BS EN 50271:2010

BSI Standards Publication

Electrical apparatus for the detection and measurement of combustible gases, toxic gases or oxygen — Requirements and tests for apparatus using software and/or digital technologies

National foreword

This British Standard is the UK implementation of EN 50271:2010. It supersedes BS EN 50271:2002, which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee GEL/31/19, Gas detectors.

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.

ISBN 978 0 580 69466 0

ICS 13.320; 29.260.20; 71.040.40

Compliance with a British Standard cannot confer immunity from legal obligations.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 30 April 2011.

Amendments issued since publication

Date	Text affected

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 50271

June 2010

ICS 13.320

Supersedes EN 50271:2001

English version

Electrical apparatus for the detection and measurement of combustible gases, toxic gases or oxygen - Requirements and tests for apparatus using software and/or digital technologies

Appareils électriques de détection et de mesure des gaz combustibles, des gaz toxiques ou de l'oxygène - Exigences et essais pour les appareils utilisant un logiciel et/ou des technologies numériques

Elektrische Geräte für die Detektion und Messung von brennbaren Gasen, giftigen Gasen oder Sauerstoff - Anforderungen und Prüfungen für Warngeräte, die Software und/oder Digitaltechnik nutzen

CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

Management Centre: Avenue Marnix 17, B - 1000 Brussels

Ref. No. EN 50271:2010 E

Foreword

This European Standard was prepared by SC 31-9, Electrical apparatus for the detection and measurement of combustible gases to be used in industrial and commercial potentially explosive atmospheres, of Technical Committee CENELEC TC 31, Electrical apparatus for potentially explosive atmospheres. It was submitted to the formal vote and approved by CENELEC as EN 50271 on 2010-06-01.

This document supersedes EN 50271:2001.

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

The State of the Art is included in Annex ZY "*Significant changes between this European Standard and EN 50271:2001*".

The following dates were fixed:

– latest date by which the EN has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2011-06-01
– latest date by which the national standards conflicting with the EN have to be withdrawn	(dow)	2013-06-01

This European Standard has been prepared under a mandate given to CENELEC by the European Commission and the European Free Trade Association and covers essential requirements of EC Directive 94/9/EC. See Annex ZZ.

———————

Contents

Introduction ..... **- 4 -**

1 Scope ..... **- 5 -**

2 Normative references ..... **- 5 -**

3 Terms and definitions ..... **- 7 -**

4 Design principles ..... **- 8 -**

4.1 Basic requirements ..... - 8 -
4.2 Displays ..... - 10 -
4.3 Software ..... - 10 -
4.4 Hardware ..... - 19 -
4.5 Digital data transmission between components of apparatus ..... - 19 -
4.6 Test routines ..... - 20 -
4.7 Instruction manual ..... - 21 -
4.8 Additional requirements for compliance with SIL 1 ..... - 22 -

5 Test of the digital unit ..... **- 22 -**

5.1 General ..... - 22 -
5.2 Verification of functional concept ..... - 23 -
5.3 Performance test ..... - 23 -

Annex A (normative) **Hardware-software integration test** ..... **- 25 -**

A.1 Functional testing/Black-box testing ..... - 25 -
A.2 Equivalence class test with boundary value analysis ..... - 25 -

Annex ZY (informative) **Significant changes between this European Standard and EN 50271:2001** ..... **- 27 -**

Annex ZZ (informative) **Coverage of Essential Requirements of EC Directives** ..... **- 28 -**

Figure

Figure 1 – Model of the software development process ..... - 12 -

Introduction

This European Standard specifies minimum requirements for functional safety of gas detection apparatus using software and/or digital technologies and defines criteria for reliability and avoidance of faults. Functional safety is that part of the overall safety which is related to the measures within the gas detection apparatus to avoid or to handle failures in such a manner that the safety function will be assured.

Gas detection apparatus will fail to function if dangerous failures occur. The aim of this European Standard is to reduce the risk of dangerous equipment failures to levels appropriate to typical applications of such apparatus.

Failure to function will also occur if such apparatus are not selected, installed or maintained in an appropriate manner. In some applications failures of this type will dominate the functional safety achieved. Users of gas detection apparatus will therefore need to ensure that selection, installation and maintenance of such apparatus are carried out appropriately. Guidance for the selection, installation, use and maintenance of gas detection apparatus are set out in EN 60079-29-2 and EN 45544-4, respectively.

This European Standard does not include requirements for operational availability which will need to be considered separately.

Regarding the requirements for the software development process, this European Standard specifies a practical approach to comply with the requirements of EN 61508-3 for SIL 1 without using this generic standard.

It is recommended to apply this European Standard for apparatus used for safety applications with SIL-requirement 1 instead of EN 50402 because EN 50402 is designed for the assessment of more complex gas detection systems with SIL-requirements greater than 1. However, the technical requirements of EN 50271 and EN 50402 are the same for SIL 1.

1 Scope

This European Standard specifies minimum requirements and tests for electrical apparatus for the detection and measurement of combustible gases, toxic gases or oxygen using software and/or digital technologies. Additional requirements are specified if compliance with safety integrity level 1 (SIL 1) according to EN 61508 series is required for low demand mode of operation.

NOTE 1 It is recommended to apply this European Standard for apparatus used for safety applications with SIL-requirement 1 instead of EN 50402. However, the technical requirements of EN 50271 and EN 50402 are the same for SIL 1.

NOTE 2 For fixed apparatus used for safety applications with SIL-requirements higher than 1 EN 50402 is applicable.

This European Standard is applicable to fixed, transportable and portable apparatus intended for use in domestic premises as well as commercial and industrial applications.

This European Standard does not apply to external sampling systems, or to apparatus of laboratory or scientific type, or to apparatus used only for process control purposes.

This European Standard supplements the requirements of the European Standards for the detection and measurement of flammable gases and vapours (e.g. EN 60079-29-1, EN 50241-1, EN 50241-2, EN 50194-1, EN 50194-2), toxic gases (e.g. EN 45544 series, EN 50291-1, EN 50291-2) or oxygen (e.g. EN 50104).

NOTE 3 These European Standards will be mentioned in this European Standard as "metrological standards".

NOTE 4 The examples above show the state of the standardisation for gas detection apparatus at the time of publishing this European Standard. There may be other metrological standards for which this European Standard is also applicable.

This European Standard is a product standard which is based on EN 61508 series. It covers part of the phase 9 "realisation" of the overall safety life cycle defined in EN 61508-1.

