Operating conditions and standards in pneumatics

What must be observed when using Festo components?

Specified limit values for technical data and any specific instructions must be adhered to by the user in order to ensure recommended operating conditions.
When pneumatic components are used, the user shall ensure that they are operated using correctly prepared compressed air free of aggressive media.

When Festo components are used in safety-oriented applications, the user shall ensure that all applicable national and local safety laws and regulations, for example the machine directive, together with the relevant references to standards are observed.
Unauthorised conversions or modifications to products and systems from Festo involve a safety risk and are thus not permissible.

Festo does not accept any liability for resulting damages.
You should contact Festo's advisors if one of the following apply to your application:

- The ambient conditions and conditions of use or the operating medium differ from the specified technical data.
- The product is to perform a safety function.
- A risk or safety analysis is required.
- You are unsure about the product's suitability for use in the planned application.
- You are unsure about the product's suitability for use in safety-oriented applications.

All technical data applies at the time of going to print.

Standards in pneumatics

Standards also have great significance in pneumatics. Standards mean harmonisation (standardisation) for general use. Standards promote rationalisation; they contribute to the safety of personnel and equipment, for example by means of internationally specified and universally comprehensible characteristics, and advance quality assurance through the use of specified quality characteristics and acceptance conditions.
The products in this catalogue are standardised. A brief overview will indicate the significance of standards in Festo's particular area of application: pneumatics and automation technology.

Festo has been actively participating in national and international standards organisations for years. Standardisation work is co-ordinated globally by the International Standardisation Organisation (ISO). The European standard is defined by EU standards. The contents of these standards are also included in national standards, e.g. the German DIN standards.

The international electrotechnical commission (IEC) works in a similar way to ISO. The IEC formulates standards for electronic components (e.g. IEC 60144 protection classes).

Chapter 1 – Pneumatic drives

- Standards-based cylinders to ISO 6432, DIN ISO 6432.
- Standards-based cylinders to ISO 15552 (ISO 6431, DIN ISO 6431, VDMA 24 562), NFE 49003.1 and UNI 10290.
- Rod clevises to DIN ISO 8140.
- Rod clevises to DIN ISO 8139.

Chapter 3 – Valves/valve terminals

- Valve terminals for standards-based valves.
- Solenoid and pneumatic valves with port pattern to ISO 15407-1.
- Valve sub-bases to ISO 15407-1.
- Valve terminals with port pattern to ISO 15407-1.
- Solenoid and pneumatic valves with port pattern to ISO 5599-1.
- Valve terminals with port pattern to DIN ISO 5599-2.
- Valve sub-bases with port pattern to ISO 5599-1 and external dimensions to VDMA 24345.
- Solenoid valves with port pattern to VDI/VDE 3845 (Namur).

Chapter 6 – Compressed air preparation/tubing and connectors

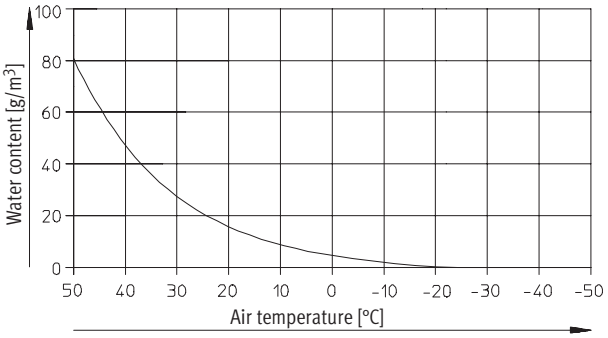
- Pressure gauges to DIN EN 837-1.
- Reservoirs to directive 97/23/EC, 87/404/EEC or EN 286-1.
- Safety couplings to ISO 4414.

Compressed air preparation

Why compressed air preparation?

Water content in air

The maximum water content of air (100% relative air humidity) is dependent on temperature. Air can only absorb a certain quantity of water (in g) per volumetric unit (in m³), irrespective of pressure. The warmer the air, the more water it can absorb. Excessive humidity manifests itself as condensation. If the air temperature drops, for example from 20 °C to 3 °C, the maximum water content of compressed air is reduced from 18 g/m³ to 6 g/m³. The compressed air can now no longer absorb more than approx. 1/3 of water. The rest (12 g/m³) is precipitated as drops (dew) and must be drawn off so that it cannot cause any malfunctions.

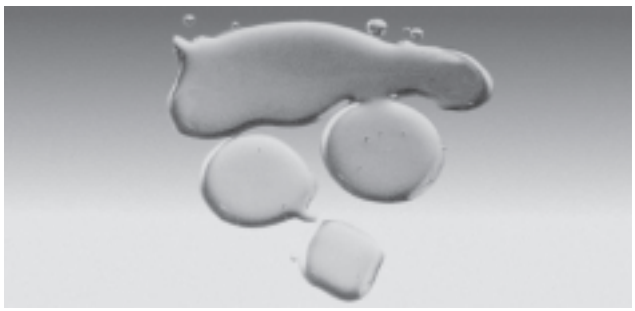


Water condensation

Water is always present in the air in the form of natural air humidity. During the cooling of compressed air, water is released in large quantities. Drying helps to prevent corrosion damage in compressed air systems and operative malfunctions in the connected consuming devices.

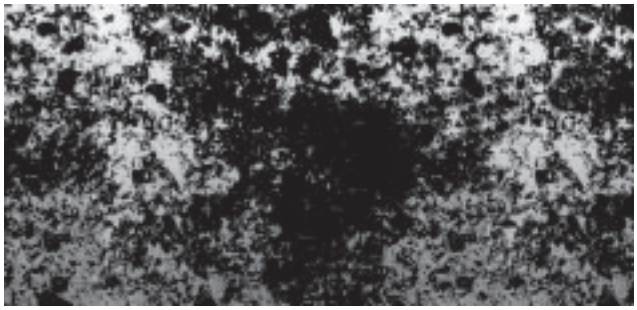
Oil contamination

Similarly, in the case of oil-free operating compressors, oil aerosols present in the drawn-in air also lead to a corresponding residue of oil pollutants. However, this oil is not suitable for the lubrication of drives and can even lead to the clogging of sensitive parts.



Dirt and rust particles

Solid particles occur in the form of dust (carbon black, abraded and corrosion particles) primarily in agglomeration points.
Coastal regions generally have lower levels of dust, but instead contain additional salt particles resulting from evaporated seawater droplets.
Dust is classified into categories of particle size, i.e.
coarse dust > 10 µm
fine dust > 1 ... < 10 µm and
atomised dust < 1 µm.



Compressed air preparation

How clean should compressed air be?

The requirements specify the degree of cleaning

The answer is quite simple:
Compressed air must be so clean that it cannot cause any malfunctions or damage.
Contamination accelerates wear on sliding surfaces and sealing elements. This can affect the function and service life of pneumatic components.

As each filter also creates a flow resistance, compressed air should be as clean as possible for economic reasons.
Compressed air quality is expressed in quality classes in accordance with DIN ISO 8573-1. This specifies the level of contamination permitted in the corresponding compressed air classes.

The wide application range of compressed air places many different requirements on compressed air quality. If high quality is required, several filtration stages are necessary. If just a single "fine" filter were used, it would become ineffective in a short time.

Specifications of quality classes should contain the following information in the sequence shown:
- The quality class for solid contamination.
- The quality class for water content.
- The quality class for total oil content (droplets, aerosols and vapours)

Sizing

- Note

Equipment at an air branching/air distribution input should have a high flow rate as it must supply the total air requirement. Further information ➔ Chapter 6

The size of the service unit depends upon system air consumption. Undersizing leads to pressure fluctuations and to reduced filter service life.
For reasons of economy, high quality compressed air should only be used where it is absolutely necessary. Branching modules between the individual filter stages allow the user to tap off compressed air of various qualities.

