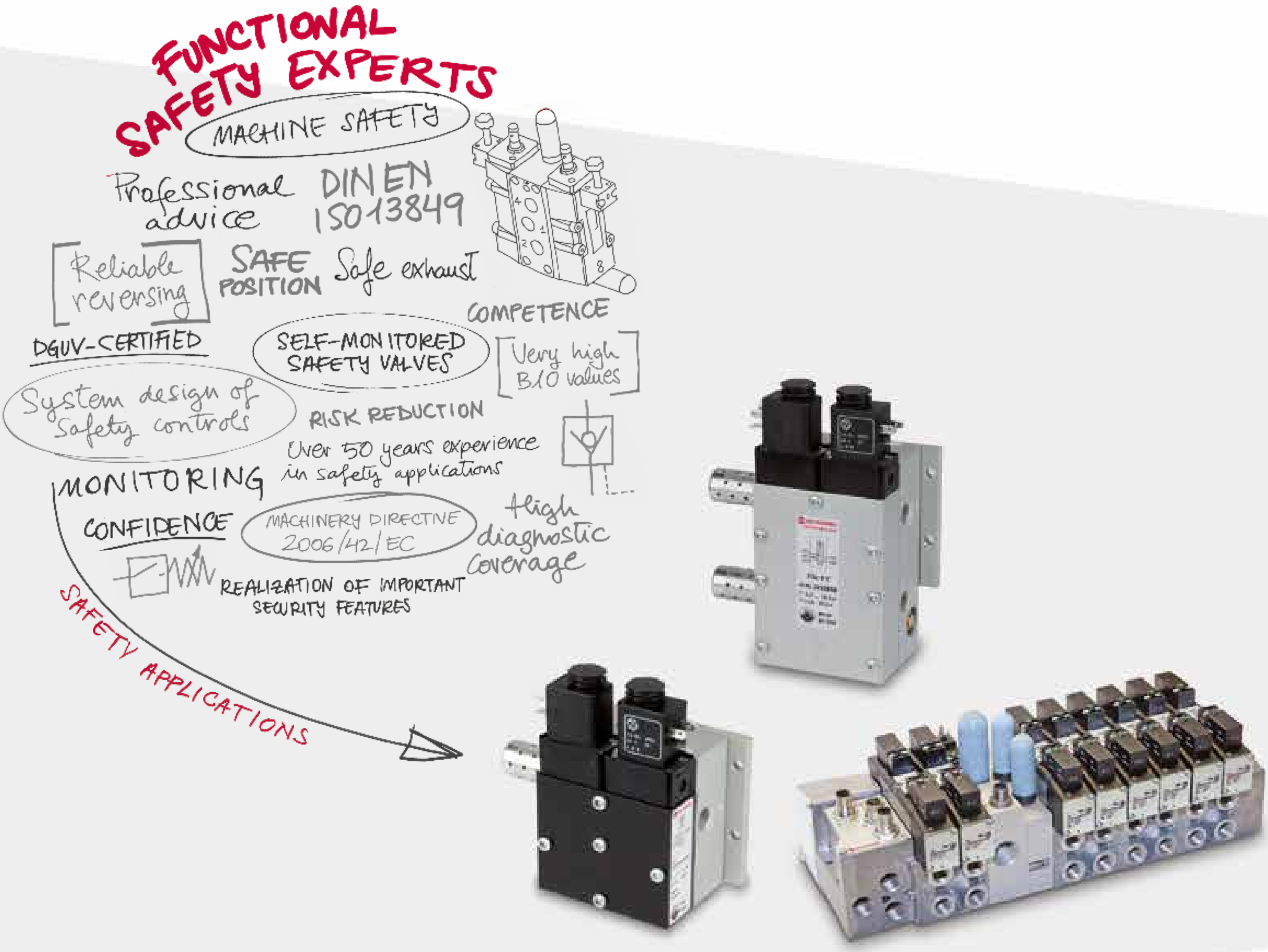
IMI
Precision Engineering

Functional safety



Engineering
GREAT
Solutions

IMI NORGREN

IMI HERION

Solutions for
Safety Technology

Contents

Innovation, Products and Service

IMI
Precision Engineering

Engineering GREAT solutions through people, products, innovation and service

IMI Precision Engineering is a world-leader in fluid and motion control. Building close, collaborative relationships with our customers, we gain a deep understanding of their engineering needs and then mobilise our resources and expertise to deliver distinctive products and solutions.

Wherever precision, speed and engineering reliability are essential, our global footprint, problem-solving capability and portfolio of high performance products enables us to deliver GREAT solutions which help customers tackle the world's most demanding engineering challenges.

> **Reliability**
> We deliver and support our high quality products through our global service network.

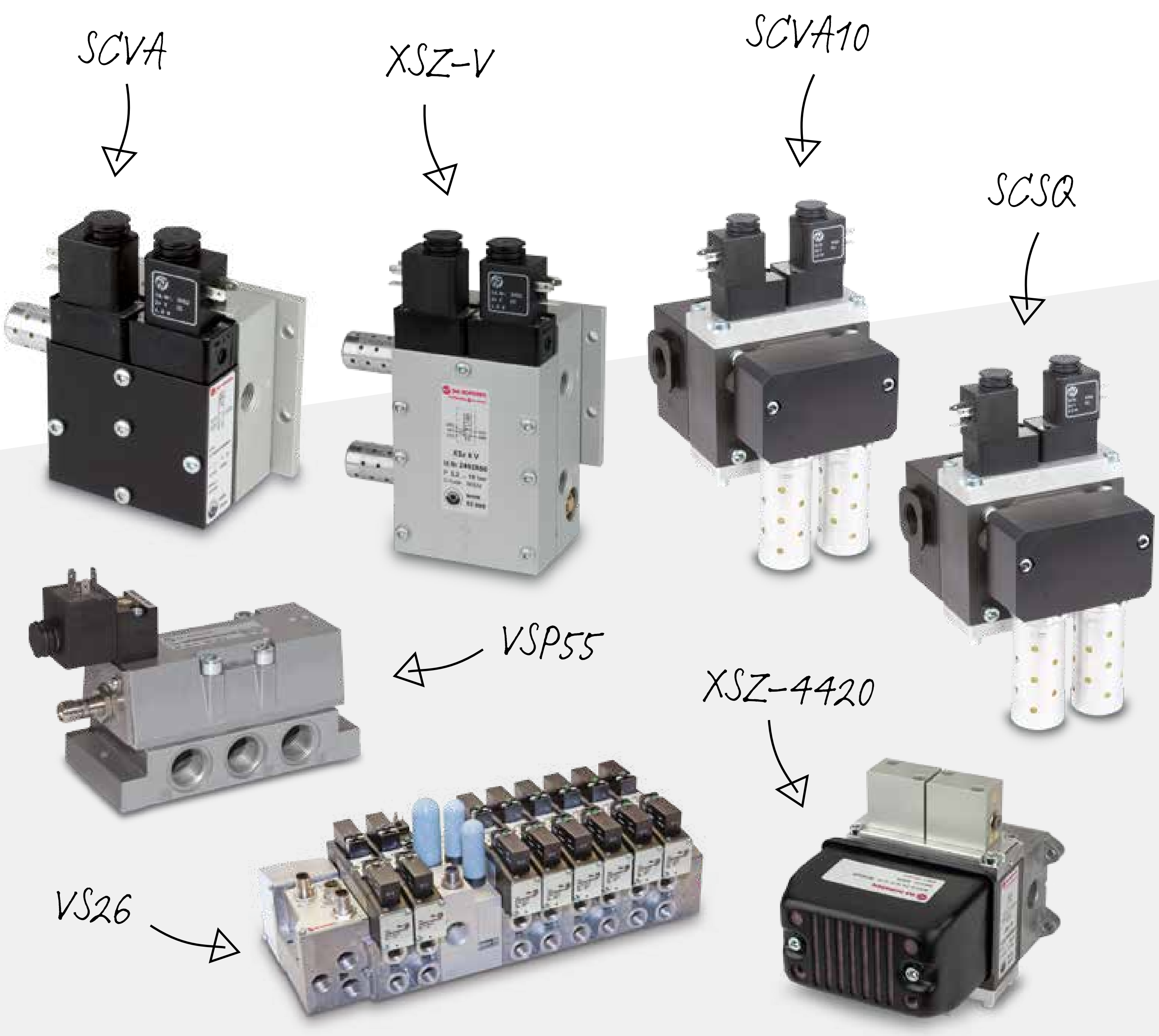
> **High performance products**
> Calling on a world-class portfolio of fluid and motion control products including IMI Norgren, IMI Buschjost, IMI FAS, IMI Herion and IMI Maxseal. We can supply these singly, or combined in powerful customised solutions to improve performance and productivity.

