UL 61496-1

STANDARD FOR SAFETY

Safety of Machinery – Electro-Sensitive Protective Equipment – Part 1: General Requirements and Tests

UL Standard for Safety of Machinery – Electro-Sensitive Protective Equipment – Part 1: General Requirements and Tests, UL 61496-1

Third Edition, Dated February 9, 2021

Summary of Topics

This new edition of ANSI/UL 61496-1 is an adoption of IEC 61496-1, Safety of Machinery – Electro-Sensitive Protective Equipment – Part 1: General Requirements and Tests (third edition issued April 2012) as an IEC-based UL standard, with US National Differences.

The new requirements are substantially in accordance with Proposal(s) on this subject dated July 3, 2020.

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UL 61496-1

Standard for Safety of Machinery – Electro-Sensitive Protective Equipment – Part 1: General Requirements and Tests

First Edition – January, 2002

Third Edition

February 9, 2021

This ANSI/UL Standard for Safety consists of the Third Edition.

The most recent designation of ANSI/UL 61496-1 as an American National Standard (ANSI) occurred on February 9, 2021. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, Title Page, or Preface. The National Difference Page and IEC Foreword are also excluded from the ANSI approval of IEC-based standards.

Comments or proposals for revisions on any part of the Standard may be submitted to UL at any time. Proposals should be submitted via a Proposal Request in UL's On-Line Collaborative Standards Development System (CSDS) at https://csds.ul.com.

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Preface (UL)

This UL standard is based on IEC Publication 61496-1: Third Edition, Safety of Machinery – Electro-Sensitive Protective Equipment – Part 1: General Requirements and Tests. IEC Publication 61496-1 is copyrighted by the IEC.

Efforts have been made to synchronize the UL edition number with that of the corresponding IEC standard with which this standard is harmonized. As a result, one or more UL edition numbers have been skipped to match that of the IEC edition number.

This is the UL Standard for Safety for Electro-Sensitive Protective Equipment – Part 1: General Requirements and Tests. This UL Part 1 is to be used in conjunction with the appropriate UL Part 2, which contains clauses to supplement or modify the corresponding clauses in Part 1, to provide relevant requirements for each type of product.

Note – Although the intended primary application of this Standard is stated in its Scope, it is important to note that it remains the responsibility of the users of the Standard to judge its suitability for their particular purpose.

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NATIONAL DIFFERENCES

National Differences from the text of International Electrotechnical Commission (IEC) Publication 61496-1, Safety of machinery – Electro-sensitive protective equipment – Part 1: General requirements and tests, copyright 2012 are indicated by notations (differences) and are presented in bold text.

There are five types of National Differences as noted below. The difference type is noted on the first line of the National Difference in the standard. The standard may not include all types of these National Differences.

DR – These are National Differences based on the **national regulatory requirements**.

D1 – These are National Differences which are based on **basic safety principles and requirements**, elimination of which would compromise safety for consumers and users of products.

D2 – These are National Differences from IEC requirements based on existing **safety practices**. These requirements reflect national safety practices, where empirical substantiation (for the IEC or national requirement) is not available or the text has not been included in the IEC standard.

DC – These are National Differences based on the **component standards** and will not be deleted until a particular component standard is harmonized with the IEC component standard.

DE – These are National Differences based on **editorial comments or corrections**.

Each national difference contains a description of what the national difference entails. Typically one of the following words is used to explain how the text of the national difference is to be applied to the base IEC text:

Addition / Add - An addition entails adding a complete new numbered clause, subclause, table, figure, or annex. Addition is not meant to include adding select words to the base IEC text.

Modification / Modify - A modification is an altering of the existing base IEC text such as the addition, replacement or deletion of certain words or the replacement of an entire clause, subclause, table, figure, or annex of the base IEC text.

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FOREWORD

INTERNATIONAL ELECTROTECHNICAL COMMISSION

SAFETY OF MACHINERY – ELECTRO-SENSITIVE PROTECTIVE EQUIPMENT – Part 1: General requirements and tests

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.

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International Standard IEC 61496-1 has been prepared by IEC technical committee 44: Safety of machinery – Electrotechnical aspects.

This third edition cancels and replaces the second edition published in 2004 and its amendment 1 (2007). The document 44/615/CDV, circulated to the National Committees as amendment 2, led to the publication of this new edition.

The main changes with respect to the previous edition are as follows: The design, test and verification requirements have been updated to make them consistent with the latest standards for functional safety and EMC.

The text of this standard is based on the following documents:

CDV	Report on voting
44/615/CDV	44/641/RVC

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all the parts in the IEC 61496 series, published under the general title *Safety of machinery – Electro-sensitive protective equipment*, can be found on the IEC website.

A vertical line in the margin shows where the base publication has been modified by amendment 2.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore. iec. ch" in the data related to the specific publication. At this date, the publication will be

• reconfirmed,

• withdrawn,

• replaced by a revised edition, or

• amended.

INTRODUCTION

An electro-sensitive protective equipment (ESPE) is applied to machinery presenting a risk of personal injury. It provides protection by causing the machine to revert to a safe condition before a person can be placed in a hazardous situation.

This part of IEC 61496 provides general design and performance requirements of ESPEs for use over a broad range of applications. Essential features of equipment meeting the requirements of this standard are the appropriate level of safety-related performance provided and the built-in periodic functional checks/self-checks that are specified to ensure that this level of performance is maintained.

Each type of machine presents its own particular hazards and it is not the purpose of this standard to recommend the manner of application of the ESPE to any particular machine. The application of the ESPE should be a matter for agreement between the equipment supplier, the machine user and the enforcing authority, and in this context attention is drawn to the relevant guidance established internationally, for example ISO 12100.