Service unit functions

Compressed air filters remove particulate and droplets of moisture from the air. Particles > 40 ... 5 µm (depending on grade of filtration) are retained by a sintered filter. Liquids are separated with the aid of centrifugal force. The condensate which accumulates in the filter bowl must be emptied from time to time, because it would otherwise be drawn in by the air flow.

Various industries often require finely filtered air: the chemicals and pharmaceuticals industries, process engineering, food processing, etc. Fine filters and micro filters are used to this end. Fine filters are used for prefiltering down to a particle size of 1 µm.

Micro filters further purify control air, removing practically all remaining water and oil droplets and contamination particles. The degree of compressed air filtration is 99.999% relative to a particle size of 0.01 µm.

The pressure regulator maintains a constant working pressure (secondary side), regardless of the pressure variations in the system (primary side) and the air consumption. Input pressure must always be greater than working pressure.
The compressed air lubricator provides pneumatic components with adequate lubricant if required. Oil is drawn from a reservoir and atomised when it comes into contact with the flowing stream of air. The lubricator is only functional when air flow is sufficiently strong.

Lubricated compressed air

The following notes must be observed when lubricated compressed air is used:
- Use the special oil OFSW-32 from Festo, or the alternative oils listed in the catalogue (in accordance with DIN 51524-HLP32, basic oil viscosity 32cSt at 40 °C).
- If lubricated compressed air is used, additional lubrication may not exceed 25 mg/m^3 (DIN ISO 8573-1 class 5). The quality of compressed air downstream from the compressor must correspond to that of unlubricated compressed air.
- Operation with lubricated compressed air leads to the lifetime lubrication needed for unlubricated operation being "flushed out". This can lead to malfunctions.
- The lubricators should, where possible, always be installed directly upstream of the cylinders used to prevent operating the entire system with lubricated air.
- Never over-lubricate the system. To determine the correct lubricator settings, the following "oil form test" can be implemented: Hold a piece of white card approx. 10 cm away from the exhaust port (without silencer) of a working valve of the most distant cylinder. Allow the system to work for some time, the card should only show a pale yellow coloration. If oil drops out, this is an indication that too much oil has been used.
- The colour and condition of the exhaust silencer provide further evidence of over-lubrication. Marked yellow colouration and dripping oil indicate that the lubrication setting is too high.
- Dirty or incorrectly lubricated compressed air will reduce the service life of the pneumatic components.
- Service units must be inspected at least twice a week for condensate and correct lubrication settings. These operations should be included in the machine maintenance plan.
- To protect the environment, as little lubrication as possible should be used. Festo pneumatic valves and cylinders have been constructed in such a manner that, under permitted operating conditions, additional lubrication is not required and yet a long service life is guaranteed.

Oil content

A differentiation must be made between residual oil for operation with unlubricated air and additional oil for operation with lubricated air.

Unlubricated operation:
Examinations involving residual oil content have revealed that the various types of oil have entirely different consequences. For this reason, a distinction must be made between the following oil types when analysing the residual oil content:

- Bio-oils: Oils based on synthetic or natural ester (e.g. rapeseed oil methyl ester). In this case, residual oil content may not exceed 0.1 mg/m³.
  This complies with DIN ISO 8573-1 class 2 (➔ Chapter 6). Larger oil quantities can cause damage to the O-rings, seals and other equipment parts (e.g. filter bowls) in pneumatic systems, that could shorten the product service life.
- Mineral oils (e.g. HLP oils to DIN 51524, Parts 1 to 3) or similar oils based on polyalphaolefins (PAO). In this case, residual oil content may not exceed 5 mg/m³.
  This complies with DIN ISO 8573-1 class 4 (➔ Chapter 6). A higher residual oil content irrespective of the compressor oil cannot be permitted, as the basic lubricant would be flushed out over time. This can lead to malfunctions.

Moisture

For operation in heated interior rooms < 15 °C, compressed air must be dried to a pressure dew point of 3 °C.

Note

The pressure dew point must be at least 10 K lower than the temperature of the medium, since ice would otherwise form in the expanded compressed air. Complies with DIN ISO 8573-1, at least class 4 (➔ Chapter 6).

Solids

Max. particle size 40 µm. Complies with DIN ISO 8573-1 class 5 (➔ Chapter 6).

Suitable oils

Special oil in 1 litre containers:
Order code
152 811 OFSW-32

Quality classes to DIN ISO 8573-1

Class	Solids		Water content	Oil content
	Max. particle size [µm]	Max. particle density [mg/m³]	Max. pressure dew point [°C]	Max. oil concentration [mg/m³]
1	0.1	0.1	–70	0.01
2	1	1	–40	0.1
3	5	5	–20	1
4	15	8	3	5
5	40	10	7	25
6	–	–	10	–
7	–	–	not defined	–

Compressed air quality in use

Applications	Classes to DIN ISO 8573-1			Recommended grades of filtration [µm]	Recommended pressure dew point [°C]
	Particle	Water	Oil		
Mining	5	5	5	40	7
Glass and stone processing	5	4	5	40	3
Shoe production	5	4	5	40	3
Welding systems	4	4	5	5	3
Standard pneumatics	5	4	5	40	3
Standard pneumatics + bio-oil	3	4	2	5 + 1 + 0.01	3
Packaging machine	5	4	3	5 + 1	3
Machine tool	5	4	5	40	3
Film development	1	2	1	5 + 1 + 0.01 + activated carbon	–40
Sensors	2	2	2	5 + 1 + 0.01	–40
Instrument air	2	3	3	5 + 1	–20
Painting system	2	4	2	5 + 1	3
Food industry	2	4	1	5 + 1 + 0.01 + activated carbon	3
Air bearing	2	3	3	5 + 1	–20
Precision pressure regulator	3	2	3	5 + 1	–40
Process engineering	2	2	3	5 + 1	–40
Transportation of granulate	3	4	3	5 + 1	3
Transportation of powder	2	3	2	5 + 1 + 0.01	–20

Operating conditions for valves

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Medium

Under normal operating conditions, pneumatic valves from Festo can be operated with lubricated or unlubricated compressed air.
If any particular product requires a different quality of compressed air, this is indicated in the technical data for the relevant product.
Operation with unlubricated compressed air is made possible by the selection of the material combinations, the shape of the dynamic seals and the basic lubrication applied ex works.
Operation with unlubricated compressed air is not possible under the following operating conditions:

- Once the valves have been operated with lubricated compressed air, it is essential that lubricated compressed air is always used subsequently since the oil in the lubricated air will have flushed away the basic lubrication.
- In all cases, a degree of filtration is required that removes contaminants up to 40 µm (standard filter cartridge version).

Micro compressed air filtration may be required for special applications.

Nominal size

The nominal size provides information about the smallest cross section in the main flow of the valve. It specifies the diameter of the orifice and is expressed in mm. This is a measurement that only provides a limited comparison between different components. To compare products, the standard nominal flow rate must also be considered.

Standard nominal flow rate

The standard nominal flow rate qn_N is the flow rate characteristic used by Festo for a unit or component expressed in l/min.
The standard nominal flow rate is the nominal flow rate based on standard temperature and pressure. Standard conditions to DIN 1314:

t_n = 20 °C
p_n = 1.013 bar
p_n = Absolute pressure (ambient pressure)

The nominal flow rate q_n is the flow rate measured under nominal conditions. The following nominal conditions apply for Festo:

- Test medium air
- Temperature 20 ±3 °C = temperature of medium
- Test specimen at ambient temperature
- The pressures to be set are: for components with constant cross section (e.g. directional control valves):
  Supply pressure p_1 = 6 bar
  Output pressure p_2 = 5 bar

Exception 1:
Silencers
Supply pressure p_1 = 6 bar
Output pressure $p_2 = p_{amb}$
p_{amb} = atmospheric pressure

Exception 2:
Low-pressure components
Supply pressure p_1 = 0.1 bar
Output pressure $p_2 = p_{amb}$

For pressure regulators:
Supply pressure p_1 = 10 bar (constant) and output pressure p_2 = 6 bar at Q = 0 l/min are set for the test specimen. Subsequently, the flow rate is slowly and constantly increased using the flow control valve until the output pressure reaches a value of p_2 = 5 bar. The resulting flow rate is measured.