> **Partnership & Problem Solving**
> We get closer to our customers to understand their exact challenges.

Safety Technology

- Over 50 years experience in safety applications
- Safety applications DIN EN ISO 13849
- Competent and professional consulting and system design of safety controls
- Very high B10 levels
- DGUV certified self-monitored safety valves
- Important safety features such as:
  - Safe exhaust
  - Safe position
  - Safe stop
  - Reliable reversing
  - Safely limited speed and more

Product overview

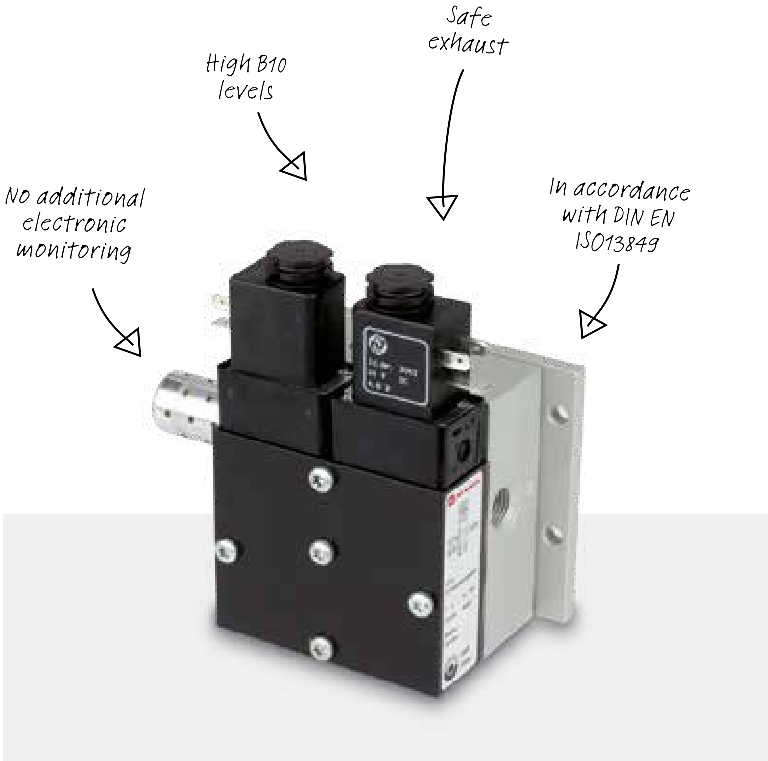


Cross monitored safety valve Series SCVA

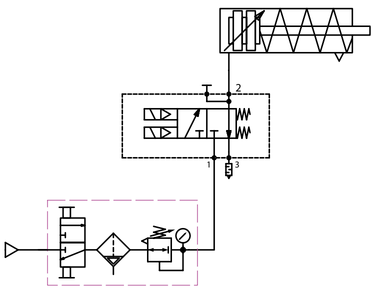
- Sizes: DN 8, 20 and 32
- Port size: G1/4 ... G1
- Control: Pneumatic

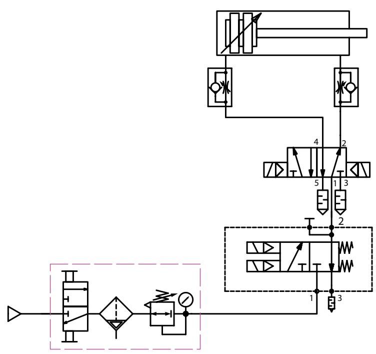
The SCVA is a pneumatically monitored valve eliminating the need for further electronic systems. With the appropriate application, performance level "e" (cat. 4) of DIN EN ISO 13849-1 is achieved for the safety function "Pressure building up from '1' to '2' and pressure dropping from '2' to '3' ".

- Four port sizes in both BSP and NPT thread forms
- Requires only 50 micron filtration for cost effective operation
- Supplied complete with highly effective exhaust silencer
- Excellent B10 values represent extremely long service life until the necessary replacement (T10d-value) of the valves



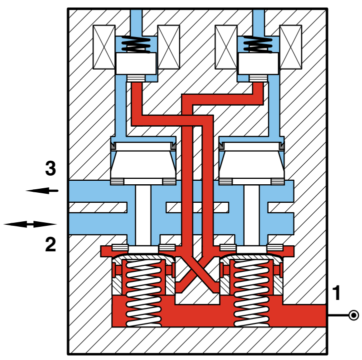
Example for safety functions for safe ventilation cat. 4 PL-e





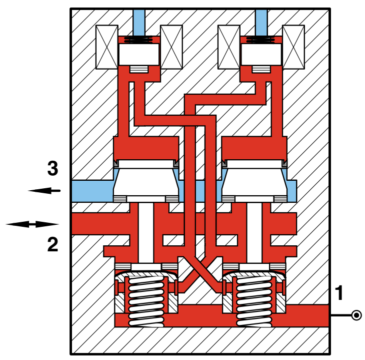
Functional diagram

Basic position



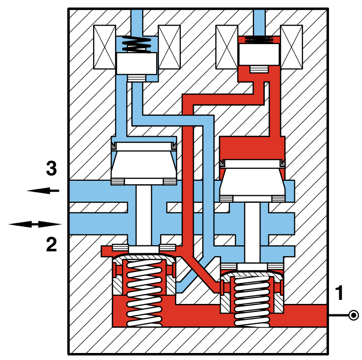
Channel "2" onto "3"
Safety silencer relived

Working position
Both solenoids energised



Channel "1" onto "2" turned on

Safety position
For unbalanced control, faulty solenoid, dirty valve, etc.