This part of IEC 61496 specifies technical requirements of electro-sensitive protective equipment. The application of this standard may require the use of substances and/or test procedures that could be injurious to health unless adequate precautions are taken. Conformance with this standard in no way absolves either the supplier or the user from statutory obligations relating to the safety and health of persons during the use of the equipment covered by this standard.

Due to the complexity of the technology used to implement ESPEs, there are many issues that are highly dependent on analysis and expertise in specific test and measurement techniques. In order to provide a high level of confidence, independent review by relevant experts is recommended.

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SAFETY OF MACHINERY – ELECTRO-SENSITIVE PROTECTIVE EQUIPMENT – Part 1: General requirements and tests

1 Scope

This part of IEC 61496 specifies general requirements for the design, construction and testing of non-contact electro-sensitive protective equipment (ESPE) designed specifically to detect persons as part of a safety related system. Special attention is directed to functional and design requirements that ensure an appropriate safety-related performance is achieved. An ESPE may include optional safety-related functions, the requirements for which are given in Annex A.

The particular requirements for specific types of sensing function are given in other parts of this standard.

This standard does not specify the dimensions or configuration of the detection zone and its disposition in relation to hazards in any particular application, nor what constitutes a hazardous state of any machine. It is restricted to the functioning of the ESPE and how it interfaces with the machine.

While a data interface can be used to control optional safety-related ESPE functions (Annex A), this standard does not provide specific requirements. Requirements for these safety-related functions can be determined by consulting other standards (for example, IEC 61508, IEC/TS 62046, IEC 62061, and ISO13849-1).

This standard may be relevant to applications other than those for the protection of persons, for example for the protection of machinery or products from mechanical damage. In those applications, different requirements can be necessary, for example when the materials that have to be recognized by the sensing function have different properties from those of persons.

This standard does not deal with electromagnetic compatibility (EMC) emission requirements.

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.

IEC 60068-2-6, *Environmental testing – Part 2-6: Tests – Test Fc: Vibration (sinusoidal)*

IEC 60068-2-27, *Environmental testing – Part 2-27: Tests – Test Ea and guidance: Shock*

IEC 60204-1:2009, *Safety of machinery – Electrical equipment of machines – Part 1: General requirements*

IEC 60445, *Basic and safety principles for man-machine interface, marking and identification – Identification of equipment terminals, conductor terminations and conductors*

IEC 60447, *Basic and safety principles for man-machine interface, marking and identification – Actuating principles*

IEC 60529, *Degrees of protection provided by enclosures (IP code)*

IEC 60947-1:2011, *Low-voltage switchgear and controlgear – Part 1: General rules*

IEC 61000-4-2, *Electromagnetic compatibility (EMC) – Part 4-2: Testing and measurement techniques – Electrostatic discharge immunity test*

IEC 61000-4-3, *Electromagnetic compatibility (EMC) – Part 4-3: Testing and measurement techniques – Radiated, radio-frequency, electromagnetic field immunity test*

IEC 61000-4-4:2004, *Electromagnetic compatibility (EMC) – Part 4: Testing and measurement techniques – Section 4: Electrical fast transient/burst immunity test*

IEC 61000-4-5:2005, *Electromagnetic compatibility (EMC) – Part 4-5: Testing and measurement techniques – Surge immunity test*

IEC 61000-4-6, *Electromagnetic compatibility (EMC) – Part 4-6: Testing and measurement techniques – Immunity to conducted disturbances, induced by radio-frequency fields*

IEC 61000-6-2, *Electromagnetic compatibility (EMC) – Part 6-2: Generic standards – Immunity for industrial environments*

IEC 61131-2:2007, *Programmable controllers – Part 2: Equipment requirements and tests*

IEC 61508 (all parts), *Functional safety of electrical/electronic/programmable electronic safety-related systems*

IEC 62061, *Safety of machinery – Functional safety of safety-related electrical, electronic and programmable electronic control systems*

IEC/TS 62046, *Safety of machinery – Application of protective equipment to detect the presence of persons*

ISO 9001, *Quality management systems – Requirements*

ISO 12100:2010, *Safety of machinery – General principles for design – Risk assessment and risk reduction*

ISO 13849-1, *Safety of machinery – Safety-related parts of control systems – Part 1: General principles for design*

ISO 13849-2:2003, *Safety of machinery – Safety-related parts of control systems – Part 2: Validation*

2DV.1 DC *Modification to Clause 2, Normative References, by deleting the following:*

IEC 60204-1:2009,
Safety of machinery – Electrical equipment of machines – Part 1: General requirements

IEC 60445,
Basic and safety principles for man-machine interface, marking and identification – Identification of equipment terminals, conductor terminations and conductors

IEC 60447,
Basic and safety principles for man-machine interface, marking and identification – Actuating principles

IEC 60947-1:2011,

Low-voltage switchgear and controlgear – Part 1: General rules

IEC 61131-2:2007,
Programmable controllers – Part 2: Equipment requirements and tests

2DV.2 DC *Modification of Clause 2, Normative References, by adding the following:*

UL 840
Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment

UL 60947-1
Low-Voltage Switchgear and Controlgear – Part 1: general Rules

UL 61131-2
Programmable Controllers – Part 2: Equipment Requirements and Tests

NFPA 79:2015,
Electrical Standard for Industrial Machinery

3 Terms and definitions

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

NOTE The index lists, in alphabetical order, the terms and acronyms defined in Clause 3 and indicates where they are used in the text of this part.

3.1
blanking
optional function that permits an object of a size greater than the detection capability of the ESPE to be located within the detection zone without causing an OFF-state of the OSSD(s)

Note 1 to entry: Fixed blanking is a technique wherein the locations of the blanked areas of the detection zone do not change during operation. The detection capability of the other parts of the detection zone remains unchanged.