2 Normative references

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

EN 45544-1	Workplace atmospheres – Electrical apparatus used for the direct detection and direct concentration measurement of toxic gases and vapours – Part 1: General requirements and test methods
EN 45544-2	Workplace atmospheres – Electrical apparatus used for the direct detection and direct concentration measurement of toxic gases and vapours – Part 2: Performance requirements for apparatus used for measuring concentrations in the region of limit values
EN 45544-3	Workplace atmospheres – Electrical apparatus used for the direct detection and direct concentration measurement of toxic gases and vapours – Part 3: Performance requirements for apparatus used for measuring concentrations well above limit values
EN 45544-4	Workplace atmospheres – Electrical apparatus used for the direct detection and direct concentration measurement of toxic gases and vapours – Part 4: Guide for selection, installation, use and maintenance
EN 50104	Electrical apparatus for the detection and measurement of oxygen – Performance requirements and test methods

EN 50194-1	Electrical apparatus for the detection of combustible gases in domestic premises – Part 1: Test methods and performance requirements
EN 50194-2	Electrical apparatus for the detection of combustible gases in domestic premises – Part 2: Electrical apparatus for continuous operation in a fixed installation in recreational vehicles and similar premises – Additional test methods and performance requirements
EN 50241-1	Specification for open path apparatus for the detection of combustible or toxic gases and vapours – Part 1: General requirements and test methods
EN 50241-2	Specification for open path apparatus for the detection of combustible or toxic gases and vapours – Part 2: Performance requirements for apparatus for the detection of combustible gases
EN 50291-1	Electrical apparatus for the detection of carbon monoxide in domestic premises – Part 1: Test methods and performance requirements
EN 50291-2	Electrical apparatus for the detection of carbon monoxide in domestic premises – Part 2: Electrical apparatus for continuous operation in a fixed installation in recreational vehicles and similar premises including recreational craft – Additional test methods and performance requirements
EN 50402:2005 + A1:2008	Electrical apparatus for the detection and measurement of combustible or toxic gases or vapours or of oxygen – Requirements on the functional safety of fixed gas detection systems
EN 60079-29-1:2007	Explosive atmospheres – Part 29-1: Gas detectors – Performance requirements of detectors for flammable gases (IEC 60079-29-1:2007, mod.)
EN 60079-29-2	Explosive atmospheres – Part 29-2: Gas detectors – Selection, installation, use and maintenance of detectors for flammable gases and oxygen (IEC 60079-29-2)
EN 61508-1:2001	Functional safety of electrical/electronic/programmable electronic safety-related systems – Part 1: General requirements (IEC 61508-1:1998 + corr. May 1999)
EN 61508-2:2001	Functional safety of electrical/electronic/programmable electronic safety-related systems – Part 2: Requirements for electrical/electronic/programmable electronic safety-related systems (IEC 61508-2:2000)
EN 61508-3:2001	Functional safety of electrical/electronic/programmable electronic safety-related systems – Part 3: Software requirements (IEC 61508-3:1998 + corr. Apr. 1999)
EN 61508-4:2001	Functional safety of electrical/electronic/programmable electronic safety-related systems – Part 4: Definitions and abbreviations (IEC 61508-4:1998 + corr. Apr. 1999)
EN 61508-5:2001	Functional safety of electrical/electronic/programmable electronic safety-related systems – Part 5: Examples of methods for the determination of safety integrity levels (IEC 61508-5:1998 + corr. Apr. 1999)
EN 61508-6:2001	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 61508-6:2000)
EN 61508-7:2001	Functional safety of electrical/electronic/programmable electronic safety-related systems – Part 7: Overview of techniques and measures (IEC 61508-7:2000)

3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 60079-29-1:2007 and the following apply.

3.1
digital unit
part of an electrical apparatus in which data is processed digitally. Analogue-digital(A/D)-converters and digital-analogue(D/A)-converters as interfaces to analogue units of the apparatus belong to the digital unit

3.2
special state
all states of the apparatus other than those in which monitoring of gas concentration take place, for example warm-up, maintenance mode (configuration, calibration, etc) or fault condition

3.3
software
intellectual creation comprising the programs, procedures, rules and associated documentation pertaining to the operation of the digital unit

3.4
failure
termination of the ability of a functional unit to provide a required function or operation of a functional unit in any way other than as required

[EN 61508-4:2001, 3.6.4, mod.]

3.5
parameters
settings by the manufacturer or user which effect the operation of the software, e.g. changing of alarm thresholds or measurement units. Parameter options are included in the software during design of the apparatus. Changes of parameter settings are not modifications of the software

3.6
specified range of input values
range of input values corresponding to the conversion range of the A/D- or D/A-converter

3.7
defined range of input values
range of input values defined by the manufacturer of the apparatus to be valid; the defined range is part of the specified range of input values

3.8
output data
result of the digital data processing, which is used for driving the output interfaces

NOTE Output interfaces may be analogue or digital displays, analogue or digital outputs and/or alarm indicators or relays.

3.9
output signal
analogue or digital signal which is available at an output interface

3.10
measured value
processed measured signal including physical unit (e.g. % LEL). A measured value may be formed from a single signal or a combination of several measurement signals. The combined measured signals may represent different physical units, e.g. gas concentration and temperature

3.11
smallest deviation of indication
value which is determined by the applicable metrological standards. In metrological standards the allowed tolerances for deviation of indication during type testing are given. If there are different requirements for the tolerances in different applicable metrological standards the smallest tolerance is the “minimum deviation of indication”.

The minimum deviation of indication is basis for the required resolution of measured signals which use digital transmission and data processing to meet the requirements of the metrological standards when using digital technologies

[EN 50402:2005, 3.21, mod.]

3.12
message
indication on a display which gives an information about the status of the apparatus (e.g. alarm, special state, warning)

3.13
software component
part of the program that consists of one or several software modules and that can also interact with other such constructs

3.14
software module
construct that consists of subroutines and/or data declarations and that can also interact with other such constructs

4 Design principles

4.1 Basic requirements

4.1.1 General

The metrological standards define performance requirements for gas detection apparatus which have direct implications on the digital units and software which may be used in such apparatus. This subclause specifies basic requirements to digital units and software to fulfil the metrological standards.

4.1.2 Analogue/digital interface

The relationship between corresponding analogue and digital values shall be unambiguous. The output range shall be capable of coping with the defined range of input values. Input values outside the specified range of the converter shall not result in a valid measured value. A/D- and D/A-converter quantisation steps shall be chosen so that the requirements in 4.1.3 for the accuracy of data representation will be fulfilled. The design shall take into account the maximum possible A/D- and D/A-converter errors.

