BS EN 13611:2015

BSI Standards Publication

Safety and control devices for burners and appliances burning gaseous and/or liquid fuels — General requirements

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National foreword

This British Standard is the UK implementation of EN 13611:2015. It supersedes BS EN 13611:2007+A2:2011 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee GSE/22, Safety and control devices for gas and oil burners and gas burning appliances.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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EN 13611

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ICS 23.060.40

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English Version

Safety and control devices for burners and appliances burning gaseous and/or liquid fuels - General requirements

Équipements auxiliaires pour brûleurs et appareils utilisant des combustibles gazeux ou liquides - Exigences générales

Sicherheits- und Regeleinrichtungen für Brenner und Brennstoffgeräte für gasförmige oder flüssige Brennstoffe - Allgemeine Anforderungen

This European Standard was approved by CEN on 14 February 2015.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the CEN-CENELEC Management Centre or to any CEN member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the CEN-CENELEC Management Centre has the same status as the official versions.

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Foreword

This document (EN 13611:2015) has been prepared by Technical Committee CEN/TC 58 “Safety and control devices for burners and appliances burning gaseous or liquid fuels”, the secretariat of which is held by BSI.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by December 2015, and conflicting national standards shall be withdrawn at the latest by December 2015.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

This document supersedes EN 13611:2007+A2:2011.

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association, and supports essential requirements of EU Directive(s).

For relationship with EU Directive(s), see informative Annexes ZA and ZB, which are integral parts of this document.

Product specific control standards of CEN/TC 58 make use of this standard by adapting this standard and stating “addition”, “modification” or “replacement” in their corresponding clauses.

It should be noted that the following significant changes compared to the previous edition have been incorporated in this European Standard:

1) Introduction, new text;

2) Clause 1 “Scope” reworded;

3) Clause 2 “Normative references” updated;

4) Clause 3 “Terms and definitions” updated and inclusion of some new definitions;

5) Clause 4 ”Classification” new subclause 4.4 "Types of DC supplied controls";

6) Clause 5 new title “Test conditions and uncertainty of measurements” updated and inclusion of new subclauses 5.1 “Test conditions” and 5.2 “Uncertainty of measurements”;

7) Clause 6 new title “Design and construction”;

8) Subclause 6.1 “General” rewording of general requirements, additional requirements to cover the risk of high pressure;

9) Subclause 6.2 “Mechanical parts of the control” reworded and inclusion of new subclauses “Auxiliary canals and orifices” and “Presetting devices”;

10) Subclause 6.3 “Materials” reworded, renumbered and modified requirements for housing and for zinc alloys, new test for zinc alloys;

11) Subclause 6.4 “Gas connections” reworded, updated and modified requirements;

12) Subclause 6.5 “Electrical parts of the control” reworded and updated, inclusion of new subclause for switching elements (requirements and test), new subclause for electrical components in the gas way (requirements and test);

13) Subclause 6.6 “Protection against internal faults for the purpose of functional safety” reworded and updated, new subclause for lock-out function;

14) Subclause 7.1 “General” reworded and new requirements for AC/DC supplied controls;

15) Subclause 7.3 „Torsion and bending“ reworded, updated and modified requirements;

16) Subclause 7.4 „Rated flow rate” reworded, updated and modified requirements;

17) Subclause 7.5 “Durability” reworded, updated and new requirements for Elastomer/cork and elastomer/cork/synthetic fibre material in contact with gas, new requirements for lubricants in contact with gas;

18) Subclause 7.6 “Performance tests for electronic controls” reworded, updated and modified;

19) Subclause 7.7 “Long-term performance for electronic controls” reworded, updated and modified;

20) New Subclause 7.8 „Data exchange“ new requirements;

21) New Clause 8 “Electrical requirements” inclusion of updated requirements of EN 13611:2007+A2:2011, 8.11, inclusion of updated requirements of EN 13611:2007+A2:2011, 6.5.2;

22) New Clause 9 “Electromagnetic compatibility (EMC)” inclusion of reworded, updated and modified requirements of EN 13611:2007+A2:2011, Clause 8;

23) New Clause 10 ”Marking, installation and operating instructions” inclusion of updated requirements of EN 13611:2007+A2:2011, Clause 9;

24) Replacement of Annex A (informative) “Gas connections in common use in various countries” by Annex A (informative) “Abbreviations and Symbols”;

25) Annex E (normative) “Electrical/electronic component fault modes”, reworded, updated and modified;

26) Annex F (normative) “Additional requirements for safety accessories and pressure accessories” reworded, updated and modified;

27) Subclause F.6.3 “Materials” new requirements;

28) Annex G (normative) “Materials for pressurized parts” updated;

29) Annex H (normative) “Additional materials for pressurized parts” updated;

30) Annex I (normative) “Requirements for controls used in DC supplied burners and appliances burning gaseous or liquid fuels” reworded, updated and modified;

31) Annex J (normative) “Method for the determination of a Safety integrity level (SIL)” reworded and updated;

32) Annex K (normative) “Method for the determination of a Performance Level (PL)” reworded and updated;

33) New Annex M (normative) “Reset functions”;

34) New Annex N (informative) “Guidance document on Environmental Aspects”;

35) New Annex O (normative) “Seals of elastomer, cork and synthetic fibre mixtures”;

36) Complete update of the Annexes ZA, ZB and the Bibliography.

According to the CEN/CENELEC Internal Regulations, the national standards organisations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

Introduction

This standard recognizes the safety level specified by CEN/TC 58 and is regarded as a horizontal standard dealing with the safety, construction and performance of controls for burners and appliances burning gaseous and/or liquid fuels and to their testing.

The general requirements for controls are given in this document and methods for classification and assessment for new controls and control functions are given in EN 14459:2007 (see Figure 1). EN 126 (see Figure 1) specifies multifunctional controls combining two or more controls and Application Control Functions, one of which is a mechanical control function. The requirements for controls and Application Control Functions are given in the specific control standard (see Figure 1, control functions).

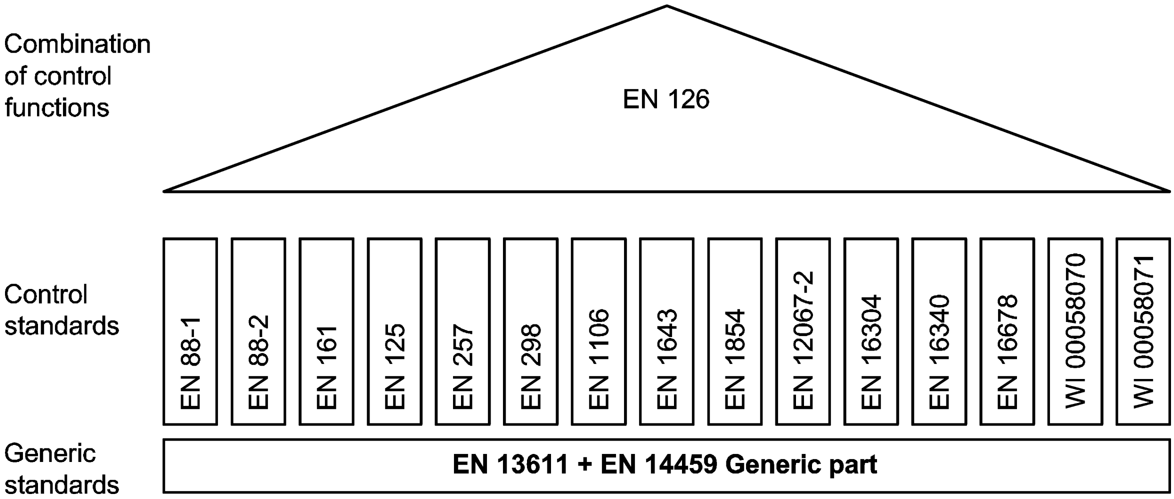

Figure 1 — Interrelation of control standards

This European Standard should be used in conjunction with the specific standard for a specific type of control, (e.g. EN 88-1:2011, EN 88-2:2007, EN 125:2010, EN 126:2012, EN 161:2011+A3:2013, EN 257:2010, EN 298:2012, EN 1106:2010, EN 1643:2014, EN 1854:2010, EN 12067-2:2004, EN 16304:2013 and EN 16340:2014), or for controls for specific applications. This standard can also be applied, so far as reasonable, to controls not mentioned in a specific standard and to controls designed on new principles, in which case additional requirements can be necessary. EN 14459:2007 provides assessment methods for new control principles.

Primarily in industrial applications it is common practice to rate the safety of a plant based on values describing the likelihood of a dangerous failure. These values are being used to determine Safety Integrity Levels or Performance Levels when the system is being assessed in its entirety.

CEN/TC 58 standards for safety relevant controls do go beyond this approach, because for a certain life span for which the product is specified, designed and tested a dangerous failure is not allowed at all. Failure modes are described and assessed in greater detail. Measures to prevent from dangerous situations are defined. Field experience over many decades is reflected in the CEN/TC 58 standards. Requirements of these standards can be considered as proven in practice.

To be able to provide values for the parameters that are needed for the determination of a Safety Integrity Level or of a Performance Level, Annex J and Annex K of this document specifies a possible methodology to derive values for the relevant parameters from the requirements of this European Standard.

Only controls that conform to the relevant CEN/TC 58 control standard can be assessed for PL classification according to this amendment.

It cannot be presumed that any Safety Integrity Level or Performance Level assessment alone would imply that requirements of a CEN/TC 58 standard have been met.

1 Scope

This European Standard specifies the general safety, design, construction, and performance requirements and testing for safety, control or regulating devices (hereafter referred to as controls) for burners and appliances burning one or more gaseous fuels or liquid fuels. This European Standard is applicable to controls with declared maximum inlet pressure up to and including 500 kPa of nominal connection sizes up to and including DN 250.

This European standard specifies general product requirements for the following controls:

— automatic shut-off valves;

— automatic burner control systems;

— flame supervision devices;

— gas/air ratio controls;

— pressure regulators;

— manual taps;

— mechanical thermostats;

— multifunctional controls;

— pressure sensing devices;

— valve proving systems;

— automatic vent valves.

This European standard applies for control functions that are not covered by a specific control standard for burners and appliances burning one or more gaseous fuels or liquid fuels.

This European Standard applies also for safety accessories and pressure accessories with a product of the maximum allowable pressure PS and the volume V of less than 600 000 kPa · dm^3 (6 000 bar· litres) or with a product of PS and DN of less than 300 000 kPa (3 000 bar) .

This European Standard applies for *AC* and *DC* supplied controls (for controls supplied by stand-alone battery system, battery systems for mobile applications or systems which are intended to be connected to *DC* supply networks controls see Annex I).

This European Standard is applicable to reset functions used for reset from lockout, e.g. due to ignition failure or temperature cut-out in burners and appliances (see Annex M).

This European Standard establishes methodologies for the determination of a Safety Integrity Level (SIL) and the determination of a Performance Level (PL) (see Annex J, Annex K and Annex L).

This European Standard gives guidelines for environmental aspects (see Annex N).

This European Standard does not apply to mechanical controls for use with liquid fuels.

The protection against environmental impact in open air (i.e. capable of withstanding UV radiation, wind, rain, snow, dirt deposits, condensation, ice and hoar frost (see IEV 441-11-05:2005), earthquake and external fire) is not covered by this standard.

This European Standard should be used in conjunction with the specific control standard (see Bibliography).

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 485-2:2013, *Aluminium and aluminium alloys - Sheet, strip and plate - Part 2: Mechanical properties*

EN 549:1994, *Rubber materials for seals and diaphragms for gas appliances and gas equipment*

EN 586-2:1994, *Aluminium and aluminium alloys - Forgings - Part 2: Mechanical properties and additional property requirements*

EN 754-2:2013, *Aluminium and aluminium alloys - Cold drawn rod/bar and tube - Part 2: Mechanical properties*

EN 755-2:2013, *Aluminium and aluminium alloys - Extruded rod/bar, tube and profiles - Part 2: Mechanical properties*

EN 1057:2006+A1:2010, *Copper and copper alloys - Seamless, round copper tubes for water and gas in sanitary and heating applications*

EN 1563:2011, *Founding - Spheroidal graphite cast irons*

EN 1559-1:2011, *Founding - Technical conditions of delivery - Part 1: General*

EN 1652:1997, *Copper and copper alloys - Plate, sheet, strip and circles for general purposes*

EN 1706:2010, *Aluminium and aluminium alloys - Castings - Chemical composition and mechanical properties*

EN 1774:1997, *Zinc and zinc alloys - Alloys for foundry purposes - Ingot and liquid*

EN 1982:2008, *Copper and copper alloys - Ingots and castings*

EN 10025-1:2004, *Hot rolled products of structural steels - Part 1: General technical delivery conditions*

EN 10028-2:2009, *Flat products made of steels for pressure purposes - Part 2: Non-alloy and alloy steels with specified elevated temperature properties*

EN 10028-3:2009, *Flat products made of steels for pressure purposes - Part 3: Weldable fine grain steels, normalized*

EN 10028-4:2009, *Flat products made of steels for pressure purposes - Part 4: Nickel alloy steels with specified low temperature properties*

EN 10028-5:2009, *Flat products made of steels for pressure purposes - Part 5: Weldable fine grain steels, thermomechanically rolled*

EN 10028-6:2009, *Flat products made of steels for pressure purposes - Part 6: Weldable fine grain steels, quenched and tempered*

EN 10028-7:2007, *Flat products made of steels for pressure purposes - Part 7: Stainless steels*

EN 10083-1:2006, *Steels for quenching and tempering - Part 1: General technical delivery conditions*

EN 10083-2:2006, *Steels for quenching and tempering - Part 2: Technical delivery conditions for non alloy steels*

EN 10087:1998, *Free-cutting steels - Technical delivery conditions for semi-finished products, hot-rolled bars and rods*

EN 10088-1:2014, *Stainless steels — Part 1: List of stainless steels*

EN 10088-3:2014, *Stainless steels — Part 3: Technical delivery conditions for semi-finished products, bars, rods, wire, sections and bright products of corrosion resisting steels for general purposes*

EN 10111:2008, *Continuously hot rolled low carbon steel sheet and strip for cold forming - Technical delivery conditions*

EN 10130:2006, *Cold rolled low carbon steel flat products for cold forming - Technical delivery conditions*

EN 10213:2007, *Steel castings for pressure purposes*

EN 10216-1:2013, *Seamless steel tubes for pressure purposes - Technical delivery conditions - Part 1: Non-alloy steel tubes with specified room temperature properties*

EN 10216-5:2013, *Seamless steel tubes for pressure purposes - Technical delivery conditions - Part 5: Stainless steel tubes*

EN 10222-1:1998, *Steel forgings for pressure purposes - Part 1: General requirements for open die forgings*

EN 10222-5:1999, *Steel forgings for pressure purposes - Part 5: Martensitic, austenitic and austenitic-ferritic stainless steels*

EN 10226-1:2004, *Pipe threads where pressure tight joints are made on the threads - Part 1: Taper external threads and parallel internal threads - Dimensions, tolerances and designation*

EN 10226-2:2005, *Pipe threads where pressure tight joints are made on the threads - Part 2: Taper external threads and taper internal threads - Dimensions, tolerances and designation*

EN 10250-1:1999, *Open die steel forgings for general engineering purposes - Part 1: General requirements*

EN 10250-2:1999, *Open die steel forgings for general engineering purposes - Part 2: Non-alloy quality and special steels*

EN 10250-4:1999, *Open die steel forgings for general engineering purposes - Part 4: Stainless steels*

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EN 10272:2007, *Stainless steel bars for pressure purposes*

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EN 10305-4:2011, *Steel tubes for precision applications - Technical delivery conditions - Part 4: Seamless cold drawn tubes for hydraulic and pneumatic power systems*

EN 10346:2009, *Continuously hot-dip coated steel flat products - Technical delivery conditions*

EN 12164:2011, *Copper and copper alloys - Rod for free machining purposes*

EN 12165:2011, *Copper and copper alloys - Wrought and unwrought forging stock*

EN 12186:2014, *Gas supply systems — Gas pressure regulating stations for transmission and distribution — Functional requirements*

EN 12279:2000, *Gas supply systems - Gas pressure regulating installations on service lines - Functional requirements*

EN 12516-1:2014, *Industrial valves — Shell design strength — Part 1: Tabulation method for steel valve shells*

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EN 61000-4-29:2000, *Electromagnetic compatibility (EMC) - Part 4-29: Testing and measurement techniques - Voltage dips, short interruptions and voltage variations on d.c. input power port immunity tests (IEC 61000-4-29:2000)*

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[1] To be published.

EN 61508-2:2010, *Functional safety of electrical/electronic/programmable electronic safety-related systems - Part 2: Requirements for electrical/electronic/programmable electronic safety-related systems (IEC 61508-2:2010)*

EN 61508-3:2010, *Functional safety of electrical/electronic/programmable electronic safety-related systems - Part 3: Software requirements (IEC 61508-3:2010)*

EN 61508-4:2010, *Functional safety of electrical/electronic/programmable electronic safety-related systems - Part 4: Definitions and abbreviations (IEC 61508-4:2010)*

EN 61508-6:2010, *Functional safety of electrical/electronic/programmable electronic safety-related systems - Part 6: Guidelines on the application of IEC 61508-2 and IEC 61508-3 (IEC 61508-6:2010)*

EN 61508-7:2010, *Functional safety of electrical/electronic/programmable electronic safety-related systems - Part 7: Overview of techniques and measures (IEC 61508-7:2010)*

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EN 61810-1:2008, *Electromechanical elementary relays - Part 1: General requirements (IEC 61810-1:2008)*

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EN ISO 3506-2:2009, *Mechanical properties of corrosion-resistant stainless steel fasteners - Part 2: Nuts (ISO 3506-2:2009)*

EN ISO 3506-3:2009, *Mechanical properties of corrosion-resistant stainless steel fasteners - Part 3: Set screws and similar fasteners not under tensile stress (ISO 3506-3:2009)*

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EN ISO 9606-4:1999, *Approval testing of welders - Fusion welding - Part 4: Nickel and nickel alloys (ISO 9606-4:1999)*

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EN ISO 15607:2003, *Specification and qualification of welding procedures for metallic materials - General rules (ISO 15607:2003)*

EN ISO 15609-1:2004, *Specification and qualification of welding procedures for metallic materials - Welding procedure specification - Part 1: Arc welding (ISO 15609-1:2004)*

EN ISO 15610:2003, *Specification and qualification of welding procedures for metallic materials - Qualification based on tested welding consumables (ISO 15610:2003)*

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ISO 1083:2004, *Spheroidal graphite cast irons - Classification*

ISO 1817:2011, *Rubber, vulcanized or thermoplastic — Determination of the effect of liquids*

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ISO 7637-3:2007, *Road vehicles — Electrical disturbances from conduction and coupling — Part 3: Electrical transient transmission by capacitive and inductive coupling via lines other than supply lines*

ISO 23529:2010, *Rubber — General procedures for preparing and conditioning test pieces for physical test methods*

API SPEC 5L:2012, *Specification for Line Pipe*

ASTM A 106/A 106 M:2013, *Standard Specification for Seamless Carbon Steel Pipe for High-Temperature Service*

ASTM A 193/A 193M:2013, *Standard Specification for Alloy-Steel and Stainless Steel Bolting Materials for High Temperature or High Pressure Service and Other Special Purpose Applications*

ASTM A 194/A 194M:2013, *Standard Specification for Carbon and Alloy Steel Nuts for Bolts for High Pressure or High Temperature Service, or Both*

ASTM A 213/A 213M:2014, *Standard Specification for Seamless Ferritic and Austenitic Alloy-Steel Boiler, Superheater, and Heat-Exchanger Tubes*

ASTM A 269:2013, *Standard Specification for Seamless and Welded Austenitic Stainless Steel Tubing for General Service*

ASTM A 312/A 312 M:2014, *Standard Specification for Seamless, Welded, and Heavily Cold Worked Austenitic Stainless Steel Pipes*

ASTM A 320/A 320M:2011, *Standard Specification for Alloy-Steel and Stainless Steel Bolting for Low-Temperature Service*

ASTM A 333/A 333M:2013, *Standard Specification for Seamless and Welded Steel Pipe for Low-Temperature Service*

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ASTM A 420/A 420M:2013, *Standard Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Low-Temperature Service*

ASTM A 536:1984, *Standard Specification for Ductile Iron Castings*

ASTM A 874/A 874M:1998, *Standard Specification for Ferritic Ductile Iron Castings Suitable for Low-Temperature Service*

ASTM B 85/B 85M:2013, *Standard Specification for Aluminum-Alloy Die Castings*

ASTM B 283/B 283M:2014, *Standard Specification for Copper and Copper-Alloy Die Forgings (Hot-Pressed)*

ASTM B 584:2013, *Standard Specification for Copper Alloy Sand Castings for General Applications*

ASTM F 593:2013, *Standard Specification for Stainless Steel Bolts, Hex Cap Screws, and Studs*

ASTM F 594:2009, *Standard Specification for Stainless Steel Nuts*

MSS SP-55:2011, *Quality Standard for Steel Castings for Valves, Flanges, Fittings, and Other Piping Components — Visual Method for Evaluation of Surface Irregularities (ANSI-approved American National Standard)*

SAE J429:2014, *Mechanical and Material Requirements for Externally Threaded Fasteners*

SAE J995:2012, *Mechanical and Material Requirements for Steel Nuts*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
control
device which provides functionality as specified in the specific control standard

3.2
control function
function providing safe operation of burners and appliances burning gaseous or liquid fuels

3.3
closure member
movable part of the control which shuts off the gas flow

3.4
breather hole
orifice which allows atmospheric pressure to be maintained within a compartment of variable volume

3.5
external leak-tightness
leak-tightness of a gas-carrying compartment with respect to atmosphere

3.6
internal leak-tightness
leak-tightness of the closure member (in the closed position) sealing a gas-carrying compartment with respect to another compartment or to the outlet of the control

3.7
inlet pressure
pressure at the inlet of the control

3.8
outlet pressure
pressure at the outlet of the control

3.9
pressure difference
difference between the inlet and outlet pressures

3.10
maximum inlet pressure
highest inlet pressure as stated in the installation and operating instructions at which the control can be operated

Note 1 to entry: The Definition of *"maximum inlet pressure"* in this document corresponds to the definition of *"maximum allowable pressure"* in the PED.

3.11
minimum inlet pressure
lowest inlet pressure as stated in the installation and operating instructions at which the control can be operated

3.12
flow rate
volume flowing through the control in unit time

3.13
rated flow rate
air flow rate at a specified pressure difference, corrected to standard conditions

3.14
maximum ambient temperature
highest temperature of the surrounding air as stated in the installation and operating instructions at which the control can be operated

3.15
minimum ambient temperature
lowest temperature of the surrounding air as stated in the installation and operating instructions at which the control can be operated

3.16
mounting position
position as stated in the installation and operating instructions for mounting the control

3.17
nominal size
DN
numerical designation of size, for reference purposes

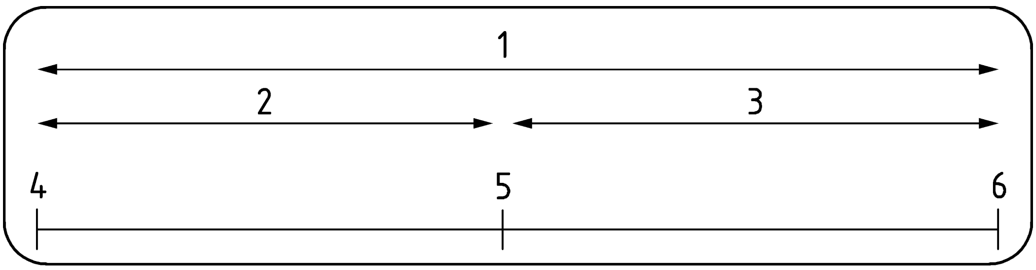
3.18
apparatus
single piece of equipment with (a) direct function(s) intended for final use

3.19
system
combination of apparatus and/or active components constituting a single functional unit and intended to be installed and operated to perform (a) specific task(s)

3.20
fault tolerating time
time between the occurrence of a fault and the shutdown of the burner, which is tolerated by the application without creating a hazardous situation

Note 1 to entry: Actions other than shutdown of a burner are possible if they can show prevention of hazardous situations.

Note 2 to entry: For illustration see Figure 2.



Key

1 fault tolerating time
2 fault detection time
3 max. fault reaction time
4 fault occurs
5 fault flagged
6 shutdown

Figure 2 — Fault tolerating time

3.21
fault reaction time
time for a control function, within the fault tolerating time, to react on a fault and initiate a shutdown

3.22
normal operation
use of the control or its associated equipment for the purpose for which it was made and in the intended manner under the conditions as specified

3.23
safety shutdown
process which is effected immediately following the response of a protection device or the detection of a fault in the control system and assumes a state in which the output terminals ensure a safe situation

3.24
reset
action releasing the control from lock-out

3.25
lock-out
safety-shutdown condition of the system, where a release from this condition can be accomplished by a reset

3.26
failure
termination of the ability of an item to perform a required function

[SOURCE: IEC 60050-191:1990, 191-04-01]

3.27
degradation
undesired departure in the operational performance of any device, equipment or system from its intended performance

Note 1 to entry: The term “degradation” can apply to temporary or permanent failure.

[SOURCE: IEC 60050-161:1990, 161-01-19]

3.28
fault
state of an item characterized by its inability to perform a required function, excluding the inability during preventive maintenance or other planned actions, or due to lack of external resources

Note 1 to entry: “Failure” is an event, as distinguished from “fault”, which is a state.

Note 2 to entry: After failure the item has a fault.

Note 3 to entry: This concept as defined does not apply to items consisting of software only.

Note 4 to entry: A fault is often the result of a failure of the item itself, but can exist without prior failure.

[SOURCE: IEC 60191-1:2007, 191-05-01]

3.29
harm
physical injury and/or damage to health or property

[SOURCE: ISO/IEC Guide 51:1999]

3.30
hazard
potential source of harm

[SOURCE: ISO/IEC Guide 51:1999]

3.31
risk
probable rate of occurrence of a hazard causing harm and the degree of severity of the harm

[SOURCE: ISO/IEC Guide 51:1999]

3.32
functional safety
safety related to the application which depends on the correct functioning of the safety-related control

[SOURCE: prEN 60730-1:2013, H.2.23.13]

3.33
program
sequence of control operations

Note 1 to entry: It can consist of switching on, starting up, supervising and switching off, safety shutdown or lock out.

3.34
presetting device
device for adjusting an intended operating condition

3.35
reset function
function that provides reset from lock-out allowing the system to attempt a restart

Note 1 to entry: The reset function can be performed by various electric/electronic (mobile) devices.

3.36
rated voltage
voltage as stated in the installation and operating instructions at which the control can be operated

3.37
rated current
current as stated in the installation and operating instructions at which the control can be operated

3.38
jointing compound
sealing material between two pipes or tubes that are to be joined

3.39
union joint
connection of pipe with union head having a male screw thread and a pipe by means of a union tail piece and a union nut

3.40
common cause failure
failures of different items, resulting from a single event, where these failures are not consequences of each other

Note 1 to entry: Common cause failures should not be confused with common mode failures.

[SOURCE: IEV 191-04-23]

3.41
non-permanent operation
operation in the running position for less than 24 h

3.42
permanent operation
operation in the running position for more than 24 h

3.43
terms and definitions for a Method to determine safety integrity level (SIL)
see J.3

3.44
terms and definitions for a Method to determine performance level (PL)
see K.3

3.45
terms and definitions for seals of elastomer, cork and synthetic fibre mixtures
see O.3

4 Classification

4.1 Classes of control

For classification of controls, see the specific control standard.

4.2 Groups of control

Controls are grouped according to the bending stresses which they are required to withstand (see Table 4).

Group 1 controls

— Controls with connection sizes up to and including DN 20, for use in an appliance where they are not subjected to bending stresses imposed by installation pipe work or in an installation if used with rigid adjacent supports.

Group 2 controls

— Controls for use in any situation, either internal or external to the appliance, typically without support.

NOTE Controls which meet the requirements of a Group 2 control also meet the requirements of a Group 1 control.

4.3 Classes of control functions

For the evaluation of protective measures for fault tolerance and avoidance of hazards it is necessary to classify control functions with regard to their fault behaviour.

At the classification of control functions their integration into the complete safety concept of the appliance shall be taken into account.

For the purpose of evaluating the design of a control function, present requirements recognize three distinct classes:

Class A: Control functions which are not intended to be relied upon for the safety of the application.

NOTE 1 Examples are: room thermostats, temperature control.

Class B: Control functions which are intended to prevent an unsafe state of the appliance. Failure of the control function will not lead directly to a hazardous situation.

NOTE 2 Examples are: thermal limiter, pressure limiter.

Class C: Control functions which are intended to prevent special hazards such as explosion or whose failure could directly cause a hazard in the appliance.

NOTE 3 Examples are: burner control systems, thermal cut-outs for closed water systems (without vent protection).

4.4 Types of *DC* supplied controls

DC supplied controls according to Annex I will fall into one of the three following types:

Type A: Stand-alone battery systems;

Type B: Battery systems for mobile applications;

Type C: Systems which are intended to be connected to *DC* supply networks.

5 Test conditions and uncertainty of measurements

5.1 Test conditions

Except where otherwise stated, the tests shall be carried out

— with air at (20 ± 5) °C,

— at ambient temperature (20 ± 5) °C.

All measured values shall be corrected to standard conditions:

15 °C, 101,325 kPa (1 013,25 mbar) dry.

Controls which can be converted to another gas type by exchanging components are additionally tested with the conversion components.

Tests shall be carried out in the mounting position as stated in the installation and operating instructions. Where there are several mounting positions, tests shall be carried out in the least favourable position. Where possible those tests already covered by other standards (e.g. by relevant parts of prEN 60730-1:2013) shall be combined.

All measurements shall be made after stable conditions have been reached.

5.2 Uncertainty of measurements

Except where otherwise stated in the particular clauses, measurements shall be carried out with the maximum uncertainties indicated below:

— Absolute pressures ± 500 Pa or ± 4 %, whichever is greater;

— Relative pressures ± 50 Pa or ± 2 % of the measured value, whichever is greater (e.g. gauge pressures or differential pressures);

— Flow rate ± 3 % of the measured value;

— Leakage rate ± 10 cm^3/h (The apparatus shown schematically in Annex C or another device giving equivalent results is used.);

— Time ± 0,1 % or ± 0,2 s, whichever is greater;

— Temperatures ± 1 K;

— Torque ± 10 %;

— Force ± 10 %;

— Current ± 1 %;

— Voltage ± 1 %;

— Electrical Power ± 2 %;

— Supply frequency ± 0,1 Hz.

The full range of the measuring apparatus is chosen to be suitable for maximum anticipated value.

The measurement uncertainties as listed above concern individual measurements. For measurements requiring a combination of individual measurements (e.g. efficiency measurements), lower uncertainties for the individual measurements can be necessary to limit the total uncertainty.

6 Design and construction

6.1 General

Controls shall be designed, so that the various functions operate correctly when installed and used as stated in the installation and operating instructions.

Mechanical controls shall be designed such that access to internal parts requires the use of tools. For other controls access to internal parts shall only be possible by the use of tools. All pressurized parts of a control shall withstand the mechanical and thermal stresses to which it is subjected without any deformation affecting safety.

Safety accessories and pressure accessories with a product of the maximum allowable pressure PS and the volume V of less than 600 000 kPa × dm^3 (6 000 bar × l) or with a product of PS and DN of less than 300 000 kPa (3 000 bar) shall conform to the requirements in Annex F, Annex G and Annex H.

If a control system consists of one apparatus and provides two or more different control functions, the system shall provide the same overall safety level as the independent control functions provide for the complete application.

Any interference between individual control functions shall be assessed with respect to both the functional condition and any fault conditions.

Failures in any function shall not affect safe operation of the control function. Each individual function shall be assessed in accordance with the requirements of this standard.

Control functions, integrated into a multifunctional system, shall be able to withstand the same long-term performance requirements as required for independent controls.

Compliance to these requirements is covered by the tests given in Clause 6, Clause 7, Clause 8 and Clause 9

6.2 Mechanical parts of the control

6.2.1 Appearance

Controls shall be free from sharp edges and corners which could cause damage, injury or incorrect operation.

6.2.2 Holes

Holes for screws, pins, etc., used for the assembly of parts of the control or for mounting, shall not penetrate gas ways. The wall thickness between these holes and gas ways shall be at least 1 mm.

Holes necessary for manufacture which connect gas ways to atmosphere but which do not affect the operation of the control shall be permanently sealed by metallic means.

NOTE Suitable jointing compounds can additionally be used.

6.2.3 Breather holes

6.2.3.1 Requirements

Breather holes in controls with diaphragms, which are not provided with a connection for a vent pipe, shall be designed in such a way that when the diaphragm is damaged, air does not escape at a rate of more than 70 dm^3/h at the maximum inlet pressure.

Conformity shall be verified by the method given in 6.2.3.2

If a leakage rate limiter is used, it shall be able to withstand 3 times the maximum inlet pressure. If a safety diaphragm is used as a leakage rate limiter, it shall not take the place of the working diaphragm if there is a fault.

Breather holes shall be protected against blockage or they shall be located such that they do not easily become blocked. They shall be positioned in such a way that the diaphragm cannot be damaged by a sharp device inserted through the breather hole.

6.2.3.2 Test for leakage of breather holes

Rupture the dynamic part of the working diaphragm. Ensure all closure members of the control, if any, are in the open position. Pressurize all gas-carrying compartments to the maximum inlet pressure and measure the leakage rate.

6.2.4 Screwed fastenings

Screwed fastenings which can be removed for service or adjustment shall have metric threads that conform to ISO 262:1998 unless a different thread is essential for the correct operation or adjustment of the control.

Self-tapping screws which cut a thread and produce swarf that can fall into the gas carrying compartment shall not be used.

Self-tapping screws which form a thread and do not produce swarf can be used provided that they can be replaced by metric machine screws conforming to ISO 262:1998, e.g. for service purposes.

