impact force
F = Impelling force
W_k = Kinetic energy
s_d = Impact stroke

2.2 Heat dissipation

The heat dissipation of the shock absorber can be improved by cooling it with air, e.g. exhaust air from the pneumatic cylinder powering the decelerated mass. Cooling can be made particularly effective by channeling the cooling air around the shock absorber.
Painting of shock absorbers should be avoided since this impairs the heat dissipation capabilities of the unit.

2.3 Parallel operation of shock absorbers

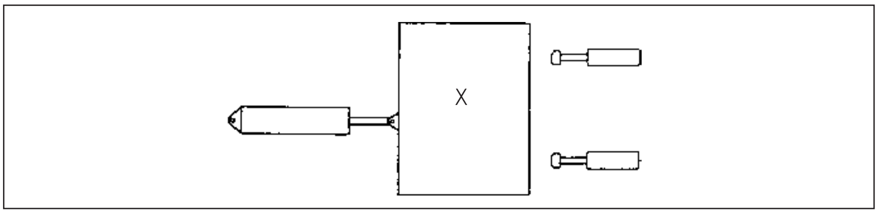


Fig. 1 Focus: Parallel operation of shock absorbers

X Center of gravity

In some cases two shock absorbers need to be operated in parallel. One reason for this can be that from a design point of view, it is necessary to decelerate a machine part with two shock absorbers.

When adjusting two shock absorbers in parallel, it is important to trim the system so that both shock absorbers brake the mass equally; otherwise there will be a risk of overloading.

The required number of shock absorbers can also be determined using the online calculation program.

2.4 Adjusting the shock absorbers

Both self-compensating and adjustable shock absorbers are available.

Self-compensating shock absorbers (SA1-MC, SA2) automatically offset the various effects of force, mass, and speed.

AVENTICS **adjustable shock absorbers** (SA1-MA, 370 series) are graded from 1 to 8 (SA1) or 1 to 5 (370 series), where 1 signifies soft cushioning, and 5 or 8 hard cushioning. The adjusting ring can be turned any number of times; however only the graduated area should be used for adjustment. The adjustment depends on the mass m and the velocity v of the load. The higher the velocity and the smaller the mass, the lower the setting.

2.5 Cushioning

A correctly set shock absorber provides a nearly constant braking force throughout the impact stroke s_d. The velocity v diminishes as shown by the parabolic curve.

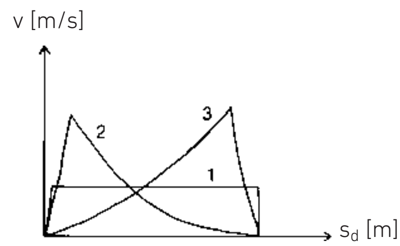


Fig. 2 Diagram: Speed, impact stroke

1 Correctly set shock absorber

2 Excessive shock absorber throttling

3 Insufficient shock absorber throttling

If the shock absorber is throttled too hard, the braking force will be too high at the beginning of the stroke s_d; if the shock absorber is not throttled enough, the force will peak at the end of the stroke s_d. In cases where a pneumatic cylinder exerts an impelling force on the shock absorber, the throttle screw in the built-in air cushioning of the cylinder must be fully open.

2.6 Dimensioning of shock absorbers

To select an industrial shock absorber, the following three points must be met in accordance with the performance table:

- **Energy absorption per stroke [Nm]**
  This value indicates the permissible energy absorption of the shock absorber. It is made up of kinetic energy (W_K) and drive energy (W_A).
- **Energy absorption per hour [Nm/h]**
  The energy absorption per hour is the product of the energy absorption per stroke and the strokes per hour. As hydraulic industrial shock absorbers convert energy into heat, this value protects the shock absorber from excessive heating.
- **Effective mass [kg]**
  Once you have defined the size of the shock absorber using the energy absorption per stroke and hour, the effective mass is used to determine the cushioning hardness. In contrast to the actual mass, this also takes e.g. additional pneumatic drive forces into account.

2.7 Shock absorber formulas

Important abbreviations – input data

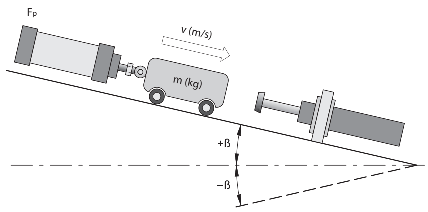


Fig. 3 Parameter overview

W_k = Kinetic energy [Nm]

W_A = Drive energy [Nm]

W_{kg} = Total energy, $W_k + W_A$ [Nm]

$W_{kg/h}$ = Total energy per hour [Nm/h]

m = Mass to be decelerated [kg]

m_e = Effective mass [kg]

v = Impact speed at shock absorber [m/s]

n = Number of strokes per hour [1/h]

s_d = Impact stroke [m]

β = Angle of inclination

F_P = Pneumatic drive force [N]

g = Acceleration of gravity (9.81 m/s²)

With this input data, an appropriate shock absorber can be chosen by calculating the energy per cycle per hour and the effective weight.

$W_k = \frac{m \times v^2}{2}$	Kinetic energy
$W_A = F_P \times s_d$	Mass with drive force, horizontal
$W_A = (F_P + m \times g) \times s_d$	Mass with drive force, vertically downward
$W_A = (F_P - m \times g) \times s_d$	Mass with drive force, vertically upward
$W_A = (F_P + m \times g \times \sin \beta) \times s_d$	Mass with drive force on inclined plane
$W_{kg} = W_k + W_A$	Total energy
$W_{kg/h} = W_{kg} \times n$	Total energy per hour
$m_e = \frac{2 \times W_{kg}}{v^2}$	Effective mass

Fig. 4 Parameter calculation

Example of shock absorber calculation

The right shock absorber can be calculated manually or with the assistance of the calculation program.

Example: **Manual calculation:**

Given:

m = 5 kg — F_P = 500 N

n = 60 cycles/h — v = 1 m/s

s_d = 8 mm (free selection)

$W_k = \frac{m \times v^2}{2}$ =	$\frac{5\ kg \times 1 m/s}{2}$	= 2.5 Nm	Kinetic energy
$W_A = F_P \times s_d$	500 N x 0.008 m	= 4 Nm	Mass with drive force, horizontal
$W_{kg} = W_k + W_A$	2.5 Nm + 4 Nm	6.5 Nm ①	Total energy
$W_{kg/h} = W_{kg} + n$	6.5 Nm + 60 1/h	= 390 Nm/h ②	Total energy per hour
$m_e = \frac{2 \times W_{kg}}{v_2}$ =	$\frac{2 \times 6.5\ Nm}{(1\ m/s)^2}$	= 13 kg ③	Effective mass

Calculating the shock absorber:
Compare the calculation results with the technical data.

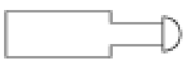
	Type	Stroke	Effective mass m_e min./max.	Return spring force	Energy absorption/ stroke max.	Energy absorption/ hour max.	Part number
		[mm]	[kg]	[N]	[Nm]	[Nm/h]	
	SA1-MC	5	0.8/2.8	2/5	1	3000	R412010284
		5	1.5/4	2/5	1	3000	R412010285
		5	0.5/4	2/5	1.5	4000	R412010286
		5	0.8/6	2/5	1.5	4000	R412010287
		8	1.3/5.3	3.6/8	10 ①	24000 ②	R412010288
		8	4.3/20 ③	3.6/8	10 ①	24000 ②	R412010289
		8	16.5/47	3.6/8	10 ①	24000 ②	R412010290
		10	0.5/1.8	3.5/7	14	30000	R412010291
		10	1.5/7.7	3.5/7	14	30000	R412010292
		10	5/57	3.5/7	14	30000	R412010293

Table 1 Excerpt from technical data

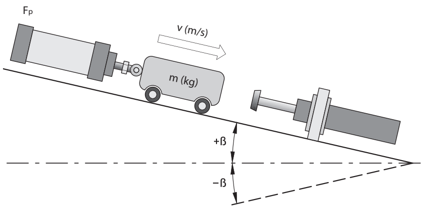
① The selected energy absorption/stroke$_{max}$ must be greater that the calculated total energy.

② The selected energy absorption/hour must be greater than the calculated total energy per hour.

③ The calculated effective mass must be within the selected effective mass m_e min/max.

Solution: SA1 MC shock absorber, material number: R4120010289

Shock absorber calculation program



Workpiece:	
Mass: m (kg)	5
Impact speed: v (m/s)	1
Drive force: F_P (N)	500
Number of strokes/hour: n (1/h)	60
Temperature: (°C)	20
Application:	
Load case:	Linear
Load movement:	Horizontal
Number of parallel shock absorbers:	1
Shock absorber:	
Shock absorber series:	SA1-MC
Preselected thread:	none
Preselected article number:	None

Table 2 Online calculation tool

Calculated by shock absorber calculation program (program information version 1.2)

Dimensioning data	Value	Minimum value:	Maximum value:	Load %
Energy/stroke: W_{kg} (Nm)	6.5		10.0	65.0
Energy/hour: $W_{kg/h}$ (Nm/h)	390		24000	2
Effective mass: m_e(kg)	13.0	4.3	20.0	OK
Impact speed: v_e (m/s)	1.0	1.0	2.2	OK
Temperature: (C°)	20	-20	80	OK
Output data				
Article number	R412010289			
Thread:	M10x1			
Stroke: sd (mm)	8			
Cushioning time: (s)	0.021			
Deceleration: (m/s^2)	94			
Cushioning force: (N)	1219			

The calculation results can be seen as a recommendation for component selection.
However, AVENTICS is not liable for damages resulting from the use of this program.

Solution: SA1 MC shock absorber, material number: R4120010289

3 Products

AVENTICS offers the following types of shock absorbers:

- Self-compensating shock absorbers
- Adjustable shock absorbers
  All adjustable shock absorbers can be adjusted for different energy values and velocities.

3.1 SA1 series

- Self-compensating shock absorbers, M6×0.5 to M25×1.5 for energy absorption up to 220 Nm
- Adjustable M12x1 to M64x2 for energy absorption from 22 to 8000 Nm

Variants

- SA1-MC: self-compensating
  The SA1-MC shock absorbers automatically offset the various effects of force, mass, and speed within a range.
  The range can be selected in the main catalog.
- SA1-MA: adjustable
  - The setting scale has a range from 0 to 8.
  - If the impact at the start of the stroke is too hard, turn the scale towards 0 (clockwise).
  - If the impact at the end of the stroke is too hard, turn the scale towards 8 (counterclockwise).

SA1-MA M12x1 – M25x1.5; adjustable

After fitting the absorber, operate the facility several times so that the setting segment is rotated until the optimal setting is reached.

The shock absorbers M14x1.5 – M20x1.5 do not have a threaded pin.

M12x1; adjustable

The control knob is blocked by a threaded pin. The control knob can be unlocked for adjustment with the enclosed hexagonal key.

SA1-MA M33x1.5 und M64x2; adjustable

The adjusting screw is blocked by a threaded pin. Settings can be made using the adjusting screw on the base or on the setting ring.

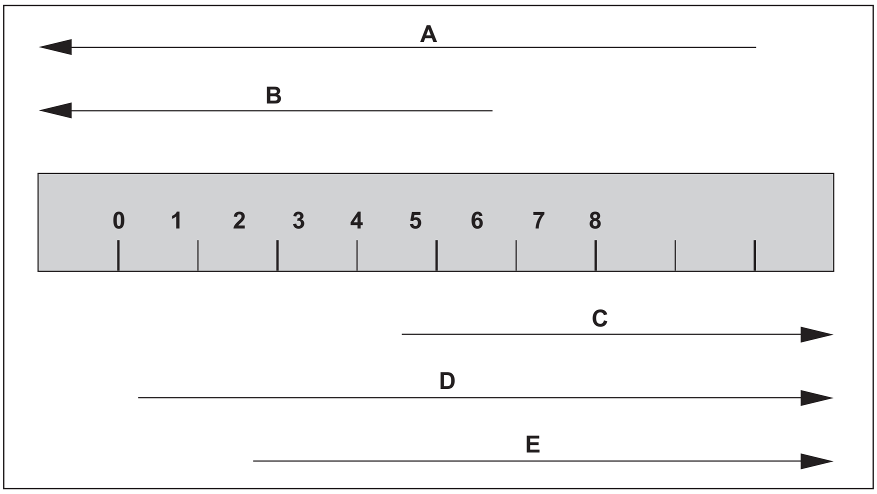


Fig. 5 SA1-MA settings

A	High speed and low mass	0-2	Soft cushioning
B	Softer	3-5	Medium cushioning
C	Harder	6-8	Hard cushioning
D	Large mass and low speed		
E	High drive energy		

Possible settings:

- Impact speed < 1.3 m/s – 6
- Impact speed > 1.3 m/s – 4
- ▸ If, during the test run, the mass hits the fixed stop too hard, continually increase the cushioning force.
- ▸ If, during the test run, the mass hits the stop cap/piston rod too hard, reduce the cushioning force.

3.2 SA2 series

Self-compensating shock absorbers automatically offset the various effects of force, mass, and speed.

- Self-compensating shock absorbers, M8x1 – M14x1.5, SA2-MS series, for energy absorption up to 130 Nm

- Shock absorbers, M6x0.5 – M14x1.5, SA2-RC series, for energy absorption up to 420 Nm

Note: The SA2 series is designed exclusively for MSC series mini slides and the RCM series rotary compact module.

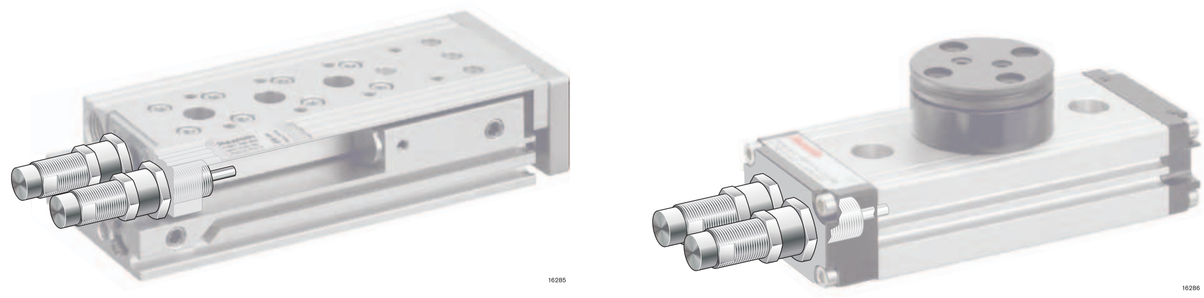


Fig. 6 Application example for mini slides and rotary module

3.3 370 series

- Adjustable shock absorbers, M27×2 to M42×3, for energy absorption from 60 to 600 Nm
- The setting scale has a range from 1 to 5.
  - 1 = minimum cushioning
  - 5 = maximum cushioning
- The 370 series of shock absorbers ensures gentle deceleration of large movable masses.
- These shock absorbers can also provide a mechanical stop function.

IV Sensors

1 Introduction

1.1 Sensors for pneumatic drives

Special sensors are available which provide simple, economical solutions for querying positions on pneumatic drives.

Magnetic-field-sensitive position sensors are mounted externally on the non-ferromagnetic cylinder tube profile (e.g. aluminum, brass, stainless steel) and operated by the magnetic field of a permanent magnet integrated in the piston.

Non-contact scanning enables wear-free sensor operation. The sensors can be connected to the drive with little mechanical effort, enabling a highly compact and easy-to-handle unit.

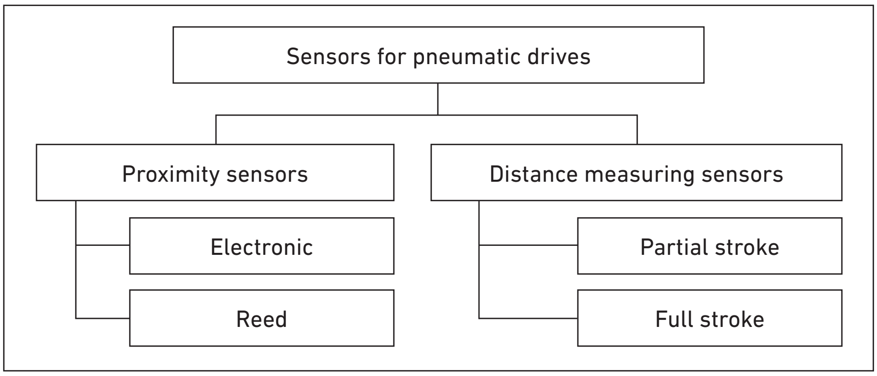


Fig. 1 Magnetic-field-sensitive position sensor variants

Proximity sensors are binary sensors that send a switching signal once the cylinder piston reaches a specified position. They are implemented as electronic switches or reed switches.

Magnetic distance measuring sensors are analog position sensors that transmit an output signal proportional to the passing cylinder stroke. They can cover all or part of the cylinder stroke.

2 Technical principles

2.1 Magnetic-field-sensitive sensors

Because the majority of pneumatic drives use end-position control, position sensors with switched outputs are particularly important.

A selection of different designs for these sensors is shown below.

Fig. 2 Sensor variants

The sensor function is shown below in the figure “Basic sensor function diagram”.

The integrated ring magnet in the cylinder piston generates a magnetic field, which permeates the non-ferromagnetic cylinder tube. When the magnetic piston moves in the area where the sensor is mounted, the magnetic field acts on the integrated sensing element in the sensor.

Once a certain magnetic induction threshold is exceeded, the sensor output switches from an inactive to an active state. A connected control can evaluate the output as a binary signal.

Only an appropriately dimensioned scanning system, i.e. optimally matched sensor and magnet, guarantees reliable function. For this reason, AVENTICS sensors are specially adapted to its own cylinder range.

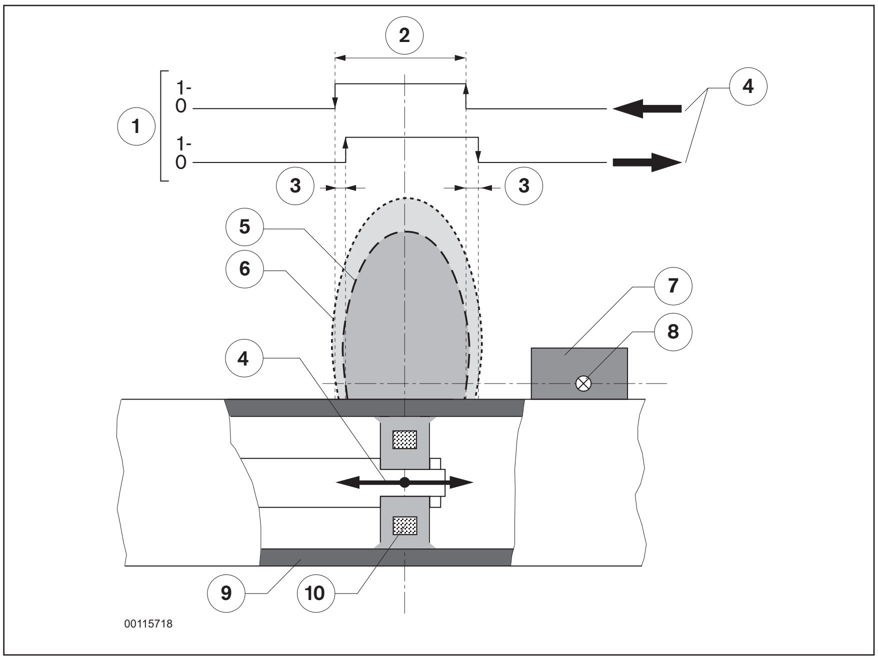


Fig. 3 Basic sensor function diagram

1 Sensor output signals
2 Response travel
3 Hysteresis
4 Piston moving direction
5 Switching threshold “ON”
6 Switching threshold “OFF”
7 Sensor
8 Sensor element position
9 Cylinder tube made from non-ferromagnetic material
10 Permanent magnet (ring-shaped)

2.2 Sensor switching characteristics

The figure “Basic sensor function diagram” provides details on the sensor switching characteristics.

The direction of travel of the piston determines the switching characteristics. Depending on the moving direction of the piston, the switch-on and switch-off points of the output signal are slightly staggered in relation to one another. The sensor requires a higher magnetic induction to switch on and only shuts off again at lower values.

The travel difference between the switch-off and switch-on points after reversing the direction of travel is referred to as hysteresis. The response travel is the difference between the switch-on and switch-off points when moving past the sensor in one direction of travel.

The reproducibility of the switch-on point when passing from the same direction is approx. 0.1 mm (at constant temperature).

The values for the hysteresis and response travel largely depend on the type of sensor and the cylinder diameter. The following values assist in orientation:

- Hysteresis: H = 0.2 to 2 mm
- Response travel: s = 5 to 20 mm

2.3 Interfaces on the sensor

The wide variety of pneumatic drives is matched by a rather broad range of corresponding sensors and accessories. This is reflected in the simplified diagram below.

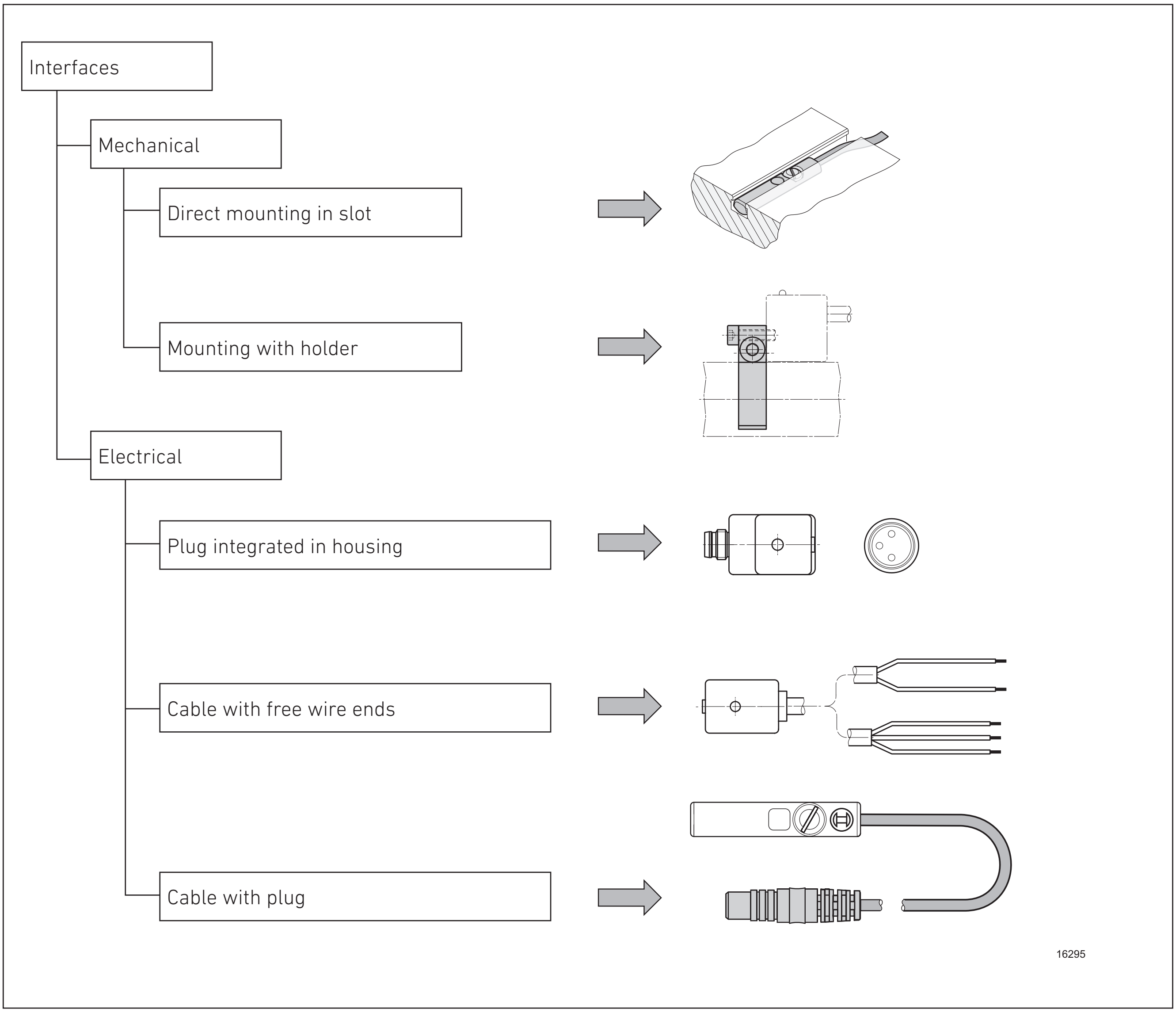


Fig. 4 Basic overview of the interface sensor

2.3.1 Mechanical interface

The mechanical interface is characterized by different drive designs. The use of profiles with special slots for sensor mounting eliminates the need for additional mounting elements (e.g. adapted holders).

Two typical slot geometries are shown in the following figure.

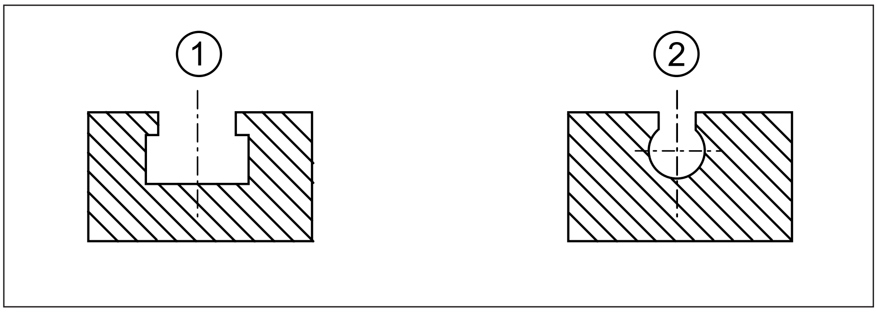


Fig. 5 Two typical slot geometries in drive profiles

1 T-slot

2 Round slot

ST6 series sensors are configured for the T-slot. The ST4 series can be mounted in the round slot.

The round slot version is optimized for minimal space requirements and is therefore normally the preferred choice for compact handling components.

Because there are no standards governing the slots for sensor mounting, manufacturer-specific differences restrict interchangeability.

2.3.2 Electrical interface

The electrical interface also exhibits significant variety based on different user requirements. There is also a wide range of options with regard to cabling material, length and plug types.

2.4 Basic types of sensors

Sensors can be divided into two basic types according to their technical design:

- Electronic sensors (PNP, NPN)
- Reed sensors

2.4.1 Electronic sensors (PNP, NPN)

The electronic sensor consists of a sensor element sensitive to magnetic fields, as well as a downstream threshold value switch which produces a switching signal when a specific magnetic induction value is exceeded. This signal is led out via an output stage.

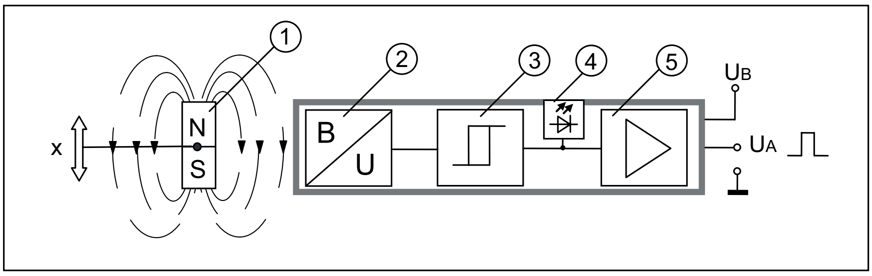
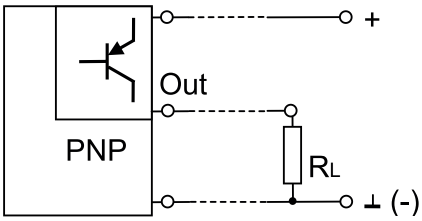


Fig. 6 Electronic sensor structure and function

1 Magnet (position indicator)
2 Sensor element (magnetic-field-sensitive)
3 Comparator
4 Switching state display (LED)
5 Output stage (PNP, NPN)

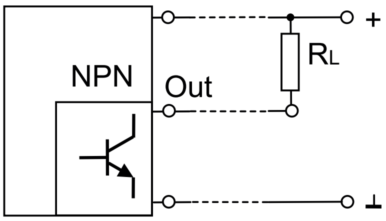
There are two variants for the output stage of electronic sensors, which are used depending on the evaluation circuit employed.



Positive switching output (PNP)

The PNP output switches the connected load to the positive supply voltage. The load is connected between the switched output and the negative supply voltage or ground (see adjacent figure). The designation “PNP”, which is used synonymously with “plus switching”, has a historical background. This switching variant initially used a PNP transistor as a switching element.

Sensors with a PNP output are mainly used in Europe, since conventional controllers in this region require an active input signal (positive input voltage).



Negative switching output (NPN)

The NPN output switches the connected load to the negative supply voltage or ground. The load is connected between the switched output and the positive supply voltage.

Sensors with an NPN output are primarily used on the Asian and U.S. markets.

The load designated with R_L can be the input resistance of a connected controller (e.g. PLC).

2.4.2 The reed proximity sensor

A reed sensor consists of a reed element installed in a housing. The reed element assumes all functions, e.g. sensor element, threshold switch and output stage, in a single component.

Two contact blades cast in a small hermetically sealed glass tube in an inert atmosphere are oppositely magnetized by the magnetic field. If a specific magnetic induction value is reached, the contact is closed and can be evaluated by a connected controller.

The following figure provides a schematic overview of two basic circuits.

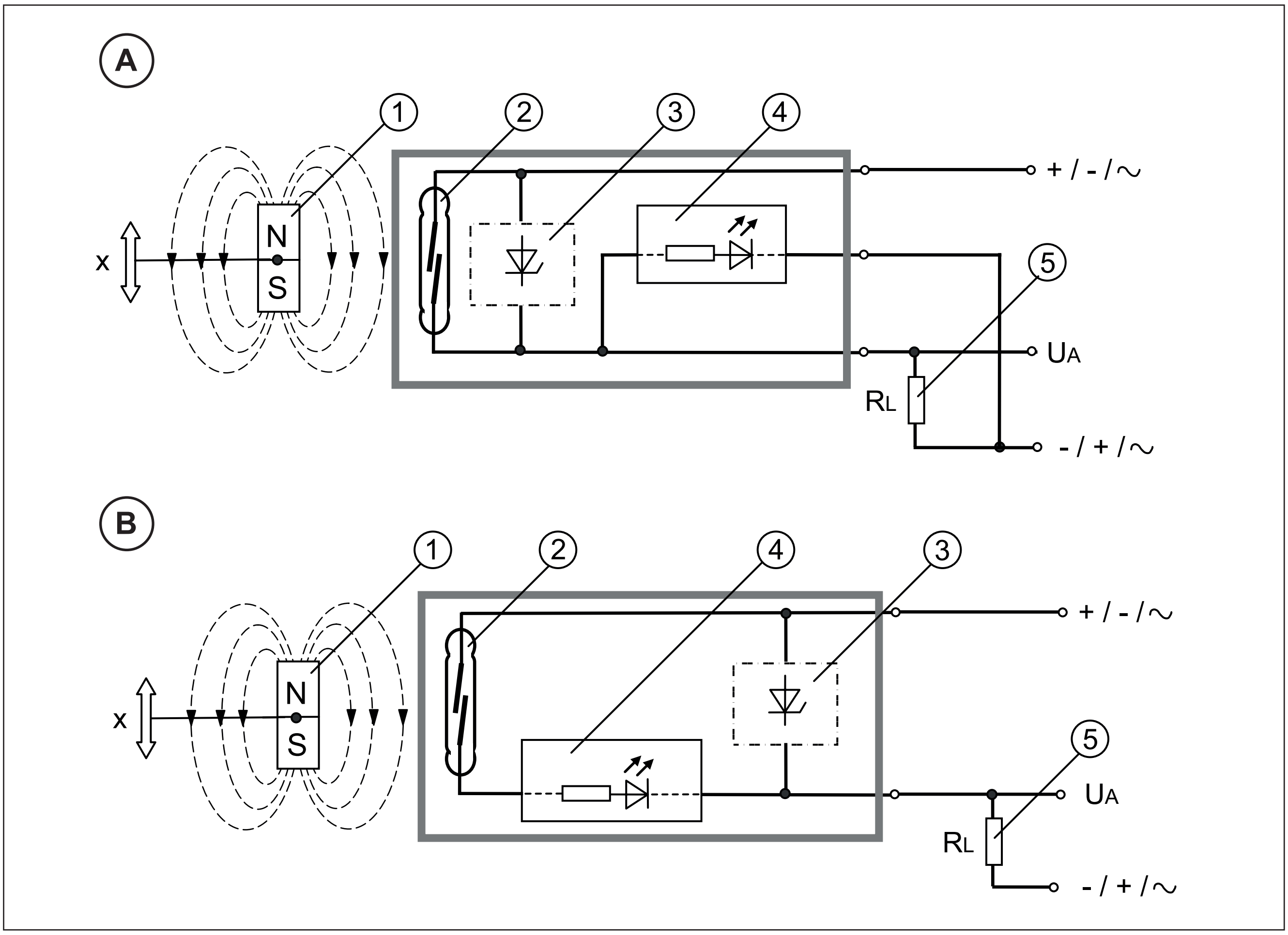


Fig. 7 Basic overview of reed switch

A 3-wire version
B 2-wire version
1 Magnet (position indicator)
2 Reed element
3 Protective circuit (only in larger designs)
4 Switching state display (LED)
5 Load resistance R_L (e.g. PLC input resistance)

Note: Do not operate a reed switch without a load resistance! Short-circuiting of the reed element will result in damage to the sensor!

Reed switch in 3-wire version

A separate contact is led out on the 3-wire reed switch for the LED function display. This decouples the sensor switching function from the display function.

Compared to the 2-wire version, this provides the advantage that the voltage drop across the switch is kept to a minimum thanks to the parallel wiring of the LED actuation and the switching function. The voltage drop is defined by the contact resistance of the reed element and potentially by an additional series resistance that is intended to minimize the capacitive loads by the consumer.

Reed switch in 2-wire version

Simplified installation is one advantage offered by 2-wire technology. This type of switch can be used as an alternative to the 3-wire version in cases where the voltage drop across the sensor is noncritical.

Because the reed element and LED display are connected in series, an additional voltage drop always needs to be taken into account for the LED actuation (U_{min} = 2.1 V).

The increased voltage drop is particularly critical for logic circuits used earlier for some applications based on multiple reed switches connected in series (logical AND operation).

Reed switch protective circuit

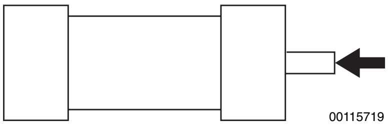
Like all mechanical switches, reed switches are subject to increased contact wear with capacitive and inductive loads. Additional protective circuits are required to switch these loads. Protective circuits are already integrated in some reed switches with larger dimensions.

2.5 Notes on sensor use

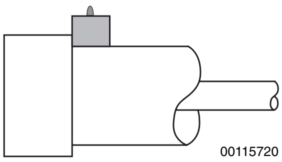
2.5.1 Adjusting the sensor

Sensors are conventionally used to monitor specific stroke positions (e.g. end positions) of pneumatic drives. The sensor is pre-mounted in the provided profile slot or with an adapted holder directly to the cylinder tube. The mounting concept is implemented to permit sliding of the position sensor along the direction of movement of the piston and fasten it in any stroke position.

The following figure can be used as a guide for adjusting the sensor. The procedure is explained based on the example of scanning the pneumatic drive end position.

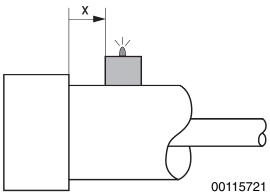


1. Move piston into end position



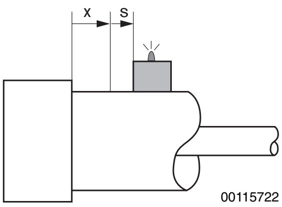
2. Pre-mount sensor; apply voltage

1. Move sensor to an outside mounting position near the end position.
2. The sensor LED should not be illuminated.



3. Determine the switching point

1. Slide the sensor axially towards the cylinder center until the sensor LED lights up.
2. The position x indicates the switch-on point.



4. Fix the sensor in place

1. Slide the sensor further by the short distance s[1)] to the cylinder center.
2. Fasten the sensor in this position.

[1)] Distance s – safety margin for mounting position (e.g. s = 1 to 3 mm)

The hysteresis of the sensor must be observed during adjustment. As shown in the section on sensor switching characteristics, the switch-on and switch-off points are slightly staggered in relation to one another. This behavior has a positive effect on the stability of the switching point. External disturbances, such as mechanical vibrations and minor magnetic interference fields, do not lead to undesirable changes in the switching state.

2.5.2 Passing the sensor at other than the end position

Sensors are mainly used to query the end positions of a pneumatic drive. However, there are special applications in which the sensor is adjusted in a stroke range other than the end positions.

Some special considerations must be observed in these cases. When moving past the switching point, depending on the direction of movement of the piston, there are other switch-on points that are offset by the response travel value.

For highly dynamic applications, depending on the scanning rate or the timing characteristics of the evaluation circuit in the control, problems in the detection of the switching signal may result. When the sensor is passed at a high speed, the pulse duration of the switching signal can be relatively short, depending on the sensor switching width.

The permissible maximum speed v_{max} can be estimated, given a known response travel s and scanning rate t_a of the control, based on the following formula.

$$v_{max} = s / t_a$$

v_{max} = Maximum speed

s = Response travel

t_a = Scanning rate

If signal detection is not ensured at the desired speed, sensors with pulse stretching present an additional option.

2.5.3 Usage limitations

Since the scanning principle is based on the evaluation of magnetic fields, the following should be noted when installing a pneumatic drive with non-contact proximity switching:

Strong external magnetic fields (e.g. welding devices) or ferromagnetic add-on parts located in the area of the scanning system could possibly affect the scanning function.

2.6 Magnetic-field-sensitive distance measuring sensors

SM6 series distance measuring sensors are analog position sensors that transmit an output signal proportional to the cylinder stroke. The systems can be attached to AVENTICS pneumatic cylinders via insertion in the corresponding slot or using adapted holders.

The magnet integrated in the cylinder piston serves as a position indicator and generates a magnetic field that acts on the sensor elements arranged in the position sensor along the longitudinal axis (see figure below). A microcontroller integrated in the device determines the current position of the cylinder piston via a special analysis of signals generated by the sensors.

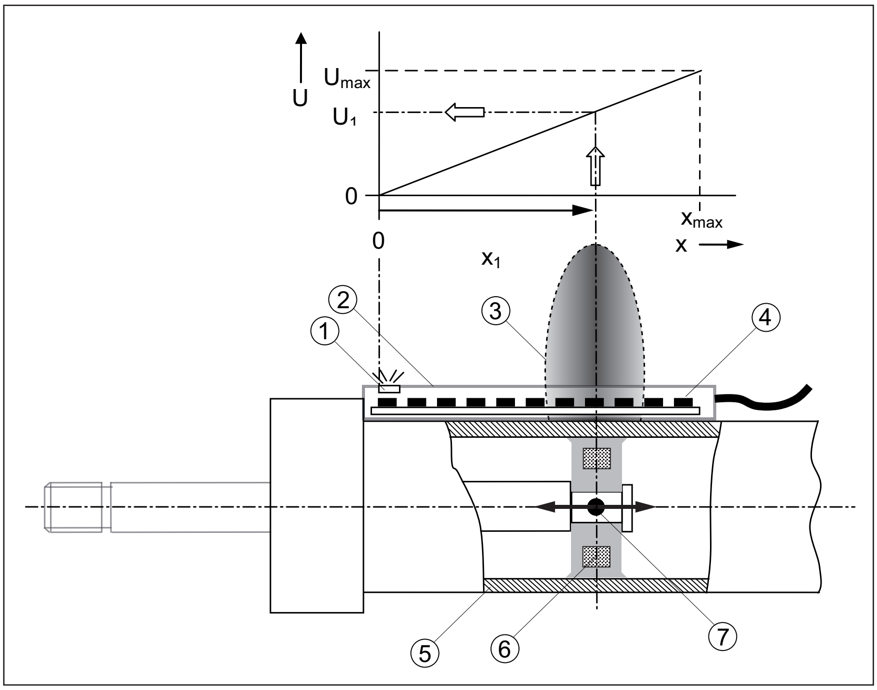


Fig. 8 Basic overview of magnetic-field-sensitive distance measuring sensor

1 LED
2 Analog distance measuring sensor
3 Magnetic field
4 Sensor element
5 Magnet
6 Cylinder tube
7 Moving direction

2.6.1 Distance measuring sensor adjustment

Pre-adjustment

To facilitate the adjustment of distance measuring sensors, an integrated LED in the sensor indicates whether the cylinder piston is in the permissible range of the measuring system. This enables basic mechanical pre-adjustment via an axial displacement of the housing.

Although regular measurements are possible after this step, an additional electronic adjustment is preferable for many applications.

Adjustment with teach-in function

The teach-in function implemented in the sensors can be used to carry out a simple adjustment of the measuring signal transmitted by the sensor to the stroke range of the pneumatic drive.

Two fixed positions are consecutively specified to represent the limits of the measured stroke range, and the positions are aligned with the standardized output signal for the zero point or end position by activating a button (see figure below).

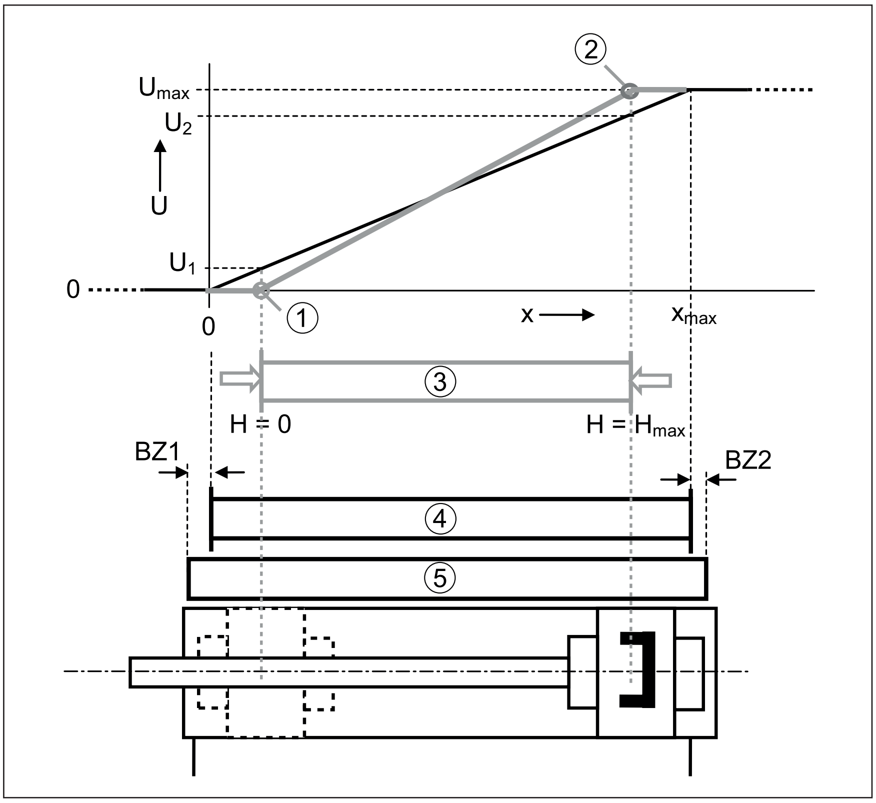


Fig. 9 Distance measuring sensor adjustment

1 Zero point
2 End point
3 Cylinder stroke to be measured
4 Measurement range as delivered
5 Measurement system length

This procedure offers several advantages.

