Operating conditions and standards in pneumatics

What must be observed when using Festo products?

The limit values specified in the technical data and any specific instructions must be adhered to by the user in order to ensure correct functioning.
The user must ensure that pneumatic components are operated using correctly prepared compressed air free of aggressive media.
The relevant national and international regulations must always be adhered to when using Festo products in safety-oriented applications.
Unauthorised conversions or modifications to products and systems from Festo involve a safety risk and are thus not permitted.
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.
- 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 are correct at the time of going to print.

Standards in pneumatics

Standards also have great significance in pneumatics. Standards mean harmonisation (standardisation). Standardisation is also the basis for the free trade of goods and services between companies nationally as well as internationally.
Standards in industry describe the state of the art technology. They provide a common basis for the evaluation of technical aspects. Standards relevant for pneumatics deal with dimensions, safety and quality. Festo has for many years been actively participating in the relevant national and international standards organisations.

Chapter 1 – Pneumatic drives

- Standards-based cylinders to ISO 6432.
- Standards-based cylinders to ISO 21 287.
- Standards-based cylinders to ISO 15552 (ISO 6431, DIN ISO 6431, VDMA 24 562), NFE 49003.1 and UNI 10290.
- Rod clevises to ISO 8140 and DIN 71 752.
- Rod eyes to ISO 12 240-4, dimensional series K.

Chapter 8/9 – Valves/valve terminals

- Valve terminals for standard 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 15407-2.
- 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 12/13 – Compressed air preparation/pneumatic connection technology

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

Compressed air preparation

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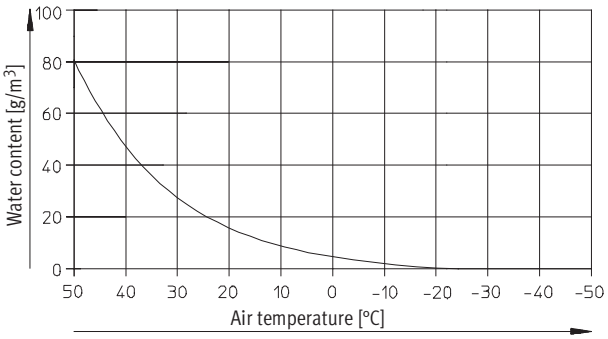
Why compressed air preparation?

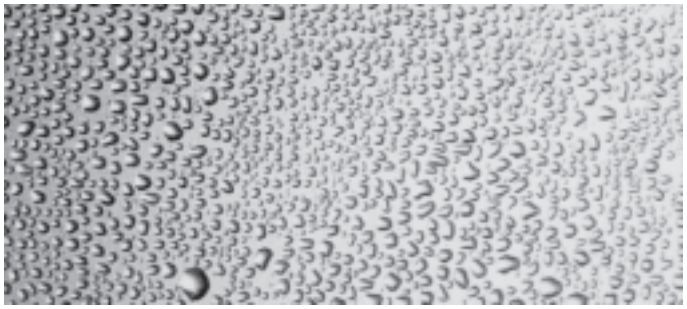
Water content in air

The maximum water content in 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.



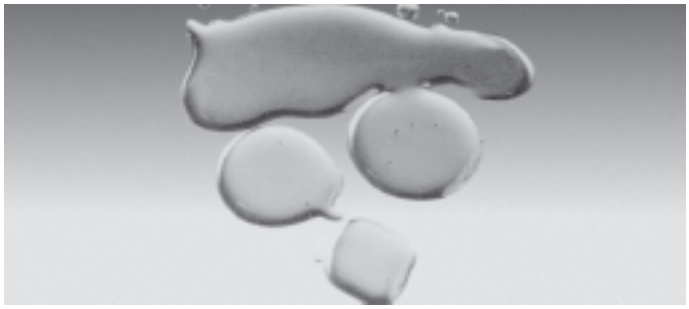
Water condensation

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 prevents malfunctions in the connected consuming devices.