NOTE This assessment may not include environmental interferences to the A/D- or D/A-converters, e.g. temperature variation.

Outputs at the limits of the specified range of D/A-converters shall result in output signals which are described as fault signal by the manufacturer.

4.1.3 Numerical errors

Deviations of measured values arising from quantisation, rounding and calculation errors shall be estimated assuming worst case conditions.

These worst case conditions shall be evaluated in detail. For example, the influence of the sensing principle such as non-linear behaviour of the signal or ageing of sensors, varying sensitivities for different gases and signal variation with temperature, pressure or humidity shall be taken into consideration.

The estimated deviation of measured values shall not be greater than 50 % of the smallest deviation of indication.

NOTE The deviation of measured values arising from the digital unit will be typically much lower than 50 % of the smallest deviation of indication. Deviations arising from other sources (e.g. sensor) are expected to be dominant.

4.1.4 Measuring operation

During data processing the digital unit shall control automatically the specified input data range and handle range violations. Zero and full scale of the converter shall not be considered to be within the specified range in order to detect stuck-at faults.

The software design and verification shall guarantee that range violations for internal and output data do not occur. Otherwise the digital unit shall control automatically the allowed data ranges and handle range violations.

During measuring operation, the maximum overall time of four successive updates of the output signals shall not exceed the response time t_{90} of the apparatus or, for alarm only apparatus, the minimum time to alarm.

NOTE This timing requirement may not be applied to output signals which are explicitly claimed by the manufacturer to be not safety-relevant.

4.1.5 Special state indication

4.1.5.1 Fixed and transportable apparatus

a) Control units

While a special state is present within the gas detection system (i.e. control unit and external sensors or transmitters) this shall be continuously indicated by a signal. This signal shall be transmittable except when the apparatus is intended to be used in domestic premises only. Signals provided for signalling that the entire gas detection system is in the special state "fault" shall use the idle current principle.

b) Gas detection apparatus (transmitters) intended to be used with control units

A special state of the gas detection apparatus shall be transmitted to the control unit continuously.

c) Apparatus having self-contained sensors

A special state shall be continuously indicated by a signal. This signal shall be transmittable except when the apparatus is intended to be used in domestic premises only. Signals provided for signalling that the entire apparatus is in the special state "fault" shall use the idle current principle.

NOTE In the case of digital data transmission, the term "continuously" is used with the meaning: continually, at the rate at which the output signal is updated (see 4.1.4).

4.1.5.2 Portable apparatus

The special state "fault" shall be continuously indicated by an optical and acoustic signal.

NOTE 1 It may be possible to silence the acoustic signal.

NOTE 2 It will not be possible to show an indication in all possible fault situations without implementing an emergency path, e.g. to detect sudden breakdown of battery voltage without second independent power supply. However it is possible to indicate the normal operation of the apparatus by a periodic optical and acoustical output signal (commonly called alive signal or confidence signal).

The special state "warm-up" shall be indicated by an optical and/or acoustic signal.

The special states "calibration mode" and "parametrisation mode" shall be indicated by an optical signal.

4.2 Displays

4.2.1 General

If a display is provided the requirements of 4.2.2 and 4.2.3 apply.

4.2.2 Indication of messages

If it is intended to indicate messages on a display:

a) it shall be possible to display all active messages simultaneously or a consolidated signal shall be generated (e.g. indicating lights for alarms or fault) and a consolidated message shall be displayed. It shall be possible to interrogate all active messages;

b) a unique message shall be provided for each individual gas alarm;

c) if no special state is activated, it shall be possible to interrogate the measured values of all gas sensors.

If a message includes another subsidiary message (e.g. exceeding the 2nd alarm threshold includes exceeding the 1st alarm threshold) it is sufficient to show the message of higher priority. After cancelling the higher order message the subsidiary message shall remain if the reason for its activation still exists.

NOTE It is recommended that the manufacturer defines an appropriate set of messages in order to enable the user an easy identification of alarms, special states, etc.

4.2.3 Indication of measured values

For measured values the displayed unit of measurement and any related sign shall be unambiguous. Any under-range or over-range measurements shall be clearly indicated.

4.3 Software

4.3.1 General

This clause defines minimum requirements for the software development process which are based on EN 61508-3. Alternative procedures are permitted provided that the applicable requirements of EN 61508-3 are fulfilled.

In general, software will consist of device software and, if applicable, an operating system and libraries (e.g. mathematical functions).

The requirements of this clause shall be applied to the entire software. A distinction between safety-related and non safety-related software is not made.

New operating systems shall be developed according to 4.3.3 to 4.3.5. Re-used or commercial operating systems shall comply with 4.3.2.

New device software and libraries shall be developed according to 4.3.3 to 4.3.5. Re-used or commercial software modules (e.g. libraries) shall be qualified (see 4.3.5.3.2).

To software for parameterization of the gas detection device, which is running on external devices (e.g. PC) on request and under control of an authorized user for a short period of time, only the requirements of 4.3.3, 4.3.4 a)-h) and 4.7 shall be applied.

4.3.2 Re-used or commercial operating systems

4.3.2.1 Requirements

Re-used or commercial operating systems may be integrated without applying 4.3.3 to 4.3.5 if the following requirements are fulfilled:

a) quasi-real time capability for compliance with the requirements of 4.1.4;

b) it shall not be possible for the user to modify the configuration of the operating system;

c) no automatic update-function for the operating system;

d) upgrades of the operating system shall only be possible under the control of the manufacturer of the apparatus;

e) if the program is executed from volatile memory the entire software shall be fully loaded at start-up of the apparatus. In special states which are entered by a deliberate action of the user (e.g. modification of parameters) loading of further modules is permitted;

f) functional safety is validated to be at least SIL 1 according to EN 61508-3 or the operating system is used with the restrictions according to 4.3.2.2.

NOTE It is pointed out that, according to 4.3.5.9, in case of modification of the operating system the impact on the device software shall be assessed and, if necessary, modification and validation procedures shall be performed.

4.3.2.2 Use of operating systems without validation of functional safety

An operating system without validation of functional safety is permitted to be used if the following requirements are fulfilled.

a) The device software has a logical and temporal monitoring of program sequence.

b) The monitoring equipment according to 4.6 d) is triggered by the device software only (that is, the device software operates the hardware IO ports and watchdog directly, without using the operating system).

c) Output ports which are part of the safety function are exclusively driven by the device software. However, functions of the operating system may be used if the correct settings of the output ports are verified by the device software.

d) Input ports which are part of the safety function are read by the device software. However, functions of the operating system may be used if the correctness of the read data is verified by the device software.

e) The test routines according to 4.6 shall be performed by the device software or hardware.