6.2.5 Jointing

Jointing compounds for permanent assemblies shall provide a leak-tight connection under normal (intended/specified/designated) operating conditions. Sealing materials for metallic threaded joints in contact with gas shall conform to EN 751-1:1996, EN 751-2:1996 or EN 751-3:1996. For other sealing materials for metallic threaded joints, not covered by EN 751 (all parts), evidence shall be provided in the technical documentation that this material is suitable for its application.

Soldering or other processes where the jointing material has a melting point below 450 °C after application shall not be used for connecting gas-carrying parts except for additional sealing.

6.2.6 Moving parts

The operation of moving parts (e.g. diaphragms, bellows) shall not be impaired by other parts. There shall be no exposed moving parts which could adversely affect the operation of controls.

6.2.7 Sealing caps

Sealing caps shall be capable of being removed and replaced with commonly available tools and sealed (e.g. by lacquer). A sealing cap shall not hinder adjustment within the whole range as stated in the installation and operating instructions.

6.2.8 Dismantling and reassembly

Parts which need to be dismantled for service or adjustment shall be capable of being dismantled and reassembled using commonly available tools. They shall be constructed or marked in such a way that incorrect assembly is impossible when following the installation and operating instructions.

Closure parts, including those of measuring and test points, which can be dismantled for service or adjustment shall be constructed such that leak-tightness is achieved by mechanical means (e.g. metal-to-metal joints or O-rings) without using jointing compounds such as liquids, pastes or tapes.

Closure parts not intended to be dismantled shall be sealed by means which will show evidence of interference (e.g. lacquer).

6.2.9 Auxiliary canals and orifices

Blockage of auxiliary canals and orifices used for safe functioning shall not lead to a situation where the specific control comes in an unsafe operating condition, otherwise they shall be protected against blockage.

6.2.10 Presetting device

A presetting device shall only be adjustable by use of a tool. The means of adjustment shall be easily accessible and shall not change of its own accord. Interference with the means of adjustment other than authorized in the installation and operating instructions shall be visible e.g. use of a sealing (lacquer).

A presetting device that connects a gas-carrying part to atmosphere shall be made sound by a means which shall not seal on the thread of the presetting means, e.g. use of an O-ring seal.

The presetting device shall not be able to fall off. If an O-ring or equivalent gasket provides a seal against the atmosphere, then when the presetting device is completely unscrewed it shall not be able to be pushed out by gas pressure and shall remain tight at the maximum inlet pressure.

If a presetting device is used for different gas families it shall have a fixed minimum orifice. A cover of any presetting device shall require a tool for removal and replacement and it shall not interfere with other settings.

NOTE Example of presetting devices are flow rate adjusters.

6.3 Materials

6.3.1 General material requirements

The quality of materials, the dimensions used and the method of assembling the various parts shall be such that construction and performance characteristics are safe. Performance characteristics shall not alter significantly during a reasonable lifetime when installed and used as stated in the installation and operating instructions. Under these circumstances, all components shall withstand any mechanical, chemical, and thermal conditions to which they can be subjected during service.

6.3.2 Housing

6.3.2.1 Requirements

Parts of the housing which directly or indirectly separate a gas-carrying compartment from atmosphere shall be made from metallic materials that:

a) have a melting point (solidus temperature) of at least 427 °C, or

b) conform to 6.3.3.

For housings according a), the external leakage after removal or fracture of non-metallic parts other than O-rings, gaskets and sealing parts of diaphragms, should be no more than 30 dm^3/h of air escapes at the maximum inlet pressure, when tested according to 6.3.2.2.

NOTE When inside the housing a diaphragm separates the gas-carrying compartment from atmosphere than this is considered to be indirectly separated.

6.3.2.2 Test

Remove all non-metallic parts of the housing which separate a gas-carrying compartment from atmosphere, excluding O-rings, gaskets and sealing part of diaphragms. Any breather holes shall be blocked. Pressurize the inlet and outlet(s) of the control to the maximum inlet pressure and measure the leakage rate.

6.3.3 Zinc alloys

6.3.3.1 Requirements

Zinc alloys (ZnAl4) for gas carrying parts shall conform to the following:

— DN size shall be ≤ DN 50;

— The maximum inlet pressure shall be ≤ 20 kPa (200 mbar);

— The maximum ambient temperature shall be 80 °C;

— Quality of ZnAl4 shall conform to ISO 301:2006;

with the following restriction:

Where zinc alloy parts are used in the part upstream of the closure member of automatic shut-off valves (stand-alone or as part of a multifunctional control) which are in contact with gas, this housing upstream of the closure member, including the inlet connection, shall conform to 6.3.2.1 a) and upon removal of those Zinc Alloy parts in the housing upstream of the closure member, the external leakage rate shall be less than 30 dm^3/h at maximum inlet pressure when measured according to 6.3.3.2. If the housing of the automatic shut-off valve contains, in addition to zinc alloy parts upstream of the closure member, also non-metallic parts in contact with gas, these parts shall also be removed for this test.

Parts made of Zinc alloy can be used inside the housing of the gas control.

6.3.3.2 Test

Remove all non-metallic parts and zinc alloy parts of the housing upstream of the closure member which separate a gas-carrying compartment from atmosphere, excluding O-rings, gaskets and sealing part of diaphragms. Any breather holes shall be blocked.

Pressurize the inlet and the outlet of the control to the maximum inlet pressure and measure the leakage rate.

6.3.4 Springs

Closing force and sealing force shall be provided by spring action.

Springs providing the sealing and/or closing force for any closure member of the control shall be made of corrosion-resistant materials and shall be designed for static and dynamic loading according to EN 13906-1:2013 or EN 13906-2:2013.

Springs with wire diameter up to and including 2,5 mm shall be made from corrosion-resistant materials.

Springs with wire diameter above 2,5 mm shall either be made from corrosion-resistant materials or shall be protected against corrosion.

6.3.5 Resistance to corrosion and surface protection

All parts in contact with gas or atmosphere and springs other than those covered by 6.3.4, shall either be made from corrosion-resistant materials or shall be suitably protected. The corrosion protection for springs and other moving parts shall not be impaired by any movement.

6.3.6 Impregnation

Where impregnation is part of the manufacturing process, it shall be carried out using an appropriate procedure (e.g. vacuum or internal pressure, using appropriate sealing materials).

6.3.7 Seals for glands for moving parts

Seals for moving parts which pass through the body to atmosphere and seals for closure members shall be made only of solid, mechanically stable material of a type which does not deform permanently. Sealing paste shall not be used.

Manually adjustable packing glands shall not be used for sealing moving parts.

NOTE Adjusted glands protected against further adjustment are considered to be non-adjustable.

Bellows shall not be used as the sole sealing element against atmosphere.

6.4 Gas Connections

6.4.1 Making connections

It shall be possible to make all gas connections using commonly available tools, e.g. by the provision of suitable spanner flats.

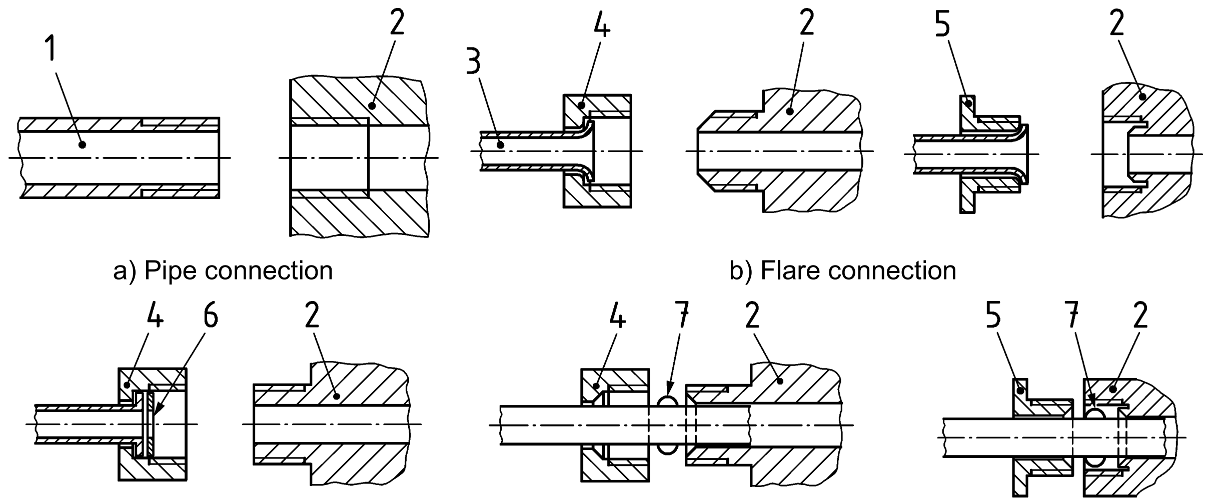
6.4.2 Connection sizes

Equivalent connection sizes are given in Table 1 and Table 2.

Table 1 — Gas connection sizes for Group 1

External thread pipe size or internal thread size flange / control	**Nominal size**	**For compression fittings, fiber seal and flare connections** [a)]					
		compression fitting		fiber seal connection		Flare connection	
	DN	union / tubing nut	tube size ≤	union nut	tube size ≤	union / tubing nut	tube size ≤
inch		Spanner size mm	mm	Spanner size mm	mm	Spanner size mm	mm
1/8	6	13	**6**	13	**6**	13	**6**
1/4	8	16	**8**	16	**8**	16	**8**
3/8	10	19	**12**	19	**12**	19	**12**
1/2	15	24	**16**	24	**16**	24	**16**
3/4	20	32	**22**	32	**22**	32	**22**
1	25	39	**28**	39	**28**	39	**28**

[a)] For illustration refer to Figure 3.



a) Pipe connection

b) Flare connection

c) Fibre seal connection

d) Compression fitting

Key

1 pipe

2 control

3 tube

4 union nut

5 tubing nut

6 fibre seal

7 olive

Figure 3 — Types of connections

Table 2 — Gas connection sizes for Group 2

Thread or flange nominal size DN	**Thread or flange designation** Inches	**Compression fitting tube outside diameter range** mm
6	1/8	2 to 5
8	1/4	6 to 8
10	3/8	10 to 12
15	1/2	14 to 16
20	3/4	18 to 22
25	1	25 to 28
32	1 1/4	30 to 32
40	1 1/2	35 to 40
50	2	42 to 50
65	2 1/2	–
80	3	–
100	4	–
125	5	–
150	6	–
200	8	–
250	10	–

Controls above DN 80 shall be flanged according to EN 1092-1:2007+A1:2013, EN 1092-2:1997, EN 1092-3:2003, EN 1092-4:2002, EN 1759-1:2004, EN 1759-3:2003 and EN 1759-4:2003.

6.4.3 Threads

Inlet and outlet threads shall be according to EN 10226-1:2004, EN 10226-2:2005 or to EN ISO 228-1:2003 and shall be chosen from the series given in Table 1 and Table 2.

6.4.4 Union joints

Where connections are made with union joints either the joints shall be included with the control or full details shall be supplied if the threads do not conform to EN 10226-2:2005 or EN ISO 228-1:2003.

6.4.5 Flanges

Where flanges are used on controls, they shall be suitable for connection to flanges according to EN 1092-1:2007+A1:2013, EN 1092-2:1997, EN 1092-3:2003, EN 1092-4:2002, EN 1759-1:2004, EN 1759-3:2003 and EN 1759-4:2003., PN 6 or PN 16. Alternatively suitable adapters shall be supplied to enable connection to these flanges or to threads according to 6.4.3, or full details of mating parts shall be supplied.

Alternatively it is recommended to use suitable adapters to enable connection to these flanges or to threads according to 6.4.3, or full details of mating parts should be supplied.

NOTE EN 1092–1:2007+A1:2013 has a different flange hole arrangement for DN 65 with PN 16. The 4-hole arrangement of the previous edition has changed into an 8-hole arrangement.

6.4.6 Compression fittings

If compression fittings are used, it shall not be necessary to form the tubes before making connections. Olives shall be appropriate to the tubes for which they are intended. Non-symmetrical olives can be used provided they cannot be fitted incorrectly.

6.4.7 Nipples for pressure test

Pressure test nipples shall have an external diameter of $9^{\,0}_{-0,5}$ mm and a useful length of at least 10 mm for connection to tubing. The equivalent diameter of the bore shall not exceed 1 mm.

6.4.8 Strainers

Where an inlet strainer is fitted the maximum strainer hole dimension shall not exceed 1,5 mm and it shall prevent the passage of a 1 mm diameter pin gauge. Strainers fitted to controls of DN 25 and above shall be accessible for cleaning or replacement without the need to remove the control body by dismantling threaded or welded pipe work.

Where an inlet strainer is not fitted, the installation and operating instructions shall include relevant information on the use and installation of a strainer conforming to the requirements of this subclause, to prevent the ingress of foreign matter.

6.5 Electrical parts of the control

6.5.1 General

The electrical components shall be designed for their intended use.

The quality of the materials, the design, and structure of the components used shall be such that the control will operate safely and in accordance with the requirements of this standard for a reasonable life time. That shall continue under the mechanical, chemical, thermal and environmental conditions normally expected, even in the event of such carelessness as can occur in normal use. This is provided that compliance with the installation and operating instructions is ensured. Compliance is checked by carrying out the tests specified in this standard.

The control shall be designed such that changes in critical circuit component values (such as those affecting timing or sequence) within the worst case specifications of the components, including the long-term stability, shall result in the control continuing to function in accordance with this standard. Compliance shall be checked by worst case analysis.

6.5.2 Switching elements

6.5.2.1 Requirements

For Class C control functions the control shall include at least two switching elements to directly de-energize the safety related output terminals to ensure a safe situation under all circumstances.

NOTE A single relay switching two independent contacts is considered to be only one switching element.

Measures shall be taken to protect against failure of two (or more) switching elements, due to a common cause, by an external short circuit that would prevent the control from performing a safety shutdown.

Acceptable methods are current limitation, overcurrent protection device or internal fault detecting functions.

When tested according to 6.5.2.2 either

— the capability to interrupt the energization of the safety related output terminals by means of at least one switching element shall be maintained

or

— a non-replaceable overcurrent protection device shall have interrupted.

6.5.2.2 Test of protecting measures against failure of switching elements

The safety related output terminals of the control are connected to a switch that is intended to switch the short circuit current. With this switch opened, the control is connected as described in prEN 60730-1:2013, H.27.1.1.2 with the outputs energized to simulate normal operation (contacts of the internal switching elements closed).

Where overcurrent protection devices are used as the protective measure the power supply to the control shall have the capability of supplying an inrush current of at least 500 A. Where current limitation techniques are used the power supply to the control shall not limit the current.

A short-circuit is applied between output terminals of the control by closing the switch.

The test is terminated if there is no current flow through the switch, or after 1 h.

If an overcurrent protection device is replaceable and operated during the test it shall be replaced and the test is repeated two more times by attempting to restart the control keeping the switch closed.

A second test procedure is conducted in the same way, with the switch closed prior to the first start-up sequence; a second test sample can be used for this second test procedure.

If an internal fault detecting function of the control either opens the switching elements or initiates a safety shutdown the test is repeated 2 times while maintaining the external short circuit by attempting to restart the control.

Compliance is checked in accordance with prEN 60730-1:2013, H.27.1.1.3 and Clause 15.

After the test at least one switching element of the control shall be able to de-energize the safety related output terminals, or a non-replaceable overcurrent protection device permanently interrupted the supply to the safety related output terminals.

Designs where at least two relays are used as switching elements with independent contacts and in series with a non-replaceable fuse (see Table E.1, h) with $I_N < 0,6 * I_e$, are considered to conform to the requirements for prevention of common cause failure, without further testing.

NOTE I_N: values for the fuse (see EN 60127–1:2006, 3.16).

I_e: rated operational current of the contact (see EN 60947–1:2007, 4.3.2.3).

6.5.3 Electrical components

6.5.3.1 Performance of electrical components

The electrical components shall be designed for their intended use.

Components shall be dimensioned on the basis of the worst-case conditions which can arise in the control.

6.5.3.2 Tests

An examination of the circuit shall be carried out in accordance with the requirements of 6.6 and Annex E.

6.5.3.3 Sensing element

Sensing elements shall remain suitable and reliable during the product's lifetime with respect to its intended purpose (e.g. the surface of a temperature sensing element shall remain suitable and reliable during the product's lifetime with respect to heat transfer).

Interchange of wiring and changing of polarity of wiring shall be prevented unless the effect is controlled and does not lead to a hazard. Connectors with a polarity key are considered to be a preventative measure.

The physical value as detected by the sensing element shall not be influenced significantly by the measurement method compared to the declared deviation in accordance with the specific control standard.

6.5.3.4 Gas controls employing electrical components in the gas way

6.5.3.4.1 Requirements

Gas controls employing electrical components in the gas way shall either meet the leakage requirements of 7.2 after the test of 6.5.3.4.2 or shall not represent an ignition source if tested according to 6.5.3.4.3.

NOTE The use of open electricity in the gas way of a gas controls represents a risk of explosion in case an explosive gas/air mixture is present in the gas way. Such a mixture can be the result of air diffusing into the gas way of the control.

6.5.3.4.2 Test by ignition trial

Ignition test shall be performed by ignition trial from those points where un-insulated electrical parts are in contact with gas, which might require a special preparation of the test sample.

The ignition test shall be done by making use of a sparking transformer with spark energy of at least 10 µAs.

Straight piping of 1,5 m shall be attached to both the inlet and outlet connections of the sample with a manual valve attached to each end of the straight piping. Piping diameter shall be equal to valve connections.

Test sequence:

- The test sample shall be activated to open position, if applicable.
- The two manual valves shall be opened.
- A gas-air test mixture comprised of 5 % propane and 95 % air (by volume) shall be introduced into the inlet end of the piping system.
- When a sufficient volume of the test mixture has been introduced to ensure a uniform distribution of the test mixture throughout the piping system and the gas way of the test sample, the inlet manual valve shall be closed.
- The outlet manual valve shall be closed immediately thereafter.
- The test sample shall remain opened, if applicable and the sparking transformer activated ensuring that there is sparking on the ignition electrodes.
- After ignition of the gas-air test mixture or if no ignition occurs after 10 seconds of sparking, the test is repeated with the test sample closed if applicable.

In addition for controls with a closure member the following test shall be performed:

- After refilling the piping system and the gas way of the test sample with the test mixture, the inlet manual valve shall be closed, and immediately thereafter the test sample shall be closed.
- The outlet manual valve shall remain opened and the gas-air test mixture ignited.

These two tests shall be performed 3 times on each of two test samples. If no ignition could be accomplished, the requirements are met.

If ignition could be accomplished, test samples that are operable shall be cycled 5 times.

After that all test samples, whether operable or not, shall be tested according the leakage tests of 7.2.2.

6.5.3.4.3 Test of ignition source

The electrical components in the gas way shall be analysed with regard to EN 1127-1:2011 as possible ignition sources in relation to the relevant gas compartment. For the assessment Class B according to 6.6.3 shall be applicable.

NOTE For electrical components representing an ignition source measures for avoidance by proper design or protective measures are specified in EN 1127–1:2011.

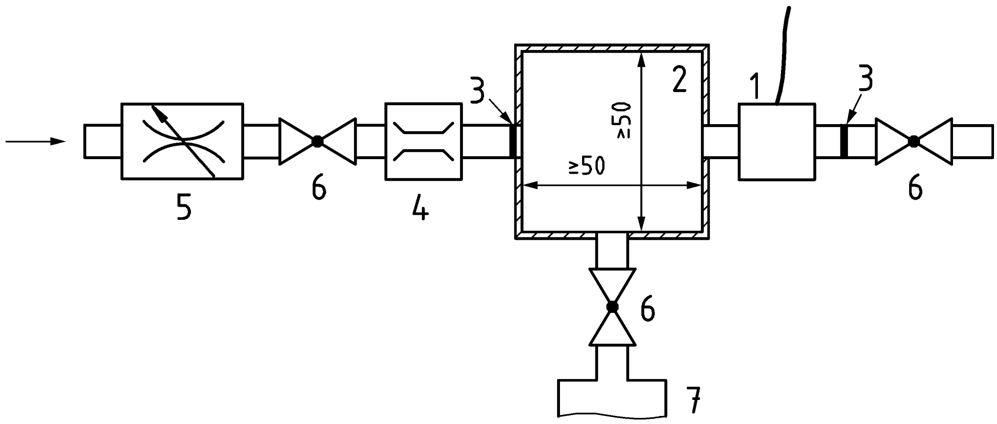
The experimental test setup is shown in Figure 4.The test chamber for explosion testing of the gas controls shall have a minimum volume of at least 1 dm^3 and shall withstand by choice of proper materials and design the changes of pressure and temperature during testing. The distance of opposite test chamber walls shall be at least 50 mm to avoid wall effects and to ensure in case of ignition, a proper ignition of the whole internal volume with the test gas.

— The test gas shall consist of a mixture of 5,2 ± 0,5 Vol.-%.propane and 94,8∓0,5 Vol.-% air.

— The absolute pressure inside the test chamber shall be 101 kPa ± 10 %.

— The gas temperature inside the test chamber shall be at least 20 °C.

The gas control shall be adapted to the test chamber, the tapering of the cross section of the connection to the test chamber shall be kept minimal. Alternatively that part of the control that might be a possible ignition source is placed inside the test chamber. During the testing the test chamber and the adapted gas control (if applicable) shall be gas tight. In case of a continuous flow the test gas shall pass the gas control, or the test chamber and an appropriate flame retarding device at the exit. The test gas composition shall be ensured by measuring the gas concentration at the exit port of the test chamber. Inadmissible pressure increases in case of continuous flow mode and an ignition shall be avoided by use of burst discs or comparable means. The pressure relief of the burned gases and the exhaust gas of the test chamber shall be handled safely.



Key

1	test sample	5	restrictor
2	test chamber	6	valve
3	flame retarding device	7	burst disc
4	flow meter		

Figure 4 — Experimental setup for ignition testing

For the ignition testing with regard to the probability of ignition the gas control shall be adapted to the test chamber as described by the manufacturer’s installation manual, which comprises the pneumatical and electrical connections, power and control lines. Alternatively that part of the control that might be a possible ignition source is placed inside the test chamber. Exposed to the test gas the gas control or the possible ignition source is operated such that each operating state is reached, but at least 10 times.

The control or the possible ignition source shall be operated under the following electrical conditions:

a) for AC supplied controls at the most unfavourable voltage in the range 85 % to 110 % of the rated supply voltage as stated in the installation and operating instructions (unfavourable in the sense of power input or a possible spark formation, e.g. in case of relay contacts);

b) for DC supplied controls within the scope of Annex I a tolerance of 20 % to the minimum and the maximum rated voltage applies. For DC supplies of other types the tolerance shall be stated in the installation and operating instructions;

c) if a heat up of any actuating member does occur equilibrium shall be achieved (hottest surface temperatures).

These tests shall be performed on each of two test samples. If no ignition is accomplished, the controls are not representing an ignition source and the requirements are met.

6.6 Protection against internal faults for the purpose of functional safety

6.6.1 Design and construction requirements

6.6.1.1 Fault avoidance and fault tolerance

6.6.1.1.1 General

Controls shall be designed in accordance with 6.6 (taking into account the fault modes of Annex E) and in accordance with prEN 60730-1:2013, H.11.12 for complex electronics being assemblies which use electronic components with the following characteristics:

a) The component provides more than one functional output.

b) It is impractical or impossible to represent the failure mode of such a component by stuck-at and cross-links at the pins or by other failure modes which are described in Annex E.

Components shall be dimensioned on the basis of the worst-case conditions which can arise in the control.

NOTE A component failure could cause a degradation of safety insulation. This is to be considered when making assessment against this clause.

Failures of complex electronics can be caused by either systematic errors (built into the design) or by random faults (component faults). Therefore, the control shall be designed in such a way that systematic errors are avoided and random faults shall be dealt with by a proper design.

6.6.1.1.2 Design

The design of the software and hardware shall be based on the functional analysis of the application resulting in a structured design explicitly incorporating the control flow, data flow and time related functions required by the application. In the case of custom-chips special attention is required with regard to measures taken to minimize systematic errors.

The result shall be a design configuration which is either inherently fail safe or in which components with direct safety-critical functions (e.g. shut-off valve drivers, microprocessors with their associated circuits, etc.) are guarded by safeguards (in accordance to prEN 60730-1:2013, Annex H, Software Class B or C). These safeguards shall be built into hardware (e.g. watch-dog, supply voltage supervision) and can be supplemented by software (e.g. ROM-test, RAM-test, etc.). It is important that these safeguards can cause a completely independent safety shutdown. Reaction times of these safeguards shall be equal or smaller than the relevant fault tolerating time.

If time slot monitoring is used, it shall be sensitive to both an upper and a lower limit of the time interval. Faults resulting in shift of the upper and/or lower limit shall be taken into account.

In case of a control that is classified as Class C, if a single fault in a primary safeguard can render the safeguard inoperative, a secondary safeguard shall be provided. The reaction time of the secondary safeguard shall be in accordance with 6.6.4.

NOTE The secondary safeguard can be realized by:

a) a physically separate circuit monitoring the primary safeguard; or

b) mutual action between the circuit being safeguarded and the primary safeguard (e.g. a watch-dog guarded by the microprocessor); or

c) action between primary safeguards (e.g. a ROM-test guarding a RAM-test).

6.6.1.2 Lock-out function

For lock-out function with a mechanical actuator a test up to, but not including the switching contacts, is sufficient. If the test of the lock-out function fails, the control shall proceed to safety shutdown. Frequency of test is given in the specific control standard. Internal faults on components of the checking circuit are not considered.

6.6.1.3 Reset device

The control shall be so constructed that a restart attempt following non-volatile lock-out shall only be possible following a manual reset, e.g. with an integrally or remotely mounted reset button.

Misuse or tampering with the reset device, whether integrally or remotely mounted (e.g. continuous pressing of the manual reset button or an internal fault of the reset device) or shorting of the connecting cables to the reset device, or between the connecting cables and earth, shall not cause the control to operate outside the requirements of this standard or prevent it from going to shutdown or lock-out.

Acceptable means for resetting from lock-out other than a reset button on the appliance shall be described in the specific control standard.

Detailed requirements are given in Annex M.

6.6.1.4 Documentation

The functional analysis of the control and the safety related programs under its control shall be documented, resulting in a specification of all functional requirements and of all safety requirements for the control.

The documentation shall be expressed and structured in such way that it is clear, precise, unambiguous, verifiable, testable, maintainable and feasible.

As a minimum the following design documentation shall be available:

a) a specification of functional requirements and of safety requirements including the following aspects:

   1) The requirements specification shall be expressed in natural or formal language and/or logic, sequence or cause and effect diagrams that define the necessary safety functions with each safety function being individually defined.

   2) The requirements specification shall be structured with a hierarchical separation into sub requirements; refined down to functional level.

3) The specification of safety requirements shall include a description of all safety-related control functions and their control function class.

4) The specification of safety requirements shall include appropriate requirements to consider

- the boundary of the appliance and possible hazards (from process, environment, etc.);
- operation, functions, interfaces, special safety regulations and environment of the appliance;
- all hazards or hazardous events of the appliance, and all potential hazards for the application arising from the control itself;
- safety requirements, safety-related control functions requirements and safety integrity requirements, dealing with the necessary constrains on the system architecture that ensure sufficient fault tolerance for the control.

5) The interfaces between safety-related control functions and non-safety-related control functions shall be well-defined. Safety-related control functions and non-safety-related control functions as well as safety-related control functions with different control function classes shall be implemented sufficiently independent, otherwise they shall be implemented with the highest class associated to a control function.

b) a specification of the system architecture including the following aspects:

1) Partitioning into modules / subsystems with a description of the modules / subsystems and a description of the interfaces between modules / subsystems.

2) The allocation of control functions to modules / subsystems.

c) a software documentation (for controls using software) in accordance with prEN 60730-1:2013, H.11.12.

There shall be a consistent relationship between the various parts of the documentation. It shall be possible to trace requirements from their definition to design / implementation and assessment / verification / validation.

6.6.2 Class A

Fault assessment is not applicable.

NOTE The requirements of electrical safety as described in Clause 8 are applicable.

6.6.3 Class B

6.6.3.1 Design and construction requirements

A Class B control function shall be designed such that under single fault conditions it complies with 6.6.3.2 and 6.6.3.3. A second independent fault is not considered. Software shall conform to software Class B of prEN 60730-1:2013.

Under the test conditions and criteria of 6.6.5, 6.6.3.2 and 6.6.3.3 are applicable.

6.6.3.2 First fault

Any first fault (see Annex E) in any one component or any one fault together with any other fault arising from that first fault shall result in either:

a) the control becoming inoperative with all safety related output terminals de-energized or assuming a status in which they ensure a safe situation;

b) the control reacting within the fault reaction time by proceeding to safety shutdown, or to lock-out, provided that subsequent reset from the lock-out condition under the same fault condition results in the control returning to the lock-out condition;

c) the control continuing to operate, the fault being identified during the next start-up sequence, the result being a) or b);

d) the control remaining operational in accordance with the safety related functional requirements of the specific control standard.

The specific control standard specifies the fault reaction time as well as the applicability of c).

6.6.3.3 Fault introduced during lock-out or safety- shutdown

Whenever the control is in lock-out or in safety shutdown without an internal fault, the following requirements shall apply.

Any first fault (together with any other fault arising from that fault) in any one component (see Annex E), induced while the control is staying in the safety shutdown or lock-out position, shall result in either:

a) The control remaining in safety shutdown or lock-out, safety related output terminals remaining de-energized;

b) the control becoming inoperative with all safety related output terminals remaining de-energized;

c) the control comes into operation again resulting in a) or b) as mentioned in this clause under the condition that the safety related output terminals are energized not longer than the fault reaction time. If the cause of the original safety shutdown or lock-out condition no longer remains and the control comes again in operation it shall operate in accordance with the safety related functional requirements of the specific control standard.

The specific control standard specifies the fault reaction time.

NOTE Safety related output terminals are terminals which are safety related even in the safety shutdown or lock-out position, e.g. shut-off valve terminal, but not a terminal for an actuator driving the controlling element of a gas air ratio control (see EN 12067–2:2004).

6.6.4 Class C

6.6.4.1 Design and construction requirements

A Class C control function shall be designed such that under first and second fault conditions it complies with 6.6.4.2, 6.6.4.3 and 6.6.4.4. A third independent fault is not considered.

Software shall conform to software Class C of prEN 60730-1:2013.

Under the test conditions and criteria of 6.6.5, 6.6.4.2, 6.6.4.3 and 6.6.4.4 are applicable.

6.6.4.2 First fault

Any first fault (see Annex E) in any one component or any one fault together with any other fault arising from that first fault shall result in either:

a) the control becoming inoperative with all safety related output terminals de-energized or assuming a status in which they ensure a safe situation;

b) the control reacting within the fault reaction time by proceeding to safety shutdown, or to lock-out, provided that subsequent reset from the lock-out condition under the same fault condition results in the control returning to the lock-out condition;

c) the control continuing to operate, the fault being identified during the next start-up sequence, the result being a) or b);

d) the control remaining operational in accordance with the safety related functional requirements of the specific control standard.

The specific control standard specifies the fault reaction time as well as the applicability of c).

6.6.4.3 Second fault

If the first fault results in the control remaining operational in accordance with the safety related functional requirements of the specific control standard (see 6.6.4.2 d)), any further independent fault considered together with the first fault shall result in either 6.6.4.2 a), b), c), or d).

The second fault shall only be considered to occur:

a) Either when a start-up sequence has been performed between the first and the second fault, or

b) 24 h after the first fault.

The specific control standard specifies the applicability of a) or b) and the fault reaction time.

It can also specify a different time span in which the second fault does not occur, if different from 24 h.

6.6.4.4 Faults during lock-out or safety- shutdown

6.6.4.4.1 General

Whenever the control is in lock-out or safety shutdown without an internal fault, 6.6.4.4.2 and 6.6.4.4.3 are applicable.

Whenever the control is inoperative with all safety related output terminals de-energized or in a status in which they ensure a safe situation, in lock-out or in safety shutdown with an internal fault, in addition 6.6.4.4.3 is applicable.

NOTE Safety related output terminal as used in 6.6.4.4.2 and 6.6.4.4.3 are terminals which are safety related even in the safety shutdown or lock-out position, e.g. shut-off valve terminals, but not a terminal for an actuator driving the controlling element of a gas air ratio control (see EN 12067–2:2004).

6.6.4.4.2 First fault introduced during lock-out or safety- shutdown

Any first fault (together with any other fault arising from that fault) in any one component (see Annex E), induced while the control is staying in the safety shutdown or lock-out position, shall result in either:

a) the control remaining in safety shutdown or lock-out, safety related output terminals remaining de-energized or in a status in which they ensure a safe situation;

b) the control becoming inoperative with all safety related output terminals remaining de-energized or assuming a status in which they ensure a safe situation;

c) the control comes into operation again resulting in a) or b) as mentioned in this clause under the condition that the safety related output terminals are energized not longer than the fault reaction time. If the cause of the original safety shutdown or lock-out condition no longer remains and the control comes again in operation, it shall operate in accordance with the safety related functional requirements of the specific control standard and the second fault assessment shall be carried out in accordance with 6.6.4.3.

6.6.4.4.3 Second fault introduced during lock-out or safety- shutdown

Any second fault (together with any other fault arising from that fault) in any one component (see Annex E), induced while the control is staying in the safety shutdown or lock-out position, shall result in either 6.6.4.4.2 a), b) or c).

The second fault shall not be considered to occur within 24 h after the first fault.

The specific control standard specifies the fault reaction time.

While conducting this test, the second fault can be applied at any time during the lock-out or safety-shutdown condition. It is not necessary to wait 24 h before applying the second fault. If the second fault was applied before 24 h and unacceptable results were obtained, the initial fault should be applied and then 24 h should pass before the second fault is applied.

6.6.5 Circuit and construction evaluation

6.6.5.1 Test conditions

The effect of internal faults shall be assessed by simulation and/or by an examination of the circuit design.

The fault shall be considered to have occurred at any stage in the control program sequence.