Note 2 to entry: Floating blanking is a technique wherein the blanked area of the detection zone follows the location of a moving object(s) during operation. The detection capability of the other areas remains unchanged.

3.2
controlling/monitoring device
part of the electro-sensitive protective equipment (ESPE) that:

– receives and processes information from the sensing device and provides signals to the output signal switching devices (OSSD),

– monitors the sensing device and the OSSD

3.3
detection capability
sensing function parameter limit specified by the supplier that will cause actuation of the electro-sensitive protective equipment (ESPE)

3.4
detection zone
zone within which a specified test piece will be detected by the electro-sensitive protective equipment (ESPE)

3.5
electro-sensitive protective equipment
ESPE
assembly of devices and/or components working together for protective tripping or presence-sensing purposes and comprising as a minimum

– a sensing device;

– controlling/monitoring devices;

– output signal switching devices and/or a safety-related data interface

Note 1 to the entry: The safety-related control system associated with the ESPE, or the ESPE itself, may further include a secondary switching device, muting functions, stopping performance monitor, etc. (see Annex A).

Note 2 to entry: A safety-related communication interface can be integrated in the same enclosure as the ESPE.

3.6
external device monitoring
EDM
means by which the electro-sensitive protective equipment (ESPE) monitors the state of control devices which are external to the ESPE

3.7
failure
termination of the ability of an item to perform a required function

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

Note 1 to entry: After failure the item has a fault.

Note 2 to entry: 'Failure' is an event, as distinguished from 'fault', which is a state.

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

Note 4 to entry: In practice, the terms fault and failure are often used synonymously.

3.8
failure to danger
failure which prevents or delays all output signal switching devices going to, and/or remaining in the OFF-state in response to a condition which, in normal operation, would result in their so doing

3.9
fault
state of an item characterized by inability to perform a required function, excluding the inability during preventive maintenance or other planned actions, or due to lack of external resources

[SOURCE: IEC 60050-191:1990, 191-05-01]

Note 1 to entry: A fault is often the result of a failure of the item itself, but may exist without prior failure.

Note 2 to entry: In English the term “fault” and its definition are identical with those given in IEV 191-05-01. In the field of machinery, the French term “défaut” and the German term “Fehler” are used rather than the terms “panne” and “Fehlzustand” that appear with this definition.

3.10
final switching device
FSD
component of the machine's safety-related control system that interrupts the circuit to the machine primary control element (MPCE) when the output signal switching device (OSSD) goes to the OFF-state

3.11
integrated circuit – complex or programmable
monolithic, hybrid or module circuit which satisfies one or more of the criteria below:

a) more than 1 000 gates are used in the digital mode,

b) more than 24 functionally different external electrical connections are available for use;

c) the functions can be programmed

Note 1 to entry: Examples include ASICs, ROMs, PROMs, EPROMs, PALs, CPUs, PLAs, and PLDs.

Note 2 to entry: The circuits may function in the analogue mode, the digital mode, or a combination of the two modes.

3.12
integrated circuit – simple
monolithic, hybrid or module circuit which satisfies none of the criteria in 3.11

Note 1 to entry: Examples are SSI or MSI logic ICs, comparators.

Note 2 to entry: The circuits may function in the analogue mode, in the digital mode, or in a combination of the two modes.

3.13
lock-out condition
condition, initiated by a fault preventing normal operation of the electro-sensitive protective equipment (ESPE). All output signal switching devices (OSSDs) and, where applicable, all secondary switching devices (SSDs) are signalled to go to the OFF-state

3.14
machine primary control element
MPCE
electrically powered element that directly controls the normal operation of a machine in such a way that it is the last element (in time) to function when machine operation is to be initiated or arrested

Note 1 to entry: This element can be, for example, a mains contactor, a magnetic clutch or an electrically operated hydraulic valve.

3.15
machine secondary control element
MSCE
machine control element, independent of the machine primary control element (s), that is capable of removing the source of power from the prime mover of the relevant hazardous parts

Note 1 to entry: When fitted, the MSCE is normally controlled by the secondary switching device (SSD).

Note 2 to entry: This element can be, for example, a mains contactor, a magnetic clutch or an electrically operated hydraulic valve.

3.16
muting
a temporary automatic suspension of a safety function(s) by safety-related parts of the control system

Note 1 to entry: For ESPE-muting see Clause A.7

3.17
OFF-state
state of the output(s) of the ESPE in which the machine under control is caused to stop running and is prevented from starting (for example, the output circuit is interrupted and disables the flow of current)

3.18
ON-state
state of the output(s) of the ESPE in which the machine under control is allowed to run (for example, the output circuit is complete and enables the flow of current)

3.19
output signal switching device
OSSD
component of the electro-sensitive protective equipment (ESPE) connected to the machine control system which, when the sensing device is actuated during normal operation, responds by going to the OFF-state

3.20
overall system stopping performance
time interval resulting from the sum of the electro-sensitive protective equipment (ESPE) response time and the time to the cessation of hazardous machine operation

3.21
response time
maximum time between the occurrence of the event leading to the actuation of the sensing device and the output signal switching devices (OSSD) achieving the OFF-state

Note 1 to entry: When an ESPE includes a safety-related data interface, the response time is defined at the output of the safety-related data interface.

Note 2 to entry: When a safety-related communication interface is included in the ESPE enclosure, then the response time is defined at the output of the safety-related communication interface. In this case, the response time is also dependent on the protocol and architecture of the communication network.

Note 3 to entry: If an ESPE has both a safety-related data interface and OSSDs, the ESPE can have a different response time for the safety-related data interface and for the OSSDs.