During signal processing, the spread of measurement signals across the entire signal stroke better utilizes the controller's A/D converter resolution. Scaled measurement signals along the full signal stroke are also generally advantageous for control sequence programming.

For service cases that may require component replacement (drive or measurement system), restarting is simplified considerably. Even when the sensor is no longer mounted at the same exact position on the drive, the original state of the measurement operation can be recreated in the electronic adjustment that occurs during the subsequent teach-in process. There is no need to make changes to the control program.

The analog position sensors only have narrow blind zones on both sides, making the available measuring length nearly as long as the length of the measurement system itself. This design feature eliminates any problems that might arise when detecting the end positions, even for extremely compact cylinder variants.

Compared to conventional distance measuring systems (e.g. linear potentiometers), sensors in the SM6 series offer users a number of decisive advantages.

A direct mechanical coupling between the moving part of the drive and the measurement system is not required. This makes connection elements and additional mechanical guides obsolete. The risk of mechanical damage due to a faulty mechanical connection is eliminated. Moreover, the sensor is non-contact and therefore wear-free.

The flat design and space-saving mounting elements result in a minimal increase of the installation dimensions of the drive. Retrofitting the distance measuring sensor on devices that are already in use can also be accomplished with ease.

Magnetic distance measuring sensors are available in two versions that are designed for different applications.

3 Products

3.1 Product selection

3.1.1 Selection of proximity sensors by sensor type

Comparison of electronic and reed sensors

Varying response characteristics for the two variants are shown in the table below.

Electronic sensor	Reed sensor
Short-circuit protected	Not protected against short circuits
For DC voltage only	For AC/DC voltage
Voltage range is generally limited (24 V DC)	Wide voltage range (0 – 240 V AC/DC)
Permissible residual ripple of supply voltage limited	Residual ripple not critical
Low current consumption, even in non-switched state	No current consumption in non-switched state
Temperatures limited to standard industry range	Temperature range not limited by reed element
Wear-free	Low wear with ohmic loads (protective circuit required for inductive and capacitive loads)
Switching function not affected by vibration or shocks	At high acceleration, faulty switching possible due to vibration or shocks
Clear switch flank (no bounce)	Bounce possible (in μs range)
Not potential-free	Potential-free
Difficult to implement direct logical operations	Easy to implement direct logical operations

Table 1 Sensor type behavior in comparison

3.2 Product details

3.2.1 Distance measuring sensors

SM6 distance measuring sensor

The SM6 makes it possible to cover partial cylinder strokes – e.g. near an end position – with a high level of accuracy (partial stroke sensor).

The SM6 has a slim plastic profile and is designed for relatively short measuring lengths. The housing geometry has been configured to enable direct mounting of the device in the T-slot of AVENTICS pneumatic cylinders. A mounting screw is located in the housing at both ends of the sensor, which permits a simple, reliable attachment without additional mounting elements (see figure below).

The sensor can be mounted at any point along the cylinder stroke and provides a corresponding output signal at the mounting position within the measuring length. The elimination of a mechanical connection decouples the stroke of the drive from the measuring length of the sensor. The SM6 detects movement of the cylinder piston within its measurement range and generates an analog output signal proportional to the position.

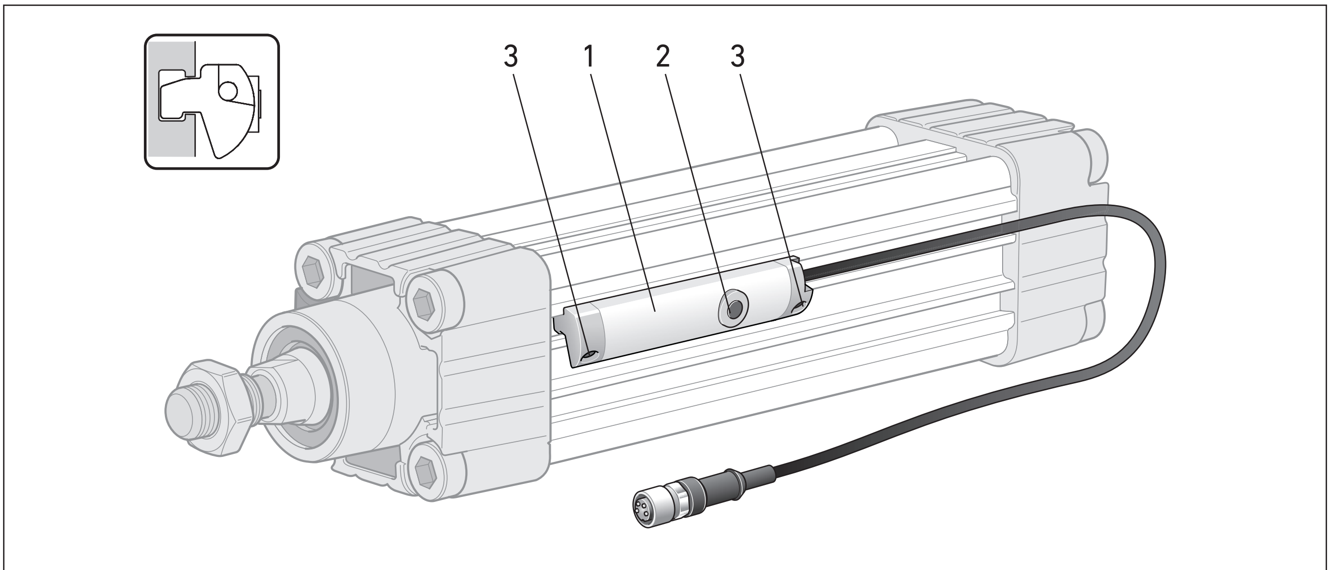


Fig. 10 Direct mounting in T-slot

1 LED
2 Button (adjustment)
3 Mounting screws

When the movement leaves the measurement range, the last measured signal is frozen. Falling below the zero point issues the minimum output signal; exceeding the end point results in the maximum output signal.

If the SM6 is mounted in the slots located on the side of the pressure connections, sensor attachment has no effect on the installation dimensions of the drive.

SM6-AL distance measuring sensor

The SM6-AL distance measuring sensor operates based on the same functional principle as the SM6. The slim plastic profile is replaced by a more robust aluminum housing and enables significantly larger measuring lengths than the SM6. The SM6-AL is primarily designed to cover the complete cylinder stroke (full stroke sensor).

The measuring lengths of the SM6-AL start at l = 107 mm and are available in 36 mm intervals up to a length of l = 1007 mm. Thanks to the extremely small blind zones of approx. 1 mm on both sides of the measurement system, the measuring length is nearly identical to the sensor housing dimensions.

The low blind zone width, in combination with the relatively fine graduation of available measuring lengths, enables use of the sensor on pneumatic drives with any stroke lengths in a range from approx. 70 mm to 1007 mm.

Note The device is installed using special mounting elements on the profile of AVENTICS pneumatic cylinders. The sensor should be aligned axially at the approximate center of the profile tube and fastened.

The correct axial mounting position of the SM6-AL can be verified by moving the drive from one end position to the other. The LED 1 must be illuminated in yellow over the entire stroke range (measuring mode signal).

The travel sensor can be used after this coarse mechanical orientation. However, an additional electronic adjustment using the "teach-in function" is preferable for many applications (for details, see “Distance measuring sensor adjustment”).

The following figure shows the installation situation of the SM6-AL on a profile cylinder. Although the position sensor is shorter than the length of the profile tube, the entire stroke can still be covered.

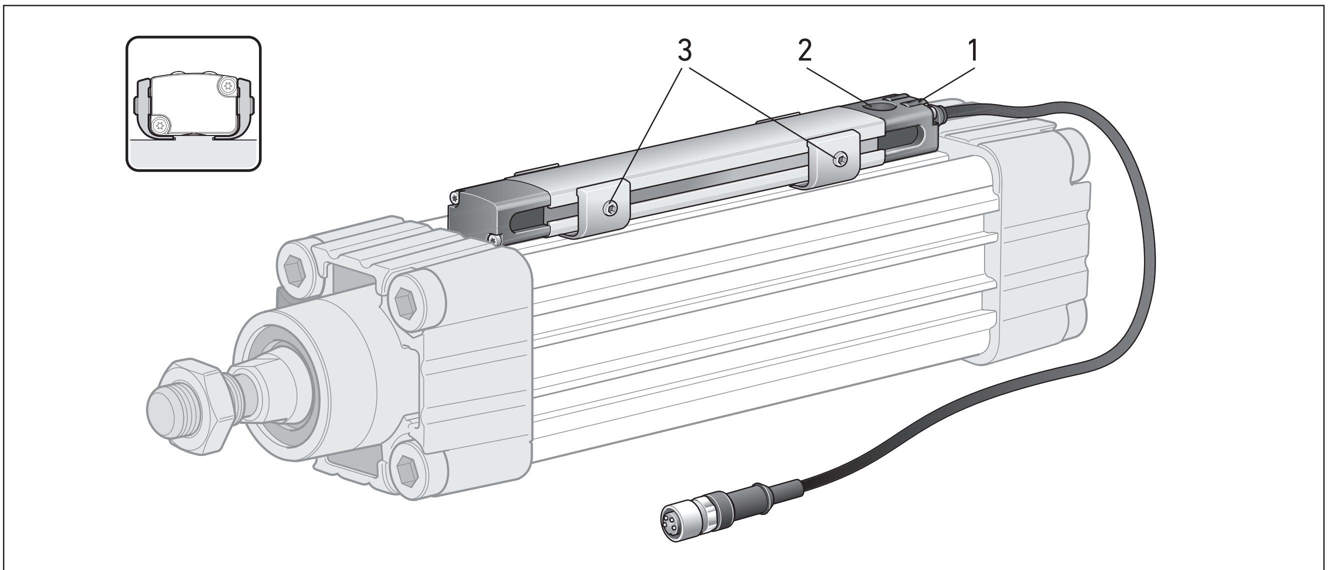


Fig. 11 Mounting with mounting elements

1 LED
2 Button (adjustment)
3 Mounting screws

3.2.2 Sensors with two switching points (ST4-2P series)

For pneumatic drives that only have a relatively small stroke (H < 50 mm), an interesting alternative to standard sensors is available. A specially designed electronic sensor with a compact operating element enables convenient programming of two individual switching points.

The sensor element must be aligned at the center of the stroke and the sensor mechanically fastened in the slot. The drive piston is moved into the first position for scanning. This position can then be permanently stored as a switching point by activating the teach-in button on the operating element. The same procedure is carried out for the second position.

The ST4-2P can therefore replace two standard sensors for applications with short strokes (see figure below). Installation effort is reduced, since only one cable is required. Installation can also be easily accomplished with extremely compact drives with limited mounting options – e.g. only one attachment slot. Thanks to the convenient teach-in function, the mechanical adjustment of the two switching points is no longer necessary. The IO-Link interface and integrated microcontroller enable the use of additional functions such as automatic parameterization and diagnostics.

Based on the above features, the ST4-2P sensor is especially suited for use in small handling modules and grippers.

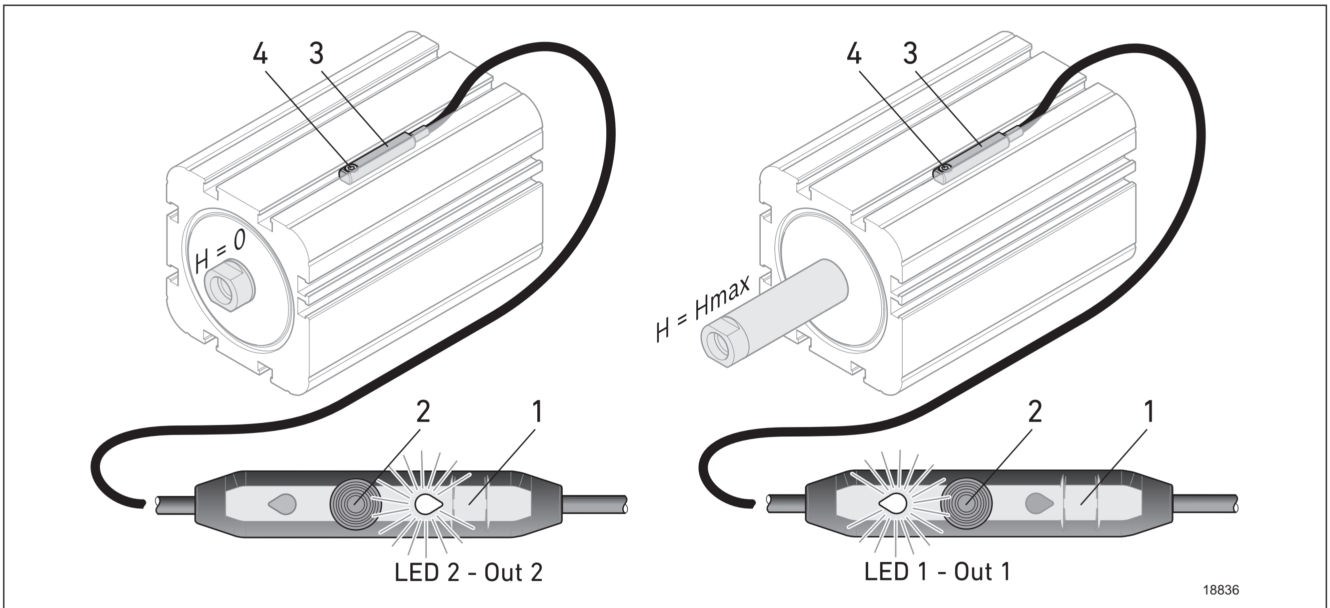


Fig. 12 Function of sensor with 2 switching points after teach-in

1 Operating and display element
2 Teach-in button
3 Sensor
4 Sensor element position (indicated by arrows)

3.2.3 Pressure sensors

PE series

Electronic pressure sensors in the PE series convert pressure into a proportional analog current signal (electrical signal). PE sensors have a high degree of switching precision and repeatability.

PM series

The PM electro-mechanical pressure switch is a P/E converter with a G1/4 connection or flange hole pattern. The switching points can be manually adjusted and fixed via the adjusting screw. Each switching point is continuously adjustable, even during operation.

3.2.4 Flow rate sensor, air flow sensor

553-001 series sensors

The air flow sensor is optimized for air flow measurement in systems that work against an open outlet nozzle. Due to its rapid measurements, the air flow sensor is particularly suited for dynamic air flow control. It can, however, also be used in a solely measurement or monitoring capacity.

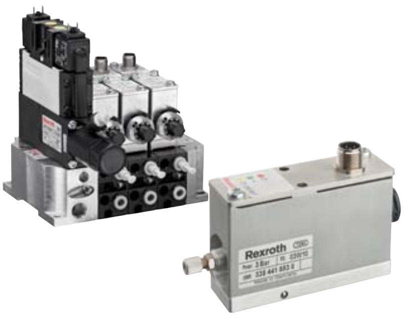
3.2.5 Special sensor models

Welding-proof sensor (SN3)

The welding-proof sensor has been specifically designed for use in AC welding systems (frequency f = 50 to 60 Hz).

The sensor detects alternating magnetic fields generated by the welding process and freezes the current switching state for the duration of the interference. This suppresses faulty switching caused by the magnetic interference field.

3.2.6 Position monitor



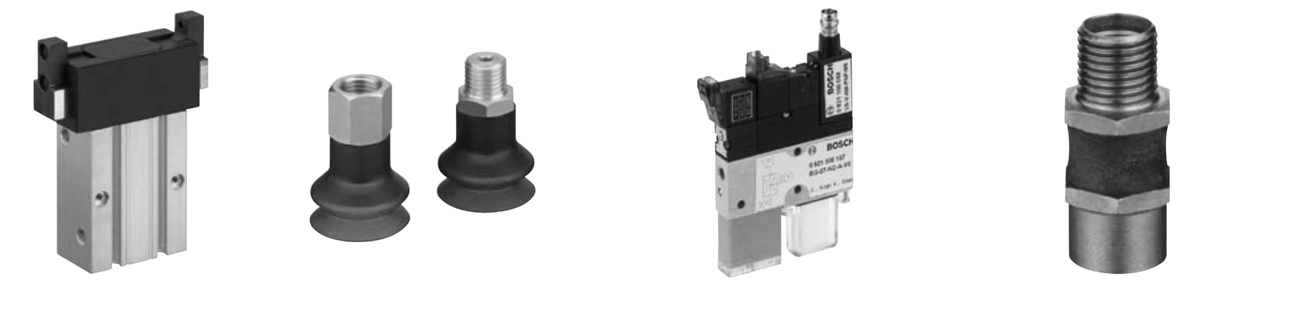
MS01 series pneumatic position monitor

The MS01 pneumatic position monitor is designed for use as a measurement and control system in production systems. It is used to check the presence and/or exact position, shape, or dimensions of workpieces.

The control function of the MS01 is implemented by non-contact scanning of the test object via an air jet. A test object approaches a dynamic pressure nozzle with an established nozzle pressure pD of: pD ~ 1/S.

This is recorded and evaluated in the test module. If the resulting gap is within the previously set tolerances, an electrical signal is sent to the system controller.

V Gripper and vacuum technology



1 Introduction

1.1 About gripper and vacuum technology

Grippers pick up workpieces at a specific point in a handling application, hold and transport them, and release them again with precision at a different location. Gripping, holding during movement, and releasing – what may sound simple turns out to be anything but in real technical settings. The movements need to retain the same quality, exactness and speed, for an extremely wide variety of workpieces. This all needs to happen with gentleness and power, precision, safety, and reliability, while ensuring energy and cost-efficiency.

Technical definition of gripping according to VDI Guideline 2860:

"A gripper is the subsystem of an industrial robot which maintains a limited number of geometrically defined workpieces for a set period of time, i.e. secures the position and orientation of the workpieces in relation to the tool's or the gripper's coordinate system. This 'secure' function is usually built up before the moving process, maintained during the moving process, and finally reversed by releasing the workpiece."

2 Technical principles

2.1 Mechanical gripper technology

2.1.1 Gripper technology methods

Complex tasks inevitably result in a demand for alternative solutions.

Over the years, different gripping methods have evolved with the development of automation technology.

Mechanical gripping

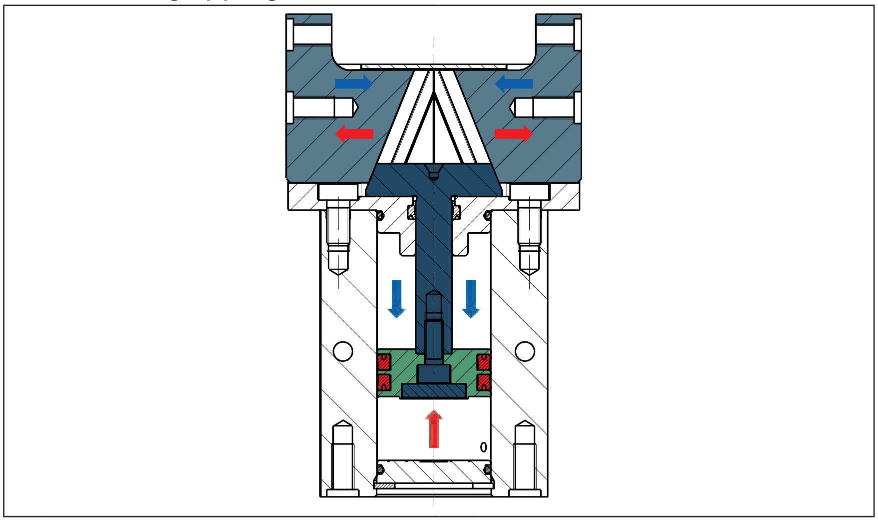


Fig. 1 Figure: Mechanical gripping

Vacuum gripping

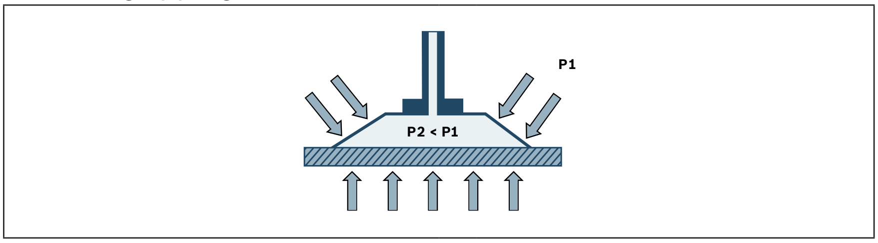


Fig. 2 Figure: Vacuum gripping

P1 Ambient pressure

P2 Vacuum pressure

Gripping based on the Bernoulli principle

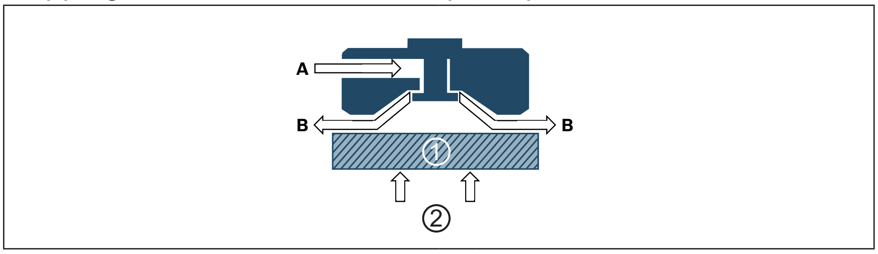


Fig. 3 Figure: Gripping based on the Bernoulli principle

A Compressed air

B Air flow

1 Workpiece

2 Lifting force

2.1.2 From the gripping principle to the right gripper concept

What is intuitive for the human hand needs to be engineered into automation technology. Important distinctions are the type and method of gripping and the design of the contact surface:

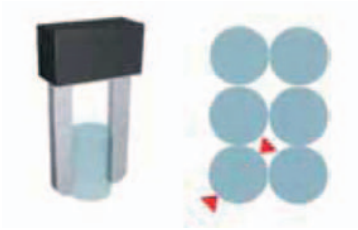


Fig. 4 Outer gripping

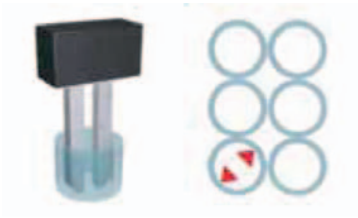


Fig. 5 Inner gripping

Fig. 6 Special gripping

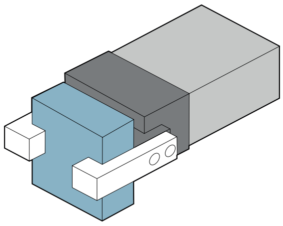


Fig. 7 Form-fit gripping

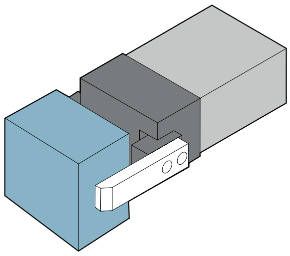


Fig. 8 Frictional gripping

The gripping principle is a key criterion when deciding on the right gripper type and required gripping force.

2.1.3 Pneumatic gripper function

Pneumatically operated mechanical grippers are driven by a piston. The conversion of the piston force into the required gripping movement and forces applied at the gripper jaws can be achieved through two different mechanisms.
With lever joint mechanics, the movement is carried out by gear drives or cam disks. With wedge hook kinematics, forces are transferred by friction through integrated angular guides.

- Gripper force adjustable via supply pressure
- Even progression of force over the entire displacement range with wedge hook kinematics
- Low friction in the lever joints with lever mechanics

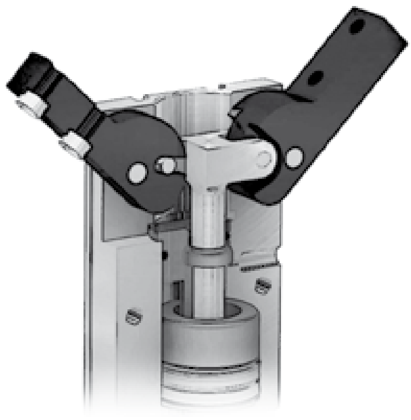


Fig. 9 Pneumatic gripper function, wedge hook kinematics

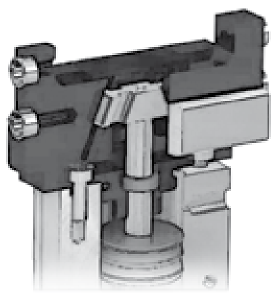


Fig. 10 Pneumatic gripper function, lever joint

The selection of an operating principle depends on the task and functional requirements of the gripper.

2.1.4 Factors influencing the right gripper solution

The optimum configuration of gripper technology is a complex, application-specific task demanding due consideration of all relevant factors.

- Type of gripping and moving task
- Characteristics of the workpiece
- Operating and ambient conditions
- Machine environment

Preventing overdimensioning

Precise calculations of the required force are not only critical for safe gripper operation; they also enable an energy-efficient design. The applied force – and thus energy used – is always just right. Detailed information on the calculations can be found in the following sections.

2.1.5 Gripper models

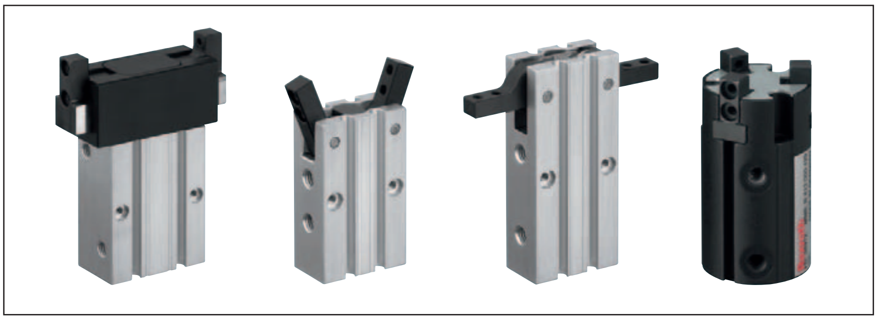


Fig. 11 Presentation of gripper types

With four basic models – parallel, radial, angular, and centric – as well as different variants and sizes, special pneumatic grippers from AVENTICS have your automated handling application covered. Moreover, the standard range features grippers designed for unusually heavy workpieces or extremely large displacements.

2.1.6 Gripper fingers

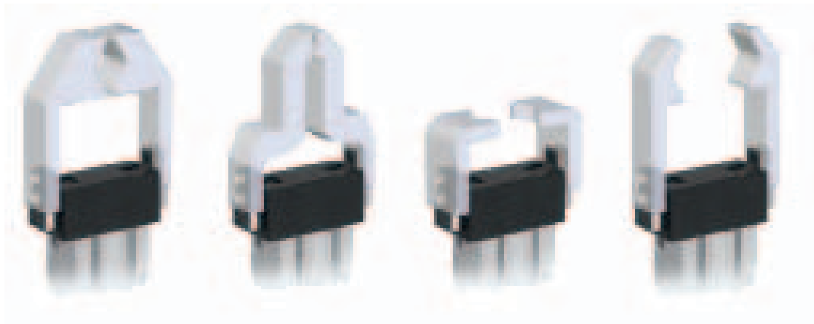


Fig. 12 Presentation of gripper fingers

Gripper fingers are the final element supporting the workpiece. They are individually prepared by the user for the specific workpiece and can be easily mounted on the gripper jaws and exchanged as needed.

- Form-fitting or with frictional gripping
- Individual gripper fingers on site

2.1.7 Calculation of friction coefficient μ

The friction factor μ (friction coefficient) is a value that describes the ratio of the force of friction between two bodies and the force pressing them together.

The following table displays the friction coefficient μ for the gripper finger-workpiece combinations.

Gripper fingers	Steel	Forged steel	Aluminum	Forged aluminum	Rubber
Steel	0.25	0.15	0.35	0.2	0.5
Forged steel	0.15	0.09	0.21	0.12	0.3
Aluminum	0.35	0.21	0.49	0.28	0.7
Forged aluminum	0.2	0.12	0.28	0.16	0.4
Rubber	0.5	0.3	0.7	0.4	1

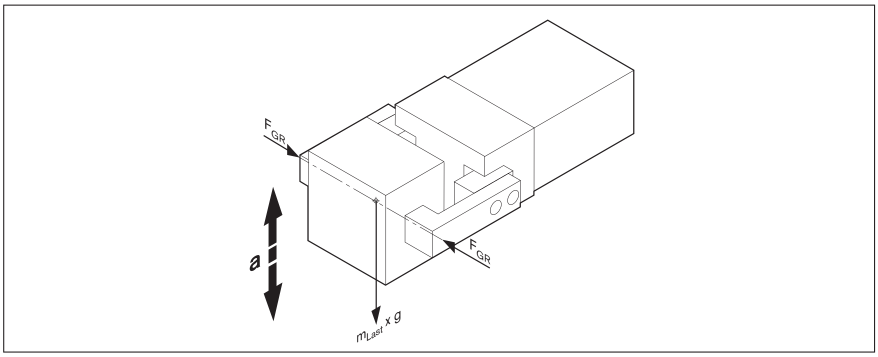
Table 1 Calculation of friction coefficient μ

2.1.8 Gripper configuration, vertical movement (frictional gripping)

1st case: lateral load

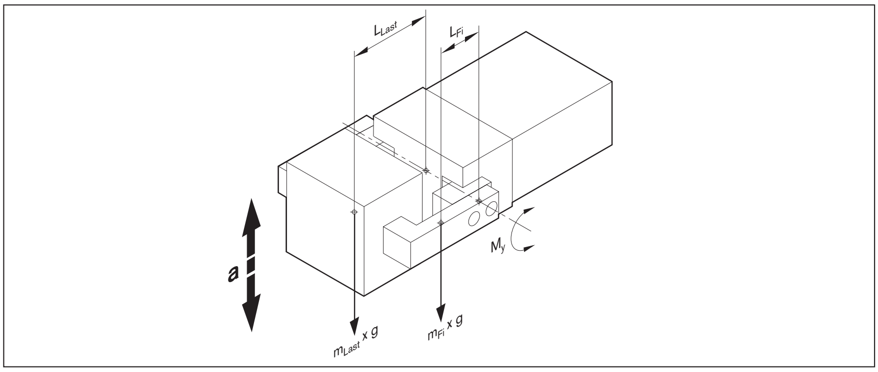
Minimum required gripping force F_{Gr}

$$F_{Gr} \geq \frac{m_{Load} \times (g + a) \times S}{n \times \mu} \text{ [N]}$$



Maximum gripper finger torque M_Y (per gripper finger)*

$$M_Y \geq \left[\frac{m_{Load} \times L_{Load} \times (g + a)}{n} + m_{Fi} \times L_{Fi} \times (g + a) \right] \times S \text{ [Nm]}$$



m_{Load} = Load mass [kg]

m_{Fi} = Gripper finger mass [kg]

L_{Load} = Load distance [m]
Center of jaw guide/center of gripper finger

L_{Fi} = Gripper finger distance [m]
Center of jaw guide/load center

g = Acceleration of gravity [9.81 m/s^2]

a = Max. gripper acceleration/deceleration [m/s^2]

n = Number of gripper fingers

μ = Friction coefficient

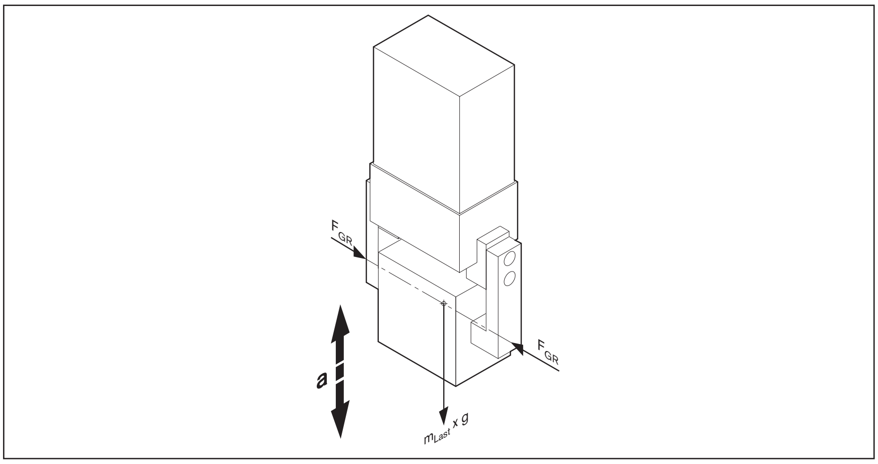
S = Safety factor 1.5 – 3

* Please note catalog information!

2nd case: load from below

Minimum required gripping force F_{Gr}*

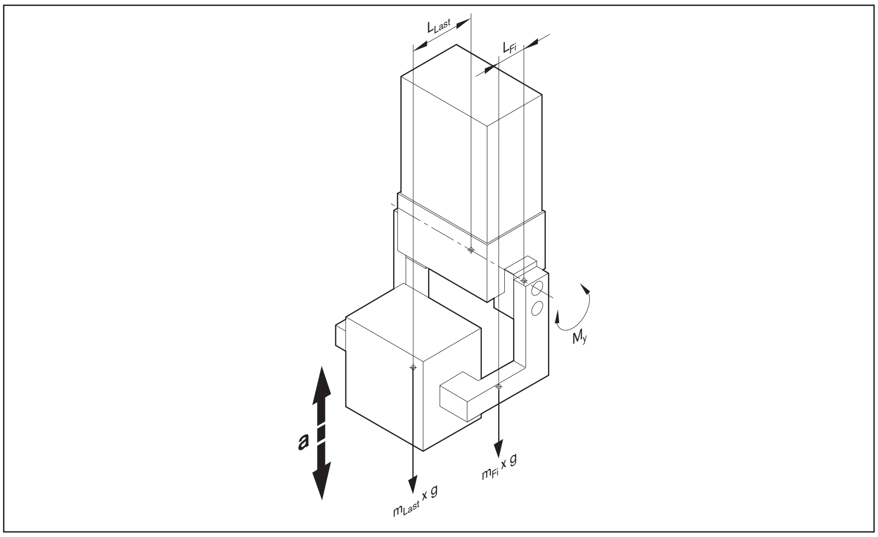
$$F_{Gr} \geq \frac{m_{Load} \times (g + a) \times S}{n \times \mu} [N]$$



* Please note catalog information!

Maximum gripper finger torque M_Y (per gripper finger)*

$$M_Y \geq \left[\frac{m_{Load} \times L_{Load} \times (g + a)}{n} + m_{Fi} \times L_{Fi} \times (g + a)\right] \times S \text{ [Nm]}$$

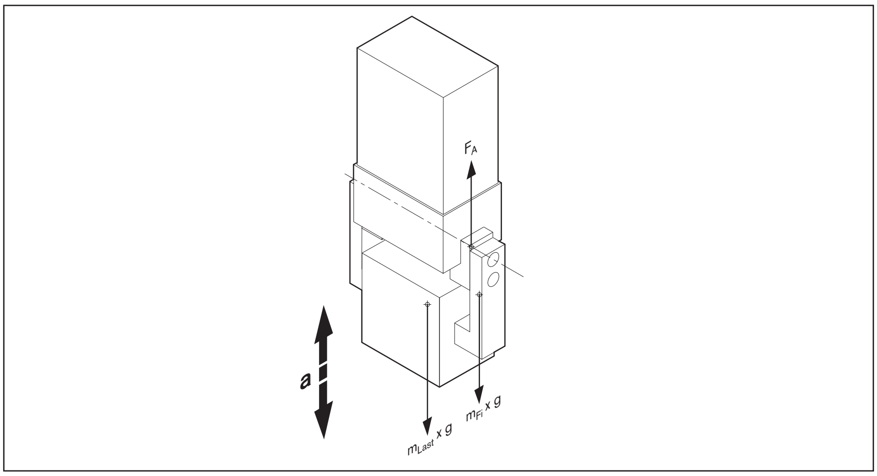


m_{Load}	=	Load mass [kg]
m_{Fi}	=	Gripper finger mass [kg]
L_{Load}	=	Load distance [m] Center of jaw guide/center of gripper finger
L_{Fi}	=	Gripper finger distance [m] Center of jaw guide/load center
g	=	Acceleration of gravity [9.81 m/s^2]
a	=	Max. gripper acceleration/deceleration [m/s^2]
n	=	Number of gripper fingers
μ	=	Friction coefficient
S	=	Safety factor 1.5 – 3

* Please note catalog information!

Maximum permissible axial force F_A (per gripper finger)*

$$M_A \geq \left[\frac{m_{Load} \times (g + a)}{n} + m_{Fi} \times (g + a) \right] \times S \text{ [Nm]}$$



m_{Load} = Load mass [kg]

m_{Fi} = Gripper finger mass [kg]

g = Acceleration of gravity [9.81 m/s^2]

a = Max. gripper acceleration/deceleration [m/s^2]

n = Number of gripper fingers

μ = Friction coefficient

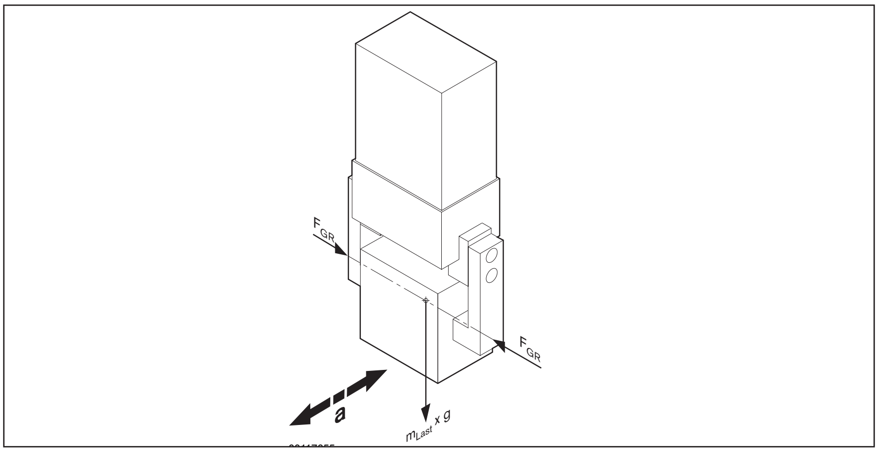
S = Safety factor 1.5 – 3

* Please note catalog information!

2.1.9 Gripper configuration, horizontal movement (frictional gripping)

Minimum required gripping force F_{Gr}*

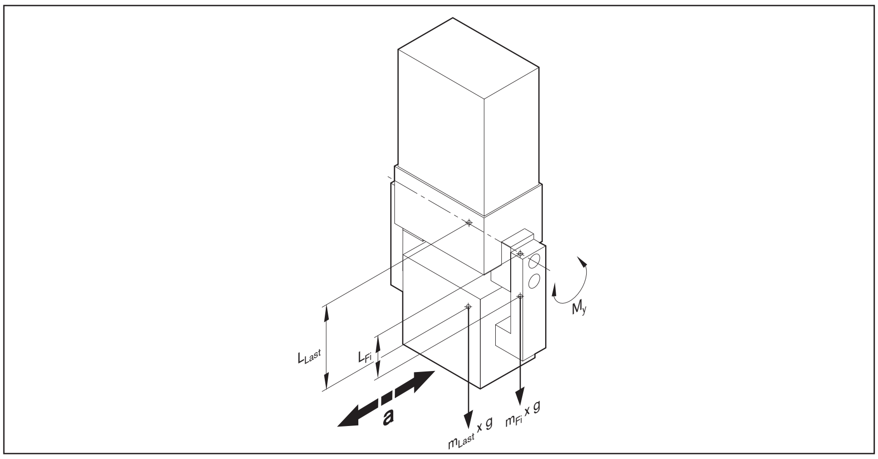
$$F_{Gr} \geq \frac{\sqrt{(m_{Load} \times a)^2 + (m_{Load} \times g)^2}}{n \times \mu} \times S \text{ [N]}$$



* Please note catalog information!

Maximum gripper torque M_Y (per gripper finger)*

$$M_Y \geq \left[\frac{m_{Load} \times L_{Load} \times a}{n} + m_{Fi} \times L_{Fi} \times a \right] \times S \text{ [Nm]}$$



m_{Load} = Load mass [kg]

m_{Fi} = Gripper finger mass [kg]

L_{Load} = Load distance [m]
Center of jaw guide/center of gripper finger

L_{Fi} = Gripper finger distance [m]
Center of jaw guide/load center

g = Acceleration of gravity [9.81 m/s^2]

a = Max. gripper acceleration/deceleration [m/s^2]

n = Number of gripper fingers

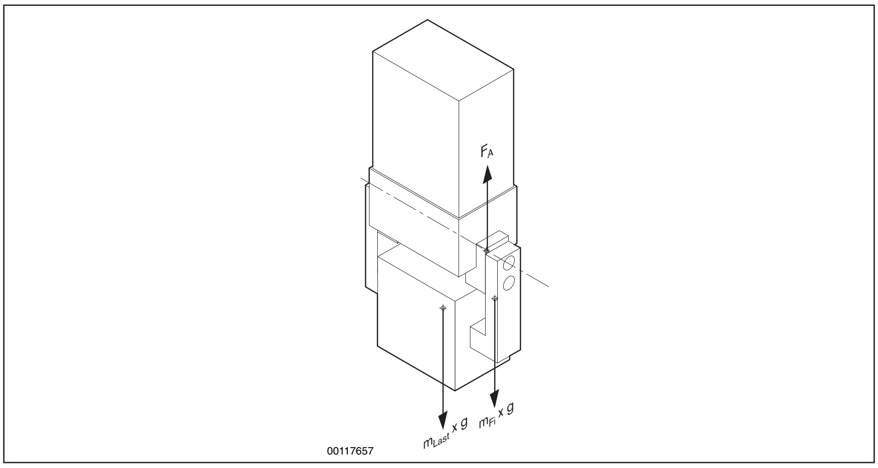
μ = Friction coefficient

S = Safety factor 1.5 – 3

* Please note catalog information!

$$F_A \geq \left[\frac{m_{Load} \times g}{n} + m_{Fi} \times g \right] \times S \; [N]$$

Maximum permissible axial force F_A (per gripper finger)*

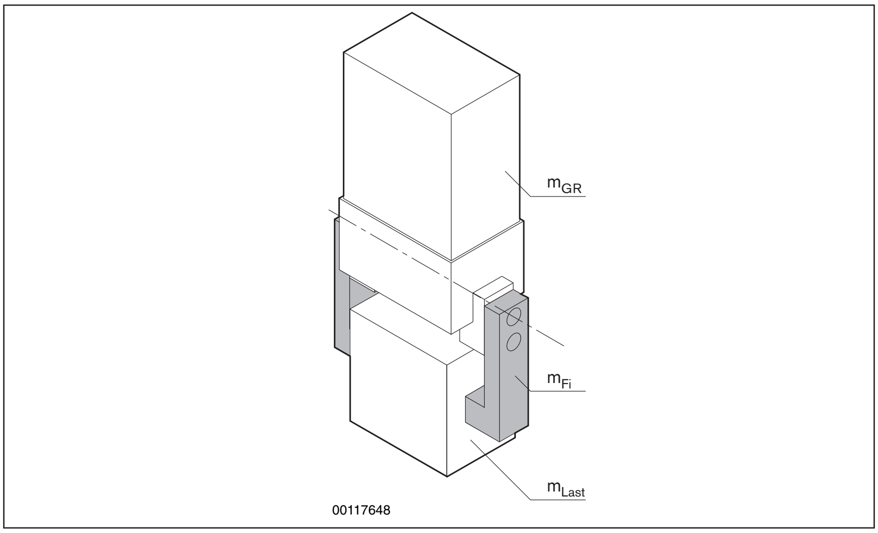


m_{Load} = Load mass [kg]
m_{Fi} = Gripper finger mass [kg]
g = Acceleration of gravity [9.81 m/s²]
n = Number of gripper fingers
S = Safety factor 1.5 – 3

* Please note catalog information!