Port 2 linked to 3

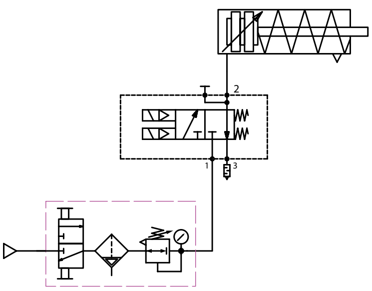
Cross monitored safety valve with Excelon connection Series SCVA10

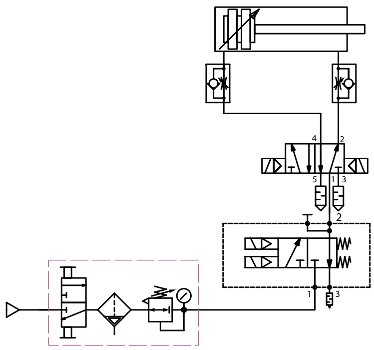
- Sizes: 10 mm
- Port size: G1/2
- Control: Pneumatic

The SCVA10 safety valve is pneumatically monitored and requires no cyclical monitoring or evaluation system. With the appropriate application, performance level "e" (cat. 4) of DIN EN ISO 13849-1 is achieved for the safety function "Pressure building up from '1' to '2' and pressure dropping from '2' to '3' ".

- Redundant valve assembly, pneumatic self-monitoring
- Meets the standard DIN EN ISO 13849, category 4, reaches Performance Level e and is DGUV certified
- Cost-efficient decentralized safety application

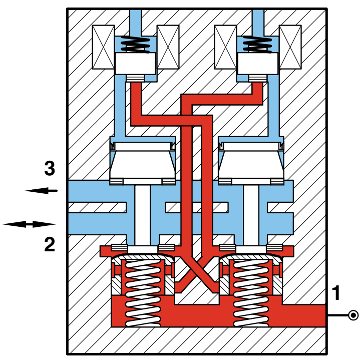
Example for safety functions for safe ventilation cat. 4 PL-e





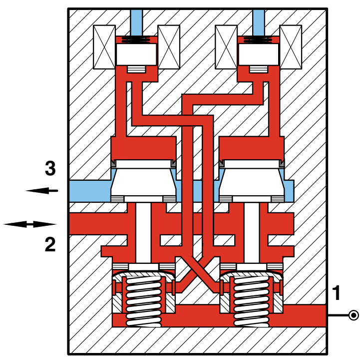
Functional diagram

Basic position



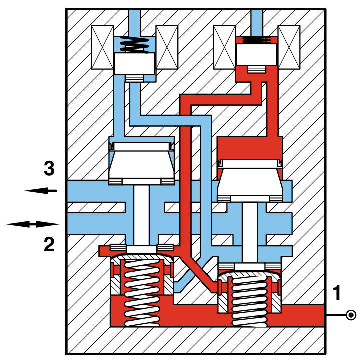
Channel "2" onto "3"
Safety silencer relived

Working position
Both solenoids energised



Channel "1" onto "2" turned on

Safety position
For unbalanced control, faulty solenoid, dirty valve, etc.



Port 2 linked to 3

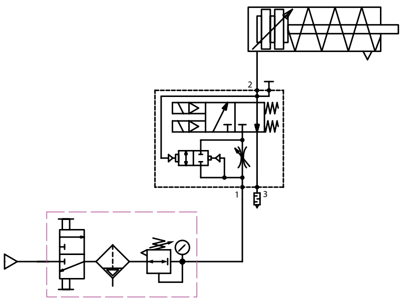
Cross monitored safety valve with integrated soft start and Excelon connection, Series SCSQ

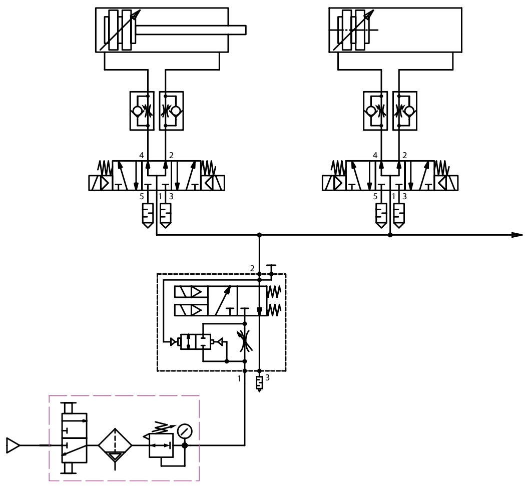
- Sizes: 10 mm
- Port size: G1/2
- Control: Pneumatic

In applications requiring a controlled re-start of the air supply, the SCSQ includes a variable soft start function. This can be adjusted to suit the downstream volume and required fill rate. Like the SCVA, the SCSQ is pneumatically monitored to meet the requirements of current safety legislation and requires no additional electronics.

- Excellent B10 values represent extremely long service life until the necessary replacement (T10d-value) of the valves
- Can be mounted as part of a control system or connected to Excelon air preparation units via integral adaptors
- Supplied complete with highly effective exhaust silencer

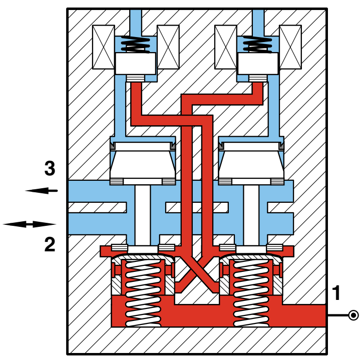
Example for safety functions for safe ventilation cat. 4 PL-e





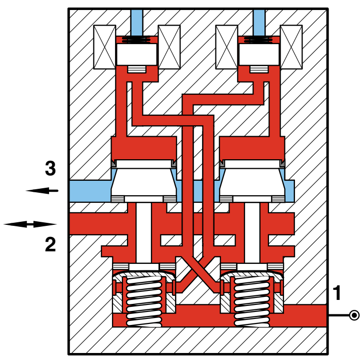
Functional diagram

Basic position



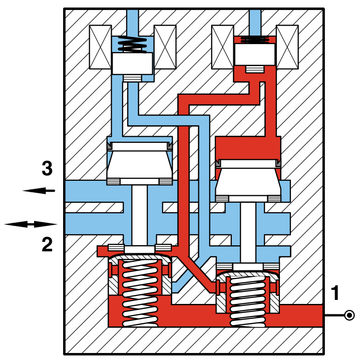
Channel "2" onto "3"
Safety silencer relived

Working position
Both solenoids energised



Channel "1" onto "2" turned on

Safety position
For unbalanced control, faulty solenoid, dirty valve, etc.



