# Operating conditions and standards in pneumatics

## What must be observed when using Festo components?

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.

## 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.
- 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 5599-1.
- Valve terminals with port pattern to DIN ISO 5599-2.

- Valve sub-bases to ISO 15407-1.
- Valve terminals with port pattern to DIN ISO 5599-2.
- 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)

The size of the service unit depends upon system air consumption. Under-sizing 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.

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

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/m³ (DIN ISO 8573-1 class 5). The quality of compressed air downstream from the compressor must correspond to that of un lubricated 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.
Compressed air preparation

Oil content

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

Un lubricated 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.

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 ).

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 particle size of the drying agent must be at least 10 K lower than the temperature of the medium, since water would otherwise form in the expanded air.

Quality classes to DIN ISO 8573-1

<table>
<thead>
<tr>
<th>Class</th>
<th>Solids</th>
<th>Water content</th>
<th>Oil content</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Max. particle size [µm]</td>
<td>Max. particle density [mg/m³]</td>
<td>Max. pressure dew point [°C]</td>
</tr>
<tr>
<td>1</td>
<td>0.1</td>
<td>0.1</td>
<td>–70</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>1</td>
<td>–40</td>
</tr>
<tr>
<td>3</td>
<td>5</td>
<td>5</td>
<td>–20</td>
</tr>
<tr>
<td>4</td>
<td>15</td>
<td>8</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>40</td>
<td>10</td>
<td>7</td>
</tr>
<tr>
<td>6</td>
<td>–</td>
<td>–</td>
<td>10</td>
</tr>
<tr>
<td>7</td>
<td>–</td>
<td>–</td>
<td>not defined</td>
</tr>
</tbody>
</table>

Compressed air quality in use

<table>
<thead>
<tr>
<th>Applications</th>
<th>Classes to DIN ISO 8573-1</th>
<th>Recommended grades of filtration [µm]</th>
<th>Recommended pressure dew point [°C]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mining</td>
<td>5</td>
<td>5 + 1 + 0.01 + activated carbon</td>
<td>–40</td>
</tr>
<tr>
<td>Glass and stone processing</td>
<td>5</td>
<td>5 + 1 + 0.01</td>
<td>–20</td>
</tr>
<tr>
<td>Shoe production</td>
<td>5</td>
<td>5 + 1 + 0.01</td>
<td>–20</td>
</tr>
<tr>
<td>Welding systems</td>
<td>4</td>
<td>5 + 1 + 0.01</td>
<td>–20</td>
</tr>
<tr>
<td>Standard pneumatics</td>
<td>5</td>
<td>5 + 1 + 0.01</td>
<td>–20</td>
</tr>
<tr>
<td>Standard pneumatics + bio-oil</td>
<td>3</td>
<td>5 + 1 + 0.01</td>
<td>–20</td>
</tr>
<tr>
<td>Packaging machine</td>
<td>5</td>
<td>5 + 1 + 0.01</td>
<td>–20</td>
</tr>
<tr>
<td>Machine tool</td>
<td>5</td>
<td>5 + 1 + 0.01</td>
<td>–20</td>
</tr>
<tr>
<td>Film development</td>
<td>1</td>
<td>5 + 1 + 0.01 + activated carbon</td>
<td>–40</td>
</tr>
<tr>
<td>Sensors</td>
<td>2</td>
<td>5 + 1 + 0.01</td>
<td>–20</td>
</tr>
<tr>
<td>Instrument air</td>
<td>2</td>
<td>5 + 1 + 0.01</td>
<td>–20</td>
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<td>Painting system</td>
<td>2</td>
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<tr>
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<td>2</td>
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<tr>
<td>Transportation of granulate</td>
<td>3</td>
<td>5 + 1 + 0.01</td>
<td>–20</td>
</tr>
<tr>
<td>Transportation of powder</td>
<td>2</td>
<td>5 + 1 + 0.01</td>
<td>–20</td>
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</tbody>
</table>

Suitable oils

- Special oil in 1 litre containers:
  Order code 152 811 0HSW-32

Key products – Subject to change – 2007/07

General information

Commercial drying to a pressure dew point of 3 °C.