NOTE 1 If the state of switching outputs is monitored by the device software, functions of the operating system may be used both for driving and reading back the switching output.

NOTE 2 For digital data transmission between spatially separated components of apparatus the requirements of 4.5 apply. The device software verifies the transmitted information thus enabling the detection of side effects (e.g. corruption) caused by the operating system of the transmitter or receiver.

4.3.3 Software requirements

a) It shall be possible for the user to identify the installed software version, for example by marking on the installed memory component, in (if accessible) or on the apparatus or by showing it on the display during power up or on user command.

b) It shall not be possible for the user to modify the software function. It shall be impossible to change the program code under any operating conditions. Upgrades shall only be possible under the control of the manufacturer.

c) Parameter settings shall be checked for validity. Invalid inputs shall be rejected. An access barrier shall be provided against parameter changing by unauthorised persons, e.g. it may be integrated by an authorisation code in the software or may be realised by a mechanical lock. Parameter settings shall be preserved after apparatus switch-off, after disconnection of the power supply and while passing through a special state.

Parameters controlling the calibration of the apparatus shall not be updated before the calibration/adjustment routine is finished successfully. It shall be possible for the user to abort the calibration/adjustment routine.

NOTE If zero and span adjustment are carried out independently in separate routines, each parameter may be updated individually after the respective routine is finished successfully.

d) Control or status bits shall be explicitly set or re-set in each program cycle.

4.3.4 Requirements for software documentation

The software documentation shall include:

a) designation of the apparatus to which the software belongs;

b) unambiguous identification of program version;

c) if applicable, version the operating system;

d) if applicable, versions of libraries;

e) any software modification provided with the date of change and new identification data;

f) documentation of the software development process (modification included, if applicable) according to 4.3.5;

g) source code;

h) functional description;

i) software structure (e.g. flow chart, Nassi-Schneidermann diagram).

4.3.5 Requirements for the software development process

4.3.5.1 General

The software development shall be carried out according to the model described in Figure 1.

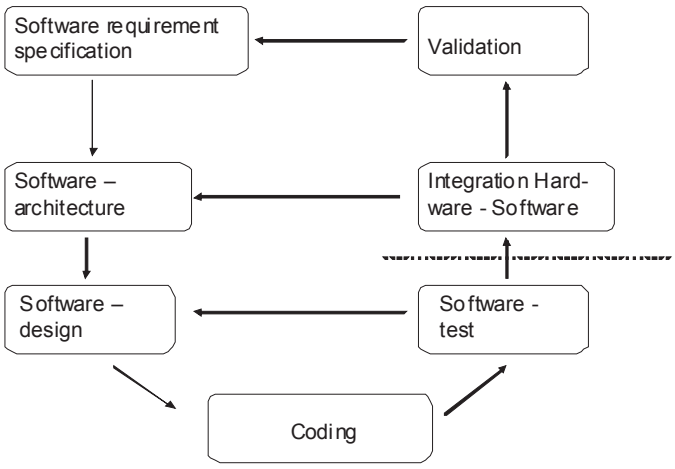

Figure 1 – Model of the software development process

It shall be ensured by suitable measures that

a) during development of the software

b) and for all modifications on the basis of an impact analysis

all applicable phases are processed and documented. For each software version, it shall be possible to identify all parts of the software (software-documentation included) with respect to their version and to identify the relationship between all parts unambiguously. That is, all parts of the software and all its documentation shall be held under configuration management.

NOTE 1 The application of these measures ensures in conjunction with the requirements for the software documentation according to 4.3.4 that the applicable requirements of EN 61508-3 to the configuration management of the software are fulfilled for the purpose of this European Standard.

The results of each phase of the software development process shall be verified for consistency with the input of the phase and for correctness as regards content and shall be reviewed and approved by a second person. The results of each phase, the results of the tests and the related verification shall be documented and held under configuration management.

NOTE 2 This includes the requirement that the test plans developed in individual phases of the software development process shall be assessed with respect to their suitability and completeness.

NOTE 3 These tests and assessments include in conjunction with further regulations described in the following clauses the applicable requirements of EN 61508-3 for software verification.

Coding standards shall be used in the coding phase. These shall

c) be used for the development of the entire software;

d) describe programming techniques to be used;

e) proscribe the use of unsafe language constructs;

f) specify procedures for source code documentation.

The documentation of each source code module shall contain at least the following:

g) legal entity (for example company, author(s));

h) intended use;

i) for each function/procedure, its inputs and outputs, their pre- and post-conditions, and their effect on global state.

j) history of versions.

4.3.5.2 Software requirements specification

The software requirements shall be specified for each interface, including: hardware devices, human interfaces, communications interfaces. A concept for handling faults on all these interfaces shall be defined.

The requirements for the software shall be complete and unambiguous and shall be documented in sufficient detail in natural language. Where practical, graphical schemes, tables, mathematical formulas etc. may be used for the sake of precision.

It shall be possible to identify each requirement for the software unambiguously.

Each requirement for the software shall be traceable to a requirement for the apparatus.

The requirements for the software shall be specified for each interface to the hardware. A concept for detection and handling of hardware faults shall be defined.

NOTE 1 The interfaces to the hardware include also the interfaces to the periphery.

A plan for validating the software shall be developed based on the specified requirements for the software. Objective of the validation is to demonstrate that all specified requirements for the software are satisfied.

NOTE 2 Parts of this validation will demonstrate that certain requirements of the metrological standards that apply to the functionality of the apparatus are fulfilled.

Validation shall be carried out with the apparatus and therefore also includes the interaction of hardware and software. Validation shall be carried out by means of a functional/black-box-test of the apparatus (see 4.3.5.8).

The validation plan shall include at least the following:

a) test methods and test cases for each specified requirement for the software;

b) environmental conditions;

c) tools (for example test gases);

d) pass / fail criteria.

4.3.5.3 Software architecture

4.3.5.3.1 Architecture

The software architecture shall be designed based on

a) hardware architecture;

b) software requirements specification (see 4.3.5.2).

The software architecture shall

c) define a structured and modular design;

d) ensure that software modules have a clearly defined interface to other modules;

e) specify each interaction between software and hardware;

f) define measures for detection and handling of hardware faults.

The design of the software architecture and the software design (see 4.3.5.4) shall be carried out in a structured manner. This includes a systematic approach including at least the following steps:

g) decomposition step by step of the software function into manageable software components;

h) assignment of data structures to the software components;

i) definition of the interfaces between the software components;

j) if applicable, selection of the operating system (see 4.3.1);

k) if applicable, selection of libraries (see 4.3.1).