Port 2 linked to 3

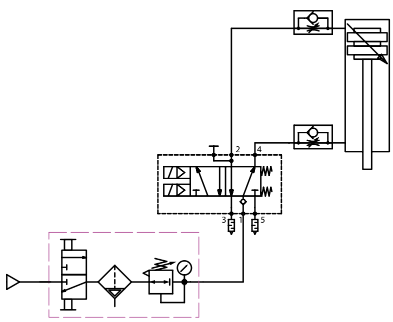
5/2 directional control valve Series XSZ-V

- Sizes: 8 mm and 10 mm
- Port size: G1/4 ... G1/2
- Control: Pneumatic

The 5/2-way safety valve consists of two mechanically separated pilot control systems and main valve systems. The valves are pneumatically operated and the dynamic self-monitoring system does not require additional electrical monitoring. With the approproate application, performance level "e" (cat. 4) of DIN EN ISO 13849-1 is achieved. Excellent B10 values represent extremely long service life until the necessary replacement (T10d-value) of the valves

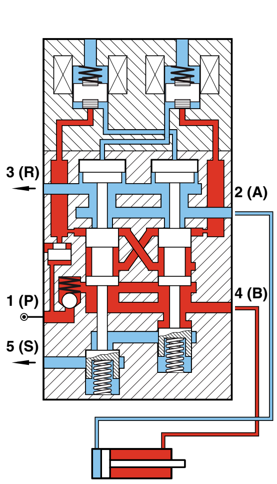
- Double valve control system, dynamic self-monitoring
- Fast exhaust capability
- Improves safety and reduces downtime
- No additional electrical monitoring required

Example of safety function safe reversing Cat 4 PL e



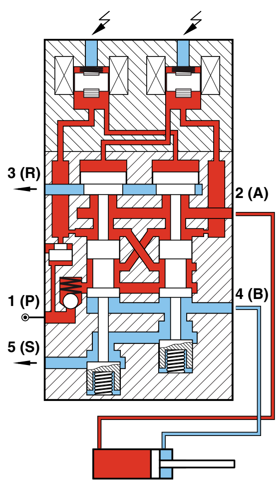
Function of the dynamic self-monitoring (diagnostic coverage 99%)

Not actuated
basic position both magnets



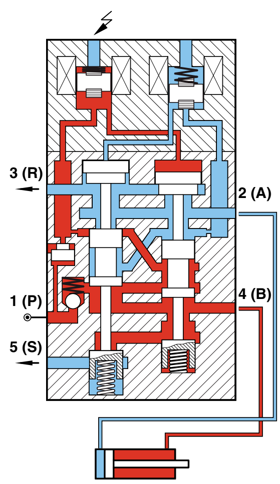
Channel 2 relieved 3
Channel 1 is switched on 4

Working position
Driven both magnets



Channel 1 is switched on 2
Channel 4 relieved 5

Safety position
With asymmetrical driving



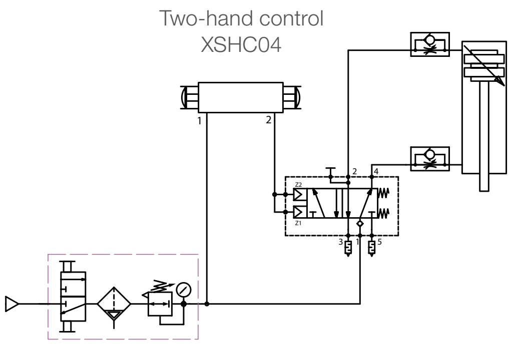
Channel 2 relieved 3
Channel 1 is switched on 4

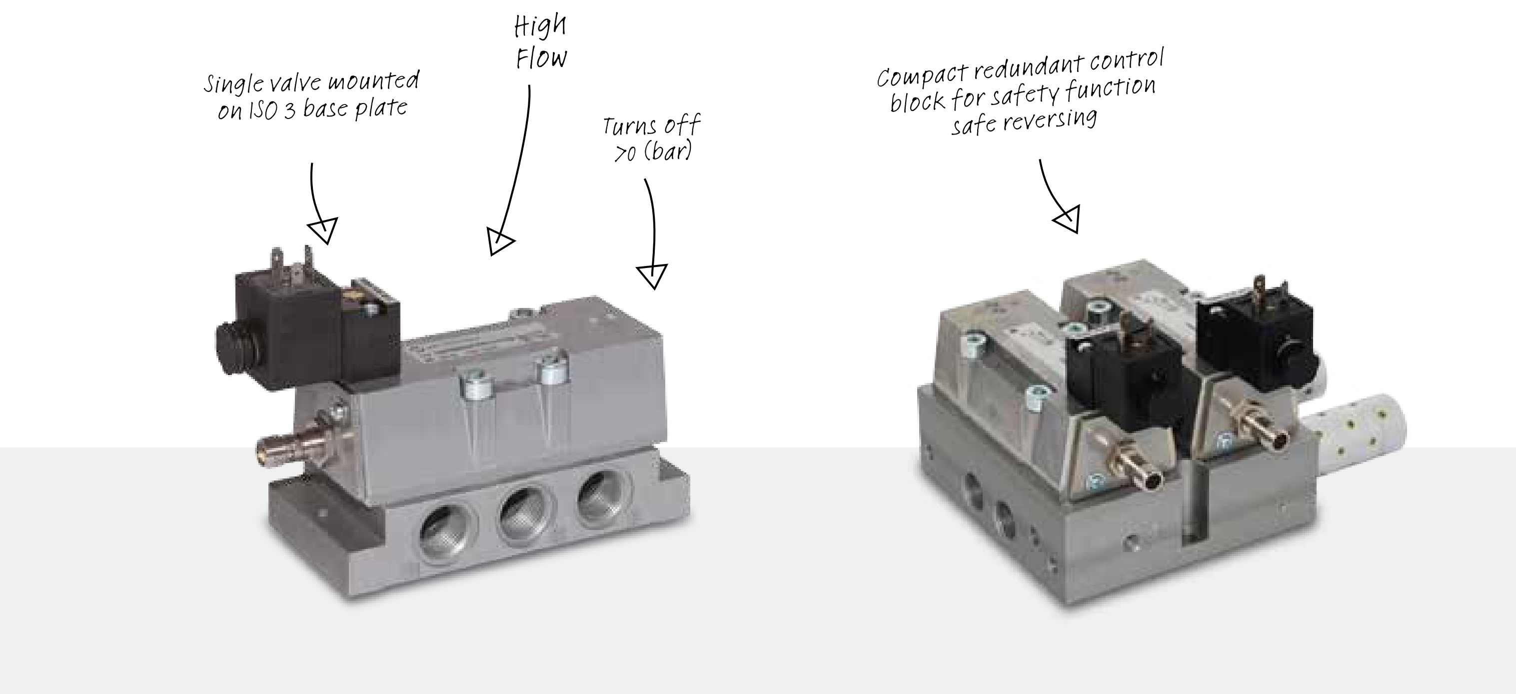
Pneumatic self-monitored 3/2- and 5/2-way Series XSZ-4420

- Sizes: 5,0...8,0 mm
- Port size: G1/2
- Control: Pneumatic

The pneumatic controlled 3/2 and 5/2-way safety valves have a redundant valve assembly. The intrinsically safe dual valve control system with dynamic self-monitoring functions guarantee the highest possible degree of diagnostic coverage at 99%, without the need for additional diagnostic components. Furthermore, this safe design does not require additional electronic diagnostics nor interval tests or cyclical circuits. These valves achieve the performance level „e“ (Category 4) in accordance with DIN EN ISO 13849, DGUV certified. High B10 levels represent optimal durability until the necessary preventative replacement (T10d-value).

Control example two-hand control with pneumatic control 5/2-way safety valve XSZ-4420



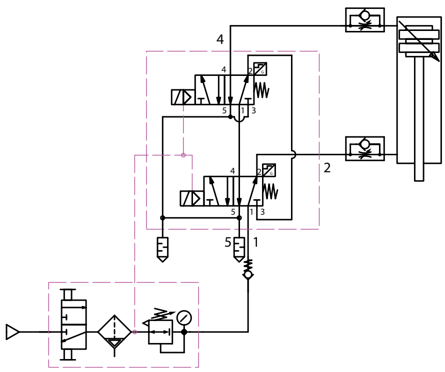


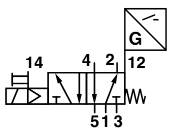
5/2-way SXE ISO of electrical position monitoring Series VSP55

> Sizes: base ISO3

5/2-way valves with additional electrical position monitoring for use in safety-related systems or subsystems. Using two valves in a redundant safety control it can realize a high performance level up to "e" (Category 4) in accordance with EN ISO13849.

