Machine Safety for PNEUMATICS
IT’S THAT EASY

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Technical Support Applications AVENTICS

AV03/AV05 with AES
Dual valve IS12-PD
SV07
LU6
AS3-SV
Introduction

Protecting people, machines, animals, and property is the primary objective of safety-related pneumatics systems and components. For all production machinery, standards and regulations define measures to prevent accidents through safe machine design. This guide covers key topics in the implementation of relevant directives and standards for safety-related pneumatics using examples, circuit diagrams, and products.

Every workplace accident that happens on a machine is one too many. With its focus on safe products and solutions, AVENTICS makes an important contribution to improving machine safety. AVENTICS has extensive, long-term experience in designing pneumatic controls. Pneumatics can be used to implement a number of technical preventive measures, such as ensuring a limited, safe speed, reducing pressure and force, safely releasing energy, and guaranteeing a safe direction of travel or blocking a movement. We advise on all matters of machine safety for pneumatic controls and offer comprehensive service to help you develop and achieve a sound safety concept. We supply the right products and the required documentation.

Your advantages with AVENTICS
- Proven expertise thanks to many years of experience in equipping machines and systems in line with standards
- Products including complete documentation with reliability ratings (B10/MTTF values)
- Free access to IFA-rated switching examples on our website
- Safety-related pneumatic components in certified quality
The European Machinery Directive 2006/42/EC on machine engineering aims to ensure a common safety level for new machines distributed and operated in the member states. It governs safety and occupational health requirements for design and engineering. The CE mark indicates that the manufacturer has achieved an adequate level of protection.

Harmonized standards from the European standards organizations provide additional assistance to machine operators and manufacturers, since they enhance compliance with the Machinery Directive through what is called “presumption of conformity”. This principle, however, only applies to the legal requirements that the harmonized standards actually cover. Almost all laws mandate a risk assessment to analyze and assess risks and finally implement risk reduction measures.

Machine-specific standards
- A-type standards (basic safety standards) define basic concepts, terminology and design principles that can be applied to machines
- B-type standards (generic safety standards) deal with a single safety aspect or protective device for a series of machines
- B1-type standards cover specific safety aspects (e.g. safety clearances, surface temperature, noise)
- B2-type standards cover protective devices (e.g. two-hand circuits, guards)
- C-type standards (machine safety standards) contain detailed safety requirements for a certain machine
Hazards and risks: Estimate - assess - eliminate

The risk assessment process provides the basis for machine safety (see figure on pages 6, 7). The machine manufacturer starts with a risk analysis, minimizes identified risks, and finally determines whether an adequate level of safety is present. If the answer is negative, risk reduction measures must be implemented and quantified in terms of effectiveness.

Let’s take a look at some basic terms defined in ISO 12100, which provides a general description of the risk assessment process:

**Hazards:**
Potential sources of harm

**Hazardous situation:**
Situation in which a person is exposed to at least one hazard. The resulting harm can be immediate or occur over time.

**Risk:**
Results from a hazard and is assessed by combining the likelihood of the occurrence of harm and the severity of consequence.
Towards safe machinery: Risk assessment

Globally, and almost without exception, statutory guidelines for the design and operation of machines mandate a risk assessment to identify potential hazards, minimize risks, and comply with applicable health and safety requirements. The process helps determine the type and quality of preventive measures or safeguards.

**Risk assessment**
- Must be performed by machine manufacturer; results remain with the manufacturer
- Must account for both proper use and any foreseeable misuse of the machine
- Provides an important body of proof for the manufacturer for liability claims in accident cases

![Risk assessment diagram](image)
The information in this guideline focuses on risk evaluation. Within the risk assessment process, we focus on implementing technical measures to mitigate risk, evaluating the safety function, and determining the performance level. The graphic below shows the risk assessment process – this guide uses examples to take you through the individual steps until the performance level is achieved. The performance level (PL) must meet or exceed the required performance level (PL_r). This depends on factors such as the control architecture (category), the mean time to dangerous failure (MTTF_D), diagnostic coverage (DC), and common cause failure (CCF).

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Select safety function

Define safety function features

Determine PL

Design and technical implementation of safety function

Define PL

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PL \geq PL_r
Risk assessment comprises three areas: risk analysis, risk evaluation, and risk reduction.

The actual risk analysis starts with defining the limits of a machine when considering all phases of its lifecycle. Once all hazards have been identified, the risk of each hazard must be estimated.

Risk analysis: machine limits
In addition to spatial limits and the overall duration of use, operating limits are a prime focus. Proper use is analyzed, including all operating modes and different intervention options, as well as reasonably foreseeable misuse.
For risk analysis, it is necessary to consider the entire machine lifecycle, from transport to installation, commissioning and cleaning, disassembly and, finally, disposal.
Warning: Contact between protected property and hazard!

Standard EN ISO 12100-1 specifies all relevant potential hazards in production that may result in injury to people or animals, or damage to property.

Harms are divided into different categories, as shown in the diagram below. Our focus is especially geared toward safe machine shut-down, safe valve exhaust, and safe pressure release in pneumatic systems and components—precisely because these mechanical hazards can result in personal injury.
Risk analysis: Risk estimation – Performance level

Risk reduction measures are derived based on the severity of possible injury, the frequency of the hazard, and the probability of its occurrence. Performance level is a technical target: it conveys the effort required to reduce risk at a machine. The target must be met as a minimum requirement.

Every safety function has a required safety level. This is described by the required performance level, PL, for short, which is defined based on the following criteria from ISO 13849-1:

S  Severity of injury
S1  Minor (normally temporary injury)
S2  Serious (normally permanent injury, including death)
F  Frequency and/or duration of exposure
F1  Rare to infrequent and/or brief
F2  Frequent to continuous and/or long
P  Possibility of avoiding hazard
P1  Possible under certain conditions
P2  Scarcely possible

PL, is distinguished based on letters from a (minimal action required) to e (extensive action required).

Where the probability of occurrence of a hazardous event can be justified as low, the PLr may be reduced by one level, for details see ISO 13849-1:2015, A.2.3.2

Risk estimation

- Manufacturers are free to apply their own process or that specified in a standard such as ISO 13849-1 or IEC 62061.
Risk estimation

- Manufacturers are free to apply their own process or that specified in a standard such as ISO 13849-1 or IEC 62061.

**Risk assessment: Risk evaluation**

During a risk analysis, should you conclude that risk reduction is required, you will need to adopt corresponding preventive measures to achieve an adequate safety level. The best solution is an inherently safe design. Instructional measures such as user information harbor the risk of non-compliance and are thus only permissible as supplement once all technical options to improve safety have been exhausted. Technical measures present an additional route.

**Preventive technical measures**

If a machine’s safety depends on a properly functioning control, this can be termed “functional safety”. The ‘active’ parts of the control are the main focus, i.e. components that detect a dangerous situation (signal recording, “I” = input), derive suitable reactions (evaluation, “L” = logic), and implement reliable measures (execution, “O” = output). The term “control” thus refers to the entire signal processing system.

**Note:**

“Safety-related parts of control systems” are not necessarily “safety components” as defined by the Machinery Directive. SRP/CS (Safety Related Parts of a Control System) can, however, be such safety components, e.g. two-hand controls or logic units with safety function.

Actuators (cylinders), energy supply (e.g. pressure supply or maintenance units) and connections are not directly factored into dangerous failure rates.

ISO 13849 is the generic standard for safety components in controls.

**Focus on safety-related parts of control systems (SRP/CS acc. to ISO 13849-1)**

<table>
<thead>
<tr>
<th>Signal recording to detect potential hazard</th>
<th>Evaluation of hazard</th>
<th>Execute reaction</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>(Opto-)electronics</strong></td>
<td><strong>Electronics</strong></td>
<td><strong>Pneumatics</strong></td>
</tr>
<tr>
<td>E.g. emergency OFF, two-hand circuit, safety door, safety mat, light barrier, laser scanner, enabling device, mode selector, camera systems...</td>
<td>Safety relay, wiring, safety PLC, safe pneumatic logic ...</td>
<td>E.g. limited or safe speed, reduce pressure and force, release energy, safe direction of travel, stop or block movement (see circuit diagram examples from page 26)</td>
</tr>
</tbody>
</table>

1. Start event, e.g. manual activation of button, opening a safeguard
2. Machine actuators

**Low risk**

**High risk**
Implementing a safety function – your go-to guide!

Now we will look at the technical safety measures in greater detail. The question is to what extent the safety function can reduce risk. After a prior risk estimation and the definition of the required performance level (PLr), the necessary degree of risk reduction is determined.

The following parameters determine whether the safety function actually mitigates risk to the required extent:

- Control architecture (category)
- Mean time to dangerous failure (MTTFd)
- Diagnostic coverage (DC)
- Common cause failure (CCF)

As a general rule:
The performance level PL must at least correspond to the required PLr.