3.22
restart interlock
means of preventing automatic restarting of a machine after actuation of the sensing device during a hazardous part of the machine operating cycle, after a change in mode of operation of the machine, and after a change in the means of start control of the machine

Note 1 to entry: Modes of operation include inch, single stroke, automatic. Means of start control include foot switch, two-hand control, and single or double actuation of the electro-sensitive protection equipment (ESPE) sensing device.

3.23
safety-related part of a control system
part or subpart(s) of a control system which respond(s) to input signals and generate(s) safety-related output signals

Note 1 to entry: This also includes monitoring systems.

Note 2 to entry: The combined safety-related parts of a control system start at the points where the safety-related signals are initiated and end at the output of the power control elements (see also ISO 12100, Annex A)

3.24
secondary switching device
SSD
device which, in a lock-out condition goes to the OFF-state. It may be used to initiate an appropriate machine control action, for example de-energizing the machine secondary control element (MSCE)

3.25
sensing device
part of the electro-sensitive protective equipment (ESPE) which uses electro-sensitive means to determine the event or state that the ESPE is intended to detect

EXAMPLE An opto-electronic sensing device would detect an opaque object entering the detection zone.

3.26
start interlock
means which prevents an automatic machine start when the electrical supply to the electro-sensitive protection equipment (ESPE) is switched on, or is interrupted and restored

3.27
stopping performance monitor
SPM
monitoring means to determine whether or not the overall system stopping performance is within the pre-set limit(s)

3.28
supplier
entity (for example manufacturer, contractor, installer, integrator) that provides equipment or services associated with the machine

Note 1 to entry: The user may act in the capacity of a supplier to himself.

3.29
safety-related data interface
direct connection (peer-to-peer) interface between the output of the ESPE and the safety-related communication interface that is used to represent the status of the OSSD(s)

NOTE 1 to entry: A data interface will not have addressing capability.

NOTE 2 to entry: The safety-related data interface can be bi-directional.

3.30
safety-related communication interface
safety-related connection to a standardized communication network intended for safety-related control functions

4 Functional, design and environmental requirements

4.1 Functional requirements

4.1.1 Normal operation

Normal operation is the state of an ESPE where no faults are detected and where the OSSD (s) are allowed to be in the ON-state or the OFF-state depending on the state of the sensing function and operating mode.

In normal operation, the ESPE shall respond by giving (an) appropriate output signal (s) when part of a person greater than or equal to the detection capability (as specified in the relevant part of IEC 61496) enters or is in the detection zone.

The ESPE response time shall not exceed that stated by the supplier. No means of adjustment of the response time shall be possible without the use of a key, key-word or tool.

4.1.2 Sensing function

The detection capability shall be effective over the detection zone specified by the supplier. No adjustment of the detection zone, detection capability or blanking function (monitored, unmonitored, fixed or floating) shall be possible without the use of a key, key-word or tool.

4.1.3 Types of ESPE

In this standard, three types of ESPEs are considered. The types differ in their performance in the presence of faults and under influences from environmental conditions. In this part, the effects of electrical and electromechanical faults are considered (such faults are listed in Annex B). Additional requirements are provided in the other parts where faults generated by the particular sensing technology employed are considered. It is the responsibility of the machine manufacturer and/or the user to prescribe which type is required for a particular application.

NOTE Requirements for a type 1 ESPE are not being considered at this time.

A type 2 ESPE shall fulfil the fault detection requirements of 4.2.2.3.

For a type 2 ESPE, in normal operation the output circuit of at least one output signal switching device shall go to the OFF-state when the sensing function is actuated, or when power is removed from the ESPE.

A type 2 ESPE shall have a means of periodic test.

A type 3 ESPE shall fulfil the fault detection requirements of 4.2.2.4.

A type 4 ESPE shall fulfil the fault detection requirements of 4.2.2.5.

For a type 3 ESPE and for a type 4 ESPE, in normal operation the output circuit of at least two output signal switching devices shall go to the OFF-state when the sensing function is actuated, or when power is removed from the ESPE.

When a single safety-related data interface is used to perform the functions of the OSSD(s), then the data interface and associated safety-related communication interface shall meet the requirements of 4.2.4.4. In this case, a single safety-related data interface can substitute for two OSSDs in a type 3 or type 4 ESPE.

4.1.4 Types and required safety performance

An ESPE shall meet a level of safety performance in accordance with IEC 62061 and/or ISO 13849-1, as stated in Table 1.

Table 1
Types and required safety performance

	Type			
	1	2	3	4
Safety performance according to IEC 62061 and/or ISO 13849-1	N/A	SIL 1 and SILCL 1 and/or PL c	SIL 2 and SILCL 2 and/or PL d	SIL 3 and SILCL 3 and/or PL e

NOTE The device dependent PFH_d values claimed for the control electronics is not restricted (for example, a manufacturer can claim a Type 2 has a PFH_d lower than 10^{-6}).

4.1.5 Required PL_r or SIL and corresponding ESPE type

In addition to the different levels of safety performance of the electrical parts of an ESPE control system, the potential risk reduction that can be provided by an ESPE is limited also by the systematic capabilities (for example, environmental influences, EMC, optical performance and detection principle). The limits are shown in Table 2.

Table 2
Required PL_r or SIL and corresponding ESPE type

	Type			
	1	2	3	4
For a safety function that includes an ESPE, the maximum PL or SIL that can be achieved by the ESPE	N/A	SIL 1 and/or PL_rc	SIL 2 and/or PL_rd	SIL 3 and/or PL_re

NOTE 1 The intention of Table 2 is to limit the minimum type that should be employed for the risk reduction of a required safety function. For example: If a safety function requires SIL 2, then from Table 2, it can be seen that a Type 2 would not be sufficient.

NOTE 2 Table 2 and related text will be included in the next edition of IEC 62046.