Example control reliable reversing Cat. 4 PL-e

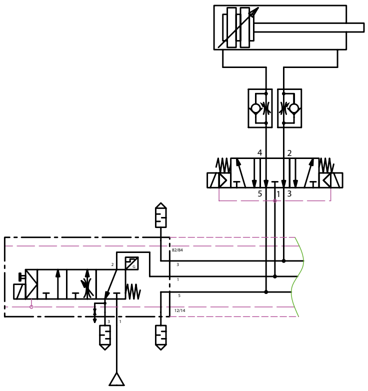


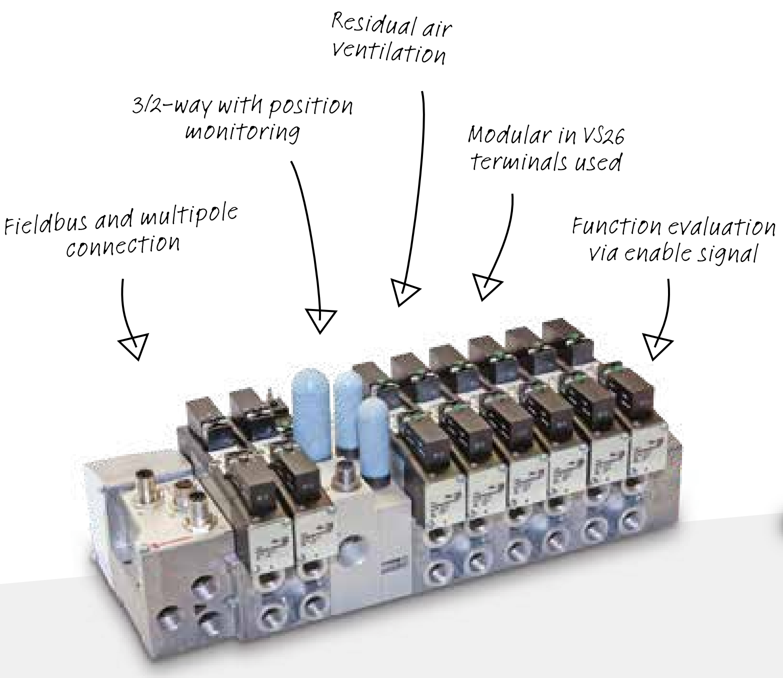


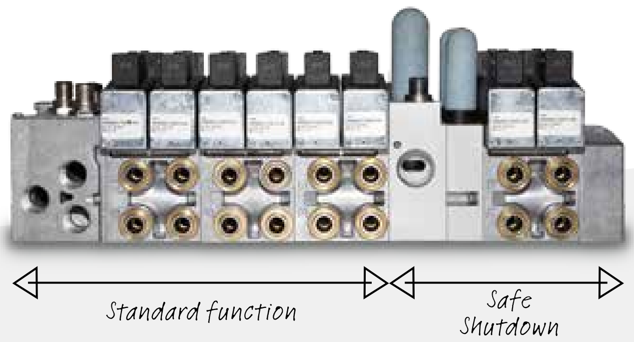
3/2-way soft start dump valve Series VS26

> Sizes: 26 mm, ISO 15407-2

Integrated in the Valve Islands VS26 Series, these valves are suitable for application in safety-related systems. The 3/2-way valves are electronically monitored and fail-safe without residual pressure suitable for safety function "safe ventilation". The soft start enables controlled increase of downstream pressure on startup. Through integration of the valve in the safety system in combination with downstream valve blanking disks, a two-channel function and high performance levels can be achieved (in accordance with DIN EN ISO 13849). Only the right-hand valve positions are pneumatically actuated and locked; the valve is closed on the left side. To order please use valve island configurator.





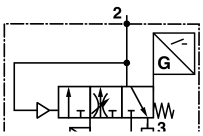


Monitored soft start dump valves Series P64S/P74S

- Port size: G3/8 … G3/4

Whilst not including the cross monitoring function, these products have the facility to provide an electrical output indicating the valve status. This can be incorporated into the machine control system where required – for example in a 2 channel system requiring a level of redundancy. Available in both Excelon and Olympian Plus ranges.

- Rate of pressure build up can be adjusted to suit the application
- High capacity dump facility for optimum performance
- Positively driven micro switch indicating valve position



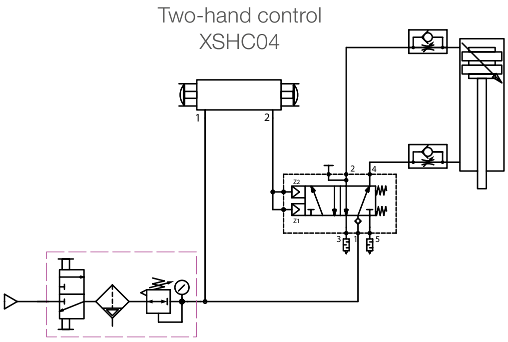
Two-hand control unit Series XSHC04

- Tube size: O/D 4 mm

The standard IMI Herion two-hand start unit can be fitted to any machine function where the requirement exists for the operator to utilise both hands in order to begin operation. Both buttons need to be operated within 0.5 seconds in order to achieve an output. The unit is supplied as a strong, sealed unit designed to prevent accidental operation.

- Meets requirements of EN574 class IIIB
- No additional setting or adjustment required

Control example two-hand control with pneumatic control 5/2-way safety valve XSZ-V

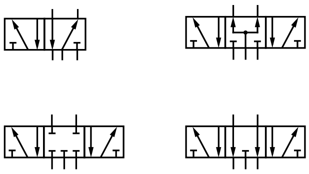


5/2- and 5/3-way valves air pilot and solenoid pilot actuated Series ISO★STAR

> ISO 1 to ISO 3

> Port size: G1/4 ... G1/2

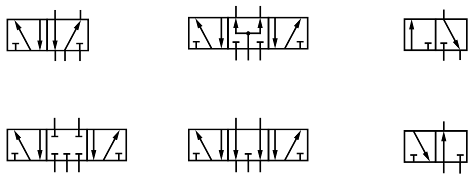
Excellent B10 values due to special valve design.



3/2-, 5/2-, and 2x 3/2 way Series V60 ... 63

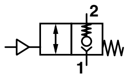
> Port size: G1/8 ... G1/2

High B10 values.



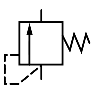
Pilot operated check valve [blocking valve] Series 102GA

> Port size: G1/4...G1/2 and 4 … 12 mm



Safety pressure relief valves Series 4440000

> Port size: G1/4 ... G3/4



3/2-way Inline lockout valve Series CR04

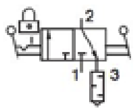
> Port size G1/2 ... G1

When carrying out maintenance on machine installations, the safety of personnel is of vital importance. “LOTO” or “lock out tag out” is a primary function required before any work begins. The air supply to the area should be isolated and the downstream air exhausted quickly and safely then locked to ensure safety of the workforce. Our lock out valves provide a solution to this task, and are easily fitted into the system.