### Application example

**Safe stop function** – halts dangerous movement and prevents unintended activation from the resting state

Procedure:

1. Identify the hazardous situation (e.g. dangerous movements).

2. Determine the trigger event.

3. Define the safe state.
   Actuator stops after crossing light grille.

4. Specify the required reaction.
   Actuator is disabled.

5. Name the safety function.
   “Controlled stopping of the movement and application of the holding brake in the rest position” (see also BGIA report 2/2008).
Define PL_r for machine part

ISO 13849-1

Low risk

S1

F1

P1

P2

S2

F2

P1

P2

F1

P1

P2

F2

P1

P2

High risk

Severity of injury
- S2: Serious injury (normally permanent, including death)

Frequency and/or duration of exposure
- F1: Rare to infrequent occurrence and/or brief exposure

Possibility of avoiding hazard
- P2 Scarcely possible

\[ PL_r = d \]

The example shows: functional failure can result in irreversible injury. The operator requires access to the machine less than once per shift. In the event of failure, he is fully exposed to the hazard.
Selecting a category

The safety control architecture determines its error tolerance. It is also the framework for all other quantifiable aspects that ultimately go into calculating the performance level of safety-related elements of the control system.

In industrial settings, the types of safety controls in machine engineering are usually limited. Most controls fit into one of the categories shown below:

### Control category properties

<table>
<thead>
<tr>
<th>Structure</th>
<th>Category B</th>
<th>Category 1</th>
<th>Category 2</th>
<th>Category 3</th>
<th>Category 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>L</td>
<td>L</td>
<td>I</td>
<td>I</td>
<td>I</td>
</tr>
<tr>
<td>L</td>
<td>O</td>
<td>O</td>
<td>L</td>
<td>L</td>
<td>L</td>
</tr>
<tr>
<td>O</td>
<td>I</td>
<td>I</td>
<td>L</td>
<td>L</td>
<td>L</td>
</tr>
<tr>
<td>TE</td>
<td></td>
<td>Test equipment output</td>
<td>Test equipment output</td>
<td>Test equipment output</td>
<td>Test equipment output</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Safety principles</th>
<th>Basic</th>
<th>Basic &amp; well-tried</th>
<th>Basic &amp; well-tried</th>
<th>Basic &amp; well-tried</th>
<th>Basic &amp; well-tried</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Well-tried components</th>
<th>-</th>
<th>Yes</th>
<th>-</th>
<th>-</th>
<th>-</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Component – MTTF (D) (service life)</th>
<th>Low–medium</th>
<th>High</th>
<th>Low–high</th>
<th>Low–high</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Redundancy (2 channels)</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Monitoring (DC)</td>
<td>None</td>
<td>None</td>
<td>Low–medium</td>
<td>Low–medium</td>
<td>High</td>
</tr>
<tr>
<td>Observation CCF</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Failure resistance / failure cumulation</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>PL (possible)</td>
<td>a–b</td>
<td>b–c</td>
<td>a–d</td>
<td>a–e</td>
<td>e</td>
</tr>
</tbody>
</table>

\* Connection between PL and categories: the higher the risk the safety function seeks to prevent, the higher the category.

### Assessment

<table>
<thead>
<tr>
<th>Assessment</th>
<th>MTTF (D)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>3 years ≤ MTTF (D) &lt; 10 years</td>
</tr>
<tr>
<td>Medium</td>
<td>10 years ≤ MTTF (D) &lt; 30 years</td>
</tr>
<tr>
<td>High</td>
<td>30 years ≤ MTTF (D) &lt; 100 years (resp. &lt; 2,500 years in Cat. 4)</td>
</tr>
</tbody>
</table>

### Designation

<table>
<thead>
<tr>
<th>Designation</th>
<th>DC range</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>DC &lt; 60%</td>
</tr>
<tr>
<td>Low</td>
<td>60% ≤ DC &lt; 90%</td>
</tr>
<tr>
<td>Medium</td>
<td>90% ≤ DC &lt; 99%</td>
</tr>
<tr>
<td>High</td>
<td>99% ≤ DC</td>
</tr>
</tbody>
</table>

\* Source: ISO 13849

\* Four DC classes in the simplified approach from ISO 13849-1
### Possible categories for the example shown:

<table>
<thead>
<tr>
<th>Category for forming example, PLₗ = d</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Category B</strong></td>
</tr>
<tr>
<td>I</td>
</tr>
<tr>
<td><strong>Category 1</strong></td>
</tr>
<tr>
<td>I</td>
</tr>
<tr>
<td><strong>Category 2</strong></td>
</tr>
<tr>
<td>I</td>
</tr>
<tr>
<td>TE</td>
</tr>
<tr>
<td><strong>Category 3</strong></td>
</tr>
<tr>
<td>I1</td>
</tr>
<tr>
<td>I2</td>
</tr>
<tr>
<td><strong>Category 4</strong></td>
</tr>
<tr>
<td>I1</td>
</tr>
<tr>
<td>I2</td>
</tr>
</tbody>
</table>

- **Performance level a**
  - $\geq 10^5$ to $< 10^4$ [h⁻¹]
- **Performance level b**
  - $\geq 3 \times 10^4$ to $< 10^3$ [h⁻¹]
- **Performance level c**
  - $\geq 10^4$ to $< 3 \times 10^4$ [h⁻¹]
- **Performance level d**
  - $\geq 10^5$ to $< 10^4$ [h⁻¹]
- **Performance level e**
  - $\geq 9 \times 10^{10}$ to $< 10^{-7}$ [h⁻¹]

<table>
<thead>
<tr>
<th>DC</th>
<th>none</th>
<th>none</th>
<th>Low</th>
<th>medium</th>
<th>Low</th>
<th>medium</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>MTTFₗ</td>
<td>low</td>
<td>n</td>
<td>$\geq 3$ to $&lt; 10$ years</td>
<td>MTTFₗ</td>
<td>medium</td>
<td>m</td>
<td>$\geq 10$ to $&lt; 30$ years</td>
</tr>
</tbody>
</table>

### Design and technical implementation of safety function

**Redundant blocking of cylinder in vertical direction:**

- With compressed air failure and in the starting position of valve 2V, the locking unit 2A can reliably stop the cylinder.
- In the locked position (center position) for valve 1V1, cylinder movement is impeded by air pressure in the chamber.
- The 2V valve can be tested with the 2S sensor. The function of the 1V1 valve and the 2A locking unit is monitored by the 1S1 distance measuring sensor.
Safety principles
Basic and well-tried safety principles (line 1 in the table on page 16 or poster) take precedence, i.e. critical errors or failures must be excluded to reduce the probability of failure.

Basic safety principles include:
- Use of suitable materials and production processes
- Correct dimensioning and forming of all components
- Highly resistant components (against various influences)
- Energy isolation (quiescent current principle)
- Ambient conditions/external protection against unexpected startup in fluid technology:
  - Pressure limitation
  - Measures to prevent contamination of pressure medium

Well-tried safety principles include:
- Overdimensioning/safety factor
- Automatic/form-fit actuation
- Limited electrical/mechanical parameters in fluid technology:
  - Secured position (excluding impulse valves)
  - Use of well-tried springs
  - Separation of safety functions from non-safety functions

Well-tried components:
In addition to the category B requirements, safety-related parts of control systems in category 1 must also be constructed as well-tried components.

Well-tried components
- Have seen successful large-scale use in the past in similar applications or
- Have been manufactured and tested by applying principles that demonstrate suitability and reliability for safety-related applications.
Further parameters to determine performance levels

Before a final answer about the performance of a safety function can be given, MTTF$_D$, DC, and CCF must be defined.

Mean time to dangerous failure (MTTF$_D$)

MTTF$_D$ describes the mean duration in years until a dangerous system component failure.

It is a statistical value for electrical/electronic components, which is identified through trials or reliability prognoses based on failure probabilities for the components.

Assessment | MTTF$_D$
---|---
Low | 3 years ≤ MTTF$_D$ < 10 years
Medium | 10 years ≤ MTTF$_D$ < 30 years
High | 30 years ≤ MTTF$_D$ < 100 years (resp. < 2,500 years in Cat. 4)

▲ Source: ISO 13849

Formula for determining MTTF$_D$ for a mechanical element in a channel:

$$\text{MTTF}_D = \frac{B_{100}}{0.1 \cdot n_{\text{op}}}$$

$B_{100} = B_{10} \times 2$ as recommended by IFA

Mean $n_{\text{op}}$ (actuations/year) for the mechanical element:

$$n_{\text{op}} = \frac{d_{\text{op}} \cdot h_{\text{op}} \cdot 3600s/h}{t_{\text{cycle}}}$$

d = day(s)
h = hour(s)
s = second(s)

Calculating the total MTTF$_D$ for two different channels:

$$\text{MTTF}_D = \frac{2}{3} \left[ \frac{1}{\text{MTTF}_{DC1}} + \frac{1}{\text{MTTF}_{DC2}} \right]$$

For our 2-channel example and taking into account the following operating data, for channel 1 this means:

220 d, 16 h/d, $T = 10$ s $\rightarrow$ nop = 1,267,200 cycles/year and a $B_{10}$ value for the CD07 5/3 directional valve of 24.8 million switching cycles results in an MTTF$_D$ value of 391.41 years;

For channel 2 with the following operating data:

220 d/y, 16 h/d, $T = 3,600$ s $\rightarrow$ nop = 3,520 cycles/year and a $B_{10}$ value for the CD04 directional valve of 32 million switching cycles as well as a $B_{100}$ value of 5 million switching cycles for the LU6 locking unit results in an MTTF$_D$ value of 181,818 years for the valve and 14,205 years for the locking unit.

Both channels therefore have a high MTTF$_D$ value.
Identification of the MTTF\(_0\) using the value \(B_{10}\) – example for lifecycle duration

The value \(B_{10}\) specifies the number of cycles until 10% of components tested in endurance trials (acc. to DIN EN ISO 19973) have exceeded the defined limits. \(B_{10}\) describes a statistical failure probability. It is an indicator for the reliability of a wearing part, evaluating the number of switching cycles for pneumatic valves, for example.