2.1.10 Calculation of total mass m_{Ges}

$$m_{Ges} = m_{Gr} + 2 \times m_{Fi} + m_{Load}$$



m_{Gr} = Gripper mass
m_{Fi} = Gripper finger mass (provided by customer)
m_{Load} = Load mass

2.2 Vacuum technology

2.2.1 Basics of vacuum technology

What is a vacuum?

According to its definition, a vacuum is a “space empty of matter” with an absolute pressure of 0 bar = absolute vacuum. However, an absolute vacuum is just a theoretical state that cannot be produced on earth. In general, for technical purposes any negative deviation from the normal atmospheric pressure of 1.013 bar is considered an underpressure or vacuum and is usually given in -bar or as a relative percentage.

Relative vacuum

Vacuum handling generally uses the relative value of a vacuum, which indicates the relation to the respective ambient pressure. The starting basis for the ambient pressure is zero. A vacuum of 60% is thus at sea level (atmospheric pressure/ambient pressure = 1.013 bar) equal to a vacuum of approx. -0.6 bar at an absolute pressure of approx. 0.4 bar.

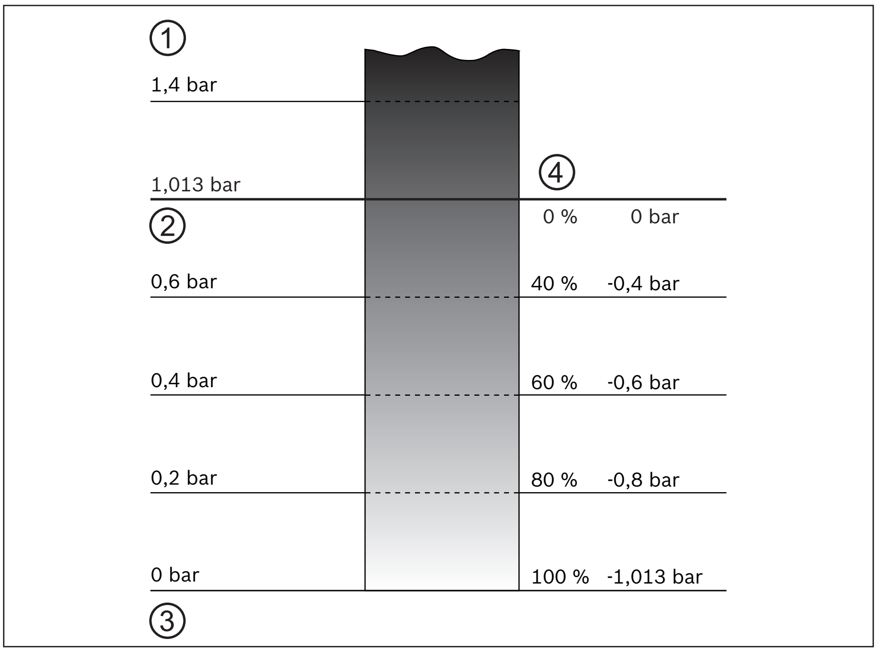


Fig. 13 Vacuum handling

1 Absolute pressure
2 Atmospheric pressure
3 Absolute vacuum
4 Relative vacuum

Effects of ambient pressure on vacuum technology

The altitude of the production location is an important factor for determining the right layout for vacuum components. The ambient pressure decreases by approx. 12.5 mbar for every 100 m increase in altitude; the achievable vacuum value and possible holding force of a suction gripper decreases proportionately. At a height of 2,000 m above sea level, the ambient atmospheric pressure is only 0.763 bar. Here, a degree of vacuum of 60% will only create a vacuum of approx. -0.45 bar at an absolute pressure of approx. 0.3 bar.

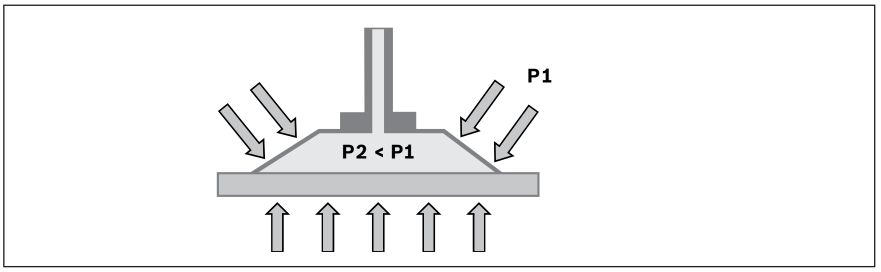


Fig. 14 Figure: Ambient pressure

P1 Ambient pressure P2 Vacuum pressure

What is the interrelation between pressure and force?

The forces used for vacuum applications are always the product of pressure and effective surface area:

F = p x A

F = Force

p = Pressure

A = Area

As the factor p is limited to the level of the ambient pressure and can only be generated in relation to this level, in case of high applied forces, the holding force must be adjusted via the surface parameter. The holding force is proportional to the degree of vacuum and the surface of a suction gripper. At an atmospheric pressure of 1.013 bar, for example, a vacuum of 60% and a suction gripper with a 16 mm diameter will generate a holding force of 8 N. This force will decrease with increasing altitudes, which should also be taken into account. At an altitude of 2,000 m, the holding force in this example will decrease by approx. 25% to roughly 6 N.

Energy required for vacuum generation

The energy required to generate a high vacuum increases disproportionally to the achieved degree of vacuum. Increasing the vacuum from 60% (-0.6 bar) to 90% (-0.9 bar) results in an increase in force by a factor of 1.5, but the energy requirement increases by a factor of 3. In order to achieve the optimum and most efficient working range, the degree of vacuum should be a maximum of 80%:

- For dense surfaces 60% to 80%
- For porous surfaces 20% to 60%

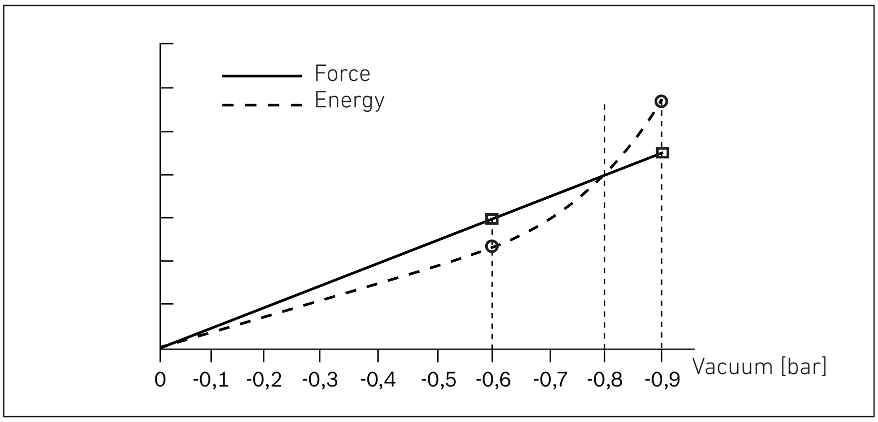


Fig. 15 Energy required for vacuum generation

Vacuum ranges

The level of the vacuum depends on the application. A relatively low vacuum (rough vacuum) is sufficient for vacuum handling. The pressure range of a rough vacuum is from -1 mbar to -0.9 bar.

The following table compares the values for absolute and relative pressure.

Absolute res. press. [mbar]	Relative vacuum	[bar]	[N/cm²]	[kPa]	[atm, kp/cm²]	[mm H_2O]	[torr; mm Hg]	[in Hg]
900	10 %	-0.101	-1.01	-10.1	-0.103	-1030	-76	-3
800	20 %	-0.203	-2.03	-20.3	-0.207	-2070	-152	-6
700	30 %	-0.304	-3.04	-30.4	-0.31	-3100	-228	-9
600	40 %	-0.405	-4.05	-40.5	-0.413	-4130	-304	-12
500	50 %	-0.507	-5.07	-50.7	-0.517	-5170	-380	-15
400	60 %	-0.608	-6.08	-60.8	-0.62	-6200	-456	-18
300	70 %	-0.709	-7.09	-70.9	-0.723	-7230	-532	-21
200	80 %	-0.811	-8.11	-81.1	-0.827	-8270	-608	-24
100	90 %	-0.912	-9.12	-91.2	-0.93	-9300	-684	-27

Table 2 Vacuum/pressure conversion table

Units for pressure and vacuum

The units pascal [Pa], kilopascal [kPa], bar [bar] and millibar [mbar] are the most accepted units for vacuum technology.

	[bar]	[N/cm²]	[kPa]	[atm, kp/cm²]	[mm H_2O]	[torr; mm Hg]	[in Hg]
bar	1	10	100	1.0197	10197	750.06	29.54
N/cm²	0.1	1	10	0.1019	1019.7	75.006	2.954
kPa	0.01	0.1	1	0.0102	101.97	7.5006	0.2954
atm, kp/cm²	0.9807	9.807	98.07	1	10332	735.56	28.97
mm H_2O	0.0001	0.001	0.01	0.0001	1	0.074	0.003
torr; mm Hg	0.00133	0.01333	0.1333	0.00136	13.6	1	0.0394
in Hg	0.0338	0.3385	3.885	0.03446	345.4	25.25	1

Table 3 Vacuum/pressure conversion table

2.2.2 Steps in vacuum system design

1. Workpiece information
2. Calculation of necessary gripping force
3. Selection of appropriate suction grippers
4. Selection of mounting elements
5. Dimensioning of tubing diameters
6. Calculation of volume to be evacuated
7. Selection and calculation of vacuum generator

2.2.3 Workpiece information

Are all important parameters present?

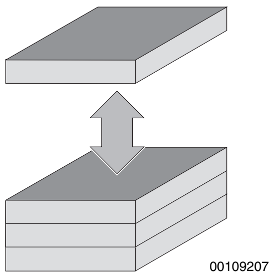
- Materials (metal, synthetics, wood, glass, ceramics, cardboard, etc.)
- Weight/mass
- Dimensions (number of suction grippers)
- Surface finish (smooth, rough, slightly rough, sensitive, structured, etc.)
- Workpiece properties (airtight, porous, flexible, hard, soft, etc.)
- Temperature range (min., max. processing temperature)

2.2.4 Calculation of required gripping force

Forces – What loads must suction grippers bear?

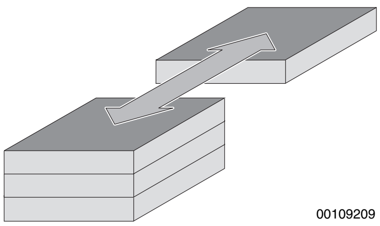
To calculate holding forces, **the mass to be moved** as well as **the acceleration forces** are needed. The three load cases presented here are the most important and the most common.

Presentation of load cases



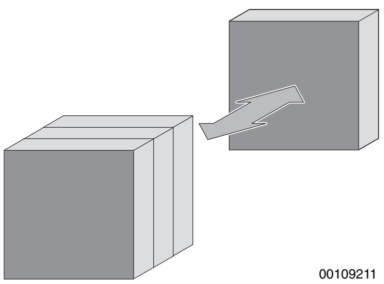
Load case 1:

The suction grippers are placed horizontally on a workpiece which is to be pulled upwards.



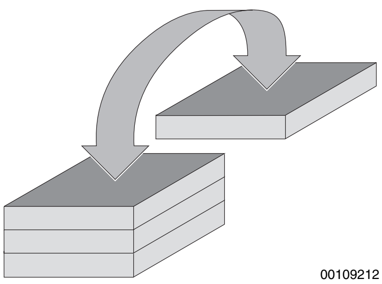
Load case 2:

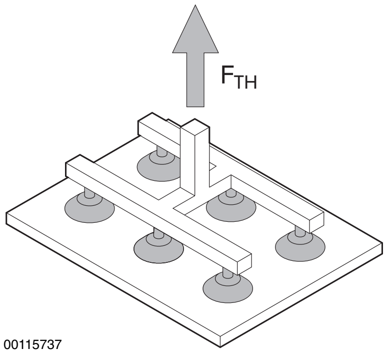
The suction grippers are placed horizontally on a workpiece which is to be moved laterally.



Load case 3:

The suction grippers are placed vertically on a workpiece which is to be moved vertically.





Calculation of the theoretical holding force F_{TH}, example

Given:

m = Load mass (steel plate) = 60 kg

g = Acceleration of gravity [9.81 m/s^2]

a = Max. acceleration of the moved mass = 5 m/s^2

μ = Friction coefficient = 0.5 (only for load cases 2 and 3)

S = Safety factor = 2

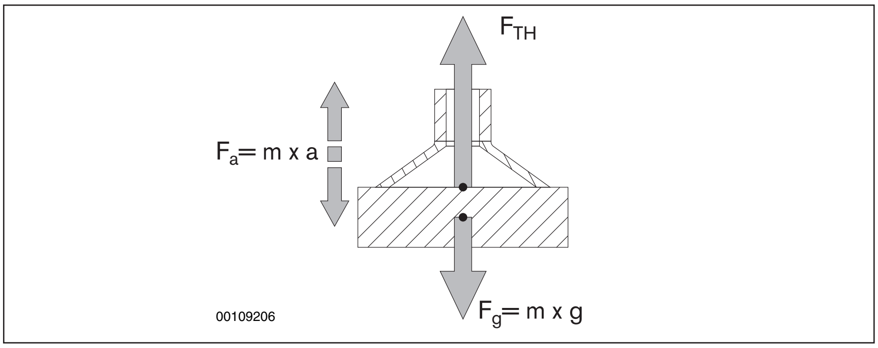
Note: When calculating combined load cases, the most unfavorable case with the highest theoretical holding force must be used.

Load case 1:

Horizontal suction gripper surface, vertical holding force F_{TH}

F_{TH} = m x (g + a) x S

F_{TH} = 60 kg x (9.81 m/s^2 + 5 m/s^2) x 2 = 1777.20 N [kg x m/s^2]

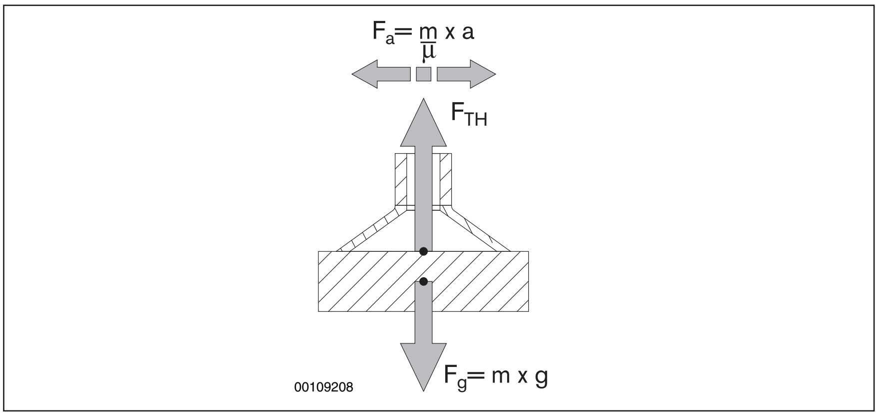


Load case 2:

Horizontal suction gripper surface, horizontal holding force F_{TH}

F_{TH} = m x (g + a/μ) x S

F_{TH} = 60 kg x (9.81 m/s^2 + 5 m/s^2/0.5) x 2 = 2377.20 N [kg x m/s^2]

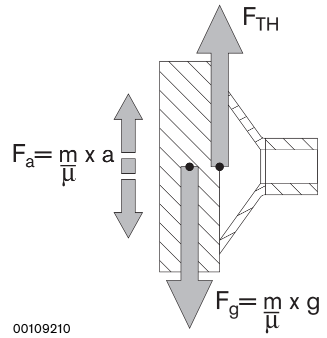


Load case 3:

Vertical suction gripper surface, vertical holding force F_{TH}

F_{TH} = (m /μ) x (g + a) x S

F_{TH} = (60 kg/0.5) x (9.81 m/s^2 + 5 m/s^2) x 2 = 3554.40 N [kg x m/s^2]

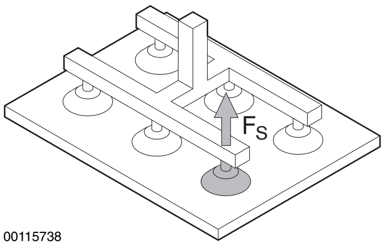


Workpiece	Friction factor
Plexiglas	0.45 – 0.7
Hard rubber	0.6 – 1
Particle board	0.7
Cardboard	0.5 – 0.75
Wood	0.5
Metal	0.5
Glass	0.5
Steel	0.5
Rough surface	0.6
Oily surface	0.25
Wet surface	0.1

Table 4 Friction coefficient μ

Safety factor S

The calculation of holding forces always remains a theoretical consideration. In practice, many factors, such as the workpiece's surface properties or inherent stability, may affect this calculation. For this reason, we recommend a safety factor of S ≥ 2.



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Calculation of holding force F_S per suction gripper

The number of suction grippers depends on holding force F_{TH} as well as the size and shape of the workpiece.

Example: Given:

6 to 8 suction grippers are normally used for a mid-sized steel plate (2500 × 1200 mm). In this example, the number of suction grippers greatly depends on the deflection during transport.

$F_S = F_{TH}/n$

F_S = 1777.20 N/6 = 296.20 N [kg x m/s^2]

F_{TH} = Theoretical holding force (see load case 1) = 1777.20 N

n = Number of suction grippers = 6

Note: Information on the carrying capacity of the suction grippers can be found in the product catalog. Please ensure that the given carrying capacity of the suction gripper lies above the calculated value F_S.

2.2.5 Selection of appropriate suction grippers

Fig. 16 Suction gripper variants

Suction grippers are widely used when objects, parts, packaging, etc. are to be lifted, transported, turned, or similarly moved. Their technical and structural form plays an important role as a “connector” between the workpiece and vacuum generator. The selection of suction gripper material is based on the following criteria:

- Use
- Load
- Shape/surface of workpiece

This information is displayed in the following table.

Particularly suited for suction gripper application	**Suction gripper materials**				
	Acrylonitrile butadiene rubber [NBR]	**Silicone [SI]**	**Polyurethane [PU]**	**Chloroprene rubber**	**Hydrogenated acrylonitrile butadiene rubber**
Food products	❍	✔	❍	❍	
Oily workpieces	✔	❍	✔	✔	✔
Low imprint	❍	✔	✔		
High temperatures	❍	✔	❍	❍	
Low temperatures	❍	✔	❍	❍	❍
High strain	❍	❍	✔		
Very smooth surfaces (glass, etc.)	✔	❍	✔		

Table 5 Selection of suction gripper materials based on application

✔ Suitable

❍ Not suitable

Strain (resistance to media with more or less aggressive properties)	**Suction gripper materials**				
	Acrylonitrile butadiene rubber [NBR]	**Silicone [SI]**	**Polyurethane [PU]**	**Chloroprene rubber [CR]**	**Hydrogenated acrylonitrile butadiene rubber [NHBR]**
Resistance to wear	●●	●	●●●●	●●	●●●
Deformation	●●	●●	●●	●●	●●
General resistance to weather	●●	●●●	●●●	●●●	●●●
Resistance to ozone	●	●●●●	●●●	●●●	●●●●
Resistance to oil	●●●●	●	●●	●●●	●●●●
Resistance to fuel	●●	●	●●	●	●●
Alcohol (ethanol 96%)	●●●●	●●●●	●●●●	●●●●	●●●●
Resistance to solvents	●●	●●	●	●●	●●
Resistance to acids	●	●	●	●●	●
Resistance to steam	●●	●●	●	●●	●●
Resistance to tearing	●●	●	●●●●	●●	●●
Working temperature °C	-10/+70	-30/+180	-40/+80	-10/+70	-20/+130
Shore hardness ISO 7619-1	40 – 90	55 – 60	72 ± 5	60 ± 5	70 ± 5

Table 6 Selection of suction gripper materials based on strain

●●●● Excellent

●●● Very good

●● Good

● Low to satisfactory

Workpiece form	Workpiece surface	Application area	Suction gripper material	Recommended suction gripper series
Even to slightly convex	Smooth to slightly rough	Synthetic plates, wood, particle and fiber board, molded parts, glass, sheet metal, electronics	Acrylonitrile butadiene rubber [NBR] Silicone [SI]	FSG-...
Even to slightly convex	Smooth to slightly rough	Oiled sheet metal, cardboard, derived timber products, automobile body sheet, synthetics	Polyurethane [PU]	FSG-...
Even to slightly convex	Sensitive to smooth	Ceramics, sintered metal (green compacts), synthetics, molded parts	Acrylonitrile butadiene rubber [NBR] Silicone [SI]	SGN-...
Even to slightly convex	Smooth to slightly rough	Synthetic plates, wood, particle and fiber board, molded parts, glass, sheet metal, electronics	Chloroprene rubber [CR] Silicone [SI] Hydrogenated acrylonitrile butadiene rubber [HBNR]	FSR-...
Even to lightly convex, narrow form	Smooth to slightly rough	Pipes and profiles, sheet metal parts, synthetics, electronics	Acrylonitrile butadiene rubber [NBR] Silicone [SI]	FSO-...
Uneven to highly convex, sagging, and/or angled	Smooth, slightly rough	Molded parts, electronics, pipes and profiles, sheet metal, glass	Acrylonitrile butadiene rubber [NBR]	BSG-...
Uneven to highly convex, sagging, and/or angled	Smooth, slightly rough	Food, molded parts, electronics, pipes and profiles, sheet metal, glass	Silicone [SI]	BSG-...
Uneven to highly convex, sagging, and/or angled	Smooth, slightly rough	Automobile body metal, cardboard, glass, synthetics, solid wood, particle and fiber board	Polyurethane [PU]	BSG-...
Very uneven to highly convex, sagging, and/or angled	Smooth, slightly rough	Molded parts, electronics, pipes and profiles, sheet metal, glass	Acrylonitrile butadiene rubber [NBR]	BSA-...
Very uneven to highly convex, sagging, and/or angled	Smooth, slightly rough	Food, molded parts, electronics, pipes and profiles, sheet metal, glass	Silicone [SI]	BSA-...
Very uneven to highly convex, sagging, and/or angled	Smooth, slightly rough	Automobile body metal, cardboard, glass, synthetics, solid wood, particle and fiber board	Polyurethane [PU]	BSA-...

Table 7 Selection of suction gripper materials based on workpiece shape and surface

2.2.6 Selection of mounting elements

Flow valve, VCK series

Flow valves in automated handling offer decisive advantages. If **airtight workpieces** of various dimensions are to be gripped, it is not necessary to adjust the suction grippers or move them individually, since the flow valve on the suction grippers not in use automatically shuts off the volume flow. This reduces the programming and equipment effort and thus saves costs. The flow valve also contributes to the security of vacuum circuits. If a leak occurs by the workpiece disengaging from the suction gripper, the flow valve shuts off automatically and a residual leakage is established via the bypass.

In addition, an installed filter screen prevents larger particles of dirt drawn in by the suction gripper from entering the vacuum circuit.

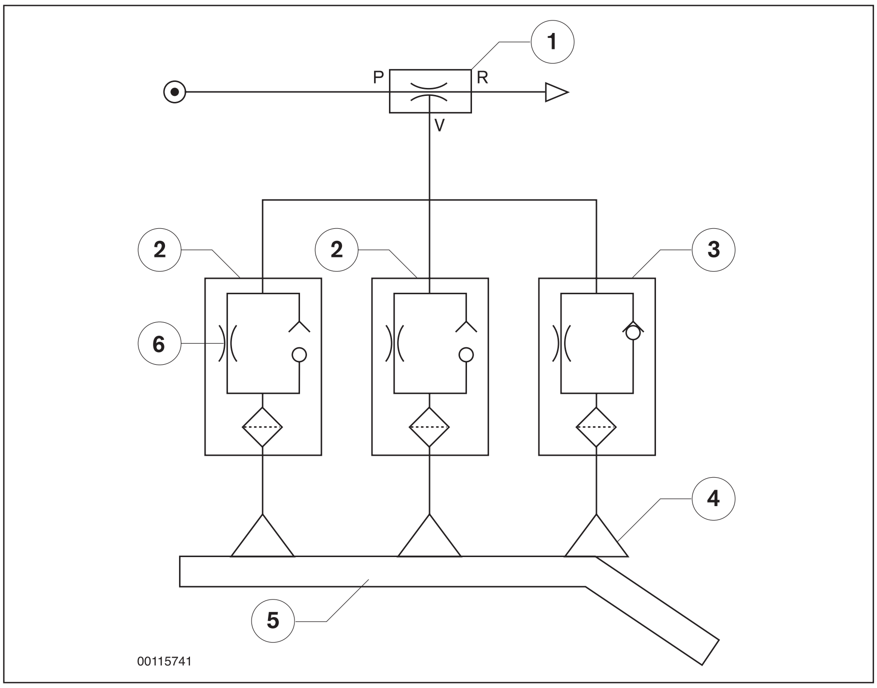


Fig. 17 Application example

1 Vacuum ejector

2 Opened flow valve

3 Closed flow valve

4 Suction gripper

5 Workpiece

6 Bypass

Dimensioning the vacuum generator

Due to their construction, unused suction grippers cause a flow leak on the bypass of the VCK series flow valve. This leak varies according to the desired negative pressure.

Dimensioning then necessitates that the minimum necessary suction capacity of the vacuum generator [l/min] varying according to the negative pressure in the system (e.g., 60% vacuum) must be greater than the sum of all bypass leaks created by open flow valves.

The minimum required suction capacity q_{min} varying according to system pressure can be found in the product catalog.

$$q = q_{min} + n \times q_L$$

q = Suction capacity

q_{min} = Minimum required suction capacity

q_L = Leak flow valve

n = Number of flow valves

VCK	FSG	SGN	BSG	BSA	FSO
					
M5	Ø 5 – 8	Ø 6 – 16	-	-	6 x 15 – 6 x 18
G1/8	Ø 10 – 50	Ø 20 – 30	Ø 11 – 22	Ø 7 – 20	8 x 24 – 10 x 30
G1/4	Ø 50 – 95	-	Ø 30 – 85	Ø 30 – 88	15 x 45 – 30 x 90

Table 8 Combination options for flow valves, VCK series, with suction grippers, FS.../BS.../SGN... series

Adapter, ACP series

The adapter can be mounted directly onto a piston rod via the internal thread connection. The vacuum push-in fitting is on the side.

ACP	FSG	FSR	BSG	BSA	FSO
					
M5 – M4	Ø 5 – 8	Ø 30	–	–	5×15 – 6×18
M5 – M5	Ø 5 – 8	Ø 30	–	–	5×15 – 6×18
G1/8 – M4	Ø 10 – 50	Ø 50	Ø 11 – 22	Ø 7 – 19	8×24 – 10×30
G1/8 – M6	Ø 10 – 50	Ø 50	Ø 11 – 22	Ø 7 – 19	8×24 – 10×30
G1/8 – M8	Ø 10 – 50	Ø 50	Ø 11 – 22	Ø 7 – 19	8×24 – 10×30
G1/4 – M8	Ø 60 – 95	Ø 75	Ø 33 – 78	Ø 32 – 88	15×45 – 30×80
G1/4 – M10×1.25	Ø 60 – 95	Ø 75	Ø 33 – 78	Ø 32 – 88	15×45 – 30×80
G3/8 – M10×1.25	–	Ø 100	–	–	–
G3/8 – M12×1.25	–	Ø 100	–	–	–
G3/8 – M16×1.25	–	Ø 100	–	–	–

Table 9 Combination options for adapters, ACP series, with suction grippers, FS.../BS... series

Angle joint, AJT series

As a supplement to a fixed or spring-loaded mounting element, the angle joint facilitates the suction gripper's better fit on an uneven workpiece surface up to an inclination of 12°.

AJT	FSG	FSR	FSO
			
G1/4 – G1/4	Ø 50 – 95	Ø 75	15×45 – 30×90
M10×1.25 – G1/4	Ø 120 – 150	–	–
G1/2 – G1/2	–	Ø 150	–

Table 10 Combination options for angle joints, AJT series, with suction grippers, FS... series

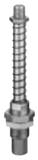
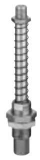
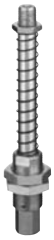
AJT	PSL-1/4	PSL-1/2
		
G1/4 – G1/4	●	–
M10×1.25 – G1/4	●	–
G1/2 – G1/2	–	●

Table 11 Combination options for angle joints, AJT series, with spring-loaded plungers, PSL series



Spring-loaded plungers, PSL series

Spring-loaded plungers compensate for differences in height and buffer sensitive workpieces with soft placement.

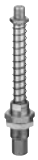
PSL	FSG	FSG	SGN	FSR
				
M3	–	Ø 2 – 3.5	Ø 6 – 16	–
M5	–	Ø 5 – 8	–	–
G1/8	Ø 15 – 50	–	–	Ø 50
G1/4	Ø 60 – 95	–	–	Ø 75
G1/2	Ø 120 – 150	–	–	Ø 150

Table 12 Combination options for spring-loaded plungers, PSL series, with suction grippers, FS.../SGN... series

2.2.7 Dimensioning of tubing diameters

Selection criteria

- Tubing is matched to suction gripper diameter and then selected. Recommended tubing inside diameters d_E for the corresponding suction grippers can be found in the table.
- When using push-in fittings, please note that the selected tubing produces completely sealed connections.
- Tubing often has dynamically stressed material, e.g., suitable for use with drag chains or similar.

Ø d_E [mm]	**V [l/m]**	**FSG**	**SGN**	**FSR**	**BSG**	**BSA**
						
2	0.0031	Ø 1 – 10	Ø 6 – 16	–	–	–
4	0.0126	Ø 15 – 50	Ø 20 – 30	–	Ø 11 – 22	Ø 7 – 20
6	0.0283	Ø 60 – 95	–	Ø 30 – 75	Ø 33 – 78	Ø 32 – 88
9	0.0636	–	–	Ø 100 – 150	–	–
11	0.1131	Ø 120	–	Ø 225 – 300	–	–

Table 13 Recommended inner tubing diameter d_E (max. length 2 m) for suction grippers, FS.../SGN.../BS... series

Dimensioning of tubing inside diameters d_S, d_E

Note: The calculation applies only to single lines with the same inside diameter d_E!

When dimensioning the inside diameter d_S for common lines, the following applies:

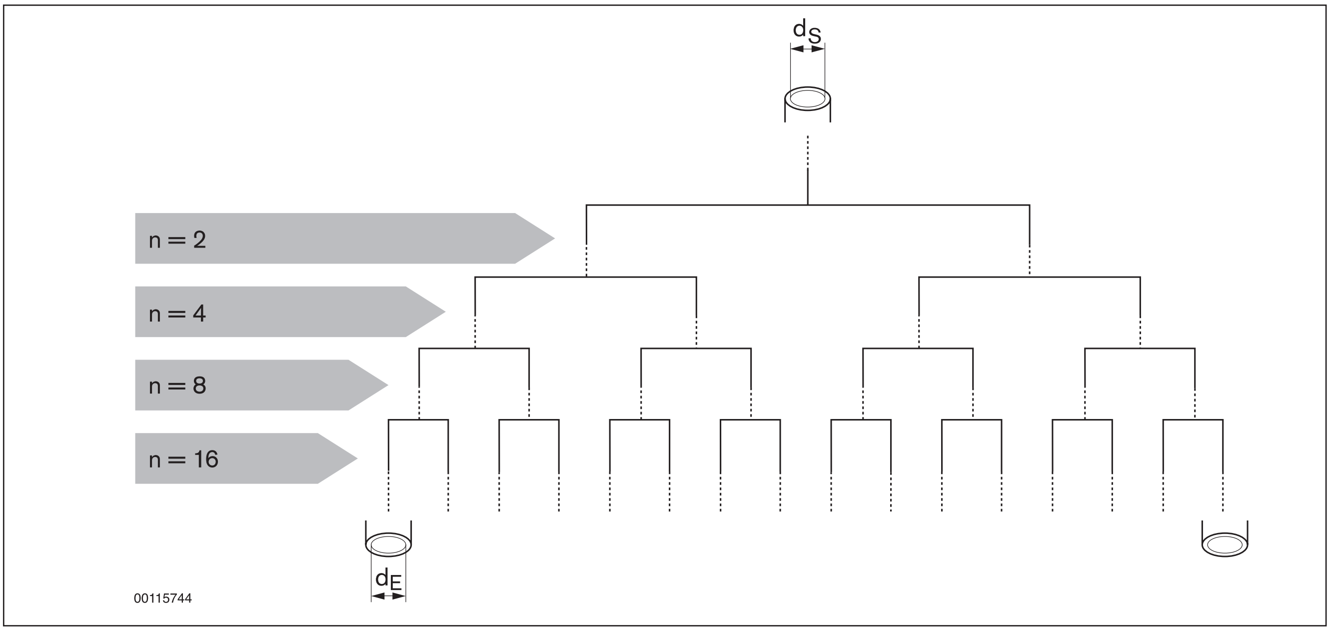


Fig. 18 Dimensioning of tubing inside diameters

d_S = Inside diameter of common lines

d_E = Single line diameter

n_L = Number of single lines

Example: Given:

4 single lines (n = 4) with inside diameter d_E = 2 mm are to be bundled on a common line.

What should the size of the common line diameter d_S be?

Find/calculate:

$d_S = d_E \times \sqrt{n}$

$d_S = 2\ \text{mm} \times \sqrt{4}$

$\mathbf{d_S = 4\ mm}$

2.2.8 Calculation of total volume V_G to be evacuated

$V_G = V_1 + V_2 + V_3 + V_4 + V_5$

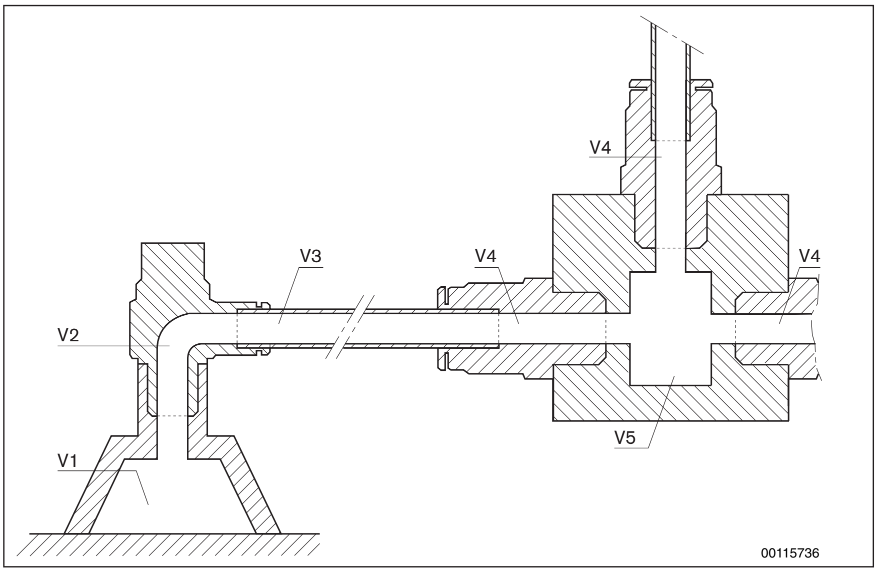


Fig. 19 Calculation example

V_G = Total volume to be evacuated

V_1 = "Suction gripper" volume (see product catalog for information)

V_2 = "Mounting elements" volume

V_3 = "Tubing" volume

V_4 = "Fittings" volume

V_5 = "Distributors, pre-filters, valves, etc." volume

2.2.9 Calculation and selection of vacuum generators

Vacuum generator selection (ejector, pump, or ventilator) is determined by several factors (also see diagram below):

- Workpiece properties (porous, airtight)
- Possible energy supply (electricity, compressed air)
- Restrictions on size and weight
- Adherence to cycle times
- Required vacuum
- Required suction capacity

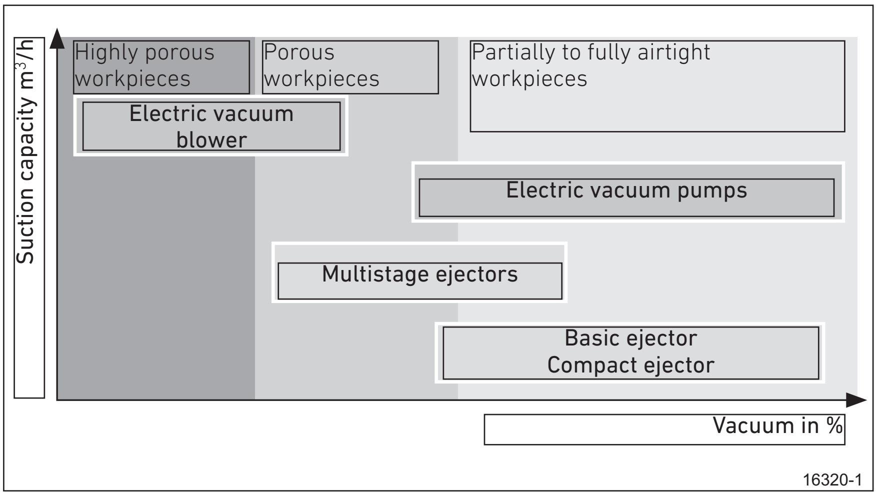


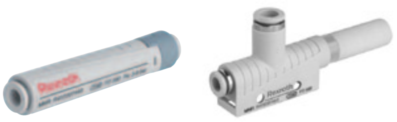
Fig. 20 Factors for selection

Vacuums in accordance with the Venturi principle

Our pneumatically-operated vacuum ejectors work in accordance with the Venturi principle. One or more inline Venturi nozzles form the core of the ejectors. The guided compressed air flows through the nozzle, where it is accelerated and compressed. The accelerated air expands directly after the Venturi nozzle, which creates an underpressure so that air is sucked in through the vacuum connection. The intake air and compressed air then escape through silencers.

3 Products

3.1 Basic and inline ejectors (single-stage)



- The EBS (Ejector Basic System) series includes single-stage vacuum generators using the Venturi principle.
  - Plastic
  - 6 performance levels
  - Minimized dimensions
  - Compressed air and vacuum in axial direction

- The EBP (Ejector Basic Pneumatically) series includes single-stage vacuum generators.
  - Aluminum

Inline ejectors have been designed with an axial compressed air and vacuum connection for direct installation in the vacuum line.

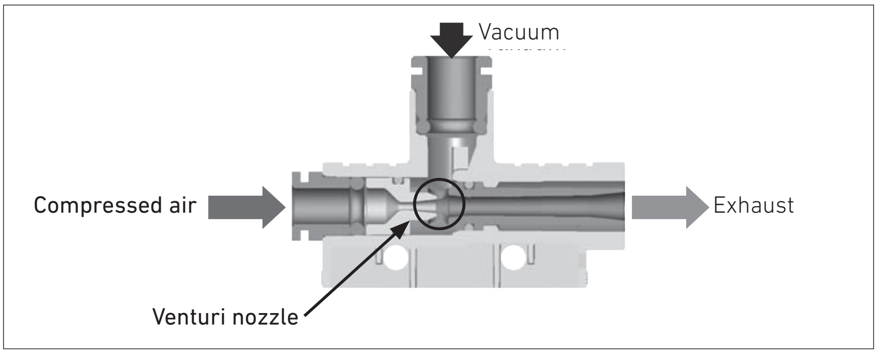


Fig. 21 Function of a single-stage ejector (EBS-PT)

Usage requirements:

- Airtight workpiece
- Compressed air energy supply
- Short distance for vacuum transport, long transport distances possible using **air economizer**

Application areas:

- Industrial robots
- Packaging industry
- Automated assembly

3.2 Multistage ejectors

EMP series

Multistage ejectors can achieve an extremely high suction capacity through the use of several Venturi nozzles connected in series.

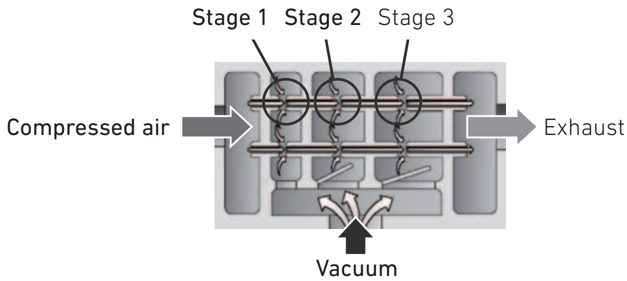


Fig. 22 Function of a multistage ejector (EMP)

Usage requirements:

- Porous workpiece
- Compressed air energy supply
- Short distance for vacuum transport
- Customer specifications

Application areas:

- Paper-processing industry
- Packaging technology

Minimum required suction capacity

- Porosity and workpiece surface structure are the general determining factors for suction capacity.
- Suction trials on porous parts are absolutely necessary in order to determine final suction capacity.

3.3 Compact ejectors

ECS, ECM series

Our compact ejectors combine vacuum generation, control valves, filters, switches, and silencers in a single unit.

Calculation of required suction capacity q

Without accounting for evacuation time t

The table displays estimated recommendations for the required suction capacity q_S per suction gripper depending on the suction gripper diameter. The given values are valid regardless of the vacuum generation type.

Note: The recommended suction capacity q_S is valid per suction gripper and on smooth, airtight surfaces!