4.2 Design requirements

4.2.1 Electrical supply

The ESPE shall be designed to operate correctly with the conditions of the nominal supply as specified below, unless otherwise specified by the user:

AC supplies

Voltage:	0,85 to 1,1 of nominal voltage
Frequency:	0,99 to 1,01 of nominal frequency (continuously)
	0,98 to 1,02 of nominal frequency (short-time)
Harmonics:	Harmonic distortion not to exceed 10 % of the total r.m.s. voltage between live conductors for the sum of the 2nd through to the 5th harmonic. An additional 2 % of the total r.m.s. voltage between live

	conductors for the sum of the 6th through to the 30th harmonic is permissible.
DC supplies	
From batteries	
Voltage:	0,85 to 1,15 of nominal voltage
	0,7 to 1,2 of nominal voltage in the case of battery-operated vehicles
From converting equipment	
Voltage:	0,9 to 1,1 of nominal voltage
Ripple (peak-to-peak):	Shall not exceed 0,05 of nominal voltage.

For protection against electric shock, see 4.2.3.2.

NOTE For protection against electrical interference, the power source should meet the requirements of IEC 61000-6-2.

4.2.2 Fault detection requirements

4.2.2.1 General

The ESPE shall respond to the faults listed in Annex B, in accordance with 4.2.2.3 to 4.2.2.5 as appropriate. The faults listed in Annex B are not exclusive and, if necessary, additional faults shall be considered. For new components not mentioned in Annex B, a failure mode and effects analysis (FMEA, see IEC 60812) shall be carried out to establish the faults that are to be considered for those components.

From a lock-out condition, it shall not be possible for the ESPE to resume normal operation (for example, by interruption and restoration of the mains power supply or by reset) while the fault which initiated the lock-out condition is still present.

At power on and prior to OSSD(s) going to the ON-state, a test shall be performed to verify the absence of faults within the ESPE.

4.2.2.2 Particular requirements for a type 1 ESPE

NOTE Particular requirements for a type 1 ESPE are not under consideration at this time.

4.2.2.3 Particular requirements for a type 2 ESPE

A type 2 ESPE shall have a means of periodic test to reveal a failure to danger (for example loss of detection capability, response time exceeding that specified).

The test shall be performed at power-on of the ESPE before going to the ON-state and at each reset as a minimum.

NOTE 1 Depending on the application, the periodic test may need to be performed more often to achieve a desired safety performance.

A single fault resulting in the loss of detection capability or the increase in response time beyond the specified time or preventing one or more of the OSSDs going to the OFF-state, shall result in a lock-out condition as a result of the next periodic test.

Where the periodic test is intended to be initiated by an external (for example machine) safety-related control system, the ESPE shall be provided with suitable input facilities (for example terminals).

The duration of the periodic test shall be such that the intended safety function is not impaired.

NOTE 2 If the type 2 ESPE is intended for use as a trip device (for example when used as a perimeter guard), and the duration of the periodic test is greater than 150 ms, it is possible for a person to pass through the detection zone without being detected. In this case a restart interlock should be included.

If the periodic test is automatically initiated, the correct functioning of the periodic test shall be monitored. In the event of a fault, the OSSD(s) shall be signalled to go to the OFF-state. If one or more OSSDs does not go to the OFF-state, a lock-out condition shall be initiated.

An ESPE with only one OSSD shall have a minimum of one SSD (see Clause A.4).

4.2.2.4 Particular requirements for a type 3 ESPE

A single fault resulting in a loss of detection capability or an increase in response time beyond the specified value or a single fault preventing one or more OSSD going to the OFF-state shall cause the ESPE to go to a lock-out condition within a time specified in the relevant part of this standard, or immediately upon any of the following demand events where fault detection requires a change in state:

– on actuation of the sensing function;

– on reset of the start or restart interlock, if available (see Clauses A.5 and A.6).

In cases where a single fault which in itself does not cause a failure to danger is not detected, the occurrence of one additional fault shall not cause a failure to danger. For verification of this requirement, see 5.3.4.

4.2.2.5 Particular requirements for a type 4 ESPE

A single fault resulting in a loss of detection capability shall cause the ESPE to go to a lock-out condition within the response time.

A single fault resulting in an increase in response time beyond the specified value or a single fault preventing one or more than one OSSD going to the OFF-state, shall cause the ESPE to go to a lock-out condition immediately, i. e. within the response time, or immediately upon any of the following demand events where fault detection requires a change of state:

– on actuation of the sensing function;

– on reset of the start or restart interlock, if available (see Clauses A.5 and A.6).

In cases where a single fault which in itself does not cause a failure to danger is not detected, the occurrence of further faults shall not cause a failure to danger. For verification of this requirement, see 5.3.5.

NOTE 1 Design measures for a type 4 ESPE may include:

– single-channel technique with dynamic fault detection measures; or

– single-channel technique with an internally generated automatic check, performed frequently so that the automatic check interval for fault detection is included in the safety device response time; and

– multiple channel techniques such that any disparity between channels results in a lock-out condition.

NOTE 2 For additional requirements for integrated circuits, complex or programmable, see 4.2.10.

4.2.3 Electrical equipment of the ESPE

4.2.3.1 General

The electrical equipment (components) of the ESPE shall:

– conform to appropriate IEC standards where they exist;

– be suitable for the intended use; and

– be operated within their specified ratings.

4.2.3.1DV D2 *Modification of Clause 4.2.3.1 by replacing the first dashed item with the following:*

– Conform to UL standards where they exist;

4.2.3.2 Protection against electric shock

Protection against electric shock shall be provided in accordance with 6.1 of IEC 60204-1:2009.