In terms of machine safety, ISO 13849-1 only considers dangerous machine failures. These are described by \(B_{100}\). Assuming that half of all failures are dangerous, we would apply the formula \(B_{100} = 2 \times B_{10}\). \(B_{100}\) is required for all safety-related components in a control that are susceptible to wear and for all components directly involved in a safety function. The value for \(B_{100}\) is used to calculate MTTF\(_0\) (see page 19).

AVENTICS provides extensive proof of reliability for its products in order to calculate performance levels. This data can also be found in our SISTEMA libraries.
When a dangerous failure does occur, despite all preventive measures, test equipment (diagnostics or monitoring system) can detect it at an early stage to return the machine to a safe state. Depending on the required performance level, there are requirements for the DC or diagnostic coverage value, i.e. the coverage which must be provided by testing equipment. The performance level therefore includes the monitoring quality of the control system.

### Diagnostic options for pneumatics

<table>
<thead>
<tr>
<th>Designation</th>
<th>DC range</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>DC &lt; 60%</td>
</tr>
<tr>
<td>Low</td>
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</tr>
<tr>
<td>Medium</td>
<td>90% ≤ DC &lt; 99%</td>
</tr>
<tr>
<td>High</td>
<td>99% ≤ DC</td>
</tr>
</tbody>
</table>

Annex E of ISO 13849-1 provides a simplified approach to estimating DC values. The engineer analyzes and evaluates the switching and the sequence of machine processes to estimate the percentage of errors that can be discovered by these measures.

Typical errors for safety-related parts of control systems are listed in ISO 13849-2. A typical error that could occur with directional valves is failure to lock, for example. Diagnosis occurs indirectly via the sensor at the cylinder; here, a diagnostic coverage level of 90% can be assumed. For the locking unit, a typical error might be “Failing to clamp although control input is vented”. Diagnosis is performed in this case directly by the sensor at the locking unit. For this component, diagnostic coverage of 99% can be assumed. Average diagnostic coverage can be calculated using the formula:

\[
DC_{\text{avg}} = \frac{DC_1 \cdot MTTF_{D_1} + DC_2 \cdot MTTF_{D_2} + \ldots + DC_N \cdot MTTF_{D_N}}{MTTF_{D_1} + MTTF_{D_2} + \ldots + MTTF_{D_N}}
\]

After accounting for all typical errors, the $DC_{\text{avg}}$ in our example is 93%. This translates to a medium level of diagnostic coverage.
CCF is a rating of measures to counteract “common cause failure,” or errors stemming from a common source, for example due to a high ambient temperature or intense electromagnetic interference.

Measures to combat these types of failures are listed in Annex F of ISO 13849-1 with associated point scores. Only the entire number of points or none at all can be received for each of the measures listed. If a measure is partially met, zero points are assigned.

Component manufacturers cannot provide any information related to CCF, because most measures are determined by the design of the machine.

### CFF in our example

<table>
<thead>
<tr>
<th>Countermeasure for CCF</th>
<th>Fluid technology</th>
<th>Electronics</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Separation of signal paths</td>
<td>Separation of tubing</td>
<td>Air and creepage distance on activated circuits</td>
<td>15</td>
</tr>
<tr>
<td>Diversity</td>
<td>E.g. different valves</td>
<td>E.g. different processors</td>
<td>20</td>
</tr>
<tr>
<td>Protection against overvoltage, overpressure ...</td>
<td>Setup acc. to EN 982 to EN 983</td>
<td>Overvoltage protection (e.g. contactors, power pack)</td>
<td>15</td>
</tr>
<tr>
<td>Use of well-tried components</td>
<td>User</td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>FMEA in development</td>
<td>FMEA during initial system conception</td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>Competence/training</td>
<td>Qualification measure</td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>Protection against contamination and EMC</td>
<td>Fluid quality</td>
<td>EMC test</td>
<td>25</td>
</tr>
<tr>
<td>Other effects (e.g. temperature, shock)</td>
<td>Compliance with EN ISO 4413 and EN ISO 4414 and product spec</td>
<td>Observe ambient conditions as described in product spec</td>
<td>10</td>
</tr>
<tr>
<td>Total CFF</td>
<td>Total points (65 ≤ CFF ≤ 100):</td>
<td></td>
<td>95</td>
</tr>
</tbody>
</table>
Further measures to assess robustness

- Safety-related properties of valves in safety systems, e.g. applying the principle of energy isolation (quiescent current principle, e.g. return spring). According to ISO 13849-1, in the event of a power outage, all system components, such as pneumatic valves, must independently assume and maintain a safe state under permissible operating conditions (vibration, temperature, etc.).
- Basic (cat. B) and well-tried safety principles (cat. 1, 2, 3, or 4), see Table, page 16

Validation – calculating PFH<br>
PFH<sub>D</sub> – probability of dangerous failure per hour – is a value for the average probability of a dangerous failure in one hour (1/h) and the associated performance level.

Required inputs
- Selected architecture expressed as category
- Average diagnostic coverage DC<sub>avg</sub>
- Mean time to dangerous failure MTTF<sub>D</sub> for a channel

Validation for our example
Input data
- Category: 3
- MTTF<sub>D</sub> for each channel: “high”
- DC<sub>avg</sub> “medium”
ISO 13849-1: read out average probability of a dangerous failure per hour (or calculate using SISTEMA)
- PL according to Table = e, PL<sub>r</sub> = d

Result: PL ≥ PL<sub>r</sub>

What if the performance level is not achieved?
- Use components with a longer service life (MTTF<sub>D</sub>, B<sub>10</sub>)
- Achieve a higher category (e.g. category 3 instead of category 1) by adding redundant components
- Invest greater resources in monitoring the control to boost the DC value
- Separate the safety function from a normal function to increase the service life (MTTF<sub>D</sub>) of components with B<sub>10</sub> values through a low number of cycles
- Implement safety functions using AVENTICS circuit examples

<table>
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To support machine and systems manufacturers, we not only provide this guide, but also offer individualized consulting based on our long-term experience. On the next pages, you will find circuit examples and parts from our product portfolio. For additional examples, please visit www.aventics.com.

**Scope of ISO 13849 for pneumatic controls**

For fluid power systems, the valve area is an especially critical control component in terms of safety. More specifically: valves that control potentially hazardous movements or system states. Required safety functions can usually be achieved by other linked controls with the appropriate valve versions or even by additional mechanical solutions such as holding devices or brakes. Drive elements as well as energy conversion and transfer components in fluid power systems are usually beyond the scope of the standard.

In pneumatic systems, components must be protected against hazards associated with energy changes. Moreover, the maintenance unit used to process compressed air must be safely connected to the valve area. To reliably control possible energy changes, an exhaust valve is often used in conjunction with a pressure switch.

**Example:**

*Maintenance unit 0Z usually comprises:*
- Manual shutoff valve 0V10
- Filter with water separator 0Z10 and filter monitoring
- Pressure regulator 0V11 with adequate relieving exhaust
- Pressure indicator 0Z11 for system parameter monitoring

The structures of most fluid power system controls are designed to comply with the categories 1, 3, or 4. Because category B already requires compliance with the relevant standards and basic safety principles, fluid power system controls in the categories B and 1 do not differ substantially in terms of their control structures, but instead in the higher reliability of relevant safety-related valves.

On the following pages you will find two detailed examples. Further examples can be found at www.aventics.com.
The basic valve position depressurizes the system. Redundant safe exhaust is guaranteed via two exhaust pathways:
- Via non-return valves 2V2 and 2V3 and the directional valve 2V1. The minimum opening pressure of the non-return valves must be taken into account.
- Via directional valve 1V1

Cylinder extension and retraction is only possible with the combined actuation of 1V1 and 2V1. The safety-related switching position is achieved by removing the electrical control signal. Failure of one of the valves does not jeopardize the safety function.

Basic valve position depressurizes the system – two exhaust pathways:
- Via non-return valves 2V2 and 2V3 and directional valve 2V1 (observe minimum opening pressure of the non-return valves)
- Via directional valve 1V1
- Valve 2V1 must be actuated to extend and retract the cylinder.

Design features
Basic and well-tried safety principles are met for all relevant components. The directional valves comply with the quiescent current principle and have sufficient positive overlap. The non-return valves must be engineered to assume an open state, even with failure, to safely exhaust the cylinder chambers. The switching valve function of 1V1 and 2V1 is periodically checked by querying the cylinder position switches 1S1 and 1S2 and the pressure switch 2S1.
A block diagram is created from the circuit diagram. The components are arranged:
- In series when the components work together to execute a function.
- In parallel “channels” if they perform the function independently (redundant).
- There are monitoring elements in addition to the functional block diagram.
- Drive-related hazards are not taken into account.

Implementing safe dual-channel exhaust with AVENTICS products
Circuit example: “Safe stop” or “holding via dual-channel chambering” (Cat. 3), potential PL a-e

In the safety function shown here, only the pneumatic control component is shown as a subsystem. For the complete safety function, additional safety-related control components (e.g. as guards and electrical logic) must be added as subsystems.

In the basic valve position, the pressure in the cylinder is chambered; the cylinder stops when forces are balanced. Stopping/holding the cylinder occurs redundantly via two paths:
- If 2V1 is not actuated, the valves 2V2 and 2V3 will remain in the locked position.
- If 1V1 is not actuated, the valve locks in the center position.