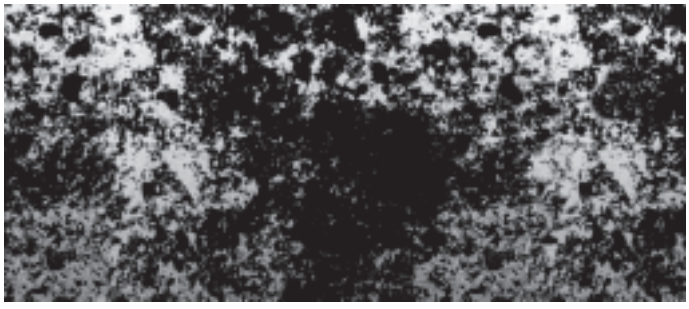
Oil contamination

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 accumulation 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

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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. The quality of the compressed air is defined by the grade of filtration, the pressure dew point and the residual oil content (droplets, aerosols and vapours).

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.

Sizing

Note

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

More information
➔ Chapter 12

The size of the service unit depends on 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 enable 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 chemical and pharmaceutical 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 pilot 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. Supply 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 air stream. The lubricator is only functional when the air flow is sufficiently strong.

Lubricated compressed air

The following notes must be observed when lubricated compressed air is used:

- Use Festo special oil OFSW-32 or the alternatives listed in the Festo catalogue (as specified in DIN 51524-HLP 32; basic oil viscosity 32 cSt at 40 °C).
- If lubricated compressed air is used, additional lubrication may not exceed 25 mg/m^3 (DIN ISO 8573-1: 1995-04). The compressed air prepared downstream of the compressor must correspond in quality to unlubricated compressed air.
- The lifetime lubrication required for unlubricated operation can be "flushed out" when products are operated using lubricated compressed air. This can lead to malfunctions.
- The lubricators should, where possible, always be installed directly upstream of the cylinders used in order 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 colouration. If oil droplets appear, 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 inspections 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.

Compressed air preparation

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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 effects. 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 must not exceed 0.1 mg/m^3.
  This corresponds to DIN ISO 8573-1: 1995-04 class 2 ➔ Chapter 12.
  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, part 2) or similar oils based on polyalphaolefin (PAO). In this case, residual oil content must not exceed 5 mg/m^3. This corresponds to DIN ISO 8573-1: 1995-04 class 4 ➔ Chapter 12.
  Greater residual oil content cannot be permitted, regardless of compressor oil, because permanent lubrication would otherwise be flushed out over a period of time. This can lead to malfunctions.

Moisture

Max. pressure dew point 3 °C.
Corresponds to DIN ISO 8573-1:1995-04 min. class 4 ➔ Chapter 12.

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.

Solids

Max. particle size 40 µm.
Corresponds to DIN ISO 8573-1:1995-04 class 5 ➔ Chapter 12.

Suitable oils

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

Note
Optimum compressed air preparation means fewer machine failures and greater process reliability. See **Compressed air quality analysis**

Classification of quality classes to DIN ISO 8573-1:1995-04

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 8573-1:1995-04			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	4	40	3
Standard pneumatics + bio-oil	3	4	2	5 + 1 + 0.01	3
Packaging machines	5	4	3	5 + 1	3
Machine tools	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 systems	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 regulators	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 grade 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 at Festo:

- Test medium air
- Temperature 20 ±3 °C = temperature of medium
- Test specimen at ambient temperature
- The pressure to be set is: 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:
Silencer
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.

Symbol
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 and 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 and highest permissible pilot pressure for correct 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). Pressure that is calculated from this theoretical zero point is absolute pressure.

Response pressure

Pressure at which a directional control valve is actuated. Catalogue specifications for response pressure 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 lines	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

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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 conveying 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.

Mounting 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 and 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 mounting 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 diameter [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, the 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 just represented by ∅ in the dimensions table.

Pressure/force table

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Piston force [N]								
Diameter	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]							
Diameter	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]