> Valves can only be locked in the “off” position and made secure with a purpose made hasp

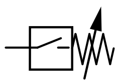
> Operating handle provides a clear, simple method of operation

> Complete with integral heavy duty silencer / muffler



Pressure Switch Series 18D

> Port size: G1/4



IMI Precision Engineering Product overview

IMI Precision Engineering offers a full suite of pneumatic and electropneumatic products for the efficiency and safety of many pneumatic applications.

Actuators

Valves

Vacuum

Air Preparation

Fittings, Tubing, Accessories

Pressure Switches

Functional Safety in brief

Machinery Directive 2006/42/EC and DIN EN ISO 13849 Part 1 and Part 2

With an effective date 29.12.2009 the Machinery Directive 2006/42/EC replaced the previous Machinery Directive 98/37/EC and defines fundamental standards of Machine Safety in the European domestic market. Only machines, that comply with the demands of the Machinery Directive, are allowed to be introduced on the European market. This includes new machines as well as existing machines that have experienced significant or considerable variations or modifications or have served a different use. In accordance with conditions of the Machinery Directive and the guideline, compliant machines must be furnished with CE-labelling, Declaration of Conformity and the required user information. The harmonized standard DIN EN ISO 13849 (Model B Standard) assists the Machinery Directive with the technical implementation of the safety demands and reliable control systems. It provides generally important principles in terms of the planning and evaluation of safety-related parts of a control system, control system architecture as well as the quality of risk mitigation and the validation procedures for the safety function, categories and Performance Levels of safety-related parts of controls.

Safety and Risk assessment

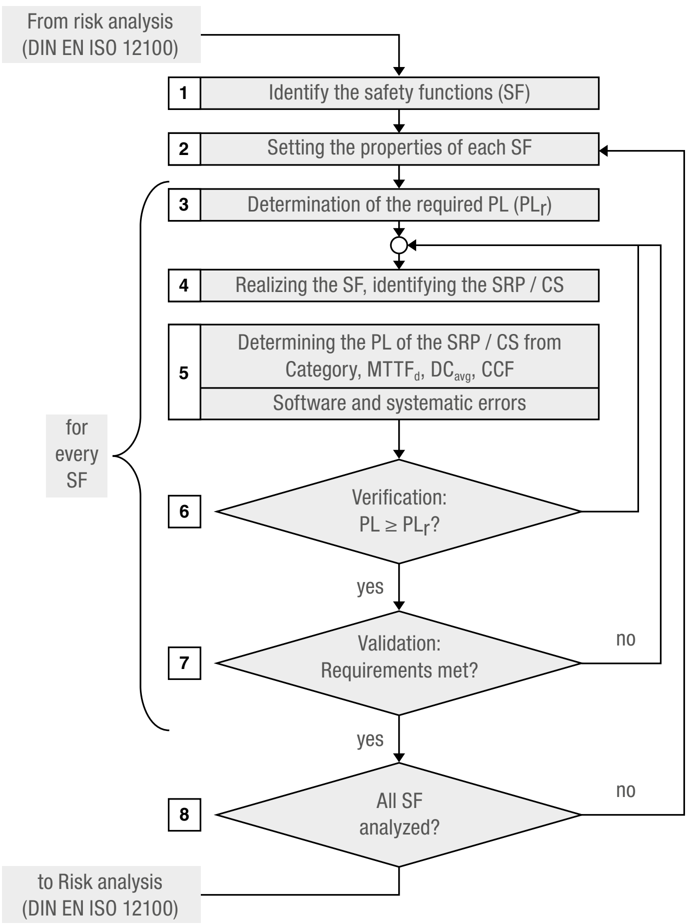
A machine should be constructed to guarantee safety as much as possible. Any potential danger must have its risk reduced/minimized by protections or measures e.g. a pneumatic safety control system. For unavoidable residual risk, the corresponding necessary documentation must be provided. A comprehensive and standardized risk assessment will take place at the beginning of the process for the evaluation of the machinery safety.

Identification of safety function

If in the risk analyses hazardous movements were detected then, in accordance with the danger, counteracting safety functions must be defined and provided. Only after more precise definition of the actual safety function can the corresponding subsystems of the safety control system be adequately executed and interpreted.

- Safe exhausting of a system
- Stop of a hazardous movement
- Stop and obstructing of a hazardous movement
- Reversing a hazardous movement
- Protection against accidental start-up and many others

Iterative process for the design of the safety-related components of the control system



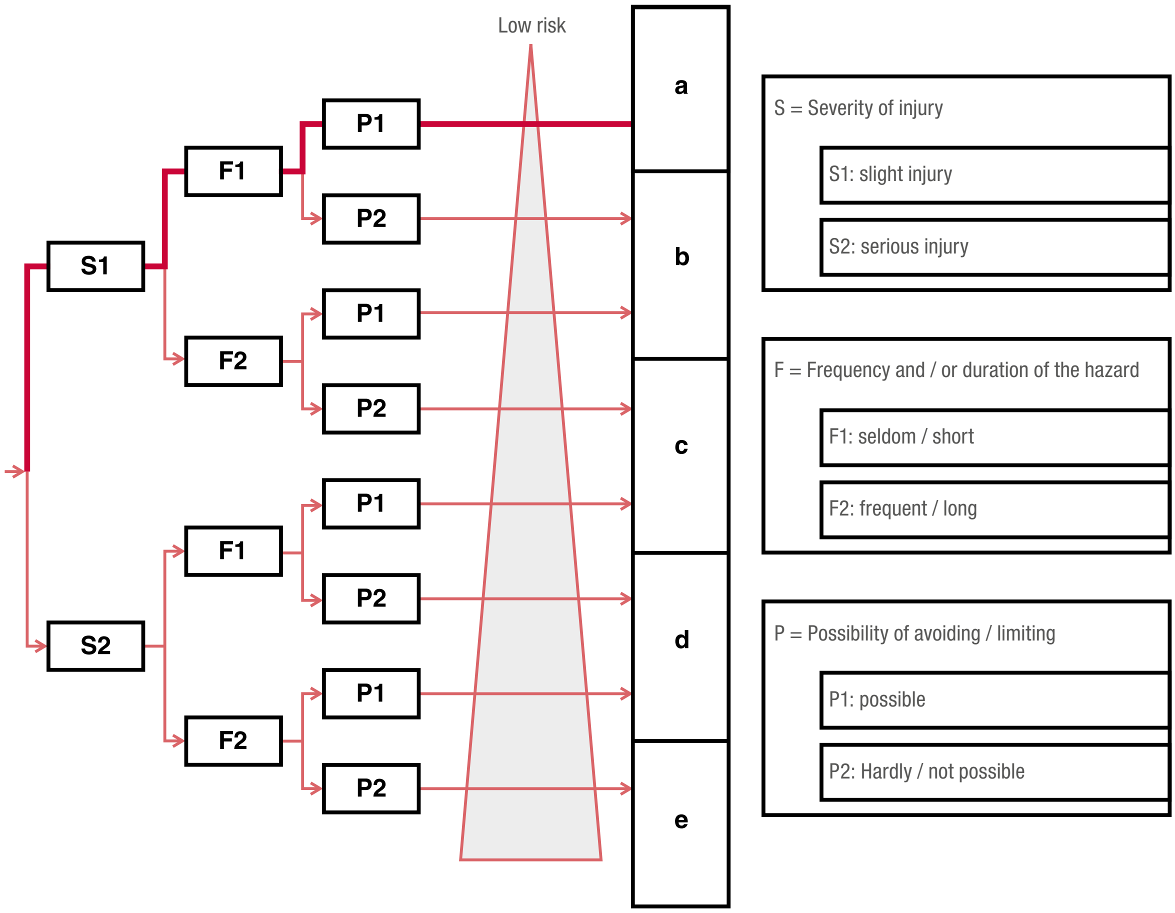
SF= safety function
PL= performance level