Extending and retracting the cylinder is only possible with the combined actuation of 1V and 2V1, and thus 2V2 and 2V3. The safety-related switching position is achieved by removing the electrical control signal. Failure of one of the valves does not jeopardize the safety function. Further measures are required if captive compressed air presents an additional hazard.

Design features
Basic and proven safety principles are met for all relevant components. The directional valves comply with the quiescent current principle and have sufficient positive overlap. The function of the switching valves 1V1, 1A1, 2V1, 2V2, and 2V3 is monitored indirectly.
With the help of cylinder switches 1S1 and 1S2, valves 2V3 and 2V2 as well as 1V1 are regularly checked in special test cycles.
A block diagram is created from the circuit diagram. The components are arranged

- In series when the components work together to execute a function.
- In parallel “channels” if they perform the function independently (redundant).
- There are monitoring elements in addition to the functional block diagram.

Implementing “holding via dual-channel chambering” with AVENTICS products
AV valve system with AES fieldbus system

Numerous electrical and pneumatic connection options make the AV system a strong performer that easily adapts to the demands of safety-related pneumatic controls. The valve system plays the long game with a service life that tops 150 million cycles without maintenance or failure in safety-related controls.

The consistent modular design offers additional functions at your fingertips and is impressively systematic. This comfortable approach simplifies your project planning for machine safety. As a result, the family concept pays off directly: you can meet even the most demanding of requirements with ease, giving you a crucial competitive edge.

Though the product is not a complete safety device in itself, it can be used as part of an overall solution.

1. AES bus coupler: Galvanic isolation between the logic voltage (UL) and actuator voltage (UA) in the bus coupler; this achieves a safe separation of other functions in the application. Consistent use of standardized and commercially available M12 connectors throughout the system.

2. AV series valves have an extremely long service life of over 150 million cycles. Good leakage values plus easy maintenance minimizes the risk of failure. Pilot air can be controlled internally or externally: should a problem occur, the valves switch to a defined safe state. The valves comply with basic and proven principles in safety-related controls.

3. Electrical supply plate: supplies actuator voltage to the valves. This enables independent voltage zones with any number of valves. Safety functions thus remain separate from other functions. In addition, the supply plate makes it possible to use separate cables for logic and actuators, thus reducing the potential for error.

4. Pressure supply plate: enables mutually independent pressure zones for customized pressure supply to different safety circuits and ensures adequate, rapid system exhaust. Optional: Module for monitoring the switch-off voltage threshold of the valves. The pneumatic supply plate with switch-off voltage monitoring sends a diagnostic message to the fieldbus if the supply voltage falls below the voltage threshold where the valve is switched off. This allows diagnosis of valve switch-off, increasing the degree of diagnostic coverage (DC).

5. The electrical valve control module for direct actuation of 2 valves in AV03 and AV05 valve systems. The valve control module can be integrated at the right end of D-Sub or fieldbus valve systems. The two following valve positions are controlled via the M12 connection. No electrical connection to the previous base plates exists. It is possible to use multiple valve control plates.

6. Throttle module: With the two-channel pressure module, the flow in both operating lines can be limited, reducing the cylinder traversing speed. Optionally, a cover plate is available to safeguard against manipulation.

7. Pressure regulator: Reduced working pressure in the operating lines for force limitation in cylinders.

8. Exhaust module: in case of emergency stop, cylinder chambers may remain under pressure. To perform maintenance, release trapped personnel, or correct workpiece positioning, the cylinder chambers must be exhausted to change the cylinder piston position. The solution: targeted system exhaust to disable
the cylinder without application of energy. Integrating the module in valve systems reduces sensitivity to actuator movements, while considerably minimizing installation space for the cylinder compared to conventional components.

9. The shut-off module serves to separate actuators from the pneumatic supply, e.g. for maintenance purposes.

10. Pressure sensor module: processes four pneumatic inputs (pressure or vacuum) from a pneumatic control and converts the pneumatic pressure into digital information of the serial transmission system for processing in the machine control. The module provides diagnostic capabilities via LED and supply voltage monitoring. All necessary functions are integrated; the module is also protected against manipulation. It safely monitors system pressures and provides reliable, fast information about the pressure conditions in all relevant modes of operation.

Optional: 3/2 directional valve with negative overlap. With the “safe exhaust” safety function, the valve’s design principle must be taken into account. The 2x3/2 directional valve with negative overlap provides an alternative to the poppet valve. Due to its design, this valve offers a connection to the exhaust lines in any position and cannot get stuck in a position where all channels are closed.

The valve has the 2x3/2 NCNC function with probing manual override. However, this valve does not have zero overlap in the switching transition: also referred to as negative overlap. This variant already exhausts if channel 1 is still open. This prevents critical pressurization of the operating line if it gets caught in the central position.

AV valve system: Your advantages

- Optimized compressed air balance thanks to a small, lightweight construction
- Universal system for a variety of applications in safety-related controls
- High flexibility thanks to easy application retrofitting
- Simplified design process with Engineering Tools

The result: one solution for all your requirements.
AS series maintenance units – cost-effective solution for pressurization and exhaust

All functions, all sizes – the modular versatility of the AS series maintenance units enables universal application. Compact, high-performance, lightweight, and easy-to-use, these units also ensure reliable, safe, and economical continuous operation with simplified assembly and maintenance. The AS series offers the most cost-effective solution for safe machine or plant section exhaust.

Technical features: AS3 and AS3/2 series directional shut-off valves with switching position sensing

- Electronic monitoring with ST6 sensor with 3 meter cable and M8, M12, or with open cable end
- Complies with requirements for configuring category 2 and 4 control circuits to performance level d
- Higher diagnostic coverage (DC = 99%) for higher PL when used as system valve
- High $B_{10}$ value: 750,000 cycles
- Components comply with basic and well-tried safety principles

The safety-related functionality of the valve is decisively influenced by the installation situation. The valve is not a safety device but can be used as part of a larger solution.
Your advantages

✔ Connection thread G3/8, G1/2, G3/4 and G1
✔ High flow rate performance: up to 12,500 std l/min
✔ Integration possible in series AS2, AS3, and AS5 maintenance units
✔ All AS series mountings can be used
✔ Sensor LEDs as visual indicator of switching state
✔ Various electrical sensor connections (M8, M12, 3 m cable)
✔ High B₁₀ value (750,000 cycles)
Safety at maximum level

The redundant structure and two-channel signal processing with self-monitoring are key: With the new AS3-SV safety valve, users can achieve category 4 safety-relevant control while realizing the maximum performance level “e” (PLe) according to ISO 13849-1. 100% safe – as a modular, integrated solution or stand-alone.

Standardized safety for man and machine, even with short cycle times

The AS3-SV valve assumes the redundant exhaust safety function, as well as protection against unexpected pressurization, reducing risks significantly. The valve only activates compressed air supply when all conditions for a safe system start-up have been met. Protection against unexpected pressurization stops the cylinder from being actuated unintentionally, preventing potential accidents. In the event of a machine fault or emergency OFF, the valve exhausts the operating lines, ensuring a de-energized and thus safe state. The AS3-SV is ideal
- for use in door switches and light barriers,
- as a reliable output for a control, or
- as a safety module for emergency OFF applications.

Safe control for various applications

Thanks to the integrated safe electric inputs, pneumatic outputs, and control, no additional effort is required to implement safety electronics in the hardware and software.

Soft-start capabilities

With the additional soft-start function, the AS3-SV can slowly increase the operating pressure before switching to full working pressure. This soft start can be customized based on requirements, or disabled entirely.

Your advantages

- Safety functions for maximum performance levels
- Internal monitoring with troubleshooting
- Wear-free electronics without relay contacts
- Safe inputs and outputs, safe controls
- No additional effort required to implement safety electronics
- Extensive accessories for flexible integration
ISO valve series IS12 – variable solution for safe exhaust and protection against unexpected start-up

In the danger zone of machinery,
- Protection against unexpected start-ups must be guaranteed and
- Safe exhaust of actuators or parts ensured.

To safely monitor the switching state of a valve and hence the safety function performance, an electronic proximity sensor queries the slider position and sends a signal with the switching state to the machine control. The valve is not a safety device but can be used as part of a larger solution.

Safety-related features
- Correct sensor mounting and positioning at AVENTICS, including all tolerances
- Tamper-proof: the sensor is protected against tampering
- 100% functionally tested before delivery
- Can be used in the higher categories 3 and 4, max. possible performance level e
- Valve increases the diagnostic coverage of a pneumatic control (99%)
- High $B_{10}$ value with 39.6 million switching cycles for ISO 1
- Implements basic and proven safety principles
Dual valve IS12-PD

The CE-certified valve block can be used with internal or external pilot air for various safety functions. This allows the implementation of redundant control architectures (dual-channel) for use in categories 3 and 4 with a maximum performance level e.

- **Redundant solution with internal pilot:**
  This solution is also available with external pilot. The system can be connected directly to working connection 2. Alternatively, an upstream startup valve can be connected to primary line 1. This startup valve is then actuated by an external pneumatic connection.

- **Dual valve with integrated non-return valve:**
  Alternatively, the ISO 1 version provides you with a variant with an integrated non-return valve, in order to bridge a connected startup valve on connection 4 in the secondary line in case of exhaust. This solution is available with external or internal pilot. Additional technical data is available in our online catalog.