Pressure and pressure ranges

Pressure

Force per area. There is a difference between differential pressure with respect to atmosphere and absolute pressure. Pressure specifications for pneumatic devices must normally be assumed to be the differential pressure with respect to atmosphere, unless expressly indicated otherwise.

Symbols
Differential pressure with respect to atmosphere p
Absolute pressure p_{abs}
Unit: bar, Pa (pascal)
1 bar = 100 000 Pa

Operating pressure

Data quoted as "max." or "max. permissible" values refer to the maximum safe pressure at which a component or system can be operated.

Operating pressure range

The range between the lowest required or highest permissible operating pressure for safe operation of a component or system. This pressure range is also referred to in pneumatics as the working pressure range.

Pilot pressure range

The range between the lowest required or highest permissible control pressure for proper operation of a valve or system.
The following pressures have been standardised to ISO 4399: 2.5; 6.3; 10; 16; 40 and 100 bar.

Drop-off pressure

Pressure which, if no longer maintained, causes a single solenoid directional control valve to return to the normal position by means of its spring.

Absolute pressure

Zero pressure occurs in a completely air-free space (100% vacuum). Pressures that are calculated from this theoretical zero point are absolute pressures.

Response pressure

Pressure at which a directional control valve is actuated. Catalogue specifications for response pressures signify that the indicated minimum pressure must be present at the signal input to safely switch the valve.

Port designations of pneumatic components to ISO 5599

Port designations		
	Using ISO 5599 numbers (5/2- and 3/2-way valves)	Using letters[1)]
Supply port	1	P
Working ports	2	B
	4	A
		C
Exhaust ports	3	S
	5	R
		T
Pilot ports (signal)	10[2)]	Z[2)]
	12	Y
	14	Z
Pilot air ports (power supply)	81 (12)	
	81 (14)	
Pilot exhaust ports	83 (82)	
	83 (84)	
Leakage lines		L

1) Still frequently used.
2) Clears the output signal.

Operating conditions for drives

Medium

Under normal operating conditions, pneumatic drives from Festo can be operated with lubricated or unlubricated dried compressed air. If any particular product requires a different quality of compressed air, this is indicated in the technical data for the relevant product. Operation with unlubricated compressed air is made possible by the choice of materials used, the material combinations, the shape of the dynamic seals and the basic lubrication applied ex-works. Operation with unlubricated compressed air is not possible under the following operating conditions:

- Once the drives have been operated with lubricated compressed air, it is essential that lubricated compressed air is always used subsequently since the oil in the lubricated air will have flushed away the basic lubrication.

Recommended operating conditions

Pneumatic drives are intended to convert pressure energy into motion energy; this process involves the transmission and dissipation of forces. "Recommended operating conditions" do not include use as a spring or cushioning device, since this would involve additional loads.

Frequency

If pneumatic drives are operated at maximum possible speed, a pause time must be taken into account between the stroke movements. For operation with unlubricated compressed air, the maximum frequency should be based on an average speed of 1 m/s.

Assembly position

In general, drives from Festo can be installed in any desired position. If any limitations or special measures apply, these are indicated in the technical data for the relevant product.

Operating pressure

Data quoted as "max." or "max. permissible" values refer to the maximum safe pressure at which a drive or system can be operated.

Operating pressure range

The range between the lowest required or highest permissible operating pressure for safe operation of a component or system. This pressure range is also referred to in pneumatics as the working pressure range.

Effective force with single-acting cylinders

Permissible deviation of spring forces in accordance with DIN 2095, quality class 2, must be taken into consideration for the cylinders' effective force. The effective force must also be reduced by the value of prevailing frictional forces.
The degree of friction depends upon the assembly position and the type of load involved. Lateral forces increase friction. Frictional force must be lower than spring return force. In as far as this is possible, single-acting cylinders should be operated without lateral forces.

Permissible stroke deviations for standard cylinders

ISO 15552 (corresponds to the withdrawn standards ISO 6431, DIN ISO 6431, VDMA 24562, NF E 49003.1, UNI 10290), ISO 6432 and ISO 21287 permit a certain amount of stroke length deviation from the nominal value due to manufacturing tolerances. These tolerances are always positive. Refer to the table for details regarding precise permissible deviations.

Standard	Piston ∅ [mm]	Stroke length [mm]	Permissible stroke deviation [mm]
ISO 6432	8, 10, 12, 16, 20, 25	0 ... 500	+1.5
ISO 15552	32	0 ... 500	+2
	40, 50	500 ... 12 500	+3.2
	63	0 ... 500	+2
	80, 100	500 ... 12,500	+4
	125, 160	0 ... 500	+4
	200, 250, 320	500 ... 2,000	+5
ISO 21287	20, 25	0 ... 500	+1.5
	32, 40, 50	0 ... 500	+2
	63, 80, 100	0 ... 500	+2.5

- Note

In the case of stroke lengths larger than those shown in the table, tolerances must be agreed upon between the manufacturer and the user.

Contactless position sensing

Pneumatic drives from Festo with contactless position sensing are fitted with a permanent magnet on the cylinder piston, the magnetic field of which is used to actuate proximity sensors. Proximity sensors can be used to detect end or intermediate positions of cylinders. One or more proximity sensors can be clamped to a cylinder, either directly or using mounting kits.

Piston diameter

- ∅ -

This pictogram is used to indicate piston diameter. This is represented by ∅ only in the dimensions table.

Pressure/force table

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Piston force [N]								
∅	Operating pressure [bar]							
	1	2	3	4	5	6	7	8
2.5	0.4	0.9	1.3	1.8	2.2	2.7	3.1	3.5
3.5	0.9	1.7	3.8	3.5	4.3	5.2	6.1	6.9
5.35	2	4	6.1	8.1	10.1	12.1	14.2	16.2
6	2.5	5.1	7.6	10.2	12.7	15.3	17.8	20.4
8	4.5	9	13.6	18.1	22.6	27.1	31.7	36.2
10	7.1	14.1	21.2	28.3	35.3	42.4	49.5	56.5
12	10.2	20.4	30.5	40.7	50.9	61.0	71.3	81.4
16	18.1	36.5	54.3	72.4	90.5	109	127	145
20	28.3	56.5	84.8	113	141	170	198	226
25	44.2	88.4	133	177	221	265	309	353
32	72.4	145	217	290	362	434	507	579
40	113	226	339	452	565	679	792	905
50	177	353	530	707	884	1,060	1,240	1,410
63	281	561	842	1,120	1,400	1,680	1,960	2,240
80	452	905	1,360	1,810	2,260	2,710	3,170	3,620
100	707	1,410	2,120	2,830	3,530	4,240	4,950	5,650
125	1,100	2,210	3,310	4,420	5,520	6,630	7,730	8,840
160	1,810	3,620	5,430	7,240	9,050	10,900	12,700	14,500
200	2,830	5,650	8,480	11,300	14,100	17,000	19,800	22,600
250	4,420	8,840	13,300	17,700	22,100	26,500	30,900	35,300
320	7,240	14,500	21,700	29,000	36,200	43,400	50,700	57,900