ProPneu software tool for sizing can be found on the DVD and at www.festo.com

Pressure/force graph

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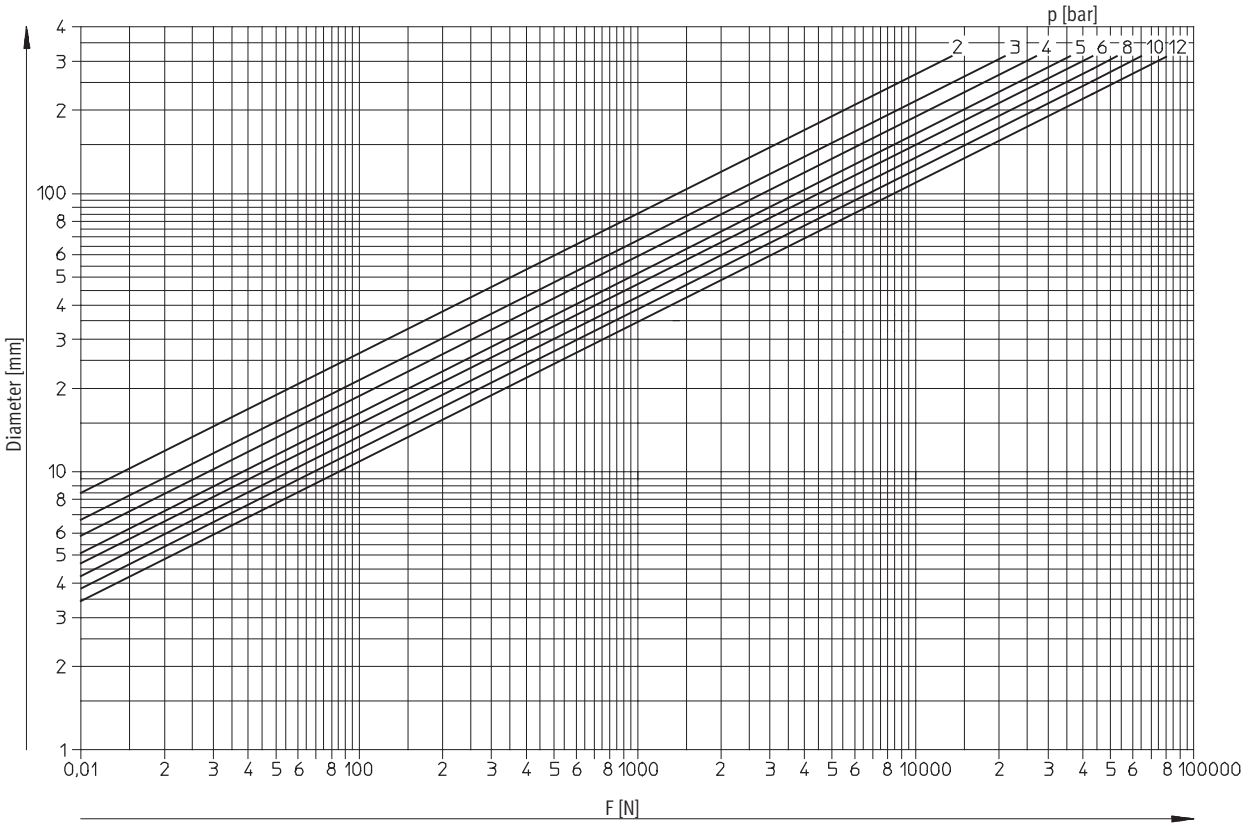
Operating pressure p as a function of piston diameter and force F