4.2.3.2DV D2 *Modification by replacing Clause 4.2.3.2 with the following:*

Protection against electric shock shall be provided in accordance with UL 60947-1.

4.2.3.3 Protection of electrical equipment

Overcurrent protection shall be provided in accordance with 7.2.1, 7.2.3, 7.2.7, 7.2.8, and 7.2.9 of IEC 60204-1:2009.

NOTE Information may need to be given to the user of the ESPE as to the maximum rating of fuses, or setting of an overcurrent protective device for the circuit(s) connected to the OSSD(s) output connection points.

4.2.3.3DV D2 *Modification by replacing Clause 4.2.3.3 with the following:*

Overcurrent protection shall be provided in accordance with NFPA 79:2015.

4.2.3.4 Pollution degree

The electrical equipment shall be suitable for pollution degree 2 (see 6.1.3.2 of IEC 60947-1:2011).

4.2.3.4DV D2 *Modification by replacing Clause 4.2.3.4 with the following:*

The electrical equipment shall be suitable for pollution degree 2 (see UL 840).

4.2.3.5 Clearance, creepage distances and isolating distances

The electrical equipment shall be designed and constructed in accordance with 7.1.4 of IEC 60947-1:2011.

4.2.3.5DV D2 *Modification by replacing Clause 4.2.3.5 with the following:*

The electrical equipment shall be designed and constructed such that the clearances, creepage distances, and isolation distances are in accordance with UL 840.

4.2.3.6 Wiring

The electrical equipment shall be wired in accordance with IEC 60204-1:2009.

4.2.3.6DV D2 *Modification by replacing Clause 4.2.3.6 with the following:*

The electrical equipment shall be wired in accordance with UL 60947-1.

4.2.4 Output signal switching devices (OSSD)

4.2.4.1 General

Separate output connection points (terminals) shall be provided for each OSSD.

The OSSD should be so rated that their loads can be switched without the use of arc suppression devices.

NOTE In the interest of improved reliability, it is strongly recommended that switching voltage-suppression devices are fitted, which should be connected across the loads and not across the contacts.

The output circuit of the OSSDs should be adequately protected to prevent failure to danger, for example welded contacts under overcurrent conditions (see 7.2.9 of IEC 60204-1:2009).

4.2.4.1DV D2 *Modification by replacing 3rd paragraph of Clause 4.2.4.1 with the following:*

The output circuit (s) of the OSSDs shall be adequately protected to prevent failure to danger, for example welded contacts under overcurrent conditions.

Measures should be provided to minimize the possibility of failure to danger from common cause failures.

Some functions of the machine safety-related control system may be performed by the ESPE, for example the OSSD may perform the function of a FSD.

Both a type 3 ESPE and a type 4 ESPE shall incorporate a minimum of two independently operated OSSDs.

A reference to an OSSD action (for example, go to the OFF-state) will also mean a corresponding action of a safety-related data interface. A single safety-related data interface can meet the requirements of having two OSSDs.

4.2.4.2 Relay OSSDs

If relay OSSDs are provided, the state (i. e. position) of the contacts shall be monitored. This can be achieved by monitoring the state of an auxiliary contact(s) on relays with mechanically linked (positively guided) contacts. The mechanical link ensures that the monitored contact follows the change of state of the OSSD contact(s).

Special design and constructional measures shall be used to ensure that the make (normallyopen) contact (s) and the break (normally-closed) contact(s) cannot be in the closed position simultaneously.

NOTE 1 The mechanical link ensures that the monitored contact follows the change of state of the OSSD contact(s).

NOTE 2 It is important that relay drop out voltage and the separation distance between the contacts are maintained at a proper level over the entire stated life of the relay.

4.2.4.3 Solid state OSSDs

Solid state OSSD outputs may be either current sourcing or current sinking types. When current sourcing outputs are provided, they shall meet the requirements of this Subclause.

NOTE 1 Requirements for current sinking outputs which may be required for certain applications are not defined in this standard. Special care should be exercised in their use (when current sinking outputs are used, a shortcircuit to the reference potential or an open circuit will be interpreted by the inputs and loads as the ON-state). The requirements of IEC 60204-1:2009, 9.4.3.1, should also be considered.

NOTE 2 For a nominal rated supply voltage of 24 V d.c., the output voltage and current values for the ON-state and the OFF-state should be in accordance with the following data:

Nominal supply voltage	Output range OFF-state	Output range ON-state	Output OFF-state (max. leakage current)	Output ON-state
24 V d.c.	-3 V ... +2 V r.m.s. (+5 V peak)	+11 V ... +30 V	< 2 mA	> 6 mA

NOTE 3 The values above meet the requirements of IEC 61131-2:2007 (see 3.3 of IEC 61131-2:2007), for a nominal rated supply voltage of 24 V d.c. When other supply voltages are used, this standard may be used as a guide. IEC 61131-2:2007 may be referred to for additional information.

The output(s) shall be protected against the effects of overvoltage, overcurrent and short circuit.

The maximum leakage current shall not exceed 2 mA.

NOTE 4 It is possible that a leakage current greater than 2 mA can lead to a failure to danger.

When there is more than one OSSD, short circuits between the outputs of the OSSDs shall be detected.

The supplier of the ESPE shall provide the following information in the accompanying documents:

– nominal and maximum output current in the ON-state for resistive and inductive loads;

– maximum OFF-state voltage;

– maximum output current in OFF-state (leakage current);

– maximum capacitive load;

– maximum resistance of the connection(s) between the OSSD(s) and the load(s).

4.2.4.4 Safety-related data interface and safety-related communication interface

When the sensing device is actuated during normal operation, the ESPE shall respond by sending information indicating the status of the sensing device or ESPE through a safety-related data interface. The status information is converted to a data telegram by a safety-related communication interface.