Piston force [N]							
∅	Operating pressure [bar]						
	9	10	11	12	13	14	15
2.5	4	4.4	4.9	5.3	5.7	6.2	6.6
3.5	7.8	8.7	9.5	10.4	11.3	12.1	13
5.35	18.2	20.2	22.2	24.3	26.3	28.3	30.3
6	22.9	25.4	28	30.5	33.1	35.6	38.2
8	40.7	45.2	49.8	54.3	58.8	63.3	67.9
10	63.6	70.7	77.8	84.8	91.9	99	106
12	91.6	101	112	122	132	143	153
16	163	181	199	217	235	253	271
20	254	283	311	339	368	396	424
25	398	442	486	530	574	619	663
32	651	724	796	869	941	1,010	1,090
40	1,020	1,130	1,240	1,360	1,470	1,580	1,700
50	1,590	1,770	1,940	2,120	2,300	2,470	2,650
63	2,520	2,810	3,090	3,370	3,650	3,930	4,210
80	4,070	4,520	4,980	5,430	5,880	6,330	6,790
100	6,360	7,070	7,780	8,480	9,190	9,900	10,600
125	9,940	11,000	12,100	13,300	14,400	15,500	16,600
160	16,300	18,100	19,900	21,700	23,500	25,300	27,100
200	25,400	28,300	31,100	33,900	36,800	39,600	42,400
250	39,800	44,200	48,600	53,000	57,400	61,900	66,300
320	65,100	72,400	79,600	86,900	94,100	101,000	109,000

The piston force F can be calculated from the piston area A, the operating pressure p and the friction R using the following formulae:

Piston force (final pressure)

$$F = p \cdot A - R$$

$$F = p \cdot 10 \cdot \frac{d^2 \cdot \pi}{4} - R$$

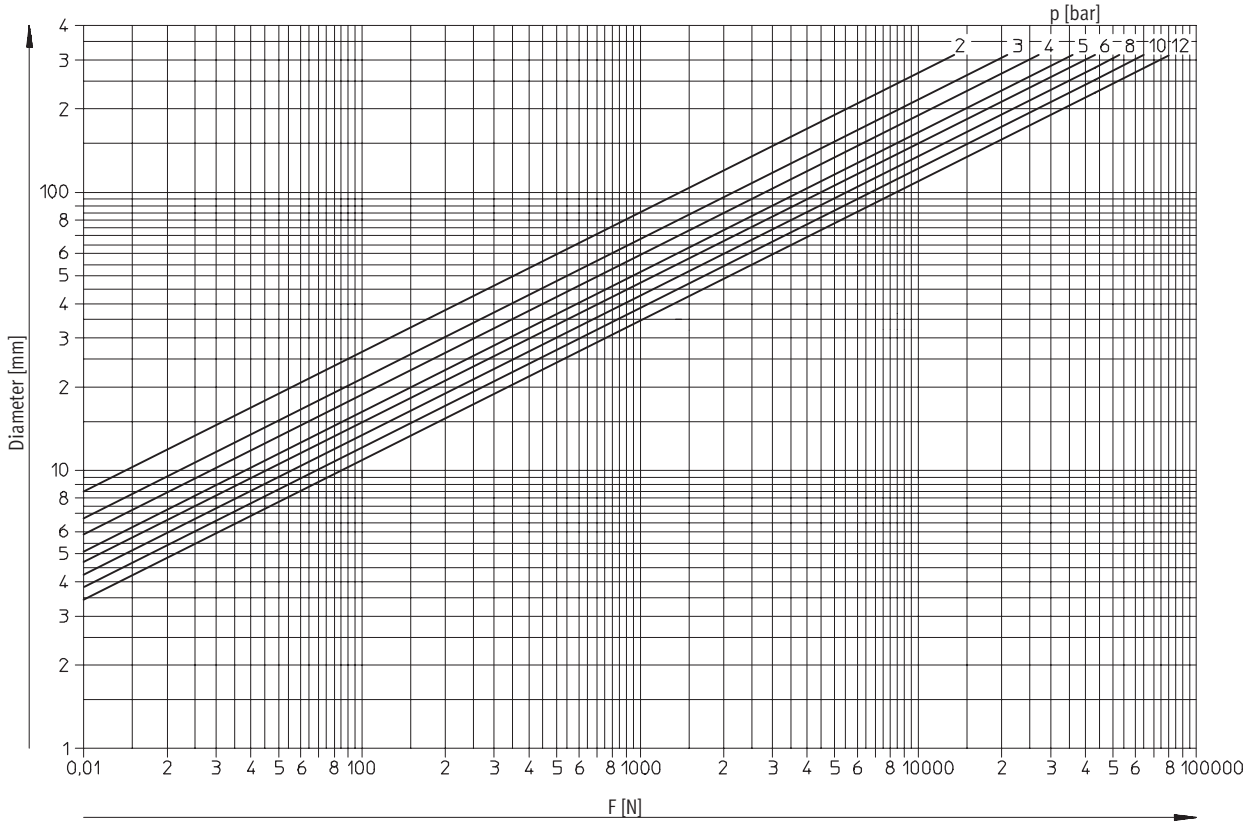
p = Operating pressure [bar]
d = Piston diameter [cm]
R = Friction ~10% [N]
A = Piston area [cm²]
F = Effective piston force [N]

Pneumatic sizing using Pro Pneu
www.festo.com/en/engineering

Pressure/force graph

Operating pressure p as a function of piston diameter and force F

An allowance of 10% has been included for frictional force



Given:
Load 800 N
Available system pressure 6 bar

To be found:
Required piston diameter
Operating pressure to be set

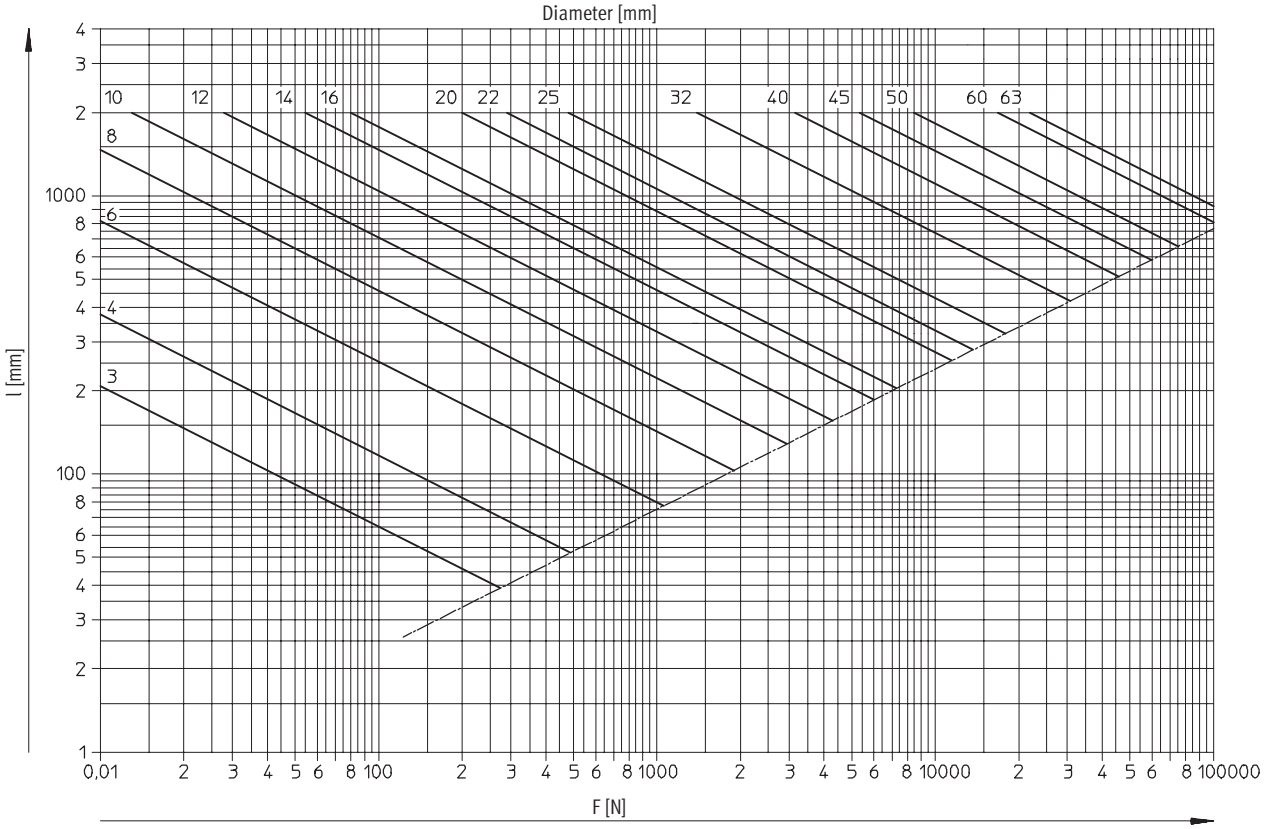
Procedure:
From F = 800 N go vertically upwards to the point of intersection with the 6 bar line. The next largest piston diameter, 50 mm, lies between the lines for 4 and 5 bar, which means that the operating pressure should be set to approx. 4.5 bar.