**Your advantages**

- Electrically operated 5/2 directional valve with spring return according to ISO 5599-1, size 1
- Very high $B_{max}$ values
- Integrated slider position detection with electronic proximity sensor
- With internal or external pilot air, without or with manual override without detent
- High flow
In safety-relevant controls, the fail-safe double valves enable safe and controlled pressurization and exhaust of machines or machine sections. SV series valves consist of two redundant 3/2 directional valves with a dirt-resistant seated design that counteracts wear. The valves feature fast switching and high flow rates. The solenoid valves mutually monitor their function and are therefore considered safe certified components for use in high control categories.

Options:
- **Error display module**: Valves include a pressure switch with potential-free changeover contact; this signal is used for error processing in the control.
- **Silencer**: All valves include silencers with high flow capacity; largely protected from clogging.
- **Dynamic monitoring with memory function**: Memory, monitor, and air control functions integrated in two identical valve elements; application conditions meet Cat. 4 requirements. Valve goes into lockout position as soon as asynchronous switching movements occur; output pressure is maintained below 1% of the supply pressure. Without memory function: Valve returns to standby after error is eliminated.
- **Reset with targeted override**: Switching air or power supply off and on does not result in a reset. A reset can only be achieved through a targeted electrical impulse (solenoid).
Safety-related features

- “Safe exhaust” safety function is ensured, even with a valve error
- DGUV certification: category 4 (CE marking), PL e
- Very high $B_{1000}$ value: 20 million cycles
- Implements basic and well-tried safety principles
- Valve increases the diagnostic coverage of a pneumatic control (99%)

Your advantages

- Variants:
  - Connection thread G1/4–G1
  - With or without electrical return unit
  - With or without status indicator unit
  - 24 V DC (other voltages on request)
  - Including safety silencer
- TeflonR bearing rings on the piston to extend the valve service life
- Operation with or without air lubrication
- Fitting: connection thread on both sides for flexible assembly
- Exhaust rate of up to 8,600 l/min
- No additional PLC or programming required
- No sensor cable required
LU6 series:
Static locking or dynamic braking

The lock element can be used as a holding unit (blocking of a movement) or as a brake unit (emergency stop/emergency off).

LU6 locking unit application: mechanical holding function for piston rods of pneumatic cylinders according to ISO 15552 or comparable round bars; suitable for use in safety-related controls. Proper use has been tested and certified by the manufacturer.

Further exemplary safety features:
- Preventing a dangerous movement (Cat. 1 to max. PL c, “proven component”)
- Secure hold in upper end position through clamping and one-sided pressurization (Cat. 4 up to max. PL e)
- Stopping a dangerous movement (emergency stop/emergency off, Cat. 4 to max. PL e)

The locking unit can be used in controls with a maximum performance level c or Cat. 1 according to ISO 13849-1 (“proven component”), e.g. to prevent a dangerous movement. When used in controls with a higher performance level, additional control measures according to ISO 13849-1 are necessary. On the next page you will find a circuit example that allows different cylinder mounting positions. For the safety function “preventing a dangerous movement” the example control – provided that the cylinder locking unit is not used as a dynamic brake – achieves a maximum performance level e (PL e), according to ISO 13849-1. Other components must be provided to meet the requirements for diagnostics and redundancy, as well as prevent common cause failure.
Your advantages

- Large stroke range, depending on the cylinder series (1 to 2,850 mm)
- Robust, clever design for excellent holding and braking functions
- High holding force up to 12,000 N
- Wide range of accessories for numerous combinations and application options
- Hexagonal wrench flats for easier mounting in limited installation spaces

Safety-related properties of the holding device

- Permitted for use in category 3 controls up to max. performance level d in accordance with EN ISO 13849-1, for the safety function "preventing a dangerous movement"
- For use in controls with a max. performance level c, category 1, as a "well-tried component"
- High $B_{100}$ dynamic braking values: 2 million cycles
- High $B_{100}$ static holding values: 5 million cycles
- Components comply with basic and well-tried safety principles
- Optional function query directly at LU6 by sensors, which directly monitor the pneumatic control signal, helping to increase diagnostic coverage to 99%
Analog distance measuring sensors: safe and reliable

For the safety of processes, it is reassuring to know that piston position detection is highly accurate and repeatable: Feedback on the piston position allows many safety-related controls to review the cylinder position and, consequently, the switching position of the directional valve. Here, analog distance measuring sensors not only provide diagnostics, but also measure the position of the pneumatic cylinder piston with great accuracy and ease.

Thanks to simple mounting in the slot from above, flexible settings within the maximum distance measurement range and an extremely high proximity switching rate, the SM6 sensor is ideal for demanding automation solutions.

Your advantages

✅ Suitable for 6 mm T-slot
✅ Zero point and measurement range settings via teach-in button
✅ Choice of any mounting position and cable exit
✅ Mounting from above in the slot ("drop-in")
✅ High accuracy and linearity
✅ Excellent repeatability and reliability through proven Hall sensors
✅ Eight different sizes offered in the series to meet all required distance measurement ranges, from 32 to 256 mm
The SM6-AL analog distance measuring sensor constantly records piston movement over the entire stroke.

It enables high-resolution distance measurement and exact positioning in measurement ranges from 107 to 1,007 millimeters. The distance measuring sensor is thus perfectly suited for the continuous recording of piston movements in pneumatic cylinders and is an ideal solution for cylinders with medium and long strokes.

The SM6-AL is suitable for all standard cylinders. Its universal design offers various assembly options. The robust, chemical-resistant aluminum housing, as well as a cable sleeve support, guarantee a long sensor service life and reduce maintenance costs.

Your advantages

- Zero point and measurement range settings via teach-in button
- Choice of any mounting position and cable exit
- High accuracy and linearity
- Excellent repeatability and reliability through proven Hall sensors
- Flexible selection of sizes in the series to meet all required distance measurement ranges, from 107 to 1,007 mm

Connection variants:
SISTEMA, the software assistant

SISTEMA provides assistance in evaluating machine control safety within the scope of ISO 13849-1.

The Windows tool simulates the structure of SRP/CS (safety-related parts of a control system) based on so-called “designated architectures” and calculates reliability values at different levels of detail, including the achieved performance level (PL).

Risk parameters to determine the required performance level (PL), category, measures to prevent common cause failures (CCF) for multichannel systems, the mean time to dangerous failure (MTTF_D), and average diagnostic coverage (DC_avg) can be registered step by step for individual components or blocks.

The effect of each parameter change on the entire system is displayed directly and can be printed as a report.

Developed by the German Institute for Occupational Safety and Health, SISTEMA has established itself as a standard. The tool is available as a free download at www.dguv.de.

From there you can also access the AVENTICS libraries, where you can directly incorporate all relevant products in your calculation.
### Declaration: Reliability indicators and information for use with respect to the utilization of EN ISO 13849-1

1. **Hereby declares that the following components,**
   **Manufacturer:**
   AVENTICS GmbH
   Informatiendrucker Forschungs-Prarivate GmbH
   Unterstr. 4
   DE-35085 Lichtenfels

2. **Product series:**
   **Product series:**
   Valve series CS04

3. **Category(ies) or material number(s):**
   **Category(ies) or material number(s):**
   5D: 3-way valve, spring return
   6D: 3-way valve, air return

4. **Date of manufacture:**
   **Date of manufacture:**
   2011/02/11

5. **Device description:**
   **Device description:**
   Can be used - under consideration of the technical list of manufacturers, the safety-related parts of a control system according to EN ISO 13849-1.

6. **The components:**
   **The components:**
   If fulfill basic safety principles.

7. **Safety principles:**
   **Safety principles:**
   If fulfill basic safety principles, as far as the safety principles apply to the components.

8. **Sistema safety function:**
   **Sistema safety function:**
   For the evaluation of the reliability of the safety function the following characteristic data can be used:

   - **5D:** 3-way valve, 32,000,000 operating cycles
   - **6D:** 3-way valve, 29,000,000 operating cycles
   - **MTTF:** 7 years
   - **MOL:** Operating cycles according to ISO 13849-1
   - **MTTF:** No. of years (electronics)

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**Note:**

- **Sistema**
- **Justificatif AVENTICS**
# Product overview with service life ratings