The software architecture shall allow for tracing each software requirement from 4.3.5.2 to its implementation in the software design according to 4.3.5.4.

The hardware-software integration tests shall be specified based on the software architecture (see 4.3.5.7).

4.3.5.3.2 Tools and coding standards

Suitable, matching tools including languages, compilers, and, if used, tools for the configuration management and automatic testing tools shall be selected. The availability of the tools over the whole lifetime of the apparatus shall be considered.

The suitability of the tools for code generation (for example code generator, compiler) and of external or re-used software (for example libraries) shall be assessed. At least the following criteria shall be considered:

a) range of functions and performance;

b) operating experience;

c) updates, release notes;

d) error lists;

e) references;

f) publications related to the tool (for example tests or validation by a third party);

g) experience with similar products of the manufacturer;

h) market presence of the manufacturer.

NOTE 1 This assessment may be omitted if EN 61508 (or similar safety standard) certified tools are used.

NOTE 2 Changing the version of the tools for code generation during the lifetime of the apparatus should be avoided because otherwise the suitability has to be re-assessed.

The programming language and the coding standards shall support measures to avoid systematic faults and foster predictable program execution. This can be achieved by applying the following criteria.

Requirements for the programming language (by using coding standards, if necessary):

i) suitability for the application;

j) complete, unambiguously defined or restricted to unambiguously defined properties;

k) contain features that facilitate the detection of programming mistakes;

l) block structure.

NOTE 3 The language should be user- or problem-orientated rather than processor/platform machine-orientated. Widely used languages or their subsets are preferred to special purpose languages.

NOTE 4 Low-level languages, in particular assembly languages, present problems due to their processor/platform machine-orientated nature. Therefore, assembly languages should only be used for tasks with low complexity. Any use of assembly language shall be justified explicitly in the software documentation.

The programming language and the use of coding standards, if necessary, shall support

m) restriction of access to data in specific software modules (encapsulation);

n) further measures for fault avoidance, for example avoidance of unsafe constructs.

If the programming language allows unsafe constructs, their use shall be avoided by definition of a subset. This subset shall be defined in coding standards.

NOTE 5 MISRA-C is an example of a language subset for the programming language C.

The use of the following unsafe constructs shall be avoided by the coding standards:

o) unconditional jumps excluding subroutine calls;

p) recursions;

q) dynamic variables or objects;

r) multiple entries or exits of loops;

s) multiple entries of subprograms or blocks;

t) implicit variable initialisation or declaration;

u) data of variable types (for example "void" in C);

v) equivalences of variables, if write access occurs at more than one place of the program.

Pointer shall only be used as far as absolutely necessary.

Subprograms and blocks shall have one exit only.

4.3.5.4 Software design

The software design shall be carried out in a structured manner (see 4.3.5.3). It shall be possible to demonstrate the implementation of each software requirement from 4.3.5.2.

The software design shall adhere to the following rules which shall be included in the software developers programming standard:

a) decomposition of the software components into systems of software modules;

b) specification of the functionality of the software modules;

c) specification of data structures and assignment to the software modules; this specification shall be consistent with the functional requirements of the apparatus, complete and free of contradictions;

d) definition of unambiguous interfaces between the software modules;

e) design of the software modules;

f) specification of test methods and test cases for each software module (specification of module testing, see 4.3.5.6);

g) specification of test methods and test cases for the entire software (specification of software integration test, see 4.3.5.6).

The software design shall be carried out according to the following rules:

h) the software modules shall be decoupled as far as possible and all interactions are explicit;

i) suitable limitation of module size;

j) each interface of a software module shall only contain only those parameters which are necessary for its function;

k) compose the software module control flow using structured constructs, that is sequences, iterations and selection;

l) keep the number of possible paths through a software module small;

m) avoid complex branching;

n) avoid complicated calculations as basis for branching or loop conditions;

o) software modules shall usually communicate with other software modules via their interfaces - where global or common variables are used:

   1) they shall be well structured;

   2) they shall be declared in one central module;

   3) access shall be controlled;

   4) their use shall be justified in each instance;

   5) competing write- and read-access by parallel running processes shall be avoided;

p) multiple calls (for example by interrupts) of subprograms which are not re-entry capable shall be avoided.

4.3.5.5 Coding

The source code shall

a) be readable, understandable, and testable;

b) implement the design of the software modules (see 4.3.5.4);

c) satisfy the requirements of the coding standards (see 4.3.5.3.2);

d) implement each software requirement from 4.3.5.2.

It shall be verified for each software module by a tool-based static code analysis and, if necessary, by supplementary measures that the coding standards (see 4.3.5.3.2) are satisfied.

4.3.5.6 Software test

The software test consists of software module tests and an integration test. These tests shall be carried out as functional/black-box tests (see Annex A).

Each software module shall be tested as specified during the software design (see 4.3.5.4). The software modules shall be combined to manageable integration units. The software integration test shall be carried out as specified during the software design (see 4.3.5.4). If appropriate, the software integration test and the hardware-software integration test according to 4.3.5.7 may be combined.

The specification of the module tests and the software integration test shall include

a) test cases and test data;

b) test methods;

c) test bed, tools, configuration and programs;

d) pass / fail criteria.

Software module tests contribute to the verification that the software modules satisfy all module specifications specified during the software design (see 4.3.5.4) completely. It is the combination of code review and software module testing that provides assurance that a software module satisfies its associated specification, i.e. it is verified.

Software integration tests contribute to the verification that the software modules and software components/-subsystems interact correctly to perform their intended function.

Both for the software module test as well as the software integration test the test configuration, the test results, the assessment and, if applicable, corrective actions shall be documented. If software is modified as a result of the software integration tests the requirements in 4.3.5.1 shall be observed.

4.3.5.7 Hardware-software integration test

The hardware-software integration test shall be carried out as specified during the design of the software architecture (see 4.3.5.3). If appropriate, the software integration test according to 4.3.5.6 and the hardware-software integration test may be combined. The hardware-software integration test shall be carried out as functional/black-box test (see Annex A).

The specification of the hardware-software integration test shall include the following:

a) split of the integration into reasonable steps;

b) test cases and test data;

c) test methods;

d) test bed, tools, equipment, support software and configuration;

e) pass / fail criteria.

The test configuration, the test results, the assessment and, if applicable, corrective actions shall be documented. If hardware or software is modified as a result of the integration tests the requirements in 4.3.5.1 shall be observed.