SRP/CS= safety related parts of control systems
MTTFd= mean time to dangerous failure
DC avg= average diagnostic coverage
CCF= control cause failure

Determination of the required Performance Levels

The Performance Level is a measure of the quality of the risk reduction and must be separately ascertained for every safety function. Within a machine with multiple safety functions and various hazard potentials, different Performance Levels could be necessary. The three deciding criteria for ascertaining the respective potential hazard areas' necessary Performance Levels are:

- How severe would a potential injury be?
- How frequently do employees come into contact with potentially hazardous areas?
- What possibilities does one have in a critical case, to escape or avoid the hazard?



Risk graph for determination of the required Performance Levels

Example:

S1 = slight injury

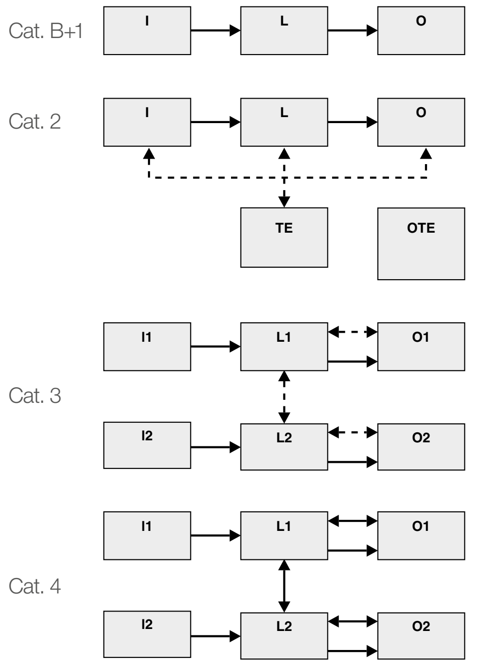
F1 = Operator comes only rarely/briefly in contact with the hazard area

P1 = It is practically impossible to avoid the risk of the occurrence in time

Select the category

DIN EN ISO 13849 outlines 5 different categories (B, 1, 2, 3, 4) describing the respective architectures of the safety control system and with that the durability and the performance in the case of an error.

- Category B: Single-channel, non-redundant safety system. One single fault leads to the loss of the safety function.
- Category 1: Like Category B, but with a higher resistance to failure through use of well-tried components.
- Category 2: Safety control system with additional test channels and cyclical tests for safety functions with suitable test rates. Errors between the test phases are not excluded and can lead to the loss of the safety function.
- Category 3: Dual-channel, redundant safety system. One single error does not lead to the loss of the safety function, but accumulated undetected faults may.
- Category 4: Dual-channel, redundant safety system. One single error or the accumulation of faults does not lead to the loss of the safety function.

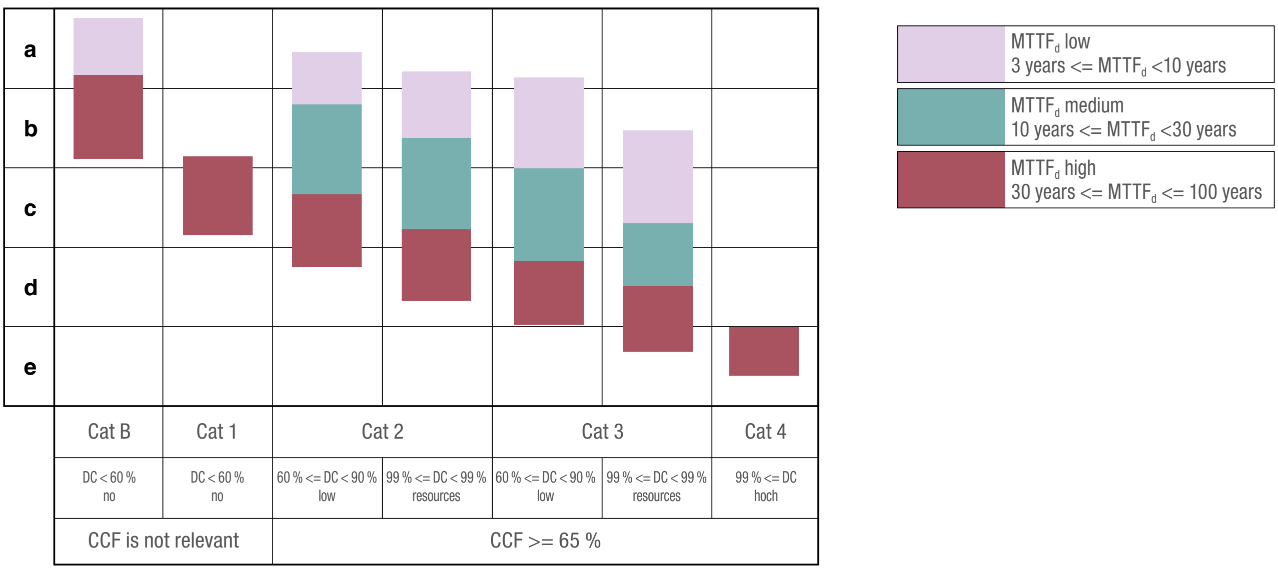


I = Input (for instance emergency stop switch)
L = Logic (for instance safety relays)
O= Output (for instance electropneumatic valves)

Determination of the Performance Levels PL

Simplified determination of the Performance Levels by means of the bar charts depending on:

- the selected control architecture (category)
- the $MTTF_d$-value
- the diagnostic coverage
- and the CCF review



B10 / $MTTF_d$ as basic parameters for determining the performance level

In accordance with the requirements of a safety control system and dependent on the necessary safety functions, suitable individual components should be selected and implemented within corresponding control architecture. IMI Precision Engineering offers, for this purpose, a very broad product range of components and supports the correct selection of components together with the provision of the necessary characteristic values as a basis for evaluation of the accomplished Performance Levels. The basis for evaluation and determination of the accomplished Performance Levels of a safety control system are the $B10_d$ / $MTTF_d$ characteristic values of the relevant individual safety components which are decisive for the safety functions.

- $B10_d$: The mean number of operating cycles until up to 10 % of the considered units have failed dangerously
- $MTTF_d$: Average operating life, until up to 10 % of the considered units have failed dangerously. For pneumatic and electro-pneumatic components the MTTF is calculated as below

$$MTTF_d = \frac{B10_d}{0{,}1 \cdot n_{op}}$$

$$n_{op} = \frac{d_{op} \cdot h_{op}}{t_{Cycle}} 3\,600 \frac{s}{h}$$

h_{op} = is the mean operating time in hours per day

d_{op} = is the mean operating time in days per year

t_{Cycle} = is the average time between the beginning two consecutive cycles of the components (i.e. switching of a valve) in seconds per cycle.

Electronic components do not age over cycles of operations but instead over time. Therefore $MTTF_d$ isn't calculated from B10d but called by the supplier of the component.