The selection of pneumatic drives is governed primarily by the forces to be overcome and the distances to be travelled. A small percentage of the piston force is used to overcome friction, the remainder is used to drive the load.

Only approximate values can be given, since frictional force depends on numerous factors (lubrication, operating pressure, back pressure, seal design, etc.). Back pressure generates a force which acts in the opposite direction and partially cancels out the effective force. Back pressure occurs in particular when exhaust air flow controls are used or the exhaust port is constricted.

Buckling load graph

Piston rod diameter as a function of stroke length l and force F



Given:
Load 800 N
Stroke length 500 mm
Piston ∅ 50 mm

To be found:
Piston rod diameter
Cylinder type: Standard cylinder

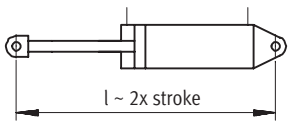
Procedure:
From F = 800 N go vertically upwards to the point of intersection with the horizontal through l = 500 mm. The next largest piston rod diameter in the graph is 16 mm. The standard cylinder DNC-50-500 with a piston rod diameter of 20 mm is suitable for this stroke length.

Due to buckling stress, the maximum permissible load for a piston rod with a long stroke length is lower than the value suggested by maximum permissible operating pressure and piston area. This load must not exceed certain maximum values. These depend upon stroke length and piston rod diameter.

The graph shows this relationship based on the following formula:

$$F_K = \frac{\pi^2 \cdot E \cdot J}{l^2 \cdot S}$$

F_K = Permissible buckling force [N]
E = Modulus of elasticity [N/mm²]
J = Moment of inertia [cm 4]
l = Buckling length
= 2x stroke length [cm]
S = Safety factor (selected value: 5)

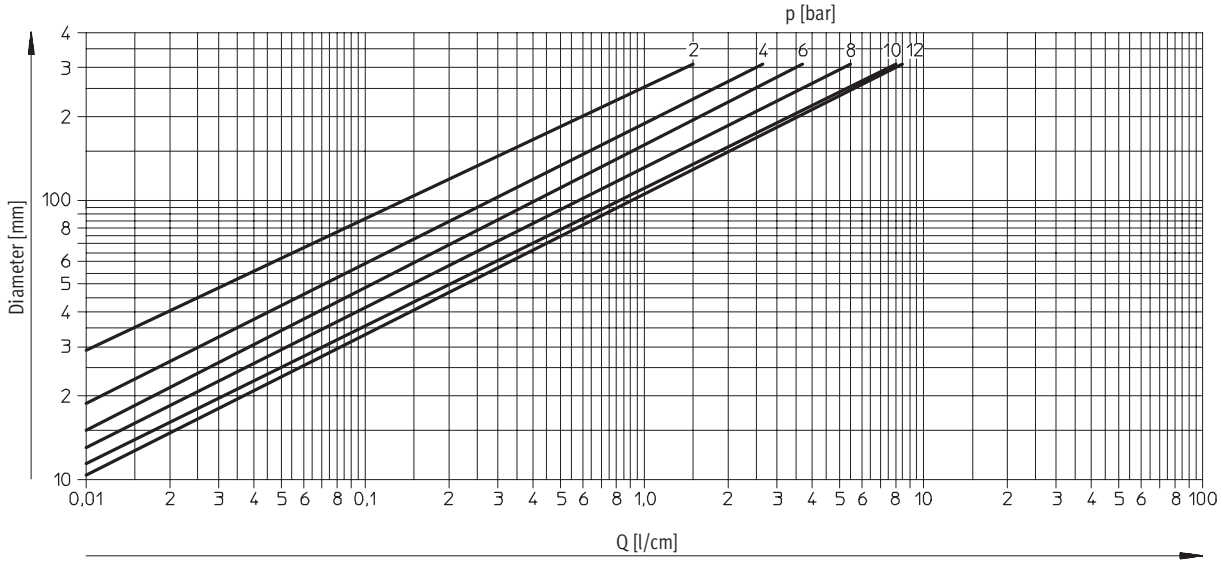


Note

The least satisfactory type of mounting for this kind of stress is a swivel mounting. The permissible load is higher for other types of mountings.

Air consumption graph

Air consumption Q as a function of piston diameter and operating pressure p



Given:
Cylinder DNC-50-500
Piston ∅ 50 mm
Piston rod diameter 20 mm
Stroke length 500 mm
Operating pressure 4.5 bar

To be found:
Air consumption

Procedure:
Starting from the selected piston diameter, follow the horizontal to the point of intersection with the operating pressure, go from here to the lower scale and read the air consumption from this. The value thus obtained must now be multiplied by the stroke length (in cm).

The result in the example according to the specifications is approx. 0.09 l/cm. This value is multiplied by 50 cm stroke length, corresponding to an air consumption for a single stroke length of approx. 4.5 l. For the return stroke, the piston rod volume must be deducted from the stroke volume (a piston rod diameter of 20 mm means 0.014 l/cm stroke length. At 50 cm stroke length, the corresponding air consumption is 0.7 l), which means the return-stroke air consumption is 3.8 l. The air consumption for a double stroke is 8.3 l.

The air consumption values determined in this way are only guide values – among the reasons for this is that, particularly with high cycle speeds, pressurised chambers are not fully exhausted, which means that actual air consumption may be significantly lower.
Air consumption represents a portion of operating costs.

The graph shows consumption based on the formula:

$$Q = \frac{\pi}{4} \cdot (d1^2 - d2^2) \cdot h \cdot p \cdot 10^{-6}$$

Q = Air consumption per cm stroke [l]
d1 = Piston diameter [mm]
d2 = Piston rod diameter [mm]
h = Stroke (a constant 10 mm in this case)
p = Operating pressure, relative [bar]

Pneumatics and explosion protection – Directive 94/9/EC (ATEX)

FESTO

What does ATEX mean?

Explosive atmospheres are a constant hazard in the chemical and petrochemical industries because of the processing techniques used in these industries. These explosive atmospheres are caused by escaping gas, vapours and mist, for example. Explosive atmospheres must also be reckoned with in mills, silos and sugar and feed processing plants because of the dust/oxygen mixtures that occur there. For that reason, electrical equipment in hazardous areas is subject to a special directive, ATEX 95a. This directive was also extended to non-electrical equipment on July 1, 2003.

What does ATEX 95a stand for and what does it mean?

ATEX is an acronym of the French expression "Atmosphère explosible". 95a refers to article 95a of the corresponding EU directive. ATEX 95a is a working title for a project related to the **directive 94/9/EC**.

- **Directive 94/9/EC** stipulates the minimum safety requirements for equipment and protective systems to be operated in explosive atmospheres.
- It applies to all EU member states.
- It relates to both electrical and non-electrical equipment.

What are the main amendments introduced by directive 94/9/EC?