The safety-related data interface shall have the same protection against faults as is appropriate for the type of ESPE.

Depending on the ESPE design, the safety-related communication interface can either be external in a separate enclosure (Figure 1a) or it can be integrated in the same enclosure of the ESPE (Figure 1b).

When the safety-related communication interface is integrated in the ESPE, the entire ESPE shall meet the relevant requirements of IEC 62061/IEC 61508.

NOTE Because of the specific technology of communication interfaces, different standards from IEC 61496-1 apply. To avoid overlapping with other standards, functional requirements for the safety-related communication interface are not defined in this standard.

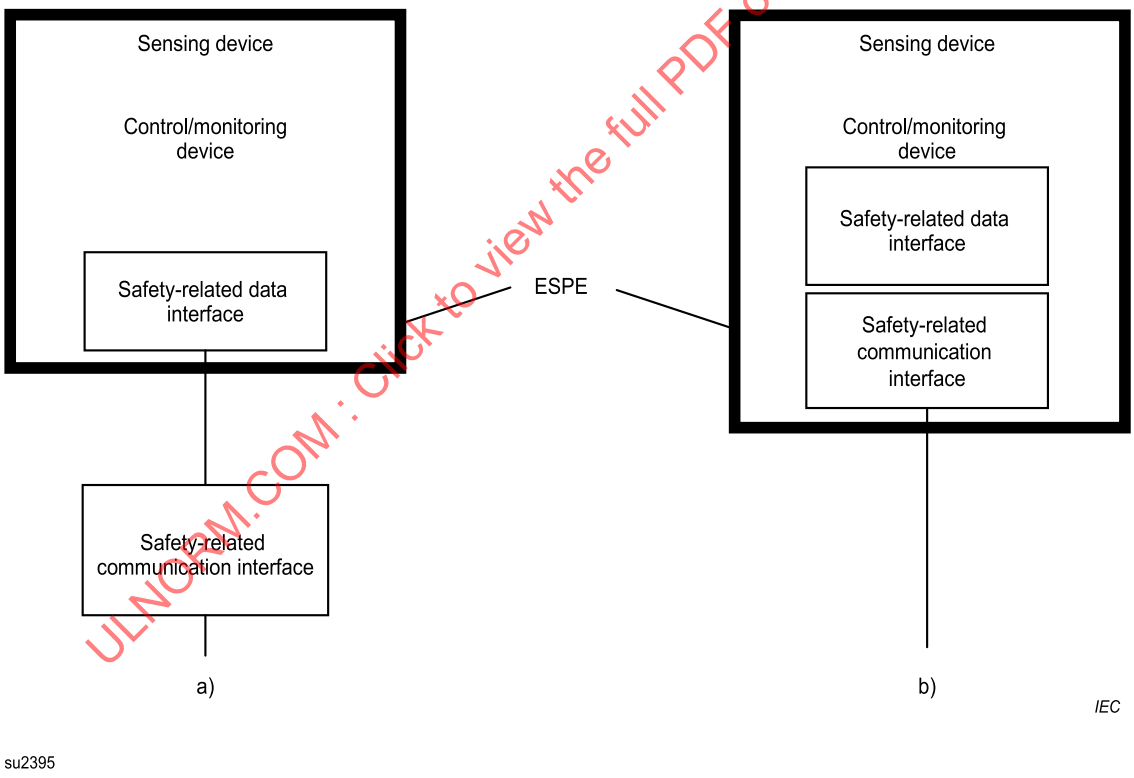

Figure 1

Examples of ESPEs using safety-related communication interfaces

4.2.5 Indicator lights and displays

Devices shall be provided by the ESPE manufacturer to:

a) indicate the actuation of the sensing device. Neither the time from the actuation of the sensing device to the indicator achieving 50 % of its final brightness (luminescence), nor the time from the de-actuation of the sensing device to the indicator brightness decaying to 50 % of its initial brightness, shall exceed 100 ms;

b) indicate the output status of an OSSD. The ON-state shall be represented by a green indicator, the OFF-state by a red indicator. When two or more OSSDs are intended to operate in co-ordination, a single set of indicators may be shared.

When there are two or more indicators of the same colour, the function of each indicator shall be unambiguously marked.

NOTE For some modes of operation, the same set of indicators for a) can also be used for b). A bi-colour indicator could be used.

The indicators are intended for the machine operator. Therefore they shall be capable of being located near the detection zone and visible when the equipment is installed. They can be integrated in the sensor elements or as an external equipment installed near by the detection zone.

4.2.6 Adjustment means

All adjustment means shall be so designed that a failure to danger is not possible at any point in the range of adjustment. A failure in the adjustment means shall not cause an unintended change to the configuration of the ESPE.

4.2.7 Disconnection of electrical assemblies

When means are provided to permit disconnection of any subsystem, part of a subsystem or any plug-in component, such disconnection shall result in at least one OSSD going to the OFF-state, in accordance with 4.2.2. This requirement includes disconnections both within a single enclosure and/or between separate enclosures (for example a master/slave sensor configuration).

4.2.8 Non-electrical components

Non-electrical components shall be suitable for the intended use.

4.2.9 Common cause failures

The design should be such as to minimize the possibility of a failure to danger from common cause failures arising from:

– environmental influences;

– multichannel systems using a common substrate;

– short circuits between channels of multichannel systems.

NOTE 1 Common cause failures can also result from the use of components degraded by mishandling, faulty manufacture, etc.

NOTE 2 Common cause failures are treated as a single failure.

None of the components in a common semi-conductor substrate shall be used for more than one channel of a multi-channel system.

4.2.10 Programmable or complex integrated circuits

Where programmable or complex integrated circuits are used in a type 4 ESPE, the safety-related performance shall be maintained by at least two independent controlling/monitoring channels. This requirement shall be verified in accordance with 5.5.