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

Oils can be mixed when used as the basic lubricant in the oil separation process. Concentrations of residual oil content:

- H- This complies with DIN ISO 8573-1 Chapter 6. Larger oil content: In this case, residual oil content may not exceed 5 mg/m³. 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.

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Operating conditions for valves

Medium

Under normal operating conditions, pneumatic valves from Festo can be operated with lubricated or un lubricated 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 un lubricated 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 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:

\[
\begin{align*}
 t_n &= 20 \, ^\circ C \\
 \rho_n &= 1.013 \, \text{bar} \\
 \rho_n &= \text{Absolute pressure (ambient pressure)}
\end{align*}
\]

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

- Test medium air
- Temperature 20 ±3 °C
- Test specimen at ambient temperature

The pressures to be set are:

- Silencers: Supply pressure \( p_1 = 6 \, \text{bar} \) Output pressure \( p_2 = \text{ambient pressure} \)
- Low-pressure components: Supply pressure \( p_1 = 0.1 \, \text{bar} \) Output pressure \( p_2 = \text{ambient} \)

Exception 1:

- Silencers: Supply pressure \( p_1 = 6 \, \text{bar} \) Output pressure \( p_2 = \text{ambient} \)
- Low-pressure components: Supply pressure \( p_1 = 0.1 \, \text{bar} \) Output pressure \( p_2 = \text{ambient} \)

For pressure regulators:

- Supply pressure \( p_1 = 10 \, \text{bar (constant)} \) and output pressure \( p_2 = 6 \, \text{bar} \) at \( Q = 0 \, \text{l/min} \) 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 \( p_2 = 5 \, \text{bar} \). 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 \( \rho_{\text{abs}} \)

Unit: bar, Pa (pascal)

1 bar = 100 000 Pa

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.

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.

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

<table>
<thead>
<tr>
<th>Port designations</th>
<th>Using ISO 5599 numbers (5/2- and 3/2-way valves)</th>
<th>Using letters&lt;sup&gt;1)&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply port</td>
<td>1</td>
<td>P</td>
</tr>
<tr>
<td>Working ports</td>
<td>2, 4</td>
<td>B, A</td>
</tr>
<tr>
<td>Exhaust ports</td>
<td>3, 5</td>
<td>S, R</td>
</tr>
<tr>
<td>Pilot ports (signal)</td>
<td>10&lt;sup&gt;2)&lt;/sup&gt;, 12, 14</td>
<td>Z&lt;sup&gt;2)&lt;/sup&gt;, Y, Z</td>
</tr>
<tr>
<td>Pilot air ports (power supply)</td>
<td>81 (12), 81 (14)</td>
<td></td>
</tr>
<tr>
<td>Pilot exhaust ports</td>
<td>83 (82), 83 (84)</td>
<td></td>
</tr>
<tr>
<td>Leakage lines</td>
<td></td>
<td>L</td>
</tr>
</tbody>
</table>

<sup>1)</sup> Still frequently used.

<sup>2)</sup> 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.

**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.

**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.

**Permissible stroke deviations for standard cylinders**

ISO 15552 (corresponds to the withdrawn standards ISO 6431, DIN ISO 6431, VDMA 24562, 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.