- Non-electrical equipment such as cylinders, pneumatic valves, service units and accessories now fall within the scope of the directive.
- Equipment will be approved for specific categories. These categories are allocated zones in which the equipment can be operated.
- Each piece of the equipment must be supplied with operating instructions and a conformity declaration.
- The manufacturer's quality system must meet specifications over and above those required under ISO 9001.
- The new equipment bears the explosion protection and CE marks.
- Dust explosion protection now falls within the scope of this directive also.
- Specifies general safety requirements.
- Applies to mining as well as all other hazardous areas.
- Applies to complete protective systems.

Dual responsibility

When equipment for explosion protection areas is being produced, system manufacturers and component suppliers must work closely together to ensure that the correct category and explosion protection zone are chosen.

Explosion protection documentation from system manufacturer	Festo/equipment supplier
System rated according to ATEX 137 Directive 99/92/EC	Equipment rated according to ATEX 95a Directive 94/9/EC
Result: • Zone classification • Temperature classes • Explosion groups • Ambient temperature	Result: • Equipment categories • Temperature classes • Explosion groups • Ambient temperature

Zone			Category		
			Equipment group	Equipment category	Area of application
			I	M1 M2	Mining
Gas zone	Dust zone	Frequency	II		All non-mining areas of application
0		Constant, frequent, long-term	II	1G	Gas, mist, vapour
	20		II	1D	Dust
1		Occasional	II	2G	Gas, mist, vapour
	21		II	2D	Dust
2		Seldom, short-term, in the event of a fault	II	3G	Gas, mist, vapour
	22		II	3D	Dust

Pneumatics and explosion protection – Directive 94/9/EC (ATEX)

ATEX at Festo? → www.festo.com/en/ex

Products requiring approval

Electrical equipment already required approval under the old directive. With these products, only the rating plate generally changes.
This directive also requires non-electrical equipment to obtain approval for the first time.
Included are:

- Piston rod drives
- Rodless drive units
- Semi-rotary drives
- Rotary drives
- Power valves
- Shock absorber

Equipment in these product groups must be supplied with operating instructions and a conformity declaration. These products also require an explosion protection mark.

Products not requiring approval

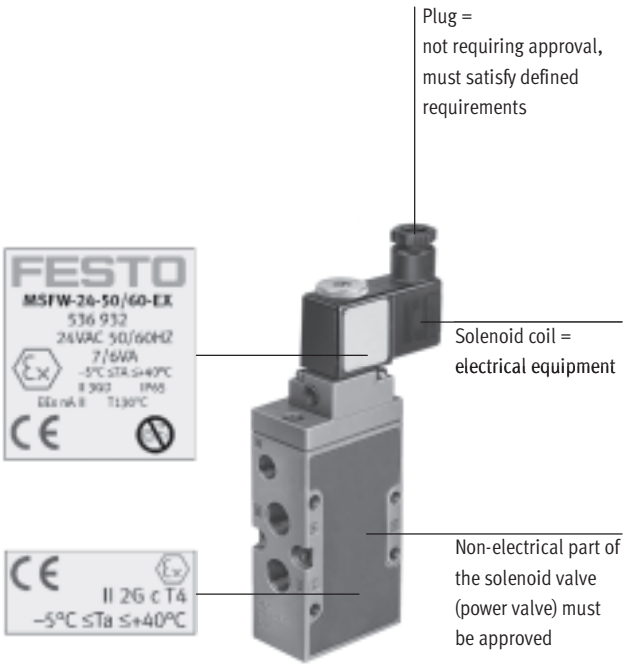
Products not requiring approval are those that do not have a potential ignition source. These products can be used in specific explosion zones in compliance with our manufacturer's instructions:

- Pneumatic accessories
- Tubing
- Fittings
- Pneumatic sub-bases
- Flow control and non-return valves
- Non-electrical service units
- Mechanical accessories

Festo's product range for explosion protection includes products for equipment category II

According to the directive 94/9/EC, both the solenoid coil and the power valve require approval in the case of valves. At Festo, each have a separate rating plate so that it is possible to tell at a glance where the valve may be used.

Important: The equipment with the lowest equipment category defines the category for the sub-assembly.



For the module in this example:
II 3G T4

- Note

The permissible technical catalogue data for the equipment in question as well as the warning notices and safety information in the enclosed (brief) operating instructions must be observed.

EC directives/approvals

EC directives (CE mark)

The EC Commission has formulated directives for the European market to harmonise the European internal market. The following EC directives are currently significant for products from Festo:

- **87/404/EEC**
  Basic pressure reservoirs
- **97/23/EC**
  Pressure equipment directive
- **2004/108/EC**
  Electromagnetic compatibility (EMC)
- **2006/95/EC**
  Low voltage directive
- **98/37/EC**
  Machine directive
  (as from 29.12.2009: 2006/42/EC)
- **94/9/EC**
  Equipment and protective systems for use in accordance with regulations in hazardous areas

The CE mark (CE = Communauté Européene) is not a quality symbol. The CE product symbol substantiates that the safety requirements of all of the EC directives relevant to the product have been complied with and the prescribed conformity evaluation process has been implemented. Festo certifies this with the following documents:

- "Conformity declaration"
- EC manufacturer's declaration according to the Machine Directive 98/37/EC
- Installation declaration according to Machine Directive 2006/42/EC for safety components and incomplete machines (from 29.12.2009)

This declaration and the resulting mandatory tests are prerequisites for products being stamped with the CE mark.

Pneumatic components and systems are not deemed to be machines or plant in the meaning of EC Machine Directive 98/37/EC and are therefore not required to have CE labels under this directive.
Festo provides a manufacturer's declaration for these components according to the EC machine directive. This largely corresponds with the conformity declaration with the note:

- "Commissioning must not take place unless the machine or unit meets the specifications.".

Products that cannot be certified according to the machine directive, but are obliged to be certified under the requirements of other EC guidelines (e.g. EMC), must be CE labelled. Festo pneumatic components and systems are designed in conformance with the manufacturing directives for pneumatic systems according to ISO 4414 and DIN 24558.

According to the new machine directive, which is to replace 98/37/EC from 29.12.2009, incomplete machines, safety components or load-carrying equipment can be Festo catalogue products.
Safety components and load-carrying equipment receive the CE mark and are provided with the conformity declaration for free movement of goods within the EU, Switzerland, Turkey and the EU accession states. Incomplete machines do not receive a CE mark and are provided with an installation declaration for the aforementioned free movement of goods.

Approvals

CE	See above
Ex	In accordance with EU directive 94/9/EC (ATEX) Equipment and protective systems for use in accordance with regulations in a hazardous atmosphere.
c US c UL us c SA us	UL certification Hazardous location Ordinary location

HACCP – Design – Clean room suitability

Food compatibility to HACCP

Type 15 CDVI

The HACCP standard (HACCP = Hazard Analysis Critical Control Points) describes a procedure for the identification, assessment and prevention of risks and hazards. The main focus is on biological, chemical and physical risks in the production process. The HACCP standard is also part of the EC directive on food hygiene (93/43/EEC).

Design awards

product design award

reddot

Festo valve terminals appear regularly on the winners' rostrum in major design competitions. There is much more to good design than being "easy on the eye". The design emphasizes and symbolises the technological edge and long-standing value of Festo products.