The control shall be operated or considered to operate under the following conditions:

a) for *AC* supplied controls at the most unfavourable voltage in the range 85 % to 110 % of the rated supply voltage as stated in the installation and operating instructions;

b) for *DC* supplied controls within the scope of Annex I a tolerance of 20 % to the minimum and the maximum rated voltage applies. For *DC* supplies of other types the tolerance shall be stated in the installation and operating instructions;

c) loaded with the most unfavourable load as stated in the installation and operating instructions;

d) in an ambient temperature of (20 ± 5) °C, unless there are significant reasons for conducting the test at another temperature within the range as stated in the installation and operating instructions;

e) with any actuating member placed in the most unfavourable position;

f) with tissue paper placed on the supporting surface(s) of the control;

g) with sparks of about 3 mm in length and having an energy of not less than 0,5 J applied to those components which are likely to liberate flammable gases during the test.

6.6.5.2 Test criteria

During the assessment, it shall be verified that under the conditions described in 6.6.5.1, the following criteria are satisfied.

a) The control shall not emit flames, hot metal or hot plastics, the tissue paper shall not ignite, no explosion shall result from the liberation of flammable gases and any flame produced shall not continue to burn for more than 10 s after switching off the spark generator. When a control is incorporated with any appliance, any enclosure afforded by the appliance is taken into consideration.

b) If the control continues to function, it shall conform to prEN 60730-1:2013, Clause 8 and Clause 13. If it ceases to function, it shall still continue to conform to prEN 60730-1:2013, Clause 8.

After the test there shall be no deterioration of the various parts of the control that would result in failure to conform to prEN 60730-1:2013, Clause 20.

NOTE Heating elements consisting of wire-wound resistors are considered to be short-circuit proof (see Annex E).

6.6.5.3 Assessment

A thorough assessment of the circuit shall be carried out to determine its performance under the specified fault conditions.

A failure mode and effect analysis (FMEA) shall be performed to determine the effect of each failure mode of each component or group of components in the element under consideration of diagnostic tests (self-tests).

The FMEA shall take the form of a theoretical analysis in combination with component fault insertion tests. Fault simulations can also be carried out to assess faults within complex devices, e.g. EPROM emulation tests.

In order to undertake this analysis the following information is required:

— a detailed block diagram of the control describing the element together with the interconnections for those parts of the control which will affect the safety function(s) under consideration;

— the hardware schematics of the element describing each component or group of components and the interconnections between components;

— the failure modes and rates of each component according to Annex E.

Only the safety related software (Software Class B and C) as identified according to 6.6.1.4 shall be subjected to further assessment.

7 Performance

7.1 General

Controls shall operate correctly under all combinations of the following:

— the full range of inlet pressures, as stated in the installation and operating instructions;

— the ambient temperature range from 0 °C to 60 °C or wider limits, if stated in the installation and operating instructions ;

— in all mounting positions as stated in the installation and operating instructions; where there are several mounting positions, tests are carried out in the least favourable position;

— for *AC* supplied controls: voltage or current range from 85 % to 110 % of the rated supply value or from 85 % of the minimum rated value to 110 % of the maximum rated value and at rated frequency;

— for *DC* supplied controls (types A, B, and C as classified in 4.4) a tolerance of 20 % to the minimum and the maximum rated voltage applies (see Annex I). For *DC* supplied controls of other types the tolerance shall be stated in the installation and operating instructions.

7.2 Leak-tightness

7.2.1 Requirements

Gas controls shall be leak tight, in accordance with the leakage rates given in Table 3.

Table 3 — Maximum leakage rates

Nominal inlet size DN	**Maximum leakage rates** cm^3/h of air	
	Internal leak-tightness	External leak-tightness
DN < 10	20	20
10 ≤ DN ≤ 25	40	40
25 < DN ≤ 80	60	60
80 < DN ≤ 150	100	60
150 < DN < 250	150	60

Closure parts shall remain leak-tight after dismantling and reassembly.

7.2.2 Tests

7.2.2.1 General

The external and internal leakage tests shall be carried out at the minimum temperature, at the maximum temperature and at (20 ± 5) °C.

For internal leakage of closure members carry out the tests with an initial test pressure of 0,6 kPa (6 mbar) then for both internal and external leakage repeat the tests at 1,5 times the maximum inlet pressure or 15 kPa (150 mbar), whichever is greater.

Where the gas control is suitable for use with third family gases with nominal inlet pressures of 11,2 kPa (112 mbar) or 14,8 kPa (148 mbar), use a test pressure of at least 22 kPa (220 mbar).

Use a method which gives reproducible results.

NOTE Examples of such methods are shown in:

— Annex B (volumetric method) for test pressures up to and including 15 kPa (150 mbar);

— Annex C (pressure loss method) for test pressures above 15 kPa (150 mbar).

The formula for conversion from the pressure loss method to the volumetric method is given in Annex D.

7.2.2.2 External leak-tightness

Pressurize the inlet and outlet(s) of the gas control to the test pressures given in 7.2.2.1 and measure the leakage rate.

Dismantle and reassemble closure parts 5 times as stated in the installation and operating instructions and repeat the test.

7.2.2.3 Internal leak-tightness

With any closure member in the closed position, pressurize the inlet of the gas control in the direction of gas flow indicated, to the test pressures given in 7.2.2.1 and measure the leakage rate.

7.3 Torsion and bending

7.3.1 General

Gas controls shall be constructed in such a way that they have adequate strength to withstand likely mechanical stress to which they can be subjected during installation and service.

After testing, there shall be no permanent deformation and any leakage shall not exceed the values specified in Table 3 or in the specific control standard.

7.3.2 Torsion and bending moments

7.3.2.1 Requirements

Gas controls shall withstand the torque given in Table 4/Table 5 when tested to 7.3.2.2.2 or 7.3.2.2.3.

Gas controls shall withstand the bending moment given in Table 4/Table 5 when tested to 7.3.2.2.4. Group 1 gas controls shall additionally be tested to 7.3.2.2.5.

Table 4 — Torque and bending moment for Group 1

<table>
<tr><th colspan="3">Internal thread [a]</th><th rowspan="4">Nominal size DN</th><th colspan="2">Internal or external thread</th></tr>
<tr><td colspan="3">For steel pipe connections</td><td colspan="2">For compression fittings / fiber seal / flare connections</td></tr>
<tr><td rowspan="2">Torque Nm</td><td colspan="2">Bending Nm</td><td rowspan="2">Torque [a] Nm</td><td>Bending Nm</td></tr>
<tr><td>10 s</td><td>900 s</td><td>900 s</td></tr>
<tr><td>15</td><td>15</td><td>7</td><td>6</td><td>10 (7)</td><td>7</td></tr>
<tr><td>20</td><td>20</td><td>10</td><td>8</td><td>15 (10)</td><td>10</td></tr>
<tr><td>35</td><td>35</td><td>20</td><td>10</td><td>25 (15)</td><td>17</td></tr>
<tr><td>50</td><td>70</td><td>40</td><td>15</td><td>40 (15)</td><td>35</td></tr>
<tr><td>85</td><td>90</td><td>50</td><td>20</td><td>50</td><td>45</td></tr>
<tr><td>125</td><td>160</td><td>80</td><td>25</td><td>75</td><td>80</td></tr>
<tr><td colspan="6">a Values in parentheses are for gas controls with flanged or saddle-clamp inlet connections on cooking appliances.</td></tr>
</table>

Table 5 — Torque and bending moments for Group 2

Nominal size DN [a]	**Torque** N·m	**Bending moment** N·m
	10 s	10 s
6	15	25
8	20	35
10	35	70
15	50	105
20	85	225
25	125	340
32	160	475
40	200	610
50	250	1 100
65	325	1 600
80	400	2 400
100	-	5 000
125 > 150	-	6 000
≤ 150	-	7 600

[a] Equivalent connection sizes are given in Table 1 and Table 2.

7.3.2.2 Tests

7.3.2.2.1 General

Use pipes in accordance with EN 10255:2004+A1:2007, medium series with a length of:

— at least 40 × DN for gas controls up to and including DN 50;

— at least 300 mm for gas controls above DN 50.

Use only non-hardening sealing paste on connections.

Determine the appropriate tightening torque to be applied to flange bolts to EN 1092 and EN 1759 from the values in Table 6.

Table 6 — Tightening torque for flange bolts

DN	6	8	10	15	20	25	32	40	50	65	80	100	125	≥ 150
Torque N·m	20	20	30	30	30	30	50	50	50	50	50	80	160	160

Test the gas control for external leak-tightness to 7.2.2.2 and internal leak-tightness to 7.2.2.3 where applicable, before carrying out torsion and bending tests.

If the inlet and outlet connections are not on a common axis, repeat the tests with the connections reversed.

If the inlet and outlet connections are not of the same nominal size, clamp the body of the gas control and apply the torque and bending moment appropriate to each connection in turn.

Gas controls with compression fittings shall be subjected to the bending moment tests by means of an adapter on the union threads.

Torsion tests are not applicable to gas controls with flanged connections if these are the only means of connection.

Bending moment tests are not applicable for gas controls with flanged or saddle-clamp inlet connections for attachment to cooking appliance manifolds.

7.3.2.2.2 10 second torsion test – Group 1 and Group 2 gas controls with threaded connections

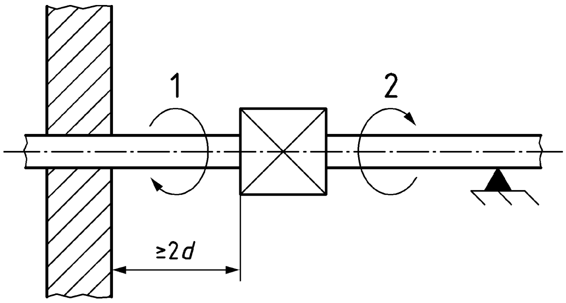
Screw pipe 1 into the gas control with a torque not exceeding the values given in Table 4/Table 5. Clamp pipe 1 at a distance at least 2*d* from the gas control (see Figure 5).

Screw pipe 2 into the gas control with a torque not exceeding the values given in Table 3. Ensure that all joints are leak-tight.

Support pipe 2 such that no bending moment is applied to the gas control.

Progressively apply the appropriate torque to pipe 2 for 10 s without exceeding the values given in Table 4/Table 5. Apply the last 10 % of the torque over a period not exceeding 1 min.

After removal of the load, visually inspect the gas control for any deformation, then test the gas control for external leak-tightness to 7.2.2.2 and internal leak-tightness to 7.2.2.3 where applicable.



Key

d external diameter

Figure 5 — Torsion test assembly

7.3.2.2.3 10 second torsion test – Group 1 and Group 2 gas controls with compression joints

7.3.2.2.3.1 Olive-type compression joints

Use a steel tube with a new brass olive of the appropriate size.

Clamp the gas control body rigidly and apply the test torque given in Table 3 to every tubing nut in turn for 10 s.

Visually inspect the gas control for deformation, discounting any deformation of the olive seating or mating surfaces consistent with the applied torque. Test the gas control for external leak-tightness to 7.2.2.2 and internal leak-tightness to 7.2.2.3 where applicable.

7.3.2.2.3.2 Flare and fibre seal compression joints

For the test use a short length of steel tube with a conical flared end for flare connections, or a flat flared end for fibre seal connections, and follow the method given in 7.3.2.2.3.1, discounting any deformation of the cone seating or mating surfaces consistent with the applied torque.

7.3.2.2.3.3 Flanged or saddle-clamp inlet connections for attachment to cooking appliance gas manifolds

Attach the gas control to a manifold as stated in the installation and operating instructions and tighten the fixing screws to the recommended torque. Connect the olive or flared type compression coupling, as appropriate, and tighten to the torque, given in parentheses in Column 2 of Table 3, in accordance with the procedures given in 7.3.2.2.3.1 or 7.3.2.2.3.2.

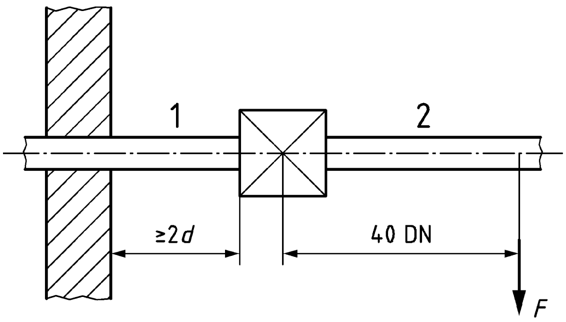
7.3.2.2.4 10 second bending moment test – Group 1 and Group 2 gas controls

Use the same gas control as for the torsion tests and the assembly as shown in Figure 6.

Apply the force for the required bending moment for Group 2 gas controls given in Table 4/Table 5 for 10 s, taking the mass of the pipe into consideration. Apply the force:

- for gas controls up to and including DN 50, 40 × DN from the centre of the gas control;
- for gas controls above DN 50, at least 300 mm from the gas control connection.

Remove the force and visually inspect the gas control for any deformation, then test the gas control for external leak-tightness to 7.2.2.2 and internal leak-tightness to 7.2.2.3 where applicable.



Key

d external diameter

Figure 6 — Bending moment test assembly

7.3.2.2.5 900 second bending moment test – Group 1 gas controls only

Use the same gas control as for the torsion tests and the assembly as shown in Figure 6.

Apply the force for the required bending moment for a Group 1 gas control given in Table 4/Table 5 for 900 s, taking the mass of the pipe into consideration. Apply the force:

- for gas controls up to and including DN 50, 40 × DN from the centre of the gas control;
- for gas controls above DN 50, at least 300 mm from the gas control connection.

With the force still applied, test the gas control for external leak-tightness to 7.2.2.2 and for internal leak-tightness to 7.2.2.3 where applicable.

7.4 Rated flow rate

7.4.1 Requirement

The maximum flow rate when measured according to 7.4.2 shall be at least 0,95 times the rated flow rate.

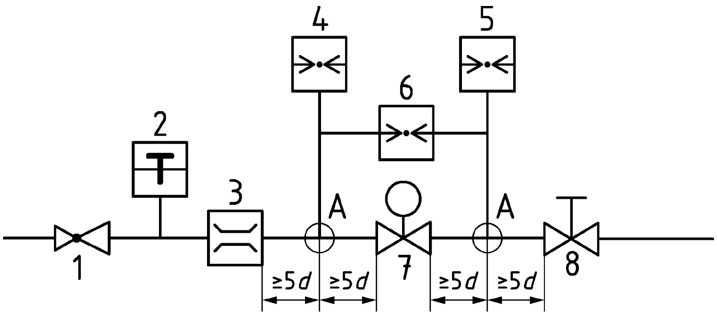
7.4.2 Test

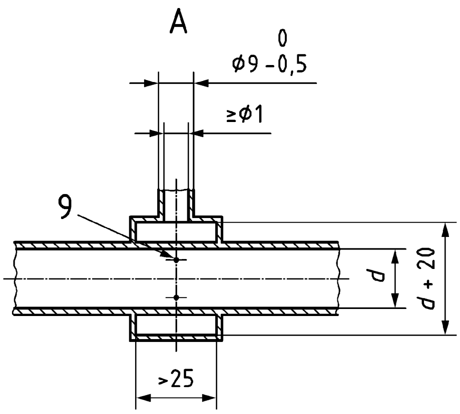
Operate and adjust the gas control as stated in the installation and operating instructions.

Adjust the air flow rate, keeping the inlet pressure constant to provide the declared pressure difference.

Carry out the test using the test apparatus shown in Figure 7.

Dimensions in millimetres





Key

1 adjustable regulator for inlet pressure
2 thermometer
3 flow meter
4 inlet pressure gauge p_1
5 outlet pressure gauge p_2
6 differential pressure gauge
7 gas control under test
8 manual gas control tap (injector orifice)
9 hole, 4 holes à Ø 1,5 mm

Nominal size DN	**Internal diameter *d*** mm
6	6
8	9
10	13
15	16
20	22
25	28
32	35
40	41
50	52
65	67
80	80
100	106
125	131
150	159
200	209
250	260

Figure 7 — Flow rate test apparatus

7.4.3 Conversion of air flow rate

Use the following formula for conversion of flow rate to standard conditions:

$$q_n = q \times \frac{p_a + p}{101{,}325} \times \frac{288}{273{,}15 + t} \tag{1}$$

where

q_n is the corrected air flow rate at reference conditions in m^3/h;

q is the measured air flow rate in m^3/h;

p is the test pressure in kPa (mbar · 10^{-1});

p_a is the atmospheric pressure in kPa (mbar · 10^{-1});

t is the air temperature in °C.

7.5 Durability

7.5.1 Elastomers in contact with gas

Elastomers in contact with gas (e.g. valve pads, O-rings, diaphragms and lip seals) shall conform to requirements given in EN 549:1994.

Elastomer/cork and elastomer/cork/synthetic fibre material in contact with gas (e.g. gaskets) shall conform to the requirements in Annex O.

7.5.2 Marking

7.5.2.1 Requirements

Adhesive labels and all marking shall be tested for resistance to abrasion, humidity and temperature. They shall neither lift nor discolour such that the marking becomes illegible.

In specific, markings on knobs shall survive the continual handling and rubbing resulting from manual operation.

7.5.2.2 Tests

Marking shall be tested in accordance with the methods given in prEN 60730-1:2013, Annex A.

7.5.3 Resistance to scratching

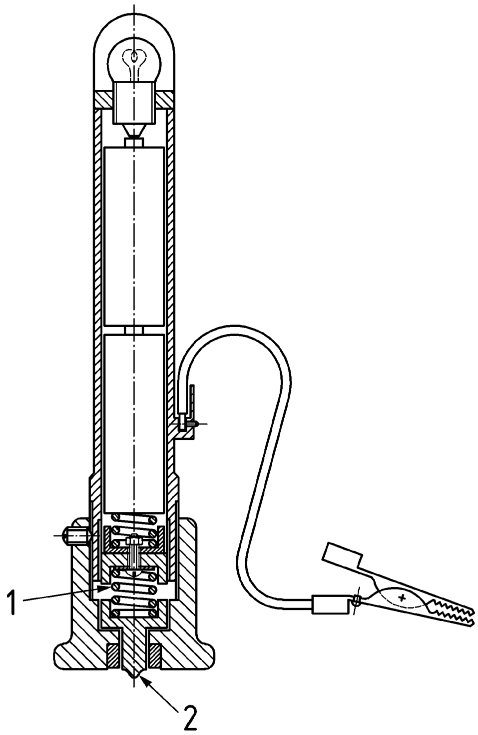
7.5.3.1 Requirement

Surfaces exclusively protected with paint shall withstand the scratch test before and after the humidity test without the ball penetrating the protective coating to expose bare metal.

7.5.3.2 Test

Draw a 1 mm diameter fixed steel ball across the surface of the gas control at a speed of 30 mm/s to 40 mm/s with a contact force of 10 N (see Figure 8).

Repeat the scratch test after the humidity test of 7.5.4.2.



Key

1 spring loading = 10 N

2 scratching point (ø 1 mm steel ball)

Figure 8 — Scratch test apparatus

7.5.4 Resistance to humidity

7.5.4.1 Requirements

All parts including those with protected surfaces, (e.g. coated with paint or plating) shall withstand the humidity test without any signs of undue corrosion, lifting or blistering visible with the naked eye.

Where evidence of minor corrosion of a gas control part exists, the part shall be substantial enough to ensure an adequate margin for the safety of the gas control.

Nevertheless, parts of the gas control, the corrosion of which could adversely affect the continued safe operation of the gas control, shall not show any signs of corrosion.

7.5.4.2 Test

Place the gas control in a chamber at an ambient temperature of (40 ± 2) °C with a relative humidity exceeding 95 % for 48 h. Remove the gas control from the chamber and examine it with the naked eye for signs of corrosion, lifting or blistering of the coated surface. Leave the gas control for a further 24 h at (20 ± 5) °C and carry out another examination.

7.5.5 Lubricants in contact with gas

Lubricants in contact with gas shall conform to relevant requirements given in EN 377:1993.

7.6 Performance tests for electronic controls

7.6.1 At ambient temperature

The safety related functions (e.g. switching times and sequence of a complete program) shall be measured in the delivered state. The control is connected and installed as stated in the installation and operating instructions.

These tests shall be performed under the following test conditions (see 5.1):

— at the rated voltage(s) as stated in the installation and operating instructions, or if this is a range, at the minimum and maximum rated voltages;

— at 85 % of the minimum rated voltage as stated in the installation and operating instructions;

— at 110 % of the maximum rated voltage as stated in the installation and operating instructions.

The results of the above measured safety related functions shall conform to the specific control standard.

7.6.2 At minimum temperature

The tests according to 7.6.1 shall be repeated at 0 °C or at the minimum ambient temperature, as stated in the installation and operating instructions, where this is lower than 0 °C.

7.6.3 At maximum temperature

The tests according to 7.6.1 shall be repeated at 60 °C or at the maximum ambient temperature, as stated in the installation and operating instructions, where this is higher than 60 °C.

7.7 Long-term performance for electronic controls

7.7.1 General

All components of the control shall be able to withstand the tests as detailed in 7.7.2 and 7.7.3. If the control function is an integral part of an apparatus the long-term performance tests can be combined. The tests of 7.7.2 and the tests of 7.7.3 shall not be carried out on the same sample control.

In the case of the control not having a clear operating cycle, the long-term performance tests shall be carried out for the minimum specified amount of time.

7.7.2 Stress test

7.7.2.1 Thermal stress test

The thermal stress test shall be carried out with the terminals loaded with the loads and power factors as stated in the installation and operating instructions.

The purpose of the tests is to expose the electronic components of the control to temperature cycles between limits likely to be reached in normal use owing to fluctuations in ambient temperature, temperature variations in the component itself, power supply fluctuation and temperature changes like from standby to operation and vice versa.

The control shall be tested as listed below:

a) 14 days at the following electrical and thermal conditions and rate of operation:

   — Electrical conditions: The control is loaded according to the ratings as stated in the installation and operating instructions, the voltage then being increased to 110 % of maximum rated voltage as stated in the installation and operating instructions except that for 30 min during each 24 h period of the test the voltage is reduced to 90 % of minimum rated voltage as stated in the installation and operating instructions. The change of voltage shall not be synchronised with the change of temperature. Each 24 h period shall also include at least one period in the order of 30 s during which the supply voltage is switched off.

— Thermal conditions: The ambient temperature and/or the mounting surface temperature are varied between the maximum ambient temperature as stated in the installation and operating instructions or 60 °C, whichever is higher, and the minimum ambient temperature as stated in the installation and operating instructions or 0 °C, whichever is lower, to cause the temperature of the components of the electronic circuit to be cycled between the resulting extremes. The rate of ambient and/or mounting surface temperature change shall be in the order of 1 °K/min and the extremes of temperature maintained for approximately 1 h.

NOTE 1 Avoid the occurrence of condensation during this test.

— Rate of operation: During the test the control shall be cycled through all of its normal operational modes (e.g. stand-by, start-up, running) up to a maximum of 6 cycles/min. The number of cycles completed during this test shall be recorded and if this number is less than 45 000 the remaining cycles shall be executed at the rated voltage as stated in the installation and operating instructions and at ambient temperature.

b) 2 500 cycles, but at least 24 h through all of its normal operational modes (e.g. stand-by, start-up, running) at the maximum ambient temperature as stated in the installation and operating instructions or 60 °C whichever is higher, and at 110 % of the maximum rated voltage as stated in the installation and operating instructions.

c) 2 500 cycles, but at least 24 h through all of its normal operational modes (e.g. stand-by, start-up, running) at the minimum ambient temperature as stated in the installation and operating instructions or 0 °C whichever is lower, and at 85 % of the minimum rated voltage as stated in the installation and operating instructions.

d) If a control is provided with a safety relevant function that on the basis of a sensor or switch is able to initiate a safety action, 5 000 cycles of such safety actions or the number as specified in the specific control standard shall be performed for each safety relevant function individually at the ambient temperature and nominal rated voltage, by simulating the sensor or switch to initiate such safety action.

NOTE 2 Combine the testing of the safety relevant functions where possible.

During the tests a), b), c) and d) as described above, the control shall be operated in such a way that the normal start-up sequence is performed.

NOTE 3 Any safety relevant times used during the above tests, as well as the time that the control is held in the running position and the time that the test sequence is interrupted before a new test cycle starts, can be specified to be as short as practicable so that the thermal stress test is not unnecessarily prolonged.

On completion of the thermal stress test, the tests of 7.6.1 shall be repeated at rated voltage only.

7.7.2.2 Vibration test

When resistance to vibration is stated in the installation and operating instructions, the sinusoidal vibration test, as described below, shall be carried out.

The object of the test is to demonstrate the ability of the control to withstand the long-term effects of vibration at levels as stated in the installation and operating instructions.

During the exposures the control shall be mounted on a rigid fixture by means of the specified fastening arrangement.

The test shall be performed in accordance with EN 60068-2-6:2008, test Fc.

The test is performed at least with the following severity conditions:

— Acceleration amplitude: 10 m/s^2 or higher as stated in the installation and operating instructions;

— Frequency range: 10 Hz to 150 Hz;

— Sweep rate: 1 octave per minute;

— Number of sweep cycles: 10;

— Number of axes: 3, mutually perpendicular.

A visual inspection shall be carried out after the termination of the exposure. No mechanical damage shall be found and the control shall conform to the construction requirements as specified in the specific control standard. On completion of the vibration test, the tests of 7.6.1 shall be repeated at rated voltage only.

7.7.3 Long-term performance tests

Without failure the control shall complete the required long-term performance tests as specified in the specific control standard or a minimum of 250 000 cycles performed through all of its normal operational modes (e.g. stand-by, start-up, running), with the terminals loaded with the loads and power factors as stated in the installation and operating instructions.

NOTE The manufacturer can declare that the required long-term performance tests have been completed.

The control shall be tested under the following conditions:

a) 90 % of the total number of cycles required or duration of time shall be performed at the rated voltage as stated in the installation and operating instructions and at ambient temperature.

b) 5 % of the total number of cycles required or duration of time shall be performed at the maximum ambient temperature as stated in the installation and operating instructions or 60 °C, whichever is higher, and at 110 % of the maximum rated voltage as stated in the installation and operating instructions.

c) 5 % of the total number of cycles required or duration of time shall be performed at the minimum ambient temperature as stated in the installation and operating instructions or 0 °C, whichever is lower, and at 85 % of the minimum rated voltage as stated in the installation and operating instructions.

d) On completion of these tests, the test sample shall still conform to prEN 60730-1:2013, 13.2.2 to 13.2.4.

7.8 Data exchange

7.8.1 General

Systems or apparatus with control functions can be connected to separate, independent apparatus or systems (which can themselves contain control functions or provide other information). Any data exchange between these systems or apparatus shall be taken into consideration regarding functional safety.

7.8.2 Type of data

Regarding safety relevance and influence, message types for data exchange in a control function or functions shall be defined according to Table 7 as:

— safety related;

— non-safety related.

NOTE Data exchange can be the transfer of single signals as well signals as complex information (see Table 7).

Table 7 — Data exchange

Data	Safety related (not exhaustive list)	Non-safety related (not exhaustive list)
Operating data	Messages such as “RESET from LOCKOUT”	Messages such as on/off instructions, room temperature information
Configuration parameters	Messages modifying parameters that determine safety related functions	Messages modifying parameters that determine performance related functions
Software modules	Modules downloaded into a system, that determine safety related functions	Modules downloaded into a system, that determine performance related functions

7.8.3 Communication of safety related data

7.8.3.1 Transmission

Safety relevant data shall be transmitted authentically concerning:

- quantity of data (i.e. all data expected to and from respective addresses);
- quality of data (i.e. in a correct and precise manner);
- appropriate transmission time.

Data variation or corrupted data shall not lead to an unsafe state. This shall be illustrated by assessment in accordance with 6.6.

In addition the following failure modes shall be met:

- permanent “auto-sending” or repetition;
- interruption of data transfer.

Adequate measures are specified in prEN 60730-1:2013, Annex H.

Further examples of measures are given in Table 8.

NOTE Attention is drawn to prEN 60730-1:2013, Table H.1, Item 6, which mentions data deformation, address deformation or wrong timing or sequences, that can be detailed further, as follows:

- data deletion from the original message;
- data insertion into the original message;
- corruption of the data in the original message;
- change in sequence of data in the original message;
- make a non-authentic message look like an authentic message;
- incomplete address;
- corruption of the address of the original message;
- wrong address;

- more addresses;
- receive message more than once;
- delay in transmitting or receiving the message;
- wrong sequence of sending/receiving.

7.8.3.2 Access to data exchange

All types of access to a safety related data exchange system shall be clearly restricted.

Safety related operating data, configuration parameters and/or software modules can be transmitted to control functions via communication, providing adequate hardware/software measures are taken to ensure that no unwanted access to the control function is possible.

Adequate measures against unauthorised access can be passwords or cryptographic techniques, as further detailed in Table 8.

Table 8 — Examples of defences against unauthorised access

	Defences							
Threats	Sequence number	Time stamp	Time-out	Feed-back message	Source and destination identifier	Identification procedure	Safety code	Crypto-graphic techniques
Repetition of a message	x	x						
Deletion of data in a message	x							
Insertion of data in a message	x			x	x	x		
changed sequence of data in a message	x	x						
Corrupted data in message							x	x
Delay in sending / receiving the message		x	x					
Masquerade, making an inauthentic message look like an authentic message				x		x		x
For further details see EN 50159:2010. NOTE This table has been taken from EN 50159:2010.								

8 Electrical requirements

8.1 General

The electrical equipment shall conform to the requirements of prEN 60730-1:2013, Clauses 8, 9, 10, 11.1, 11.2, 11.7.2, 11.8, 11.9, 11.10, 11.11.1, 11.11.2, 11.11.4, 11.11.5, 11.11.7, 11.12, 13.1, 13.2, 14, 18.1, 18.2, 18.4, 18.9, 19, 20, 21, 24, 27.2 and 28.

If the supply voltage polarity can affect the safety, provisions shall be taken to avoid that the safety relevant output terminal(s) cannot be de-energized or in case this is not feasible, clear warnings shall be given in the installation and operating instruction (see 10.2).

8.2 Protection by enclosure

The degree of protection for controls with their own enclosure shall be a minimum of IP40 in accordance with EN 60529:1991 or protection shall be provided by the appliance in which it is installed. For controls for use in the open air the protection shall conform to at least EN 60529:1991, IP 54.

9 Electromagnetic compatibility (EMC)

9.1 Protection against environmental influences

If any components specifically intended for protection against EMC disturbances fail during any of these tests, this shall lead to non-compliance with this standard. Controls performing Class B or C control functions are considered to be protective controls as specified in prEN 60730-1:2013.

***Criterion* I:**

When tested at the test levels given in 9.2 to 9.11, the control shall continue to function in accordance with the relevant requirements of the specific control standard.

***Criterion* II:**

When tested at the severity levels given in 9.2 to 9.11 the control shall conform to

— Criterion I or

— the control reacting within the fault reaction time by proceeding to safety shutdown, or to lock-out or

— for tests from 9.4 to 9.11: the control becoming inoperative with all safety related output terminals de-energized or assuming a status in which they ensure a safe situation.

For severity level 4 where in addition to level 3 testing is required, the control shall conform to the relevant requirements of the specific application standard.

NOTE 1 In the basic EMC publications “control” is commonly referred to EUT (Equipment under test).

NOTE 2 A separate sample, as submitted, can be used for each test. As an option, multiple tests can be performed on a single sample.

For *DC* supplied controls alternative requirements are given in Annex I. For *DC* supplies not covered by Annex I the *AC/DC* supply for testing EMC requirements shall be stated in the installation and operating instructions.

9.2 Supply voltage variations below 85 % of rated voltage

The control is supplied at rated voltage. After approximately 1 min, the power supply voltage is reduced to a level such that the control ceases to operate. This value of supply voltage is recorded.

The tests are performed according to prEN 60730-1:2013, H.26.5.2. For these tests Table H.15 is replaced by Table 9.

Table 9 — Test levels

Voltage test level	Time for decreasing voltage	Time at reduced voltage	Time for increasing voltage
Recorded value – 10 %	(60 ± 12) s	(10 ± 2) s	(60 ± 12) s
0 V	(60 ± 12) s	(10 ± 2) s	(60 ± 12) s

Chosen time shall be suitable to determine the operating point.

In the voltage range of operation (from rated voltage to the recorded value), the control shall conform to *Criterion* I, as specified in 9.1. In the voltage range below the recorded value, the control shall conform to *Criterion* II, as specified in 9.1. When the voltage is increased the *Criterion* II applies up to the voltage at which the control starts to operate.

For the test purpose precautions shall be taken to ensure that signals e.g. from sensors or switches that can initiate a safety action and which presence normally can be independent of the supply voltage, are present at any level of the supply voltage. The signal can be artificially simulated to prevent that the control de-energizes the safety relevant output(s) as a result of disappearance of such signals. Any non-operation of an actuator connected to the safety relevant output(s) shall be ignored.

9.3 Voltage dips and interruptions

The control shall be tested in accordance with prEN 60730-1:2013, H.26.5.1. For interruptions or dips up to and including 1 cycle of the supply wave form, the control shall conform to the *Criterion* I as specified in 9.1.

For interruptions or dips exceeding 1 cycle of the supply wave form the control shall conform to *Criterion* II as specified in 9.1.

9.4 Supply frequency variations

The control shall be tested in accordance with prEN 60730-1:2013, H.26.13.

For test level 2 the control shall conform to the *Criterion* I as specified in 9.1.

For test level 3 the control shall conform to *Criterion* II as specified in 9.1.

9.5 Surge immunity tests

The control shall be tested in accordance with prEN 60730-1:2013, H.26.8 with the following modification:

NOTE 1 of Table H.16 is replaced by the following:

NOTE 1 For test level 2 requirements apply the next lower installation class. For test level 3 requirements apply installation class 3. For test level 4 requirements apply the next higher installation class.

— When tested at test level 2 the control shall conform to *Criterion* I as specified in 9.1.

— When tested at test level 3 and 4 the control shall conform to *Criterion* II as specified in 9.1.

For controls having surge protective devices incorporating spark gaps, the tests at test level 3 and 4 is repeated at a level that is 95 % of the flashover voltage.

If surge protective devices are used they shall conform to EN 61643-11. Additionally they shall be selected to withstand the impulses corresponding to the overvoltage category for which the control is intended to be used.

9.6 Electrical fast transient/burst

The control shall be tested in accordance with prEN 60730-1:2013, H.26.9.