An allowance of 10% has been included for frictional force



Given:
Load 800 N
Available system pressure 6 bar

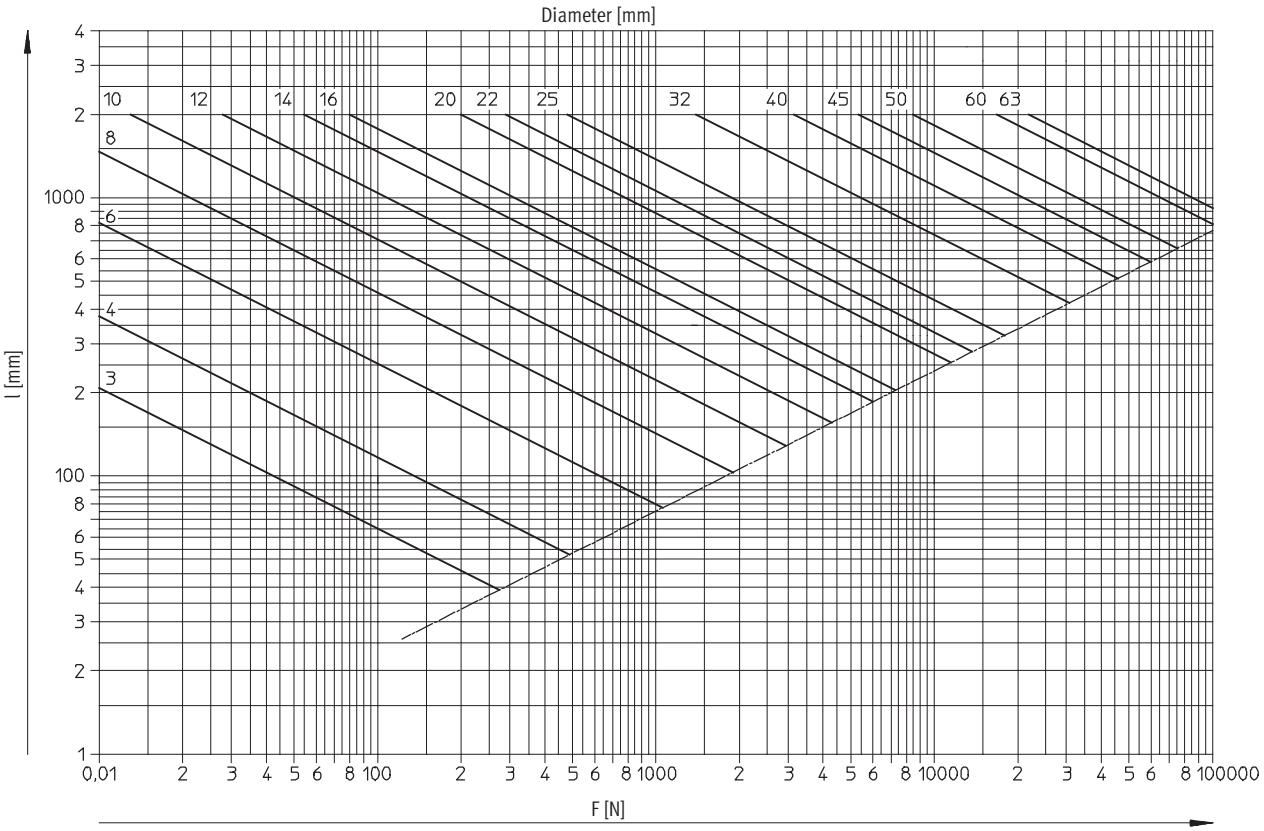
To be calculated:
Required piston diameter
Operating pressure to be set

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 calculated:
Piston rod diameter
Cylinder type: Standard cylinder

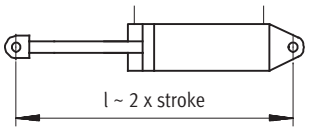
Procedure:
From F = 800 N go vertically upwards to the point of intersection with the horizontal line through l = 500 mm. The next largest piston rod diameter in the graph is 16 mm. The standard cylinder DNC-50-500 with a piston rod diameter of 20 mm is suitable for this stroke length.

Due to buckling stress, the maximum permissible load for a piston rod with a long stroke length is lower than the value suggested by the 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 [cm⁴]
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 mounting.

Air consumption

Air Consumption sizing software

The “Air Consumption” sizing software determines the air consumption of a cylinder (reference value) taking into account the following conditions:

- Mode of operation of the cylinder
- Piston diameter
- Number of cycles
- Stroke length
- Operating pressure

This tool can be found online under support in the sizing software area.

Calculation using the sizing software

Given:
Cylinder: DNC-32-500
Piston ∅: 32 mm
Piston rod diameter: 12 mm
Stroke length: 500 mm
Operating pressure: 6 bar
Number of cycles per minute: 60 1/min

To be calculated:
Air consumption

Result:
The parameters entered produce the following values for air consumption:
Per cycle: 5.23 l
Per minute: 314.03 l

Calculation using the formula

$$Q = \frac{\pi}{4} \cdot (d1^2 - d2^2) \cdot h \cdot (p + 1) \cdot 10^{-6}$$

Q = Air consumption per cm stroke [l]
d1 = Piston diameter [mm]
d2 = Piston rod diameter [mm]
h = Stroke [mm]
p = Operating pressure, relative [bar]