Clean room suitability

Festo tests some of its products for clean room suitability to VDI2083-8. Special testing laboratories are available for this purpose. Certification takes place in close cooperation with the Fraunhofer Institute and the Nanyang Technological University in Singapore.
The following products are available with certification for clean room classes to ISO 14644:

ISO4, FS209E class 10

- Pneumatic drives
  - Standard cylinders DSNU, ISO 6432
  - Standard cylinders CDN, ISO 15552, Clean Design
  - Compact cylinders ADN
  - Compact cylinders ADVU
  - Round cylinders DSNU
  - Linear drives DGPL-...-KF
  - Semi-rotary drives DRQD, twin pistons
  - Fluidic muscle MAS
  - Guided drives DFM-...-KF
  - Precision parallel grippers HGPP
  - T-slot grippers HGPT
- Electric drives
  - Toothed belt axes DGE
- Valves
  - Solenoid valves MHP1/MHA1, miniature
  - Solenoid valves MHE2, fast switching valves
  - Solenoid valves CPA-SC, Smart Cubic
  - One-way flow control valves GRLA/GRLZ
  - Flow control valves GRLO
- Valve terminals
  - Valve terminals type 82 CPA-SC, Smart Cubic
- Sensors
  - Proximity sensors for T-slot SME-8
  - Proximity sensors for C-slot SME-10
- Compressed air preparation
  - Filters LF, D series, metal design
  - Fine and micro filters LFMB/LFMA, D series, metal design
  - Pressure regulators LR, D series, metal design
  - On-off valves HE, D series, metal design
  - Branching modules FRM, D series, metal design
  - Distributor blocks FRZ, D series, metal design
  - Precision pressure regulators LRP
  - Precision pressure gauges MAP, DIN EN 837-1

ISO4, FS209E class 100

- Pneumatic drives
  - Standards-based cylinders DNC, ISO 15552
  - Linear drives DGC-...-KF
  - Linear drives DGPL-...-KF
  - Semi-rotary drives DRQD, twin pistons
  - Clamping modules EV
  - Linear/swivel clamps CLR
  - Mini slides SLT
- Electric drives
  - Toothed belt axes DGE
- Valves
  - Solenoid valves CPE, Compact Performance
- Valve terminals
  - Valve terminals type 15 CDVI, Clean Design
- Compressed air preparation
  - Filter regulators LFR, D series, metal design

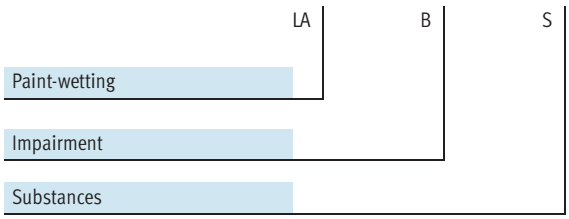
Detailed information on clean room suitability for selected products from Festo can be found in the following special catalogues:

- Clean Room Technology Part No. 054078
- Clean Room Products Part No. 052003

Paint-wetting impairment substances and resistance to media

FESTO

PWIS-free products



PWIS are substances that cause small concave indentations at various points in the paint layer when surfaces are painted.
Silicone, fluoric materials, certain oils and greases may contain substances of this kind.

Components used in the automobile industry, and especially in painting equipment, must be free of paint-wetting impairment substances.
Because it is impossible to determine the level of paint-wetting impairment substances contained in substances and components with the naked eye, Volkswagen developed the testing standard PV 3.10.7.
All products from Festo and the lubricants used in them undergo this test.
Products from Festo are free of paint-wetting impairment substances as standard.
However, it is necessary to use grease containing paint-wetting impairment substances for some products for functional and other reasons.

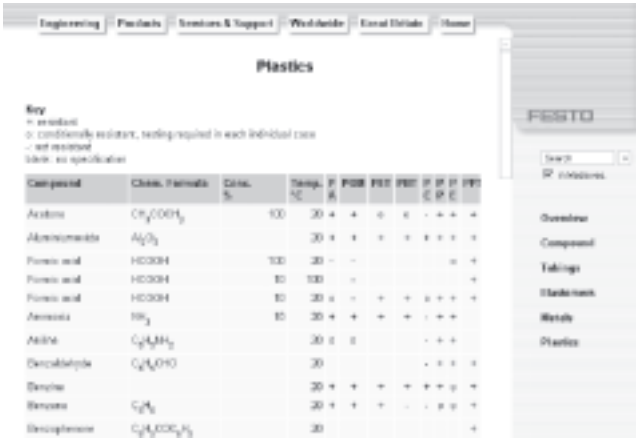
The following are PWIS-free

- Individual parts and modules that are manufactured without using components containing paint-wetting impairment substances in the material or consumables or sundry materials containing paint-wetting impairment substances. Tests carried out during the sampling procedure as well as random sample testing of incoming goods by means of extraction must not cause any paint-wetting impairment effects.
- Liquid or paste-like sundry materials (e.g. lubricating greases) that do not cause any paint-wetting impairment effects by means of application according to the test.
- Products that consist of PWIS-free parts and contain PWIS-free lubricants.

Media resistance database

➔www.festo.com/media_resistance

It is well known that the resistance of materials depends on many parameters such as concentration of contact medium, temperature, pressure, length of contact, stroke speed and switching frequency, surface finish in the case of mating frictional parts, current speed and stress as well as ageing.
This applies in particular to the compatibility of elastomers with special chemical compounds.
The Festo resistance database shows you the suitable material and its resistance to chemical substances.
The information contained in this database is based on lab tests from raw material manufacturers, material tables from semi-finished product and seal suppliers and practical experience.
The information is evaluated and the tables are created based on the knowledge available. Although every effort has been made to ensure the accuracy of this database, its contents should only be used for reference purposes.
Please note that the recommendations in this resistance database can neither be guaranteed nor serve as the basis for a warranty claim.
Wherever possible and always in cases of doubt, it is advisable to perform a field test with the desired product under genuine operating conditions.



Protection classes according to IEC/EN 60529

FESTO

Protection of electrical equipment

The standard IEC/EN 60529 "Degrees of protection provided by enclosures (IP code)" describes the protection of electrical equipment using enclosures, covers, etc. and deals, amongst other things, with the following:

- Protection of persons against contact with live or moving components within enclosures.
- Protection of electrical equipment against ingress of solid foreign matter, including dust.
- Protection of electrical equipment against the harmful effects of water.
- Codes for the internationally agreed types and degrees of protection.

The IP code to IEC/EN 60529

The protection class with an enclosure is shown using standardised testing methods. The IP code is used for classification of this protection class. The IP code is made up of the letters IP and a two-digit code number. The definition of both digits is explained in the table on the next page ➔ i-18.

Meaning of digit 1:
Digit 1 rates, on the one hand, the protection of persons. It specifies the extent to which the enclosure prevents persons from coming into contact with dangerous parts. The enclosure prevents or restricts the entry of body parts or of objects held by a person. On the other hand, digit 1 specifies the extent to which the equipment is protected against the ingress of solid foreign matter.

Meaning of digit 2:
Digit 2 refers to the protection of equipment. It rates the protection class of the enclosure with respect to the harmful effects on the equipment due to water entering the enclosure.

- Note

The food industry generally uses components with IP protection class 65 (dustproof and hose-water proof) or IP67 (dustproof and capable of brief submersion). The use of IP65 or IP67 depends on the specific application, as each is governed by completely different test criteria. IP67 is not necessarily better than IP65. A component that fulfils the IP67 criteria does therefore not automatically satisfy the criteria for IP65.

Protection classes according to IEC/EN 60529

FESTO

IP codes

IP 6 5

Code letters	
IP	International Protection

Digit 1	Brief description	Definition
0	Not protected	–
1	Protected against solid foreign matter, 50 mm and larger	A probing object, a ball of 50 mm in diameter, must not penetrate the enclosure.
2	Protected against solid foreign matter, 12.5 mm and larger	A probing object, a ball of 12.5 mm in diameter, must not penetrate the enclosure.
3	Protected against solid foreign matter, 2.5 mm and larger	A probing object, a ball of 2.5 mm in diameter, must not enter at all.
4	Protected against solid foreign matter, 1.0 mm and larger	A probing object, a ball of 1 mm in diameter, must not enter at all.
5	Protected against dust	The ingress of dust is not completely prevented. The quantity of dust that enters must not impair satisfactory operation of the equipment or safety.
6	Dustproof	No ingress of dust.