Suction gripper Ø [mm]	Required suction capacity per suction gripper q_S [l/min]
60	8.3
60 – 120	16.6
121 – 215	33.3
216 – 450	66.6

Table 14 Required suction capacity

$q = n \times q_s$

q = Required suction capacity of vacuum generator

q_S = Suction capacity per suction gripper

n = Number of suction grippers

Example: Given:

Suction gripper Ø 95 mm

Suction capacity q_S per suction gripper = 16.6 l/min (from table)

Number of suction grippers n = 6

Find/calculate:

$q = n \times q_s$

q = 6 x 16.6 l/min = 99.6 l/min

$$q = \frac{1{,}3 \times V_G \times K}{t}$$

Accounting for evacuation time t

$$K = \ln\left(\frac{p_{amb}}{p_{abs}}\right)$$

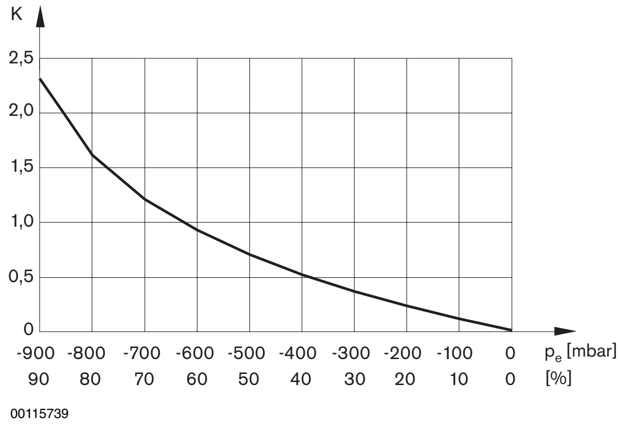


Fig. 23 Evacuation correction factor K

q = Required suction capacity of vacuum generator

p_{abs} = Absolute pressure

p_{amb} = Atmospheric pressure (1013 mbar)

p_e = Pressure (vacuum)

V_G = Total volume to be evacuated

K = Evacuation correction factor

T = Evacuation time

Example: Given:

V_G = Total volume to be evacuated = 0.5 l

K = Evacuation correction factor = 0.929 (from diagram) at 60% vacuum

T = Evacuation time = 0.4 s

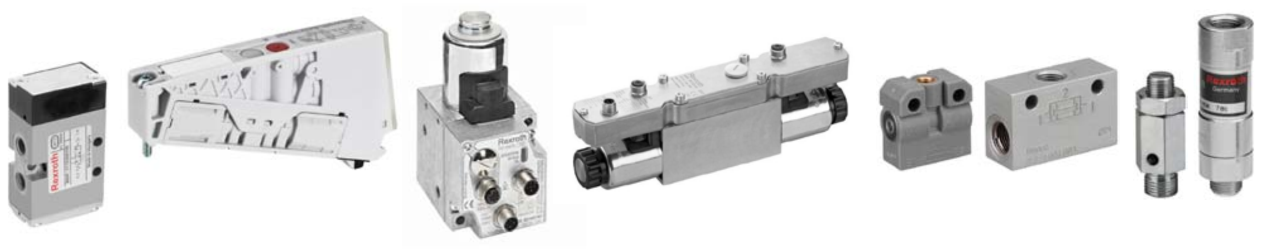
Find/calculate:

$$q = \frac{1{,}3 \times V_G \times K}{t}$$

$$q = \frac{1{,}3 \times 0{,}5\ l \times 0{,}929}{0{,}4\ s}$$

q = 90.6 l/min

VI Valves



1 Introduction

Valves control and affect the air pressure flow. For example, they meter it and guide it to actuators (e.g. cylinders) at a defined point in time.

As actuator elements, valves are therefore crucial components in pneumatic control and can be represented in a control chain.

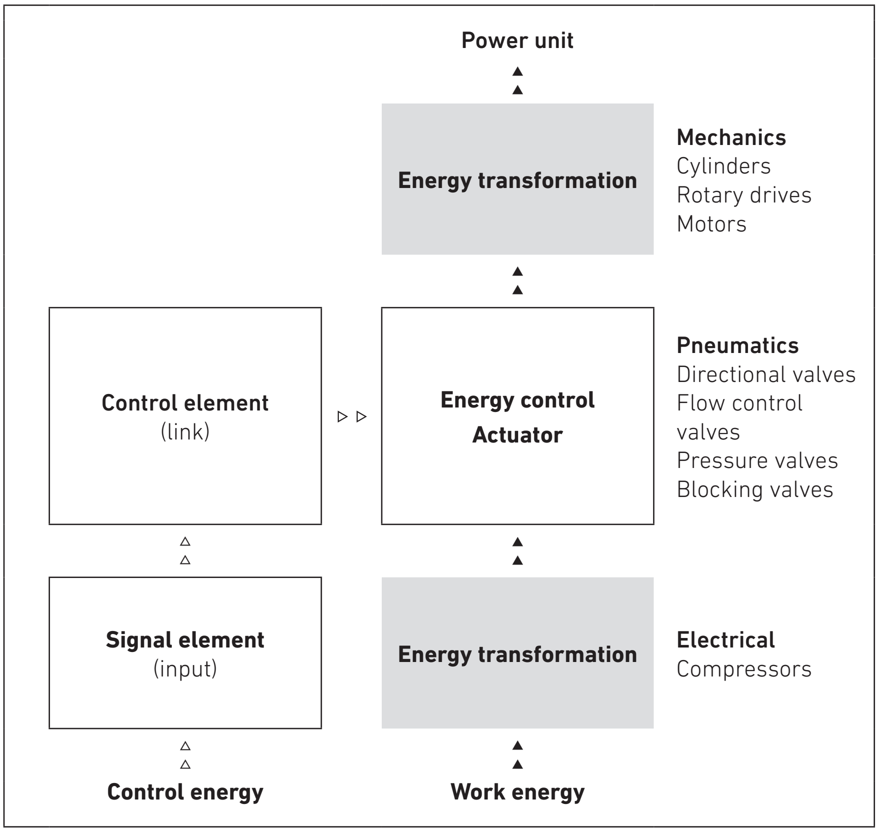


Fig. 1 Basic structure of a pneumatic control

In a control chain, valves can assume the following functions:

- Signal elements (e.g. to detect drive positions via rollers)
- Control elements (e.g. to link signals)
- Actuator elements (e.g. to control pneumatic cylinders)

With purely pneumatic control, the actuator elements are supplied with pneumatic control energy. With electropneumatic controllers, “converters” (solenoid valves) are used as actuator elements and work with electrical control energy.

2 Technical principles

2.1 Connection size

The connection thread is specified as the connection size:

- Metric (e.g. M 5)
- Whitworth pipe thread
  - E.g. G 1/8": According to DIN ISO 228, the G stands for a pipe thread for connections that are not sealed in the thread.
  - E.g. R 1/8": According to DIN ISO 228, the R stands for a pipe thread with cylindrical internal thread and tapered external thread.

2.2 Flow rate

2.2.1 General description

Flow values allow for the comparison of different products (valves) and provide an indication of the performance capability.

The flow value is normally indicated in standard liters per minute (std l/min). Reference to a standard is necessary, as air is compressible and changes its volume under pressure and temperature.

For pneumatics, the standard state is defined by ISO 8778 as follows:

- Pnorm = 1 bar a (a = absolute)
- Tnorm = 293.15 K (20°C)
- Humidity = 65%

Conversions of states follow the ideal gas law P * V = m * R * T.

2.2.2 Flow characteristic values based on ISO 6358

Generally, the flow state within a test object should be divided into two areas. Depending on the pressure gradients, the air flows either at a speed below sonic speed (subcritical area) or at most sonic speed (supercritical area) of approx. 340 m/s.

In the supercritical area, the flow is linearly dependent on the pilot pressure and is relatively simple to calculate. For the subcritical status, ellipses equations can be used for theoretical calculation of the flow.

2.2.3 “b” value

The critical pressure ratio “b” is the ratio of the absolute output pressure to the absolute input pressure, at which the transition to sonic speed takes place.

Normal valves have a “b” value of approx. 0.2 to 0.4.

Ideal nozzles can achieve a maximum of 0.528.

2.2.4 "C" value

$$C = \frac{Q_{norm}}{P_1}$$

For critical flow, the following relationship applies: The conductance "C" of a component is the ratio of the flow to the absolute pressure on the input side (pilot pressure).

2.2.5 Flow calculation

The characteristics "b" and "C" can be used to calculate the flow for any pressure ratio. You can find the appropriate calculation programs in the AVENTICS online catalog.

2.2.6 Nominal flow

The nominal flow is also stated in catalogs, in addition to the "b" and "C" values.

The nominal flow is defined for an input pressure (pilot pressure) of 7 bar absolute and a pressure difference of 1 bar.

2.3 Nominal width

The nominal width (NW) is the diameter of the smallest opening of the compressed air route within a valve.

2.4 Switching times

According to ISO 12238, the switching time is defined as the interval beginning with the change of the control signal up to the point at which the pressure at the output has changed by 10% of the measured pressure. This process measures only one output at a time.

The switching time is measured at 6.3 bar or the maximum permissible operating pressure if it is lower than 6.3 bar. The filling time is designated by t_F and the air exhaustion time by t_E.

Filling time t_F [ms]

Time from the switching signal (t_0) until pressure build-up to 10% of the pilot pressure in the working line.

Exhaust time t_E [ms]

Time from the switching signal (t_0) until pressure release to 90% of the pilot pressure in the working line

Valve switching times are in the millisecond range; for example, the fast AV03 series double solenoid 5/2 directional valve achieves switch-on and switch-off times of 8 ms.

2.5 Overlap

The term overlap describes the behavior of the valve in the switching phase.

The term zero overlap means that the compressed air channels in the valve are securely separated and no airflow overlap can occur. This is a requirement for example for valve dual pressure operation (e.g. cylinder operation with different load and relief pressures).

2.6 Manual override

Pneumatically or electrically operated valves are frequently equipped with a manual override for easy handling. This allows for switching without control energy.

2.7 Return types

A valve can be returned by means of a **mechanical spring** and/or air pressure. The permanently integrated return via air pressure implements a so-called **air spring**.

Using valves with a mechanical spring

When using a mechanical spring, the spool (piston) is returned to its original position via the spring force as soon as no air pressure is present. The use of valves with mechanical return can cause problems in ATEX applications since a possible spring break could result in sparks. In addition, the service life of the valves may be reduced because the metal spring applies a certain transverse force on the spool.

Using valves with an air spring

The use of air springs has the advantage that more force can be applied to the spool at high pressures. This results in faster switching times.

For safety-relevant applications, it must be ensured that the spool returns to its original position in the event of a sudden drop in pressure.

3 Products

The different valve types are categorized by their application:

- **Directional valves affect the** path (start, stop, and direction) of the compressed air to the energy converters (e.g. cylinders).
- **Blocking valves** affect the **flow direction**. They block the flow in one direction in particular and permit it in the opposite direction.
- **Flow control valves** affect the flow of the **compressed air**.
- **Pressure valves** affect the **pressure** of the compressed air used.

3.1 Directional valves

Directional valves affect the path of the compressed air to the energy converters (e.g. cylinders). They serve to free or block the path for the working medium (e.g. compressed air) or to change the flow direction.

Directional valves are categorized based on defined criteria:

- Design principle (poppet valve, spool valve)
- Number of switching positions
- Actuation type (electrical, pneumatic, mechanical, manual)
- Number of ports

3.1.1 Design principles

Directional valves are divided into spool (piston) and poppet valves.

Spool valves (spool principle)

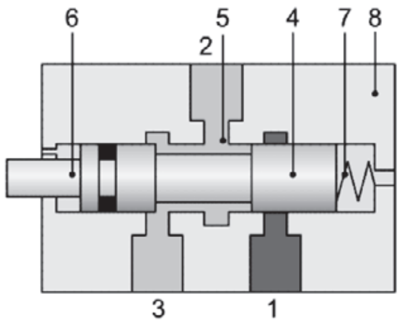


Fig. 2 Spool valve design principle

1, 2, 3	Valve connections	6	Actuating plunger
4	Piston spool	7	Return spring
5	Valve channel	8	Housing

Advantages	Disadvantages
Low actuating force	Susceptible to impurities in compressed air
More than two switching positions possible	Longer switching distances
Flow is reversible	Minimal leakage may occur
Compact dimensions	

Table 1 Advantages and disadvantages of spool valves

Poppet valves (poppet principle)

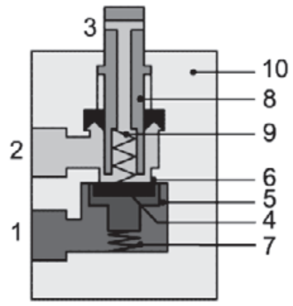


Fig. 3 Poppet valve design principle

1, 2, 3	Valve connections	7	Spring for seal plate
4	Seal plate	8	Actuating plunger
5	Valve channel	9	Return spring for plunger
6	Valve seat	10	Housing

Advantages	Disadvantages
Resistant to impurities	Higher, pressure-dependent actuating force
Shorter switching distances	Flow only possible in one direction
Self-adjusting seal (minimal leakage)	Only two switching positions possible
No oil is required for lubrication	–

Table 2 Advantages and disadvantages of spool valves

3.1.2 Seal type

Metal-metal sealing

For metal-metal sealing valves, the seal is created by a ground-in steel spool contacting the housing.

Soft sealing

For soft sealing valves, the seal is created by elastomers.

3.1.3 Description and presentation

Switching symbols are presented in accordance with standard ISO 1219 (Fluid power system and component graphical symbols and circuit diagrams – Pneumatics and hydraulics).

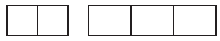
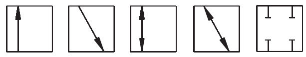
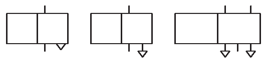
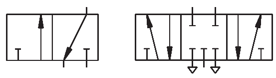
Switching positions	
Flow direction and blocks	
Connections and exhausts	
Directional valve symbols	

Table 3 Presentation of directional valves

Directional valves are displayed by individual squares. The number of squares corresponds to the number of switching positions. The respective location of the lines and arrows indicates the connections (only the main connections are counted, not pilot connections). Small dashes on the connections indicate blocks.

With two switching positions, the connecting lines are drawn on the right square and for three switching positions on the center square.

The outlet connections are represented by a small triangle. If the outlet runs over an additional pipeline, this is referred to as "**restricted exhaust**". "**Unrestricted exhaust**" is the process of air escaping into the environment directly or through a silencer.

The designation for a directional valve consists of the number of connections and the number of switching positions. The first number indicates the number of connections while the second indicates the number of switching positions.

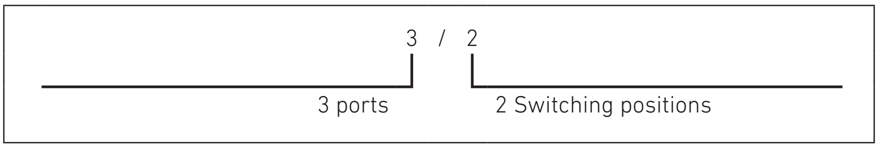


Fig. 4 Example: 3/2 directional valve (spoken: three two directional valve)

3.1.4 Valve positions

Normal position: The normal position is the position of the valve in the non-actuated state (e.g. through spring force).

Valves without a normal position, called pulse valves, do not switch when the actuating force (e.g. compressed air) is removed. They do not have a defined normal position.

Initial position: The initial position is the switching position taken after switching on the network pressure and the voltage (if applicable).

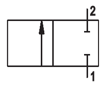
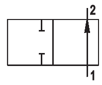
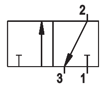
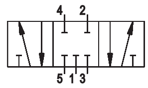
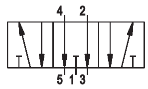
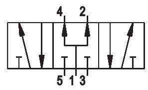
Designation	Description	Symbol
2/2 directional valves	Initial position closed	
	Initial position open	
3/2 directional valve	Initial position 1 closed; 2-3 open	
5/3 directional valves	Closed center	
	Open center (exhausted)	
	Open center (pressurized)	

Table 4 Designation examples

Note The valve symbol does not in any way indicate the design of the directional valve.

3.1.5 Connection designation

The pressure connections (also referred to as ports) are labeled with numbers (standard ISO 5599). You may also find old designations with capital letters.

Port	ISO 5599	Old designation
Pressure connection	1	P
Working connections	2.4	A, B
Exhaust ports	3.5	R, S
Pilot connections	10, 12, 14	Z, Y, X

Table 5 Designation examples

3.1.6 Categorization by valve actuation type

There are different options to actuate (control) a valve and thus trigger a switching operation on the valve:

- Manually
- Mechanically
- Pneumatically through pressure
- Electrically

The types of actuation are standardized in DIN ISO 1219. The graphical symbols are drawn directly at the end of the valve.

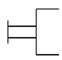
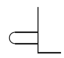
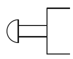
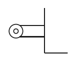
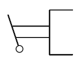
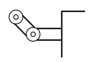
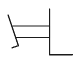
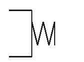
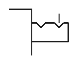
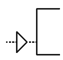
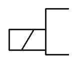
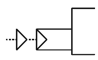
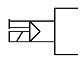
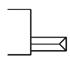
Type of actuation	Symbols	Type of actuation	Symbols
Manual		**Mechanical**	
• Muscle power		• Plunger	
• Button		• Roller	
• Lever		• Roller lever	
• Pedal		• Spring	
		• Detent	
Type of actuation	**Symbols**	**Type of actuation**	**Symbols**
Pneumatic		**Electrical**	
• General		• Solenoid coil	
• Pneumatic pilot		• Solenoid coil pilot, manual override	
• Pneumatic spring			

Table 6 Types of actuation for valves

Example of types of actuation

Manual actuation

With manual actuation, the valve is manually switched by hand or foot.

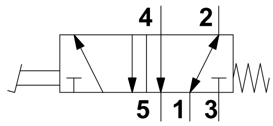


Fig. 5 Example: CD07 series 5/2 directional valve, manually actuated with pedal

Mechanical actuation

With mechanical actuation, the valve is switched by a plunger or roller, for example.

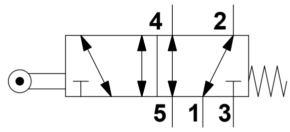


Fig. 6 Example: CD07 series 5/2 directional valve, mechanically operated with roller

Electrical actuation

Electrically actuated valves are solenoid valves.

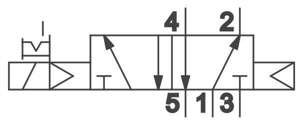


Fig. 7 Example: TC08 series 5/2 directional valve, electrically operated

Pneumatic actuation

With pneumatic actuation, the valve is actuated by compressed air.

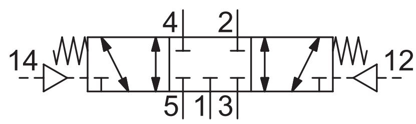


Fig. 8 Example: TC15 series 5/3 directional valve, pneumatically operated

3.1.7 Solenoid valves

Electrically operated valves are referred to as solenoid valves. These valves require solenoid coils, whose method of operation is briefly explained here.

Solenoid coils

A coil (winding of copper wires) establishes a magnetic field when current flows through it. The magnetic field strength increases with the number of windings, which is a measurement of the magnetic force field and can be made visible by lines of force.

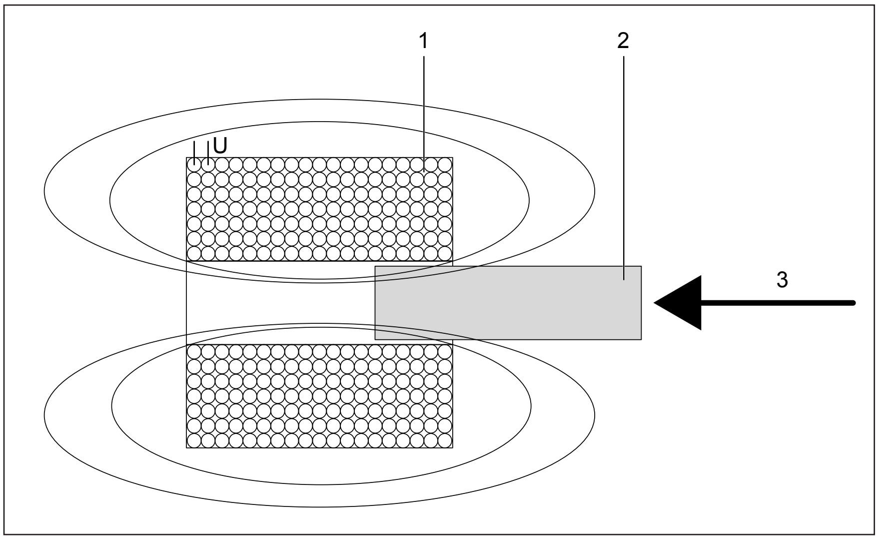


Fig. 9 Solenoid coil, principle

1 Coil
2 Iron armature
3 Movement through the magnetic field ("attract")

Lines of force are self-contained and prefer to spread out in iron (little magnetic resistance). As a result of this property, iron parts are drawn towards the coil. Because the density of the field lines is greatest inside a coil, the dynamic effect is also greatest there. This is taken advantage of in order to attract an iron armature (plunger or spool) into the coil. This mechanical, straight-line movement is used to switch a valve.

Solenoid coils with different voltages and outputs are installed in valves. Since coils heat up during operation (electrical power dissipation), the manufacturer indicates the relative duty cycle (%).

For valves held in a permanent position (duty cycle = 100%), it must be ensured that the valves used are checked and approved for continuous load.

3.1.8 Reduction in holding current

To prevent overheatin due to continuous switching and reduce current consumption, the required holding current is lowered to a value that is just enough to hold the valve open.

3.1.9 Direct and indirect control

Solenoid valves can be controlled directly or indirectly.

Direct control

Smaller directional valves can be controlled directly via levers, pedals, etc. if the control piston is actuated directly.

For directly actuated solenoid valves, the compressed air flow is controlled directly by the solenoid valve. The piston is moved from its initial position just by the force of the electromagnetic drive (coil).

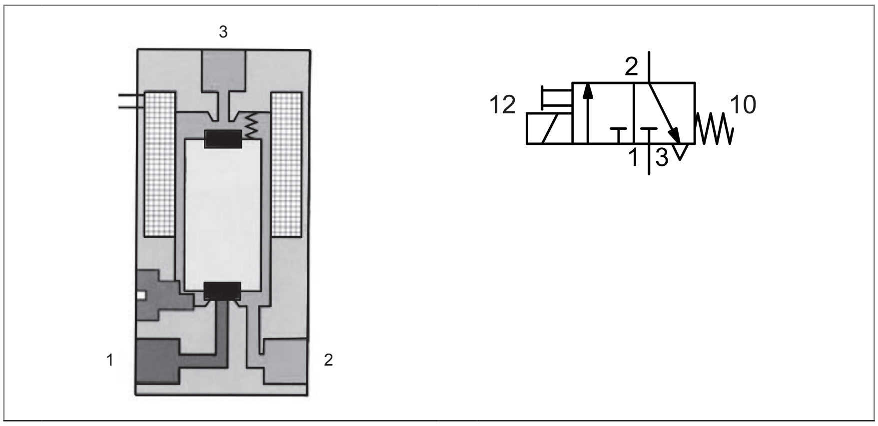


Fig. 10 Directly actuated 3/2 directional valve, solenoid valve with spring return

1 Compressed air
2 Working line
3 Ventilation

Directly controlled solenoid valves are only produced with small nominal widths because otherwise large actuation forces and thus excessive electrical energy are required. This would lead to impermissible temperature increases.

Indirect control (pilot)

For externally piloted valves, the actuation does not affect the main valve but rather an additional pilot valve. This indirect actuation is either pneumatic or electrical.

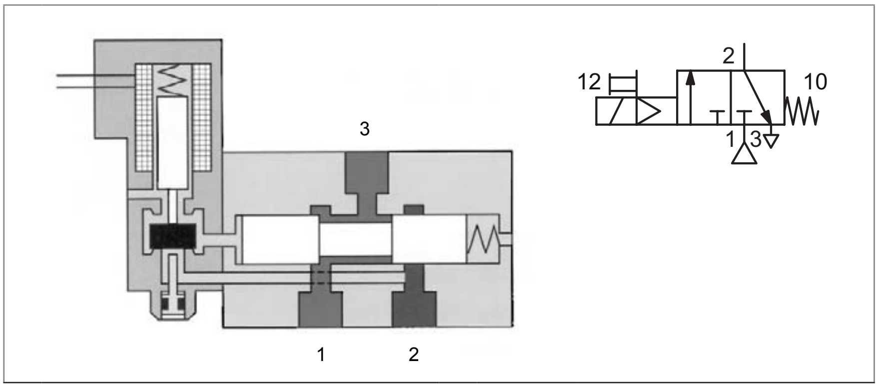


Fig. 11 Indirectly actuated (externally piloted) 3/2 directional valve with spring return

1 Compressed air
2 Working line
3 Ventilation

3.1.10 Internal and external pilot

Valves can be externally piloted indirectly, as described in the previous section. A small switching force releases a large flow that controls the valve.

With **internal pilot control**, the compressed air for the pilot is drawn from the compressed air connection (1) on the valve.

With **external pilot control**, a separate pressure connection is applied to the pilot valve. This layout is used, for example, when the pilot valve is designed for application in a vacuum and no internal pressure exists to actuate the valve.

With electrically operated valves, the pilot principle is frequently implemented because it can be used to control large flows with small, inexpensive solenoids. At this same time, it requires little electrical energy and the solenoids do not heat up as much.

3.1.11 Single and double solenoid valves

Valves are classified as single or double solenoid depending on the number of signals required for operation.

Single solenoid valves (change-over valves) require only one signal for operation. With these valves, the return element is unstable and does not require an external signal. Return takes place automatically (e.g. via a spring and/or differential pressure) as soon as the control signal is no longer applied. Single solenoid valves require constant actuation (voltage) to maintain their working position.

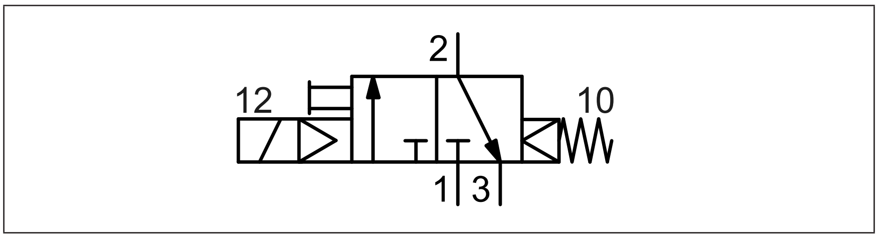


Fig. 12 Example: 3/2 directional valve, return through mechanical and pneumatic spring

Double solenoid valves (pulse valves) require two external signals for operation. This includes, for example, valves with stable actuation that maintain their position until they receive a counter-signal.

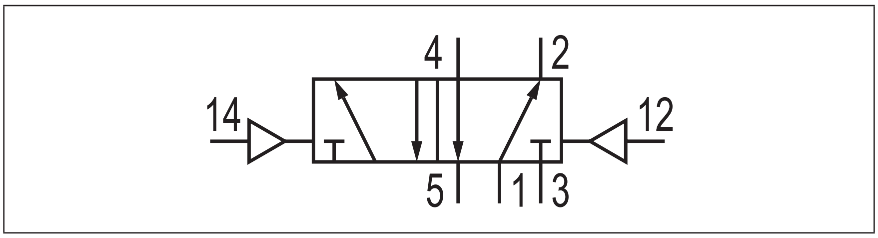


Fig. 13 Example: 3/2 directional solenoid valve, pneumatically operated

3.1.12 Directional valve summary

Directional valves are characterized by their function, actuation, size, version, etc. The most important features are summarized below.

Function	Number of ports
	Number of switching positions
	Type of normal or center position
Actuation	Manual
	Mechanical
	Pneumatic
	Electrical
Size	Connection thread
	Nominal width (nominal size)
	Flow rate values
Version	Version (design principle: poppet or spool valve)
	Control type (directly actuated or externally piloted)
	Overlap, zero overlap
Technical data	Permissible operating pressure
	Minimum control pressure
	Flow rate values
	Connection dimensions
	...

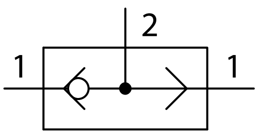
3.2 Blocking valves

Blocking valves are valves that block or release the flow of the compressed air in one direction in particular. Blocking valves include:

- Logic valves (shuttle valves, twin pressure valves)
- Non-return valves
- Quick exhaust valves

3.2.1 Logic valves

Blocking valves perform a special function as logic elements (shuttle and twin pressure valves) in pneumatic control technology.



Shuttle valves

A shuttle valve is a pneumatic valve with two inputs (pilot connections) and one output. It represents the technical implementation of an OR operation in pneumatics.

If different pressures are applied to the two inputs, the output pressure corresponds to the greater of the two input pressures.

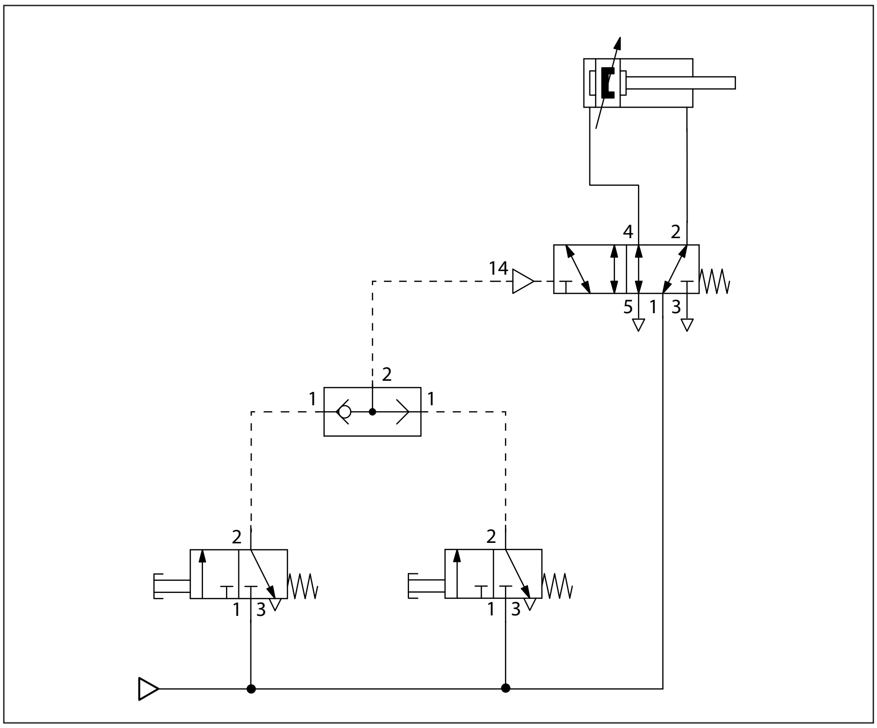
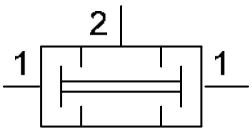


Fig. 14 Example of application controlling a cylinder with two buttons

Exhaust must take place via signal elements because the shuttle valve does not have its own exhaust.

Note: When handling shuttle valves, fast pressure build-up for actuation must be ensured; otherwise the airflow may be redirected and thus cause incorrect switching.



Twin pressure valves

As with the shuttle valve, the twin pressure valve is used to perform logical operations on pneumatic signals. An output signal is only emitted if both input signals are present at the same time. This represents the technical implementation of an AND operation in pneumatics.

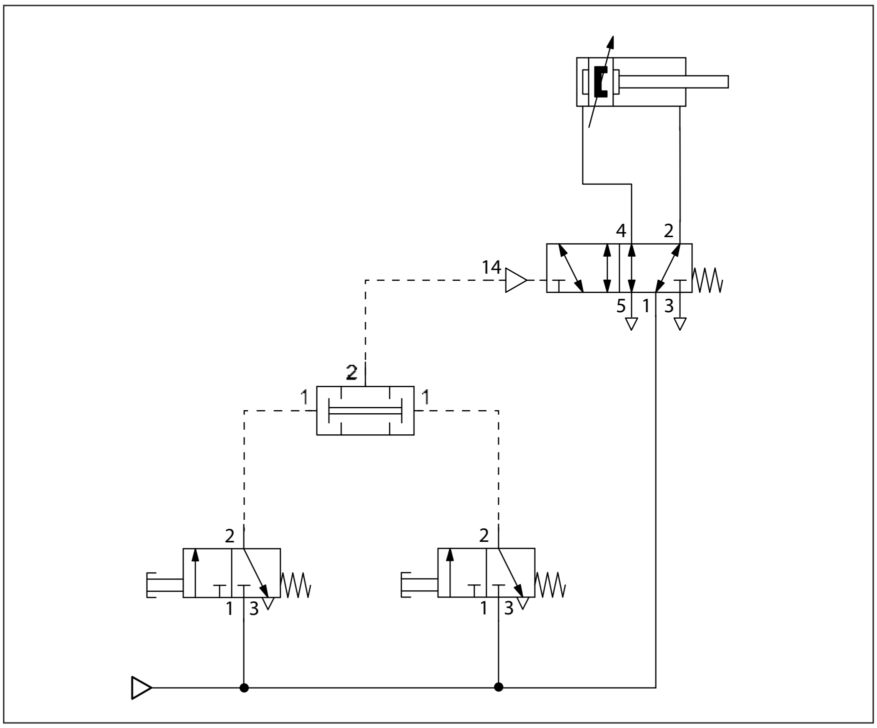


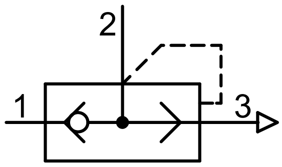
Fig. 15 Example of an AND operation

A cylinder is actuated by two valves (buttons) and can only extend if both buttons are actuated as the same time.

3.2.2 Non-return valves

Non-return valves block the flow in one direction and permits it in the other direction. They are installed with or without a spring. Balls or cones are used as seals, for example.

Non-return valves are used in combination with a throttle to control the speed of pneumatic drives and to delay signals. In addition, they serve to block a backward flow in different applications.



3.2.3 Quick exhaust valves

Quick exhaust valves can be used to directly and quickly exhaust e.g. cylinders and lines via a large exhaust cross-section on the quick exhaust valve. This can speed up a double-acting cylinder since the piston speed depends on several factors:

- The reduction of the flow rate via throttle and check-choke valves
- The mechanical conditions, the load, and the load changes
- The flow cross-section of the actuator elements
- The tubing or piping diameter and the line lengths

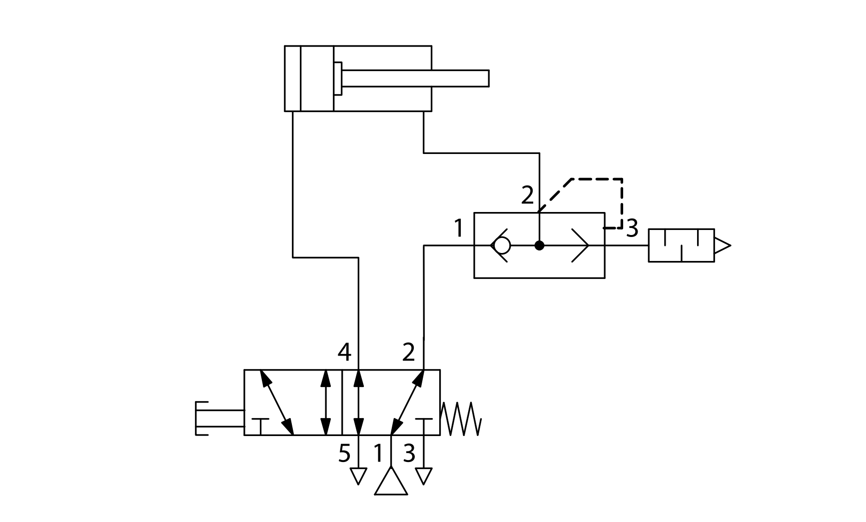


Fig. 16 Application example for cylinder quick exhaust

If the compressed air flows from the cylinder to the quick exhaust valve (cylinder extends), the sealing element seals off connection 1 of the quick exhaust valve. The compressed air can now quickly escape via exhaust port 3 via a large cross-section.

As a result, the cylinder is no longer exhausted via the actuating element (in this case, the 3/2 directional valve) and the long lines in between, but rather directly via the quick exhaust valve exhaust.

If the compressed air flows in the direction of the cylinder (cylinder retraction), the sealing element in the quick exhaust valve seals off the exhaust port and the compressed air can flow through the exhaust valve to the cylinder through a relatively large cross-section with negligible resistance.

Note: A quick exhaust valve is installed as close to the cylinder as possible so that the compressed air can escape quickly upstream of the piston during cylinder extension. A sudden pressurization of the cylinder chambers is associated with a very high level of noise, especially with large-volume cylinders. For this reason, silencers should always be fitted to quick exhaust valves to comply with the applicable noise protection regulations.

3.3 Flow control valves

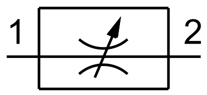
Flow control valves affect the flow rate by constricting the flow cross-section. They enable a simple, inexpensive option for setting the working speed of cylinders and rotary actuators and therefore offer a major advantage in pneumatic control technology.

Flow control valves include:

- Throttle valves
- Check-choke valves

3.3.1 Throttle valves

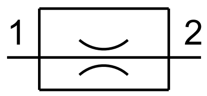
Throttle valves affect the flow rate of the compressed air in both directions. They are fitted in the lines as closely as possible to the actuator (e.g. cylinder) and prevent sudden exhaust and the associated high mechanical load, for example, on a cylinder piston. They are also used to delay switching operations. Both adjustable and fixed throttle valves exist.



Adjustable throttle valve

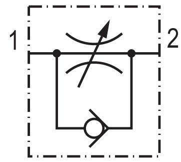
The throttle cross-section is adjusted manually.

For modular units for special functions (e.g. for timers), fixed throttles are also used.



Fixed throttle valve

3.3.2 Check-choke valves



Combining a throttle (usually adjustable) and a non-return valve results in a check-choke valve. This valve is used to affect the flow in one direction.

Check-choke valves are subject to the following assessment criteria:

- Adjustment accuracy, sensitivity (characteristic curve)
- Free flow in the direction of throttle when throttle is open completely
- Free flow via the non-return valve

The check-choke valve is used in the following areas:

- Reducing the speed of pneumatic drives (cylinders, motors)
- Time delays
- Influencing the flow rate

When using check-choke non-return valves, a differentiation is made between and inlet-side throttling and exhaust air throttling.

Inlet-side throttling during extension

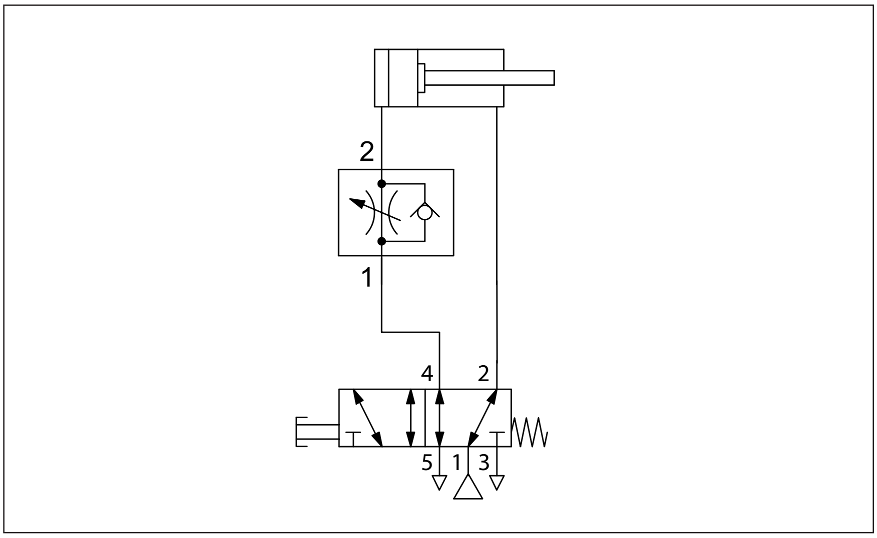


Fig. 17 Inlet-side throttling

Due to the compressibility of compressed air, when using inlet-side throttling particularly for slow piston speeds, an even working movement cannot be achieved. The piston in the cylinder experiences a stick-slip effect.

Cylinder piston movements depend on the cylinder diameter and fluctuations in loads the cylinder experiences.

Inlet-side throttling is only common for very small cylinders and single-acting cylinders.

Exhaust air throttling during extension

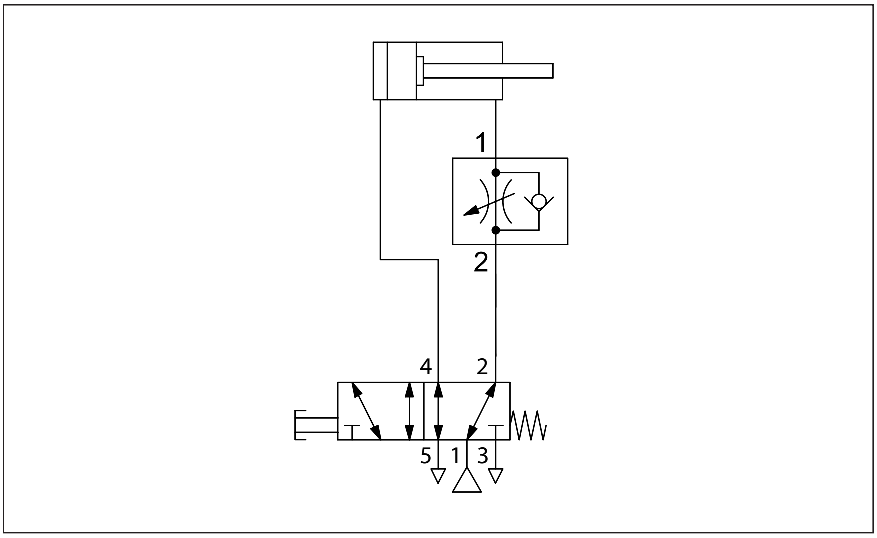


Fig. 18 Exhaust air throttling

For exhaust air throttling, the piston of the double-acting cylinder is positioned between two air cushions. On the inlet air side, full pressure is applied, while the exhaust air side is throttled. This results in the largely even movement of the cylinder piston.

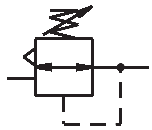
For this reason, exhaust air throttling should be used as a matter of principle for double-acting cylinders. An exception to this rule is mini or short-stroke cylinders, because the pressure build-up for these cylinders is not strong enough on the exhaust side.

3.4 Pressure valves

Pressure valves affect the pressure of the compressed air or respond to certain pressure values.

Pressure valves include:

- Pressure regulators (pressure reducers)
- Pressure switching valves (P/E converters)
- Pressure relief valves (overpressure valves)



3.4.1 Pressure regulators (pressure reducers)

In pressure regulators, the secondary pressure is held constant, regardless of the input pressure (primary pressure).

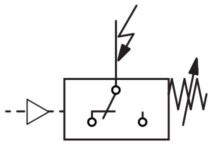
Pressure regulators are used primarily for fluctuating network pressure and compressed air reduction to maintain a constant network pressure.

Characteristic values pressure controllers include:

- Pressure drop at the corresponding flow
- Response sensitivity
- Pressure range for reliable, problem-free work (minimum and maximum values)
- Response time (control characteristics with pressure fluctuations)

Control behavior in the event of highly fluctuating pressure can also be improved through:

- The use of an additional flow for calming
- The series connection (cascading) of multiple pressure controllers



3.4.2 Pressure switching valves (pressure switches)

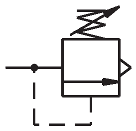
After reaching a certain pressure, a pressure switching valve (pressure switch, P/E converter) emits an output signal. This output signal can be pneumatic or electrical.