When tested at test level 2 the control shall conform to *Criterion* I as specified in 9.1.

When tested at test level 3 and 4 the control shall conform to *Criterion* II as specified in 9.1.

9.7 Immunity to conducted disturbances induced by radio frequency fields

The control shall be tested in accordance with prEN 60730-1:2013, H.26.12.2.

When tested at test level 2 the control shall conform to *Criterion* I as specified in 9.1.

When tested at test level 3 the control shall conform to *Criterion* II as specified in 9.1.

9.8 Immunity to radiated disturbances induced by radio frequency fields

The control shall be tested in accordance with prEN 60730-1:2013, H.26.12.3.

When tested at test level 2 the control shall conform to *Criterion* I as specified in 9.1.

When tested at test level 3 the control shall conform to *Criterion* II as specified in 9.1.

9.9 Electrostatic discharge tests

The control shall be tested in accordance with prEN 60730-1:2013, H.26.11.

When tested at test level 2 the control shall conform to *Criterion* I as specified in 9.1.

When tested at test level 3 and 4 the control shall conform to *Criterion* II as specified in 9.1.

9.10 Power frequency magnetic field immunity tests

The control shall be tested in accordance with prEN 60730-1:2013, H.26.14.

When tested at test level 2 the control shall conform to *Criterion* I as specified in 9.1.

When tested at test level 3 the control shall conform to *Criterion* II as specified in 9.1.

9.11 Harmonics and interharmonics including mains signalling at a. c. power port, low frequency immunity tests

The control shall be tested in accordance with prEN 60730-1:2013, H.26.4.

When tested the control shall conform to *Criterion* II as specified in 9.1.

10 Marking, installation and operating instructions

10.1 Marking

The following information, at least, shall be durably marked on the control in a clearly visible position:

— manufacturer and/or his identification symbol;

— type reference;

— date of manufacture (at least year) — can be in code.

10.2 Installation and operating instructions

The instructions shall include all relevant information on use, installation, operation and servicing.

Also all relevant information shall be given, when requirements have to be fulfilled, stated in an annex of this standard or the specific control standard.

10.3 Warning Notice

A warning notice shall be attached to each consignment of controls. This notice shall state: ‘Read the instructions before use.

Annex A
(informative)

Abbreviations and Symbols

A.1 Abbreviations

BSI	British Standards Institution
CEN	Comité Européen de Normalisation; eng: European Committee for Standardization
EU	European Union
DC	Diagnostic coverage
TC	Technical Committee
FMEA	Failure mode and effect analysis
FMEDA	Failure modes, effects and diagnosis analysis
EMC	Electromagnetic Compatibility
NDT	Non-destructive testing
DN	Diameter in nominal
PS	Maximum allowable pressure
SIL	Safety Integrity Level
PL	Performance Level
UV	Ultraviolet
PED	Pressure Equipment Directive
ROM	Invariable memory
RAM	Variable memory
CPU	Processing unit
EUT	Equipment under test
CRC	Cyclic redundancy check
SMD	Surface mounted device
LF	Low frequency
RF	Radio frequency
FET	Field effect transistor
NTC	Negative temperature coefficient
PTC	Positive temperature coefficient
SCR	Silicon controlled rectifier
IC	Integrated circuit
EAM	European approved materials
MOS	Metal oxide semiconductor
ASIC	Application specific integrated circuit
PLD	Programmable logic device

EEPROM	Electrical erasable programmable read only memory
CMOS	Complementary metal oxide semiconductor
ADC	Analogue to digital converter
PIN	Positive intrinsic negative
HFT	Hardware failure tolerance
CCF	Common cause failure
ERs	Essential Requirements
EFTA	European Free Trade Association

A.2 Symbols

AC	Alternating current
A_{min}	Minimum percentage elongation after fracture of material
b	*form parameter* b *of the Weibull distribution*
d	*internal/external diameter*
DC	diagnostic coverage *or* direct current
DC_1	diagnostic coverage of subsystem element 1
DC_2	diagnostic coverage of subsystem element 2
fit	failure in time
F_n	function block
$MTTF_D$	mean time to dangerous failure
n	number of samples failed
n_{op}	estimated number of operating cycles per time
p_{max}	maximum inlet pressure
PFH_D	probability of dangerous failures per hour
q_L	leakage rate in cm^3/h
V_g	total volume of the control under test and the test apparatus in cm^3
SFF	safe failure fraction
SIL_{max}	maximum safety integrity level achievable
s_{log}	logarithmic standard deviation
T	characteristic life time
T_1	proof test interval or lifetime whichever is the smaller
T_2	diagnostic test interval
T_{10d}	expected maximum time for safe operation of the control
V_{CC}	voltage of common collector
S_{min}	Minimum score
p'_{abs}	absolute pressure at the beginning of the tests in kPa

p''_{abs}	absolute pressure at the end of the tests in kPa
R_Z	roughness
B_{10d}	expected life time cycles for safe operation
πU	voltage dependence factor
π_T	temperature dependence factor
πL	load dependence factor
β	susceptibility to common cause failures
λ	component failure rate
λ_B	basic failure rate
λ_{open}	failure rate for fault mode 'open'
λ_{short}	failure rate for fault mode 'short'
λ_n	failure rate of function block F_n
λ_S	safe failure rate
λ_D	dangerous failure rate (SIL) or probability of dangerous failure per hour (PL)
λ_{DD}	dangerous detected failure rate
λ_{DU}	dangerous undetected failure rate
λ_{De}	dangerous failure rate of subsystem element 1 or 2
λ_{De1}	dangerous failure rate of subsystem element 1
λ_{De2}	dangerous failure rate of subsystem element 2
$\lambda_{De\ n}$	dangerous failure rate of subsystem element *n*
x	number of endurance cycles before the failure occurs
x_i	ordinal number $_i$ is used in rising order for x_i

Annex B
(informative)

Leak-tightness tests for gas controls – volumetric method

B.1 Apparatus

The apparatus is shown schematically in Figure B.1, with the dimensions indicated in mm.

The apparatus is made of glass. Taps 1 to 5 are also are made of glass, and are spring loaded. The liquid used is water.

The distance *l* between the water level in the constant level bottle and the end of tube G is adjusted so that the height of water corresponds to the test pressure.

The apparatus is installed in a temperature-controlled room.

B.2 Test method

Close all taps (1 to 5 and L).

Fill C, then open tap 2 in order to fill D; and close tap 2 when the water in the constant level bottle D overflows into the overflow bottle E.

Open tap 5 to adjust water level to zero in H and close tap 5.

Open taps 1 and 4 in order to adjust the pressure of the compressed air at the inlet of 4 from the atmospheric pressure to the test pressure 1 by setting the pressure regulator F.

Close 4 and connect the control under test to the apparatus.

Open taps 3 and 4 and readjust 1 with the water level at the top of tube G by operating L and 2 if necessary.

Close tap 1 when the measuring burette H and control under test have become pressurized under 1.

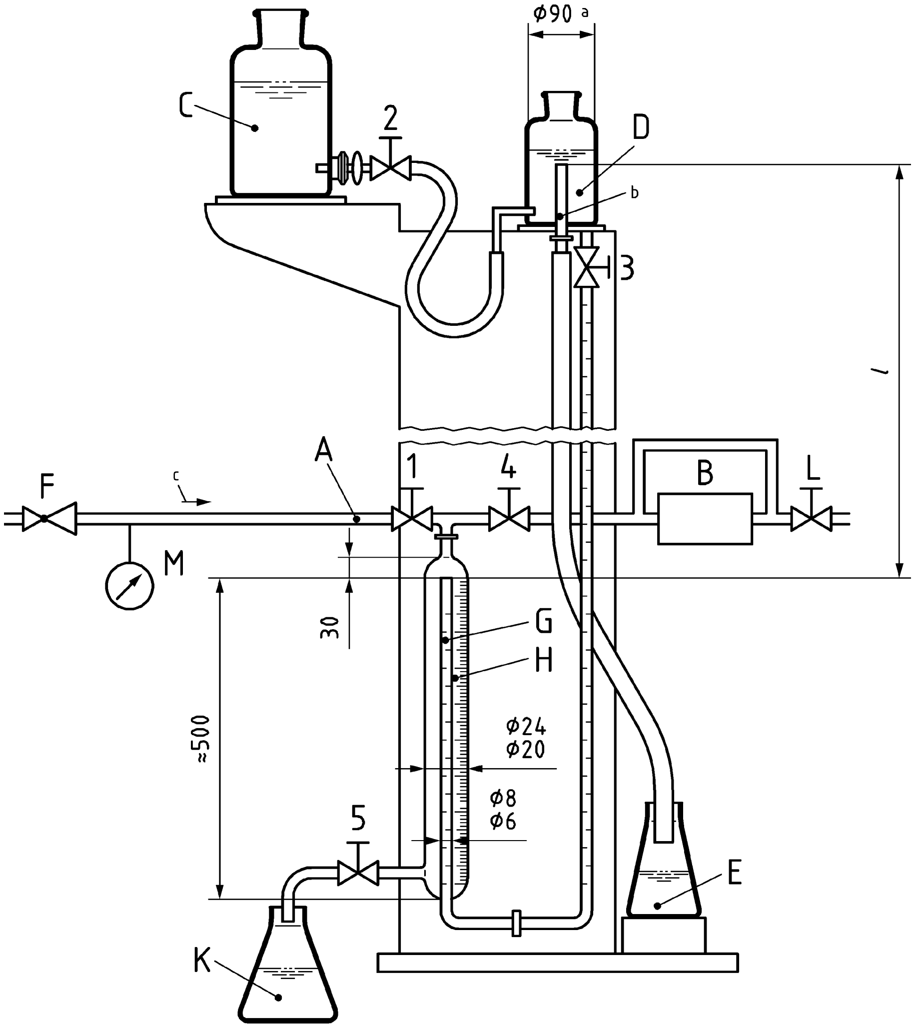
Allow approximately 15 min for the air in the test apparatus and the control under test to reach thermal equilibrium.

Any leakage is shown by water overflowing from tube G into measuring burette H. Measure the leakage by the water level rise in H within a given time.

Close taps 3 and 4 in order to disconnect the control.

Reduce the outlet regulator pressure to zero by opening taps 1 and 4.

Dimensions in millimetres



Key

A	inlet	L	outlet tap
B	test sample	M	manometer
C	water tank	1 to 5	Manual taps
D	constant level bottle	a	inner diameter
E	overflow bottle	b	10–12 diameter pipe
F	regulator	c	compressed air
G	pipe	*l*	distance between the water level in the constant level bottle D and the end of pipe G
H	measuring burette		
K	draining bottle		

Figure B.1 — Leak-tightness tests apparatus (volumetric method)

Annex C
(informative)

Leak-tightness tests for gas controls – pressure loss method

C.1 Apparatus

The apparatus is shown schematically in Figure C.1 with the dimensions indicated in mm.

The apparatus consists of a thermally insulated pressure vessel A, which is filled with water such that the volume of air above the water is 1 dm^3. An open-ended glass tube B of internal diameter 5 mm has its lower end in the water in A. This tube is used to measure the pressure loss.

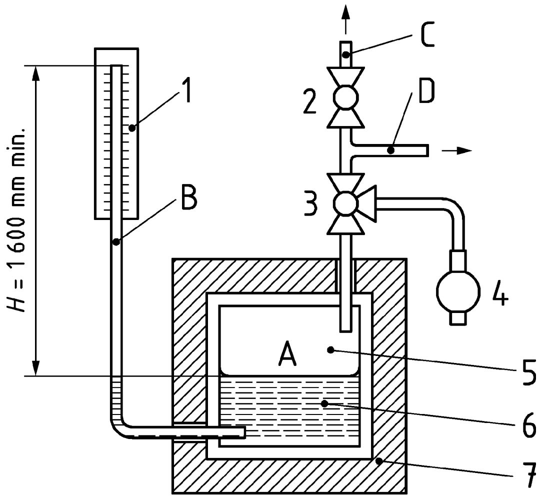
The test pressure is applied to a second tube C, which enters the air chamber of the pressure vessel to which the control under test is connected by means of a flexible tube of length 1 m and internal diameter 5 mm attached to connection D.

C.2 Test method

Using a governor, adjust the air pressure through the three-way tap 3 to the test pressure. The rise in water level in the measuring tube B corresponds to the test pressure.

Open the three-way tap 3 to connect the control under test to A.

Allow 10 min for thermal equilibrium to be established. Wait a further 5 min and read the pressure loss directly from measuring tube B.



Key

1	scale divided into millimetres	A	thermally insulated pressure vessel
2	vent	B	measuring tube
3	three way tap	C	pressure tube
4	air pump	D	connection to *control* under test
5	1 dm^3 air volume		
6	water		
7	thermal insulation		

Figure C.1 — Leak-tightness tests apparatus (pressure loss method)

Annex D
(normative)

Calculation of pressure loss into leakage rate

The following formula shall be used to calculate the leakage rate (e.g. in cm^3/h) from the pressure loss.

$$q_L = 1{,}185 \times 10^{-3} \times V_g \; (p'_{abs} - p''_{abs})$$

where

q_L is the leakage rate in cm^3/h;

V_g is the total volume of the control under test and the test apparatus in cm^3;

p'_{abs} is the absolute pressure at the beginning of the tests in kPa;

p''_{abs} is the absolute pressure at the end of the tests in kPa.

The pressure loss shall be measured over a period of 5 min and the leakage rate is based on 1 h.

Annex E
(normative)

Electrical/electronic component fault modes

Table E.1 — Electrical/electronic component faults modes

Component type	Short	Open[a]	Remarks
Fixed resistors: Thin film (wound filament) Thick film (flat) Wire-wound (single layer) All other types	x	x x x x	Includes SMD type Includes SMD type
Variable resistors (e.g. potentiometer/trimmer)**:** Wire-wound (single layer) All other types	x[b]	x x	
Capacitors: X1 and Y types according to EN 60384–14:2013 Metallized film according to EN 60384–16:2005 All other types	x	x x x	
Inductors: Wire-wound (single layer) All other types	x	x x	
Diodes: All types	x	x	
Transistors: All types (e.g. Bipolar: LF; RF; microwave; FET; Thyristor; Diac; Triac; Uni junction)	x[b]	x	c
Hybrid circuit	d	d	
Integrated circuits	x[e]	x	For IC outputs note[c] applies
Photocouplers	x[f]	x	
Relays:			
Coils	x	x	If the relay complies with EN 61810–1:2008 the failure mode short circuit need not be considered.
Contacts	x[g h o]	x	
Reed-relays	x	x	Contacts only
Electromechanical lock-out elements:			
Coils	x	x	
Contacts	x[p]	x	
Transformers:	x	x	

Component type	Short	Open[a]	Remarks
According to EN 61558–2-6:2009 or EN 61558–2-16:2009 All other types			
Crystals	x	x	i
Switches	x	x	j
Connections (jumper wire)		x	k
Cable, wiring and connectors		x	
Printed circuit board conductors	x[m]	x[l]	
Temperature sensors: All types (e.g. NTC, PTC, PT 100 and thermocouples)	x[n]	x[n]	

[a] Only opening of one pin at a time.

[b] Short circuit each pin in turn with every other pin; only two pins at a time.

[c] For discrete or integrated thyristor type devices such as triacs and SCRs, fault conditions shall include short circuit of any terminals with the third terminal open circuited. The effect of any full wave type component, such as a triac going into a half wave condition, either controlled or uncontrolled (thyristor or diode, respectively) shall be considered.

[d] Failure modes for individual components of the hybrid circuit are applicable as described for the individual components in this table.

[e] The short circuit of any two adjacent terminals and the short circuiting of:

a) each terminal to the IC-supply, when applicable at the IC,

b) each terminal to the IC-ground, when applicable at the IC.

The number of tests implied for integrated circuits can normally make it impracticable to apply all the relevant fault conditions or to assess the likely hazards from an appraisal of the circuit diagram of the integrated circuit.

It is therefore permissible first to analyse in detail all the possible mechanical, thermal and electrical faults which can develop either in the control itself or its output, due to the malfunction of the electronic devices or other circuit components, separately or in any combination.

An analysis (e.g. a fault tree analysis) shall be conducted to include the results of multiple steady-state conditions to outputs and programmed bi-directional terminals for the purpose of identifying additional fault conditions for consideration. The failure mode "short circuit" is excluded between isolated sections for such ICs that have isolated sections. The isolation between the sections shall conform to the requirements of prEN 60730–1:2013, 13.2 for operational insulation.

[f] When photocouplers conform to EN 60747–5-2:2001, Clause 8 "Photocouplers (optocouplers) providing protection against electrical shock", and with the requirements for double or reinforced insulation of prEN 60730–1:2013, Clause 20, short circuits between the input and output pins are not considered.

[g] The failure modes "short circuit" and "mechanical break-down" need not to be considered when the control– including the relay – successfully completed the long-term performance tests of 7.7 (under nominal load of relay contacts) and if the relay is successfully tested for 3 million cycles under no load condition in compliance with EN 60947–5-1:2004, C.2, and if special precautions have been taken to prevent welding of contacts, see 6.5.1. All of the following special precautions shall be fulfilled:

1. Measures to avoid welding:

1.1 Contacts closing on short-circuit:

Rating of the fuse: (I_N) < 0,6 * (I_e).

NOTE 1 I_N: values for the fuse (see EN 60127–1:2006, 3.16).

I_e: rated operational current of the contact (see EN 60947–1:2007, 4.3.2.3).

NOTE 2 The manufacturer can declare that the relay is successfully tested for 3 million cycles under no load condition.

1.2 Lifetime/load cycle rating: proof that the contact does not weld after 1 000 000 cycles (fourfold safety) on max. rated contact load as stated in the installation and operating instructions based on a test of

Component type	Short	Open[a]	Remarks

3 samples.

NOTE 3 The manufacturer can declare that the contact does not weld after 1 000 000 cycles (fourfold safety) on max. rated contact load.

2. Measures to avoid microwelding:

2.1 Proof that the permissible (maximum) capacitance loads have been part of the lifetime-test according to 1.2.

2.2 Proof that no mains-synchronous switching occurs, or the mains synchronous switching has not resulted in non-compliance with the lifetime test according to 1.2 (see also 7.7.1).

Spontaneous closing of a relay contact without energy is not considered, if the relay is designed for the mechanical stress and the rating of the relay is appropriate to avoid mechanical breakdown.

[h] If a fuse is used to protect against the hazard of relay contact welding either the fuse shall not be replaceable, or external measures shall be necessary to avoid un-authorized replacement. These measures shall be included in the instruction manual, see 10.2.

[i] For crystal based clocks, harmonic and sub-harmonic frequency variations affecting the timings should be considered.

[j] If switches are applied for the selection of declared safety times, programs and/or other safety related settings, these devices should function so that in the event of their opening, the safest possible condition arises (for example, the shortest safety time or the longest purge time).

[k] The requirements are the same as footnote j, except they are applied to jumper wires intended for clipping when selecting a setting.

[l] The open circuit failure mode, i.e. interruption of a conductor, is excluded if the thickness of the conductor is equal to or greater than 35 µm and the breadth of the conductor is equal to or greater than 0,3 mm or the conductor has an additional precaution against interruption, e.g. roll-tinned, etc. If a short circuit at the output terminals causes the opening of a printed circuit board conductor, that conductor shall be subject to an open circuit fault analysis.

[m] The short circuit failure mode is excluded if the requirements of prEN 60730–1:2013, Clause 20 are fulfilled.

[n] Failure modes of sensing elements and their assemblies as indicated below shall be examined for being applicable for fault assessment of the function

— a sensing element does not respond to the actual temperature value as was to be expected (e.g. “stuck at”);

— the temperature related sensing element characteristic changes in principle or by an offset;

— specific failure modes related to the sensing element technology.

Any failure mode shall not result in the simulation of a temperature that can cause a potential hazardous situation.

[o] If no measures to avoid contact welding according to g) are taken, the fault mode “short” shall be considered to occur both in the instance of closing of the contact and when the contact is already closed.

[p] 1) The electromechanical lock-out element shall withstand 60 000 cycles without load.

2) The contacts of the electromechanical lock-out element shall be protected against welding by a fuse dimensioned according to footnote g) 1.1.

3) The contacts of the electromechanical lock-out element shall withstand 20 000 cycles according to footnote g) 1.2.

4) Footnotes g) 2.1 and 2.2 shall be fulfilled accordingly.

5) In the operating position the contacts of the electromechanical lock-out element shall withstand 1 000 000 cycles of maximum load current in the closed position without contact welding.

6) All load conditions shall consider inductive and/or capacitive loads, “cos phi”.

Annex F
(normative)

Additional requirements for safety accessories and pressure accessories as defined in EU Directive 97/23/EC

F.1 Introduction

This annex makes use of the corresponding clauses in this standard by adapting them and stating “addition”, “modification” or “replacement”. Only the affected subclauses are mentioned in this annex, hence the following numbering is non-consecutive.

F.6.1 General

Shall be according to 6.1 with the following addition:

The safety function(s) of a control shall be independent of other functions, unless its safety function(s) cannot be affected adversely by such other functions.

The risk philosophy adopted in this document is based on the analysis of hazards on account of pressure. The document applies to principles to eliminate or reduce hazards. Where these hazards cannot be eliminated appropriate protection measures are specified.

Any residual hazard are identified and communicated to the user where appropriate.

Depending on the installation situation additional requirements can apply to cover the risks arising from traffic, wind, earthquake loading and external fire.

F.6.2 Mechanical parts of the control

Shall be according to 6.2 with the following addition:

F.6.2.11 Design of pressurized parts

Pressurized parts shall be designed for loadings appropriate to their intended use and other reasonably foreseeable operating conditions.

NOTE Pressurized parts are typically designed by calculation using simulation programmes.

Pressurized parts designed without calculation shall withstand a pressure strength test according to F.7.9.

F.6.3 Materials

Shall be according to 6.3 with the following addition:

F.6.3.8 Materials for pressurized parts

Materials of pressurized parts, which are subject to a maximum allowable pressure > 50 kPa, shall be suitable for the scheduled lifetime of the control unless replacement is foreseen. Such materials shall:

- conform to harmonized standards (see Table G.1), or
- be covered by a European approval of pressure equipment materials, or

— be constructed of materials conforming to the restrictions given in Table F.1 and be subject of a particular material appraisal.

Table F.1 — Materials

Restrictions					
Material		Regulator			
Group	Properties				
	*A*min [a] %	PS_{max} bar	$(PS \cdot DN^{b})_{max}$ bar · mm	$DN^{b}{}_{max}$ mm	
Pressure containing parts and inner metallic partition walls					
Rolled and forged steel [c]	16	100	-	-	
Cast steel [c]	15	100	-	-	
Spheroidal graphite cast iron [d]	7	20	1 500	1 000	
	15	50	5 000	300	
Malleable cast iron	6	20	1 000	100	
Copper-zinc wrought alloys	15	100	-	25	
Copper-tin and copper-zinc cast alloys	5	20	1 000	100	
	15	100	-	25	
Aluminium wrought alloys	4	20	-	50	
	7	50	-	50	
		100	-	25	
Aluminium cast alloys	1,5	10	250	150	
	4	20	1 600	1 000	
Integral process and sensing lines					
Copper	-	25	-	-	
Steel	-	100	-	-	
Connectors					
Steel	8	-	-	-	
Fasteners					
Steel for bolts, screws, studs	9	50	-	-	
	12	100	-	-	

NOTE For castings the specified mechanical characteristics are those measured on machined test piece prepared from separately cast test samples in accordance with the relevant document for the selected materials.

[a] *A* = percentage elongation after fracture (according to the applicable document relevant to the chosen material).

[b] For the bodies of pilots or fixtures this term shall refer to their inlet connections.

[c] Bending rupture energy measured in accordance with EN ISO 148-1:2010 shall be not less than 27 J as average of three test pieces with minimum individual of 20 J at minimum operating temperature (−10 °C or −20 °C).

[d] Bending rupture energy measured in accordance with EN ISO 148-1:2010 shall be not less than 12 J as an average of three test pieces and no less than 9 J as a minimum individual value at a temperature of −20 °C for PS > 25 bar when used in regulator class 2.

(See EN 334:2005+A1:2009, Table 5)

Subject to a particular material appraisal, materials used in similar applications under similar operating conditions, which have been recognized as being safe to use (see Table H.1) are also regarded as suitable. The safety of controls using such materials shall also be verified in combination with the pressure strength test according to F.7.9.

NOTE An official list of European approved materials (EAM) and harmonized standards are published by the European Commission, see http://ec.europa.eu/enterprise/sectors/pressure-and-gas/documents/ped/materials/index_en.htm.

F.6.3.9 Manufacturing

Fabrication welds in all pressure containing parts shall be made using qualified welding procedures in accordance with standards EN ISO 15607:2003, EN ISO 15609-1:2004, EN ISO 15610:2003, EN ISO 15611:2003, EN ISO 15612:2004, EN ISO 15613:2004, EN ISO 15614-1:2004 and EN ISO 15614-2:2005, where applicable, and by welders or welding operators qualified according to applicable standards EN ISO 9606-1:2013, EN ISO 9606-2:2004, EN ISO 9606-3:1999, EN ISO 9606-4:1999, and EN ISO 14732:2013.

In addition, for fabrication welds to make bodies, blind flanges, bonnets and actuator casings:

— only full penetration welds shall be used;

— weld fabrication and heat-treatment shall conform to EN 13445-4:2014.

These additional requirements are not applicable to seal welding.

For all pressure containing parts and inner metallic partition walls, the manufacturer shall identify the material throughout the production from receipt up to the final routine tests by markings or labelling.

F.6.3.10 Non-destructive testing (NDT)

Steel bodies shall be non-destructively tested in accordance with Table F.2 and Table F.3.

Table F.2 — Non destructive testing

<table>
<tr><th colspan="2" rowspan="3"></th><th colspan="5">Type of non destructive testing</th></tr>
<tr><th colspan="2">Volumetric</th><th colspan="3">Surface</th></tr>
<tr><th>Radiographic</th><th>Ultrasonic</th><th>Visual</th><th>Magnetic particle</th><th>Liquid penetrant</th></tr>
<tr><td rowspan="3">Sections to be examined and/or extent of coverage</td><td>Steel castings</td><td colspan="2">EN 12516–1:2014, 10.3.2</td><td>Accessible surfaces</td><td colspan="2" rowspan="2">EN 12516–1:2014, 10.3.3</td></tr>
<tr><td>Forgings, bars, plates and tubular products</td><td colspan="2">EN 12516–1:2014, 10.4 and 10.5</td><td>Not applicable</td></tr>
<tr><td>Fabrication welds</td><td colspan="2">According to E and F in Table F.3</td><td>Accessible surfaces</td><td colspan="2">According to B in Table F.3</td></tr>
<tr><td colspan="2">NDT procedures and acceptance criteria for castings, forgings and their fusion weld repairs</td><td>EN 12516–1:2014, Annex B</td><td>EN 12516–1:2014, Annex E</td><td>MSS SP 55:1985[a] and EN ISO 17637 :2011[b]</td><td rowspan="2">EN 12516–1:2014, Annex C</td><td rowspan="2">EN 12516–1:2014, Annex D</td></tr>
<tr><td colspan="2">NDT procedures and acceptance criteria for fabrication welds, including their repairs</td><td>EN 12516–1:2014, 10.6 and Annex B</td><td>EN 12516–1:2014, 10.6 and Annex E</td><td>EN ISO 17637 :2011[b]</td></tr>
<tr><td>General requirements</td><td colspan="6">Examinations shall be performed on the material after any heat treatment required by the material or welding either before or after the finish machining at the option of the manufacturer.
Accessible surfaces in case of surface examination include exterior and interior surfaces but no threads, drilled or threaded holes etc.</td></tr>
<tr><td colspan="7">a This document is applicable only to steel castings.
b This document is applicable only to fusion weld repairs.</td></tr>
<tr><td colspan="7">NOTE EN 12516–1:2014 is equivalent to ASME B16.34:1996 mentioned in the previous edition of this document.</td></tr>
</table>

Table F.3 — Minimum inspection sample

<table>
<tr><th rowspan="2"></th><th rowspan="2">p_{max}</th><th colspan="5">DN</th></tr>
<tr><th>< 100</th><th>≥ 100 < 150</th><th>≥ 150 < 200</th><th>≥ 200 < 25 0</th><th>≥ 250</th></tr>
<tr><td rowspan="3">Castings</td><td>100</td><td rowspan="2">A + B</td><td>A + C</td><td rowspan="2">A + C</td><td colspan="2" rowspan="2">A + D</td></tr>
<tr><td>50 ≤ p_{max} < 100</td><td>A + B</td></tr>
<tr><td>< 50</td><td colspan="5">A</td></tr>
<tr><td rowspan="2">Forgings, bars, plates and tubular products</td><td>100</td><td colspan="2" rowspan="2">/</td><td>C</td><td rowspan="2">C</td><td rowspan="2">D</td></tr>
<tr><td>50 ≤ p_{max} < 100</td><td>/</td></tr>
<tr><td rowspan="2">Full penetration fabrication welds</td><td>> 16</td><td colspan="5">A + F</td></tr>
<tr><td>5 < p_{max} ≤ 16</td><td colspan="5">A + E</td></tr>
<tr><td>Partial penetration fabrication welds</td><td>> 16</td><td colspan="5">A + B</td></tr>
<tr><td colspan="7">A is the visual examination of 100 % of the production batch.
B is the magnetic particle or liquid penetrant examination of 100 % of the production batch.
C is the volumetric examination of 10 % of the production batch, selected on random basis.
D is the volumetric examination of 20 % of the production batch, selected on random basis.
E is the volumetric examination of 10 % of the circumferential, corner and nozzle seams of the production batch, selected on random basis, and 100 % of the longitudinal seams of the production batch.
F is the volumetric examination of 20 % of the circumferential, corner and nozzle seams of the production batch, selected on random basis, and 100 % of the longitudinal seams of the production batch.
NOTE A production batch consists of castings or forgings from the same melt and the same heat treatment or welds made by the same process and/or welder or welding operator. An inspection sample is a percentage of the production batch.</td></tr>
</table>

In the case of random inspection, if a casting, forging or weld does not conform to the acceptance criteria, a further inspection sample of twice the original sample size from the production batch shall be examined. If one of these castings, forgings or welds fails, the examination shall be extended to all castings, forgings or welds in the production batch.

Any casting, forging or weld that does not conform to the acceptance criteria shall be repaired according to an applicable procedure and then re-examined.

The NDTs shall be carried out by qualified personnel in accordance with EN ISO 9712:2012.

F.7 Performance

Shall be according to Clause 7 with the following addition:

F.7.9 Pressure strength test

F.7.9.1 General

The pressure strength test shall be performed by using a safety factor $\boldsymbol{f}$ for the test pressure where $\boldsymbol{f}$ is the multiplication factor for the maximum inlet pressure.

If not otherwise defined by harmonized design standards, a safety factor $\boldsymbol{f} = \mathbf{4}$ shall be considered.

NOTE Experimental test factors dependent on the type of the device and on the material are given in appropriate design standards for pressurized parts, harmonized with EU Directive 97/23/EC, e.g. EN 12516–3:2002.

F.7.9.2 Performance test

A pressure of ***f*** times the maximum inlet pressure is applied to the control at maximum ambient temperature for a minimum of 5 min. Then the control is cooled to (20 ± 5) °C.

Following this, leak-tightness test(s) according to 7.2 shall not exhibit significant leaks. Deformation exceeding a determined threshold shall not occur.

F.10 Marking, installation and operating instructions

F.10.1 Marking

Shall be according to 10.1 with the following addition:

- maximum inlet (allowable) pressure in kPa;
- ambient temperature range.

F.10.2 Installation and operating instructions

Shall be according to 10.2 with the following addition:

Information to the user shall be given of residual hazards to take appropriate special measures at the time of installation and/or use.

Additional information:

- maximum inlet (allowable) pressure in kPa;
- ambient temperature range;
- scheme and related functional description;
- technical data for the series of controls and a list of performance data;
- overall dimensional drawing;
- list of spare parts;
- installation, operation and maintenance manual;
- information on safe use of the connections;
- safety requirements concerning commissioning and de-commissioning procedures;
- safety requirements on filling/discharge of gas of/from the control;
- data on the nameplate except serial number, year of manufacturing and specific set range;
- hazards arising from misuse and particular features of the design when appropriate;
- provisions, if any, for transport and handling;
- storage requirements for spare parts; and
- a statement on installation according to the provisions of EN 12186:2014 / EN 12279:2000.

Annex G
(normative)

Materials for pressurized parts

Table G.1 — List of materials covered by harmonized standards

Materials			**Restrictions**				
Group	Type	Relevant standard	Regulator / safety device				
			Operating temperature		PS_{max}	$[PS \times DN^{b}]_{max}$	DN_{max}[b]
			−10 °C to 60 °C[a]	−20 °C to 60 °C	bar	bar × mm	mm
Pressure containing parts and inner metallic partition walls							
Rolled and forged steel	P235GH / 1.0345, P265GH / 1.0425, P295GH / 1.0481, P355GH / 1.0473 all with thickness ≤ 150 mm	EN 10028–2:2009	x		100	—	—
	P275NH / 1.0487, P355NH / 1.0565 with thickness ≤ 150 mm, P355NL1 / 1.0566 with thickness ≤ 150 mm	EN 10028–3:2009		x			
	All types	EN 10028–4:2009 EN 10028–5:2009		x			
	All grades from P355. to P500 with thickness ≤ 150 mm	EN 10028–6:2009		x			
	All steel designation with A_{min} ≥ 16 %	EN 10028–7:2007		x			

Materials			Restrictions				
Group	Type	Relevant standard	Regulator / safety device				
			Operating temperature		PS_{max}	$[PS \times DN^{b}]_{max}$	$DN_{max}{}^{b}$
			−10 °C to 60 °C[a]	−20 °C to 60 °C	bar	bar × mm	mm
	All steel designations with A_{min} ≥ 16 % and at –20 °C KV 27 J av. of three and 20 J minimum	EN 10222–1:1998		x	100	—	—
	All steel designations martensitic type	EN 10222–5:1999	x				
	All steel designations austenitic type			x			
	All steel designations with A_{min} ≥ 16 %, and at –20 °C KV 27 J av. of three and 20 J minimum	EN 10272:2007		x			
Cast Steel	All steel designations	EN 10213:2007		x			

[a] These materials can be used for operating temperature from –20 °C to 60 °C when PS ≤ 25 bar.