Digit 2	Brief description	Definition
0	Not protected	–
1	Protected against water drops	Vertically falling drops must not have any harmful effect.
2	Protected against water drops	Vertically falling drops must not have any harmful effect when the enclosure is inclined up to 15° either side of the vertical.
3	Protected against spray water	Water sprayed at any angle up to 60° either side of the vertical must not have any harmful effect.
4	Protected against splashed water	Water splashing against the enclosure from any angle must not have any harmful effect.
5	Protected against water jets	Water directed at the enclosure from any angle in jet form must not have any harmful effect.
6	Protected against powerful water jets	Water directed against the enclosure from any angle in powerful jet form must not have any harmful effect.
7	Protected against the effect of brief submersion in water	Water must not enter the equipment in amounts that can have a harmful effect if the enclosure is briefly submerged in water under standardised pressure and time conditions.
8	Protected against the effect of continuous submersion in water	Water must not enter the equipment in amounts that can have a harmful effect if the enclosure is continuously submerged in water. The conditions must be agreed between the manufacturer and the user. The conditions must, however, be more severe than code 7.
9K	Protected against water from high-pressure and steam jet cleaning	Water directed at the enclosure from any angle under high pressure must not have any harmful effect.

Functional earthing – Protective earth – PELV

FESTO

Concepts for ensuring protection against electric shock to IEC 60364-4-41/VDE 0100 Part 410

Definitions

Protection against electric shock means protection against indirect and direct contact.

Protection against direct contact implies that live parts (active parts), which are not insulated under normal operating conditions, are protected against accidental contact.

Protection against indirect contact implies that in the event of an insulation fault between active parts and bodies or enclosures, no contact voltages outside of the permissible range can occur or are disconnected promptly.

The three best-known and most widely used concepts for ensuring protection against electric shock are also referred to as protection class I through III in specialist literature and standardisation work.

Protection class I – Protective earth conductor

In the case of electrical equipment in protection class I, protection against direct contact is ensured by means of basic insulation.
Protection against indirect contact is provided by means of prompt disconnection of the fault voltage. This disconnection is ensured by the contacting of the protective earth conductor on the equipment enclosure with protective earth.
If an insulation error occurs in the equipment, the fault current flows via the protective circuit against the earth potential, thereby triggering the upstream fuse element (e.g. residual current device protection or circuit-breaker).

Equipment in protection class I includes lights, white goods (washing machines, dryers, etc.) and industrial machinery. Symbol:

Protective class II – Protective insulation

In the cases of equipment in protection class II, the protection refers to direct and indirect contact with the improved enclosure insulation. The enclosure insulation is reinforced or doubled so that it is not possible to come into contact with contact voltages outside of the permissible range either in the event of a fault or during operation.

Equipment in protection class II must not be connected to the protective circuit. This equipment does not therefore have the protective contact on the plug.

Equipment in protection class II includes hi-fi components, electric power tools and household appliances and is identified with the following symbol:

Protective class III – Protective extra-low voltage (PELV)

In the case of equipment in protection class III, protection against direct and indirect contact is ensured both by means of a sufficiently high IP protection class (protection against direct contact with active parts) and electrical supply of the component with protective extra-low voltage (protection against indirect contact in the event of a fault).

Equipment in protection class III is frequently identified (no mandatory identification) with the following symbol:

Functional earthing – Protective earth – PELV

FESTO

Special protection class for components from Festo

Protection class III

On the basis of the information currently available, all 24 V DC valve terminals (type 02, 03, 04, 05, 06, CPV, CPA...), positioning controllers (PLC..., etc.), sensors (proximity sensors, pressure switches, pressure sensors) and proportional valves from Festo belong to protection class III.

This means in the case of the 24 V DC components from Festo, protection against direct and indirect contact is ensured by means of a sufficiently high IP protection class as well as a protective extra-low voltage supply to the component: PELV.

The use of a PELV supply ensures that no contact voltages outside of the permissible range can occur in the event of a fault due to the high dielectric strength (4 kV) from the primary to the secondary side.

The earth terminal therefore has a functional earthing (discharge of electromagnetic disturbances) rather than a protective earth function and must always be contacted.

Why does Festo use protection class III?

Due to the increasingly compact designs of modern automation components, protection class I is no longer the optimum solution with respect to the construction size because the standards specify minimum distances for the air and leakage paths, which means that a further minimising of the size of the components is no longer possible.
It is for this reason that protection class III (no protective earth conductor, protection against electric shock provided by protective extra-low voltage) is used in modern automation components.

What do customers need to know about installing equipment in protection class III?

To supply the equipment, only power supply units that guarantee reliable electrical isolation of the operating voltage to IEC 742/EN 60742 with at least 4 kV insulating strength must be used. Switch power packs are permitted, providing they guarantee reliable isolation as per EN 60950/VDE 0805.

For PELV circuits, suitable supply sources are safety isolating transformers, which carry the following symbol:

The earth terminals on the components, where available, are used for discharging electromagnetic disturbances, equipotential bonding and thus ensuring proper functioning. They must be connected with low resistance (short lines with large cross section) to the earth potential.

Spark arresting

Spark arresting of switch contacts in circuits with solenoid coils

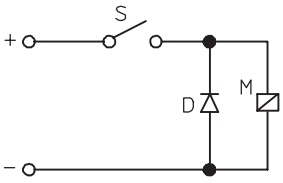
The inductance of solenoid coils stores electromagnetic energy when the circuit is switched on and this is discharged when switched off. Depending on the switch used, this energy is either converted to a voltage peak (switch-off overvoltage), which can cause pitting in the insulation, or an arc which can burn away the contacts (material corrosion). Various types of components can be used to avoid these effects by slowly and constantly discharging the electromagnetic energy.

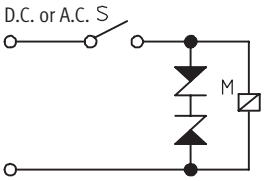
Electronic arc arrestors

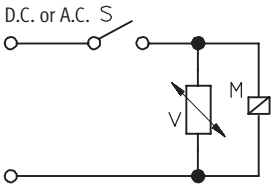
If the polarity in DC circuits is clearly defined, a simple diode can be used, wired parallel to the coil. It must be noted that this considerably increases the solenoid switch-off time.

A more suitable arrangement consists of two zener diodes, wired with opposing polarity parallel to the coil, which can be used for DC and AC. This prevents switch-off delay. However, several zener diodes must be wired in series for voltages over 150 V.

Varistors are ideal elements for reducing switch-off overvoltage; their leakage current only rises if the rated voltage is exceeded. They are suitable for DC and AC.







100% duty cycle

Within DIN VDE 0580, the 100% duty cycle test covers only the electrical part of the solenoid coil. Festo also includes the pneumatic part in this test.
The worst-case scenario is reviewed in the test. The test represents a function testing of the solenoid. If the solenoid is also used on valve terminals, the 100% duty cycle test is performed on the individual device and on equipment in a manifold assembly.

Conditions

- The solenoids are operated with the maximum permissible voltage (continuous operation S1 to DIN VDE 0580).
- The solenoids are subjected to the maximum permissible ambient temperature in a temperature cabinet (non-convecting).
- The solenoids are supplied with the maximum permissible operating pressure with sealed working lines.

Implementation

The solenoids are operated for at least 72 hours under the above conditions. At the end of this period, the following tests are carried out:

- Drop-out current measurement: drop-out behaviour when switched to de-energised state.
- Starting behaviour when immediately energised with the minimum operating voltage and with the least favourable pressure ratios for pick-up.
- Leakage measurements.
- Once the results have been recorded, this process is repeated again until the units under test have reached a total duty cycle of at least 1,000 hours or a termination criterion has been fulfilled.
- Following completion of the 100% duty cycle test, the sealing nipples are inspected visually for damage.

Termination criterion

The drop-out behaviour, starting behaviour or leakage exceeds or falls below the following limit values:

- Drop-out current: > 1.0 mA
- Starting voltage: > UN+10%
- Leakage: > 10 l/h