The following characteristic values and selection criteria can be applied:

- Response pressure range (minimum and maximum values)
- Repeatability
- Adjustment accuracy
- Hysteresis (difference between connecting and release pressure)
- Nominal flow
- Resistance of the pilot connection to different media
- Function of the basic valve

Pressure switching valves are primarily used in the following applications:

- Querying the pressure in cylinder lines to monitor the pressure force
- Monitoring pressures in different areas and triggering switching procedures
- Substitute signal for monitoring cylinder standstills via supply air pressure
- Triggering safety equipment in the event that a defined pressure value is exceeded



3.4.3 Pressure relief valves (overpressure valves)

In pneumatics, pressure relief valves are primarily used as safety valves.
They prevent a permitted pressure in the system from being exceeded.

If the pre-defined pressure is exceeded, a passage is opened and the compressed air is exhausted either restricted or unrestricted.

VII Valve systems

1 Introduction

The term valve system describes a linking of multiple valves into a cluster. This arrangement allows for central compressed air and exhaust air supply, as well as central valve actuation. This allows for all valves in the valve system to be supplied with compressed air or exhausted with one common connection.

In general, a valve system has a central electrical supply and actuator. Valves can be actuated in parallel via a multipole connection or in series via a fieldbus interface.

Normally, the number of valves in a valve system can be expanded later.

Valve systems offer the following advantages:

- Complete approved, ready-to-use system
- Common electrical control and compressed air supply
- Simple installation, assembly, and commissioning
- Fewer interfaces (e.g. connections and tubing lines)
- Low space requirement
- Increased energy efficiency and cost reduction
- Reduced effort for maintenance and service

Note Using insufficient air supply to the valve or valve system can cause incorrect switching and valve failure. If too many individual functions in a valve system are switched at the same time without the necessary supply of additional air, this can also result in the control pressure dropping, incorrect switching, and valve failure.

2 Technical principles

2.1 Valve system types

A differentiation is made between the following types of valve systems:

- Valve systems according to the base plate principle
- Valve systems based on the plate principle
- Valve systems based on the manifold strip principle (RPS strips)
- Valve systems based on ISO standards

2.1.1 Valve systems according to the base plate principle

These valve systems feature a modular design consisting of base plates with valves. Valve exchanges are easy and fast – the valve system does not have to be disassembled.

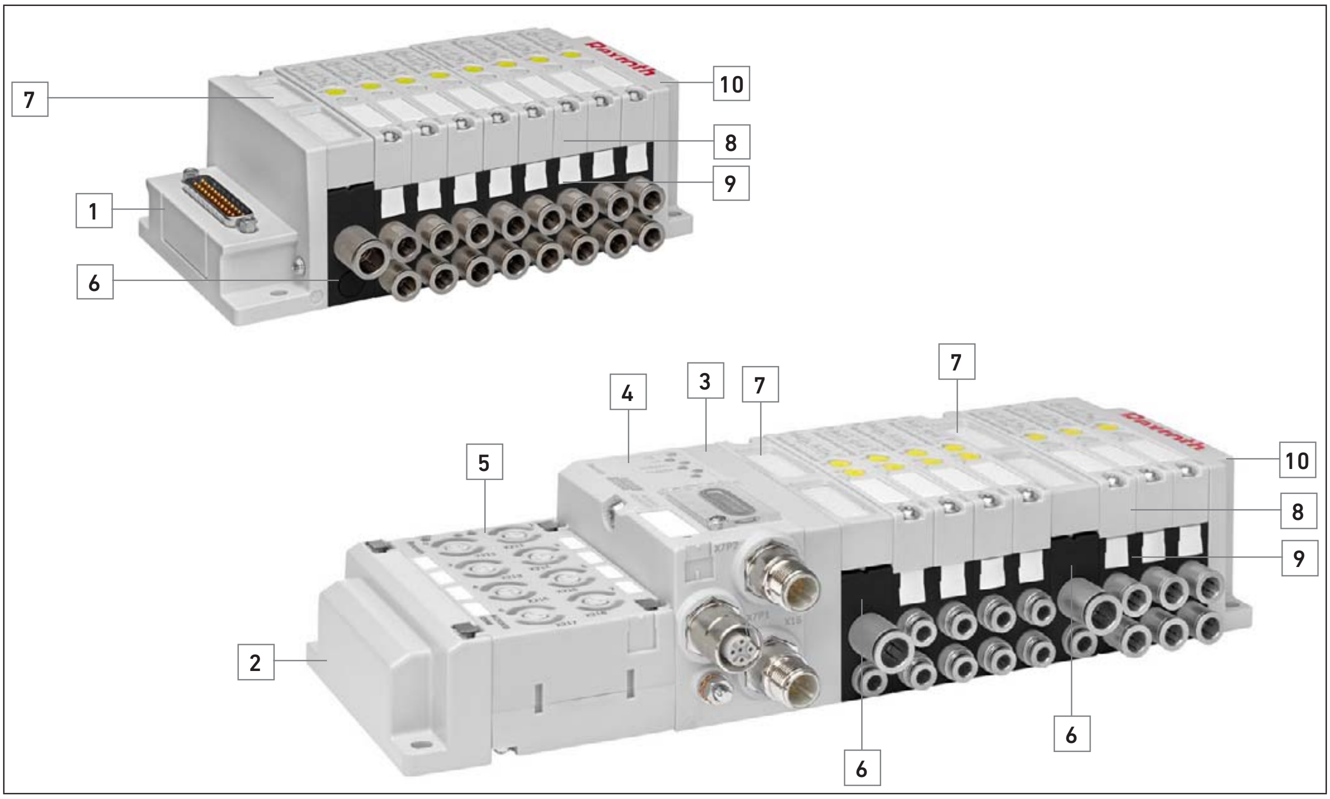


Fig. 1 Valve system according to the base plate principle, example: AV03 series

1 Left end plate with D-Sub connection
2 Left end plate
3 Transition plate
4 Bus coupler
5 I/O module
6 Pressure supply plate
7 Exhaust module with surface silencer
8 Base plate valve
9 Base plate, 3x
10 Right end plate

2.1.2 Valve systems based on the plate principle

These valve systems feature a modular structure consisting of individual valve plates. The plate valves are connected directly without a base plate and held together with tie rods.

Valve systems based on the plate principle require fewer seals than a base plate valve system, for example. However, valve exchange requires more effort because the entire valve system has to be disassembled.

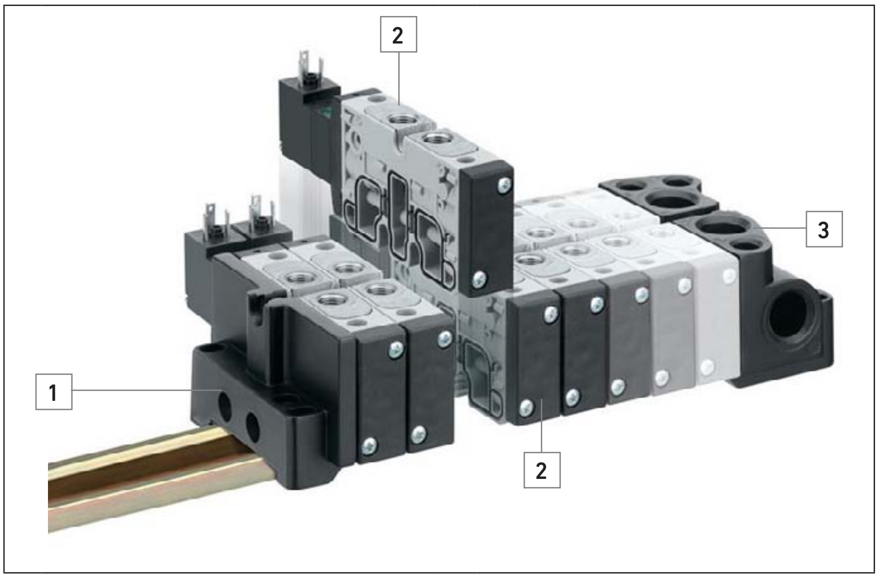


Fig. 2 Valve system based on the valve plate principle, example: TC08 valve series

1 Left end plate
2 Plate valve
3 Right end plate with compressed air connections 1, 3, 5, X, R

2.1.3 Valve systems based on the manifold strip principle (RPS strips)

These valve systems use a common manifold strip for connections 1 (pressure P), 3, and 5 (exhaust R and S).

Sometimes, the manifold strip is used only for connection 1 (P).

The valves are located directly on a manifold strip, which supplies them with compressed air and controls them electrically and individually.

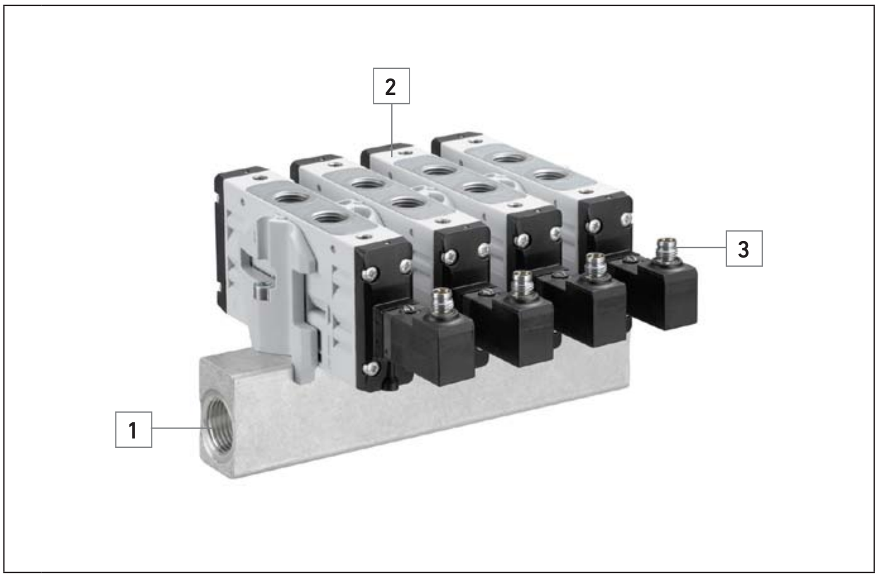


Fig. 3 Example: TC08 valve series, common P strip

1 P strip for common connection 1
2 Plate valve
3 Electrical single connection

2.1.4 ISO valve systems

ISO valve systems are valve systems with a standardized porting configuration between the valve and base plate. They are defined with pneumatic connections only or with electrical and pneumatic connections. Only the porting configuration is standardized. Dimensions and output can vary for different valves.

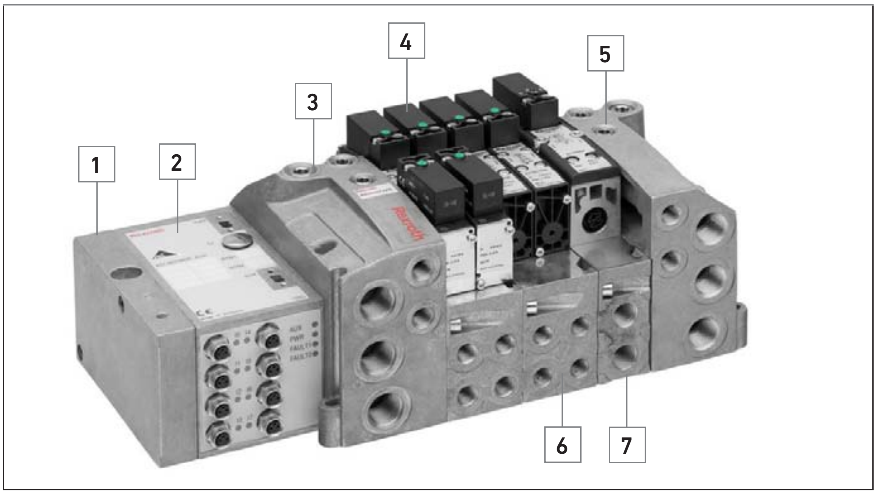


Fig. 4 Design of a standardized valve system, example: CD01/02-PI series acc. to ISO 15407-2

1 Left end plate for AS-i bus coupler, B-design, and I/O modules
2 Bus coupler
3 Left end plate with compressed air connections 1, 3, 5, X, R
4 Base plate valve
5 Right end plate with compressed air connections 1, 3, 5, X, R
6 Base plate, 2x
7 Base plate, 1x

2.2 Valve system compressed air supply

Valve systems are supplied with compressed air via either the end plates, so-called supply plates, or blanking plates with RPS function.

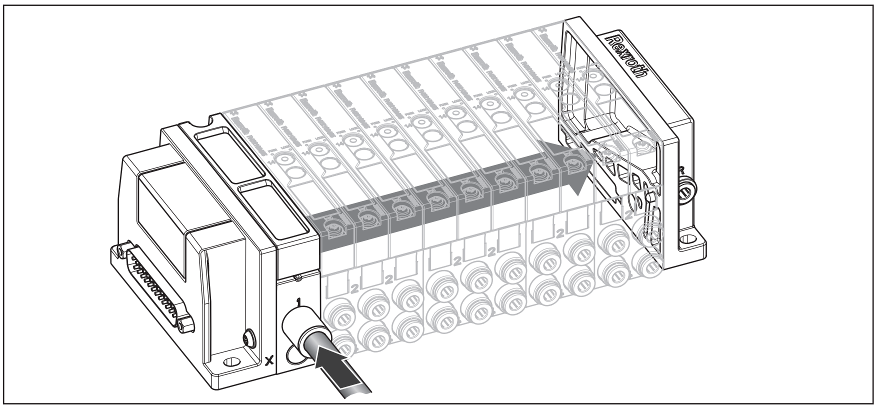


Fig. 5 Compressed air supply via the left supply plate, example: AV03 series valve system

The compressed air for controlling the actuators (e.g. cylinders) escapes the valve system via the respective valve directly on working connections 2 and 4. They can be integrated directly into the valves or be located in the base plates (e.g. in the case of the AV03 valve system).

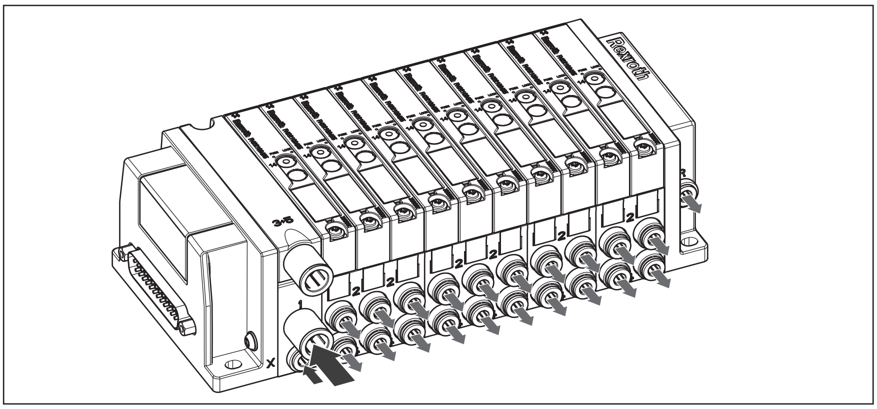


Fig. 6 Compressed air supply via the supply plates (1 operating pressure, X control pressure) and compressed air connection on the actuators via valve outputs 2 and 4, example: AV03. R = pilot exhaust air; 3 and 5 = restricted exhaust

Supply plates are used for the following tasks:

- Dividing the system into different pressure zones
- Maintaining a constant pressure within a valve system with a larger number of valves
- Exhausting the supplied compressed air via an exhaust module

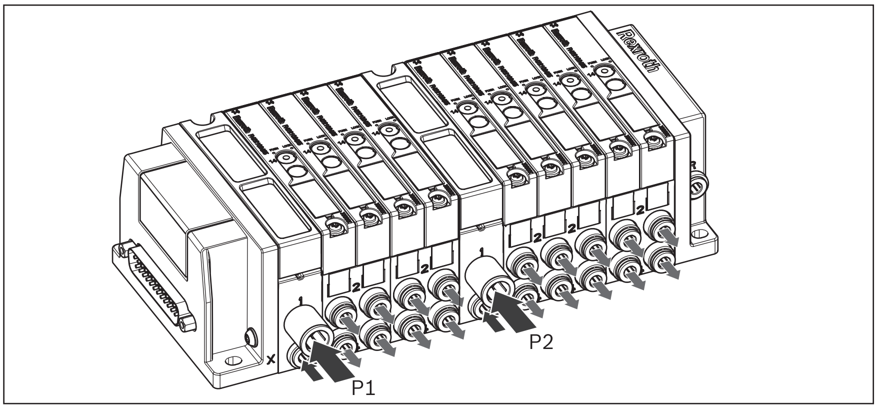


Fig. 7 Supply plates in the valve system, example: AV03.
P 1 = first pressure supply, P 2 = second pressure supply.
The supply plates are available in several designs with different opened or closed channels: 1, 3, 5, X, and R

2.3 Internal and external piloting in the valve system

In the case of **internal** piloting in the valve system, an additional X compressed air connection is not required to supply the pilot valves on the system, since the pilot is achieved using applied working pressure 1. This is referred to as an internally piloted system.

In the case of **external** piloting in the system, the pilot valve has its own X input with compressed air for supply. This is also referred to as an externally controlled system. The pilot air can be exhausted via a surface silencer and/or a separate R connection.

2.4 Valve system mounting

The following options are available for mounting a valve system:

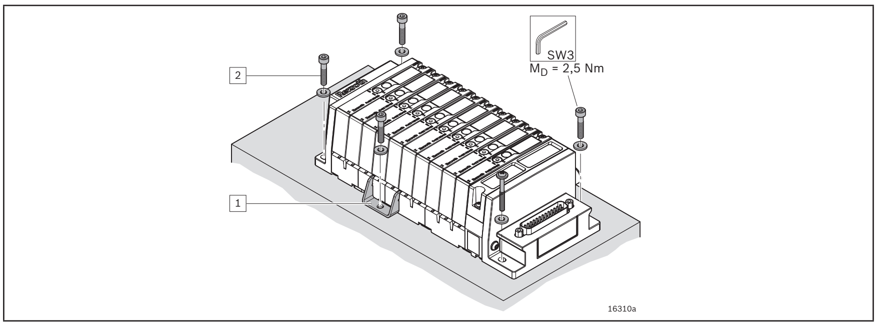


Fig. 8 Direct mounting of the valve system on a flat surface with screws (2) and retaining brackets (1), example: AV03 series

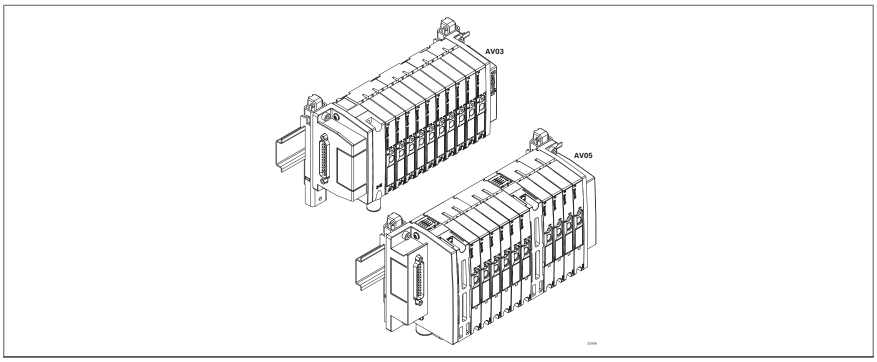


Fig. 9 Mounting of the valve system on a hat (DIN) rail, example: AV03 and AV05 series (note the limited number)

2.5 Valve system exhaust

A valve system can be exhausted into the environment, for example, via an exhaust module with silencer or via exhaust modules with restricted exhaust.

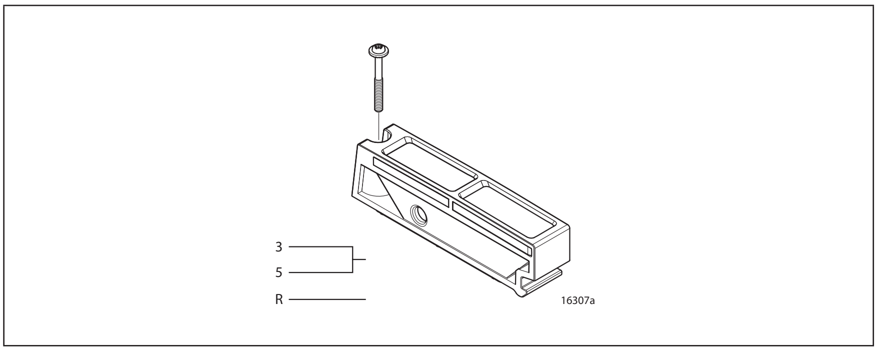


Fig. 10 Exhaust via exhaust modules with surface silencer for 3, 5, and R. Example: AV03 series

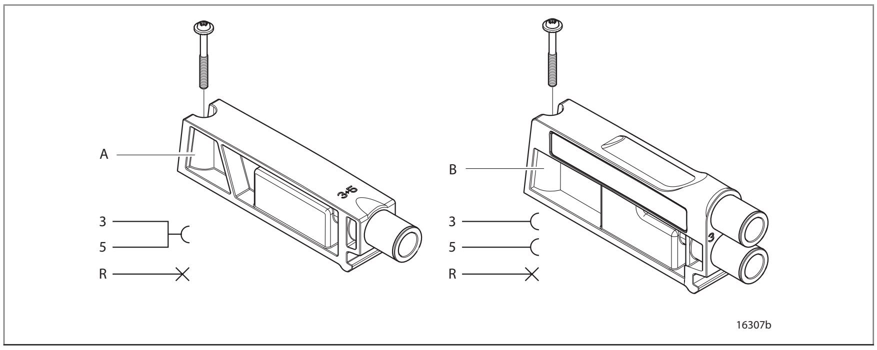


Fig. 11 Exhaust module (A) with restricted exhaust 3 & 5 together or (B) with separate restricted exhaust for 3 and 5. Example: AV03 series

For the AV family, the exhaust modules are placed on the pressure supply plates and fixed with screws.

Note For other valve systems, a silencer can be screwed into the thread in connections 3 and 5 or the exhaust can be restricted with a tubing connection.

2.6 Electrical connection and control of valve systems

There are three different options for electrically controlling valve systems:

- Single connection (e.g. M8 standard plug)
- Parallel manifold (multipole connection)
- Serial manifold with fieldbus interface

2.6.1 Single connection

Each valve is controlled electrically with a single connection.

Fig. 12 Electrical connection of the valves via single connection with M8 plug, example: TC08 series

2.6.2 Parallel connection (multipole connection)

The valve system is controlled centrally via a multipole plug. In the valve system, the control signals are distributed to the individual pilot valves via boards or internal wiring.

Each valve coil requires one wire for its control and a common wire for the ground connection. This allows up to 24 single solenoid or 12 double solenoid valves to be actuated with a 25-pin D-Sub plug, for example. One pin is always reserved for the ground connection.

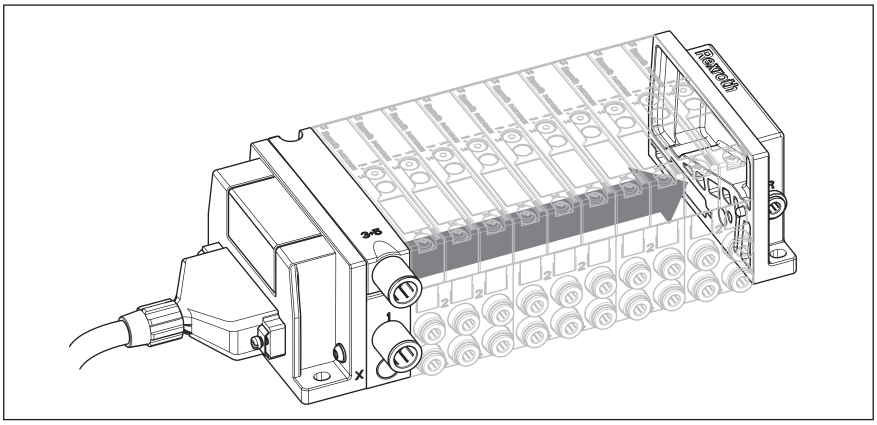


Fig. 13 Electronic control of valves via a multipole connection, example: AV03 series

2.6.3 Serial connection (fieldbus interface)

A valve system can also be controlled via a fieldbus interface. The control signals are sent electronically via a telegram and received by the bus coupler. The valves are controlled via power transistors, also called valve drivers, within the system.
The necessary valve drivers can be placed in the bus coupler (e.g. in the case of the HF series) or be located directly on the boards in the base plates (e.g. AV series).

Fig. 14 Example: AV03

3 Products

3.1 Valve system product overview

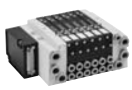
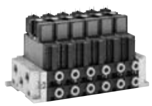
Valve systems					
Qn [l/min]		**Series**	**Functions**	**Connections**	**Control**
300		AV03	2x3/2, 5/2, 5/3 E/P	Ø 4, Ø 6	Multipole, AES fieldbus
400		HF04	2x3/2, 5/2, 5/3	Ø 6	Multipole, BDC, CMS, and DDL fieldbus
600-800		TC08	5/2, 5/3	G1/8, NPTF 1/8	Individual plug, pneumatic
700		AV05	2x3/2, 5/2, 5/3 E/P	Ø 4, Ø 6, Ø 8	Multipole, AES fieldbus
700-850		HF03-LG	2x3/2, 5/2, 5/3	G1/8, Ø 8, NPTF 1/8	Multipole, BDC, CMS, and DDL fieldbus
850		CL03	2x3/2, 5/2, 5/3	G1/4, Ø 5/16, Ø 3/8	Multipole, BDC and DDL fieldbus
950-6000		581	2x3/2, 5/2, 5/3	G1/8, G1/4, G3/8, G1/2, G3/4	Individual plug, multipole, pneumatic
1010		CD01	2x3/2, 5/2, 5/3	G1/8, G1/4, NPTF 1/4 Ø 4, Ø 6, Ø 8, Ø 10	Individual plug, multipole, pneumatic
1100		CL03-XL	2x3/2, 5/2, 5/3	G1/8, G1/4, G3/8, G1/2, G3/4	Individual plug, Multipole Pneumatic
1100-1500		TC15	5/2, 5/3	G1/4, NPTF 1/4	Individual plug, pneumatic
1400		HF02-LG	2x3/2, 5/2, 5/3	G1/4, Ø 10	Multipole, BDC, CMS, and DDL fieldbus

Table 1 Valve system overview

3.2 Product selection

In planning the overall system, a suitable valve solution is required after laying out the actuators and defining the pressure and air consumption parameters in the system. The process is basically the same as for valve selection.

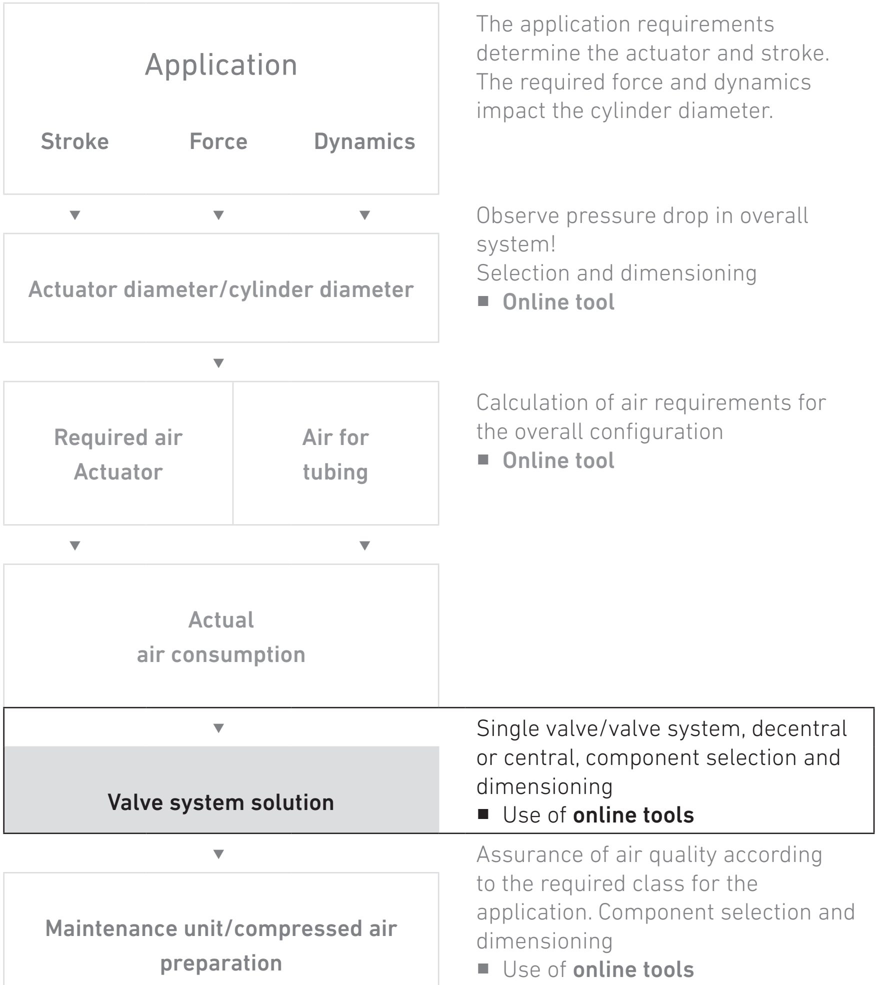


Fig. 15 Valve system selection process

Note If you are unable to implement your planning using the configurator, contact us for customer-specific solutions.

3.3 Compact design

When it comes to compactness, the expression of installation volume per flow rate is a major factor for valves. In the course of continual optimization of machines and systems, a reduced installation volume is becoming ever more important. Size, weight, and simple integration options in compact machine designs are crucial for many applications.

Qn [l/min]	<400	400 - 850	850 -1100	1100 - 3000	3000 - 6000
Extremely compact	AV03	AV05			
Compact		TC08		TC15	
Standard	HF04	HF03-LG		HF02-LG	
		CL03	CD01		581
				CL03-XL	

Fig. 16 Compact valve system design

3.4 Flow as a function of pipe length and diameter

Valves are selected based not only on the drive air consumption but also on the valve connections and flow throttling in the piping. This throttling should be taken into consideration during configuration.

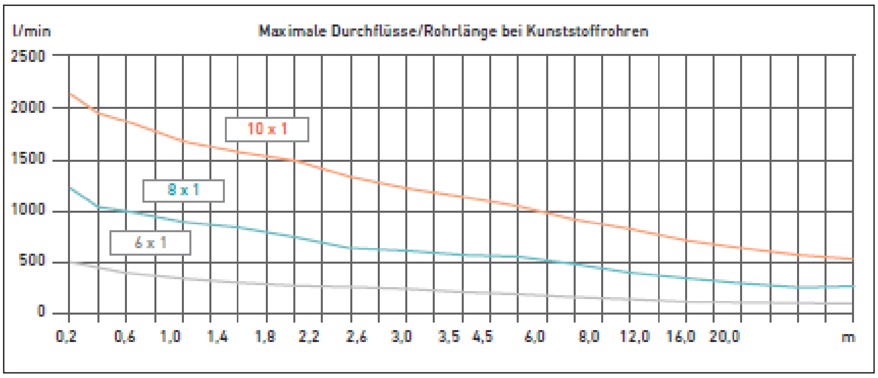


Fig. 17 Flow as a function of pipe length and diameter

VIII Preparation of compressed air

1 Introduction

The composition of atmospheric air, compressed and used as a medium, varies according to geographical and climatic conditions. When the objective is to boost process reliability by increasing the availability of equipment, even the most basic production elements need to be rethought – starting with the compressed air supply.

1.1 Why compressed air preparation?

As consistent quality of the compressed air used as possible is important for the operation of pneumatic systems. The provided compressed air must be cleaned and its supply to the pneumatic system regulated. This is made possible by, for example, maintenance units that consist of a combination of filters, dryers, lubricators, and valves.

The air quality required for specific applications and industries is defined in quality classes, based on decades of practical experience („2.6 Compressed air qualities in accordance with ISO 8573-1:2010“). To achieve these compressed air quality levels, and thus guarantee smooth working processes, air preparation components are used exactly where they are needed. They provide pressure regulation, filter compressed air using individual filter systems, and ensure just the right oil quantity with lubricator components.

Correct, efficient compressed air preparation offers the following advantages:

- Prevention of malfunctions (e.g. stuck pilot valves, increased seal wear, leaks)
- Minimized component corrosion
- Increased service life and system component safety
- Minimized machine failure and downtimes
- Compliance with environmental standards
- Optimized energy efficiency of the pneumatic system and thus cost minimization of operation
- Reduced maintenance effort (maintenance intervals)

2 Technical principles

Two subsystems are required for automated motion with air:

The generation of compressed air through compression and compressed air processing via pneumatic actuators.

Compressed air generation	Compressed air processing
• Central compressed air generation and preparation	• Decentral compressed air preparation • Valve technology • Actuators

2.1 Stages of compressed air preparation

To be able to efficiently use compressed air as a working medium in pneumatic systems, the following must be observed during preparation:

- Condensate must be removed (-> condensate separation, drying)
- Particles contained in the compressed air must be removed (-> filtering)
- The pressure must be regulated at a constant value (-> pressure regulation)
- If necessary, the oil content must be set (-> lubrication)

2.1.1 Condensate separator

The water content of the air depends on the temperature. The higher the temperature, the more water vapor is absorbed. If the temperature sinks while the volume remains constant, the saturation point can be exceeded and the water turns into condensate in the compressed air mains.

To remove the condensate, condensate separators with drain valves must be installed at the lowest point of the lines.

If the air is not dried artificially, the condensate separators are only installed at the points where the air cools significantly as well as at the end of each line branch.

2.1.2 Drying

If pure condensate separation is not sufficient, the air is dried to achieve a correspondingly low moisture content. Primarily two process are used:

- **Refrigeration drying**
  Drying coming close to the freezing point and discharging the resulting condensate
- **Absorption drying**
  Air coming into contact with hygroscopic material (e.g. silica gel). Water is drawn out of the air.

2.1.3 Filtering

After condensate separation and drying, the compressed air is guided through filters to remove any contained particles. In order to achieve the required purity, combinations of filters are generally used (see „2.6 Compressed air qualities in accordance with ISO 8573-1:2010").

2.1.4 Pressure regulation

Pressure controllers are used to maintain a constant pressure in the mains and compensate for pressure fluctuations (e.g. through compressors, temperature fluctuation in the mains). They consist of an adjustable throttle whose opening cross-section is adjusted automatically.

The constant pressure zone upstream of the controller is designated the secondary zone.

The pressure zone between the compressor and pressure controller is designated the primary zone.

The controlled pressure in the secondary zone is always lower than in the primary zone. This results in a pressure gradient in the mains. To keep this pressure gradient to a minimum, the pressure difference on the pressure controller must be as small as possible when adjusting the controller.

2.1.5 Oiling

Under certain conditions, it is necessary to lubricate the compressed air with oil. This is performed by lubricators. A flow pressure causes oil to exit a nozzle, which is atomized and absorbed by the directed compressed air.

To prevent environmental loads caused by air/exhaust lubricated with oil, oil lubrication should be avoided whenever possible.

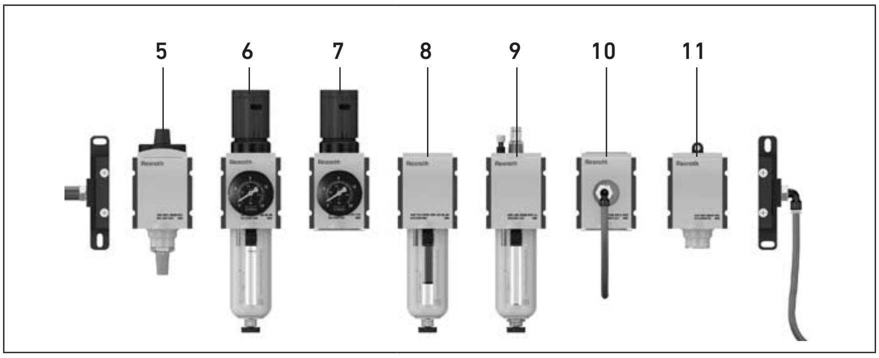
Oil lubrication may however be necessary if exceptional loads on the actuators are to be expected, for example with high switching frequencies of connected switching valves (> 100 switching operations per minute per switching valve) or at high actuator piston speeds (> 1 m/s).

2.2 Compressed air preparation components within pneumatic systems

Pneumatic system			
Compressed air generation/central compressed air preparation ►	**Decentral compressed air preparation** ►	Valve technology ►	Actuators
• Compressed air generation • Compressed air pretreatment (e.g. drying) • Compressed air storage	• Compressed air conditioning	• Compressed air control and regulation	• Drive components

Components	**Function**
Compressed air generation/central compressed air preparation	
1 Compressor	Compressed atmospheric air
2 Compressed air reservoir with	Stored compressed air
• Condensate drain	Draining of formed condensate
• Safety valve	Protection from critical overpressure
3 Compressed air dryer	Removes liquids from the compressed air
4 Mains line	Compressed air supply/provision

2.2.1 Decentral compressed air preparation



5 Shut-off valve	Blocks the compressed air supply
6 Filter pressure regulator	Reduces the applied system pressure to a maximum, controlled operating pressure and ensures coarse filtration of the compressed air
7 Pressure regulator	Reduces operating pressure p1 to the set secondary pressure p2 (p2 remains constant)
8 Filter	Removes particles, vapors, and volatile substances (e.g. odors)
9 Lubricator	Ensures a constant compressed air oil content
10 Distributor	Distributes the compressed air and enables the connection of a pressure switch
11 Filling valve/filling unit	Slowly builds up the operating pressure during recommissioning after a mains pressure failure or emergency OFF switching procedure and prevents dangerous, jerky cylinder movements.

Optional:	
Diaphragm-type dryer	Removes liquids from the compressed air
Non-return valve	During assembly, prevents oiled air from flowing back into the air filter in the event of a pressure drop upstream of the maintenance unit.

2.3 What is compressed air composed of?

Compressed ambient air contains the standard percentages of gases (78% nitrogen, 19% oxygen, 0.9 % argon, 0.04 % carbon dioxide), as well as fluctuating portions of solids, water, and oil.

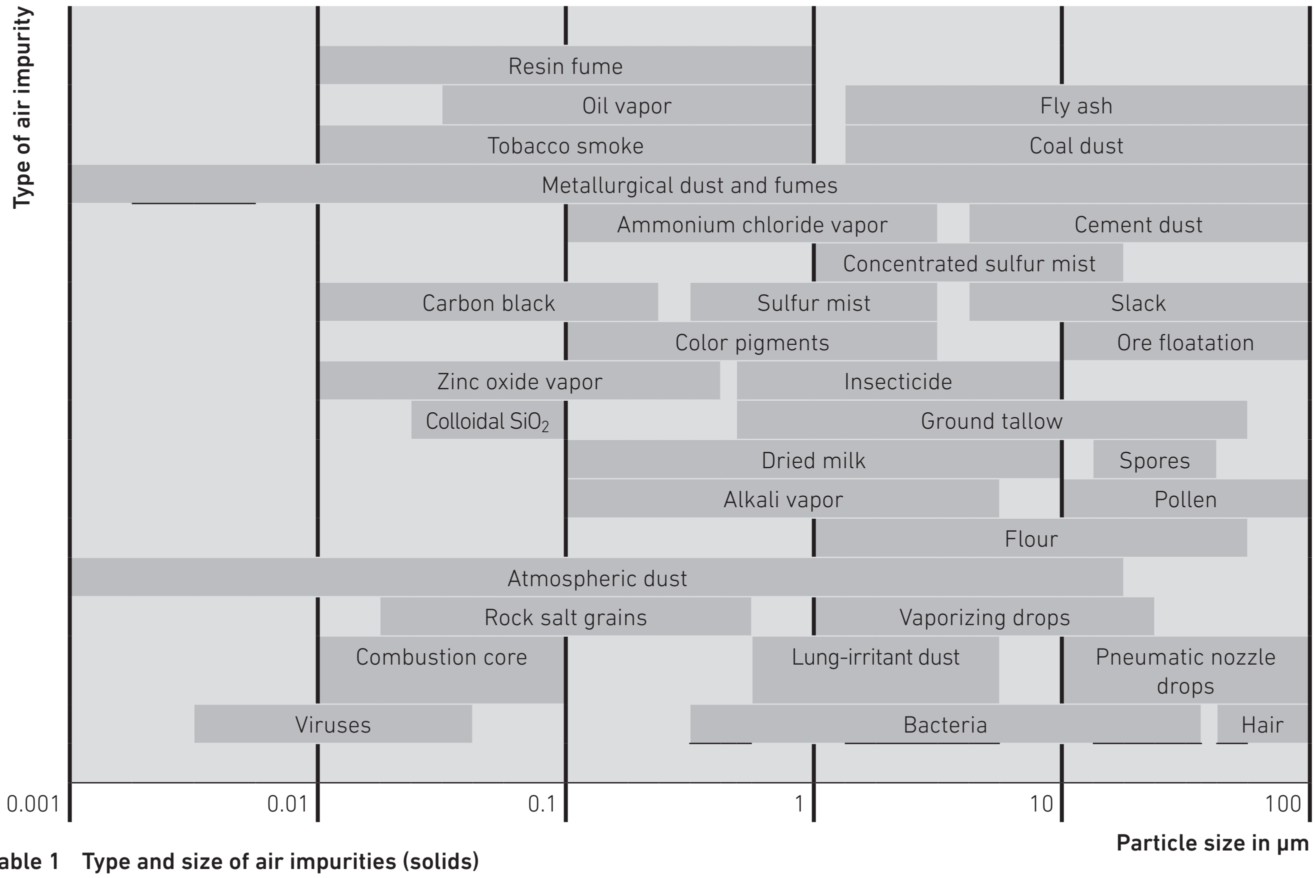


Table 1 Type and size of air impurities (solids)

One cubic meter of compressed air contains up to 180 million dirt particles, 80 g of water, 0.03 mg of oil as well as traces of lead, cadmium and mercury.
Individual contaminants can react and combine to form emulsions that impair component function and, in the worst case, render products useless.

Solids

Solids appear in the form of dust of the most various shapes and sizes (amorphous, crystalline). They cause wear on the sealing elements and sliding surfaces.

Moisture and water content

Water occurs in a liquid or gaseous state depending on the temperature. It may lead to component corrosion, or it may slowly wash off lubrication in the devices. Drying the air prevents these consequences.

Oils

Residual oils from the compressor, or oil aerosols that have been sucked in, do not aid in lubricating. They can damage components and cause increased wear. This risk can be reduced by using suitable filters.

2.4 Compressed air generation

In order to achieve the required air quality, the central air preparation system must separate water and oil, condense excess residual water, and separate solid and liquid aerosols.