## Directional valves, electric and pneumatic operation

<table>
<thead>
<tr>
<th>Qn</th>
<th>Series</th>
<th>Control</th>
<th>Connections</th>
<th>Function</th>
<th>B&lt;sub&gt;\text{mf} &lt;/sub&gt; value in millions of cycles</th>
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<tbody>
<tr>
<td>300 l/min</td>
<td>AV03</td>
<td>Electric</td>
<td>Ø 4, Ø 6, Ø 8</td>
<td>5/2 AS, 5/2 AR</td>
<td>71</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5/3 CC, 2x3/2 CC, 2x3/2 00, 2x3/2 OC</td>
<td>52.9</td>
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<td>700 l/min</td>
<td>AV05</td>
<td>Electric</td>
<td>Ø 6, Ø 8</td>
<td>5/2 AS, 5/2 AR</td>
<td>44.6</td>
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<td></td>
<td></td>
<td></td>
<td>5/3 CC</td>
<td>19.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2x3/2 CC, 2x3/2 00, 2x3/2 OC</td>
<td>24.8</td>
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<td>400 l/min</td>
<td>HF04</td>
<td>Electric</td>
<td>Ø 6</td>
<td>5/2 SR, 5/2 AR, 5/3 CC, 2x3/2 CC</td>
<td>20</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
<td>2x3/2 00, 2x3/2 OC</td>
<td>10</td>
</tr>
<tr>
<td>700 l/min</td>
<td>HF03</td>
<td>Electric</td>
<td>G 1/8, Ø 8, NPTF 1/8</td>
<td>5/2 AS, 5/2 AR, 5/3 CC</td>
<td>26</td>
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<tr>
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<td>2x3/2 CC, 2x3/2 00, 2x3/2 OC</td>
<td>24</td>
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<td>1,400 l/min</td>
<td>HF02</td>
<td>Electric</td>
<td>G 1/4, Ø 10</td>
<td>5/2 SR, 5/2 AR, 5/3 CC</td>
<td>15</td>
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<td></td>
<td>2x3/2 CC, 2x3/2 00</td>
<td>24</td>
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<tr>
<td>950 – 1,400 l/min</td>
<td>581 ISO size 1</td>
<td>Electric, pneumatic</td>
<td>G 1/8, G 1/4, Ø 6, Ø 8, 1/4&quot; NPT, 3/8&quot; NPT, (G 1/8, for direct mounting on the cylinder))</td>
<td>5/2 SR, 5/2 AR, 5/3 EC, 5/3 PC, 5/3 CC</td>
<td>20</td>
</tr>
<tr>
<td>2,100 – 2,700 l/min</td>
<td>581 ISO size 2</td>
<td>Electric, pneumatic</td>
<td>G 1/4, G 3/8, Ø 8, 3/8&quot; NPT, 1/2&quot; NPT, (G 3/8 for direct mounting on the cylinder)</td>
<td>5/2 SR, 5/2 AR, 5/3 EC, 5/3 PC, 5/3 CC</td>
<td>20</td>
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<td>4,100 – 4,800 l/min</td>
<td>581 ISO size 3</td>
<td>Electric, pneumatic</td>
<td>G 3/8, G 1/2, 1/2&quot; NPT, 3/4&quot; NPT</td>
<td>5/2 SR, 5/2 AR, 5/3 CC, 5/3 EC, 5/3 PC</td>
<td>6.1</td>
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<tr>
<td>5,000 – 6,000 l/min</td>
<td>581 ISO size 4</td>
<td>Electric, pneumatic</td>
<td>G 1/2, G 3/4, G1, 1&quot; NPT</td>
<td>5/2 SR, 5/2 AR, 5/3 EC, 5/3 PC, 5/3 CC</td>
<td>6.2</td>
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<tr>
<td>1,100 l/min</td>
<td>CD01-PA/PI</td>
<td>Electric, pneumatic</td>
<td>G 1/8, G 1/4, NPTF, Ø 4, Ø 6, Ø 8, Ø 10, Ø 3/8&quot;</td>
<td>5/2 AS, 5/2 AR</td>
<td>20</td>
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<td></td>
<td></td>
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<td>2x3/2 CC, 2x3/2 00, 2x3/2 OC</td>
<td>32</td>
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<tr>
<td></td>
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<td></td>
<td></td>
<td>5/3 CC, 5/3 EC, 5/3 PC</td>
<td>14.9</td>
</tr>
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</table>

The values in the table reflect the current status as of the editorial deadline. This data is updated on a regular basis and can be downloaded from our website. We also provide explanations (reliability values and further information for the application of ISO 13849-1) as downloads online: www.aventics.com/machinesafety.
# Electrical, Pneumatic, and Mechanical Operated Valves

<table>
<thead>
<tr>
<th>On</th>
<th>Series</th>
<th>Control</th>
<th>Connections</th>
<th>Function</th>
<th>$B_v$ value in millions of cycles</th>
</tr>
</thead>
<tbody>
<tr>
<td>900 l/min</td>
<td>CD04</td>
<td>Electric, pneumatic</td>
<td>G 1/8, NPTF 1/8</td>
<td>3/2 SR</td>
<td>29</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5/2 SR, 5/2 AR</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5/3</td>
<td>12.9</td>
</tr>
<tr>
<td>900–1,400 l/min</td>
<td>CD07</td>
<td>Electric, pneumatic</td>
<td>G 1/4, M14 x 1.5</td>
<td>3/2 SR</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5/2 SR, 5/2 AR</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5/3 CC, 5/3 EC, 5/3 PC</td>
<td>24.8</td>
</tr>
<tr>
<td>3,800–4,100 l/min</td>
<td>CD12</td>
<td>Electric, pneumatic</td>
<td>G 1/2, M22 x 1.5</td>
<td>3/2</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5/2 SR, 5/2 AR</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5/3 CC, 5/3 EC, 5/3 PC</td>
<td>10</td>
</tr>
<tr>
<td>800 l/min</td>
<td>TC08</td>
<td>Electric, pneumatic</td>
<td>G 1/8, NPTF 1/8</td>
<td>5/2 SR, 5/2 AR, 5/3 CC, 5/3 EC, 5/3 PC</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2x3/2 CC, 2x3/2 OO, 2x3/2 OC</td>
<td>15</td>
</tr>
<tr>
<td>1,500 l/min</td>
<td>TC15</td>
<td>Electric, pneumatic</td>
<td>G 1/4, NPTF 1/4</td>
<td>5/2 SR, 5/2 AR, 5/3 CC</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2x3/2 CC, 2x3/2 OO, 2x3/2 OC</td>
<td>29.7</td>
</tr>
<tr>
<td>1,060 l/min</td>
<td>IS12-PDISO1</td>
<td>Electric</td>
<td>G 1/8, G 1/4, Ø 6, Ø 8, 1/4&quot; NPT, 3/8&quot; NPT, (G 1/8, for direct mounting on the cylinder)</td>
<td>5/2 SR</td>
<td>39.6</td>
</tr>
<tr>
<td>2,500 l/min</td>
<td>IS12-PDISO2</td>
<td>Electric</td>
<td>G 1/4, G 3/8, Ø 8, 3/8” NPT, 1/2” NPT, (G 3/8 for direct mounting on the cylinder)</td>
<td>5/2 SR</td>
<td>10</td>
</tr>
<tr>
<td>700–1,000 l/min</td>
<td>IS12-PDISO1</td>
<td>Electric</td>
<td>1/4 ISO1</td>
<td>5/2 SR</td>
<td>7.5 (w/o NRV)</td>
</tr>
<tr>
<td>1,300–2,000 l/min</td>
<td>IS12-PDISO2</td>
<td>Electric</td>
<td>1/2 ISO2</td>
<td>5/2 SR</td>
<td>10</td>
</tr>
<tr>
<td>3,000–8,600 l/min</td>
<td>SV07</td>
<td>Electric</td>
<td>G 1/4, G 3/8</td>
<td>5/2 SR</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>SV09</td>
<td>Electric</td>
<td>G 1/2, G 3/4, G 1</td>
<td>5/2 SR</td>
<td>10</td>
</tr>
</tbody>
</table>
## Product overview with service life ratings

### Electrical, pneumatic, and mechanical operated valves

<table>
<thead>
<tr>
<th>Qn</th>
<th>Series</th>
<th>Control</th>
<th>Connections</th>
<th>Function</th>
<th>B(_{10}) value in millions of cycles</th>
</tr>
</thead>
<tbody>
<tr>
<td>175–310 l/min</td>
<td>LS04-AF</td>
<td>Electric</td>
<td>Ø 4 – Ø 6</td>
<td>5/2 SR, 5/3CC 2x3/2</td>
<td>34</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>20</td>
</tr>
<tr>
<td>280 l/min</td>
<td>ST</td>
<td>mechanically operated</td>
<td>G 1/8</td>
<td>5/2 plunger SR, 3/2 plunger SR, 5/2 roller SR, one-way trip</td>
<td>5</td>
</tr>
</tbody>
</table>

5/2 SR single solenoid with spring return  
5/2 AR single solenoid with air return  
5/2 AS single solenoid with combined spring/air return  
5/2 DS double solenoid (bistable)  
5/3 CC closed center  
5/3 EC exhausted center  

### Blocking valves

<table>
<thead>
<tr>
<th>Qn</th>
<th>Series</th>
<th>Connections</th>
<th>Function</th>
<th>B(_{10}) value in millions of cycles</th>
</tr>
</thead>
<tbody>
<tr>
<td>340 l/min</td>
<td>Shut-off valve G 1/8</td>
<td>G 1/8</td>
<td></td>
<td>20</td>
</tr>
<tr>
<td>340 l/min</td>
<td>Pilot-operated non-return valve NR02 G 1/8</td>
<td>G 1/8</td>
<td></td>
<td>59</td>
</tr>
<tr>
<td>680 l/min</td>
<td>Pilot-operated non-return valve NR02 G 1/4</td>
<td>G 1/4</td>
<td></td>
<td>39</td>
</tr>
<tr>
<td>680 l/min</td>
<td>Shut-off valve G 1/4</td>
<td>G 1/4</td>
<td></td>
<td>10</td>
</tr>
</tbody>
</table>

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### Pressure sensors and sensor technology