4.3.5.8 Validation

Validation shall be carried out with the apparatus and therefore also includes the interaction of hardware and software. It is allowed to adopt results of the hardware-software integration test if these results were achieved with the hardware and software versions to be validated.

The validation shall be carried out as specified in the validation plan (see 4.3.5.2). The validation shall be carried out completely and demonstrate for the hardware and software versions to be validated that all specified requirements for the software are fulfilled. If validation results are used which were achieved with former versions of hardware or software it shall be verified by an impact analysis that the modifications have no impact on the validation results.

Tools and equipment used for software validation shall be suitable for purpose.

Validation shall be carried out as functional/black-box test (see Annex A).

Discrepancies between expected and actual results shall be analysed and decision taken on whether to continue the validation for the time being, or to issue a change request immediately and return to an earlier phase of the software development process.

The documentation of the validation shall include the following:

a) a record of all validation activities which allows a chronology and identification of the validated versions of software and hardware for all activities;

b) the validated software function with respect to the validation plan and version of the validation plan;

c) tools and equipment used together with calibration data unless otherwise documented;

d) impact analysis concerning usability of validation results obtained with former versions of hardware and software, if applicable;

e) discrepancies between expected and actual results as well as the results of the analysis and the decision concerning further action;

f) assessment result "passed" or "failed" including justification.

4.3.5.9 Software modification

Corrections, enhancements or adaptations to the validated software shall be carried out in such a manner that the software safety is not affected.

A software modification request shall be prepared and released. The software modification request shall describe the proposed change and the reasons for change.

An impact analysis of the proposed software modification shall be carried out. Based on this analysis decision shall be taken

a) to which phase of the software development process it shall be returned;

b) the extent of the modifications to be made in this phase and each of those following.

The results of the impact analysis shall be documented.

On this basis a modification plan shall be developed. It shall include the following:

c) a detailed specification of the modification;

d) planning of the tests according to 4.3.5.6 and 4.3.5.7;

e) planning of the validation according to 4.3.5.8.

The tests according to d) shall include all modified subroutines and all subroutines which are affected by the modification. All original test cases, if applicable, and, if necessary, new test cases to be defined shall be carried out.

The modification shall be carried out as specified in the modification plan.

The requirements to the documentation according to 4.3.5.1 to 4.3.5.8 shall be fulfilled.

4.4 Hardware

Safety relevant components shall only be used within their specifications. For interconnection between components, cabling and other interface specifications shall be adhered to.

To store parameters and variables, which should be permanent even after switch-off or during a special state, storage parts shall be used in which the data content remains permanent when the supply voltage is removed. Where a back-up supply (e.g. battery, capacitor) is used for this purpose the test routine for the parameter memory (see 4.6) shall be able to detect a discharged supply.

NOTE It is not recommended to use a rechargeable battery.

4.5 Digital data transmission between components of apparatus

The measures for ensuring reliable data transmission between spatially separated components shall take into account transmission errors, repetitions, deletion, insertion, resequencing, corruption, delay and masquerade.

In case of data transmission between components within a single enclosure a one-bit redundancy scheme shall be used (for example, parity checking) as the very minimum.

If the data transmission is used for more than one channel, e.g. bus connection or multiplex transmission, the correct assignment of the channels shall be monitored.

NOTE 1 Data transfer between a microcontroller and external A/D- or D/A-converters is not to be considered here. The respective requirements are described in 4.1.2 and 4.1.4.

NOTE 2 Data transfer between a microcontroller and external memory components is not to be considered here. The respective requirements are described in 4.6.

NOTE 3 Data transfer from a microcontroller to a display is not to be considered here. The respective requirements are described in 4.6.

Plug connections shall be protected against erroneous connection or disconnection.

Delays resulting from transmission errors shall not extend the response time t_{90} or time to alarm for alarm only apparatus by more than 1/3. If not the apparatus shall pass over to a defined special state.

If the non-ambiguity of the measured values of the whole apparatus at gas concentrations above the upper limit of the measuring range (e.g. when catalytic sensors are used) is affected by transmission errors the apparatus shall pass over to a defined latching special state.

4.6 Test routines

Computerised digital units shall incorporate test routines. On failure detection, the apparatus shall pass over to a defined special state. The tests except for tests b) and c) shall be done automatically, performed after switching on and repeated cyclically at least once within 24 h. The tests after switching on shall be completed before the special state "warm-up" is left.

NOTE 1 For fixed or transportable apparatus, the test after switching on may be skipped on user intervention for maintenance purposes.

NOTE 2 Test routines for stuck-at faults of A/D-converters and multiplexers are not included because the failure rates of these components are usually very low. It is recommended that the manufacturer should verify that the failure rates of these components are negligible in comparison with the failure rates of the other digital components used in the apparatus.

The following minimum tests shall be performed by the apparatus:

a) supply voltage of digital units shall be monitored against under-range within time intervals of maximum ten times response time t_{90} or time to alarm for alarm only apparatus;

b) all visible and audible output functions shall be tested. The test shall be carried out automatically after starting operation. For portable apparatus which cannot be switched off and for transportable and fixed apparatus this test shall also be carried out on user request. It is permissible that the result is assessed by the user;

c) all safety relevant output signals shall be tested on user request. It is permissible that the result is assessed by the user;

   NOTE 3 Visible or audible output functions according to b) are not considered here.

d) monitoring equipment with its own time base (e. g. watchdog) shall work independently and separately from the parts of the digital unit which perform the data processing. Triggering of the monitoring equipment shall be based on the program execution and shall not be only time-related (e.g. based on a periodic timer interrupt);

   NOTE 4 Independent operation is considered to be fulfilled if the operation of the monitoring equipment cannot be controlled by the digital unit which performs the data processing.

   NOTE 5 Separate operation of the monitoring equipment is considered to be fulfilled if

   - the voltage supply is separately connected to the power supply of the digital unit,
   - negative affects (e.g. ESD, EMC) on the operation of the data processing unit are not likely to influence the operation of the monitoring equipment,
   - malfunction of the data processing unit caused by thermal or electrical overload will not influence the operation of the monitoring equipment.

NOTE 6 Independent and separate operation will typically be ensured by using an external monitoring component.