The following components are required:

- Use of water separators
- Condensation with compressed air refrigeration dryers
- Specific compressed air filters, depending on purity requirements

2.4.1 Pressure dew point

The pressure dew point is understood to be the temperature to which the compressed air can be cooled without forming condensate.

If this compressed air expands, the actual moisture content per unit volume is reduced. The following figure shows the relationship between the pressure dew point and atmospheric dew point.

For example: compressed air at 7 bar and a pressure dew point of 5°C corresponds to an atmospheric dew point of -20°C for expanded air.

Converting the pressure dew point into the atmospheric dew point

Determining the pressure dew point while relieving the compressed air from a higher pressure to a lower pressure from the diagram:

- Read off the temperature (1) and pressure parameters (2) at which the compressed air was dried
- Read off the expanded pressure of the compressed air (3), the corresponding pressure dew point (4), and the temperature of the atmospheric dew point (5)

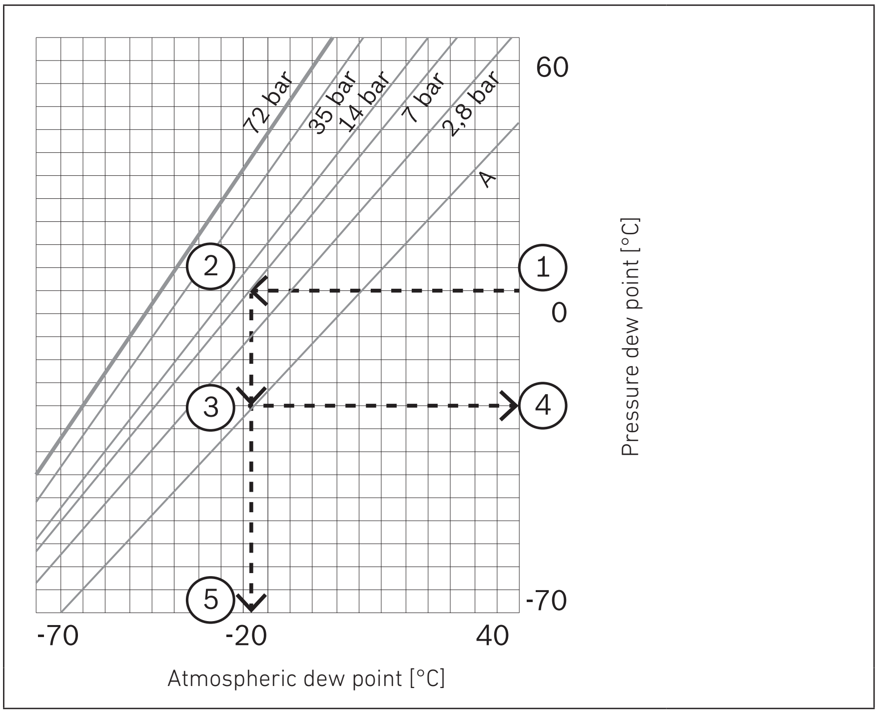


Fig. 1 Diagram: Pressure dew point atmospheric dew point; A = atmospheric (figure based on VDMA Specification 15390: 2013)

1 Temperature
2 Pressure parameter
3 Expanded pressure
4 Pressure dew point
5 Temperature of the atmospheric dew point

2.4.2 Particle content in intake air

Solid contaminants include atmospheric pollution, microorganisms, rust and condensate deposits. The size and concentration of particles are key factors. 80% of the dirt particles are smaller than 2 micrometers and are not caught by the compressor intake filter due to their small size. As a result, they end up in the compressed air system.

The table shows the estimated particle quantities for intake air.

Size	Approx. per m^3	Approx per day (24 h)
< 2 µm	120 million	2880 billion
> 2 µm	30 million	720 billion

Table 2 Solid particle introduction with a suction capacity of 1000 m^3/h (for ambient conditions: 20°C, 1 bar) with a final compressor pressure of 8 bar

2.4.3 Water content in intake air

Water occurs in a liquid or gaseous state depending on the temperature. Water content can be reduced by drying air.

The table shows the water content of the intake air.

Temperature	Saturation humidity	50% relative humidity	70% relative humidity
15°C	12.8 g/m³	153.6 L	215.2 L
20°C	17.3 g/m³	207.6 L	290.8 L
25°C	23.1 g/m³	277.2 L	388.0 L
30°C	30.4 g/m³	364.8 L	510.8 L
35°C	39.6 g/m³	475.2 L	665.2 L
40°C	51.1 g/m³	613.2 L	858.4 L
45°C	65.4 g/m³	784.8 L	1098.8 L

Table 3 Overall moisture deposit in liters per day (24 h) with a suction capacity of 1000 m³/h, ambient pressure: 1 bar

2.4.4 Residual oil content after compression

Oils are used in compressors as media that insulate, lubricate, and cool. The table shows the quantity of oil remaining in intake air after compression depending on the compressor type. This includes both liquid and gaseous residual oil, for a suction capacity of 1000 m³ at 24 h full load operation, final pressure 8 bar.

Compressor design	Residual oil content after compression	
	Per m³	Per day
Piston compressor, oil-lubricated	10 – 180 mg	240 – 4,320 g
Multi-vane compressor, oil-lubricated	5 – 180 mg	120 – 4,320 g
Screw compressor, oil-lubricated	1 – 20 mg	24 – 480 g
Compressors, oil-free compression	0.1– 3 mg	2.4 – 72 g

Table 4 Typical oil content in compressed air for various compressor designs

2.5 Blowing air, pilot air, process air

Blowing air

Blowing air is used to clean machines and workpieces, e.g. to remove dust.

Pilot air

Pilot air used for driving, energy, and operation. It is used to operate controls as well as linear and rotary drives.

The definitions of compressed air properties and compressed air quality classifications are described in ISO 8573-1:2010, supplemented by VDMA Specification 15390: 2013.

Note Pilot air specifications apply for pneumatics.

Process air

As a medium, process air is physically or chemically introduced in a handling or processing procedure.

2.6 Compressed air qualities in accordance with ISO 8573-1:2010

Water, as well as dust, aerosols, chemicals, organisms etc., are found in the air and are sucked in by the compressor. This mixture must be prepared corresponding to the use and the selected devices. ISO 8573-1 lists contaminants and their state of aggregation. Quality levels and their limit values are defined in this standard.

This standard has been binding for automated applications with pneumatic components since 2010. Certain parameters are therefore essential for compliant, energy-efficient compressed air preparation.

The following questions should be clarified as a preliminary step:

- What is the maximum required flow rate?
- Do all consumers require an identical compressed air quality?
- What is the compressed air quality delivered by the compressor? The following table presents the compressed air qualities as defined in standard ISO 8573-1: 2010.

Class	Solids				Water		Oil
	Max. number of particles per m^3			Particle concentration	Pressure dew point, vapor[1)]	Liquid	Total oil content (liquid, aerosol, and mist)
	0.1 – 0.5 µm	0.5 – 1 µm	1 – 5 µm	[mg/m^3]	[°C]	[g/m^3]	[mg/m^3]
0	According to user specifications; stricter requirements than class 1						
1	≤ 20,000	≤ 400	≤ 10	—	≤ –70	—	≤ 0.01
2	≤ 400,000	≤ 6,000	≤ 100	—	≤ –40	—	≤ 0.1
3	—	≤ 90,000	≤ 1,000	—	≤ –20	—	≤ 1
4	—		≤ 10,000	—	≤ +3	—	≤ 5
5	—		≤ 100,000	—	≤ +7	—	—
6	—		—	≤ 5	≤ +10	—	—
7	—		—	5 – 10	—	≤ 0.5	—
8	—		—	—	—	0.5 – 5	—
9	—		—	—	—	5 – 10	—
X	—	—	—	> 10	—	> 10	> 10

1) The pressure dew point should be at least 15°C below the ambient temperature.

Table 5 Overview of classification according to ISO 8573-1

In accordance with ISO 8573-1, the compressed air quality is indicated in the following format:

(– : – : –)

Class: total oil content

Class: moisture (vaporous)

Class: solid pollutants

Depending on the required compressed air (class), a suitable combination of filter, lubricator, dryer, and valve must be selected for the respective maintenance unit.

Typical quality combinations for different industries are shown below.

Industries	**Typical classes**				
	Solid pollutants	**Moisture (vaporous)**		**Total oil content**	**Sterile**
	A	B_1	B_2	C	D
Mining	7	4	2 – 3	4	
Food industry	2	4	2 – 3	1	
Packaging/air molded products	1	4	2 – 4	1	Yes
Textiles	3	4	2 – 3	2	
Printing and paper	3	4	2 – 3	2	
Pharmaceutical industry	2	4	2 – 3	2	
Metal production and processing	3 – 4	4	2 – 3	3	
Surface finishing	1	3 – 4	3 – 4	1	
Mechanical and plant engineering	3	4	2 – 3	3	
Electrical engineering, electronics	2	4	2 – 3	2	
Battery production, dry room	2	1	1	1	

B1 = Ambient temperature >+10°C   B2 = Ambient temperature ≤+10°C

Table 6 Typical quality class combinations for different industries as per ISO 8573-1: 2010 and VDMA Specification 15390: 2013

2.6.1 Reference conditions

According to ISO 8573-1:2010, the reference conditions for the gas volume are:

- Air temperature: 20°C
- Absolute air pressure: 100 kPa = [1 bar](a)
- Relative water vapor pressure: 0

2.7 Energy efficiency

Energy-efficient pneumatic applications can only be implemented with high-quality compressed air in accordance with ISO 8573-1:2010. Optimally dimensioned, intelligent maintenance units ensure clean compressed air and monitor consumption levels in the system. Correctly dimensioned components for compressed air distribution can go a long way in terms of cost efficiency.

2.8 Filter

Compressed air filters target and remove all types of solid and liquid impurities from the compressed air and are essential components for compressed air preparation.

Selecting the correct filter combination can achieve the required compressed air purity.

2.8.1 Standard filters

Depending on the selected pore width, the filter retains particles from 5 µm to 40 µm in the reservoir. The contaminants (both liquid and solid) are separated from the compressed air by the centrifugal effect of the swirling plate and are cast onto the reservoir wall.
The vertical installation of the filters causes the condensate to collect on the reservoir floor. The condensate can then exit via the drain.

The polyethylene filters can be easily removed, washed with water or replaced.

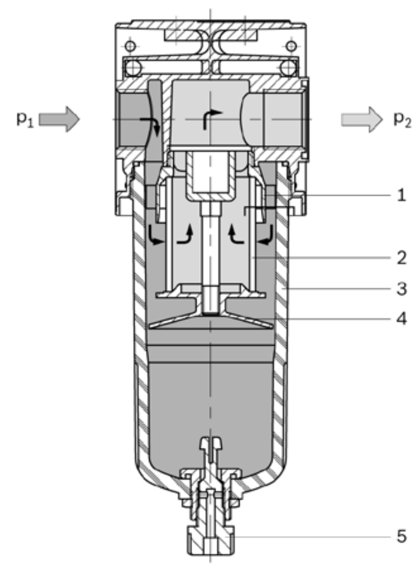


Fig. 2 Example: NL series standard filter

1 Swirling plate
2 Filter insert
3 Filter reservoir
4 Partition plate
5 Condensate drain

2.8.2 Microfilters, ultramicrofilters, and active carbon filters

The particle size is reduced to < 0.01 µm by further filtration using a microfilter (< 0.3 µm) and a downstream ultramicrofilter. A downstream active carbon filter minimizes the amount of residual oil to < 0.005 mg/m^3.

In general, filtration with a pore width of 5 µm is sufficient. The drop in pressure across the filter rises with increasing contamination of the filter insert. This drop may be displayed with a differential pressure gauge.

Metal and synthetic reservoirs, with and without protective guards, are available for various pressure ranges or areas of application.

Microfilters, ultramicrofilters, and active carbon filters are used in applications that require an extremely high level of compressed air purity.

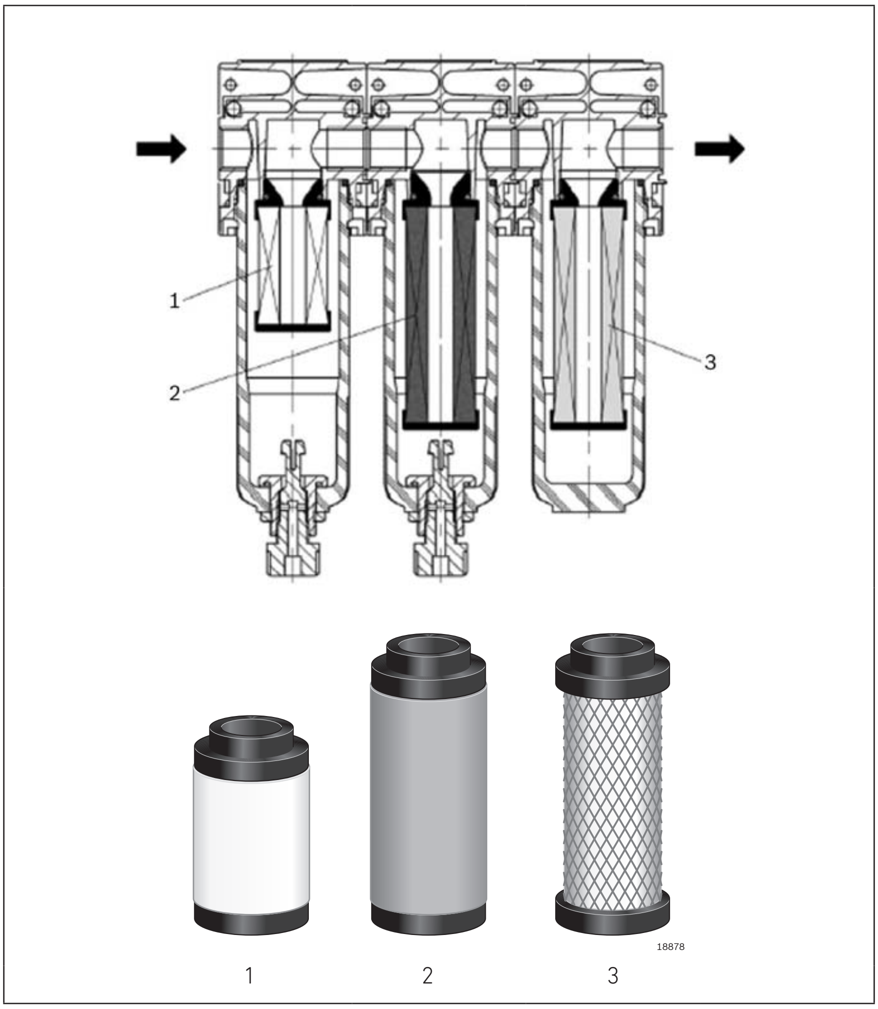


Fig. 3 Microfilters, ultramicrofilters, and active carbon element

1 Microfilter element (paper/aluminum 0.3 µm)
2 Ultramicrofilter element (aluminum borosilicate 0.01 µm)
3 Active carbon element (active carbon/aluminum)

Microfilter

For demanding compressed air purity requirements. The microfilter removes microparticles > 0.3 µm, which could easily pass through the sintered filter elements (5 µm).

The application areas of microfilters include:

- Paint spraying equipment
- Pharmaceutical industry
- Precision machinery/devices

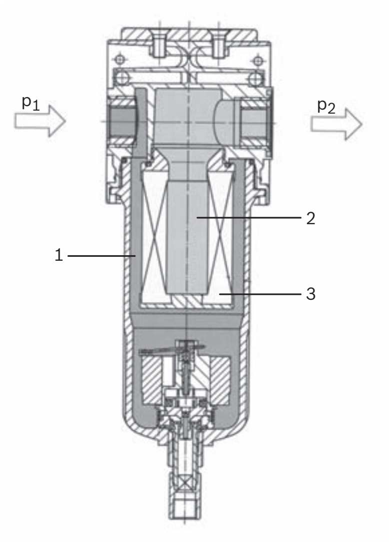


Fig. 4 Microfilter

1 Unfiltered compressed air
2 Filtered compressed air
3 Microfilter element

The filter inserts in microfilters should be changed after a pressure drop of > 0.35 bar or after one year.

Ultramicrofilter

Ultramicrofilters filter water and oil mist flowing into the filter. The finest droplets are collected in the filter material and migrate to the exterior, where they drain off. Saturation occurs with a pressure increase > 0.35 bar. When 0.35 bar is shown on the differential pressure gauge, the filter element should be replaced.

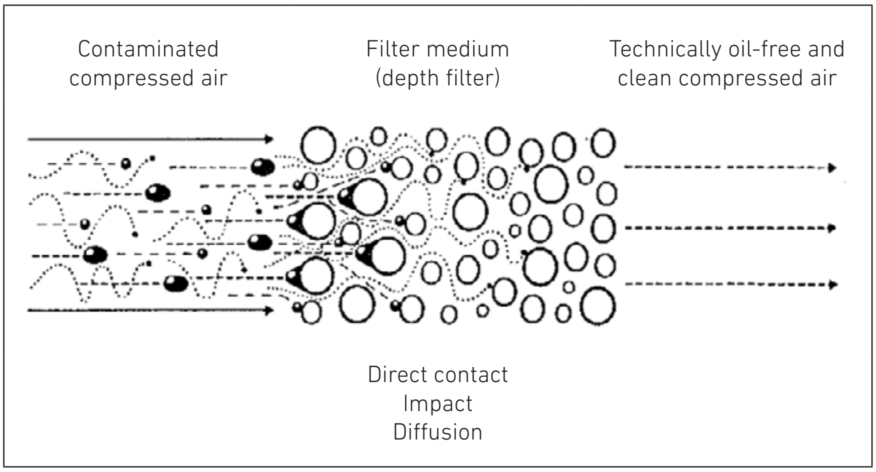


Fig. 5 Microfilter function

The application areas of ultramicrofilters include:

- Paint spraying equipment
- Food industry
- Pharmaceutical industry
- Precision machinery/devices

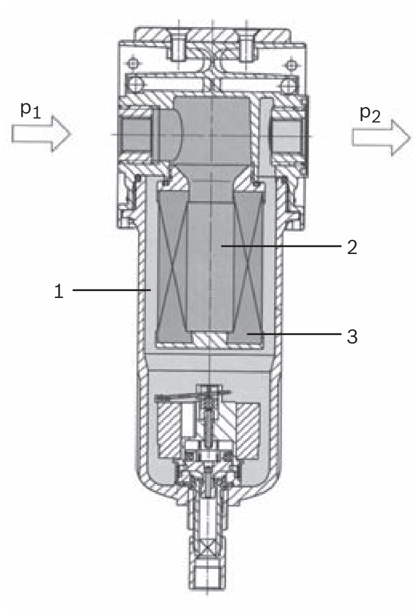


Fig. 6 Ultramicrofilter

1 Filtered compressed air
2 Unfiltered compressed air
3 Ultramicrofilter element

Active carbon filter

For filtering odors out of compressed air. The oil vapor molecules held in the compressed air are absorbed by the active carbon. Paper filters do not permit the exit of carbon particles. Saturation is not detectable.

Filters become contaminated with use and must be changed every 6 months at the latest.

This, however, is only a recommendation, since the interval depends on the quality of the compressed air and the amount of air throughput.

The application areas of active carbon filters include:

- Food industry
- Medical technology
- Pharmaceutical industry

Fig. 7 Active carbon filter

2.8.3 Differential pressure gauge for microfilters

The differential pressure gauge serves to continuously monitor the microfilters for compressed air. It monitors the filter element for critical operating conditions, such as:

- Overaging
- Excessive contamination
- Excessive differential pressure
- Pressure shocks

Fig. 8 Differential pressure gauge for microfilters, example: PG1-DIM

Fig. 9 Differential pressure gauge for microfilters, example: PG1-DIE

2.8.4 Design and function

The differential pressure gauge has two pressure chambers separated by a diaphragm, one chamber for the pressure upstream and one chamber for the pressure downstream of the filter. The differential pressure is displayed by the state of the piston connected to the diaphragm. The piston path is transferred to the scale display either magnetically (see PG1... example above) or directly as an indicator (see PG1... example above).

Note If the measurement system is subject to a pressure shock of > 1 bar, the pointer stops above the red area on the display scale. In this case:

- Check filter elements for damage and replace them if necessary
- Check the function of the differential pressure gauge and readjust it

For the AS series, a color differential pressure display can be mounted on the microfilter to monitor the differential pressure on the filter element (see following figures). The display indicates when the filter element should be changed due to impurities or oil contamination.

In the initial state, the color **green** (1) indicates the proper operating state in case of correct use.

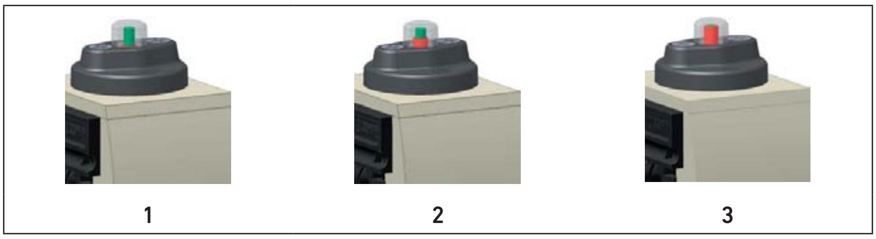


Fig. 10 Differential pressure display, example: AS series

1 Green: proper operating state

2 Green/red: filter element contaminated/oily

3 Red: contaminated

The drop in pressure rises with increasing impurities or oil contamination of the filter element. The display then changes from green (1) to gree**n/red** (2), then to red (3).

The differential pressure display covers a differential pressure range of 0.02–0.50 bar Δp.

Note The filter element should be changed before the display turns red, at least once per year.

Contamination display

Filters become contaminated with use and must be changed punctually:

- For filters with contamination displays (AS series), a red marking shows when a change is needed.
- Filters without contamination display (AS series) should be changed every 6 months (active carbon filters) or yearly (all other filters).

This is only a recommendation, since the interval depends on the quality of the compressed air and the amount of air throughput.

2.8.5 Condensate drain

The reservoir should be emptied regularly. The water level should not rise up to the partition cap. Otherwise, the separated water will be picked up again by the air flow.

Manual condensate drain

Emptying may occur during operation by turning the drain screw to open the drain valve. The outflowing air carries the collected condensate into the surroundings. Diverting the mixture into a reservoir protects both the user and the environment.

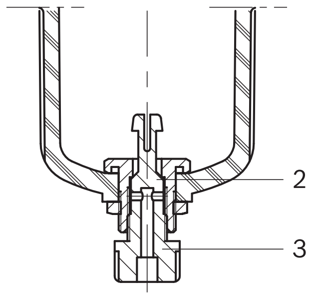


Fig. 11 Manual condensate drain

2 Drain valve

3 Drain screw

Semiautomatic condensate drain

The drain valve opens when the operating pressure in the reservoir falls below 1.5 bar. With the help of the expanding air the collected condensate is carried into the ambient air or drops to the ground. A drip reservoir prevents contamination.

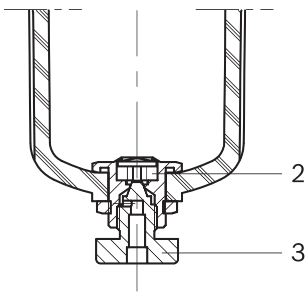


Fig. 12 Semiautomatic condensate drain

2 Drain valve

3 Drain screw

Fully automatic condensate drain

The drain valve opens automatically as soon as the floater reaches the highest point. The condensate is carried into the surrounding environment with the expanding air. The drain valve closes again when the floater reaches the lowest point.

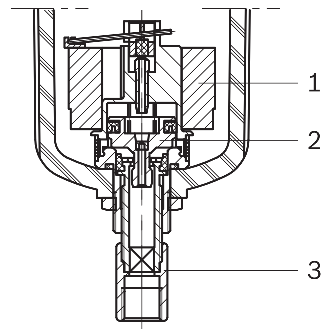


Fig. 13 Fully automatic condensate drain

1 Floater
2 Drain valve
3 Drain screw (a restricted condensate drain can be retrofitted on a G 1/8 drainage connection)

The condensate drain valve is available in two versions:

- **NO version**
  With no pressure on the reservoir, the piston (4) is held in the open position by the pressure spring (6). When pressure is applied to the reservoir, the piston at the collar (5) closes the drain opening at 1.5 bar or above.

  Use:

  - With high levels of condensate
  - When compressed air is seldom switched off
  - When no condensate should remain in the reservoir after pressure is switched off

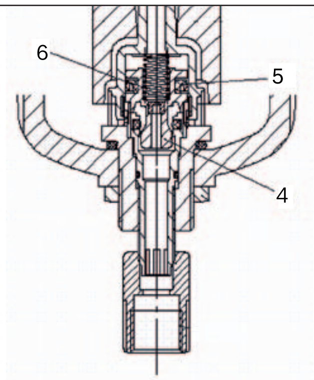


Fig. 14 Condensate drain, NO version

4 Piston
5 Collar
6 Pressure spring

- **NC version**
  With no pressure on the reservoir, the piston (4) is held in the closed position by the pressure spring (7).

  Use:

  - With high levels of condensate
  - When compressed air is seldom switched off
  - With very gradual pressure accumulation, e.g. due to low compressor power or a heavy load on the compressed air system

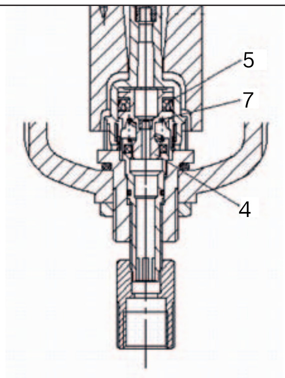


Fig. 15 Condensate drain, NC version

4 Piston
5 Collar
7 Pressure spring

2.9 Diaphragm-type dryer

The damp compressed air flows through the central tube and the diaphragm. A portion of the steam is diffused through the diaphragm material. Before the dried compressed air exits the device, the so-called scavenging air expands in the area in which the diaphragm outer wall is located. The scavenging air carries the diffused steam into the atmosphere via the scavenging air outlet holes.

This process of regeneration is dependent on pressure, volume flow, entry temperature, and diaphragm surface (parallel connection of diaphragm-type dryers).

A pre-filter and ultramicrofilter (< 0.01 µm) are added upstream of the diaphragm-type dryer in order to clean the compressed air of particles, liquids, and oils before drying.

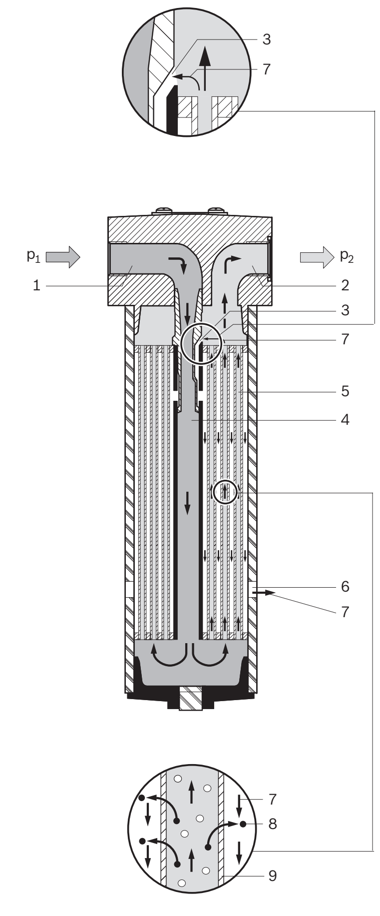


Fig. 16 Diaphragm-type dryer, example: NL series

1 Damp compressed air
2 Dry compressed air
3 Scavenging nozzle
4 Central tube
5 Diaphragms
6 Diaphragm scavenging outlet holes
7 Purge air
8 Steam
9 Diaphragm material

Use:

- To lower the pressure dew point
- To reduce the water content in the compressed air

2.10 Pressure regulator

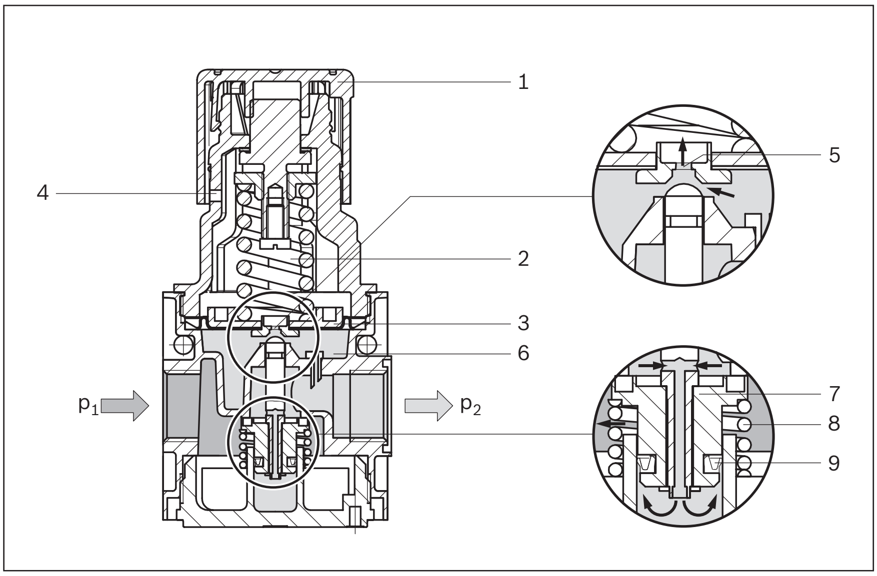


Fig. 17 Example shown is the NL series

1 Setting knob
2 Pressure spring
3 Spring seat with bead diaphragm
4 Secondary air exhaust outlet hole
5 Secondary air exhaust hole
6 Secondary pressure chamber
7 Valve cone
8 Counter pressure spring
9 Non-return valve (lip seal)

The pressure regulator valve reduces the operating pressure p_1 to the set secondary pressure p_2 and holds it constant to a large extent, independent of the operating pressure fluctuations Δp_1 and the secondary pressure loads p_2. The input pressure must not fall below the set value. These disturbance variables become less important as the difference between operating pressure p_1 and secondary pressure p_2 increases.

Increased secondary pressures p_2 are relieved to a limited extent via the secondary exhaust system (secondary pressure chamber, secondary air exhaust hole, and secondary air exhaust outlet hole). If operating pressure p_1 is non-existent, the system is ventilated via the non-return valve (lip seal) integrated in the valve cone.

2.10.1 Relieving exhaust

The pressure regulator has two secondary relieving exhaust functions.

Function: Relieving exhaust

Input pressure p_1 constant.

From a pressure increase of approx. 0.3 bar, the relieving exhaust corresponds to set pressure P_2.

Exhaust is performed via small exhaust holes under the handwheel.

Function: Exhaust p_2 via main seal/input P_1

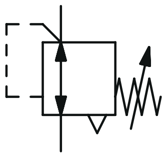
Input pressure on p_1 is exhausted.

The installed lip ring is filled with air starting at a differential pressure of $p_2 - p_1 \geq 1$ bar. As soon as the current pressure p_2 0.1 – 0.5 bar (depending on system) falls below the set pressure p_2, the main seal opens (for readjustment) and p_2 is exhausted via the main seal.

Note The time required to open the main seal depends on pressure p_2 and the available exhaust volumes.

The greater the differential pressure $p_2 - p_1$ and the smaller the volume to be exhausted for p_2, the smaller the opening of the main seal or the "exhaust".

2.11 Pressure regulator with continuous pressure supply



On the pressure regulator with continuous pressure supply, the regulated secondary pressure p_2 is discharged downward. The operating pressure p_1 provides an additional pressure supply.

Fig. 18 Unilateral pressure supply

Fig. 19 Continuous (bilateral) pressure supply

2.12 Precision pressure regulator

A precision pressure regulator has the same basic function as a pressure regulator (see „2.10 Pressure regulator"), but has more complex regulator constructions, such as a larger, metallically sealing exhaust hole and other sealing materials. These measures result in a better regulation.

Compared with standard pressure regulators, precision pressure regulators have the following additional features:

- Metallically sealing secondary air exhaust seal with greater exhaust capacity and early opening of the relieving exhaust in case of p_2 pressure increase
- Internal air consumption
- Extremely low hysteresis
- Extremely low pressure loss during flow
- Excellent responsive sensitivity of relieving exhaust (≤ mbar)
- Greater relieving exhaust capacity
- Restricted exhaust via R connection

2.13 Filter pressure regulator

The filter pressure regulator is a compact unit for the reduction of existing system pressure to a maximum, controlled pressure while coarsely filtering the compressed air.

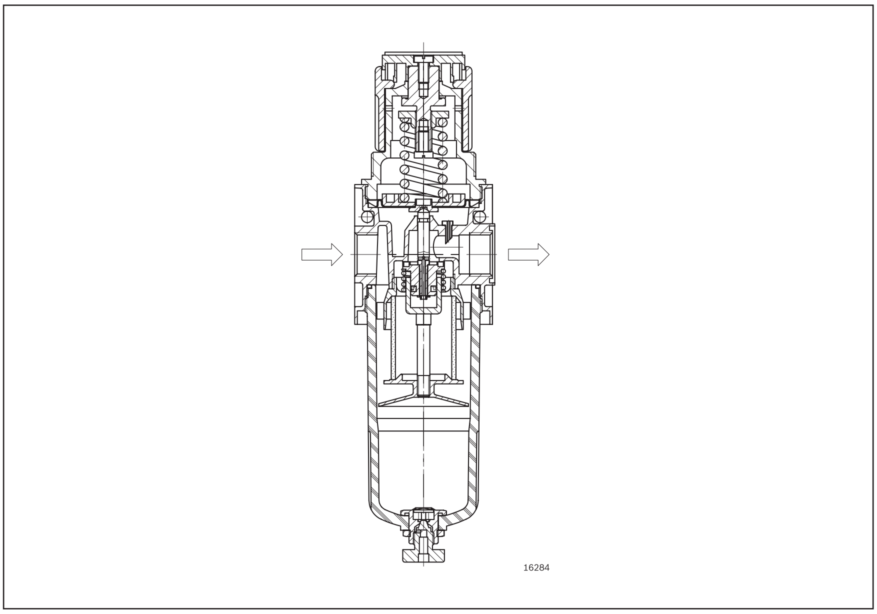


Fig. 20 Filter pressure regulator

2.14 Pressure gauge

Pressure measurement devices (pressure gauges) are used to measure and display the physical pressure. There are three different measuring types:

- Relative pressure gauges (measures the relative pressure in relation to the air pressure)
- Absolute pressure gauges with vacuum as a reference pressure
- Differential pressure gauges (difference between any two pressures)

Based on the measuring principle and technical dimensioning, a differentiation can be made between the following pressure gauge types:

Direct pressure gauges

- Piston pressure gauges
- Fluid pressure gauges

Indirect pressure gauges
Measuring instruments with spring-loaded measurement element

- Bourdon tube pressure gauge
- Diaphragm pressure gauges (with diaphragm spring)

Absolute and differential pressure gauges

- Diaphragm pressure gauge
- For differential pressure measurement for prefilters and ultramicrofilters
- Flange version

Special pressure measurement devices

- Barometer
- Pressure sensors

2.14.1 Bourdon tube pressure gauge

Bourdon tube pressure gauges are pressure gauges whose measurement element consist of a radial, spiral, or helical spring tube. During pressurization, the spring tube bends upward. The fixed end of the spring performs a movement that is a measurement for the pressure. A pointer indicates this movement. Bourdon tube pressure gauges are the most common pressure gauges.

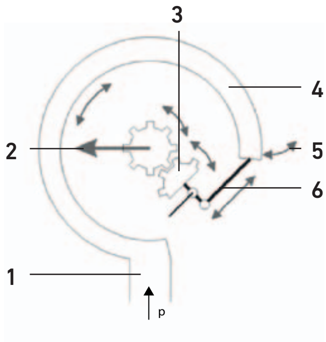


Fig. 21 Bourdon tube pressure gauge schematic diagram

1 Spring tube connection
2 Pointer
3 Toothing
4 Spring tube
5 Spring tube extension
6 Tie rod

Features:

- Possible measurement range: Vacuum up to 10^{-6} bar (fused quartz spring tubes), 0.6–60 bar (radial springs), 60–1000 bar (spiral springs), and up to 4000 bar (helical springs)

Advantages:

- Variable adjustment to the measurement range through the form of the spring tube and by varying the tube thickness, the tube cross-section geometry, and the spring tube material

Disadvantages:

- Spring tubes can only be protected against overload to a limited extent.

2.14.2 Diaphragm pressure gauges

Diaphragm pressure gauges have radial, corrugated diaphragms that are either fixed at the edge between two flanges or welded and supplied with compressed air from one side. The resulting deflection is used as a measurement for pressure and displayed via a pointer.

Features:

- The possible measurement range is between 16 mbar and 40 bar.

Advantages:

- Highly robust, high overload capacity compared to common tube spring gauges
- Large selection of materials possible

Disadvantages:

- Based on the short spring path (approx. 1.5 mm), they have a comparably low precision of only 1.6%.

2.14.3 Accuracy classes

The accuracy class corresponds to the margin of error for the displayed scale end value in percent.

Therefore, a class 4 measurement precision means that the pressure gauge for the range of 10 bar in the entire measurement range must not deviate by more than ± 4% (± 0.4 bar).

Accuracy class	Maximum permissible deviation in percent
0.1	± 0.1%
0.25	± 0.25%
0.6	± 0.6%
1	± 1%
1.6	± 1.6%
2.5	± 2.5%
4	± 4%

Table 7 Accuracy class

2.14.4 Diaphragm pressure gauge for differential pressure measurement

The differential pressure gauge serves to continuously monitor the microfilters for compressed air. It monitors the filter element for critical operating conditions, such as:

- Overaging
- Excessive contamination
- Excessive differential pressure
- Pressure shocks

Design and function

The differential pressure gauge has two pressure chambers separated by a diaphragm, one chamber for the pressure upstream and one chamber for the pressure downstream of the filter. The differential pressure is displayed by the state of the piston connected to the diaphragm. The piston path is transferred to the scale display either magnetically or directly as an indicator.

2.15 Lubricator

AVENTICS products come with an initial lubrication and may be operated with oil-free compressed air. In general, no further lubrication is required. Using oiled compressed air washes out the drive's initial lubrication. In such cases, lubricated compressed air should always be used thereafter in order to guarantee the basic lubrication of the drive. Larger amounts of oil lead to overlubrication of the system, which causes a swelling of the sealing elements and considerably reduces service life. For reasons of environmental protection, oil-free operation should be the goal.

The use of lubricators is necessary under the following conditions:

- For the operation of steel spool valves and compressed air tools
- At high operating speeds > 1.5 m/s
- Whenever required by connected system components or system documentation

Lubricators are maintenance unit components. They are used to regulate oil release to the compressed air. The lubricator should always be installed vertically near the consumer and in the direction of flow. The amount of oil used can be replaced even when the system is under pressure.

Metal and synthetic reservoirs, with and without protective guards, are available for various pressure ranges or areas of application. A sensor with reed contact can be connected for external electrical level detection.

Note If oil is necessary, 1 to 2 drops of oil per m^3 air (standard oil-mist lubricator) or 10 to 20 drops per m^3 air (micro oil-mist lubricator) should be sufficient. Mineral oils are customary, such as HLP oils in accordance with DIN 51524 Part 2. Standard oil-mist lubricators permit refilling of oil during normal operation.

Application	Flash point Min. [°C]	Pour point Min. [°C]	Density at 15°C [g/cm^3]	Viscosity class	Kinematic viscosity at [°C]	Kinematic viscosity [cSt]
In building	240	-24	0.88	ISO VG 68	40	68
In winter temperatures (low-viscosity oil)	188	-42	0.87	ISO VG 32	40	35.9

Table 8 AVENTICS recommends the oils named in the table

2.15.1 Standard oil-mist lubricator

Flow resistance (retention shutter) leads to a pressure drop $p_{1,2}$, which changes in proportion to the volume flow. The pressure differential affects the oil in the reservoir (primary through hole) and transports it via the oil suction tube into the metering cone. The amount of oil is set using the metering screw. This oil is then fed to the discharging compressed air p_2.

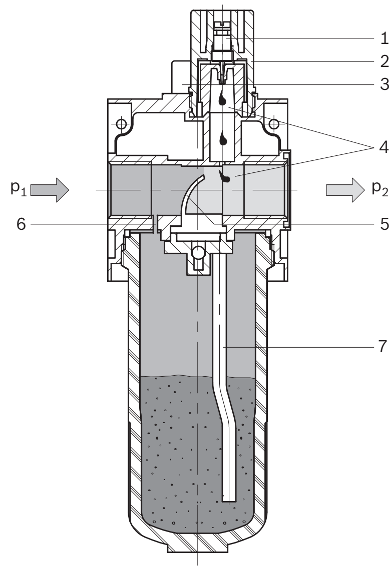


Fig. 22 Standard oil-mist lubricator, example: NL series

1 Metering screw
2 Metering cone
3 Refill screw
4 Oil drops
5 Retention shutter
6 Primary through hole
7 Oil suction tube

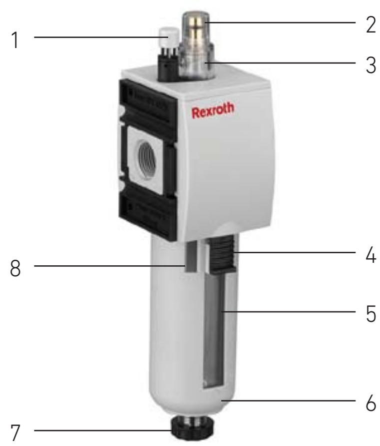


Fig. 23 Oil-mist lubricator components, AS series

1 Control button for automatic oil filling
2 Metering screw for the desired oil quantity
3 Inspection glass (lubricator dome) for oil drop recognition
4 Reservoir unlocking
5 Plastic reservoir/window
6 Protective guard
7 Connection thread for automatic oil filling
8 Maximum filling level

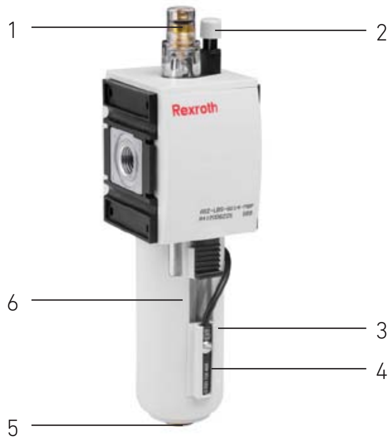


Fig. 24 Oil-mist lubricator with ST4 sensor for oil filling level monitoring, AS series

1 Metering screw for the desired oil quantity
2 Control button for automatic oil filling
3 Mounting element for sensor
4 Reed sensor, example: ST6 series
5 Connection for compressed air tubing for automatic oil filling
6 Oil reservoir with floating magnet to measure the filling level via a sensor

2.15.2 Micro oil-mist lubricator

The basic functions "flow resistance, oil transport, and oil metering" are identical on standard and micro oil-mist lubricators. The micro oil-mist lubricator has an additional Venturi insert as well as an impact plate which atomizes the oil into the smallest drops possible. The oil mist (approx. 10% of the transported oil amount) is sucked into the discharging compressed air p_2 via the secondary through hole.