<table>
<thead>
<tr>
<th>Standard</th>
<th>Piston [mm]</th>
<th>Stroke length [mm]</th>
<th>Permissible stroke deviation [mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISO 6432</td>
<td>8, 10, 12, 16, 20, 25</td>
<td>0 … 500</td>
<td>+1.5</td>
</tr>
<tr>
<td>ISO 15552</td>
<td>32</td>
<td>0 … 500</td>
<td>+2</td>
</tr>
<tr>
<td></td>
<td>40, 50</td>
<td>500 … 12 500</td>
<td>+3.2</td>
</tr>
<tr>
<td></td>
<td>63</td>
<td>0 … 500</td>
<td>+2</td>
</tr>
<tr>
<td></td>
<td>80, 100</td>
<td>500 … 12,500</td>
<td>+4</td>
</tr>
<tr>
<td></td>
<td>125, 160</td>
<td>0 … 500</td>
<td>+4</td>
</tr>
<tr>
<td></td>
<td>200, 250, 320</td>
<td>500 … 2,000</td>
<td>+5</td>
</tr>
<tr>
<td>ISO 21287</td>
<td>20, 25</td>
<td>0 … 500</td>
<td>+1.5</td>
</tr>
<tr>
<td></td>
<td>32, 40, 50</td>
<td>0 … 500</td>
<td>+2</td>
</tr>
<tr>
<td></td>
<td>63, 80, 100</td>
<td>0 … 500</td>
<td>+2.5</td>
</tr>
</tbody>
</table>

**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.

**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.

**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**

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.

**Piston diameter**

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

---

General information

2007/07 – Subject to change – Key products
<table>
<thead>
<tr>
<th>Piston force [N]</th>
<th>Operating pressure [bar]</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
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</thead>
<tbody>
<tr>
<td>2.5</td>
<td>0.4</td>
<td>0.9</td>
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<td>0.9</td>
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<td>12.1</td>
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<td>16.2</td>
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<td>6</td>
<td>2.5</td>
<td>5.1</td>
<td>7.6</td>
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<td>9</td>
<td>13.6</td>
<td>18.1</td>
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<td>27.1</td>
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<td>14.1</td>
<td>21.2</td>
<td>28.3</td>
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<td>56.5</td>
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<tr>
<td>12</td>
<td>10.2</td>
<td>20.4</td>
<td>30.5</td>
<td>40.7</td>
<td>50.9</td>
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<td>56.3</td>
<td>72.4</td>
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<td>127</td>
<td>145</td>
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<td>20</td>
<td>28.3</td>
<td>56.5</td>
<td>84.8</td>
<td>113</td>
<td>141</td>
<td>170</td>
<td>198</td>
<td>226</td>
<td>226</td>
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<tr>
<td>25</td>
<td>44.2</td>
<td>88.4</td>
<td>133</td>
<td>177</td>
<td>221</td>
<td>265</td>
<td>309</td>
<td>353</td>
<td>353</td>
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<td>32</td>
<td>72.4</td>
<td>145</td>
<td>217</td>
<td>290</td>
<td>362</td>
<td>434</td>
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<tr>
<td>40</td>
<td>113</td>
<td>226</td>
<td>339</td>
<td>452</td>
<td>565</td>
<td>679</td>
<td>792</td>
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<tr>
<td>50</td>
<td>177</td>
<td>353</td>
<td>530</td>
<td>707</td>
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<td>1,240</td>
<td>1,410</td>
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<td>281</td>
<td>561</td>
<td>842</td>
<td>1,120</td>
<td>1,400</td>
<td>1,680</td>
<td>1,960</td>
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<tr>
<td>80</td>
<td>452</td>
<td>905</td>
<td>1,360</td>
<td>1,810</td>
<td>2,260</td>
<td>2,710</td>
<td>3,170</td>
<td>3,620</td>
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<tr>
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<td>707</td>
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<td>2,830</td>
<td>3,530</td>
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<td>2,210</td>
<td>3,310</td>
<td>4,420</td>
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<td>5,430</td>
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<td>10,900</td>
<td>12,700</td>
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<td>17,000</td>
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<td>13,300</td>
<td>17,700</td>
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<td>26,500</td>
<td>30,900</td>
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<td>43,400</td>
<td>50,700</td>
<td>57,900</td>
<td>57,900</td>
</tr>
</tbody>
</table>

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

\[
F = p \cdot A - R
\]