[b] For the bodies of pilots or fixtures this term refers to their inlet connections.

Annex H
(normative)

Additional materials for pressurized parts

Table H.1 is a list of materials which have been recognized as being safe.

Table H.1 — List of materials which have been recognized as being safe

Materials			Restrictions				
Group	Type	Relevant standard	Regulator / safety device				
			Operating temperature		PS_{max}	$[PS \times DN^{b}]_{max}$	$DN_{max}{}^{b}$
			−10 °C to 60 °C[a]	−20 °C to 60 °C	bar	bar × mm	mm
Pressure containing parts and inner metallic partition walls							
Rolled and forged steel	S235JR / 1.0037 with thickness ≤ 40 mm, S275JR / 1.0044 with thickness ≥ 1,5 mm, S355JR / 1.0045 with thickness ≥ 1,5 mm	EN 10025–1:2004	x		100	—	—
	S235J2G3 / 1.0116 and S235J2G4 / 1.0117 both with nominal thickness ≤ 150 mm, S275J2G3 / 1.0144 and S275J2G4 / 1.0145 and S355J2G3 / 1.0570 all with 1,5 mm < nominal thickness ≤ 150 mm			x			
	S275JO / 1.0143 and S355JO / 1.0553 both with 1,5 mm < nominal thickness ≤ 250 mm and at –20 °C KV 27 J av. of three and 20 J min						
	25 CrMo4 / 1.7218 and 25CrMoS4 / 1.7213 both with 100 mm < *d* ≤ 160 mm or 60 mm < t ≤ 100 mm, 36CrNiMo4 / 1.6511 with A_{min} = 16 %. All types shall be quenched and tempered (+QT) and with cast analysis C ≤ 0,25 % or, when 0,25 % < C ≤ 0,40, Ni ≥ 1 %.	EN 10083–3:2014	x				

Materials			Restrictions				
Group	Type	Relevant standard	Regulator / safety device				
			Operating temperature		PS_{max}	$[PS \times DN^{b}]_{max}$	$DN_{max}{}^{b}$
			−10 °C to 60 °C[a]	−20 °C to 60 °C	bar	bar × mm	mm
	36CrNiMo4 / 1.6511 quenched and tempered (+QT) with A_{min} ≥ 16 % and KV 27 J av. of three and 20 J min at –20 °C	EN 10250–3:1999		x	100	—	—
	All steel designations quenched and tempered (+QT) with A_{min} ≥ 16 % and with cast analysis C ≤ 0,25 %.	EN 10083–2:2006	x				
	11SMn30 / 1.0715, 11SMn37 / 1.0736, 11SMnPb30 / 1.0718, 11SMnPb37 / 1.0737 all with 16 ≤ *d* ≤ 100 and A_{min} 16 %	EN 10277–3:2008	x				25
	As above and types 35S20 / 1.0726, 35SPb20 / 1.0756, 36SMn14 / 1.0764, 36SMnPb14 / 1.0765, 38SMn28 / 1.0760, 38SMnPb28 / 10761, 44SMn28 / 1.0762, 44SMnPb28 / 1.0763, 46SPb20 / 1.0757 with KV 27 J av. of three and 20 J min at –20 °C			x			
	All austenitic steel designations with longitudinal A_{min} ≥ 16 % and other steel designations with longitudinal A_{min} ≥ 16 % and KV 27 J av. of three and 20 J min at –20 °C	EN 10088–3:2014		x			—
Rolled and forged steel	DD11 / 1.0332, DD12 / 1.0398, DD13 / 1.0335	EN 10111:2008	x				
	All steel designations used for skin-pass	EN 10130:2006	x				
	All low carbon content types	EN 10346:2009	x		100	—	—
	All steel designations with A_{min} ≥ 16 % and at –20 °C KV 27 J av. of three and 20 J min	EN 10250–1:1999		x			
	All steel designations with cast analysis C ≤ 0,25 % and with longitudinal	EN 10250–2:1999	x				

Materials			Restrictions				
Group	Type	Relevant standard	Regulator / safety device				
			Operating temperature		PS_{max}	$[PS \times DN^{b}]_{max}$	$DN_{max}{}^{b}$
			−10 °C to 60 °C[a]	−20 °C to 60 °C	bar	bar × mm	mm
	A_{min} ≥ 16 %						
	S235J2G3 / 1.0116, S355J2G3 / 1.0570 with t_R ≤ 500 mm			x			
	All steel designations with A_{min} ≥ 16 % except X30Cr13 / 1.4028	EN 10250–4:1999	x				
	All austenitic grades	EN 10088–1:2014		x			
	Fe 35.2, Fe 52.2 with cast analysis C ≤ 0,25 %	EN 10216–1:2013	x				
	Fe 52.2 with KV 27 J av. of three and 20 J min at –20 °C			x			
	Fe 510	EN 10297–1:2003	x				
	Fe 510 with KV 27 J av. of three and 20 J min at –20 °C			x			
Cast steel	Fe G-450	EN 10293:2015	x				
Spheroidal graphite cast iron	EN-GJS400–18 / EN-JS1020, EN-GJS400–18-LT / EN-JS1025, EN-GJS400–15 / EN-JS1030, EN-GJS400–18U-LT / EN-JS1049	EN 1563:2011		x			
	A 395M	ASTM A 395/A 395M:1999		x			
	A 536 Grades 60–40–18 and 65–45–12	ASTM A 536:1984		x	20	1 500	1 000
	A 874M	ASTM A 874/A 874 M:1998		x			
	400–18, 500–7	ISO 1083:2004		x			
	420–12	EN 1563:2011		x			

Materials			Restrictions				
Group	Type	Relevant standard	Regulator / safety device				
			Operating temperature		PS_{max}	[PS × DN[b]]$_{max}$	DN_{max}[b]
			−10 °C to 60 °C[a]	−20 °C to 60 °C	bar	bar × mm	mm
	EN-GJS400–18-LT / EN-JS1025, EN-GJS-400–18U-LT / EN-JS1049 with wall thickness ≤ 60 mm	EN 1563:2011		x	50	5 000	300
	EN-GJS400–15 / EN-JS1030, EN-GJS-400–18U-RT / EN-JS1059 with wall thickness ≤ 60 mm		x				
	400–18L	ISO 1083:2004		x			
	400–18		x				
	A 395M	ASTM A 395/A 395 M:1999	x				
	A 536 Grade 60–40–18	ASTM A 536:1984	x				
	GGG 40 / 0.7940	EN 1563:2011		x			
Malleable cast iron	Grades 60–40–18, 65–45–12 and 80–55–06	ASTM A 536:1984		x	20	1 000	100
Copper-zinc wrought alloys	All material designations with A ≥ 15 %	EN 1652:1997		x	100	—	25
	All material designations with A ≥ 15 %	EN 12164:2011		x			
	All material designations with A ≥ 15 %	EN 12165:2011		x			
	ASTM B 283/B 283Ma - UNS No C 37700 and 64200	ASTM B 283/B 283 Ma:2011		x			
	P-Cu Zn 37 with A ≥ 15 %	EN 12167:2011		x			
	P-Cu Zn 33 with A ≥ 15 %	EN 12163:2011		x			
	P-Cu Zn 40 Pb 2 with A ≥ 15 %	EN 12167:2011		x			
Copper-tin and copper-zinc cast alloys	Cu Sn5Zn5Pb5-B (CB491K) and CuSn5Zn5Pb5-C (CC491K)	EN 1982:2008		x	20	1 000	100
	ASTM B 584 all UNS nos with elongation ≥ 15 %	ASTM B 584:2013		x	100	—	25

Materials			Restrictions				
Group	Type	Relevant standard	Regulator / safety device				
			Operating temperature		PS_{max}	$[PS \times DN^{b}]_{max}$	$DN_{max}{}^{b}$
			−10 °C to 60 °C[a]	−20 °C to 60 °C	bar	bar × mm	mm
Aluminium wrought alloys	All metallurgic state and thickness for which A_{min} ≥ 4 %	EN 485–2:2013		x	20	—	50
	All metallurgic state and dimensions for which A_{min} ≥ 4 %	EN 586–2:1994		x			
		EN 754–2:2013		x			
Aluminium wrought alloys	All metallurgic state and thickness for which A_{min} ≥ 4 %	EN 755–2:2013		x			
	Al 99,5 (1050A)	EN 573–3:2013		x	20	—	50
	Al Cu 5.5 Pb 0,4 Bi 0,4, new designation Al Cu6BiPb (2011)			x			
	Al Si 1 Mg 0,9 Mn 0,7 (6082) in T6 conditions with 0,5 ≤ plate thickness ≤ 30 mm, pipe thickness ≤ 20 mm, bar diameter ≤ 200 mm			x			
	All metallurgic state and thickness for which A_{min} ≥ 7 %	EN 485–2:2013		x	50	—	50
	All metallurgic state and dimensions for which A_{min} ≥ 7 %	EN 586–2:1994		x			
		EN 754–2:2013		x			
	All metallurgic state and thickness for which A_{min} ≥ 7 %	EN 755–2:2013		x			
Aluminium wrought alloys	Al Mg 0,5 Si 0,4 Fe 0,2 (6060) in T6 conditions with pipe thickness ≤ 20 mm, bar diameter ≤ 180 mm	EN 573–3:2013		x	50	—	50
	Al Si 1 Mg 0,9 Mn 0,7 (6082) in T6 conditions with 0,5 ≤ plate thickness ≤ 30 mm, pipe thickness ≤ 20 mm, bar diameter ≤ 200 mm			x			

Materials			Restrictions				
Group	Type	Relevant standard	Regulator / safety device				
			Operating temperature		PS_{max}	$[PS \times DN^b]_{max}$	$DN_{max}{}^b$
			−10 °C to 60 °C[a]	−20 °C to 60 °C	bar	bar × mm	mm
	All metallurgic state and thickness for which A_{min} ≥ 7 %	EN 485–2:2013		x	100	—	25
	All metallurgic state and dimensions for which A_{min} ≥ 7 %	EN 586–2:1994		x			
		EN 754–2:2013		x			
	All metallurgic state and dimensions for which A_{min} ≥ 7 %	EN 755–2:2013		x			
	Al Mg 0,5 Si 0,4 Fe 0,2 (6060) in T6 conditions with pipe thickness ≤ 20 mm, bar diameter ≤ 180 mm	EN 573–3:2013		x			
	Al Si 1 Mg 0,9 Mn 0,7 (6082) in T6 conditions with 0,5 ≤ plate thickness ≤ 30 mm, pipe thickness ≤ 20 mm, bar diameter ≤ 200 mm			x			
Aluminium cast alloys	All alloy designations with elongation ≥ 1,5 %	EN 1706:2010		x	10	250	150
	All alloy designations with elongation ≥ 1,5 %	ASTM B 85/B 85M:2013		x			
	LM4, LM6, LM 24, LM25,	EN 1559–1:2011, EN 1706:2010, EN 1774:1997		x			
	All alloy designations with elongation ≥ 4 %	EN 1706:2010		x	20	1 600	1 000
	All alloy designations with elongation ≥ 4 %	ASTM B 85/B 85M:2013		x			
Integral process and sensing lines							
Pipes	Cu 999	EN 1057:2006+A1:2010		x	25	—	—

Materials			Restrictions				
Group	Type	Relevant standard	Regulator / safety device				
			Operating temperature		PS_{max}	$[PS \times DN^{b}]_{max}$	$DN_{max}{}^{b}$
			−10 °C to 60 °C[a]	−20 °C to 60 °C	bar	bar × mm	mm
	X6CrNiMoTi17–12–2 / 1.4571	EN 10088–1:2014		x	100	—	—
	All grades	API SPEC 5L:2007+Errata:2009		x			
	All grades	ASTM A 106/A 106 M:2013		x			
	TP 304, TP 304L, TP 316, TP 316L	ASTM A 213/A 213 M:2014		x			
	TP 304, TP 304L, TP 316, TP 316L	ASTM A 269:2013		x			
	TP 304	ASTM A 312/A 312 M:2014		x			
Pipes	Grade 6	ASTM A 333/A 333 M:2013		x	100	—	—
	Screwed and socket steel tube	EN 10255:2004+A1:2007		x			
	St 37.4 / 1.0255	EN 10305–4:2011		x			
	St 35 / 1.0308	EN 10305–1:2010		x			
	X6 Cr Ni Ti 1810 / 1.4541	EN 10216–5:2013		x			
Connectors							
Compression fittings	All steel designations in Table 5, 11SMn30 / 1.0715 with A_{min} 8 % and 10 ≤ d ≤ 16, 11SMnPb30 / 1.0718 and 11SMnPb37 / 1.0737 both with A_{min} 8 % and 5 ≤ d ≤ 100	EN 10087:1998		x	100	—	—
	All steel designations	EN 10088–3:2014		x			
	All steel designations	EN ISO 8434-1:2007		x			
	All grades	ASTM A 420/A 420		x			

Materials			Restrictions				
Group	Type	Relevant standard	Regulator / safety device				
			Operating temperature		PS_{max}	$[PS \times DN^{b}]_{max}$	$DN_{max}{}^{b}$
			−10 °C to 60 °C[a]	−20 °C to 60 °C	bar	bar × mm	mm
		M:2013					
Fasteners							
Bolts, screws, studs and nuts	Class 10.9	EN ISO 898-1:2013		x	50	—	—
	Class 10	EN ISO 898-2:2012		x			
	All alloy groups and types with A_{min} ≥ 9 % for bolts, screws and studs	ASTM F 593:2013		x			
Bolts, screws, studs and nuts	Class 4.6, 5.6, 8.8	EN ISO 898-1:2013		x	100	—	—
	Grade A2ss, A4ss	EN ISO 3506-1:2009 , −2:2009 and −3:2009		x			
	Classes 5, 8, 9 for nuts	EN ISO 898-2:2012		x			
	All grades	ASTM A 193/A 193 M:2013		x			
	All grades for nuts	ASTM A 194/A 194 M:2013		x			
	All classes and grades	ASTM A 320/A 320 M:2011		x			
	All alloy groups and types with A_{min} ≥ 12 % for bolts, screws and studs	ASTM F 593:2013		x			
	All alloy groups	ASTM F 594:2009		x			
	Grade 8 for bolts etc.	SAE J429:2014		x			
	Grade 8 for nuts	SAE J995:2012		x			
The following remarks apply to all sheets of this table							

Materials			Restrictions				
Group	Type	Relevant standard	Regulator / safety device				
			Operating temperature		PS_{max}	$[PS \times DN^{b}]_{max}$	DN_{max}[b]
			−10 °C to 60 °C[a]	−20 °C to 60 °C	bar	bar × mm	mm

[a] These materials can be used for operating temperature from –20 °C to 60 °C when PS ≤ 25 bar.

[b] For the bodies of pilots or fixtures this term refers to their inlet connections.

Annex I
(normative)

Requirements for controls used in DC supplied burners and appliances burning gaseous or liquid fuels

I.1 Introduction

This annex makes use of the corresponding clauses in this standard by adapting them and stating “addition”, “modification” or “replacement”. Only the affected subclauses are mentioned in this annex, hence the following numbering is non-consecutive:

I.7.1 General

Shall be according to 7.1 with the following addition:

Controls with a *DC* power input port intended for use with an *AC/DC* power adaptor shall be tested on the *AC* power input of the *AC/DC* power adaptor.

Therefore *AC* supplied *DC* controls are not covered by this Annex I.

I.7.6.1 At ambient temperature

Shall be according to 7.6.1 with the following modification:

Replace “85 % of the minimum rated voltage” *by* “80 % of the minimum *DC* voltage”.

Replace “110 % of the maximum rated voltage” *by* “120 % of the maximum *DC* voltage”.

I.7.7.2.1 Thermal stress tests

Shall be according to 7.7.2.1 with the following modification:

Replace “85 % of the minimum rated voltage” *by* “80 % of the minimum *DC* voltage”.

Replace “110 % of the maximum rated voltage” *by* “120 % of the maximum *DC* voltage”.

I.7.7.3 Long-term performance tests

Shall be according to 7.7.3 with modification:

Replace “85 % of the minimum rated voltage” *by* “80 % of the minimum *DC* voltage”.

Replace “110 % of the maximum rated voltage” *by* “120 % of the maximum *DC* voltage”.

I.9.2 Supply voltage variations below 85 % of rated voltage

Shall be according to 9.2 with the following modification:

Replace “85 % of the rated voltage” *by* “80 % of the rated *DC* voltage”.

I.9.3 Voltage interruptions and dips

9.3 is replaced by the following:

These tests are only applicable for type C controls.

The control is tested in accordance with EN 61000-4-29:2000 with the test pulse durations and with a voltage according to the amplitudes specified in Table I.1.

The voltage interruptions shall be applied with “high impedance” and “low impedance”, which refers to the output impedance of the test generator as seen by the EUT during the voltage interruption.

NOTE According to EN 61000–4-29:2000, the *DC* supply network presents either a “high impedance” or “low impedance” condition during a short interruption, The first condition can be due to switching from one source to another; the second condition can be due to the clearing of an overload or fault condition on the supply bus. The latter can cause reverse current (negative peak inrush current) from the load. Additional information is given in the definitions of the test generator and test procedures of EN 61000–4-29:2000.

The interruptions or decreases are carried out at least 3 times under the test condition(s) specified in the specific control standard. There is an interval of at least 10 s between the interruptions or decreases.

Table I.1 — Short-term voltage interruptions and decreases

Duration [seconds]	Test levels (% of the rated voltage or mean value of the rated voltage range)		
	30 % decrease	60 % decrease	100 % (interruption)
0,01	X		X
0,03	X		X
0,1		X	X
0,3		X	X
1		X	X

a) For interruptions or decreases up to and including 0,03 s, the control shall conform to *Criterion* I as specified in 9.1;

b) For interruptions or decreases of 0,1 s and above, the control shall conform to *Criterion* II as specified in 9.1.

I.9.4 Supply frequency variations

9.4 is not applicable.

I.9.5 Surge immunity tests

Shall be according to 9.5 with the following modification:

This test is not applicable for *DC* supplied controls type B.

I.9.6 Electrical fast transient/burst

Shall be according to 9.6 with the following modification:

This test is not applicable for *DC* supplied controls type B.

I.9.7 Immunity to conducted disturbances

Shall be according to 9.7 with the following addition:

DC supplied controls type B shall conform to the following requirements on electrical transient conduction immunity:

Requirements:

Battery systems type B shall tolerate electrical transient conduction on the supply lines, so that when tested in accordance with I.9.7.2:

a) for the values of Table I.2 and I.3 line a): it shall continue to function in accordance with the requirements of this standard. It shall neither go to safety shutdown or lock-out, nor shall it reset from lock-out;

b) for the values of Table I.2 and I.3 line b): either it shall perform as in a) or it can proceed to safety shutdown which can be followed by an automatic restart, or if in volatile lock-out it can proceed to an automatic restart. If in non-volatile lock out it shall remain in that condition.

Table I.2 — Electrical transient conduction immunity in accordance with ISO 7637-2:2011

Assessment criteria	Test levels	Test pulses							
		1	2a	2b	3a	3b	4	5a	5b
a)	Level III (12V Systems) (24V Systems)	–75 –450	+37 +37	+10 +20	–112 –150	+75 +150	–6 –12	–6 –12	+65 +123
b)	Level IV (12V Systems) (24V Systems)	–100 –600	+50 +50	+10 +20	–150 –200	+100 +200	–7 –16	–7 –16	+87 +173

Table I.3 — Electrical transient conduction immunity in accordance with ISO 7637-3:2007

Assessment criteria	Test levels	Test pulses	
		a	b
a)	Level III (12V Systems) (24V Systems)	–40 –56	+30 +56
b)	Level IV (12V Systems) (24V Systems)	–60 –80	+40 +80

Tests:

For values in Table I.2 the system is tested in accordance with ISO 7637-2:2011 and for values in Table I.3 the system is tested in accordance with ISO 7637-3:2007.

For systems with different power supply voltage levels, the values for test pulses shall be adapted according to the required test levels.

Annex J
(normative)

Method for the determination of a Safety integrity level (SIL)

J.1 Scope

Shall be according to Clause 1 with the following addition:

This annex is only applicable to controls for which the manufacturer specifies a SIL Level.

This annex specifies a set of additional requirements to determine the safety integrity level (SIL) according to EN 61508 (all parts) for electrical/electronic/programmable control systems in industrial and thermo processing applications classified as Class B or Class C according to 4.3. The highest safety integrity level according to the method used in this annex is SIL 3 maximum, independent of the hardware architecture.

The current status of this document does only include requirements for controls operated in high demand or continuous mode according to EN 61508-4:2010, 3.5.12.

J.2 Normative references

Shall be according to Clause 2.

J.3 Terms and definitions

Shall be according to Clause 3 with the following addition.

J.3.1
common cause factor
ß
fraction of undetected failures that have a common cause
[SOURCE: EN 61508–6:2010, B.1]

J.3.2
failure modes and effects analysis
FMEA
analytical technique in which the failure modes of each hardware component are identified and examined for their effects on the safety-related functions of the control
[SOURCE: prEN 60730–1:2013, H.2.20.3]

J.3.3
failure modes, effects and diagnosis analysis
FMEDA
FMEA (see J.3.2) taking into account any automatic diagnostics to detect failures

J.3.4
proof test interval
interval between two proof tests

Note 1 to entry: For further information see EN 61508–4:2010, 3.8.5.

J.3.5

diagnostic test interval

interval between two automatic diagnostic tests which have a specified diagnostic coverage

Note 1 to entry: For further information see EN 61508–4:2010, 3.8.7.

J.3.6

1 out of 1 architecture

1oo1 architecture

controls that have a simple linear structure without redundant modules

J.3.7

1 out of 2 architecture

1oo2 architecture

controls where a single failure of any subsystem element does not cause a loss of the safety related control function(s)

J.4 Symbols

fit	**F**ailure **i**n **t**ime (failure rate of components): Number of components which fail within 10^9 h of operation ($1 fit = \frac{1}{10^9 \text{h}}$).
PFH_D	**P**robability of **d**angerous **f**ailures per **h**our for continuous or high demand mode
λ_D	Rate of dangerous failures per hour
λ_{DU}	Rate of undetected dangerous failures per hour
λ_{DD}	Rate of detected dangerous failures per hour
SFF	Safe failure fraction
DC	Diagnostic coverage
B_{10d}	Mean number of cycles until 10 % of electromechanical components fail dangerously [EN ISO 13849-1:2008]
n_{op}	Number of operating cycles per year

NOTE For further information see EN 61508–4:2010.

J.5 Special requirements to determine a Safety Integrity Level (SIL)

J.5.1 Functional safety

This annex deals with the requirements resulting from EN 61508 (all parts) and which apply in addition to the requirements of this document.

The hardware requirements of J.5.4 are based on EN 61508-2:2010.

For software the requirements of prEN 60730-1:2013, Annex H, which are based on EN 61508-3:2010, apply.

The requirements are only applicable to controls performing safety-related control functions (Class B or Class C). If the circuit of a device includes components which are not relevant for safety-related control functions, only the absence of interaction with the safety-relevant components shall be considered.

J.5.2 Management of functional safety

J.5.2.1 Methods of fault prevention

Methods of fault prevention shall be applied in all of the following phases:

- specification of safety requirements;
- design and construction;
- implementation;
- integration of hardware and software;
- definition of operation and maintenance activities with respect to functional safety.

The methods to avoid faults shall be based on a formal system, called Functional Safety Management System.

J.5.2.2 Functional Safety Management System

J.5.2.2.1 General

The manufacturer of a control shall draw up and specify

- management and technical activities which are necessary to achieve the required functional safety of the control;
- responsibilities applicable to persons, departments and organizations responsible for activities relating to the development of a control.

The management activities shall include definitions of actions and responsibilities; scheduling and resource allocation; training of relevant personnel; consistency checks after modifications.

NOTE For detailed examples see EN 61508–7:2010, B.1.1.

The management activities shall include procedures for periodic review and maintenance of the Functional Safety Management System.

J.5.2.2.2 Documentation

The Functional Safety Management System shall include requirements for the documentation of each activity or procedure.

The documentation management shall consider the following aspects:

- information to be documented;
- availability of documentation;
- accurate documentation;
- standardized documentation;
- company documentation structure;
- document revision index;

- structured documentation;
- review of documentation.

Documentation shall be structured. It shall use natural language and graphical descriptions, such as block diagrams and flow diagrams. The use of contents check-lists is highly recommended.

NOTE For detailed examples see EN 61508–7:2010, B.1.2.

J.5.2.2.3 Functional safety plan

J.5.2.2.3.1 General

The Functional Safety Management System shall include requirements to set up a functional safety plan for each project. If certain requirements for the functional safety plan apply generally to any project, the relevant measures and procedures can be part of the Functional Safety Management System to be referred to by the functional safety plan.

A functional safety plan shall be drawn up, documented and maintained to control the activities specified for each control design project.

The activities resulting from J.5.2.2.3.2 shall be implemented and progress monitored.

The requirements developed as a result of J.5.2.2.3.2 shall be formally reviewed by the organizations concerned, and agreement reached. The functional safety plan shall be updated as necessary.

J.5.2.2.3.2 Requirements

The functional safety plan shall be implemented to ensure prompt follow-up and satisfactory resolution of issues relevant to a control arising from:

- specification activities;
- design and development activities;
- integration activities;
- verification activities;
- validation activities;
- operation and maintenance activities.

If not already covered by the general requirements J.5.2.2.1, the functional safety plan shall in particular include the following activities:

a) Selection of appropriate measures and techniques used to meet the requirements of this annex. This includes references to guidelines and standards which have to be observed.

b) Identification of the relevant activities specified in l).

c) Identification of the policy and strategy to achieve specified functional safety requirements.

d) Identification of the strategy to achieve functional safety for the software procurement, development, integration, verification, validation and modification.

e) Identification of persons, departments or other units, and organizations (including, where relevant, licensing authorities or safety regulatory bodies) that are responsible for carrying out and reviewing each of the activities specified in l). All those persons specified as responsible for management of functional safety activities shall be informed of the responsibilities assigned to them. Procedures shall be defined to ensure that applicable parties involved in any activities are competent to carry out the activities for which they are accountable, e.g. by training.

f) Definition of the way in which information is to be structured and the extent of the information to be documented.

g) Identification and establishment of procedures to record and maintain information relevant to the functional safety of a control. The procedures shall be based on the information which is related to the activities described in l). The compilation of the information shall result in

- a functional requirements specification for the control;
- a safety requirements specification for the control.

h) Description of the procedures for functional safety assessment activities. The plan for the functional safety assessment shall specify:

- those to undertake the functional safety assessment;
- the outputs from each functional safety assessment;
- the scope of the functional safety assessment;

NOTE In establishing the scope of the functional safety assessment, it will be necessary to specify the documents, and their status, which are to be used as inputs for each assessment activity.

- the safety bodies involved;
- the resources required;
- the level of independence of those undertaking the functional safety assessment;
- the competence of those undertaking the functional safety assessment.

i) Establishment of a verification plan for all activities described in l). It shall include:

- details of when the verification shall take place;
- details of the persons, departments or units who shall carry out the verification;
- the selection of verification strategies and techniques;
- the selection and utilization of test equipment (including environment, tools, programs);
- the selection of verification activities;
- acceptance criteria; and
- the means to be used for the evaluation of verification results.

j) Establishment of a validation plan comprising:

- details of when the validation shall take place;
- requirements against which the control is to be validated;
- the technical strategy for validation, for example analytical methods or statistical tests;
- the test environment, tools, configuration and programs;
- acceptance criteria; and
- action to be taken in the event of failure to meet the acceptance criteria.

The validation plan shall include all activities and methods during development, implementation and integration, which are necessary to prove the control against its functional requirements specification and its safety integrity requirements specification.

k) Description of the procedures for configuration management taking into account relevant technical and organisational issues, such as authorized persons and internal structures of the organization.

l) Description of the procedures for modifications on controls and the required approval procedures and authorities for modifications. For software configuration management prEN 60730-1:2013, H.11.12.3.4.3 applies.

J.5.2.3 Specification of safety requirements

J.5.2.3.1 The specification shall be structured with a hierarchical separation into sub requirements; refined down to functional level.

J.5.2.3.2 The safety requirements specification shall include a description of all safety-related control functions.

For each safety-related control function the description shall

- provide comprehensive detailed requirements sufficient for the design and development of the control;
- include the manner in which the control is intended to achieve or maintain a safe state for the appliance;
- specify the relevant modes of operation (e.g. permanent/non-permanent operation of the appliance), and other time related aspects to achieve or maintain a safe state of the application;
- specify whether the control operates the safety-related control function in high demand/continuous mode;
- define the safety integrity level (SIL) for each safety-related control function, if necessary.

J.5.2.3.3 The safety requirements specification for the control shall include appropriate requirements to consider

- the boundary of the application and possible hazards (from process, environment, etc.);
- operation, functions, interfaces, special safety regulations and environment of the appliance;
- all hazards or hazardous events of the appliance, and all potential hazards for the application arising from the control itself;
- safety requirements, safety-related control functions requirements and safety integrity requirements for the control.

J.5.2.3.4 The interfaces between safety-related control functions and non-safety-related control functions shall be well-defined.

Safety-related control functions and non-safety-related control functions as well as safety-related control functions with different safety integrity levels shall be implemented sufficiently independent, otherwise they shall be implemented with the highest safety integrity level associated to a function.

During design, the method of achieving independence and the justification of the method shall be documented to show independence between functions as required above.

J.5.2.3.5 For software safety requirements specification prEN 60730-1:2013, H.11.12.3.2 applies.

J.5.2.3.6 The safety requirements specification shall be inspected by an independent person using a formal procedure with correction of all faults found.

NOTE For detailed examples see EN 61508–7:2010, B.2.6.

J.5.2.4 Design and development

J.5.2.4.1 Hardware and, if applicable, software shall be split into easy comprehensible modules of limited size, with each module functionally isolated.

NOTE For detailed examples see EN 61508–7:2010, B.3.2.

J.5.2.4.2 Design shall be based on semi-formal methods. The use of computer aided design tools is recommended.

NOTE For detailed examples see EN 61508–7:2010, B.2.3 and B.3.5.

J.5.2.4.3 Common cause failures shall be considered during design and the related reviews.

J.5.2.4.4 For software design and development see prEN 60730-1:2013, H.11.12.3.2.3 applies.

J.5.2.5 Integration

J.5.2.5.1 During integration all functions shall be tested based on predefined test cases. These tests shall be performed as a black-box tests under consideration of boundary values combined with critical cases.

These tests shall also cover diagnostic methods realized as software to detect hardware faults.

NOTE For detailed examples see EN 61508–7:2010, B.5.2.

J.5.2.5.2 For software integration prEN 60730-1:2013, H.11.12.3.2.1 applies.

J.5.2.6 Validation

J.5.2.6.1 Validation activities shall be independent from design activities.

J.5.2.6.2 Validation shall make use of static analysis and dynamic analysis by using detailed diagrams. The analysis shall result in a specification of test cases which are basis for functional tests (see J.5.2.6.3) and for fault insertion tests (see 6.6).

NOTE For detailed examples see EN 61508–7:2010, B.6.4 and B.6.5.

J.5.2.6.3 Validation shall be based on expanded functional tests, proving that all safety-related control functions are maintained in the case of static input states and/or unusual input changes, caused by faulty process or operating conditions.

NOTE For detailed examples see EN 61508–7:2010, B.6.8.

J.5.2.6.4 Appropriate information shall be communicated to the appliance manufacturer for the safety validation of the control system within the appliance (see J.5.2.8).

J.5.2.6.5 For software validation prEN 60730-1:2013, H.11.12.3.3.3 applies.

J.5.2.7 Operation and maintenance

J.5.2.7.1 The instructions shall be user and maintenance friendly.

NOTE For detailed examples see EN 61508–7:2010, B.4.2 and B.4.3.

J.5.2.7.2 Access to operation possibilities shall be limited by appropriate safety measures, such as password protection.

Safety related functions of the control shall be protected against operator mistakes by input acknowledgement and consistency checks on each operating command.

NOTE For detailed examples see EN 61508–7:2010, B.4.4 and B.4.6.

J.5.2.7.3 If necessary to maintain functional safety of the control within the application, appropriate information shall be communicated to the appliance manufacturer (see J.5.2.8).

J.5.2.8 Information to the appliance manufacturer

If not covered by the controls standard additional information shall be provided to the appliance manufacturer concerning:

- hazards for the application arising from the control itself;

NOTE With reference to the appliance standards, a hazard analysis for the control is usually not required if all hazards are completely covered by the appliance standard.

- actions and methods for installation, commissioning, decommissioning and disposal of the control within the application;
- actions and methods for safety validation of the control within the application;
- actions and methods for operation, maintenance, repair, modification and retrofit of the control within the application;
- actions to maintain the required functional safety of the control during operation and maintenance. This shall include:
  - the substitution of the complete control;
  - the inspection of components with limited operating life (e.g. UV photo tubes);
  - the substitution of components with limited operating life.

J.5.3 Software requirements

See prEN 60730-1:2013, Annex H.

J.5.4 Hardware requirements

J.5.4.1 General

J.5.4.1.1 The determination of the SIL level is based on a fault assessment according to 6.6, under additional consideration of

— J.5.4.3 Diagnostic measures and their maximum coverage,

— J.5.4.4 Failure rates and failure modes,

— J.5.4.5 Determination of common cause factors for complex systems.

J.5.4.1.2 All hardware modules of the control that perform safety functions according to the functional specification of the control standard shall be considered in the analysis. Thus all components within those modules which had been subject of fault assessment of 6.6, shall be identified to be subject of this additional examination. This does also include components which are shared between safety and non-safety functions or provide de-coupling from non-safety related functions.

J.5.4.1.3 All requirements of J.5 consider controls to be operated in high demand mode according to EN 61508-4:2010, 3.5.12. Thus a PFH_D value needs to be determined.