Forward stroke:

$$Q = \frac{\pi}{4} \cdot (32mm)^2 \cdot 500mm \cdot (6bar + 1bar) \cdot 10^{-6}$$

$$Q = 2.815l$$

Return stroke:

$$Q = \frac{\pi}{4} \cdot ((32mm)^2 - (12mm)^2) \cdot 500mm \cdot (6bar + 1bar) \cdot 10^{-6}$$

$$Q = 2.419l$$

Air consumption per cycle:

$$Q = 2.815l + 2.419l = 5.234l$$

Pneumatics and explosion protection – EU 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. These explosive atmospheres are caused by escaping gas, vapours and mist, for example. Explosive atmospheres can also be expected in mills, silos and sugar and feed processing plants because of the dust/oxygen mixtures that occur there. For this reason, electrical equipment in hazardous areas is subject to a special directive, 94/9/EC. This directive was also extended to non-electrical equipment on 01.07.03.

ATEX - Directive 94/9/EC

ATEX is an acronym of the French expression “Atmosphère explosible”.

- **Directive 94/9/EC** stipulates the minimum safety requirements for equipment and protective systems that are to be operated in explosive atmospheres and that have their own ignition sources.
- It applies to the sale of equipment and protective systems in/within the European Economic Area.
- It relates to both electrical and non-electrical equipment, if they have their own potential ignition source.

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 rating Directive 99/92/EC  Result: • Zone classification • Temperature classes • Explosion groups • Ambient temperature	Equipment rating Directive 94/9/EC  Result: • Equipment categories • Temperature classes • Explosion groups • Ambient temperature
Zone	**Category**

Explosion protection classes

Gas zone	Dust zone	Frequency	Equipment group	Equipment category	Area of application
–	–	–	I	M	Mining
				M1	
				M2	
			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 – EU directive 94/9/EC (ATEX)

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ATEX at Festo ➔ www.festo.com/en/ex

Products requiring approval

Products requiring approval are those that have their own potential ignition risk. They are labelled with the CE marking and the explosion protection hexagon; operating instructions and the EC declaration of conformity are provided.

Products not requiring approval

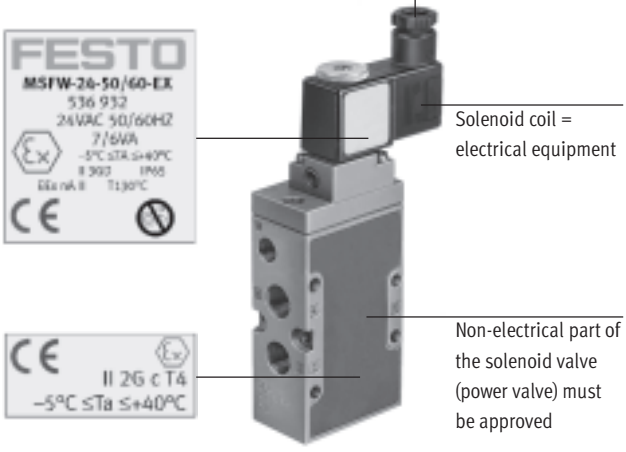
Products not requiring approval are those that do not have their own potential ignition source. These products can be used in specific explosion zones in compliance with our manufacturer's instructions:

- 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 module.



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 special documentation provided (including operating instructions, if applicable device document) must be observed.

EC directives/approvals

EC directives (CE symbol)

Festo AG & Co. KG adheres in principle to the applicable regulations. All information is based on the state of knowledge today and is subject to change. We carefully follow any amendments/additions to these regulations and will produce our products accordingly.
This guarantees that products from Festo AG & Co. KG always comply with the currently valid requirements.

Most pneumatic products are not subject to any EC directive and consequently must not be labelled with the CE marking. As things currently stand, products from the sales range of Festo AG & Co. KG that are labelled with the CE marking are subject to one or more of the following six EC directives in Europe.

1. EC machinery directive 2006/42/EC
Pneumatic products from Festo AG & Co. KG are designed in compliance with the standards for pneumatic systems to ISO 4414 as well as EN 983 "Safety requirements for fluid systems and their pneumatic components". Our pneumatic products do not fall within the scope of application specified in the EC Machinery Directive.