Classification of $MTTF_d$ of each channel

$MTTF_d$ for each channel	
Designation	**Area**
not acceptable	0 years ≤ $MTTF_d$ <3 years
low	3 years ≤ $MTTF_d$ < 10 years
medium	10 years ≤ $MTTF_d$ <30 years
not applicable	30 years ≤ $MTTF_d$ ≤ 100 years
invalid	100 years < $MTTF_d$

Calculated values >100 years are limited to 100 years for further calculation, MTTFd values less than 3 years are not acceptable.

Calculating $MTTF_d$ total of a single channel

$$\frac{1}{MTTF_d} = \sum_{i=1}^{\tilde{N}} \frac{1}{MTTF_{di}} = \sum_{j=1}^{\tilde{N}} \frac{nj}{MTTF_{dj}}$$

Calculating $MTTF_d$ total of two channels (redundant overall system)

$$MTTF_d = \frac{2}{3}\left[MTTF_{dC1} + MTTF_{dC2} - \frac{1}{\frac{1}{MTTF_{dC1}} + \frac{1}{MTTF_{dC2}}} \right]$$

Being $MTTF_{dC1}$ and $MTTF_{dC2}$ values for the two individual channels.

DC Diagnostic Coverage

The Diagnostic Coverage (DC) is a measure of the effectiveness of the self-test and monitoring measures in a control system. It is determined by the proportion of detectable dangerous failures amongst all dangerous failures. For higher-ranking control architecture, (2 to 4) the corresponding failure detection must be implemented in the control system.The value of the degree of diagnostic coverage is dependent on the respective selected measures of failure detection and must amount to at least 60 %. The top category 4, for example, requires diagnostic coverage of 99 %.

Classification of diagnostic coverage

DC (Diagnostic Coverage)	
Designation	**Area**
none	DC < 60 %
low	60 % ≤ DC < 60 %
medium	99 % ≤ DC < 99 %
high	99 % ≤ DC

Examples of evaluation of diagnostic coverage

Input unit	
Action	**DC**
Cyclical test pulse by dynamically changing the input signals	90 %
Plausibility check i.e. usage of the closing and opening contacts of the forcibly actuated relays	99 %
Cross-comparison of input signals without dynamic test	0% to 99%, depending on how often a signal change by the application
Cross-comparison of input signals with dynamic test, if short circuits could not be observed (for multiple I/O)	90 %
Cross-comparison of input signals and intermediate results in the Logic (L) and temporal and logic program run monitoring and detection of static faults and short circuits (for multiple I/O)	99 %
Indirect monitoring (e.g. monitoring by pressure switches, electrical position monitoring of actuators)	90% to 99%, depending on the application
Direct monitoring (e.g. electrical position monitoring of control valves, monitoring of electro-mechanical devises by mechanically linked contact elements)	99 %
Error detection during the process	0% to 99%, depending on the application; this measure is not sufficient for the required performance level "e"!
Monitoring of some features of the sensors (Response time, range of analogue signals, e.g. electronic resistance, capacitance)	60 %

Within a safety control system various measures for fault detection can be provided appropriate to the individual safety components.

Calculation of diagnostic coverage of an entire safety control

$$DC_{avg} = \frac{\frac{DC_1}{MTTF_{d1}} + \frac{DC_2}{MTTF_{d2}} + \cdots + \frac{DC_N}{MTTF_{dN}}}{\frac{1}{MTTF_{d1}} + \frac{1}{MTTF_{d2}} + \cdots + \frac{1}{MTTF_{dN}}}$$

CCF – Common Cause Failures

To evaluate the robustness of a dual-channel safety position and possibilities of failures common cause must be considered. The CCF is quantified in accordance with specific criteria, which is connected to a Point system and must reach a minimum score of >=65 in order to meet the requirements.

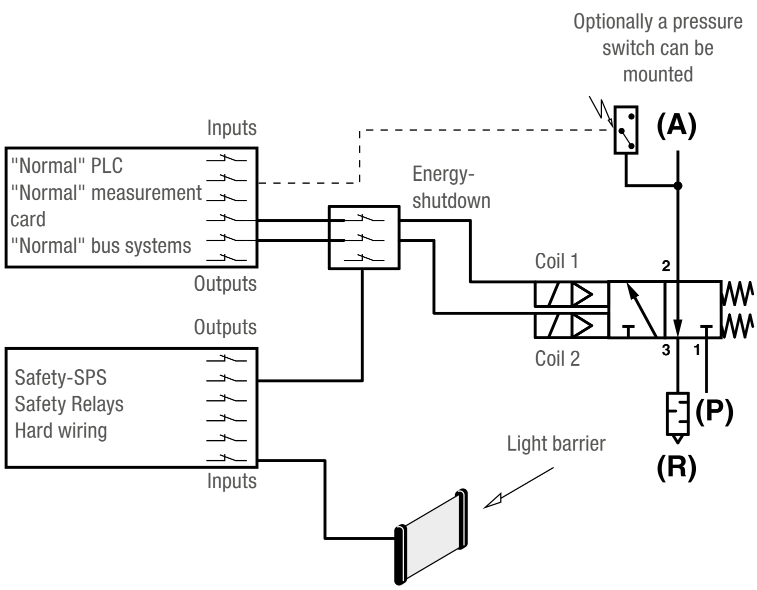
A potential Common Cause Failure can be caused for example through incorrect upstream compressed air preparation. If the compressed air is not accordingly pre-filtered, under some circumstances the valves' two redundant channels could become simultaneously contaminated and possibly, as a result, simultaneously fail. For prevention adequate and effective compressed air treatment is to be provided.

Measure against CCF	Score
Separation / Segregation	
Physical separation between the signal paths: separation in wiring/piping, sufficient clearances and creep age distances on printed-circuit boards.	15
Diversity	
Different technologies/design or physical principles are used, for example: first channel programmable electronic and second channel hardwired. Different kind of initiation, pressure and temperature sensing. Valves from different manufactures.	20
Design / application / experience	
Protection against over loading, over-pressure, over-current, etc.	15
Components used are well-proven	5
Assessment / analysis	
Are the results of a failure mode and effect analysis taken into account to avoid common-cause-failures in design.	5
Competence / training	
Have designers/technicians been trained to identify the causes and consequences of common cause failures?	5
Environmental	
Prevention of contamination and electromagnetic compatibility (EMC) against CCF in accordance with appropriate standards. Fluidic systems: filtration of the pressure medium, prevention of dirt intake, drainage of compressed air e.g. in compliance with the component manufacturer's requirements concerning purity of the pressure medium. Electric systems: Has the system been checked for electromagnetic immunity, e.g. as specified in relevant standards against CCF? For combined fluidic and electric systems, both should be considered.	25
Other influences. Have the requirements for immunity to all relevant environmental influences such as temperature, shock, vibration, humidity (e.g. as specified in relevant standards) been considered?	10
Total	
Max. achievable: 100 points, minimum requirement to pass CCF: 65 points.	

Control chain of a safety system

A complete safety chain consisting of three subsystems, each with an independent function

- Subsystem 1: Input
  Acquisition of information
  i.e.: photocell, limit switches, emergency stop switch etc.
- Subsystem 2: Logic
  Processing of the information for the introduction of necessary safety function
  i.e.: Safety-SPS, safety relays etc.
- Subsystem 3: Output
  i.e.: Electropneumatic valves, etc



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