J.5.4.1.4 1oo1 architecture

J.5.4.1.4.1 General

Controls that have a simple linear structure without redundant modules are classified as 1oo1 architecture.

Those controls are represented by the following architecture models A and C based upon EN 62061:2005, 6.7.8.2.

J.5.4.1.4.2 Basic architecture A: 1oo1 architecture without diagnostic function

Any dangerous failure of a subsystem element causes a failure of the control function (see Figure J.1 for a subsystem with basic architecture A). The subsystem does not include diagnostic measures.

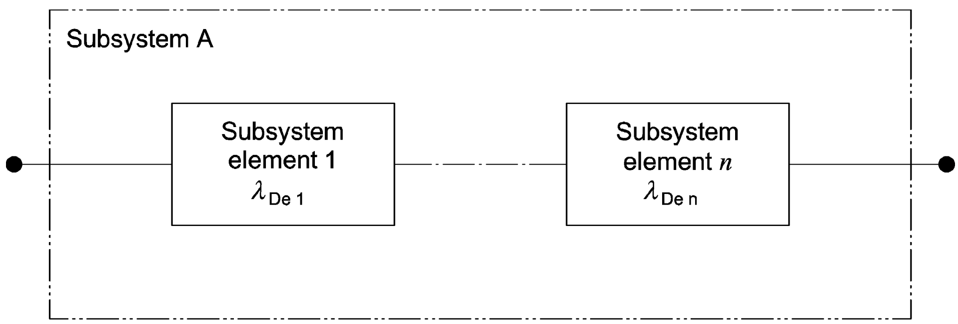


Figure J.1 — Subsystem with basic architecture A – logical representation

Figure J.1 is a logical representation of the Subsystem A architecture and should not be interpreted as its physical implementation (e.g. flame sensor without self check or O_2 probe without self check).

J.5.4.1.4.3 Basic architecture C: 1oo1 architecture with diagnostic function(s)

Any undetected dangerous fault of a subsystem element results in a dangerous failure of the safety related control function(s) (see Figure J.2 for a subsystem with basic architecture C). Where a fault of a subsystem element is detected, the diagnostic function(s) initiates a fault reaction function. The diagnostic functions are carried out by either:

— the subsystem which requires diagnostics; or

— other subsystems of the safety related control function(s); or

— subsystems not involved in the performance of the safety-related control function.

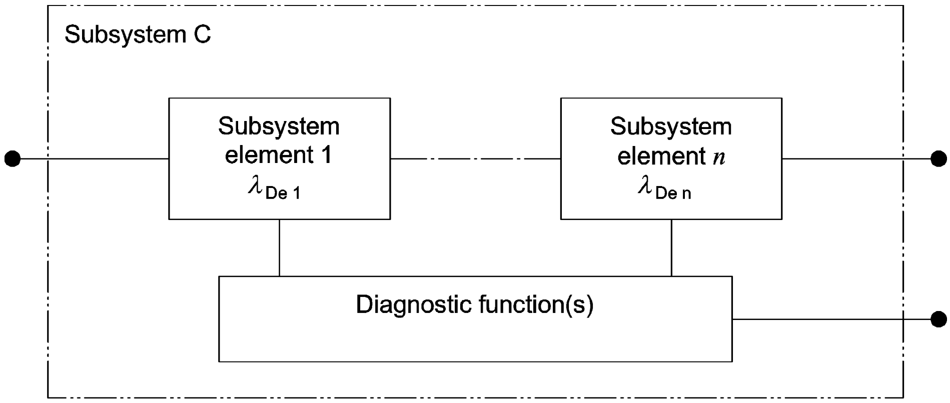


Figure J.2 — Subsystem with basic architecture C - logical representation

Figure J.2 is a logical representation of the Subsystem C architecture and should not be interpreted as its physical implementation (e.g. flame sensor with self check or O_2 probe with self check).

J.5.4.1.5 Complex architecture

J.5.4.1.5.1 General

All systems other than 1oo1 systems shall be split into subsystems such that the methods of J.5.4.6.7.2 can be applied to calculate the overall PFH_D.

Complex architectures require a common cause factor β to be determined for calculation according to J.5.4.5.

Those controls are represented by a combination of subsystems with architecture models A, B, C or D based upon EN 62061:2005, 6.7.8.2.

J.5.4.1.5.2 Basic architecture B: 1oo2 architecture without diagnostic function

This architecture is such that a single failure of any subsystem element does not cause a loss of the safety related control function(s) (see Figure J.3 for a subsystem with basic architecture B). Thus, there would have to be a dangerous failure in more than one element before failure of the safety related control function(s) can occur. The subsystem does not include diagnostic measures.

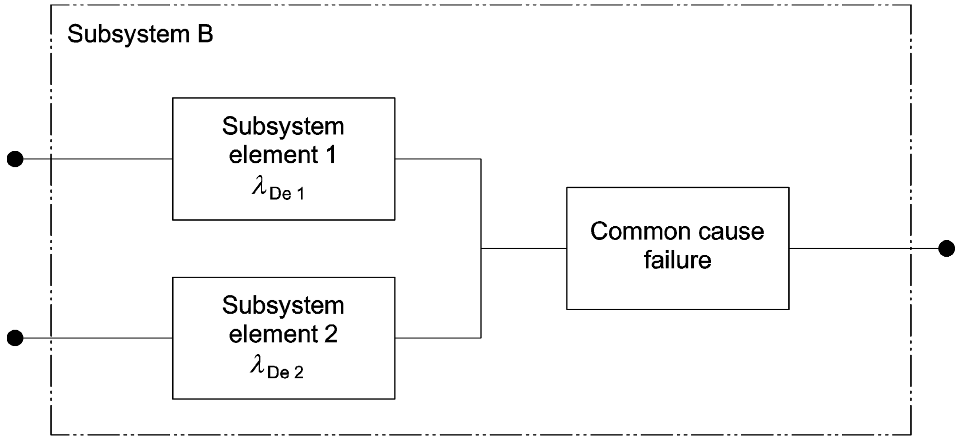


Figure J.3 — Subsystem with basic architecture B - logical representation

Figure J.3 is a logical representation of the Subsystem B architecture and should not be interpreted as its physical implementation.

J.5.4.1.5.3 Basic architecture D: 1oo2 architecture with diagnostic function(s)

This architecture is such that a single failure of any subsystem element does not cause a loss of the safety related control function(s) (see Figure J.4 for a subsystem with basic architecture D). Where a fault of a subsystem element is detected, the diagnostic function(s) initiates a fault reaction function. The diagnostic functions are carried out by either

— the subsystem which requires diagnostics; or

— other subsystems of the safety related control function(s); or

— subsystems not involved in the performance of the safety-related control function.

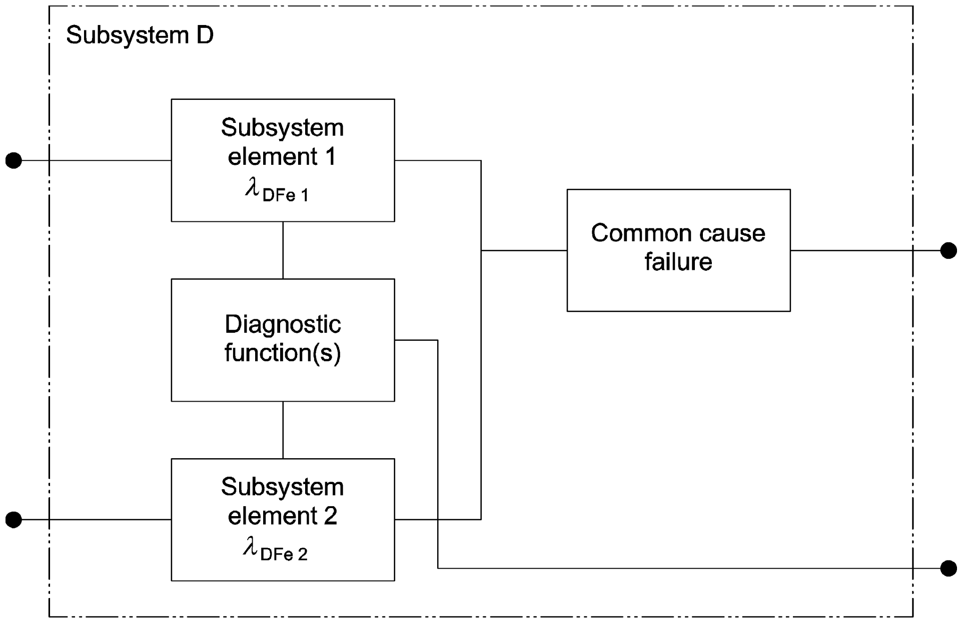


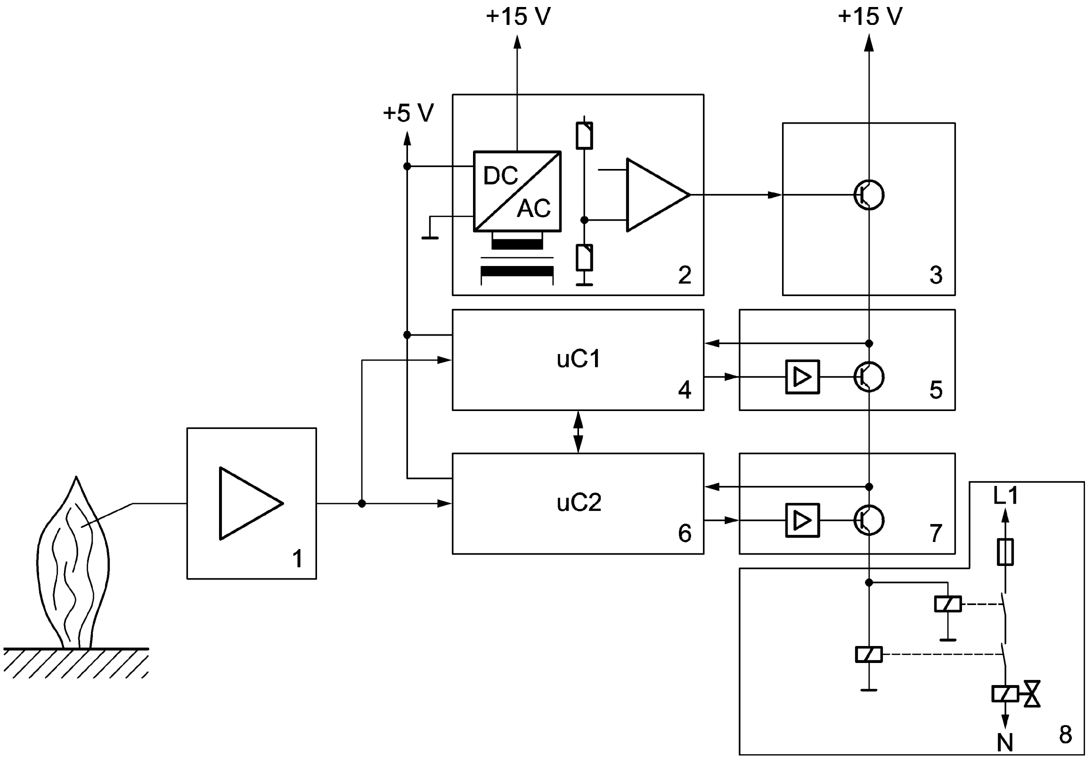
Figure J.4 — Subsystem with basic architecture D logical representation

Figure J.4 is a logical representation of the Subsystem D architecture and should not be interpreted as its physical implementation.

NOTE The fault reaction for this subsystem is assumed to be termination of the relevant operation. Online repair, as defined in EN 62061:2005, is not assumed to be applicable for controls according to this document.

J.5.4.1.5.4 Examples of complex architecture systems

Figure J.5 represents the physical fragmentation of the circuit of a burner control system into hardware modules (hardware block diagram).



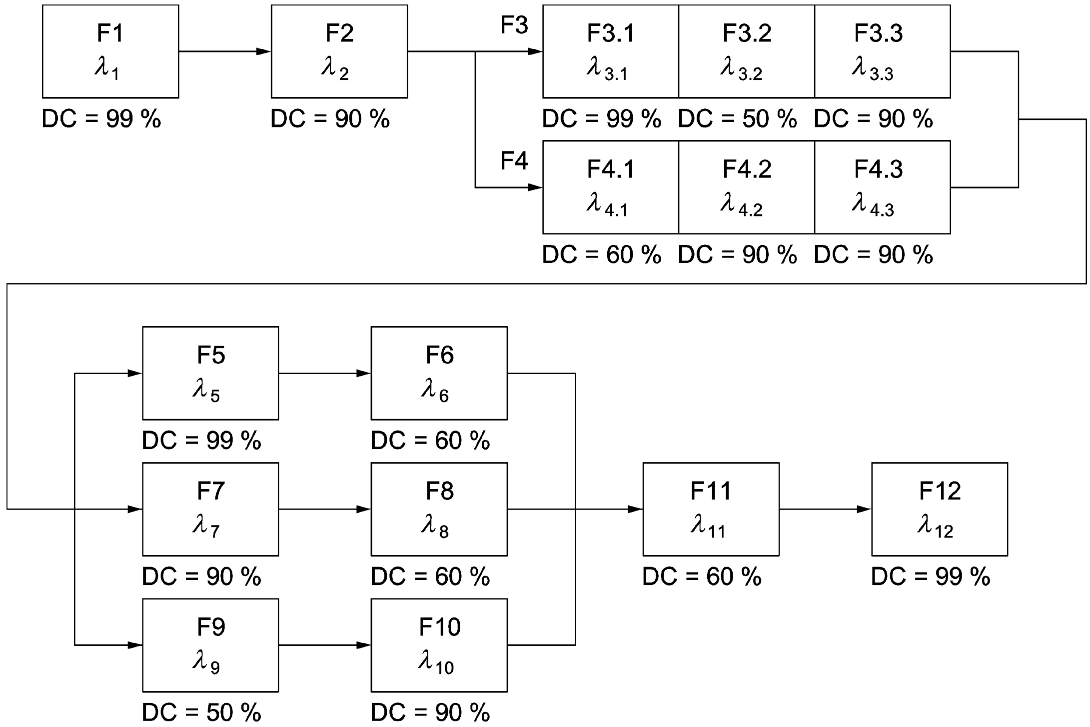
Key

1)	flame amplifier	5)	disconnecting element for uC1
2)	power supply (NT)	6)	uC2 = Microcontroller 2 module
3)	disconnecting element for NT	7)	disconnecting element for uC2
4)	uC1 = Microcontroller 1 module	8)	output module

Figure J.5 — Example of complex architecture: Burner control system (symbolized schematic)

Figure J.6 demonstrates the logical segregation of a burner control system into function blocks. Each function block represents a subsystem element, or a common cause failure of redundant subsystem elements. The function blocks are connected to form a reliability block diagram of the system.

NOTE The control systems represented by Figures J.5 and J.6 are different.



Key

F1 … F12 function blocks, e.g.

- power supply (with voltage monitoring)
- microcontroller
- EEPROM
- relay driver
- relay contact
- flame sensor and flame signal amplifier
- common cause failures
- control and monitoring of external component
- etc.

DC diagnostic coverage (example) for function block F_n

λ_n failure rate of function block F_n

Figure J.6 — Example of a complex architecture: Reliability block diagram of a burner control system based on segregation into function blocks

J.5.4.1.6 The calculation of λ (failure rate), *DC* (Diagnostic Coverage) and *SFF* (Safe Failure Fraction) according to J.5.4.6 is based on the single failure assessment under consideration of all control functions.

J.5.4.1.7 In accordance with EN 61508-2:2010, C.1, the hardware failure effects are classified as follows:

— **dangerous**: failures which, under absence of diagnostic methods, would cause a dangerous failure of the control (e.g. short circuit of one of the components in the shut-off path; open circuit of a crystal resonator).

— **safe**: failures which, under absence of diagnostic methods, would **not** cause a dangerous failure of the control, but can impair the reliability (e.g. open circuit of components for safety related inputs, open circuit of components in the shut-off path).

— **do not care**: Failures which do not impair safety integrity (e.g. open circuit of emc protection capacitors).

NOTE Controls are assumed to be safe if they conform to the requirements for functional safety of 6.6, which include the assumption of up to two independent faults, as well as the diagnostic methods and the reaction on detected faults.

Thus there is no direct relationship between the fault effect categorization “a”, “b”, “c” or “d” of EN 13611:2007+A2:2011, 6.6.3.2 and 6.6.4.2 and the classifications “dangerous” or “safe” of this document.

J.5.4.2 Procedural approach

J.5.4.2.1 Based on the parts list for each control (or its subsystem) a failure modes and effects analysis (according to definition J.3.2) is performed with a classification of failures into “dangerous” or “safe” according to J.5.4.1.7.

NOTE “Do not care failures are not considered in further calculations”:

J.5.4.2.2 Failures which are classified as “dangerous” are subject to an analysis considering their possible detection by diagnostic measures or techniques described in J.5.4.3 (FMEDA = failure modes, effects and diagnosis analysis, see J.3.3) resulting in detected and undetected failures.

J.5.4.2.3 Two independent faults shall not be considered for calculation of λ, DC and SFF.

J.5.4.2.4 If the control is not separated into subsystems a 1oo1 structure is assumed (see J.5.4.1.4).

J.5.4.2.5 A separation into subsystems helps to analyse the effectiveness of diagnostic measures in complex design structures more accurately. This requires determining the evidence of common cause failures according to the method described in J.5.4.5.

It is assumed that any safety related control system can be separated into subsystems of basic architecture types A, B, C or D according to J.5.4.1.4 and J.5.4.1.5.

Concerning the failure effects each subsystem shall be analysed separately.

NOTE In particular a separation into subsystems can apply to Class C / SIL 3 controls.

J.5.4.2.6 Finally an overall calculation is performed using all individual results of the subsystems. The system architecture will influence the calculation method.

J.5.4.3 Diagnostic measures and their maximum coverage

The following information is only valid if the diagnostic measures are performed automatically by the control (but not by the process), either periodically or on demand.

Table J.1 provides techniques, and Table J.2 provides measures of diagnostic tests to detect and to control random hardware failures in order to achieve the relevant level of diagnostic coverage (DC).

If diagnostic tests conform to the requirements of “Reference”, the mentioned diagnostic coverage (*DC*) can be used for calculation. Other measures and techniques can be used, provided evidence is produced to support the claimed diagnostic coverage.

Table J.1 — Diagnostic techniques

Diagnostic technique	**Reference**	*DC*	**Notes**
Failure detection by online monitoring	EN 61508–2:2010, A.2, A.3	90 %	Depends on diagnostic coverage of failure detection
Idle current principle	EN 61508–2:2010, A.2, A.15	60 %	Electromechanical systems, actuators
Monitoring of relay contacts	EN 61508–2:2010, A.2, A.15	99 %	Electromechanical systems, actuators
Comparator	EN 61508–2:2010, A.2, A.3	99 %	High if failure modes are predominantly in a safe direction
Majority voter	EN 61508–2:2010, A.2, A.3	99 %	Depends on the quality of the voting
Tests by redundant hardware	EN 61508–2:2010, A.3	90 %	Depends on diagnostic coverage of failure detection
Dynamic principles	EN 61508–2:2010, A.3	90 %	Depends on diagnostic coverage of failure detection
Monitored redundancy	EN 61508–2:2010, A.3	90 %	Depends on diagnostic coverage of failure detection
Watch-dog with separate time base without time window	EN 61508–2:2010, A.10, A.12	60 %	Program sequence, clock
Watch-dog with separate time base with time window	EN 61508–2:2010, A.10, A.12	90 %	Program sequence, clock
Combination of temporal and logical monitoring of the program sequence	EN 61508–2:2010, A.10, A.12	99 %	Program sequence, clock
Overvoltage protection with safety shut-off	EN 61508–2:2010, A.9	60 %	Power Supply
Secondary voltage control and protection with safety shut-off	EN 61508–2:2010, A.9	99 %	Power Supply

Table J.2 — Diagnostic measures

Diagnostic measure	Reference	*DC*	Notes
Test pattern	EN 61508–2:2010, A.7	99 %	I/O units
Analogue signal monitoring	EN 61508–2:2010, A.3, A.14	60 %	I/O units, sensors
Reference sensor	EN 61508–2:2010, A.14	90 %	Sensors
Modified checksum	EN 61508–2:2010, A.5	60 %	Invariable memory (ROM)
Single word (8-bit) signature (CRC)	EN 61508–2:2010, A.5	90 %	Invariable memory (ROM). The effectiveness of the signature depends on the width of the signature in relation to the block length of the information to be protected
Double word (16-bit) signature (CRC)	EN 61508–2:2010, A.5	99 %	Invariable memory (ROM) The effectiveness of the signature depends on the width of the signature in relation to the block length of the information to be protected
RAM tests “checkerboard” or “march”	EN 61508–2:2010, A.6	60 %	Variable memory (RAM)
RAM tests “walk-path”	EN 61508–2:2010, A.6	90 %	Variable memory (RAM)
RAM tests “galpat” or “transparent galpat” or “Abraham”	EN 61508–2:2010, A.6	99 %	Variable memory (RAM)
Double RAM with hardware or software comparison and read, write tests	EN 61508–2:2010, A.6	99 %	Variable memory (RAM)
Single-channel self-tests by software (walking bit)	EN 61508–2:2010, A.4	90 %	Processing unit (CPU)
Reciprocal comparison by software	EN 61508–2:2010, A.4	99 %	Processing unit (CPU); depends on the quality of comparison
Information redundancy	EN 61508–2:2010, A.8	99 %	Internal communication

J.5.4.4 Failure rates and failure modes

J.5.4.4.1 Failure modes of components

Table E.1 of this document applies with the modifications of Table J.3.

Certain faults can be excluded, provided that the theoretical probability of their occurrence is very low in relation to the safety integrity requirements of the subsystem.

Any such fault exclusions shall be justified and documented, and shall be based on:

— the technical improbability of their occurrence in combination with specific requirements to components,

— the generally accepted technical experience, independent from the application, and

— the technical requirements related to the application and the specific hazards.

NOTE 1 See EN ISO 13849-1:2008, 7.3.1 and EN 61508–2:2010, 7.4.3.1.1.c.

NOTE 2 The failure mode “drift” is only considered for those components which are known as safety-related control functions being impaired by drift effects (e.g. thermistors, or electrolytic capacitors used to determine safety related timing).

J.5.4.4.2 Failure rates of components

The failure rates of components are determined according to Table J.3 under consideration of an average ambient temperature between the min. and max. temperature or 40°C, and under consideration of a de-rating of components to 67 %.

If the ambient conditions and/or load conditions differ from the values specified by this standard, the failure rates shall be recalculated.

For components others than included in Table J.3 the individual failure rates shall be determined using the failure rates provided by the manufacturer. This can in particular apply to relays, flame sensing elements, etc.

A method to determine the failure rate for relays by using the B_{10d} value is provided in J.5.4.4.3.

NOTE 1 For easier calculation the failure rates are split into equivalent fractions considering the number of failure modes. E.g. for diodes the basis failure rate λ_B is split for fault modes “open” and “short” into $\lambda_{open} = \lambda_{short} = \lambda_B/2$.

NOTE 2 The failure rates provided in Table J.3 and the methods to calculate ambient and load conditions have been extracted from SN 29500 series database.

Table J.3 — Failure rates and failure modes

Component type	failure modes							failure rates	
	short	open	Drift 1/2x	Drift 2x	others	no. of pins	no. of faults	component failure rate λ [*fit*] [a]	failure rate [*fit*] per fault
Column	1	2	2a	2b	2c	3	4	5	6
Resistors									
Carbon film		1				2	1	1,6	1,6
Metal film		1				2	1	0,3	0,3
Metal oxide		1				2	1	8,0	8,0
Wire wound	1	1				2	2	8,0	4,0
Networks per resistor element	1	1				2	2	0,2	0,1
Variable resistors									
Wire-wound (single layer)		1				3	3	48,0	16,0
Capacitors									
Metallized film acc. to EN 60384–16:2005 MKT, MKP, MKU		1				2	1	4,3	4,3
Metallized film acc. to EN 60384–16:2005 MKC		1				2	1	7,3	7,3
Metal foil: KC		1				2	1	20,9	20,9
Metal foil: KS, KP, KT		1				2	1	7,4	7,4
Metallized paper (film): MP, MKV	1	1				2	2	12,4	6,2
Ceramic: NDK/ LDC, COG, NPO	1	1				2	2	4,8	2,4
Ceramic: HDK/MDC, X7R, X5R	1	1				2	2	9,7	4,8
Ceramic: HDK/HDC, Z5U,Y5V, Y4T	1	1				2	2	24,2	12,1
Aluminium electrolyte (solid electrolyte)	1	1	1			2	3	2,2	0,75
Tantalum electrolyte (solid electrolyte)	1	1	1			2	3	51,8	17,3
Adjustable	1	1				2	2	14,0	7,0
Inductors, transfomers									
LF inductors, transformers	1	1				2	2	7,0	3,5
Inductors for emc suppression	1	1				2	2	2,1	1,05
Main transformers and transformers for switched mode power supplies [b]	1	1			–4	4	6	48,0	8,0
Main transformers and transformers for switched mode power supplies	1	1				4	10	48,0	4,8

Component type	failure modes							failure rates	
	short	open	Drift 1/2x	Drift 2x	others	no. of pins	no. of faults	component failure rate λ [*fit*] [a]	failure rate [*fit*] per fault
Diodes etc.									
Universal, Schottky diodes	1	1				2	2	2,3	1,15
Suppressor diodes	1	1				2	2	16,8	8,4
Z diodes < 1W	1	1				2	2	2,4	1,2
Z diodes > 1W	1	1				2	2	47,5	23,8
Reference diodes	1	1	1	1		2	4	16,1	4,0
Rectifier diodes	1	1				2	2	4,0	2,0
Rectifier bridges	1	1				4	10	20,0	2,0
Diacs [c]	1	1			2	2	4	150,0	37,5
Transistors etc.									
bipolar, universal, e.g. TO18, TO92, SOT23	1	1				3	6	7,6	1,3
bipolar low-power, e.g. TO 5, TO39	1	1				3	6	52,8	8,8
Transistor arrays per transistor	1	1				3	6	38,0	6,3
bipolar power, e.g. TO3, TO220	1	1				3	6	132,0	22,0
FET junction, MOS	1	1				3	6	12,7	2,1
MOS, power, e.g. TO3, TO220	1	1				3	6	264,0	44,0
Thyristors [c]	1	1			2	3	8	100,0	12,5
Triacs [c]	1	1			2	3	8	150,0	18,5
Integrated circuits [d] [e]									
µC / ASIC / PLD ≤ 32 pin [CORE]								50,0	
[IC]	1	1				16	57	90,5	1,59
µC / ASIC / PLD > 32 pin [CORE]								100,0	
[IC]	1	1				40	153	201,3	1,32
EEPROM	1	1				28	105	120,9	1,15
OpAmp bipolar	1	1				8	25	13,8	0,55
OpAmp CMOS, reference elements	1	1				8	25	8,8	0,35
Controller (switching regulator)	1	1				6	17	23,0	1,35
Transmitter / Receiver / ADC	1	1				8	25	23,0	0,9

Component type	failure modes							failure rates	
	short	open	Drift 1/2x	Drift 2x	others	no. of pins	no. of faults	component failure rate λ [*fit*] [a]	failure rate [*fit*] per fault
CMOS / TTL logic gates	1	1				16	57	11,5	0,2
Opto electronic components									
Optocoupler, bipolar output	1	1				4	10	42,0	4,2
Optocoupler, FET output	1	1				4	10	104,0	10,4
Si photo diode / Si PIN photo diode	1	1				2	2	5,7	2,9
Ge photo diode	1	1				2	2	185,0	92,5
Si photo transistor	1	1				3	6	6,3	1,05
Photo element	1	1				2	2	6,0	3,0
Flame sensors (foto resistors, etc.) [f]	1	1				2	2		
UV tubes	1	1				2	2	50 000	25 000
Relays [g]									
coils	1	1				2	2		
contacts	1	1				2	2		
Crystals, Quartz oscillators [h]	1	1				2	2	15,0	7,5
Ceramic resonators [h]	1	1				2	2	5,0	2,5
Fuses		1				2	1	25,0	25,0
Surge arresters (gas filled)	1	1				2	2	1,0	0,5
Switches									
DIP switches, per contact	1	1				2	2	0,3	0,15
Power switches, per contact	1	1				2	2	80,0	40,0
Jumpers (per contact)		1				2	1	1,0	1,0
Cable, wiring and connectors		1				2	1	1,0	1,0

Component type	failure modes							failure rates	
	short	open	Drift 1/2x	Drift 2x	others	no. of pins	no. of faults	component failure rate λ [*fit*] [a]	failure rate [*fit*] per fault

NOTE Explanation of columns:

1; 2 Failure modes taken from this document

2a, 2b Failure modes "drift to half nominal value" and "drift to double nominal value",

2c Special failure modes (see footnote)

3 Number of connecting pins per component

4 Number of faults resulting from 1, 2, 2a, 2b, 2c and 3

5 Failure rate per component (see foot note [a])

6 Failure rate per fault

[a] The failure rate is calculated from the basis failure rate, a temperature dependence factor π_T based upon this document maximum ambient temperature conditions (+60 °C), a voltage dependence factor πU calculated for U/U_{max} = 0,7 (Derating to 67 % according to EN 61508–2:2010, 7.4.2.13) and a load dependence factor πL.

[b] Failure mode exclusion "short circuit primary/secondary" ("–4" means: the total number of faults is decreased by the number of excluded short circuits).

[c] Failure modes "half wave mode A/K" resp. "half wave mode K/A" in column | 2c |.

[d] Input no. of pins in column | 3 | (n = no. of pins).

[e] Failure rate$_{[IC]}$ = failure rate$_{[CORE]}$ + (n * failure rate $_{[bipol. transistor]}$/3) ➔ column | 4 |

$N_{[IC]}$ = no. of failure modes = $N_{[short circuit]} + N_{[open]}$

$N_{[short circuit]} = (n - 1) + (n - 2) + (n - 4)$;
short circuit of adjacent pins, and short circuits between any pin and $+V_{CC}$,
and any pin and $-V_{CC}$ (GND)

$N_{[open]} = n$

[f] To be determined individually; see J.5.4.4.2.

[g] The failure rate shall be determined for each individual component; see J.5.4.4.3. Failure rates apply to each contact.

[h] Sub harmonics/harmonics are covered by this document.

J.5.4.4.3 Failure rates for relays

As the failure rate of relays depends on the conditions for the specific application, a B_{10d} value shall be supplied by the relay manufacturer or determined by the controls manufacturer. The B_{10d} value shall consider the specified conditions, as electrical load, ambient conditions and operating frequency (load cycles per time).

The B_{10d} value is transformed into λ_D according to K.4.6.1, Formula (K.6).

The assumed total number of operations during lifetime shall be less than B_{10d}.

The following simplification is assumed:

$$\lambda = \lambda_d + \lambda_s = 2 \cdot \lambda_d$$

NOTE Thus λ_d is the mean failure rate equivalent to the B_{10d} value considering normal operation. For SIL calculation the “theoretical” mean failure rate λ_d derived from the statistical value B_{10d} does include failures excluded by Table E.1; however, the philosophy of this document assumes the occurrence of such failures to be sufficiently “unlikely” due to the assumed lifetime for the component.

J.5.4.5 Determination of common cause factors for complex system architectures

J.5.4.5.1 For complex system architectures the susceptibility to common cause failures is expressed by a common cause factor β which shall be determined based upon the modified methods of EN 61508-6:2010, Annex D, as follows:

J.5.4.5.2 If no item of Table J.4 applies, the following common cause factor shall be used for the calculation: β = 2 %.

J.5.4.5.3 If at least one of the items in Table J.4 applies, the values X and Y are summed up using score Table J.4.

Table J.4 — Scoring electronics or sensors/actuators

Item	Electronic controls		Sensors/actuators	
	X	Y	X	Y
Redundant channels employ different electrical technologies (e.g. one programmable, the other relay) or different physical principles for the sensing elements resp. actuators	7		7,5	
Redundant channels employ different electronic technologies (e.g. one electronic, the other programmable electronic), or different electrical principles/designs for the sensors (e.g. digital, analogue) resp. actuators (e.g. different manufacturer or technology)	5		5,5	
Use of medium diversity, for example hardware diagnostic tests using different technologies	3	1,5		
Cross-connection between channels precludes the exchange of any information other than that used for diagnostic testing or voting purposes	0,5	0,5	0,5	0,5
More than 5 years experience with the same hardware used in similar environments	1,0	1,5	1,5	1,5
Are all field failures fully analysed with feedback into the design? (Documentary evidence of the procedure is required.)	0,5	3,5	0,5	3,5
Is there a written system of work to ensure that all component failures (or degradations) are detected, the root causes established and other similar items inspected for similar potential causes of failure?		1,5	0,5	1,5
The control has a medium diagnostic coverage ≥ 90 % … < 99 %)	1,5	1,0		
The control has a high diagnostic coverage (≥99 %)	2,5	1,5		
Have designers been trained (with training documentation) to understand the causes and consequences of common cause failures?	2,0	3,0	2,0	3,0
Is the control likely to operate always within the range of temperature, humidity, corrosion, dust, vibration, etc., over which it has been tested, without the use of external environmental control?	3,0	1,0	3,0	1,0

The score value $S = X + Y + 40$ is calculated to obtain the value of β from Table J.5 (see NOTE).

Table J.5 — Calculation of β

Score (S)	Corresponding value of β for	
	Electronic controls	Sensors or actuators
100 or above	0,5 %	1 %
60 to 100	1 %	2 %
40 to 60	2 %	5 %

NOTE 1 The following aspects of EN 61508–6:2010, Table D.1 are fulfilled by this document and the applicable product standard in principle, and are honoured with X_{min} = 17 and Y_{min} = 23 ($S_{min} = X_{min} + Y_{min}$ = 40):

— Use of low diversity, for example hardware diagnostic tests with the same technology.

— Design based on techniques used in equipment that has been used successfully in the field for > 5 years.

— Simple control (low I/O complexity).

— I/O protected against over voltage / over current (validation by obligatory EMC and electrical strength tests).

— Sources of common cause failures have been detected by FMEA and eliminated by design.