<table>
<thead>
<tr>
<th>Switching pressure range/switching current/measurement range</th>
<th>Series</th>
<th>Connections</th>
<th>$B_{10}$ value in millions of cycles</th>
<th>MTTF in years</th>
</tr>
</thead>
<tbody>
<tr>
<td>-0.9 to 16 bar</td>
<td>PM1 (new)</td>
<td>G 1/4, flange with O-ring, Ø 5x1.5, CNOMO</td>
<td>15</td>
<td>-</td>
</tr>
<tr>
<td>-1 to 12 bar</td>
<td>PE5</td>
<td>G 1/4, Ø 4</td>
<td>-</td>
<td>243-261</td>
</tr>
<tr>
<td>-1 – 10 bar</td>
<td>PE6</td>
<td>Flange with O-ring, Ø 1.2x1</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>0.1 A, DC max.</td>
<td>ST4</td>
<td>M8, M12, and open cable ends</td>
<td>-</td>
<td>915</td>
</tr>
<tr>
<td>0.15 A DC max.</td>
<td>ST4-2P</td>
<td>M8 and open cable ends</td>
<td>-</td>
<td>1832</td>
</tr>
<tr>
<td>0.07 – 0.1 A DC max.</td>
<td>ST6</td>
<td>M8, M12, and open cable ends</td>
<td>-</td>
<td>1629</td>
</tr>
<tr>
<td>107 – 1,007 mm</td>
<td>SM6-AL</td>
<td>M8</td>
<td>-</td>
<td>76-221</td>
</tr>
<tr>
<td>32 – 256 mm</td>
<td>SM6</td>
<td>M8, open cable ends</td>
<td>-</td>
<td>180-379</td>
</tr>
</tbody>
</table>

In accordance with ISO 13849-1, service life ratings ($B_{10}$/MTTF) are not required for components used exclusively for diagnosis. (Exception: category 2 controls).
# Product overview with service life ratings

<table>
<thead>
<tr>
<th>Locking unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cylinder Ø</td>
</tr>
<tr>
<td>32, 40, 50, 63, 80, 100, 125</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>FRL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Qn</td>
</tr>
<tr>
<td>1,000–14,500 l/min</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

- **SOV**: Shut off valve 3/2
- **SSV**: Soft-start valve
- **SSU**: Soft-start unit
- **RGS**: Pressure regulator
- **FRE**: Filter pressure regulator
- **RGP**: Precision pressure regulator

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### E/P Pressure Regulators

<table>
<thead>
<tr>
<th>Qn</th>
<th>Series</th>
<th>Control</th>
<th>Connections</th>
<th>Hysteresis</th>
<th>B10 Value in Millions of Cycles</th>
<th>MTTF in Years</th>
</tr>
</thead>
<tbody>
<tr>
<td>150 l/min</td>
<td>ED02</td>
<td>mA and V</td>
<td>G 1/8, 1/8 NPT</td>
<td>&lt; 0.05 bar</td>
<td>10</td>
<td>30</td>
</tr>
<tr>
<td>1,000 l/min</td>
<td>ED05</td>
<td>mA, V, and bus</td>
<td>G 1/4</td>
<td>&lt; 0.06 bar</td>
<td>10</td>
<td>26</td>
</tr>
<tr>
<td>1,300 - 2,600 l/min</td>
<td>ED07/12</td>
<td>mA, V, and bus</td>
<td>G 3/8, Ø 12, G 3/4</td>
<td>&lt; 0.03 bar</td>
<td>10</td>
<td>25</td>
</tr>
<tr>
<td>800 l/min</td>
<td>EV07</td>
<td>mA and V</td>
<td>G 1/4</td>
<td>0.03 bar</td>
<td>10</td>
<td>25</td>
</tr>
</tbody>
</table>
Product overview with service life ratings

<table>
<thead>
<tr>
<th>Fieldbus technology</th>
<th>Series</th>
<th>Fieldbus protocol</th>
<th>Can be combined with valve series</th>
<th>MTTF in years</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BDC-B-CanOpen</td>
<td>CanOpen</td>
<td>HF, CD01-PI</td>
<td>107</td>
</tr>
<tr>
<td></td>
<td>BDC-B-DevNet</td>
<td>DeviceNet</td>
<td>HF, CD01-PI</td>
<td>107</td>
</tr>
<tr>
<td></td>
<td>BDC-B-DP</td>
<td>PROFIBUS DP</td>
<td>HF, CD01-PI</td>
<td>119</td>
</tr>
<tr>
<td></td>
<td>BDC-B-Sercos</td>
<td>SERCOS III</td>
<td>HF, CD01-PI</td>
<td>92</td>
</tr>
<tr>
<td></td>
<td>BDC-B-EtherCat</td>
<td>EtherCAT</td>
<td>HF, CD01-PI</td>
<td>92</td>
</tr>
<tr>
<td></td>
<td>CMS-B-Ethernet IP</td>
<td>Ethernet IP</td>
<td>HF, CD01-PI</td>
<td>69</td>
</tr>
<tr>
<td></td>
<td>AES</td>
<td>PROFIBUS, CANopen, DeviceNet</td>
<td>AV</td>
<td>125</td>
</tr>
<tr>
<td></td>
<td>AES</td>
<td>EtherNet/IP, PROFINET IO, EtherCAT, POWERLINK</td>
<td>AV</td>
<td>75</td>
</tr>
<tr>
<td></td>
<td>AV</td>
<td>IO-Link</td>
<td>AV</td>
<td>196</td>
</tr>
</tbody>
</table>

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### Fieldbus technology

<table>
<thead>
<tr>
<th>Series</th>
<th>Module type</th>
<th>Can be combined with valve series</th>
<th>MTTF in Years</th>
</tr>
</thead>
<tbody>
<tr>
<td>AV</td>
<td>Valve driver 2x</td>
<td>AV</td>
<td>920</td>
</tr>
<tr>
<td>AV</td>
<td>Valve driver 3x</td>
<td>AV</td>
<td>730</td>
</tr>
<tr>
<td>AV</td>
<td>Valve driver 4x</td>
<td>AV</td>
<td>630</td>
</tr>
<tr>
<td>AV</td>
<td>Power supply unit</td>
<td>AV</td>
<td>854</td>
</tr>
<tr>
<td>AV</td>
<td>Pneumatic supply plate with switch-off voltage monitoring UAoff</td>
<td>AV</td>
<td>1094</td>
</tr>
<tr>
<td>AES</td>
<td>Digital input module (8DI), M8/M12</td>
<td>AV</td>
<td>513</td>
</tr>
<tr>
<td>AES</td>
<td>Digital output module (8DO), M8/M12</td>
<td>AV</td>
<td>346</td>
</tr>
<tr>
<td>AES</td>
<td>Digital input module (16DI), M12/spring clamp connection</td>
<td>AV</td>
<td>306</td>
</tr>
<tr>
<td>AES</td>
<td>Digital output module (16DO), M12/spring clamp connection</td>
<td>AV</td>
<td>203</td>
</tr>
<tr>
<td>AES</td>
<td>Digital output module (24DO), D-Sub</td>
<td>AV</td>
<td>91</td>
</tr>
<tr>
<td>AES</td>
<td>Digital combination module (8DI/DO), M8/M12</td>
<td>AV</td>
<td>74</td>
</tr>
<tr>
<td>AES</td>
<td>Analog input module (2AI), M12</td>
<td>AV</td>
<td>93</td>
</tr>
<tr>
<td>AES</td>
<td>Analog output module (2AO), M12</td>
<td>AV</td>
<td>74</td>
</tr>
<tr>
<td>AES</td>
<td>Analog combination module (2AI2AO), M12</td>
<td>AV</td>
<td>74</td>
</tr>
<tr>
<td>AES</td>
<td>Pressure measurement module with 4 compressed air ports (4P4D4)</td>
<td>AV</td>
<td>93</td>
</tr>
</tbody>
</table>
Glossary