NOTE 7 Particular attention should be paid on appropriate triggering conditions of the monitoring equipment in the program. It is recommended to monitor the execution of the relevant software modules in the correct order.

e) program (operating system included, if applicable) and parameter memory shall be monitored by procedures which allow the detection of all single bit errors and most of the two bit errors. Copies of program and/or parameters in volatile memory shall be included in the test routines. In the event of fault detection, parameters shall not be changed automatically. Restoring the valid values e.g. from redundant copies is allowed if the restored parameters are verified immediately afterwards;

NOTE 8 Copies of constants in volatile memory at the time of program execution should be avoided. If such copies are used, it is recommended to monitor these copies by procedures which are used for monitoring parameter memory.

f) volatile memory shall be monitored by procedures that test the readability and writeability of the memory cells.

NOTE 9 Areas of the volatile memory which are not used for safety relevant data may be excluded from this test.

NOTE 10 Internal registers of the microprocessor, e.g. program counter, may be excluded from the test.

4.7 Instruction manual

The metrological standards contain requirements on the instruction manual. In addition, the following information shall be included:

a) instructions how fault and status outputs shall be wired and monitored for safe operation;

b) if provided, relevance of the alive signal or confidence signal for safety;

c) description of all special states including cause, signalling and termination;

d) description of all messages available to the user and methods for interrogation;

e) behaviour of displays, measuring outputs and all signal outputs at underscale or overscale;

f) minimum refresh rates of all safety relevant output signal(s);

g) all user changeable parameters and their valid ranges;

h) life time of data storage if a back-up battery is used for preserving the data content of parameter memory when the supply voltage is removed;

i) instruction for fixed or transportable apparatus, that the apparatus shall be re-started after end of maintenance work if the power-on self test has been skipped for this maintenance work;

j) description of the tests for the visible and audible output functions and the safety relevant output signals and instruction in which time intervals these tests shall be carried out;

k) instruction that after changing parameters by using an external device (e.g. PC), the user shall check the correctness of the parameter settings

   1) by checking the parameter settings at the gas detection apparatus; or alternatively

   2) by reading back the parameters from the gas detection apparatus and manually verifying the received values;

l) if compliance with SIL 1 is claimed:

1) description of the safety function(s);

2) PFD, λ_{DU} and λ_{DD}, proof-test interval T_1, assumed mean time to restoration (MTTR);

3) all special operating conditions which were the basis for the calculation of these figures;

4) content of the proof test;

5) recommended working life time.

4.8 Additional requirements for compliance with SIL 1

This clause shall be applied only if compliance with safety integrity level 1 (SIL 1) according to EN 61508 series is required.

Regarding the software development process, there are no additional requirements to 4.3.

If a gas detection apparatus complies with the metrological standards and with the requirements of 4.1, 4.2, 4.4, 4.5 and 4.6 a safe failure fraction (SFF) of 60 % to 90 % is assumed to be achieved.

NOTE This SFF is sufficient for complex apparatus with a hardware fault tolerance (HFT) of zero to comply with SIL 1.

The following figures shall be calculated for the entire apparatus:

a) failure rates λ_{DU} and λ_{DD};

b) average probability of failure on demand PFD:

$$PFD_{avg} = \lambda_{DU}\left(\frac{T_1}{2} + MTTR\right) + \lambda_{DD}MTTR$$

where

λ_{DU} is the dangerous undetected failure rate;

λ_{DD} is the dangerous detected failure rate;

T_1 is the specified proof test interval;

MTTR is the assumed mean time to restoration.

5 Test of the digital unit

5.1 General

The testing of the digital units is part of the testing of the apparatus for compliance with the performance requirements. It is divided into two phases. In the first phase the functional concept of the digital unit is inspected with regard to meeting the requirements to the design and to the software development process (Clause 4) within the framework of the entire apparatus. The second phase comprises a performance test of the digital units. It shall detect errors that can occur when transferring the design concept into hard- and software.

Because of multiple modes of realisation and application of digital units the testing scheme shall be adapted to the conditions of each apparatus.

5.2 Verification of functional concept

Functional concept analysis and evaluation depend on the documentation from the manufacturer. The verification shall be performed by using the following list.

a) Functional description of the digital unit which is preferably structured like Clause 4:

   1) measuring sequence (including all possible variations);

   2) handling of range violations of input, internal and output data (see 4.1.4);

   3) estimation of numerical errors according to 4.1.3;

   4) possible special states (see 4.1.5);

   5) parameters and their permitted adjustment range;

   6) representation of measured values and messages;

   7) generation of alarms and signals;

   8) extent and realisation of remote data transmission;

   9) extent and realisation of test routines.

b) Hardware description:

   1) design of the digital unit (circuit diagrams, bill of materials (parts lists), relevant data sheets);

   2) block functional description of the digital unit;

   3) resolution, errors and input/output ranges of A/D- or D/A-interfaces;

   4) specification of interfaces between functional parts (with description of the coding procedure used for the digital data transmission).

c) Software documentation:

   1) according to 4.3.4.

   NOTE The software documentation is only for the use of the test laboratory. All information is confidential and is the property of the manufacturer.

The design of the digital units and the software development process shall conform to the requirements of Clause 4.

5.3 Performance test

The apparatus shall be operated during the performance test in such a manner that, starting from the measuring state, it enters all special states.

The following operation states shall be performed if applicable:

a) four measured values distributed over the measuring range;

b) measuring range under- and overflow;

c) special states if they can be entered without destruction of the hardware or modification of the software;

d) activation of every message;

e) test routines if they can be tested without destruction of the hardware or modification of the software;

f) change of parameters.

Operation states a) and b) shall be performed for a selection of measuring ranges, including the minimum and maximum range.

The tests are executed under the normal conditions for test given in the applicable metrological standards.

The function of the digital unit shall be identical to the function described in the instruction manual and the documentation according to 5.2.

Annex A
(normative)

Hardware-software integration test

A.1 Functional testing/Black-box testing

Aim:

To reveal faults which were brought in during the software development process up to the phase coding, by testing the dynamic behaviour under real functional conditions. To reveal incomplete specification or failure to comply with the specification and to assess utility and robustness.

Description:

The functions of the software, its components or modules are executed in a specified environment with specified test data which are derived systematically from the respective specification. This exposes the behaviour of the software, its components or modules and permits a comparison with the respective specification. Information about the internal structure of the software is not used for testing. The outputs and the behaviour are monitored and compared with the respective specification. Deviations from the specification and indications of an incomplete specification are documented. Suitable test data shall be defined so that all functions required in the respective specification are tested. An equivalence class test with boundary value analysis shall be performed.

A.2 Equivalence class test with boundary value analysis

Aim:

To test the software adequately using a manageable amount of test data. The test data set is obtained by suitable dividing the input data space into a limited number of equivalence classes. To detect software errors occurring at boundary values.

Description:

The input data space is subdivided into specific input value ranges (equivalence classes) with the aid of the specification.