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

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

<table>
<thead>
<tr>
<th>Diameter [mm]</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>8</th>
<th>10</th>
<th>20</th>
<th>30</th>
<th>40</th>
<th>50</th>
<th>60</th>
<th>80</th>
<th>100</th>
</tr>
</thead>
<tbody>
<tr>
<td>$F$ [N]</td>
<td>0.01</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
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<td>8</td>
<td>10</td>
<td>100</td>
<td>200</td>
<td>300</td>
<td>400</td>
<td>500</td>
<td>600</td>
<td>800</td>
</tr>
<tr>
<td>$p$ [bar]</td>
<td>0</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>8</td>
<td>10</td>
<td>100</td>
<td>200</td>
<td>300</td>
<td>400</td>
<td>500</td>
<td>600</td>
<td>800</td>
</tr>
</tbody>
</table>

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 $\phi$ 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:

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

- $F_K$ = Permissible buckling force [N]
- $E$ = Modulus of elasticity [N/mm²]
- $J$ = Moment of inertia [cm⁴]
- $P$ = Buckling length
- $S$ = 2x stroke length [cm]

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 $\varnothing$ 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 that 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:

$$Q = \frac{\pi}{4} \cdot (d_1^2 - d_2^2) \cdot h \cdot p \cdot 10^{-6}$$

- $Q$ = Air consumption per cm stroke length [l]
- $d_1$ = Piston diameter [mm]
- $d_2$ = 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)

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.

<table>
<thead>
<tr>
<th>Zone classification</th>
<th>Equipment group</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>M1</td>
</tr>
<tr>
<td></td>
<td>M2</td>
</tr>
<tr>
<td>II</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Explosion protection documentation from system manufacturer
System rated according to ATEX 137 Directive 99/92/EC
Result:
- Zone classification
- Temperature classes
- Explosion groups
- Ambient temperature

Festo/equipment supplier
Equipment rated according to ATEX 95a Directive 94/9/EC
Result:
- Equipment categories
- Temperature classes
- Explosion groups
- Ambient temperature

Zone Category

<table>
<thead>
<tr>
<th>Gas zone</th>
<th>Dust zone</th>
<th>Frequency</th>
<th>Area of application</th>
</tr>
</thead>
<tbody>
<tr>
<td>II</td>
<td>All non-mining areas of application</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>Mining</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>Constant, frequent, long-term</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Occasional</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Seldom, short-term, in the event of a fault</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>20</td>
<td>II</td>
<td>1G</td>
</tr>
<tr>
<td>1</td>
<td>21</td>
<td>II</td>
<td>2G</td>
</tr>
<tr>
<td>2</td>
<td>22</td>
<td>II</td>
<td>3G</td>
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<td>II</td>
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<td>24</td>
<td>II</td>
<td>2D</td>
</tr>
<tr>
<td>5</td>
<td>25</td>
<td>II</td>
<td>3D</td>
</tr>
</tbody>
</table>
### Pneumatics and explosion protection – Directive 94/9/EC (ATEX)

#### ATEX at Festo?

**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.

#### 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.

---

**Solenoid coil =**

Electrical equipment

**Non-electrical part of the solenoid valve (power valve) must be approved**

For the module in this example:

II 3G T4
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:

<table>
<thead>
<tr>
<th>EC directive</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>87/404/EEC</td>
<td>Basic pressure reservoirs</td>
</tr>
<tr>
<td>97/23/EC</td>
<td>Pressure equipment directive</td>
</tr>
<tr>
<td>2004/108/EC</td>
<td>Electromagnetic compatibility (EMC)</td>
</tr>
<tr>
<td>2006/95/EC</td>
<td>Low voltage directive</td>
</tr>
<tr>
<td>94/9/EC</td>
<td>Equipment and protective systems for use in accordance with regulations in hazardous areas</td>
</tr>
</tbody>
</table>

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

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

<table>
<thead>
<tr>
<th>Label</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>CE</td>
<td>See above</td>
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<tr>
<td>Ex</td>
<td>In accordance with EU directive 94/9/EC (ATEX) Equipment and protective systems for use in accordance with regulations in a hazardous atmosphere.</td>
</tr>
<tr>
<td>UL</td>
<td>UL certification Hazardous location Ordinary location</td>
</tr>
</tbody>
</table>

**General information**

- **Commercial**
**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).