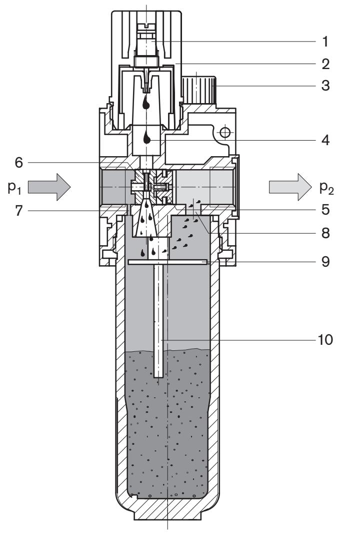


Fig. 25 NL series micro oil-mist lubricator

1 Metering screw
2 Metering cone
3 Refill screw
4 Oil drops
5 Retention shutter
6 Venturi insert
7 Primary through hole
8 Secondary through hole
9 Impact plate
10 Oil suction tube

2.16 3/2 directional shut-off valve

The 3/2 directional shut-off valve is available in mechanically, electrically, and pneumatically operated versions.

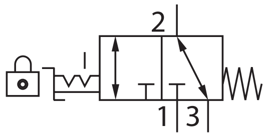
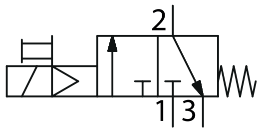
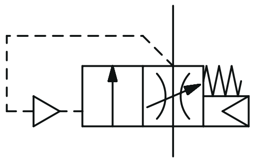
Wiring diagram	3/2 directional shut-off valve
	Mechanically operated
	Electrically operated
	Pneumatically operated

Fig. 26 SOV-...-024 3/2 directional shut-off valve, AS1 series, electrically operated

1 Socket coupling with electrical connection DIN 43 650, form C, alternatively with M12x1

2 Pilot valve, series DO16,
adapter available for DO30, e.g. for automotive applications

3 Exhaust port G1/4 (for silencer or connector for restricted exhaust)

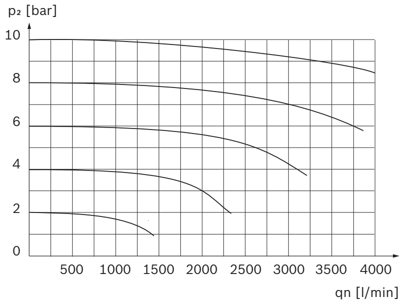
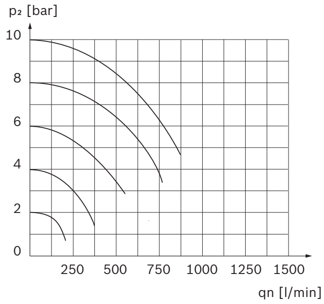
<table>
<tr><th colspan="2">Mechanical/ball valve</th></tr>
<tr><td>Flow rate 1 – 2:
2,600 std l/min</td><td>Flow rate 2 – 3 (bottom):
310 std l/min</td></tr>
<tr><td>
</td><td>
</td></tr>
</table>

Table 9 Mechanical flow rates

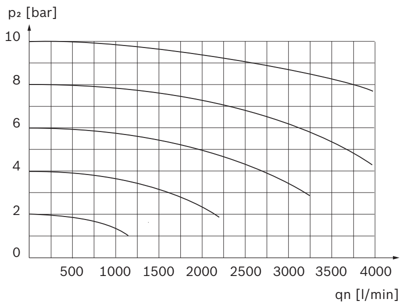
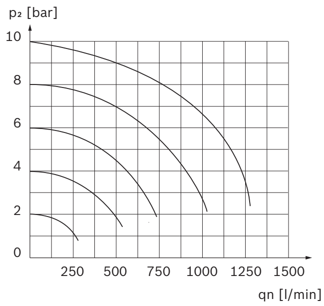
<table>
<tr><th colspan="2">Electrical, pneumatic</th></tr>
<tr><td>Flow rate 1 – 2:
2,000 std l/min</td><td>Flow rate 2 – 3 (bottom):
380 std l/min</td></tr>
<tr><td>
</td><td>
</td></tr>
</table>

Table 10 Electrical, pneumatic flow rates

2.17 Filling valve/filling unit

A filling valve gradually increases the operating pressure p_2 to 50% of p_1. Once 50% of p_1 bar is achieved, the complete operating pressure p_1 set via the controller is switched on fully. This prevents a sudden pressure build-up during a restart after a mains pressure failure or avoids emergency OFF switching, and thus dangerous, jerky cylinder movements.

The picture to the left shows the version with adjustable change-over pressure. Variants with adjustable filling time and change-over pressure are also available.

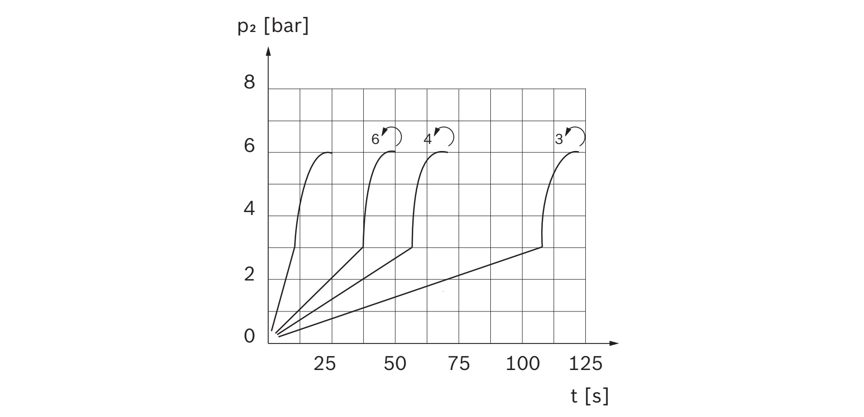


Fig. 27 Adjustable filling time

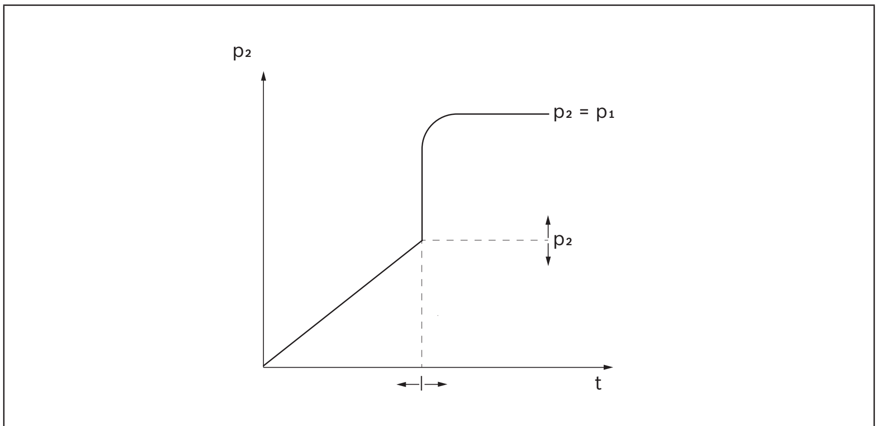
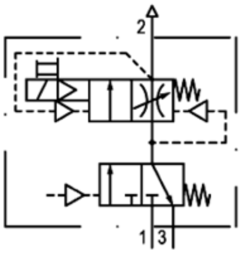


Fig. 28 Adjustable filling time and change-over pressure



2.17.1 Filling unit

The filling unit combines the filling valve with an electrically or pneumatically operated 3/2 directional shut-off valve.

Filling valve/filling unit with electrical priority circuit

Actuating the electrical priority circuit disrupts the slow pressure build-up and pressure p_1 is immediately applied.

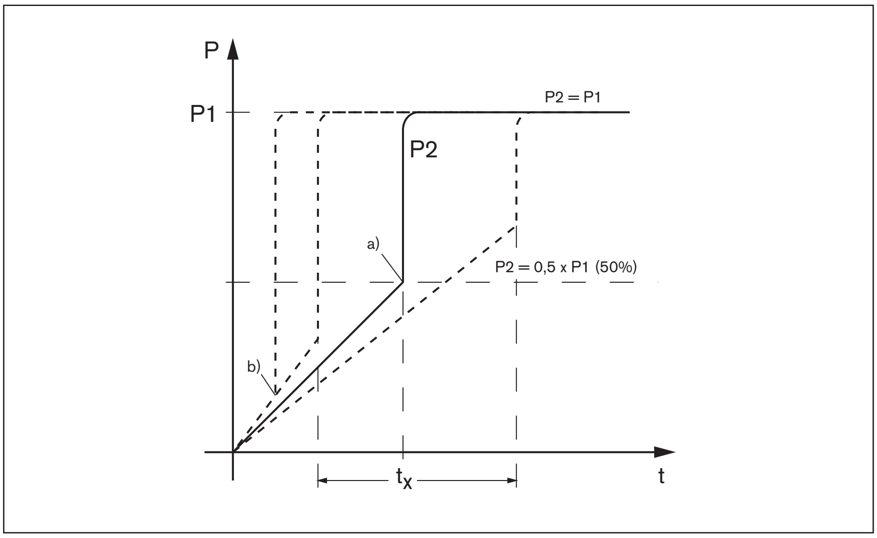


Fig. 29 Characteristic curve for SVV filling valve with electrical priority circuit (P2 = outlet pressure, t_x = adjustable fill time, a = switching point, b = electrically triggered switching point)

2.18 Distributor

Distributors are used to distribute compressed air. They also permit the connection of a pressure switch. Variants with different numbers of air ports are available for all series.

2.19 Non-return valve

Mounted between filter and lubricator, the non-return valve prevents oiled air from flowing back into the air filter in the event of a pressure drop upstream of the maintenance unit.

The AS3 series is shown in the figure on the left and the diagrams.

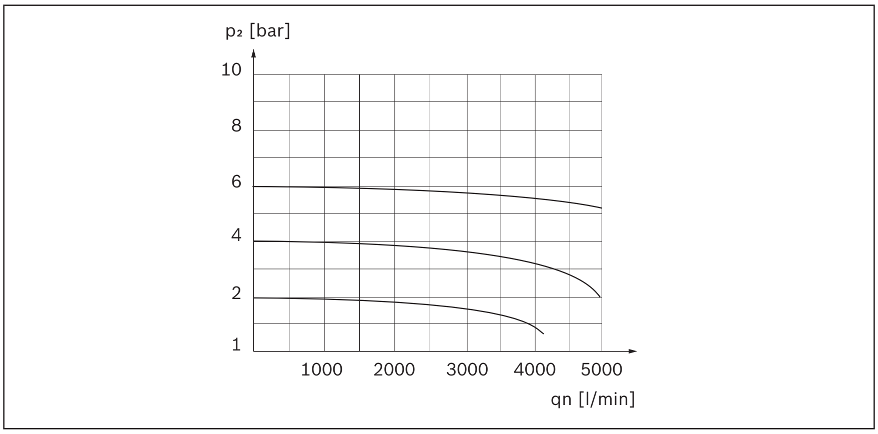


Fig. 30 AS3 series, nominal flow 1->2

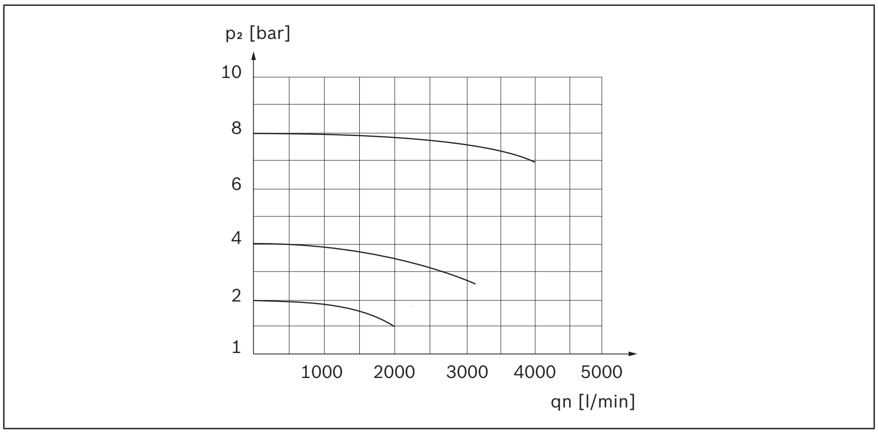
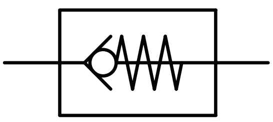


Fig. 31 AS3 series, nominal flow 1->3



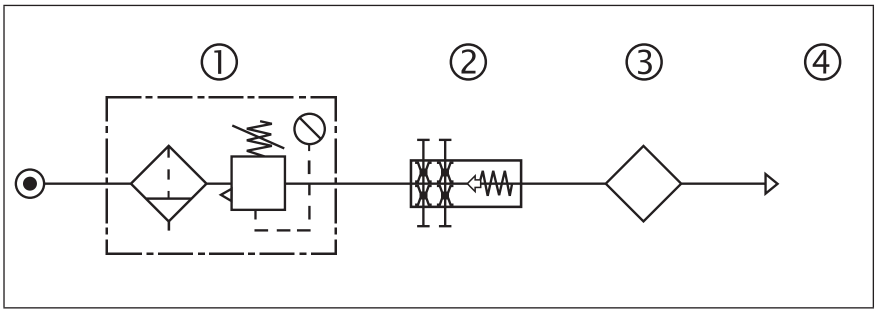


Fig. 32 Example of use and installation of a distributor with non-return valve

1	Filter pressure regulator	3	Lubricator
2	Non-return valve	4	Compressed air

3 Products

3.1 Product overview

From simple standard to user-specific solutions with the highest demands on compressed air quality. The AS, NL, PR1, MH1, and MU1 series are available for compressed air preparation.

	Series	Nominal flow	Connections	Filter porosity	Component width
	**AS1**[1]	1000 l/m	G 1/4	0.01 – 5 µm	43 mm
	AS2[1]	2200 – 2700 l/m	G 1/4 – G 3/8 1/4 NPT – 3/8 NPT	0.01 – 40 µm	52 mm
	AS3[1]	1600 – 5200 l/m	G 3/8 – G 1/2 3/8 – 1/2 NPT	0.01 – 40 µm	63 mm
	AS5[1]	14500 l/m	G 3/4 – G 1 3/4 NPT – 1 NPT	0.01 – 40 µm	85 mm
	**NL1**[1]	1000 l/m	G 1/8 – G 1/4	0.01 – 5 µm	40 mm
	NL2	1500 – 2000 l/m	G 1/4 – G 3/8	0.01 – 40 µm	45 mm
	NL4[1]	5600 – 6000 l/m	G 1/2 – G 3/4	0.01 – 40 µm	66 mm
	NL6[1]	12500 l/m	G 3/4 – G 1	0.01 – 40 µm	100 mm
	**PR1**	480 – 5600 l/m	G 1/4 – G 1/2	10 µm	—
	**MH1**	510 – 3000 l/m	G 1/4 – G 1/2	0.01 – 5 µm	35.8 mm
	**MU1**	300 – 50000 l/m	G 1/2 – G 2	8 – 60 µm	—

[1] Also available with active carbon filter

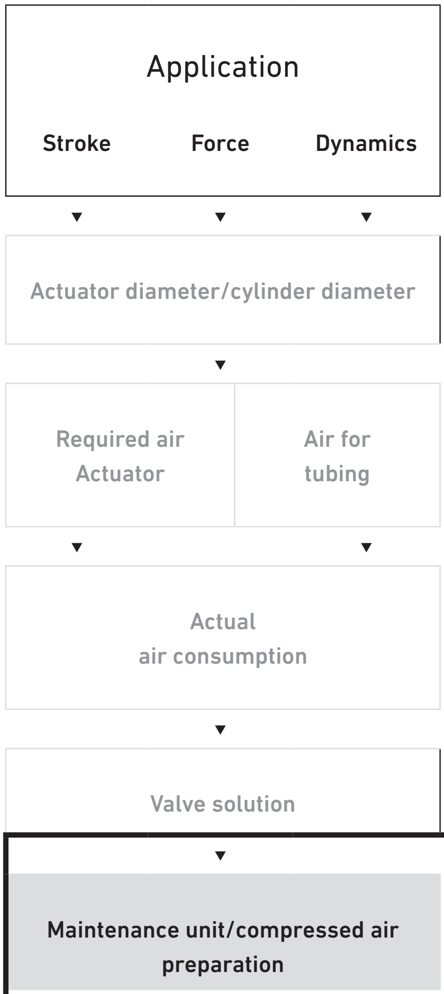
Table 11 Series and technical data in comparison

3.2 Product selection

Individual devices may be installed on the basis of the modular assembly system. Individual devices can be combined within a product range and threaded port size.

3.2.1 General procedure for selecting components for compressed air preparation

Finding a suitable air preparation solution is the last step in planning your system.



The application requirements determine the actuator and stroke. The required force and dynamics impact the cylinder diameter.

Observe pressure drop in overall system!
Selection and dimensioning
- **Online tool**

Calculation of air requirements for the overall configuration
- **Online tool**

Single valve/valve system, decentral or central, component selection and dimensioning
- **Online tool**

Assurance of air quality according to the required class for the application. Component selection and dimensioning
- **Online tool**

Note The required compressed air quality according to ISO 8573-1 2010 is the decisive factor here!

3.2.2 Selection of suitable series according to the general requirement profile

The individual series have strengths depending on the requirement profile.

Series Requirement	AS	NL	MU	PR
Functionality	++	++	+	+
Component variety	++	++	– –	– –
Modularity	++	++	– –	– –
Flow rate	++	+	++	o
Robustness	+	++	++	+
Lightweight	++	–	– –	–
Easy-to-service	++	+	+	+
Temperature range	+	++	++	+
Modern design	++	o	–	o
Energy efficiency	++	+	o	++

Table 12 Selection matrix for AS, NL, MU, and PR series

++ Highly recommended
+ Recommended
o Suitable
– Less suitable
– – Not suitable

Note The MH1 series (not shown) is designed primarily for use in areas with stringent requirements for corrosion resistance and hygiene (see „3.2.7 MH1 series“).

3.2.3 Maximum achievable compressed air classes

The following table lists the maximum possible compressed air classes with reference to the content of the air as per ISO 8573-1 2010.

Filter	Solid pollutants	Moisture (vaporous)	Total oil content	Sterile
40 µm	7 : – : –	– : 7 : –		
25 µm	7 : – : –	– : 7 : –		
5 µm	6 : – : –	– : 7 : –		
0.3 µm	2 : – : –		– : – : 3	
0.01 µm	1 : – : –		– : – : 2	
Active carbon filter			– : – : 1	Yes
Diaphragm-type dryer		– : 2 : –		

Table 13 Maximum possible compressed air classes with filter and dryer units

Example Basic conditions

- Compressed air generation with air refrigeration dryers – pressure dew point approx. 3°C
- Compressed air quality class from compressed air generation (-:5:4)

Compressed air mains

(-:5:4)	-	1	2	-	-	-	-	-	(6:5:4)
(-:5:4)	-	1	2	3	4	5	-	-	(1:5:1)
(-:5:4)	-	1	2	3	4	5	6	-	(1:4:1)

1 On-off valve
2 Filter regulator 5 µm
3 Pre-filter 0.3 µm
4 Ultramicrofilter, 0.01 µm
5 Active carbon filter
6 Diaphragm-type dryer

Note When using diaphragm-type dryers, the pressure dew point and the compressed air class from the compressed air mains (generator) are decisive.

Diaphragm-type dryer enable a reduction of max. 20°C.

Functional compressed air preparation depends on the following measures:

- Suitable arrangement of the filters considering the respective application
- Regular change intervals for the filter elements

Maintenance unit/component	Resulting class acc. to ISO 8573-1 2010			
	Solid pollutants	Humidity (vaporous form)	Total oil content	Sterile
AS series				
Maintenance unit, 2-part	6 : – : –	– : 7 : –	– [1]	
Maintenance unit, 3-part	6 : – : –	– : 7 : –	– [1]	
Filter pressure regulator				
• 40 µm	7 : – : –	– : 7 : –	– [1]	
• 25 µm	7 : – : –	– : 7 : –	– [1]	
• 5 µm	6 : – : –	– : 7 : –	– [1]	
Filter				
• 40 µm	7 : – : –	– : 7 : –	– [1]	
• 25 µm	7 : – : –	– : 7 : –	– [1]	
• 5 µm	6 : – : –	– : 7 : –	– [1]	
Microfilter, 0.3 µm	2 : – : –	– [1]	– : – : 3	
Ultramicrofilter, 0.01 µm	1 : – : –	– [1]	– : – : 2	
Active carbon filter	– [1]	– [1]	– : – : 1	Yes
Diaphragm-type dryer	– [1]	– : 2 : –	– [1]	
NL series				
Maintenance unit, 2-part	6 : – : –	– : 7 : –	– [1]	
Maintenance unit, 3-part	6 : – : –	– : 7 : –	– [1]	
Maintenance unit, 4-part	1 : – : –	– [1]	– : – : 2	
Filter				
• NL 1 – NL 4 = 5 µm	6 : – : –	– : 7 : –	– [1]	
• NL 6 = 40 µm	7 : – : –	– : 7 : –	– [1]	
Microfilter, 0.3 µm	2 : – : –	– [1]	– : – : 3	
Ultramicrofilter, 0.01 µm	1 : – : –	– [1]	– : – : 2	
Active carbon filter	– [1]	– [1]	– : – : 1	Yes
Filter pressure regulator				
• NL1 – NL4, 5 µm	6 : – : –	– : 7 : –	– [1]	
• NL6, 8 µm	7 : – : –	– : 7 : –	– [1]	
• NL5, 40 µm	7 : – : –	– : 7 : –	– [1]	
PR1 series				
Precision filter pressure regulator, filter porosity 10 µm	7 : – : –	– : 7 : –	– [1]	
MU1 series				
Filter pressure regulator, 40 µm	7 : – : –	– : 7 : –	– [1]	
Filter				
• 40 µm	7 : – : –	– : 7 : –	– [1]	
• 8 – 60 µm	7 : – : –	– : 7 : –	– [1]	
MH1 series				
Filter pressure regulator, 5 µm	6 : – : –	– : 7 : –	– [1]	
Filter, 5 µm	6 : – : –	– : 7 : –	– [1]	
Microfilter, 0.01 µm	1 : – : –	– : – : 2	– [1]	
Active carbon filter	– [1]	– [1]	– : – : 1	Yes

[1] Class is not affected by component

Reference conditions: 1 bar absolute, 20°C, 0% r.h.

Table 14 Overview of the possible compressed air class with AVENTICS maintenance units and components

3.2.4 AS series

	Series	Flow rate [l/min]	Width [mm]
	**AS1**	1,000	43
	**AS2**	2,600	52
	**AS3**	4,500	63
	**AS5**	14,500	85

Table 15 AS series overview

The maintenance units in the AS family not only perform the standard functions of filtering, regulation, and lubrication, they also allow for the integration additional function units such as shut-off valves, filling valves, distributors, and non-return valves. The components can be combined, providing for the best solution for compressed air preparation for the respective pneumatic system.

Characteristics

- Working range up to a flow of 14,500 std l/min
- No block widths
- Light and robust thanks to the use of premium polymers
- High performance data and flexibility
- Optimized condensate drain valves ensure increased energy efficiency
- Easier exchange of individual components and subsequent expansion (including when installed)
- With the appropriate ATEX equipment, these maintenance units can also be used in explosive areas
- Reduced maintenance effort
- Modular concept enables custom, branch-specific configuration

Individual components and functions

- Semi or fully-automatic condensate drain valves
- Finely-tuned filter pore widths for all applications
- Contamination display for prefilter and ultramicrofilter
- Patented system for semi-automatic oil filling
- Capacity monitor for oil
- Reservoir made of transparent PC polymer with PA protective guard as standard
- Easy reservoir release via a bayonet catch
- Large inspection windows
- Optional metal reservoir with inspection glass
- Smooth polymer surfaces can withstand cleaning
- ATEX approval

Individual devices may be installed on the basis of the modular assembly system. Any combination of series sizes with transition plates is possible.

	AS1	AS2		AS3		AS5	
	G 1/4	G 1/4	G 3/8	G 3/8	G 1/2	G 3/4	G 1
Maintenance unit, 2-part	●	●	●	●	●	●	●
Maintenance unit, 3-part	●	●	●	●	●	●	●
Pressure regulator	●	●	●	●	●	●	●
• With E11 locking	●	●	–	–	●	–	–
• with continuous pressure supply	●	●	●	●	●	–	–
Filter pressure regulator, 5 µm	●	●	●	●	●	●	●
• 25 µm	–	●	●	–	●	●	●
• 40 µm	–	●	●	●	●	●	●
• With E11 locking	●	●	–	–	●	–	–
Precision pressure regulator	–	●	●	●	●	–	–
• With E11 locking	–	●	–	–	●	–	–
• with continuous pressure supply	–	●	●	●	●	–	–
Filter – 5 µm	●	●	●	●	●	●	●
• 25 µm	–	●	–	–	●	●	●
• 40 µm	–	●	●	●	●	●	●
Microfilter, 0.3 µm	●	●	●	●	●	●	●
Ultramicrofilter, 0.1 µm	●	●	●	●	●	●	●
Active carbon filter	●	●	●	●	●	●	●
Diaphragm-type dryer	–	–	●	–	●	–	–
Micro lubricator	●	–	–	–	–	–	–
Oil-mist lubricator	–	●	●	●	●	●	●
Filling unit	●	●	●	●	●	●	●
• With electrical priority circuit	–	●	–	–	●	–	●
3/2 directional valve	●	●	●	●	●	●	●
• With switching position monitoring	–	–	–	●	●	–	–
• Electrical connection: M12x1	–	–	–	–	–	–	●
3/2 shut-off valve	●	●	●	●	●	●	●
Filling valve	●	●	●	●	●	●	●
• Adjustable filling time and change-over pressure	–	●	–	●	●	–	–
• With electrical priority circuit	–	●	–	●	●	●	●
Distributor	●	●	●	●	●	●	●
• Center infeed	–	●	–	–	●	–	–

● = connection, – = no connection

Table 16 Combination options for AS series

3.2.5 NL series

	Series	Flow rate [l/min]	Width [mm]
	**NL1**	600	40
	**NL2**	1,500	45
	**Nl4**	5,600	66
	**NL6**	12,500	100

Table 17 NL series overview

The NL family features a particularly robust maintenance unit concept with high flexibility and modularity. These units can deal with the most difficult ambient conditions and are reliable and precise.

Characteristics

- NL series maintenance units cover the entire working range up to a flow of 11000 std l/min.
- Robust component versions with longer service life
- Thread connections of 1/8 to 1" possible
- Filter components with a pore width of up to 0.01 µm available
- Nominal pressure up to 16 bar
- Easy-to-assemble under all conditions
- Manual, semi-automatic or fully-automatic condensate drain

Individual components and functions

- Components can optionally be equipped with clear reservoirs made of plastic or metal reservoirs
- Bayonet catches for easy handling
- Differential pressure display for microfilters

Any combinations of the individual devices within a model series and threaded port size is possible in the modular system. Additionally, the following threaded port sizes of the ranges NL2 or NL4 can be combined:

3.2.6 PR1 series

The precision pressure regulators in the PR1 series are ideal for applications that demand fast responses to the slightest fluctuation in compressed air.

They can be adjusted exactly and are a good alternative to electronic pressure regulators.

Precision pressure regulator PR1

	Series	G 1/4	G 3/8	G 1/2
	Precision pressure regulator, mechanically operated			
	• 480 l/m	●	–	–
	• 3000 l/m	●	–	–
	• 5600 l/m	●	●	●
	Precision pressure regulator, pneumatically operated			
	• 5600 l/m	–	–	●
	• 5600 l/m, cold-resistant	–	●	●
	Precision filter pressure regulator	●	–	–

Table 18 Connection sizes for PR1

Mechanically operated

The PR1 is a precision pressure regulator with internal air consumption.

The regulator has a metallic bearing, with the advantage that there are no breakaway moments from a seal. Unlike with other regulators, this prevents the flow characteristic curve from fluctuating at the beginning. A disadvantage of the metallic seal is the resulting internal air consumption.

The regulator actually consists of two regulators. Instead of one powerful spring with a very large handwheel above the bottom diaphragm, a further regulator is installed above the diaphragm to control the pilot air on this diaphragm.

This design reduces the force on the handwheel and enables the use of relatively small control springs with a small handwheel that forward the pressure to the primary diaphragm. As a result, regulators with a large surfaces can also be controlled with small forces. Very fine adjustment with two fingers is possible.

It has the following features:

- Extremely low hysteresis
- Extremely low pressure loss during flow
- Metal secondary air exhaust seal enables early opening of secondary air exhaust with pressure surge to p_2
- High relieving exhaust capacity

Pneumatically operated

Characteristics of the pneumatically operated version:

- Rapid exhaust of p_2 when p_1 is disabled
- Excellent responsive sensitivity of secondary air exhaust (≤ 10 mbar)
- Restricted exhaust via R connection G 3/8 (NW 6 mm)
- Various possibilities for control operation:
  - Purely pneumatic
  - Pneumatic and manual fine adjustment (1 bar)
  - Pneumatic and manual adjustment (6 bar)

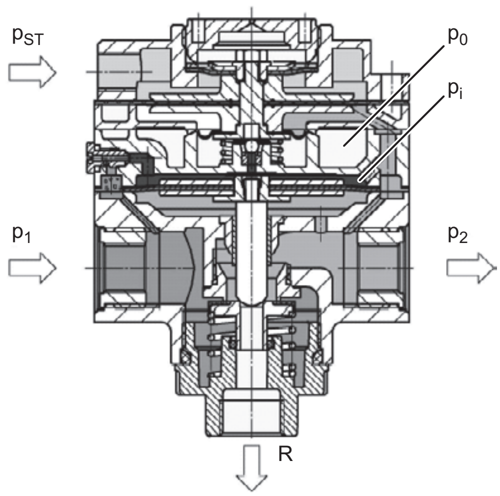


Fig. 33 Pneumatically operated precision pressure regulator

p_0 Ambient pressure
p_1 Input pressure
p_2 Outlet pressure
p_{ST} Control pressure
p_i Pilot pressure
R Restricted exhaust

Components	Function	Nominal flow Qn at p_1 = 6.3 bar and Δp = 1 bar	Pressure (Min./max.)		Filter porosity	Temperature range (Min./max.)
			Setting range	Operation		
		[l/min]	[bar]	[bar]	[μm]	[°C]
Precision pressure regulator - 380, mechanical - 480, mechanical - 450–1000, mechanical - 2200–6500, mechanical - 5600, pneumatic	Controlling the pressure	- 380 - 480 - 450–1000 - 2200–6500 - 5600	0.1/4 or 8	0.5/12		-10/ +60
- 5600, pneumatic, cold-resistant		- 5600	0.05 or 10	0.5/16		-35/ +60
Precision filter pressure regulator	Filtering, controlling pressure	750	0.1/2 or 0.2/5	0.2 /16	10	-10/ +60

Table 19 PR1 series parameter overview

3.2.7 MH1 series

Characteristics

- High corrosion resistance (version in 316 SS (V4A) stainless steel)
- Robust version
- Pressure regulators available for standard and special conditions (e.g. hygienically-sensitive areas)
- Relieving exhaust with M5 thread connection to pressure regulators
- Equipped with NBR seals (acrylonitrile butadiene rubber)
- Maintenance-friendly fully automatic condensate drain for filters and filter pressure regulators
- Use of special greases (NSF H1-certified, approved for the areas of food and drink)

Use

- Applications in corrosive environments (e.g. chemical industry, emissions protection, sewage treatment plants, car washes, printing, & paper)
- Suitable for use in the oil industry (meet the specifications of NACE-MR0175/ ISO 15156)
- RGS Hygienic version for use in hygienically-sensitive areas:
  - Food industry/beverage industry/dairies
  - Food zone (only "Hygienic" pressure regulator)
  - Suitable for wet areas in the food industry (laid out according to the EHEDG guidelines)

<table>
<tr><th></th><th></th><th></th><th>G 1/4</th><th>1/4 NPT</th><th>G 1/2</th><th>1/2 NPT</th></tr>
<tr><td rowspan="2"></td><td rowspan="2">Pressure regulator</td><td>Standard</td><td>●</td><td>●</td><td>●</td><td>●</td></tr>
<tr><td>Hygienic</td><td>●</td><td></td><td>●</td><td></td></tr>
<tr><td></td><td>Filter pressure regulator</td><td></td><td>●</td><td></td><td>●</td><td></td></tr>
<tr><td></td><td>Filter</td><td></td><td>●</td><td></td><td>●</td><td></td></tr>
</table>

Table 20 Connection sizes for MH1 components

<table>
<tr><th rowspan="2">Components</th><th rowspan="2">Function</th><th rowspan="2">Nominal flow Qn at p_1 = 6.3 bar and Δp = 1 bar
[l/min]</th><th colspan="2">Pressure (Min./max.)</th><th rowspan="2">Filter porosity
[µm]</th><th rowspan="2">Temperature range (Min./max.)
[°C]</th></tr>
<tr><th>Setting range
[bar]</th><th>Operation
[bar]</th></tr>
<tr><td>**Pressure regulator**</td><td>Controlling the pressure</td><td>325–2000</td><td rowspan="2">0.5/9</td><td rowspan="4">0.5/17</td><td></td><td rowspan="5">-30/ +80</td></tr>
<tr><td>**Filter pressure regulator**</td><td>Filtering, controlling pressure</td><td>170–2000</td><td rowspan="2">5</td></tr>
<tr><td>**Filter**</td><td>Filters</td><td>850–3800</td><td></td></tr>
<tr><td>**Ultramicrofilter**</td><td>Filters</td><td>170–680</td><td></td><td>0.01</td></tr>
<tr><td>**Active carbon filter**</td><td>Filters/absorbers</td><td>170–680</td><td></td><td>0/17</td><td>< 0.01</td></tr>
</table>

Table 21 MH1 series parameter overview

3.2.8 MU1 series

MU1 series components are always the perfect choice for applications in tough environments where large dimensions, thread connections or flow rates are a matter of course.

The largest G2 (2") connection enables a compressed air flow of up to 25,000 l/min. and reliable filtering, regulation, and lubrication.

	Series	Actuation	Flow rate [l/min]	Connections
	Pressure regulator	Mechanical	450	G 1/8, G 1/4
		Mechanical	5,000	G 1/2, G 1
	Pressure regulator	Pneumatic	5,500	G 1/2
		Pneumatic	15,000–50,000	G 1/4, G 1, G 2

Table 22 MU1 series overview

The MH1 series includes the following components for compressed air preparation:

- Pressure regulator
- Filter pressure regulator (40 µm, 8–60 µm)
- Filter
- Standard oil-mist lubricator, pressure relief valve, oil separator,

3.3 Accessories

Information on additional components can be found in our online catalog at http://www.aventics.com/pneumatics-catalog.

3.4 Product details

The compressed air supplied by the compressor is not qualitatively defined. To maximize efficiency, the air should be prepared as much as necessary before use. The following device series are available for individual processing steps and quality levels:

4 Applications

4.1 Filling a system

Requirements For safety reasons it is advisable to fill a complex system slowly during start-up.

Solution A filling valve as well as a 3/2 shut-off valve are added to the maintenance unit for this procedure.

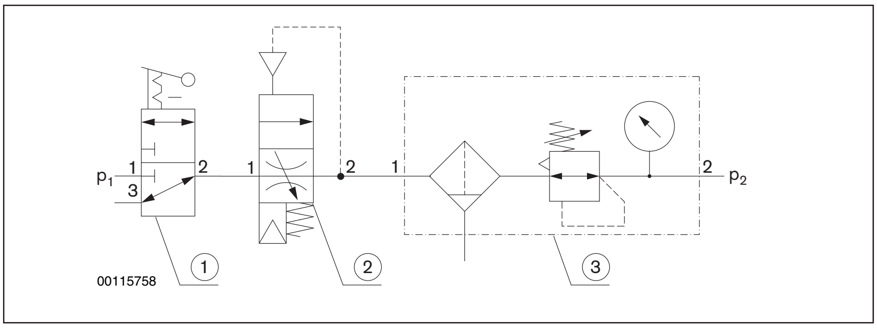


Fig. 34 Variant 1: The filling valve precedes the maintenance unit

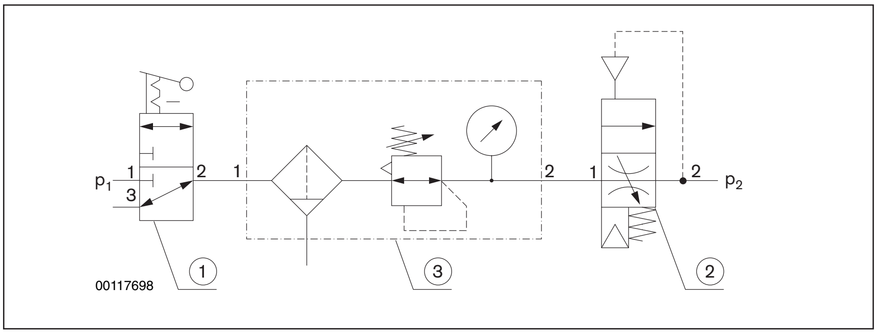


Fig. 35 Variant 2: The filling valve follows the maintenance unit.

p_1	Oil-free operating pressure mains	1	3/2 shut-off valve
p_2	Lubricated compressed air mains “System”	2	Filling valve
		3	Maintenance unit

4.2 Ventilating a system

4.2.1 Maintenance unit with lubricator

Requirement/task

While ventilating the system via a maintenance unit with lubricator, the oil found in the reservoir may be transported into the oil-free operating pressure mains p_1 or the environment. This is to be prevented.

Solution

A 3/2 shut-off valve installed after the lubricator and which ventilates the system can prevent this risk.

Design

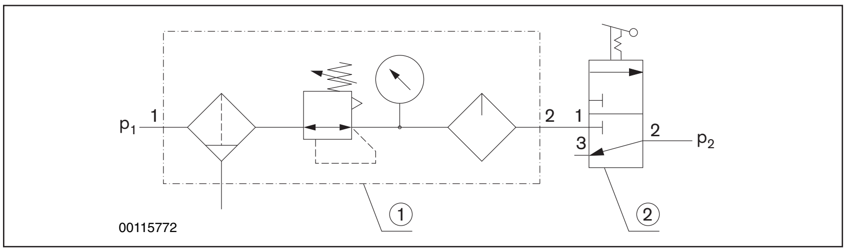


Fig. 36 Shut-off valve is installed after the lubricator

p_1 Oil-free operating pressure mains
p_2 Lubricated compressed air mains "System"

1 Maintenance unit with lubricator
2 3/2 shut-off valve

4.2.2 Quick exhaust

Requirement/task

The system should be exhausted automatically during an emergency OFF switching procedure.

Solution

The system is completely ventilated via the quick exhaust valve "emergency OFF."

Design

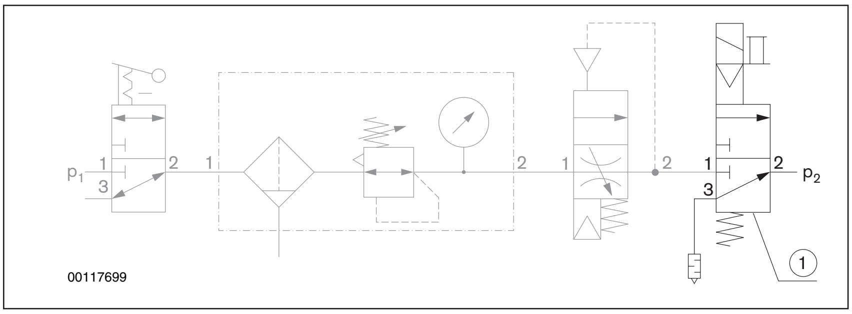


Fig. 37 Exhaust via quick exhaust valve

p_1 Oil-free operating pressure mains
p_2 Lubricated compressed air mains "System"

1 Emergency OFF quick exhaust valve (3/2 directional valve)

4.3 Mains supply with compressed air in various filtration stages

Requirement/task

Compressed air with different degrees of particle purity is required within the pneumatic system.

Solution

Filters with increasing degrees of separation are connected in series with distributor blocks between them. The compressed air in the selected filtration stage can be removed using the distributor blocks and fed to the consumer.

Design

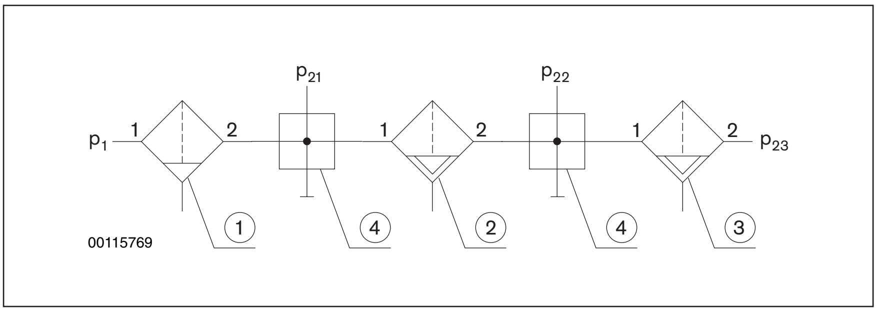


Fig. 38 Gradual particle separation with a filter cascade

p_1 Operating pressure mains
p_{21} Compressed air mains < 5 µm (NL 1 to NL 4) or < 40 µm (NL 6)
p_{22} Compressed air mains < 0.3 µm
p_{23} Compressed air mains < 0.01 µm
1 Filter
2 Microfilter
3 Ultramicrofilter
4 Distributor

4.4 Mains supply with various pressures

Requirement/task

Compressed air with different pressures is required within the pneumatic system.

Solution

Pressure regulator valves can be installed in parallel in the operating pressure line. The common inlet line should be sufficiently dimensioned to prevent extreme fluctuations in the operating pressure p_1.

When pressure regulator valves with a continuous pressure supply are used, a separate supply of operating pressure p_1 should be installed after every third pressure regulator valve.

Design

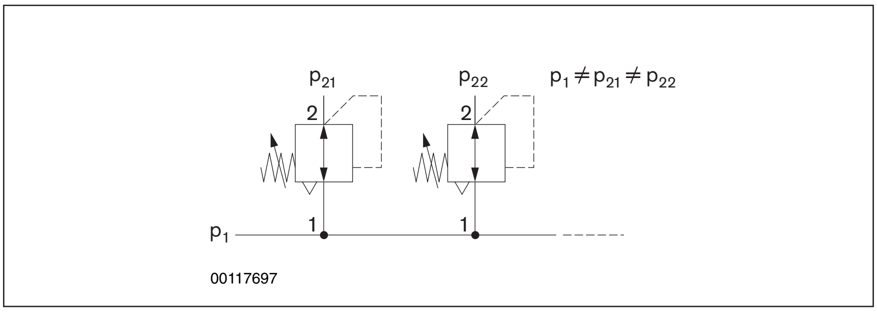


Fig. 39 Gradual particle separation with a filter cascade

p_1 Oil-free operating pressure mains
p_{21}, p_{22} Oil-free operating pressure mains

4.5 Mains supply with various oil content

Requirement/task Compressed air with different oil content is required within the pneumatic system.