This subdivision can be made input orientated or output orientated. For input orientated division all values of an equivalence class are treated in the same way; for output orientated division all values of an equivalence class lead to the same functional result.

NOTE 1 Example for an input orientated division: 1 is added to numbers between 1 and 9, 2 is added to numbers between 10 and 99, 3 is added to numbers between 100 and 999, a fault message is released for numbers higher than 999. Each number range represents an equivalence class, all numbers of one range are treated in the same way.

NOTE 2 Example for an output orientated division: Triples of numbers designate the lengths of the sides of a triangle. The triples are used to determine whether the triangle is equilateral, isosceles or nothing of this. Triples with three identical elements lead to the same result (equilateral triangle) and form the equivalence class "equilateral triangle"; triple with two identical elements form the equivalence class "isosceles triangle" etc.

Test cases are selected with the aim of covering all the equivalence classes previously specified. At least one test case is taken from each equivalence class. For each equivalence class the following test cases shall be formed:

a) data from permissible ranges;

b) data from inadmissible ranges;

c) data from the range limits;

d) extreme values;

e) and combinations of the above classes, where reasonable.

Other criteria can be effective in order to select test cases in the various test activities (software test, hardware-software integration test).

The tests at the range limits of the equivalence classes check that the boundaries in the input domain of the specification coincide with those in the program. The use of the value zero, in a direct as well as in an indirect use, is often error-prone and demands special attention:

f) zero divisor;

g) blank ASCII characters;

h) empty stack or list element;

i) full matrix;

j) zero table entry.

Normally the boundaries for input have a direct correspondence to the boundaries for the output range. Test cases shall be defined to force the output to its limit values. It shall also be considered whether it is possible to specify a test case which causes the output to exceed the specified boundary values. If the output is a sequence of data, for example a printed table, special attention shall be paid to the first and the last element and to lists containing none, one or two elements.

Annex ZY
(informative)

Significant changes between this European Standard and EN 50271:2001

This European Standard supersedes EN 50271:2001.

The significant changes with respect to EN 50271:2001 are as listed below.

	Type		
	Minor and editorial changes	**Extension**	**Substantial change regarding ESR´s [a]**
Modification of the scope		X	
Normative references	X		
Definitions modified and extended	X	X	
Old Subclauses 4.1, 4.3 and 4.5 are rearranged and modified for clarification and adaption to the state of the art; new Subclauses 4.1, 4.2, 4.4 and 4.6	X	X	X
Old Subclause 4.4 was changed in order to cover also internal data transmission (adjustment to EN 50402); new Subclause 4.5		X	X
Old Subclause 4.2 (software) was completely re-written. The new Subclause 4.3 and Annex A provide a practical approach to comply with the requirements of EN 61508-3 for SIL 1 without using this generic standard.	X		
New Subclause 4.8 was introduced which defines additional requirements if conformity to SIL 1 is claimed.		X	
Requirements to the instruction manual are removed from the individual clauses, extended and listed in an own Subclause 4.7.	X	X	X
Clause 5 (Test of the digital unit) was modified.	X	X	
[a] ESR = Essential Health and Safety Requirements (Annex II of Directive 94/9/EC)			

General conclusion on the change of the State of the Art by this European Standard

CLC/SC 31-9 as the responsible body has concluded that this new edition contains substantial changes regarding the ESRs.

Annex ZZ
(informative)

Coverage of Essential Requirements of EC Directives

This European Standard has been prepared under a mandate given to CENELEC by the European Commission and the European free Trade Association and within its scope the Standard covers only the following essential requirements given in Annex II, Articles 1.5.5 to 1.5.8 of the EC Directive 94/9/EC:

- ER 1.5.5 to 1.5.7 – the essential safety requirements for devices with a measuring function for explosion protection when used in conjunction with EN 60079-29-1 or EN 50104 or EN 50241-1 + EN 50241-2;
- ER 1.5.8 – the risks arising from software.

Compliance with this standard provides one means of conformity with the specified essential requirements of the Directive concerned.

WARNING: Other requirements and other EC Directives can be applied to the products falling within the scope of this standard.

This page deliberately left blank

British Standards Institution (BSI)

BSI is the independent national body responsible for preparing British Standards and other standards-related publications, information and services.
It presents the UK view on standards in Europe and at the international level.

It is incorporated by Royal Charter.

Revisions

British Standards are updated by amendment or revision. Users of British Standards should make sure that they possess the latest amendments or editions.

It is the constant aim of BSI to improve the quality of our products and services. We would be grateful if anyone finding an inaccuracy or ambiguity while using this British Standard would inform the Secretary of the technical committee responsible, the identity of which can be found on the inside front cover.

Tel: +44 (0)20 8996 9001 Fax: +44 (0)20 8996 7001

BSI offers Members an individual updating service called PLUS which ensures that subscribers automatically receive the latest editions of standards.

Tel: +44 (0)20 8996 7669 Fax: +44 (0)20 8996 7001
Email: plus@bsigroup.com

Buying standards

You may buy PDF and hard copy versions of standards directly using a credit card from the BSI Shop on the website **www.bsigroup.com/shop.** In addition all orders for BSI, international and foreign standards publications can be addressed to BSI Customer Services.

Tel: +44 (0)20 8996 9001 Fax: +44 (0)20 8996 7001
Email: orders@bsigroup.com

In response to orders for international standards, it is BSI policy to supply the BSI implementation of those that have been published as British Standards, unless otherwise requested.

Information on standards

BSI provides a wide range of information on national, European and international standards through its Knowledge Centre.

Tel: +44 (0)20 8996 7004 Fax: +44 (0)20 8996 7005
Email: knowledgecentre@bsigroup.com

Various BSI electronic information services are also available which give details on all its products and services.

Tel: +44 (0)20 8996 7111 Fax: +44 (0)20 8996 7048
Email: info@bsigroup.com

BSI Subscribing Members are kept up to date with standards developments and receive substantial discounts on the purchase price of standards. For details of these and other benefits contact Membership Administration.

Tel: +44 (0)20 8996 7002 Fax: +44 (0)20 8996 7001
Email: membership@bsigroup.com

Information regarding online access to British Standards via British Standards Online can be found at **www.bsigroup.com/BSOL**

Further information about BSI is available on the BSI website at **www.bsigroup.com/standards**

Copyright

BSI Group Headquarters

389 Chiswick High Road London W4 4AL UK

Tel +44 (0)20 8996 9001
Fax +44 (0)20 8996 7001
www.bsigroup.com/standards

raising standards worldwide™