— Common cause failures have been considered in design reviews and results fed back to design.

— Control has at least a low diagnostic coverage (≥60 % … < 90 %).

— User access is restricted by technical and/or organisational measures.

— Signal and supply lines are sufficiently separated (validation by obligatory EMC and electrical strength tests).

— The control is subject of comprehensive environmental tests under consideration of safety aspects.

NOTE 2 Those aspects have been excluded from Table J.4 for a better overview.

J.5.4.6 Calculation of PFH_D

J.5.4.6.1 Calculation of the safe failure rate ($\Sigma\ \lambda_S$)

In controls with 1oo1 architecture the addition of the *fit* values (see Table J.3) for all "safe" failures (λ_S) will result in $\Sigma\ \lambda_S$.

In controls with complex architecture the addition of the *fit* values (see Table J.3) for all "safe" failures (λ_S) of each subsystem will result in $\Sigma\ \lambda_S$ for this subsystem.

J.5.4.6.2 Calculation of the dangerous failure rate ($\Sigma\ \lambda_D$)

In controls with 1oo1 architecture the addition of the *fit* values (see Table J.3) for all "dangerous" failures (λ_D) will result in $\Sigma\ \lambda_D$.

In controls with complex architecture the addition of the *fit* values (see Table J.3) for all "dangerous" failures (λ_D) of each subsystem will result in $\Sigma\ \lambda_D$ for this subsystem.

J.5.4.6.3 Calculation of the dangerous detected failure rate ($\Sigma\ \lambda_{DD}$)

For each λ_D value is multiplied with the diagnostic coverage (DC) of the related diagnostic measure (see Tables J.1 and J.2). This will result in a fraction of detected failures $\lambda_{DD} = \lambda_D \cdot DC$.

In controls with 1oo1 architecture the addition of all "dangerous detected" failures (λ_{DD}) will result in

$$\sum \lambda_{DD} = \sum (\lambda_D \cdot DC) \qquad \text{(J.1)}$$

In controls with complex architecture the addition of all λ_{DD} for each subsystem n will result in

$$\left[\sum \lambda_{DD}\right]_n = \left[\sum (\lambda_D \cdot DC)\right]_n \qquad \text{(J.2)}$$

J.5.4.6.4 Calculation of the dangerous undetected failure rate (Σ λ_{DU})

In controls with 1oo1 architecture the difference of all “dangerous” failures (λ_D) and all “dangerous detected” failures (λ_{DD}) will result in

$$\sum \lambda_{DU} = \sum \lambda_D - \sum \lambda_{DD} \qquad (J.3)$$

In controls with complex architecture the difference of all “dangerous” failures (λ_D) and all “dangerous detected” failures (λ_{DD}) for each subsystem n will result in

$$\left[\sum \lambda_{DU}\right]_n = \left[\sum \lambda_D\right]_n - \left[\sum \lambda_{DD}\right]_n \qquad (J.4)$$

J.5.4.6.5 Calculation of the diagnostic coverage (*DC*)

The overall diagnostic coverage of the control or of the subsystem shall be calculated as

$$DC = \frac{\sum \lambda_{DD}}{\sum \lambda_D} \qquad (J.5)$$

J.5.4.6.6 Calculation of the safe failure fraction (*SFF*)

The overall safe failure fraction of the control or of the subsystem shall be calculated as

$$SFF = \frac{\left(\sum \lambda_S + \sum \lambda_{DD}\right)}{\left(\sum \lambda_S + \sum \lambda_D\right)} \qquad (J.6)$$

J.5.4.6.7 Determination of PFH_D

J.5.4.6.7.1 1oo1 architecture systems

In subsystems of architecture type A (see J.5.4.1.4.2), the probability of dangerous failure shall be the sum of the probabilities of dangerous failure of all subsystems elements:

$$PFH_D = \sum \lambda_{DU} = \sum \lambda_D = \lambda_{De1} + ... + \lambda_{Den} \qquad (J.7)$$

In subsystems of architecture type C (see J.5.4.1.4.3), the probability of dangerous failure shall be:

$$PFH_D = \sum \lambda_{DU} = \lambda_{De1} \cdot (1 - DC_1) + ... + \lambda_{Den} \cdot (1 - DC_n) \qquad (J.8)$$

J.5.4.6.7.2 Complex architecture systems

For subsystems in complex architecture systems of architecture type B (see J.5.4.1.5.2), the probability of dangerous failure shall be:

$$PFH_D = (1 - \beta)^2 \cdot \lambda_{De1} \cdot \lambda_{De2} \cdot T_1 + \beta \cdot \frac{(\lambda_{De1} + \lambda_{De2})}{2} \qquad (J.9)$$

where

T_1 is the proof test interval or lifetime whichever is the smaller;

β is the susceptibility to common cause failures (see J.5.4.5).

For subsystems in complex architecture systems of architecture type D (see J.5.4.1.5.3) with subsystem elements of different design, the probability of dangerous failure of the complete subsystem shall be:

$$PFH_{\mathrm{D}} = (1-\beta)^2 \cdot \left[\lambda_{\mathrm{De1}} \cdot \lambda_{\mathrm{De2}} \cdot (DC_1 + DC_2)\right] \cdot \frac{T_2}{2} + (1-\beta)^2 \cdot \left[\lambda_{\mathrm{De1}} \cdot \lambda_{\mathrm{De2}} \cdot (2 - DC_1 - DC_2)\right] \cdot \frac{T_1}{2} + \beta \cdot \frac{(\lambda_{\mathrm{De1}} + \lambda_{\mathrm{De2}})}{2} \quad \text{(J.10)}$$

where

T_1 is the proof test interval or lifetime whichever is the smaller (see NOTE);

T_2 is the diagnostic test interval;

β is the susceptibility to common cause failures (see J.5.4.5);

$\lambda_{\mathrm{D}} = \lambda_{\mathrm{DD}} + \lambda_{\mathrm{DU}}$;

where

λ_{DD} is the rate of detectable dangerous failures and

λ_{DU} is the rate of undetectable dangerous failure;

$\lambda_{\mathrm{DD}} = \lambda_{\mathrm{D}} \cdot DC$; $\lambda_{\mathrm{DU}} = \lambda_{\mathrm{D}} \cdot (1 - DC)$;

λ_{De1} is the dangerous failure rate of subsystem element 1;

λ_{De2} is the dangerous failure rate of subsystem element 2;

DC_1 is the diagnostic coverage of subsystem element 1;

DC_2 is the diagnostic coverage of subsystem element 2.

For subsystems in complex architecture systems of architecture type D with subsystem elements of equal design, the probability of dangerous failure of the complete subsystem shall be:

For subsystem elements of the same design:

$$PFH_{\mathrm{D}} = (1-\beta)^2 \left\{ \left[\lambda_{\mathrm{De}}^2 \cdot DC\right] \cdot T_2 + \left[\lambda_{\mathrm{De}}^2 \cdot (1 - DC)\right] \cdot T_1 \right\} + \beta \cdot \lambda_{\mathrm{De}} \quad \text{(J.11)}$$

where

T_1 is the proof test interval or lifetime whichever is the smaller (see NOTE);

T_2 is the diagnostic test interval;

β is the susceptibility to common cause failures (see J.5.4.5);

$\lambda_{\mathrm{D}} = \lambda_{\mathrm{DD}} + \lambda_{\mathrm{DU}}$;

where

λ_{DD} is the rate of detectable dangerous failures and

λ_{DU} is the rate of undetectable dangerous failure;

$\lambda_{DD} = \lambda_D \cdot DC$; $\lambda_{DU} = \lambda_D \cdot (1 - DC)$;

λ_{De} is the dangerous failure rate of subsystem element 1 or 2;

DC is the diagnostic coverage of subsystem element 1 or 2.

NOTE For controls according to this document proof tests are usually not required. Thus, for PFH_D calculation the intended life time of the control is used as an equivalent for the proof test interval.

J.5.4.6.8 Architectural constraints for subsystems

J.5.4.6.8.1 In the context of hardware safety integrity, the highest safety integrity level that can be claimed for a control is limited by the architecture and by the safe failure fractions of the subsystems. Table J.6 specifies the highest safety integrity level SIL_{max} that can be claimed for a control that uses subsystem(s) taking into account the architecture and the safe failure fraction of that subsystem.

J.5.4.6.8.2 The architectural constraints of Table J.6 shall apply to each subsystem of the control. In particular this does apply to controls that comprise only one single subsystem element (architecture type A).

Table J.6 — Requirements to the safe failure fraction of subsystems

subsystems in 1oo1 systems, architecture type A	**subsystems in 1oo1 systems, architecture type C**	**subsystems in 1oo2 systems, architecture types B / D**	**Control function**	**Maximum safety integrity level achievable**
Safe failure fraction (see NOTE)	**Safe failure fraction** (see NOTE)	**Safe failure fraction**	**Class**	SIL_{max}
60 % to 90 %	60 % to 90 %	< 60 %	**B**	**1**
90 % to 99 %	90 % to 99 %	60 % to 90 %	**B**	**2**
–	90 % to 99 %	< 60 %	**C**	**2**
–	≥ 99 %	60 % to 90 %	**C**	**3**

NOTE It is assumed that Class C controls according to this document have a complex architecture.

J.5.4.6.9 Determination of the overall safety integrity level for the control

With *SFF* and PFH_D calculated for the control and with SIL_{max} (determined according to J.5.4.6.8) the Safety Integrity Level (SIL) is determined from Table J.7. Each of *SFF*, PFH_D and SIL_{max} limits the overall safety integrity level of the control.

Table J.7 — Determination of the overall Safety Integrity Level (SIL)

Control function	**Overall Safe failure fraction**	**Maximum safety integrity level due to architectural constraints** (J.5.4.6.8)	**Overall probability of dangerous failures per hour**	**Overall Safety integrity level**
Class	*SFF*	SIL_{max}	PFH_D 1/h	**SIL**
B	60 % to 90 %	1	$10^{-5} > PFH_D > 10^{-6}$	**1**
B	60 % to 90 %	1	$10^{-6} > PFH_D > 10^{-7}$	**1**
	90 % to 99 %	2		**2**
C	< 60 %	1	$10^{-5} > PFH_D > 10^{-6}$	**1**
C	< 60 %	1	$10^{-6} > PFH_D > 10^{-7}$	**1**
	60 % to 90 %	2		**2**
C	< 60 %	1	$10^{-7} > PFH_D$	**1**
	60 % to 90 %	2		**2**
	90 % to 99 %	3		**3**

NOTE 1 To fulfil SIL 3 requirements with Class C controls according to this document not all components need to exist necessarily physically redundant. It is sufficient to provide redundant means in order to ensure that one single fault does not result in the loss of the ability to perform the required safety-related control function(s).

NOTE 2 It is not possible to achieve SIL 3 for Class B controls according to this document due to architectural constraints.

Annex K
(normative)

Method for the determination of a Performance Level (PL)

K.1 Scope

Shall be according to Clause 1 with the following addition:

This annex is only applicable to pneumatic, hydraulic, electromechanical controls and multifunctional controls which are declared to conform to performance level requirements (PL) according to EN ISO 13849-1:2008, Clauses 1, 2, 3, 4.1, 4.2, 4.5, 7, 8, 9, 10, 11, and Annexes C.4, E, and F.

This annex specifies a set of additional requirements to determine the *probability of dangerous failures per hour for continuous or high demand mode* (PFH_D) and the performance level (PL) for pneumatic, hydraulic, and electromechanical controls or multifunctional controls used in commercial, industrial and thermoprocessing applications (e.g. EN 746-2:2010).

This annex specifies requirements for performance levels PL d or PL e.

K.2 Normative references

Shall be according to Clause 2

K.3 Terms and definitions

Shall be according to Clause 3 with the following addition:

K.3.1

performance level
PL

discrete level used to specify the ability of safety-related parts of controls to perform a safety function under foreseeable conditions

[SOURCE: EN ISO 13849-1:2008, 3.1.23]

K.3.2

hardware failure tolerance
HFT

ability of a control to maintain the required safety function under existence of failures or deviations

K.3.3

failure in time
fit

number of controls which fail within 10^9 h of operation

Note 1 to entry: $1 fit = \frac{1}{10^9 \text{h}}$

K.3.4

high demand or continuous mode

frequency of demands for operation made on a safety-related system is greater than one per year or greater than twice the proof-test frequency

[SOURCE: EN 61508–4:2010, 3.5.16 modified]

K.3.5

proof test

periodic test performed to detect dangerous hidden failures in a safety related control so that, if necessary, a repair can restore the control to an as new condition or as close as practical

[SOURCE: EN 61508–4:2010, 3.8.5 modified]

K.3.6

probability of dangerous failure per hour
PFH_D, λ_D

value describing the likelihood of dangerous failure per hour of a control for high demand mode

K.3.7

mean time to dangerous failure
$MTTF_D$

expectation of the mean time to dangerous failure

[SOURCE: EN ISO 13849-1:2008, 3.1.25, modified]

K.3.8

safe failure fraction
SFF

fraction of safe failures related to all failures, which are assumed to appear

K.3.9

expected lifetime cycles
B_{10d}

mean number of cycles until 10 % of the controls fail dangerously

K.3.10

expected lifetime
T_{10d}

mean time until 10 % of the controls fail dangerously

K.4 Performance

K.4.1 Operation mode

This document is only applicable for controls that are specified in the relevant product standard for the operation mode “high demand mode”.

K.4.2 PL and field data evaluation

This annex does not include methods for the determination of PL on the basis of field data evaluation.

NOTE Field data evaluation is not taken into consideration because it is hardly possible to comprise ambient conditions like temperature, supply voltage, or contamination in the gas flow. The approach to determine the PL with respect to field data evaluation is only possible with controls which have been on the market in high volume for a long time under a comparable set of ambient conditions.

K.4.3 Hardware failure tolerance (HFT)

The hardware failure tolerance shall be as specified in Foreword and Clause 1.

K.4.4 Common cause failure (CCF)

K.4.4.1 General

For electromechanical controls the measures against common cause failures in Table K.1 are applicable.

NOTE 1 A comprehensive procedure for measures against CCF for sensors/actuators and separately for control logic is given in EN 61508–6:2010, Annex D.

NOTE 2 In this European Standard it is assumed that for redundant systems a ß-factor according to EN 61508–6: 2010, Annex D is equal to 2 % according to J.5.4.5.

K.4.4.2 Estimation of effect of CCF

Table K.1 lists the measures and contains associated values, based on engineering judgement, which represent the contribution each measure makes in the reduction of common cause failures.

Every safety-related part of the control shall be reviewed and scored according to the measures against CCF as given in Table K.1.

For each listed measure, only the full score or nothing can be claimed. If a measure is only partly fulfilled, the score according to this measure is zero.

Where applicable the score shall be evaluated by consideration of the specific product standard.

Table K.1 — Scoring process and quantification of measures against CCF

No.	Measure against CCF	Score
1	**Separation/segregation**	
	Physical separation between signal paths that are clearances and creepage distances on printed-circuit boards for integrated electronics. These influences have been considered in control standards as specified in Foreword and Clause 1 and therefore this score is always 15 points.	**15**
2	**Diversity**	
	Different technologies/design or physical principles are used. For single controls the score can only be 0.	**20**
3	**Design/application/experience**	
3.1	Protection against over-voltage, over-pressure, etc. as covered in control standards as specified in Foreword and Clause 1.	**15**
3.2	Components used are well-tried under comparable operating modes (e.g. number of cycles per hour) and conditions.	**5**
4	**Assessment/analysis**	
	Are the results of a failure mode and effect analysis taken into account to avoid common cause-failures in design?	**5**
5	**Competence/training**	
	Have designers/maintainers been trained to understand the causes and consequences of common cause failures? For controls the score can only be 0.	**5**
6	**Environmental**	
6.1	This score can be taken, if the operating instructions give sufficient information for installers and users to prevent conditions for up-stream pressure (overpressure at the inlet in case of failure of upstream components), dirt, corrosion products; it has to contain requirements on filtration of the medium for maintaining this level.	**25**
6.2	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? These influences have been considered in control standards as specified in Foreword and Clause 1 and therefore this score is always 10 points.	**10**
	Total	**[max. achievable 100]**

Total score	Measures avoiding CCF[a]
65 or better	Meets the requirements
Less than 65	Process failed → choose additional measures

[a] Where technological measures are not relevant, points attached to this column can be considered in the comprehensive calculation.

NOTE Table K.1 is a quotation from EN ISO 13849-1:2008, Table F.1.

K.4.5 Safe failure fraction (*SFF*)

K.4.5.1 Failure effects are classified as follows:

- **dangerous**: failures which, under absence of diagnostic methods, would cause a dangerous failure of the control (e.g. controls are leaking externally or internally above limits in this European Standard);
- **safe**: failures which, under absence of diagnostic methods, would **not** cause a dangerous failure of the control, but can impair the reliability (e.g. control stays closed instead of releasing the gas flow);
- **do not care**: failures which neither affects safety integrity nor reliability.

Certain faults can be excluded, provided that the theoretical probability of their occurrence is very low in relation to the safety integrity requirements of the control (EN ISO 13849-1:2008, 7.3).

Any such fault exclusions shall be justified and documented, and shall be based on:

- the technical improbability of their occurrence in combination with specific requirements to controls;
- the generally accepted technical experience, independent from the application; and
- the technical requirements related to the application and the specific hazards.

Two independent faults are **not** considered.

The result of the FMEA, which is the *SFF*, shall be valued according to EN ISO 13849-1:2008, 4.5.3, and shall be used to determine the PFH_D value according to Table K.2.

K.4.6 Determination of the B_{10d} value

K.4.6.1 Requirements

As the failure rate of electromechanical controls depends on the conditions for the specific application, a B_{10d} value according to EN ISO 13849-1:2008 shall be supplied by the manufacturer. The tests shall be carried out with a representative number of samples, at least 11, with exactly the same combination of parts which are subject to wear and tear during operation.

NOTE 1 The minimum number of samples is based on statistic calculation rules.

At a certain number of cycles (e.g. every 100 000 or 200 000), as determined by the manufacturer, of the endurance tests described in K.4.6.2, the control shall be checked to meet the requirements of the relevant product standard.

The B_{10d} value is calculated with the assumption of a Weibull distribution from the last number of cycles where a control fulfilled all requirements as described below. If some controls conform to all requirements at the end of the tests, these controls are calculated with the number of cycles of the tests. If all controls conform to all requirements at the end of the tests, 90 % of the controls are calculated with the number of cycles of the tests, and 10 % of the controls are calculated with 1,05 times the number of cycles of the tests.

a) Evaluation of the samples which fail according to at least one of above mentioned requirements:

   The following data are needed:

   - number of samples failed, called n;
   - respective number of endurance cycles before the failure occurs, called x_i.

The ordinal number $_i$ is used in rising order for x_i. Number 1 designates the lowest number of x_i, number 2 the second lowest (e.g. n = 1, x_1 = 300 000; n = 2, x_2 = 400 000; n = 3, x_3 = 500 000; etc.).

b) Calculation of the median value, called log $x_{50\ \%}$:

With n and x_i the median value log $x_{50\ \%}$ is calculated with the following Formula (K.1):

$$\log x_{50\%} = \frac{1}{n} \cdot \left(\sum_{i=1}^{n} \log(x_i) \right) \quad \text{(K.1)}$$

Calculation of the logarithmic standard deviation $s_{\log}$:

With n, x_i, and log $x_{50\ \%}$ the logarithmic standard deviation $s_{\log}$ is calculated with the following Formula (K.2):

$$s_{\log} = \sqrt{\frac{1}{n-1} \cdot \sum_{i=1}^{n} \left(\log(x_i) - \log(x_{50\%}) \right)^2} \quad \text{(K.2)}$$

c) Calculation of the form parameter b of the Weibull distribution:

With $s_{\log}$ the form parameter b of the Weibull distribution (which is equivalent to the slope of the balancing straight line), using the calculation method according to Gumbel, is calculated with the following Formula (K.3):

$$b = \frac{0{,}557}{s_{\log}} \quad \text{(K.3)}$$

d) Calculation of the characteristic life time T:

With n, x_i, and b the characteristic life time T (which is equivalent to a failure probability of 63,2 %), using the calculation method according to Gumbel, is calculated with the following Formula (K.4):

$$T = 10^{\left(\sum_{i=1}^{n} \log(x_i) \right) \cdot \frac{1}{n} + \frac{0{,}2507}{b}} \quad \text{(K.4)}$$

e) Calculation of the B_{10d} value:

With b and T the B_{10d} value is calculated with the following Formula (K.5):

$$B_{10d} = T \left(\ln\left(\frac{1}{1-0{,}1} \right) \right)^{\frac{1}{b}} = 0{,}1054^{\frac{1}{b}} \cdot T \quad \text{(K.5)}$$

According to EN ISO 13849-1:2008, C.4.2 the B_{10d} value is transformed into λ_D, PFH_D, $MTTF_D$, or T_{10d} as follows:

$PFH_D = \lambda_D \cong (0{,}1 \cdot n_{op}) / B_{10d}$; (K.6)

$MTTF_D = 1/PFH_D$.

$T_{10d} = B_{10d}/n_{op}$.

whereas n_{op} is the estimated number of operating cycles per time (see Figure K.1).

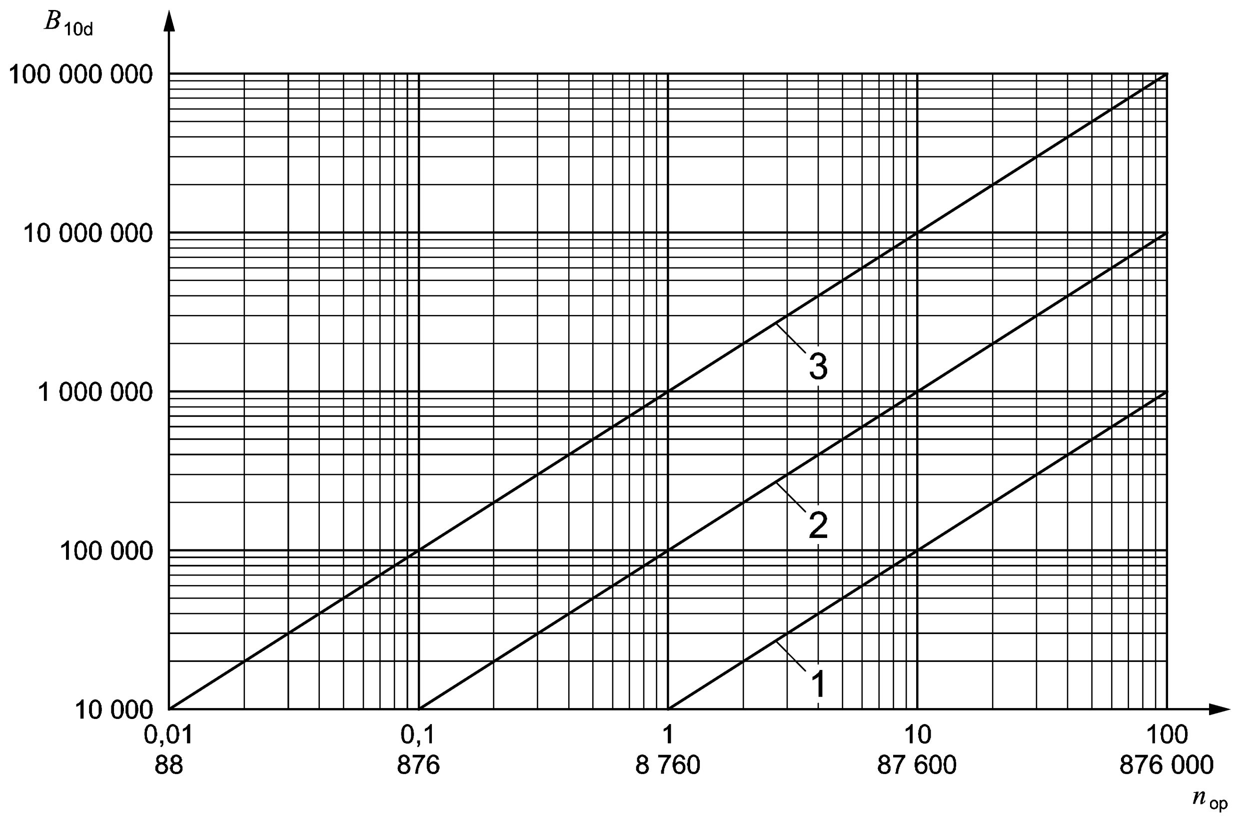
The assumed total number of operations during lifetime n_{op} shall be less than B_{10d}. T_{10d} is the maximum time for safe operation of the control.

NOTE 2 Thus λ_D is the mean failure rate equivalent to the B_{10d} value considering normal operation. Failures arising from abnormal conditions (i.e. beyond control specification) are not included.

EXAMPLE B_{10d} = 800 000;

n_{op} = 25 000 a^{-1} = 2,85 h^{-1};

$PFH_D = \lambda_D$ = (0,1 × 25 000) / (8 760 × 800 000) h^{-1} = 3,56 × 10^{-1} h^{-1} = 356 *fit*



Key

1 above graph, in a system controls can be suitable up to PL c

2 above graph, in a system controls can be suitable up to PL d

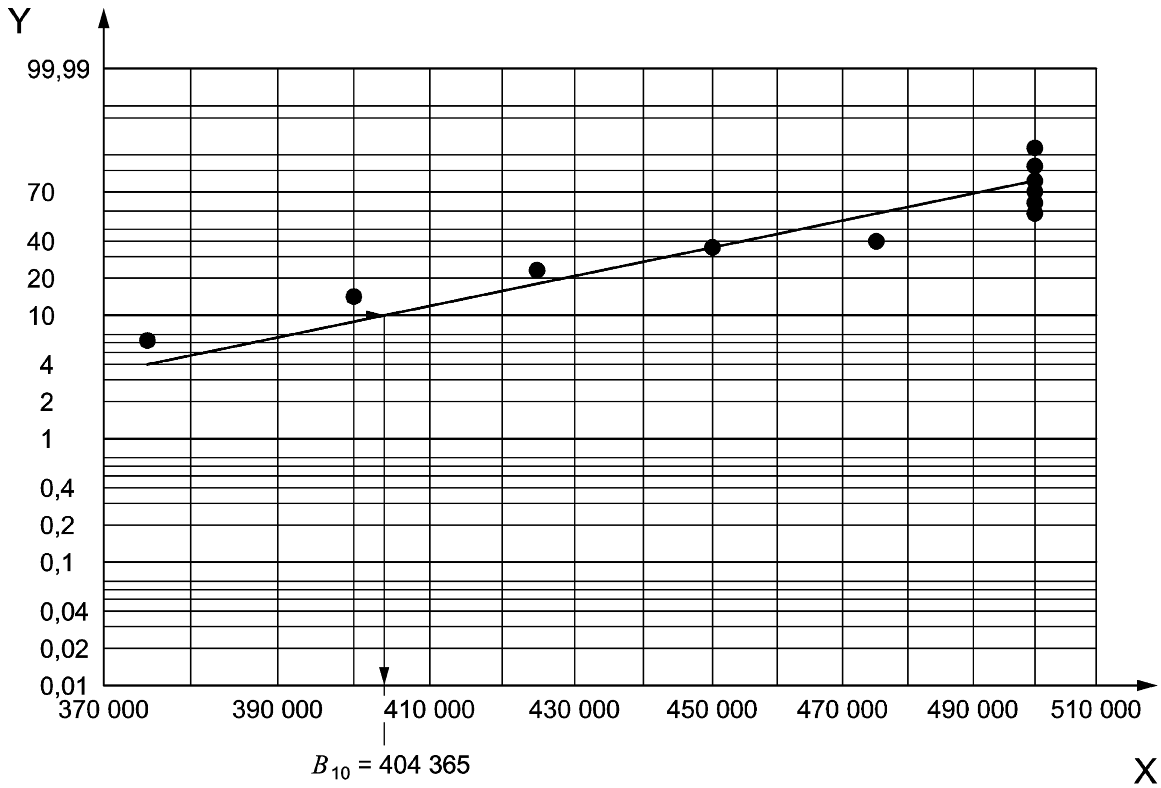
3 above graph, in a system controls can be suitable up to PL e

Figure K.1 — Dependencies of n_{op}, B_{10d}, and PL

K.4.6.2 Tests

The B_{10d} calculation shall be based on values measured according to the endurance tests of the relevant product standard.

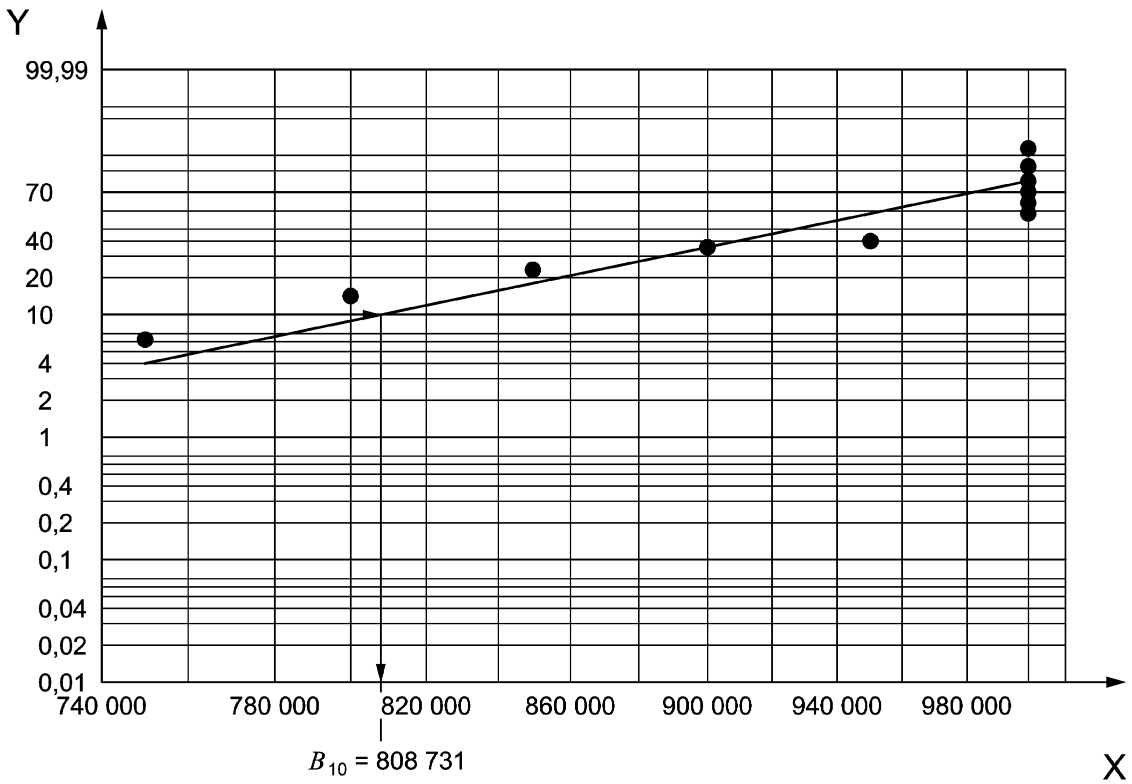
Examples for Weibull distribution are shown in Figures K.2 and K.3.



Key

X number of cycles Y probability of dangerous failure

Figure K.2 — Weibull distribution example A (max. test duration 500 000 cycles)



Key

X number of cycles Y probability of dangerous failure

Figure K.3 — Weibull distribution example B (max. test duration 1 000 000 cycles)

K.4.7 Determination of performance level (PL)

With SFF and PFH_D calculated for the overall system the PL is determined from Table K.2. Each of SFF and PFH_D limits the maximum PL values.

Table K.2 — Determination of the performance level (PL)

Probability of dangerous failures per hour (PFH_D)	**Safe failure fraction (*SFF*)**	**Performance Level (PL)**
$PFH_D < 10^{-7}$	> 90 % to 99 %	**e**
$10^{-7} \leq PFH_D < 10^{-6}$	> 60 % to 90 %	**d**

K.4.8 PFH_D values for structures consisting of two controls

Structures consisting of two controls (e.g. two automatic shut-off valves according to EN 126:2012) are considered as subsystem “1oo2 without diagnostic function” (architecture B).

This architecture is such that a single failure of any subsystem element does not cause a loss of the safety related control function(s) (e.g. two relays or valves connected in series). Thus, there would have to be a dangerous failure in more than one element before failure of the safety related control function(s) can occur. The subsystem does not include diagnostic measures (see Figure K.4, according to Figure J.3).

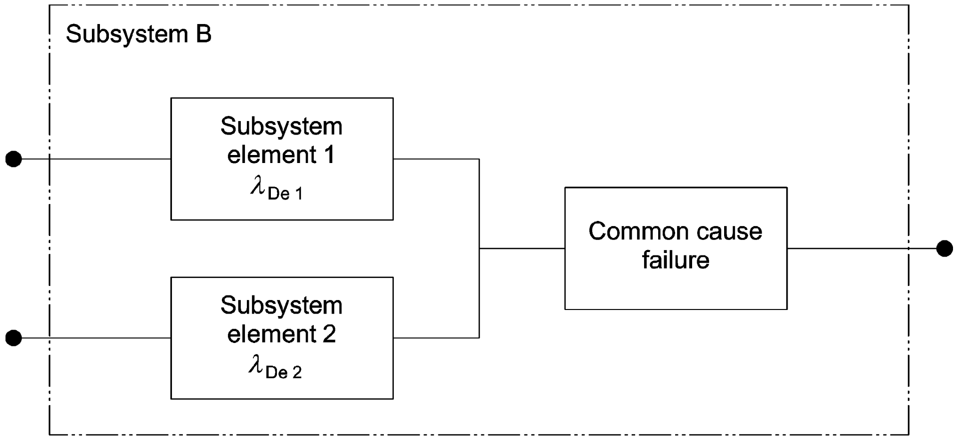


Figure K.4 — Subsystem with basic architecture B - logical representation

Figure K.4 is a logical representation of the Subsystem B architecture and should not be interpreted as its physical implementation.