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>a, b, c, d, e</td>
<td>Performance level designation</td>
</tr>
<tr>
<td>B, 1, 2, 3, 4</td>
<td>Category designation</td>
</tr>
<tr>
<td>$B_{10}$</td>
<td>Quality descriptor (for wear); number of cycles until failure occurs in 10% of components (including for pneumatic and electromechanical components). Unit: millions of cycles</td>
</tr>
<tr>
<td>$B_{100}$</td>
<td>Quality descriptor (for wear); number of cycles until a dangerous failure occurs in 10% of components (including for pneumatic and electromechanical components). Unit: millions of cycles</td>
</tr>
<tr>
<td>BGIA</td>
<td>BG Institute for Occupational Safety and Health, since January 1, 2010 renamed Institute for Occupational Safety and Health (IFA) of the German Social Accident Insurance (DGUV)</td>
</tr>
<tr>
<td>Cat.</td>
<td>Category</td>
</tr>
<tr>
<td>CCF</td>
<td>Common cause failure [ISO 13849-1]</td>
</tr>
<tr>
<td>DC</td>
<td>Diagnostic coverage [ISO 13849-1: Diagnostic effectiveness that can be described as the ratio between detected dangerous failures and all dangerous failures.] Unit: percent</td>
</tr>
<tr>
<td>DC$_{avg}$</td>
<td>Average diagnostic coverage Unit: percent</td>
</tr>
<tr>
<td>F, F1, F2</td>
<td>Frequency and/or time of exposure to the hazard</td>
</tr>
<tr>
<td>FMEA</td>
<td>Failure mode and effects analysis</td>
</tr>
<tr>
<td>Functional safety</td>
<td>When the safety of a machine depends on the correct function of the control, the term “functional safety” applies, along with special demands on the availability of the safety function.</td>
</tr>
<tr>
<td>Dangerous failure</td>
<td>Failure that potentially results in a dangerous state or malfunction in the SRP/CS</td>
</tr>
<tr>
<td>Hazard</td>
<td>Potential source of injury or ill health</td>
</tr>
<tr>
<td>Hazard area</td>
<td>Zone within and/or around a machine in which a person can be exposed to a hazard</td>
</tr>
<tr>
<td>I, I1, I2</td>
<td>Input device, e.g. sensor (failure mode and effects analysis)</td>
</tr>
<tr>
<td>I/O</td>
<td>Inputs/outputs</td>
</tr>
<tr>
<td>Channel</td>
<td>Element or group of elements that perform a function independently</td>
</tr>
<tr>
<td>L, L1, L2</td>
<td>Logic</td>
</tr>
<tr>
<td>MTBF</td>
<td>Mean operating time between failures</td>
</tr>
<tr>
<td>MTTF</td>
<td>Mean time to failure Unit: year</td>
</tr>
<tr>
<td>MTTF$_{D}$</td>
<td>Mean time to dangerous failure Unit: year</td>
</tr>
<tr>
<td>Protective device</td>
<td>Mechanical or electrical devices that prevent the execution of hazardous machine functions under specified conditions</td>
</tr>
<tr>
<td>(not guard)</td>
<td></td>
</tr>
<tr>
<td>n$_{op}$</td>
<td>Number of operations Unit: cycles/year</td>
</tr>
<tr>
<td>Term</td>
<td>Definition</td>
</tr>
<tr>
<td>------</td>
<td>------------</td>
</tr>
<tr>
<td>Emergency OFF</td>
<td>Power cut-out in emergency cases [ISO 13849-1: Manually operated control unit that disconnects the electrical power supply to all or part of an installation in an emergency]</td>
</tr>
<tr>
<td>Emergency stop</td>
<td>Stops machine in an emergency</td>
</tr>
<tr>
<td>O, O1, O2</td>
<td>Output device, e.g. actuator</td>
</tr>
<tr>
<td>P, P1, P2</td>
<td>Possibility of avoiding the hazard</td>
</tr>
<tr>
<td>PFD</td>
<td>Average probability of failure to perform its design function on demand</td>
</tr>
<tr>
<td>PFH</td>
<td>Probability of failure per hour. Unit: per hour</td>
</tr>
<tr>
<td>PFH_D</td>
<td>Probability of a dangerous failure per hour. Unit: per hour</td>
</tr>
<tr>
<td>PL</td>
<td>Performance level [ISO 13849-1: Discrete level which specifies the capability of safety-related parts of control systems to perform a safety function under foreseeable conditions]</td>
</tr>
<tr>
<td>PL_r</td>
<td>Required performance level [ISO 13849-1: Applied performance level necessary to achieve the required risk reduction for each safety function]</td>
</tr>
<tr>
<td>Redundancy</td>
<td>Presence of multiple functionally identical or comparable technical resources (mainly for security reasons) that are not needed for trouble-free normal operation</td>
</tr>
<tr>
<td>Residual risk</td>
<td>Risk that remains after a preventive measure is executed</td>
</tr>
<tr>
<td>Risk</td>
<td>Combined probability</td>
</tr>
<tr>
<td>Risk estimation</td>
<td>Determines likely extent of damage and probability of its occurrence</td>
</tr>
<tr>
<td>Risk analysis</td>
<td>Combines the limits of a machine, identified hazards, and estimates risks</td>
</tr>
<tr>
<td>Risk assessment</td>
<td>Overall process comprising risk analysis and risk evaluation</td>
</tr>
<tr>
<td>Risk evaluation</td>
<td>Assessment of whether risk reduction objectives have been met based on risk analysis</td>
</tr>
<tr>
<td>S, S1, S2</td>
<td>Severity of injury</td>
</tr>
<tr>
<td>Preventive measure</td>
<td>Action to eliminate a hazard or to reduce a risk</td>
</tr>
<tr>
<td>SF</td>
<td>Safety function</td>
</tr>
<tr>
<td>Safety component</td>
<td>Independently marketed component that performs a safety function which in the event of failure and/or malfunction would endanger the safety of persons. The component’s function is not necessary for machine operation and can be replaced by other conventional components</td>
</tr>
<tr>
<td>Safety function</td>
<td>For normal machine operation, a safety function is an additional function that maintains or recovers safe operation in the event of malfunctions or critical operating conditions. A failure or an error in this function would increase the security risk of the machine.</td>
</tr>
<tr>
<td>SIL</td>
<td>Safety integrity level</td>
</tr>
<tr>
<td>SRP/CS</td>
<td>Safety-related part of a control system Part of a control system that responds to safety-related input signals and generates safety-related output signals</td>
</tr>
<tr>
<td><strong>T10_w</strong></td>
<td>Wear-related indicator: Mean time until 10% of the components fail dangerously. Unit: year</td>
</tr>
<tr>
<td><strong>TE</strong></td>
<td>Test equipment</td>
</tr>
<tr>
<td><strong>Technical safeguards</strong></td>
<td>Protection measures involving protection devices to protect people against hazards that cannot be appropriately eliminated through inherently safe design, or to protect against risks that cannot be sufficiently mitigated.</td>
</tr>
<tr>
<td><strong>TM</strong></td>
<td>Mission time Unit: year</td>
</tr>
<tr>
<td><strong>Guard</strong></td>
<td>Protective physical barrier designed as part of the machine</td>
</tr>
</tbody>
</table>
Benefit from our experience

Around-the-clock information

The AVENTICS Internet portal is available day or night. In the online catalog, you can view our entire product assortment along with comprehensive technical details. To use our refined Engineering Tools, visit: www.engineering-tools.com

**Online catalog**
The fastest point of entry is via our online catalog. Here you can start your search directly by entering a part number or keyword.

**CAD**
Your desired object can be issued here directly as a CAD file in various formats, as a PDF file, or for further configuration in your software.

**Configurators**
The configurator can be reached by clicking the selected product. After selecting your product, you can begin to adapt it to your own specifications.

**Calculation programs**
Here you can specify the dimensions or load-bearing capacity of your components with a wide variety of calculation options. As a special feature, you can also use the air consumption calculator.

**Circuit diagram software**
With the D&C Scheme Editor, you can quickly and easily create circuit diagrams that are based on your component layout and linked to your catalog selection.

**eShop**
The eShop is our online shop that answers your price requests and monitors the whole order process up to delivery.

**Product liability warning:** The responsibility for a safe machine design remains with the customer as the machine manufacturer. In this capacity, the customer must make the final call. AVENTICS does not assume any liability for the machine! This disclaimer does not apply in cases of intentional or grossly negligent conduct, or if an error has been fraudulently concealed.

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Benefit from our experience

Online catalog

1. Online catalog - Select a product to view or online catalog. There you can select your search directly by entering a part number or by using the search function.

2. CAD - Your desired object can be issued here directly as a CAD file in various formats, as a PDF file or for further configuration in your software.

3. Configurators - The configurator can be reached by clicking the selected product. After selecting your product, you can begin to adapt it to your own specifications.

4. Calculation programs - You can enter data for the dimensioning or load-bearing capacity of your components with a wide variety of convenient options. The software allows you to enter your own calculation.

5. Check Design of software - With the CAD software, you can quickly and easily create circuit diagrams that are based on your component layout and feed your catalog selection.

6. Expert team - The AVENTICS expert team will handle any questions you may have on topics related to your industry or process.

7. Online documentation - The AVENTICS online portal is available day or night. In the online catalog, you can view our entire product assortment along with comprehensive technical details. For more information, visit www.engineering-tools.com.

8. Calculation programs - Here you can specify the dimensions or load-bearing capacity of your components with a wide variety of convenient options. The software allows you to enter your own calculation.

9. Component - MTTFD (service life) - None

10. Monitoring (CCF) - None

11. Observation CCF - No

12. Observation CCF - Yes

13. PL (possible) - a-e

Control category properties

- Redundancy (2 channels) - No
- Failure resistance / failure correlation - No
- Safety principles - Basic & Well tried
- Well-tried components - Yes
- Component - MTTFD (service life) - Low
- Monitoring (CCF) - None
- Observation CCF - No
- PL (possible) - a

Product liability warning:
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Machine Safety for PNEUMATICS
IT’S THAT EASY

Control category properties

<table>
<thead>
<tr>
<th>Structure</th>
<th>Category B</th>
<th>Category 1</th>
<th>Category 2</th>
<th>Category 3</th>
<th>Category 4</th>
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<tbody>
<tr>
<td>Redundancy (2 channels)</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
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<td>Safety principles</td>
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<td>Basic &amp; Well tried</td>
<td>Basic &amp; Well tried</td>
<td>Basic &amp; Well tried</td>
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<tr>
<td>Well-tried components</td>
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<td>-</td>
<td>-</td>
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<tr>
<td>Component - MTTFD (service life)</td>
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<tr>
<td>Monitoring (CCF)</td>
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<td>Observation CCF</td>
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<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>PL (possible)</td>
<td>a-b</td>
<td>b-c</td>
<td>a-d</td>
<td>e-a</td>
<td>e</td>
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</table>

Control category properties

- Redundancy (2 channels) - No
- Failure resistance / failure correlation - No
- Safety principles - Basic & Well tried
- Well-tried components - Yes
- Component - MTTFD (service life) - Low
- Monitoring (CCF) - None
- Observation CCF - No
- PL (possible) - a
Your contact:

The data specified above only serve to describe the product. No statements concerning a certain condition or suitability for a certain application can be derived from our information. The information given does not release the user from the obligation of own judgment and verification. It must be remembered that our products are subject to a natural process of wear and aging.