They must therefore also not be labelled with the CE marking in accordance with Machinery Directive. Exceptions to this are safety components. As of 29.12.2009, incomplete machines also fall under the scope of application of the Machinery Directive. These include handling systems intended for installation in machines, for example. Incomplete machines are not labelled with the CE marking. The corresponding declaration of conformity and the operating instructions are available.

2. EC Directive on Electromagnetic Compatibility (2004/108/EC), including amendments.
The directive must be applied to our electronic and electronic/pneumatic products. This means that corresponding products have had the CE marking since 01.01.96 and the corresponding declaration of conformity is available.
For you, this means a guarantee that this equipment complies with the fundamental requirements in industrial areas. The use of this equipment in residential areas is restricted if no additional measures are taken to guarantee compliance with the fundamental requirements of the directive for residential areas.
Solenoid coils are not affected by the EMC Directive.

3. EC Low Voltage Directive (2006/95/EC), including amendments.
Since 01.01.97, electrical and electronic products from Festo designated for use within specific voltage limits (50 ... 1,000 V AC and 75 ... 1,500 V DC) must be labelled with the CE marking. The corresponding declarations of conformity are available.

4. EC Directive on Simple Pressure Vessels (2009/105/EC), including amendments.
In force since 30.06.1991. The simple pressure vessels made from non-alloyed steel offered by Festo AG & Co. KG comply with the requirements of this directive. These air reservoirs require CE marking above a certain volume.

These products are labelled with the CE marking. The declaration of conformity is available.

5. EC Directive on Pressure Equipment (97/23/EC), including amendments.
In force since 29.05.2002.
The pressure vessels offered by Festo AG & Co. KG comply with the requirements of this directive. These pressure vessels require CE marking above a certain pressure/volume product or pressure/diameter product.

These products are labelled with the CE marking. The declaration of conformity is available.

Reservoirs made from stainless steel are subject to the Directive on Pressure Equipment rather than the Directive on Simple Pressure Vessels.

6. EC Directive on Equipment and Protective Systems intended for use in Potentially Explosive Atmospheres - ATEX (94/9/EC).
In force since 01.07.03.
The products offered by Festo AG & Co. KG which are intended for use in potentially explosive atmospheres and which have their own potential ignition risk comply with the requirements of this directive. Products that are subject to this directive are correspondingly labelled with the CE marking and identified in compliance with the directive. The corresponding declaration of conformity and the operating instructions are available.

Product markings

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 UL us	UL certification for use in Canada and the USA. Recognized Product intended for installation, for example MPA valve terminal.
c UL us	UL certification for use in Canada and the USA. Listed Product, a ready-to-use device, for example limit switch with cable and plug.
c SP us	CSA certification for Canada and the USA.

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 products appear regularly on the winners' rostrum in major design competitions. There is much more to good design than being “pleasing to the eye”. The design emphasises and symbolises the technological edge and long-standing value of Festo products.

Clean room suitability

➔ www.festo.com/en/cleanroom

Cost-effective series for clean room class 7
At Festo, cost-effective standard pneumatic components take the place of complex special designs. This is possible because the quality concept is compatible with almost all standard production products. These standard pneumatic components are suitable for use in a class 7 clean room according to ISO 14644-1.

Close-to-standard products for clean rooms to class 4
Stringent requirements but still an optimum cost/benefit ratio. Class 4 is also a standard product at Festo with one restriction, i.e. they are not kept in stock. Nonetheless, they can be delivered to you within the shortest possible time.

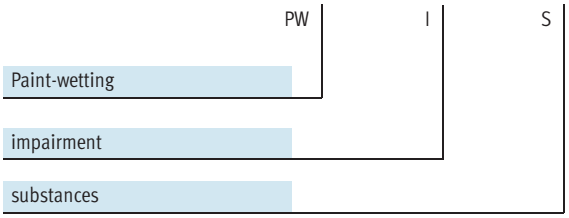
Individuality made to measure
If you need to go as far as class 1, the products will be manufactured according to your specific requirements. Festo integrates these application-oriented solutions in close-to-standard production, which means they will be available the next time you need them.

The reliability to meet the highest requirements
Festo works with the Fraunhofer Institute for Production Technology and Automation (IPA) and the renowned Nanyang Technological University in Singapore to ensure that its products meet the high requirements for clean room products. A dedicated Competence Center for Cleanroom Technology at Festo Singapore offers the necessary infrastructure for the production of pneumatic clean room products.