Solution Lubricators can be integrated in parallel circuits and set and filled according to need.

Design

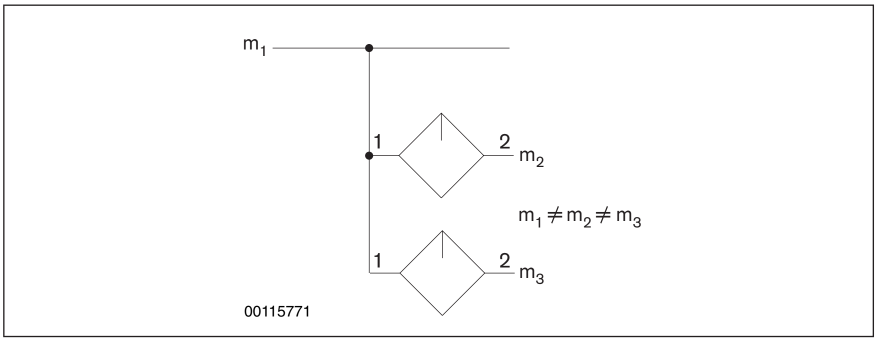
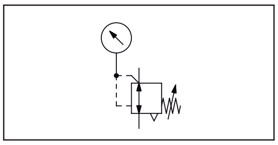


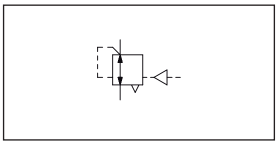
Fig. 40 Parallel connection of lubricators

m_1	Oil-free operating pressure mains
m_2, m_3	Lubricated compressed air mains

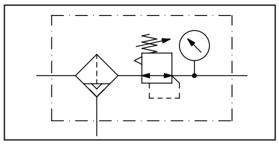
4.6 Circuit symbols for compressed air preparation



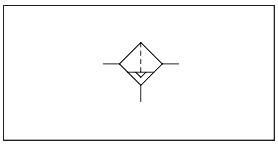
Pressure regulator, mechanically operated



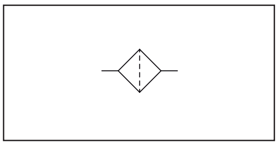
Pressure regulator, pneumatically operated



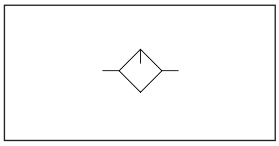
Filter pressure regulator



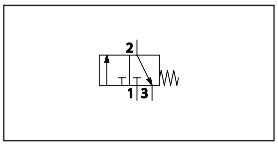
Filter



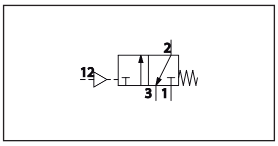
Active carbon filter



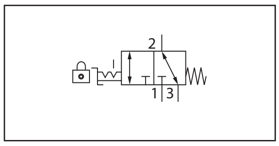
Lubricator



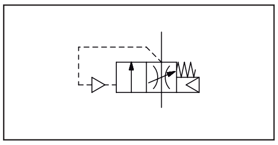
3/2 directional valve, electrically operated



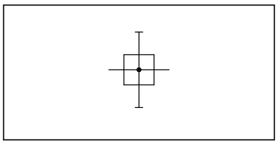
3/2 directional valve, pneumatically operated



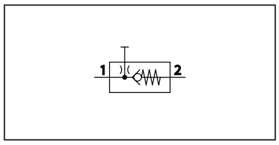
3/2 shut-off valve, mechanically operated



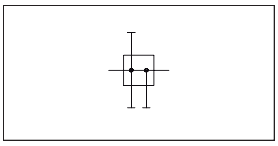
Filling valve, pneumatically operated



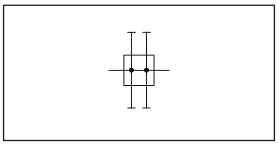
Distributor, 2x



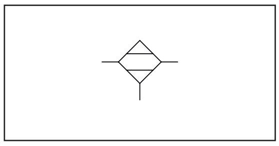
Distributor, 2x as non-return valve



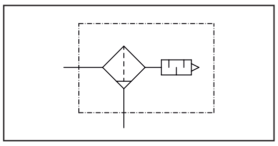
Distributor, 3x



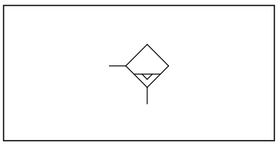
Distributor, 4x



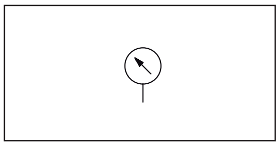
Diaphragm-type dryer



Oil separator



Condensate separator



Pressure gauge

IX Pneumatic connection technology

1 Introduction

Pneumatic connection technology is understood to be the combination and connection of pneumatic components. Generally, this is a fitting connected to tubing. These connections can be removed at any time.

The basic connection types include push-in fittings and fittings with union nuts.

The following components are available to realize optimal tubing and connections between the participants in a pneumatic system:

- Push-in fittings
- Fittings with union nuts
- Couplings

2 Technical principles

2.1 Push-in fittings

Push-in fittings hold the compressed air tubing via a tooth lock washer. O-rings or molded seal are used for sealing.

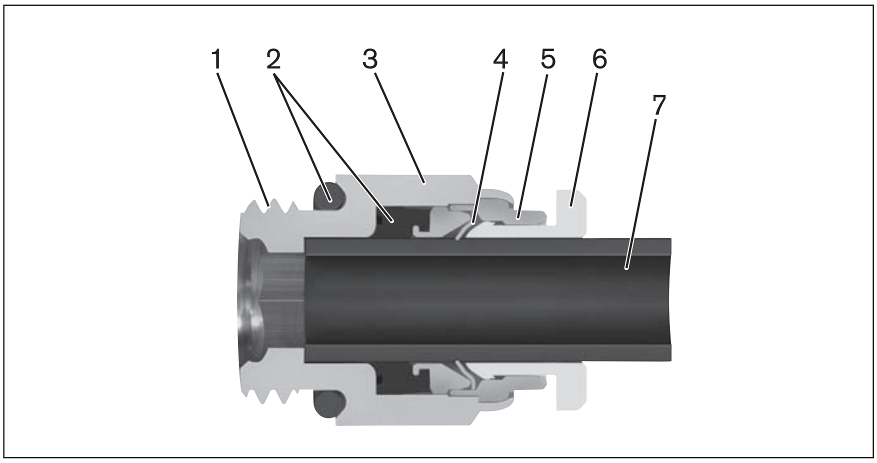


Fig. 1 Push-in fitting structure, taking the QR1 series as example

1 Thread
2 Seal
3 Housing
4 Tooth lock washer
5 Release ring receptacle
6 Release ring
7 Tubing

2.2 Fittings with union nuts

After establishing the friction fit between the tubing and fitting nipple (sliding the tube over the nipple), the tubing is also fixed by clamping or pressing with a union nut.

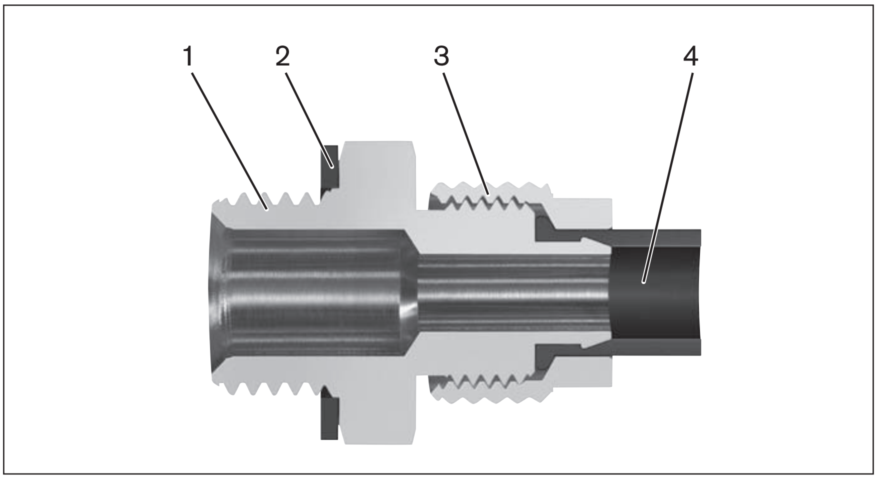


Fig. 2 Push-in fitting structure, taking the NU2 series as example

1 Housing
2 Seal
3 Union nut
4 Compressed air tubing

2.3 Compressed air tubing mounting and removal

Note: Push-in fittings are intended to be connected permanently. They can, however, be mounted and removed several times without impairing the holding force.

2.3.1 Mounting

<table>
<tr><th>Push-in fittings</th><th>Fittings with union nuts</th></tr>
<tr><td colspan="2">1. Cut the tubing at a right angle.</td></tr>
<tr><td colspan="2">2. Check the cut surface of the tubing that will be installed for damage.</td></tr>
<tr><td colspan="2">3. Deburr the edges and remove all contamination.</td></tr>
<tr><td>4. Carefully slide the tubing into the push-in fitting up to the first stop (tooth lock washer).
5. Turn the tubing and slide it further over the tooth lock washer and seal until it hits the stop in the push-in fitting.
The holding and sealing functions are now ensured.
6. Check the holding function of the tubing by pulling on it.</td><td>4. Slide the union nut over the tubing so that the thread can be fixed on the housing.
5. Slide the tubing over the nipple up to the stop.
6. Slide the union nut up to the thread connection.
7. Tighten the union nut by hand and then turn approximately 1.5 more times with an open-end wrench.
8. Check the holding function of the tubing by pulling on it.</td></tr>
</table>

2.3.2 Removal

Push-in fittings	Fittings with union nuts
▸ Use two fingers or an appropriate tool to press the release ring (towards the housing, see product overview) and simultaneously pull the tubing out.	1. Loosen the union nut with an open-end wrench. 2. Carefully remove the tubing.

2.4 Resistance of plastic and sealing materials

The employed components made of plastic and sealing elements feature a high service life under standard application conditions for industrial use in pneumatic components.

Direct sunlight, disproportionate changes in temperature, chemical attack caused by lubricants and anti-corrosion agents, paints, solvents, ozone, etc. can induce early aging and brittling processes that can impair the functionality of the products and possibly render them inoperative.

This is why these components should regularly be subjected to a visual inspection and checked for leaks as needed.

2.5 Product selection

2.5.1 Selection of the suitable series according to the general requirement profile

The individual series have particular strengths depending on the requirement profile.

Requirement	QR1-S Mini	QR1-S Standard	QR2-S Standard	QR2-C Stainless steel	QR2-F Heat-resistant
Product variants	+	++	+	o	o
Compactness	++	+	+	+	+
Pressure resistance	+	+	++	++	++
Temperature resistance	o	o	+	++	++
Tube connection in acc. with ISO 14743	++	++	++	++	++
O-ring seal in acc. with ISO 16030	+	+	–	–	–
Weight	++	++	o	o	o

Table 1 Selection matrix for QR1 and QR2 series push-in fittings

++ Highly recommended
+ Recommended
o Suitable
– Less suitable
– – Not suitable

3 Products

3.1 Pneumatic connection technology product overview

Push-in fittings	Thread	Tubing connection Ø [mm]	Push-in fitting material
QR1-S mini	M3, M5, M6 M7, G1/8	3–6	PBT[1)]
QR1-S standard	M5, M7, G1/8, G1/4, G3/8, G1/2	4–16	PBT[1)]
QR2-S standard	M5, G1/8, G1/4, G3/8, G1/2	4–16	Brass, nickel-plated
QR2-C stainless steel	M5, M7, G1/8, G1/4, G3/8, G1/2	4–12	Stainless steel
QR2-F heat-resistant	M5, G1/8, G1/4, G3/8, G1/2	4–12	Brass, nickel-plated

[1)] PBT = polybutylene terephthalate

Table 2 QR1 and QR2 series parameters

QR series push-in fittings can be used with a tubing diameter from 3 to 16 mm and are available in polymer, metal, and stainless steel versions. As a result, you can always find the most suitable fitting for the most varied applications and industries.

With QR fittings, pneumatic tubing can be connected and disconnected repeatedly without problems. Even the smallest fittings for tubing with a diameter of only 3 mm are easy to handle.

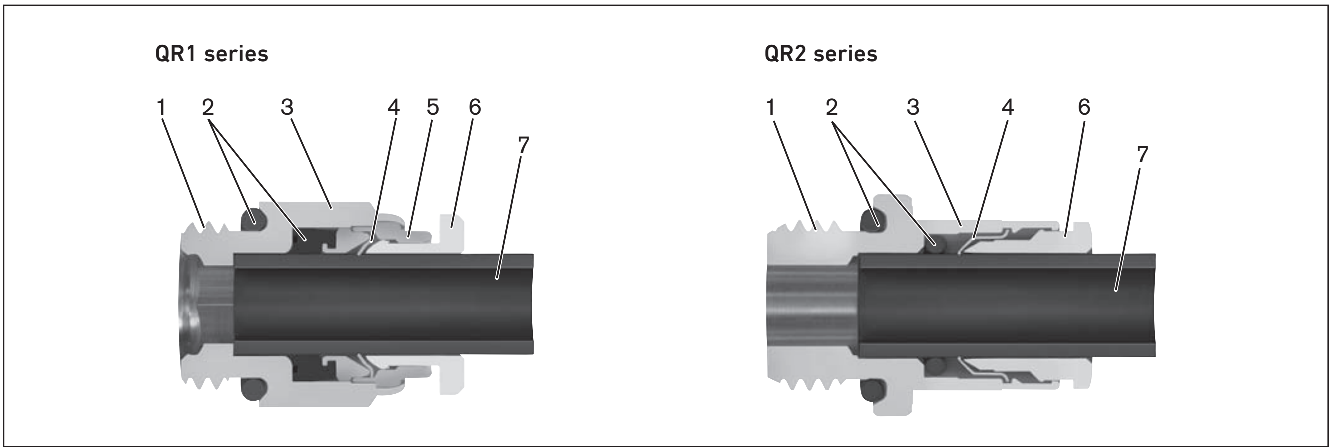


Fig. 3 QR series push-in fitting structure

		QR1-S Mini	QR1-S Standard	QR2-S Standard	QR2-F Heat-resistant	QR2-C Stainless steel
1	Thread	Brass, nickel-plated	Brass, nickel-plated	Brass, nickel-plated	Brass, nickel-plated	Stainless steel[1]
2	Seal	Acrylonitrile butadiene rubber	Acrylonitrile butadiene rubber	Acrylonitrile butadiene rubber	Fluororubber	Fluororubber
3	Housing	Polybutylene terephthalate/ brass, nickel-plated[2]	Polybutylene terephthalate/ brass, nickel-plated[2]	Brass, nickel-plated	Brass, nickel-plated	Stainless steel[1]
4	Tooth lock washer	Stainless steel[1]	Stainless steel[1]	Stainless steel[1]	Stainless steel[1]	Stainless steel[1]
5	Release ring receptacle	Die-cast zinc	Die-cast zinc	–	–	–
6	Release ring	Polyoxymethylene	Polyoxymethylene	Brass, nickel-plated	Brass, nickel-plated	Stainless steel[1]
7	Compressed air tubing	Polyurethane, polyethylene, or polyamide, tubing measured as outside diameter				

1) AISI 316
2) Only for straight fittings

Table 3 Series in comparison

3.2 QR 1 series mini and standard

Description

The QR1 series contains the following versions:

- QR1-S mini (for tubing Ø 3–6 mm)
- QR1-S standard (for tubing Ø 4–12 mm)

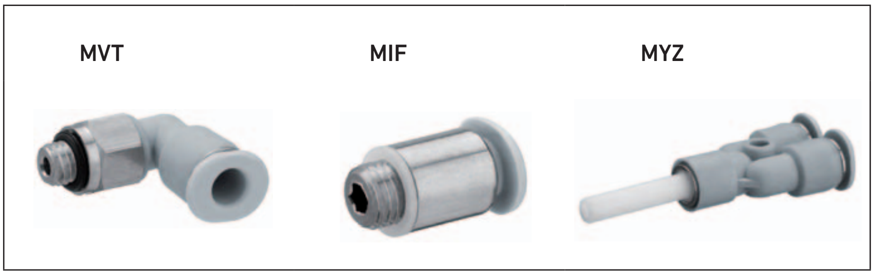


Fig. 4 QR1-S series, mini

Fig. 5 QR1-S standard series

Characteristics

- Cylindrical thread
- Optimum sealing, also after repeated release, through captive O-ring
- Lightweight
- Safe handling with defined pressure points
- Easy release through oval release ring with a considerably enlarged gripping surface

Applications

- In all areas of general pneumatics
- QR1 fittings are ideal for small handling.

3.3 QR2 series: standard, stainless steel, and heat-resistant

Description

The QR2 series contains the following versions:

- QR2-S standard (for tubing Ø 4–16 mm)
- QR2-C stainless steel (for tubing Ø 4–12 mm)
- QR2-F heat-resistant (for tubing Ø 4–12 mm)

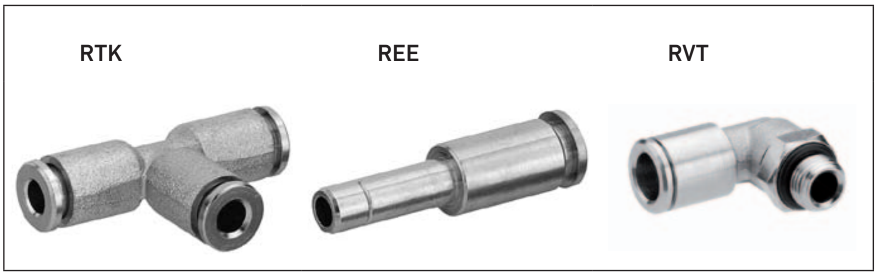


Fig. 6 QR2-S standard series

Fig. 7 QR2-C series, stainless steel

Characteristics

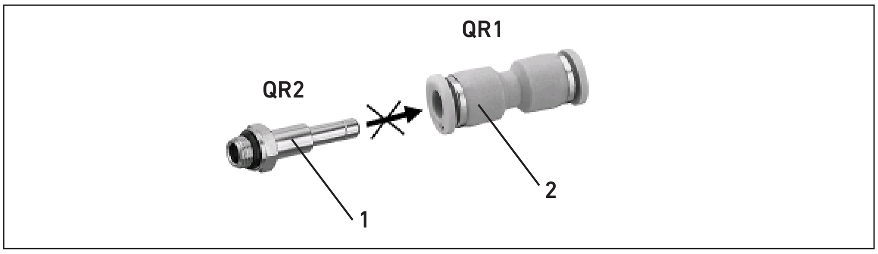
- Cylindrical threads/tapered threads
- Optimum sealing, also after repeated release, through captive O-ring
- Suitable for elevated temperatures thanks to a corrosion-resistant design (QR2-C)
- Simple connection and release via metal release ring

Applications

- In general pneumatics
- Suitable for use in the food industry and work environments with aggressive media thanks to their robust design

3.4 Combination of QR1 and QR2 series

QR1 and QR2 series fittings may not be connected to each other via the push-in fitting and pin bushing ports. The reliable holding function of the pin bushing slot (1)/ tooth lock washer (2) cannot be ensured with this combination.



1 QR 2: Pin bushing slot

2 QR1: tooth lock washer

3.5 NU1 and NU2 series

NU1 series

The NU1 series, push-in fittings with union nuts, is available in the following versions:

- Elbow fitting
- T-banjo connection
- Bulkhead connector
- Banjo union
- Union nut

NU2 series

The NU2 series, push-in fittings with union nuts, is available in the following versions:

- Straight female thread connection/straight fitting
- Bulkhead connector
- Elbow fitting/swivel banjo connection
- T-union/T-connector
- T-banjo connection
- X-connector
- Union nut; banjo union

Requirement	NU1-S	NU2-S
Product variants	o	+
Compactness	+	+
Pressure resistance	+	++
Temperature resistance	o	+
Weight	++	+

Table 4 Selection matrix for NU1 and NU2 series fittings with union nuts

++ Highly recommended
+ Recommended
o Suitable
– Less suitable
– – Not suitable

3.5.1 Fittings with union nuts

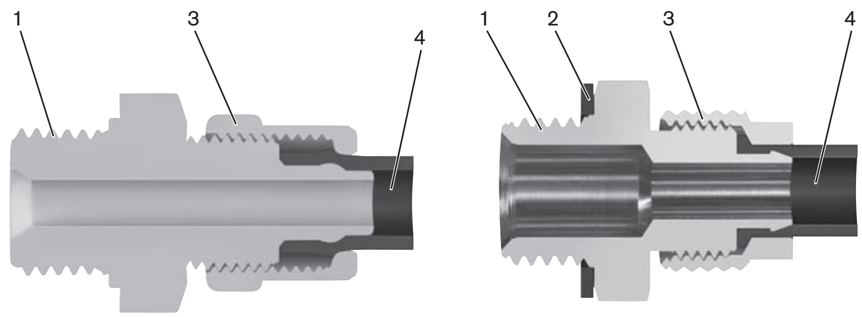


Fig. 8 Structure of NU series fittings

	NU1	NU2 (aluminum)	NU2 (brass)
1 Housing	Polyoxymethylene	Aluminum, anodized	Brass, nickel-plated
2 Seal	–	Acrylonitrile butadiene rubber	Polyvinyl chloride
3 Union nut	Polyoxymethylene	Aluminum, anodized	Brass, nickel-plated
4 Compressed air tubing	Polyamide/polyurethane	Polyvinyl chloride[1)]	Polyamide/polyurethane

1) Fabric-reinforced

Table 5 Series in comparison

Fittings with union nuts	Thread	Tubing connection Ø [mm]	Push-in fitting material
• NU1	G1/8, G1/4, G3/8	6–12	Polyoxymethylene
• NU2	M5, G1/8, G1/4, G3/8, G3/4, G1/2, G1	4–27	• Aluminum, anodized • Brass, nickel-plated

Table 6 NU1 and NU2 series parameters

Thread size	Tightening torque	Thread size	Tightening torque
M3	0.5 + 0.2 Nm	G 1/8	5 + 1 Nm
M5	1.2 + 0.3 Nm	G 1/4	10 + 1 Nm
M6	1.2 + 0.3 Nm	G 3/8	25 + 2 Nm
M7	2.2 + 0.5 Nm	G 1/2	25 + 2 Nm

Table 7 Thread: Tightening torque

3.6 Compressed air tubing

The following three basic types of pneumatic tubing are available:

Single tubing, TU1 series

The TU1 series is the foundation of the range of tubing products.

The TU1 series includes the following tubing types:

- Tubing for direct contact with food products
- Tubing for extremely high flow rates
- Tubing that is resistant against aggressive media
- Tubing that is completely antistatic

This series is designed to match the AVENTICS range of fittings and available in several colors and materials.

Dual tubing, TU2 series

Dual tubing consists of two joined parallel lengths of tubing in a combination of blue/black. Dual tubing simplifies assembly in standard applications.

Spiral tubing, TU3 series

Spiral tubing is specifically designed for applications that need to cover a flexible range of motion.

Requirement	TU1-...-PUR	TU1-S-PAM	TU1-S-PET	TU1-S-TEF	TU1-S-PVC
Pressure resistance	+	++	+	+	+
Temperature resistance	+	+	+	++	o
Media resistance	+	+	++	++	–
Flexibility (bending strength)	++	+	+	o	o

Table 8 Selection matrix for compressed air tubing by material properties

++ Highly recommended
+ Recommended
o Suitable
– Less suitable
– – Not suitable

Requirement	TU1-S-PUR	TU1-A-PUR	TU1-E-PUR	TU1-F-PUR	TU1-X-PUR
Anti-static	–	+	–	–	–
Resistant to microbes	o	+	o	+	+
Flame protection (UL94V), resistant to welding sparks	–	–	–	–	+
Halogen-free/fluorine-free	+	+	+	+	+
Resistance to hydrolysis	o	+	o	+	+
Suitable for dynamic laying	+	+	+	+	+
UV resistant	o	+	o	o	+
High pressure resistance	+	+	–	+	+

Table 9 Selection matrix for PUR tubing by material properties

++ Highly recommended
+ Recommended
o Suitable
– Less suitable
– – Not suitable

3.6.1 tubing product overview

AVENTICS has a high-quality range of polymer tubing that complies with specific technical or economic factors.

The following series are available:

- Simple TU1 series tubing
- TU2 series dual tubing
- TU3 series spiral tubing

	Series	Material
	**TU1 series tubing**	
	TU1-S-PUR	Polyester polyurethane
	TU1-X-PUR	Polyether polyurethane
	TU1-F-PUR	Polyether polyurethane
	TU1-A-PUR	Polyether polyurethane
	TU1-E-PUR	Polyester polyurethane
	TU1-S-PAM	Polyamide
	TU1-S-PET	Polyethylene
	TU1-S-TEF	Polytetrafluoroethylene
	TU1-S-PVC	Polyvinyl chloride
	**TU2 series dual tubing**	
	TU2-S-PUR	Polyester polyurethane
	**TU3 series spiral tubing**	
	TU3-S-PAM	• Polyamide

Table 10 tubing overview

Note For safety reasons, the use of tubing and accessories from the AVENTICs pneumatics catalog is recommended for push-in fittings. When using PU tubing (e.g. TU1-...-PUR series), we also recommend using pin bushings.

The general rules and safety requirements for pneumatic systems and their components in accordance with EN ISO 4414 must be observed.

3.7 CP1 series couplings

CP1 series couplings enable the following connections:

- Standard lock couplings with various connection types
- Safety couplings
- Special multi-couplings (bundling of pneumatic tubing)

Couplings are used to connect tubing systems to supply machines/systems with gaseous (here, compressed air) or liquid media.

Both single and double blocking versions are in use. In general, single blocking couplings are used at AVENTICS. With single-handed operation, these couplings allow for flexible, efficient, and reliable connection and changing of systems. The socket coupling is equipped with a non-return valve and closes the tubing during decoupling.

Safety couplings offer increased protection during decoupling.

Complete release is not possible until the pressure has been relieved at the coupling plug.

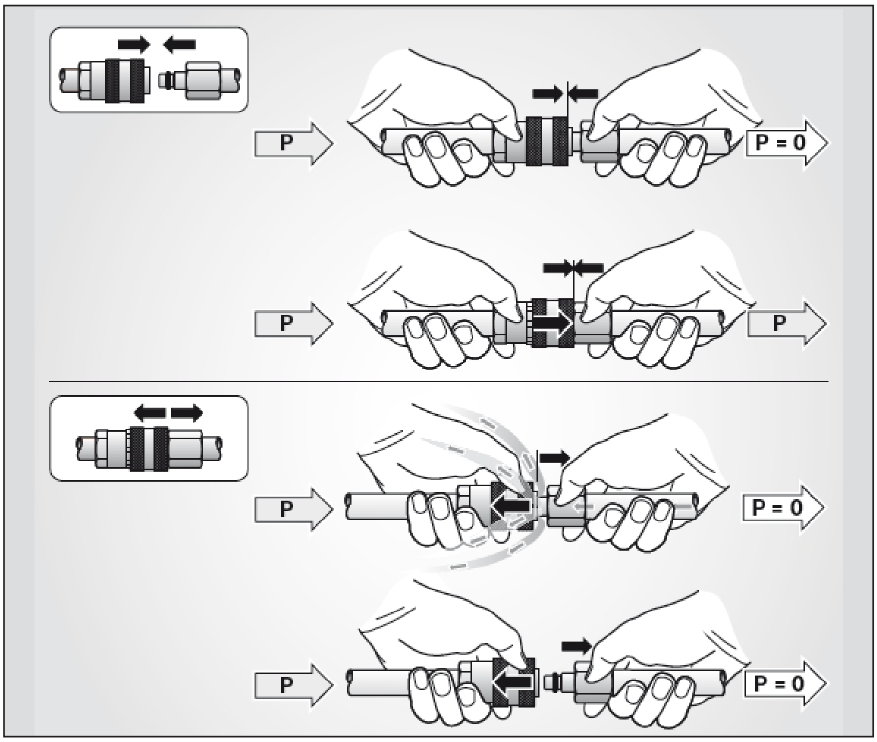
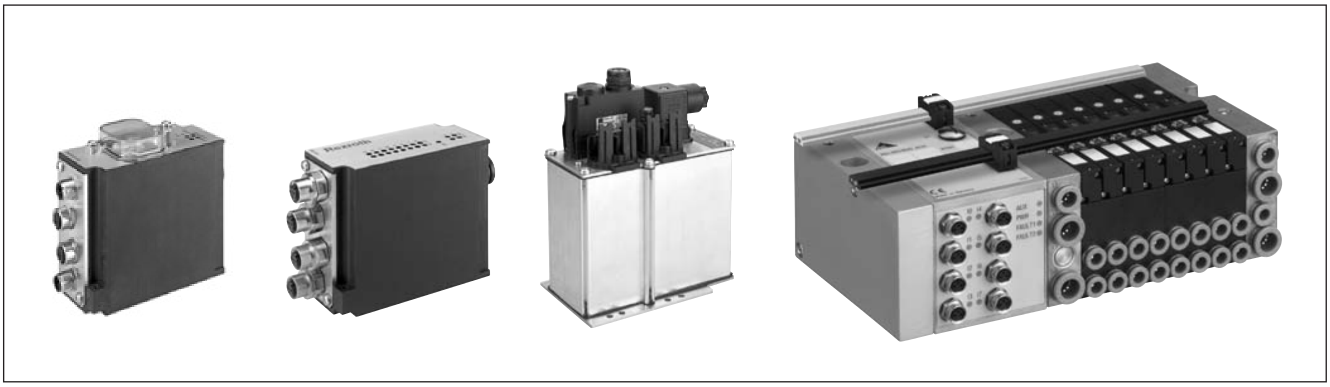


Fig. 9 Connection and release for CP1 series safety couplings

Couplings	Thread	Nominal width [mm]	Push-in fitting material
CP1	M5, G1/8, G1/4, G3/8, G1/2	Ø 2.7–10	• Brass, nickel-plated • Galvanized steel

Table 11 CP1 series parameters

X Fieldbus interfaces



1 Introduction

1.1 Integrated fieldbus systems

The more complex the controls of a system, the more it pays to use fieldbus systems. Fieldbus systems minimize cabling effort, increase system-level diagnostic capabilities, and reduce the number of possible error sources in a system. Our modern link structures not only make fast and secure data transmission possible, but also allow you to perform diagnoses, even down to individual valve coils.

Each application requires a suitable fieldbus system solution to get the job done. That is why AVENTICS has organized its extensive range of fieldbus systems into a single concept with four link structures.

1.1.1 Single wiring

For less complex systems, single wiring is a simple, safe electrical solution. Due to simple assembly, it is essential to machinery production. Single wiring in particular is required by standards such as EN and VDMA. This is why AVENTICS has a complete range of M12 connections in its portfolio.

1.1.2 Multipole systems

For valve systems with multipole plug, the assembly effort is reduced compared with single wiring. The versatility and flexibility of our valve systems with multipole plug contribute to fast solutions for customer-specific automation tasks. The valve systems are completely assembled according to the individual specifications and delivered inspected. Modular construction allows existing systems to be expanded or converted at any time.

1.1.3 Custom configuration

In the AVENTICS Internet portal (http://www.aventics.com/de/engineering-tools/konfiguration.html), you can use the product configurator to individually configure the right valve systems and link structure concepts you need.

Our complex, polished system thinks of every detail and guides you through a series of logical selection steps to let you to create your valve system solution with confidence and ease.

2 Technical principles

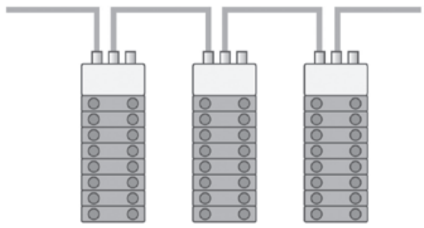
2.1 Characteristics evaluation

Criteria	BDC	DDL	VDS	CMS
System design should be as independent of the fieldbus as possible.	+	++	+	–
Several valves systems are controlled by the fieldbus.	o	++	+	o
Electropneumatic pressure regulator valves are controlled via the fieldbus.	o	++	+	o
Several individual valves are controlled by the fieldbus.	––	o	++	–
Only a few pneumatic components are controlled via the fieldbus.	++	o	+	–
Diagnostic functions are output.	–	++	o	+
Binary sensor signals are processed and output signals set.	––	++	++	++
Analog input and output signals are processed.	––	++	––	––
The separate components to be controlled are far apart from each other.	++	+	o	++
Addressing of individual participants is flexible.	+	++	––	o
An emergency OFF circuit can be used.	++	++	++	++

++ Extremely suitable
+ Very suitable
o Suitable
– Not recommended
– – Not suitable

2.2 Structured bus technology

2.2.1 BDC – Bus Direct Control



BDC is the direct link from your pneumatic system to the fieldbus.

This link structure is pared down to the essentials and provides a solid solution for applications without numerous additional functions. Extras, such as sensor inputs, are not implemented, to cut back on costs.

The fieldbus connection is forwarded from unit to unit. Up to 32 coils can be actuated per valve system.

The BDC system features a simple layout. All components are on one level and connected directly to the PLC.

As a result, each BDC valve system is a direct slave to the superior fieldbus.

Even components that are far apart from each other can thus be controlled via the fieldbus.

The BDC is particularly suitable for systems controlled by a fieldbus.

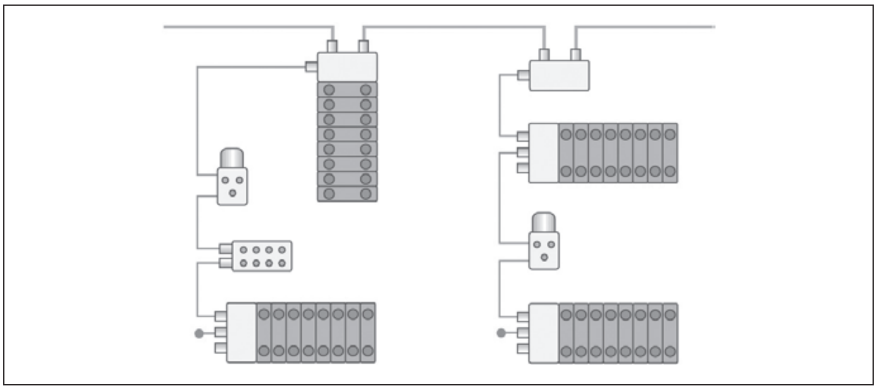
Characteristics

- Compact assemblies with a high density of functions for broad areas of application
- Low installation and fieldbus connection costs
- Cutting-edge connection technology
- Few pneumatic actuators
- Pneumatic components that are far apart from each other

BDC enables direct connection to valve systems. Each unit is an individual bus participant in the overall structure.

This structure offers universal application options in a wide variety of standard environments.

2.2.2 DDL – Drive & Diagnostic Link



This structure is made up of a bus coupler for communication with the superior fieldbus and up to 14 participants in the DDL line.

Diagnostic functions make it possible to quickly recognize and find errors, which significantly reduces downtime in production systems. The DDL structure can process 128 inputs and 128 outputs independent of the fieldbus. Analog input and output signals can also be integrated.

A bus coupler for communication with fieldbuses is the first component in every DDL line. It is not important which fieldbus protocol is used with the DDL line itself. The system control sequence can thus be designed independently from the fieldbus protocol, which means that the parts variety can be greatly reduced.

The length of a DDL line, from the bus coupler to the last participant, can be up to 40 m at standard transmission speeds.

The transmission technology ensures a very high level of data security. The DDL system diagnostic function simplifies troubleshooting by enabling switching states to be called up at any time via the fieldbus.

Fast remedial action reduces machine downtimes.

In addition, the coils in valve systems are monitored for "open load" (open contacts) and short circuits. Some DDL participants also allow you to define the reaction to a fieldbus failure by adjusting parameters.

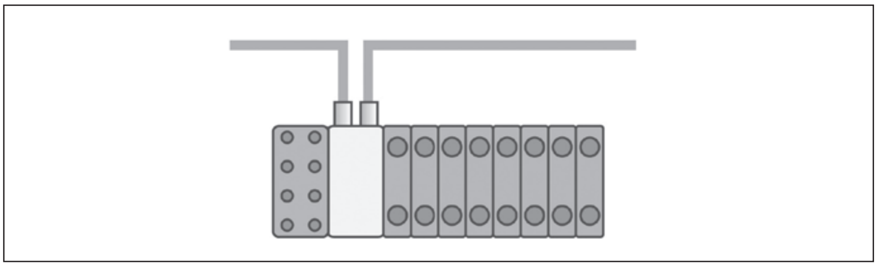
By linking the diagnostic data to feedback from sensors, electropneumatic pressure regulator valves, and appropriate programs in the PLC, for example, the status of the system is quickly and clearly displayed.

Characteristics

- Diagnosis down to the valve/coil level
- High data security
- Independent of fieldbus protocol
- 1 line for 128 inputs and outputs
- DDL M12 connection (5-pin)
- Fast data transmission
- Up to 40 m cable length
- Easy handling
- Combination options for up to 14 different components/devices per line
- Small sized bus couplers and valve drivers

The AVENTICS DDL system is a fieldbus interface with detailed functional diagnostics. It can control solenoid valves, pressure regulator valves, and digital and analog I/O modules with different fieldbus systems.

2.2.3 CMS – Central Mounted System



The modular and configurable valve system with integrated bus coupler and I/O modules offers a mechanically complete unit for applications without additional cabling. A gateway to the AS-i and even control functions can be optionally integrated in the units.

The increasing automation of systems frequently means an increase in time and effort for installation. Our completely wired CMS valve systems with sensor inputs can be used as control centers in complex systems.

Each CMS unit contains a bus coupler, a valve system, as well as I/O modules that are assembled and tested according to your individual configuration. This high-performance, complete modular system can be put into full operation in your system within a very short period of time. CMS valve systems are available in various designs to meet the widest range of demands.

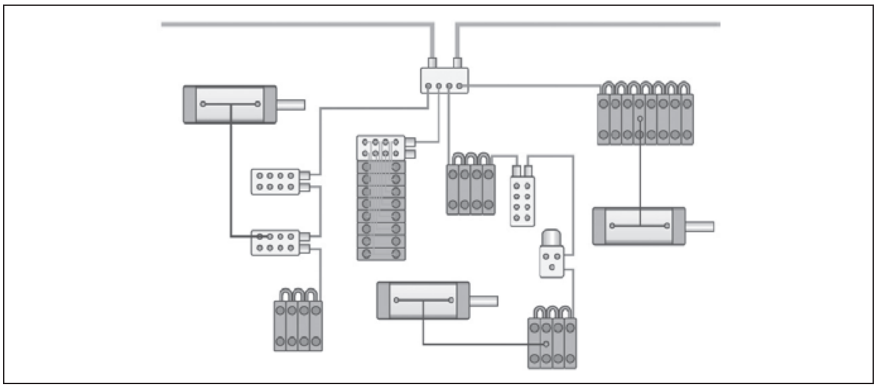
Characteristics

- All standard fieldbus protocols
- Input modules integrated in the valve system
- Output modules integrated in the valve system
- Valves with different flow rates can be assembled into blocks
- Easy installation on walls

Even though CMS valve systems are fixed units, they still feature exceptional versatility and flexibility. Convenient configuration of the unit in the product configurator offers a wide range of options. A power module for supplying additional power, as well as different input and output modules are available, among other options. For individual valves in the system periphery, a gateway to the AS-i can be integrated in the unit.

CMS is always the right solution if you want to reduce the planning and installation effort for pneumatic system actuation to a minimum.

2.2.4 VDS – Valve Driver System



The structure with up to four lines – a bus coupler for communication with the superior fieldbus is the core of each line. All the valve systems and individual valves with electrical connections (via A or C plugs) in the VDS structure can be controlled via contact bridges, which optionally include sensor inputs.

Modular intelligence with many advantages. As many pneumatic actuators can be controlled as needed in the VDS structure via contact bridges or valve driver modules.

The link to the fieldbus is established using a bus coupler. Depending on the fieldbus protocol, this bus module provides 2 or 4 VDS lines, each with 32 inputs and 32 outputs.

Characteristics

- Fieldbus-independent design possible
- Almost all valves with electrical connection (type A or C) can be controlled.
- For all standard fieldbus protocols
- Extremely modular thanks to contact bridges
- Emergency OFF function
- Very convenient inputs possible via contact bridges
- Up to 4 lines with 5 or 10 m length
- Line error diagnosis in the F design

The evaluation of sensor messages is an elementary requirement to ensure processes for nearly all applications in automation technology. Control-relevant information must be reported and evaluated, and subsequent program steps initiated.

In pneumatics, cylinders and pressure switches are the primary candidates for automatic control via their sensor messages. The VDS link structure concept achieves effective use through the universal integration of sensor connections in the individual components.

The valves are connected to the bus coupler via plug-in contact bridges that are interconnected with cables and that contain the drivers for the valves and the evaluation electronics for the sensors. A valve system can be equipped with up to 16 valves and connected to the bus coupler with bridges. Depending on the valve series or type, a wide variety of VDS contact bridges can be used – meaning limitless, modular flexibility.

3 Products

Series	Design	Fieldbus protocols
BDC	B	PROFIBUS DP / CANopen / CANopen sb / DeviceNet / EtherCAT / sercos III
	S	PROFIBUS DP / CANopen / DeviceNet
	V	PROFIBUS DP / CANopen / DeviceNet / Interbus S / installation remote bus
CMS	B	PROFIBUS DP / CANopen / DeviceNet / Interbus S / EtherNET/IP / PROFIBUS IO
	M	PROFIBUS DP, with integrated PLC / CANopen / Interbus S
DDL	S	PROFIBUS DP / CANopen / DeviceNet / Interbus S / PROFIBUS IO / EtherCAT
VDS	S	PROFIBUS DP / CANopen / Interbus S
	F	PROFIBUS DP / CANopen / DeviceNet / Remote I/O
	C	PROFIBUS DP / CANopen / Interbus S / ABB/CS31

Table 1 Fieldbus connection parameter overview

4 Applications

The AVENTICS integrated fieldbus program offers a suitable solution for all tasks.

No matter the industry or production level, from complete solutions for fully automatic production processes to the optimum integration of individual pneumatic workstations, our link structures permit the integration of our entire valve range as well as the secure control of all pneumatic components. You can benefit from a high level of flexibility and neutrality during planning, since our portfolio is compatible with all conventional fieldbus protocols.

4.1 Assembly technology

AVENTICS pneumatic components move, position, and fix installation parts, control automatic parts handling, and support manual assembly work with special balancer systems.

4.2 Inspection technology

During the final inspection of engines and transmissions, AVENTICS pneumatic solutions are responsible for the exact positioning of the objects under test and connection units, as well as safe fixation during the test phase.

4.3 Vacuum technology

It can be both forceful and gentle, which is why AVENTICS vacuum technology is used for handling a wide variety of products, materials, and parts in a broad spectrum of specific industry solutions.

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