**Clean room suitability**

Festo tests some of its products for clean room suitability to VDI 2083-8. 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 100
  - Pneumatic drives
    - Standards-based cylinders DNC, ISO 15552
    - Linear drives DGC−...KF
  - Electric drives
    - Toothed belt axes DGE

- ISO4, FS209E class 10
  - Pneumatic drives
    - Standard cylinders DSNU, ISO 6432
    - Compact cylinders ADN
  - Valves
    - Solenoid valves MHP1/MHA1, miniature
  - 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
  - Valve terminals
    - Valve terminals type 15 CDVI, Clean Design

**Design awards**

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.
Paint-wetting impairment substances and resistance to media

**Key products – Subject to change – 2007/07**

PWIS-free products

<table>
<thead>
<tr>
<th>LA</th>
<th>B</th>
<th>S</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paint-wetting Impairment Substances</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

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.

Visit [www.festo.com/media_resistance](http://www.festo.com/media_resistance) for more information.
Protection classes according to IEC/EN 60529

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.

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

### Code letters

<table>
<thead>
<tr>
<th>IP</th>
<th>International Protection</th>
</tr>
</thead>
<tbody>
<tr>
<td>IP</td>
<td></td>
</tr>
</tbody>
</table>

### Digit 1

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

### Digit 2

<table>
<thead>
<tr>
<th>Digit</th>
<th>Brief description</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Not protected</td>
<td>–</td>
</tr>
<tr>
<td>1</td>
<td>Protected against water drops</td>
<td>Vertically falling drops must not have any harmful effect.</td>
</tr>
<tr>
<td>2</td>
<td>Protected against water drops</td>
<td>Vertically falling drops must not have any harmful effect when the enclosure is inclined up to 15° either side of the vertical.</td>
</tr>
<tr>
<td>3</td>
<td>Protected against spray water</td>
<td>Water sprayed at any angle up to 60° either side of the vertical must not have any harmful effect.</td>
</tr>
<tr>
<td>4</td>
<td>Protected against splashed water</td>
<td>Water splashing against the enclosure from any angle must not have any harmful effect.</td>
</tr>
<tr>
<td>5</td>
<td>Protected against water jets</td>
<td>Water directed at the enclosure from any angle in jet form must not have any harmful effect.</td>
</tr>
<tr>
<td>6</td>
<td>Protected against powerful water jets</td>
<td>Water directed against the enclosure from any angle in powerful jet form must not have any harmful effect.</td>
</tr>
<tr>
<td>7</td>
<td>Protected against the effect of brief submersion in water</td>
<td>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.</td>
</tr>
<tr>
<td>8</td>
<td>Protected against the effect of continuous submersion in water</td>
<td>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.</td>
</tr>
<tr>
<td>9K</td>
<td>Protected against water from high-pressure and steam jet cleaning</td>
<td>Water directed at the enclosure from any angle under high pressure must not have any harmful effect.</td>
</tr>
</tbody>
</table>
Functional earthing – Protective earth – PELV

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:

Protection class II – Protective insulation

In the case 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:

Protection 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**

### Special protection class for components from Festo

<table>
<thead>
<tr>
<th>Protection class III</th>
<th>Protection class II</th>
<th>Protection class I</th>
</tr>
</thead>
<tbody>
<tr>
<td>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.</td>
<td>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.</td>
<td>The earth terminal therefore has a functional earthing (discharge of electromagnetic disturbances) rather than a protective earth function and must always be contacted.</td>
</tr>
</tbody>
</table>

### 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:

![Safety Isolating Transformer Symbol](symbol.png)

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.

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