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 automotive 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

- For the manufacture of individual parts and modules neither the materials nor the sundries should contain 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 through application as a result of the test.
- Products that consist of PWIS-free parts and contain PWIS-free lubricants.

Media resistance database

➔ www.festo.com/mediaresistance

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 practical test with the desired product under actual operating conditions.

Protection classes according to IEC/EN 60529

Protection of electrical equipment

The terminology for designating the extent of electrical protection provided by an enclosure is "IP" (International Protection) and is defined by IEC/EN 60529 "Degree of Protection Provided by Enclosures (IP Code)" and DIN 40050 "IP Protection Classes" (standard for electrical equipment in road vehicles). These standards describe the classification of degrees of protection provided by enclosures for electrical equipment with rated voltages of up to and including 72.5 kV. They set forth requirements for the following:

- Protection of individuals against contact with live or moving components within enclosures (protection against accidental contact)
- Protection of equipment inside the housing against ingress of solid foreign matter, including dust (foreign matter protection)
- Protection of electrical equipment against damage that would result if water were to enter the enclosure (protection against water)

The IP code to IEC/EN 60529

The protection class provided by an enclosure is demonstrated using standardised testing methods. The IP code is used for classifying 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 ➔ 1844.

Meaning of digit 1:
Digit 1 denotes firstly the protection of individuals. It specifies the extent to which the enclosure prevents individuals from coming into contact with dangerous parts. The enclosure prevents or restricts the entry of body parts or of objects held by an individual. Secondly, 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

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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 enter or 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 enter or 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 penetrate 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 penetrate at all.
5	Protected against dust	The ingress of dust is not completely prevented. The quantity of dust that enters must not impair the safety or satisfactory operation of the equipment.
6	Dustproof	No ingress of dust.

Digit 2	Brief description	Definition
0	Not protected	–
1	Protected against water droplets	Vertically falling droplets must not have any harmful effect.
2	Protected against water droplets	Vertically falling droplets must not have any harmful effect when the enclosure is at an angle of 15° either side of the vertical.
3	Protected against spray water	Water sprayed at any angle of up to 60° either side of the vertical must not have any harmful effect.
4	Protected against water splashes	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 earth – 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, contact voltages outside of the permissible range cannot 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 to 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 via protective earth.
If an insulation fault 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 earth – 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 that 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 "Protective Extra-Low Voltage".

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 is a functional earthing (discharge of electromagnetic disturbances) rather than a protective earth function and must always make contact.

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 construction size. This is 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, as protection against electric shock is 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?

The electrical supply to the equipment must only be provided by PELV circuits to IEC/EN 60204-1. The general requirements for PELV circuits as per IEC/EN 60204-1 must be taken into account. Power sources are permitted if reliable electrical isolation of the operating voltage to IEC/EN 60204-1 is guaranteed.
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 to the earth potential with low resistance (short lines with large cross section).

Spark arresting

Spark arresting of switch contacts in circuits incorporating solenoid coils

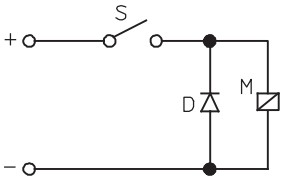
The inductance of solenoid coils stores electromagnetic energy when the circuit is switched on and this is discharged when switched off. Depending on the switch used, this energy is either converted to a voltage peak (switch-off overvoltage), which can cause a breakdown in the insulation, or an arc which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

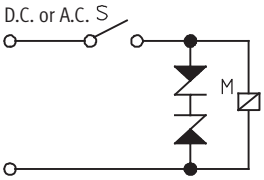
Electronic arc arrestors

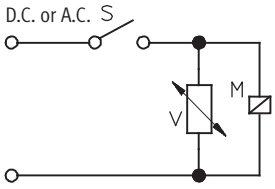
If the polarity in DC circuits is clearly defined, a simple diode can be used, wired parallel to the coil. It must be noted that this considerably increases the solenoid switch-off time.

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.

Procedure

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-off current measurement: drop-off 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 excitation.
- Leakage measurements.
- Once the results have been recorded, this process is repeated again until the units being tested 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-off behaviour, starting behaviour or leakage exceeds or falls below the following limit values:

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