For subsystems of architecture type B according to J.5.4.1.5.2 and J.5.4.6.7.2, the probability of dangerous failure is:

$$PFH_{DS} = (1-\beta)^2 \times \lambda_{De1} \times \lambda_{De2} \times T_1 + \beta \times (\lambda_{De1} + \lambda_{De2})/2 \qquad \text{(K.7)}$$

where

T_1 is the proof test interval or lifetime whichever is the smaller;

β is the susceptibility to common cause failures (according to J.5.4.5)

λ_{De1} is the dangerous failure rate of subsystem element 1 (e.g. relay 1 or valve 1);

λ_{De2} is the dangerous failure rate of subsystem element 2 (e.g. relay 2 or valve 2).

According to J.5.4.5 β is assumed to be 2 %.

EXAMPLE $B_{10d1} = B_{10d2}$ = 800 000;

$n_{op1} = n_{op2}$ = 25 000 a^{-1} = 2,85 h^{-1};

→ $PFH_{D1} = PFH_{D2} = \lambda_{D1} = \lambda_{D2}$ = (0,1 × 25 000) / (8 760 × 800 000) h^{-1} = 3,56 × 10^{-7} h^{-1} = 356 *fit*;

T_1 = 5 a = 43 800 h;

$PFH_{DS} = \lambda_{DS}$ = ((1 - 0,02)^2 × 3,56 × 10^{-7} × 3,56 × 10^{-7} × 5 × 8 760 + 0,02 × (3,56 × 10^{-7} + 3,56 × 10^{-7})/2) h^{-1} = 0,125 × 10^{-7} h^{-1} = 12,5 *fit*.

K.5 Marking, installation and operating instructions

Additional information shall be specified in the applicable product standard.

Annex L
(informative)

Relationship between Safety Integrity Level (SIL) and Performance Level (PL)

Table L.1 specifies the relationship between performance level (PL) according to Annex K and safety integrity level (SIL) according to Annex J.

Table L.1 — Relationship between SIL and PL

Probability of dangerous failures per hour (PFH_D)	Safe failure fraction (*SFF*)	Performance Level (PL)	Safety Integrity Level (SIL)
$PFH_D < 10^{-7}$	> 90 % to 99 %	**e**	**3**
$10^{-7} \leq PFH_D < 10^{-6}$	> 60 % to 90 %	**d**	**2**

Annex M
(normative)

Reset functions

M.1 Scope

Shall be according to Clause 1 with the following addition:

For automatic controls that are used for the automatic ignition of burners and appliances, provisions are present to ensure that the appliance can be reset from a lock-out condition (e.g. caused by overheating of the appliance or no flame establishment).

Traditional methods for resetting heating appliances are:

a) conventional mechanical reset switch (no or minor simple electronic components present);

b) removing the power supply to the control unit (only accepted in case of volatile lock-out applications).

New technologies provide more complex reset devices, such as:

c) remote reset devices (e.g. through communication lines/protocols);

d) intelligent complex reset devices (e.g. by means of additional hardware and/or software);

e) infrared or radio frequency controlled reset devices;

f) combinations of a) and b) and c) (e.g. through Internet by means of a modem and a portable telephone).

M.2 Normative references

Shall be according to Clause 2.

M.3 Terms and definitions

Shall be according to Clause 3.

M.4 Classification

Shall be according to Clause 4 with the following addition:

The reset function shall be Class B.

M.5 Units of measurement and test conditions

Shall be according to Clause 5.

M.6 Construction requirements

M.6.1 General

6.1 is applicable.

M.6.2 Mechanical parts of the control

6.2 is not applicable.

M.6.3 Materials

6.3 is not applicable.

M.6.4 Gas Connections

6.4 is not applicable.

M.6.5 Electrical parts of the control

6.5 is applicable.

M.6.6 Protection against internal faults for the purpose of functional safety

Shall be according to 6.6 with the following modification:

The applicability of 6.6.3.2 c) shall be considered together with the control function that will be reset.

The fault reaction time shall be as stated in the installation and operating instructions.

Any fault within the reset function shall not cause the appliance to operate outside the applicable requirements. It shall be detected before the next start-up or shall not prevent the appliance from going to shutdown or lock-out.

M.7 Performance

M.7.1 General

Shall be according to 7.1 with the following modification:

The following shall be fulfilled in addition to the relevant performance requirements in Clause 7.

A reset action of an appliance is supposed to be a clear defined manual action. An automatic reset (e.g. resets generated by automatic devices, like timers etc.) shall not be possible unless it is accepted by specific applications.

The reset device shall be capable of resetting the control in a proper way. Unintended or spontaneous resets from lockout shall not occur.

Whenever the reset function is performed by a mobile device at least two manual actions are required to activate a reset.

For reset functions where the manual action is initiated without being within the visible sight of the appliance the following additional requirements apply:

— actual status and relevant information of the process under control shall be visible to the user before, during and after the reset action;

— maximum number of resets shall be limited to 5 actions within a time span of 15 min. Following this, any further resets shall be denied unless the appliance is checked.

If the reset is activated by manual switching a thermostat or device with a similar function, this shall be as stated in the installation and operating instructions for approval with the final appliance.

It is noticed that not all types of reset functions can be found suitable for specific applications. The reset function shall be evaluated on the final application.

M.7.2 Leak-tightness

7.2 *is not applicable.*

M.7.3 Torsion and bending

7.3 *is not applicable.*

M.7.4 Rated flow rate

7.4 *is not applicable.*

M.7.5 Durability

7.5 *is not applicable.*

M.7.6 Performance tests for electronic controls

Shall be according to 7.6.

M.7.7 Long-term performance for electronic controls

Shall be according to 7.7 with the following modification:

The performance as given in M.7.1 shall be verified after the long-term performance tests in 7.7.

M.7.8 Data exchange

Shall be according to d).

M.8 Electrical requirements

Shall be according to Clause 8.

M.9 Electromagnetic compatibility (EMC)

Shall be according to Clause 9.

M.10 Marking, installation and operating instructions

M.10.1 Marking

Shall be according to 10.1.

M.10.2 Installation and operating instructions

Shall be according to 10.2 with the following addition:

— fault reaction time and applicability of 6.6.3.2 c);

— reset by switching of a thermostat, if applicable.

Annex N
(informative)

Guidance document on Environmental Aspects

N.1 General

CEN/TC 58 standards deal with safety related functions, where safety will always have priority over environmental aspects if no alternative is available.

The scope of CEN/TC 58 standards is limited to product design aspects. For the design of products according CEN/TC 58 standards not only safety and performance aspects should be considered, but also design aspects related to the impact of the product on the environment during its life-cycle.

The checklist below should be used during the standards drafting process to identify all relevant environmental aspects, either as requirements or as guidance to the user of the standard.

In addition some guidance is given in N.2 on specific aspects in relation the environment that can be brought to the attention of the standard user.

This annex does not cover environmental aspects related to the production process.

N.2 Guidance on Environmental Aspects in standards

N.2.1 General

Develop standards for technologies that increase the appliance efficiency and make the control recyclable.

Under “Construction Requirements” the following aspects can be considered:

— the Environmental Aspects checklist for the life cycle of the product (see below);

— designs that use less parts / components;

— re-usable gas connections;

— the impact of base material on environment, e.g. metal / plastics / elastomer;

— the impact of coatings / surface treatments on the environment;

— the use of jointing compounds;

— requirements on the use of recycled materials;

— type of liquid in the bulb type temperature sensing element;

— constructions that need lower grade materials in respect to heat and fire resistance;

— Size and weight of product (transport / packaging).

Under “Performance Requirements” the following aspects can be considered:

— reduction in power consumption;

- power saving circuits for electro-magnetic actuators;
- airborne noise.

Table N.1 — Environmental Checklist

<table>
<tr><td colspan="3">Document number
(if available):</td><td colspan="5">Title of standard:</td><td colspan="4">TC/SC/WG number:</td></tr>
<tr><td colspan="3">Work item number
(if available):</td><td colspan="5">Version of the environmental checklist:</td><td colspan="4">Date of last modification of the environmental checklist:</td></tr>
<tr><th rowspan="3">Environmental Issue</th><th colspan="10">Stages of the life cycle</th><th rowspan="2">All stages</th></tr>
<tr><th colspan="2">Acquisition</th><th colspan="2">Production</th><th colspan="3">Use</th><th colspan="3">End-of-Life</th></tr>
<tr><th>Raw materials and energy</th><th>Pre-manufactured materials and components</th><th>Production</th><th>Packaging</th><th>Use</th><th>Maintenance and repair</th><th>Use of additional products</th><th>Reuse/ Material and Energy Recovery</th><th>Incineration without energy recovery</th><th>Final disposal</th><th>Transportation</th></tr>
<tr><td colspan="12">Inputs</td></tr>
<tr><td>Materials</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Water</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Energy</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Land</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="12">Outputs</td></tr>
<tr><td>Emissions to air</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Discharges to water</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Discharges to soil</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Waste</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Noise, vibration, radiation, heat</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Document number (if available):	Title of standard:	TC/SC/WG number:
Work item number (if available):	Version of the environmental checklist:	Date of last modification of the environmental checklist:

<table>
<tr><th rowspan="3">Environmental Issue</th><th colspan="10">Stages of the life cycle</th><th rowspan="2">All stages</th></tr>
<tr><th colspan="2">Acquisition</th><th colspan="2">Production</th><th colspan="3">Use</th><th colspan="3">End-of-Life</th></tr>
<tr><th>Raw materials and energy</th><th>Pre-manufactured materials and components</th><th>Production</th><th>Packaging</th><th>Use</th><th>Maintenance and repair</th><th>Use of additional products</th><th>Reuse/ Material and Energy Recovery</th><th>Incineration without energy recovery</th><th>Final disposal</th><th>Transportation</th></tr>
<tr><td colspan="12">Other relevant aspects</td></tr>
<tr><td>Risk to the environment from accidents or unintended use</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Customer information</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="12">Comments:</td></tr>
<tr><td colspan="12">NOTE 1 The stage of packaging refers to the primary packaging of the manufactured product. Secondary or tertiary packaging for transportation, occurring at some or all stages of the life cycle, is included in the stage of transportation.
NOTE 2 Transportation can be dealt with as being a part of all stages (see checklist) or as separate sub-stage. To accommodate specific issues relating to product transportation and packaging, new columns can be included and/or comments can be added.</td></tr>
</table>

Annex O
(normative)

Seals of elastomer, cork and synthetic fibre mixtures

O.1 Scope

This annex specifies requirements and tests for seals made from

- mixtures of elastomer and cork with a maximum operating temperature of 100 °C and a maximum operating pressure of 100 kPa, and
- mixtures of elastomer, cork and synthetic fibres with a maximum operating temperature of 150 °C and a maximum operating pressure of 400 kPa.

for use in mechanical gas controls as specified in Clause 1.

O.2 Normative references

Shall be according to Clause 2.

O.3 Terms and Definitions

O.3.1
elastomer, cork seal
vulcanised material composed of cork granulate and rubber compound

O.3.2
elastomer / cork / synthetic fibre seal
vulcanised material composed of cork granulate, synthetic fibres and rubber compound

O.4 Materials

O.4.1 General

The type of rubber compound, the amount of cork (and synthetic fibres) and its granulate size determine the characteristics of the elastomer / cork seal (and synthetic fibre) material.

Each material combination shall have its own material specification.

Concerning compression set, there are two classes:

- Class 25 for lower compression set;
- Class 40 for higher compression set.

For identification of seal materials there are three classes:

- elastomer / cork A 25;
- elastomer / cork A 40;

— elastomer / cork / synthetic fibres C.

O.4.2 Thickness tolerances

O.4.2.1 Requirements

Sealing material shall meet requirements as specified in Table O.1 when tested according O.4.2.2.

Table O.1 — Thickness tolerances

	Nominal thickness	Maximum deviations
Elastomer / cork (A)	≤ 1,5 mm	± 0,2 mm
	> 1,5 mm	± 15 %
Elastomer / cork / synthetic fibres (C)	≤ 1 mm	± 0,15 mm
	> 1 mm	± 15 %

O.4.2.2 Thickness tests

Thickness is measured according ISO 23529:2010.

O.5 Performance

O.5.1 Cork / Elastomer / Synthetic fibres material in contact with gas

O.5.1.1 Initial performance of seal material

O.5.1.1.1 Requirements

Sealing material shall meet requirements as specified in Table O.2 when tested according O.5.1.1.2.

Table O.2 — Performance of seal material

	Units	Elastomer / cork (A)		Elastomer / cork/ synthetic fibre (C)	Tests according to
		A25	A40		
a) Compression	%	≥ 25, < 40	≥ 40, < 65	≥ 15, < 35	O.5.1.1.2 a)
a) Relaxation	%	≥ 75	≥ 75	≥ 40	O.5.1.1.2 a)
b) Tensile strength	MPa (N/mm^2)	≥ 1,0	≥ 0,5	≥ 8	O.5.1.1.2 b)
c) Gas permeability	cm^3/min	≤ 0,05	≤ 0,05	≤ 0,05	O.5.1.1.2 c)

O.5.1.1.2 Tests

a) Compression and relaxation

Condition the test samples for 48 h in a climatic chamber at 23 °C and 50 % relative humidity (RH) and measure compression and relaxation according to ISO 815-1:2008.

b) Tensile strength

Condition the test samples for 48 h in a climatic chamber at 23 °C and 50 % RH and measure tensile strength according to ISO 37:2011.

c) Tests of gas permeability

Elastomer / cork

Gas permeability is tested making use of the test setup of Figure O.1.

All parts of the test equipment, including the test sample, are centred to each other.

The sealing surfaces of both flanges have to be polished centric to a roughness $R_Z \leq 2$.

From the sealing material under test, having a thickness of 2 ± 0,3 mm, sealing rings are punched out with an outside diameter of 75 +0/-1 mm and width of 10 +1/-0 mm.

Each sealing ring is examined for damages and measured on 3 points, each 120°from the other around the sealing ring.

Prior to testing, the sealing rings are conditioned at 23 °C, 50 % RH for at least 48 h.

Next sealing ring sample is placed centric between the carefully cleaned flanges and compressed:

— for A25 up to 40 % of its original thickness;

— for A40 up to 50 % of its original thickness.

The equal deformation is checked with 3 µm, equally distributed around the sealing ring.

In this condition the gas permeability test system is checked.

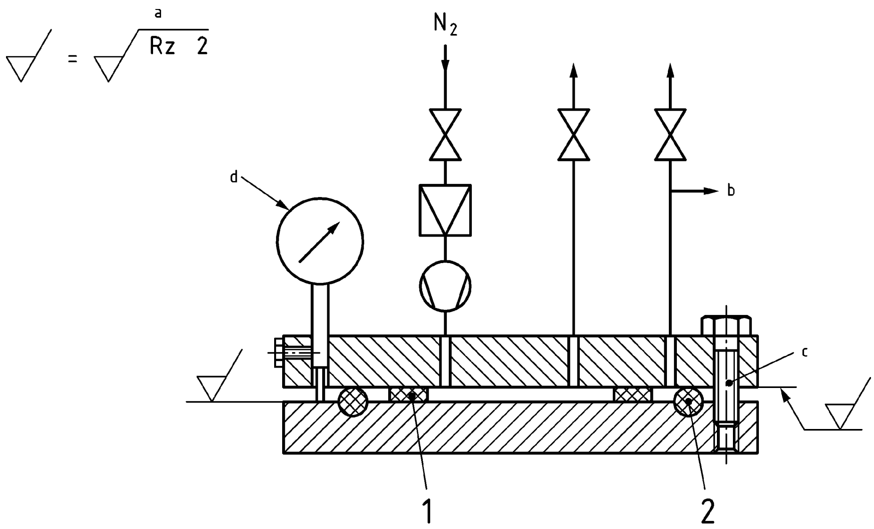
After a minimum of 10 min, the test gas Nitrogen (N_2) is applied with 100 kPa pressure.

2 h after having compressed the sealing ring, the N_2 gas leakage is measured in cm^3/min for 10 min with a resolution of 0,01 cm^3/min.

Results of 5 samples are averaged and corrected for standard conditions.

These tests with these samples are followed by the ageing tests O.5.1.2.2 b).

Dimensions in millimetres



Key

1)	Sealing	a	polished
2)	O-ring	b	gas burette
R_Z	roughness	c	6 bolts on circumference
		d	3 micro meters

Figure O.1 — Gas permeability test setup for cork / elastomer material

Elastomer / cork / synthetic fibres

The gas permeability of seals made of elastomer / cork / synthetic fibre mixtures is tested in a test setup as shown in Figure O.2, where all parts are centred to each other including the test sample.

The sealing surfaces of both flanges shall be polished centric to a roughness $R_Z \leq 2$.

With suitable measures, an equal compression of the test sample shall be ensured.

From the sealing material under test sealing rings, having a thickness of 2 ± 0,2 mm, are punched out with an outside diameter of 90 +1/-0 mm and width of 20 −1/+0 mm.

Each sealing ring is examined for damages and measured on 3 points each 120°from the other around the sealing ring.

Prior to testing, the sealing rings are conditioned at 23 °C, 50 % RH for at least 48 h.

On both sides of the sealing ring, a polyethylene foil in the shape of the sample is applied.

Next the sealing ring sample with polyethylene foil is placed centric between the carefully cleaned flanges and compressed equally with 10 N/mm^2.

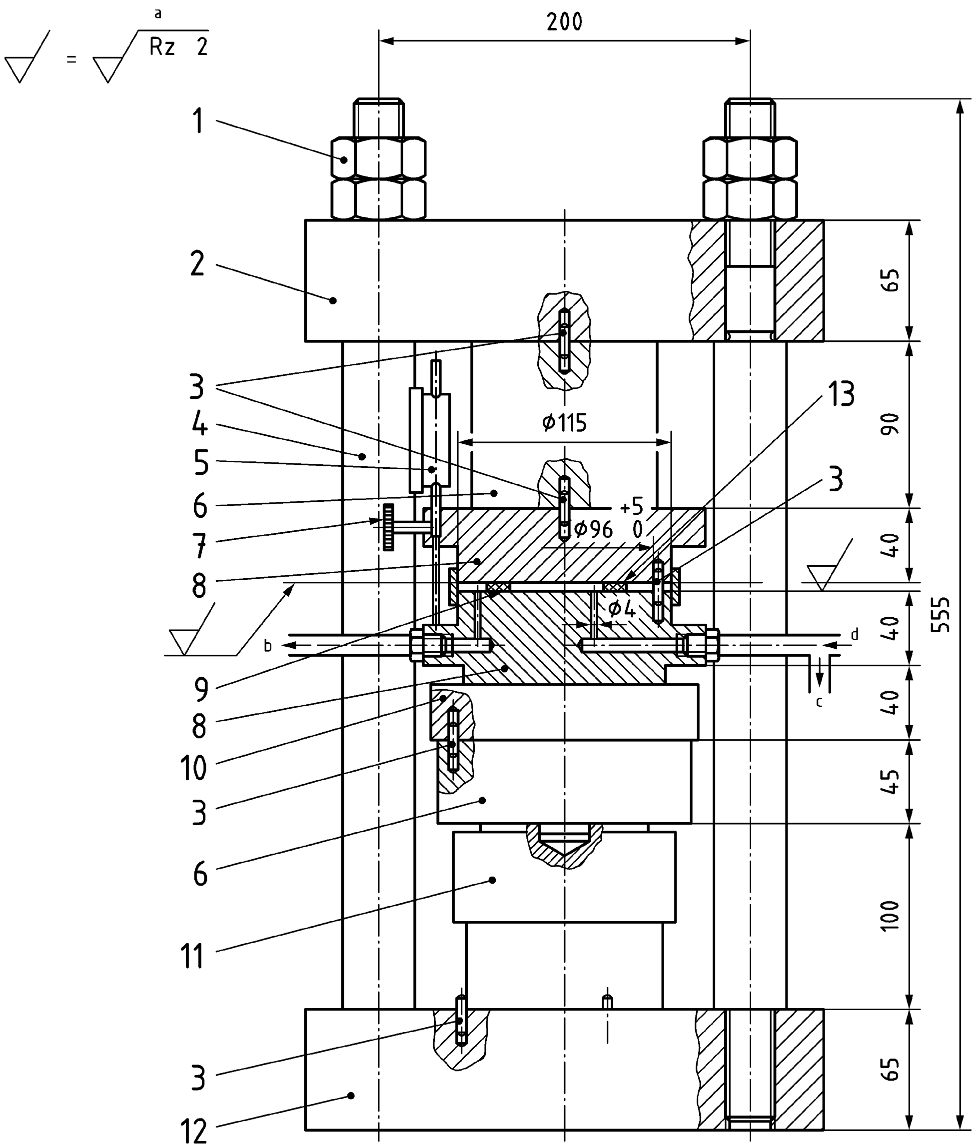
In this condition the gas permeability test system is checked.

After 10 min the N_2 test gas pressure is gradually increased within 4 min to 6 bars.

2 h after having compressed the sealing ring, the N_2 gas leakage is measured in cm^3/min for 10 min with a resolution of 0,01 cm^3.

Results of 5 samples are averaged and corrected for standard conditions.

Dimensions in millimetres



Key

1)	nut	10)	load cell with joint
2)	traverse	11)	hydraulic press
3)	dowel	12)	base plate
4)	pillar	a	polished
5)	micro meter	b	to gas burette
6)	spacer	c	pressure measuring equipment
7)	knurled screw	d	pressure regulator
8)	flange	R_Z	roughness
9)	, 13) rubber cuff		

Figure O.2 — Gas permeability test setup for cork / elastomer / synthetic fibre material

O.5.1.2 Performance after ageing

O.5.1.2.1 Requirements

Sealing material shall meet requirements as specified in Table O.3 when tested according to O.5.1.2.2.

Table O.3 — Performance of seal material after ageing

	Units	Elastomer / cork (A)		Elastomer / cork / synthetic fibre I	Tests according to
		A25	A40		
a) Tensile strength	MPa (N/mm^2)	≥ 1,0	≥ 0,5	≥ 8	O.5.1.2.2 a)
b) Gas permeability of elastomer/cork material	cm^3/min	≤ 0,05	≤ 0,05	n.a.	O.5.1.2.2 b)
c) Pressure withstand ability of cork / elastomer / synthetic fibre material	MPa (N/mm^2)	n.a.	n.a.	≥ 10	O.5.1.2.2 c)

O.5.1.2.2 Tests

a) Tensile strength

Following the tests according O.5.1.1.2 b), the test samples shall be aged for 168 +0/-2 h in a temperature test chamber:

— at a temperature of 125 ± 2 °C for elastomer / cork seals;

— at a temperature of 175 ± 2 °C for elastomer / cork / synthetic fibre seals;

After the ageing the tests of O.5.1.1.2 b) shall be repeated.

b) Gas permeability of elastomer / cork seals

Following the tests according O.5.1.1.2 c), the assembly of test flanges with sealing material are subjected to ageing for 168 +0/-2 h in a temperature test chamber:

During the tests, ambient air shall flow through the test chamber.

After this ageing process and when the assembly has cooled down to 23 °C, the tests of O.5.1.1.2 c) are repeated.

c) Pressure withstand ability of elastomer / cork / synthetic fibres seals

Condition the test samples for 48 h in a climatic chamber at 23 °C and 50 % RH with a test pressure of 25 MPa (N/mm^2).

At a test temperature of 125 °C, the ability to withstand high pressure is tested according to ISO 23529:2010 – with the values according to EN 13555:2014.

O.5.1.3 Performance after immersion and drying

O.5.1.3.1 Requirements

Sealing material shall meet requirements as specified in Table O.4 when tested according O.5.1.3.2.

Table O.4 — Performance after immersion and drying

	Unit	Elastomer / cork (A)	Elastomer / cork / synthetic fibl(C)	Tests according to
Thickness change	%	≤ 3	n.a.	O.5.1.3.2
Weight change	%	n.a.	≤ 3	O.5.1.3.2

O.5.1.3.2 Tests

Tests shall be performed on 3 samples of 30 mm × 30 mm × 2 mm.

Elastomer / cork samples shall be subjected to the test fluid Isooctane (fuel type no 1 according ISO 1817:2011).

Elastomer / cork / synthetic fibre samples shall be subjected to the test fluid Isooctane (fuel type no 2 according ISO 1817:2011).

Per test sample 160 cm^3 test fluid is used.

Test sequence is as follows:

- Samples shall be conditioned for 1 h at 100 ± 2 °C.
- Samples shall be cooled down for 1 h in an exsiccator (drying apparatus) using Calcium Chloride.
- Samples shall be weighted and their thickness is measured according O.4.2.2.
- Samples shall be submerged in a test bottle with test fluid at 23 °C without touching other samples.
- or other bottle wall, with at least every 24 h a stirring of the test fluid.
- After 7 days of submerging in a closed test bottle, samples shall be removed and conditioned:
- first 3 h at 100 °C in a temperature chamber with air circulation;
- next 1 h in an exsiccator at ambient temperature (18 °C to 28 °C) using Calcium Chloride.

Samples shall be weighted and thickness is measured according O.4.2.2.

Annex ZA
(informative)

Relationship between this European Standard and the Essential Requirements of EU Directive 2009/142/EC

This European Standard has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association to provide a means of conforming to Essential Requirements of the New Approach Directive 2009/142/EC relating to appliances burning gaseous fuels.

Once this standard is cited in the Official Journal of the European Union under that Directive and has been implemented as a national standard in at least one Member State, compliance with the clauses of this standard given in Table ZA.1 confers, within the limits of the scope of this standard, a presumption of conformity with the corresponding Essential Requirements of that Directive and associated EFTA regulations.

Table ZA.1 — Correspondence between this European Standard and Directive 2009/142/EC

Clause(s)/sub-clause(s) of this EN	Essential Requirements (ERs) of Directive 2009/142/EC	Qualifying remarks/Notes
6.1	1.1, 2.1, 3.1.4, 3.1.5, 3.1.6, 3.1.8, 3.1.10, 3.2.1	
6.2.1	1.1, 3.1.1, 3.1.8	
6.2.2	1.1, 3.1.1, 3.1.8, 3.1.11, 3.1.12	
6.2.3.1	1.1, 3.1.1, 3.1.8, 3.1.11, 3.2.1	
6.2.4	1.1, 3.1.1, 3.1.8, 3.2.1	
6.2.5	1.1, 2.1, 3.1.1, 3.1.8, 3.2.1	
6.2.6	1.1, 3.1.1, 3.1.8	
6.2.7	1.1, 3.1.1, 3.1.8, 3.1.11, 3.2.1	
6.2.8	1.1, 3.1.1, 3.1.8, 3.1.11, 3.1.12	
6.2.9	1.1, 3.1.1, 3.1.8, 3.1.11	
6.2.10	1.1, 3.1.1, 3.1.8, 3.1.11, 3.1.12, 3.2.1	
6.3.1	1.1, 2.1, 3.1.1, 3.1.3, 3.1.8	
6.3.2.1	1.1, 3.1.1, 3.1.3, 3.1.8, 3.2.1	
6.3.3.1	1.1, 2.1, 3.1.1, 3.1.3, 3.1.8	
6.3.4	1.1, 3.1.1, 3.1.4, 3.1.8, 3.2.1	
6.3.5	1.1, 2.1, 3.1.1, 3.1.8	
6.3.6	1.1, 2.1, 3.1.1, 3.1.8	
6.3.7	1.1, 2.1, 3.1.1, 3.1.4, 3.1.8, 3.1.11, 3.2.1	
6.4	1.1, 3.1.1, 3.1.4, 3.1.8, 3.2.1	
6.5.1	1.1, 2.1, 3.1.1, 3.1.3, 3.1.5, 3.1.6, 3.1.7, 3.1.9, 3.1.10	
6.5.2.1	1.1, 3.1.1, 3.1.9	

Clause(s)/sub-clause(s) of this EN	Essential Requirements (ERs) of Directive 2009/142/EC	Qualifying remarks/Notes
6.5.3.1	1.1, 3.1.1, 3.1.7, 3.1.9	
6.5.3.3	1.1, 3.1.1, 3.1.7, 3.1.9	
6.5.3.4.1	1.1, 3.1.1, 3.1.7, 3.1.8, 3.1.9	
6.6.1.1.1	1.1, 3.1.1, 3.1.7, 3.1.9, 3.1.10	
6.6.1.1.2	1.1, 3.1.1, 3.1.7, 3.1.9, 3.1.10	
6.6.1.2	1.1, 3.1.1, 3.1.6, 3.1.7, 3.1.9, 3.1.10	
6.6.1.3	1.1, 3.1.1, 3.1.6, 3.1.7, 3.1.9, 3.1.10	
6.6.1.4	1.1, 3.1.1, 3.1.7, 3.1.9, 3.1.10	
6.6.3	1.1, 3.1.1, 3.1.7, 3.1.9, 3.1.10	
6.6.4	1.1, 3.1.1, 3.1.7, 3.1.9, 3.1.10	
7.1	1.1, 3.1.1, 3.1.4, 3.1.5, 3.1.8, 3.2.1	
7.2.1	1.1, 3.1.1, 3.1.4, 3.1.8, 3.2.1	
7.3.1	1.1, 3.1.1, 3.1.4, 3.1.8, 3.2.1	
7.3.2.1	1.1, 3.1.1, 3.1.4, 3.1.8, 3.2.1	
7.4.1	1.1, 3.1.1, 3.2.1	
7.5.1	1.1, 2.1, 3.1.1, 3.1.4, 3.1.8	
7.5.2.1	1.1, 2.1, 3.1.1, 3.1.4	
7.5.3.1	1.1, 2.1, 3.1.1, 3.1.4	
7.5.4.1	1.1, 2.1, 3.1.1, 3.1.4	
7.7.1	1.1, 3.1.1	
7.8	1.1, 3.1.1, 3.1.10	
8.1	1.1, 2.1, 3.1.1, 3.1.3, 3.1.5, 3.1.6, 3.1.7, 3.1.9, 3.1.10	
8.2	1.1, 3.1.1, 3.1.4, 3.1.7	
9.1	1.1, 3.1.1, 3.1.5, 3.1.6, 3.1.7, 3.1.9, 3.1.10	
9.2	3.1.5	
9.3	3.1.5	
10.2	1.3	
10.3	1.3	
I.7.1	1.1, 3.1.1, 3.1.4, 3.1.5, 3.1.8	
M.6.1	1.1, 3.1.1, 3.1.4, 3.1.5, 3.1.6, 3.1.8, 3.1.10	
M.6.5	1.1, 3.1.1, 3.1.3, 3.1.5, 3.1.6, 3.1.7, 3.1.8, 3.1.9, 3.1.10	
M.6.6	1.1, 3.1.1, 3.1.6, 3.1.7, 3.1.9, 3.1.10	
M.7.1	1.1, 3.1.1, 3.1.4, 3.1.5, 3.1.8	
M.7.7	1.1, 3.1.1	
M.7.8	1.1, 3.1.1, 3.1.10	

Clause(s)/sub-clause(s) of this EN	Essential Requirements (ERs) of Directive 2009/142/EC	Qualifying remarks/Notes
M.8	1.1, 3.1.1, 3.1.3, 3.1.5, 3.1.6, 3.1.7, 3.1.8, 3.1.9, 3.1.10	
M.9	1.1, 3.1.1, 3.1.3, 3.1.5, 3.1.6, 3.1.7, 3.1.9, 3.1.10	
O.4.1	1.1, 3.1.1, 3.1.3, 3.1.8	
O.4.2.1	1.1, 3.1.1	
O.5.1.1.1	1.1, 3.1.1, 3.1.8	
O.5.1.2.1	1.1, 3.1.1, 3.1.8	
O.5.1.3.1	1.1, 3.1.1, 3.1.8	

WARNING — Other requirements and other EU Directives may be applicable to the product(s) falling within the scope of this standard.

Annex ZB
(informative)

Relationship between this European Standard and the Essential Requirements of EU Directive 97/23/EC

This European Standard has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association to provide a means of conforming to Essential Requirements of the New Approach Directive 97/23/EC concerning pressure equipment.

Once this standard is cited in the Official Journal of the European Union under that Directive and has been implemented as a national standard in at least one Member State, compliance with the clauses of this standard given in Table ZB.1 confers, within the limits of the scope of this standard, a presumption of conformity with the corresponding Essential Requirements of that Directive and associated EFTA regulations.

Table ZB.1 — Correspondence between this European Standard and Directive 97/23/EC

Clause(s)/sub-clause(s) of this EN	Essential Requirements (ERs) of Directive 97/23/EC	Qualifying remarks/Notes
6.2.1	2.1	
6.2.2	2.1	
6.2.3.1	2.1	
6.2.3.2	2.2.4	
6.2.4	2.1	
6.2.5	2.1	
6.2.6	2.1	
6.2.7	2.1	
6.2.8	2.1	
6.2.9	2.1	
6.2.10	2.1	
6.3.1	2.1, 2.2.1	
6.3.2.1	2.1	
6.3.2.2	2.2.4	
6.3.3.1	2.1	
6.3.3.2	2.2.4	
6.3.4	2.1, 2.2.1, 2.6	
6.3.5	2.1, 2.2.1, 2.6	
6.3.6	2.1, 2.2.1	
6.3.7	2.1, 2.2.1	
6.4.3	2.1, 2.2.1	
6.4.5	2.1, 2.2.1	
6.5.3.4	2.2.4	
7.1	2.1, 2.2.1	

Clause(s)/sub-clause(s) of this EN	Essential Requirements (ERs) of Directive 97/23/EC	Qualifying remarks/Notes
7.2.1	2.1	
7.2.2	2.2.4	
7.3	2.2.1, 2.2.4	
7.5.1	2.2.4, 2.6	
7.5.3.1	2.2.1, 2.2.4, 2.6	
7.5.4.1	2.2.1, 2.2.4, 2.6	
F.6.1	2.1, 2.2.1, 2.11.1	
F.6.2.11	2.2.1, 2.11.1	
F.6.3.8	2.2.3, 4.2 b),	
F.6.3.9	3.1.2	
F.6.3.10	3.1.3, 3.2.1	
F.7.9.1	3.2.2	
F.10.1	3.3 a)	
F.10.2	3.4	
O.4.1	2.2.4	
O.5.1.1.1	2.2.4	
O.5.1.2.1	2.2.4	
O.5.1.3.1	2.2.4	

WARNING — Other requirements and other EU Directives may be applicable to the product(s) falling within the scope of this standard.

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