4.2.11 Software, programming, functional design of integrated circuits

4.2.11.1 General

Where an ESPE implements its safety-related performance by any of the following means, the additional requirements of 4.2.11.2 shall apply:

a) a software program(s) executed during operation;

b) a programmed device (s), the functions of which were set by a process subsequent to its original manufacture, for example PAL, PLA, PLD, PROM;

c) a device (s) manufactured to a specific user functional specification, for example ASIC, mask programmed microprocessor, ROM.

Conformance to these requirements shall be validated in accordance with 5.5.

4.2.11.2 Requirements

The software, device program and the device functional design shall be developed in accordance with IEC 61508-3 for the appropriate SIL or in accordance with ISO 13849-1 for the appropriate PL.

4.3 Environmental requirements

4.3.1 Ambient air temperature range and humidity

The ESPE shall comply with the requirements of this standard when subjected to ambient temperature variations from 0 °C to 50 °C. Where it is intended for use outside this range, the supplier shall specify the temperature range over which the system will continue normal operation. Compliance with this requirement shall be verified by the tests specified in 5.4.2 at a non-condensing humidity of 95 % for temperatures between 20 °C and the highest ambient temperature according to 5.4.2.

4.3.2 Electrical disturbances

4.3.2.1 Supply voltage variations

The ESPE shall not fail to danger when the external supply voltage is reduced steadily and continuously from the nominal voltage to zero voltage, over a period of 10 s to 20 s, and then increased in a similar manner from zero voltage to the nominal voltage.

The ESPE shall not fail to danger when each internally derived supply voltage, in turn, is varied steadily and continuously over a period of 10 s to 20 s, from nominal voltage to zero voltage, and then increased in a similar manner from zero voltage to nominal voltage.

4.3.2.2 External supply voltage interruptions and dips

When supply voltage interruptions (dips) are applied as in Table 4:

Table 4
Supply voltage interruptions

Test number	Dip value of rated voltage %	Dip time ms	Dip repetition rate Hz
1)	100	10	10
2)	50	20	5
3)	50	500	0,2

the ESPE shall respond to test 1) and to test 2) by continuing in normal operation, and to test 3) by not failing to danger.

When the ESPE is designed to be supplied from a specific type of power supply(s) (for example, supplied direct from a safety-related communication interface), the supply interruptions in this clause may be applied to the primary input of the specified power supply instead of direct to the ESPE.

4.3.2.3 Fast transient/burst

4.3.2.3.1 General requirements

The ESPE shall continue in normal operation when subjected to fast transient/burst in accordance with IEC 61000-4-4:2004:

Ports for power lines for less than 50 V a.c. or d.c.	1 kV (peak) according to test severity level 2 of IEC 61000-4-4:2004
Ports for signal lines, etc. with a length exceeding 1 m	
Ports for power lines for 50 V a.c. and above	2 kV (peak) according to test severity level 3 of IEC 61000-4-4:2004

4.3.2.3.2 Additional requirements

A type 3 ESPE and a type 4 ESPE shall not fail to danger when subjected to fast transient/burst in accordance with IEC 61000-4-4:2004:

Ports for power lines for d.c. and for less than 50 V a.c. Ports for signal lines, etc. with a length exceeding 1 m	2 kV (peak) according to test severity level 3 of IEC 61000-4-4:2004
Ports for power lines for 50 V a.c. and above	4 kV (peak) according to test severity level 4 of IEC 61000-4-4:2004

4.3.2.4 Fast transient/surge

4.3.2.4.1 General requirements

The ESPE shall continue in normal operation when subjected to surge in accordance with IEC 61000-4-5:2005:

Ports for signal lines with a length exceeding 1 m Power ports for d.c. and for less than 50 V a.c.	1 kV (peak) common mode according to test severity level 2 of IEC 61000-4-5
Ports for power lines for 50 V a.c. and above	2 kV (peak) common mode and 1 kV (peak) differential mode according to test severity level 3 of IEC 61000-4-5:2005

4.3.2.4.2 Additional requirements

A type 3 ESPE and a type 4 ESPE shall not fail to danger when subjected to fast transient/surge in accordance with IEC 61000-4-5:2005:

Ports for signal lines with a length exceeding 1 m Power ports for d.c. and for less than 50 V a.c.	2 kV (peak) common mode according to test severity level 3 of IEC 61000-4-5:2005
Power ports for 50 V a.c. and above	4 kV (peak) common mode and 2 kV (peak) differential mode according to test severity level 4 of IEC 61000-4-5:2005

4.3.2.5 Electromagnetic field

4.3.2.5.1 General requirements

The ESPE shall continue in normal operation when subjected to an electromagnetic field in accordance with IEC 61000-4-3:

10 V/m (80 Mhz-1 GHz)

3 V/m (1,4 GHz-2 GHz)

1 V/m (2,0 GHz-2,7 GHz)

4.3.2.5.2 Additional requirements

A type 3 and a type 4 ESPE shall not fail to danger when subjected to an electromagnetic field in accordance with IEC 61000-4-3:

30 V/m (80 MHz-1 GHz)

10 V/m (1,4 GHz-2 GHz)

3 V/m (2,0-2,7 GHz)

4.3.2.6 Conducted disturbances induced by radio-frequency fields

4.3.2.6.1 General requirements

The ESPE shall continue in normal operation when subjected to conducted radio-frequency disturbances in accordance with IEC 61000-4-6:

Ports for signal lines, etc. with a length of 1 m to 10 m	3 V (r.m.s.) according to test severity level 2 of IEC 61000-4-6
Ports for signal lines with a length exceeding 10 m Power ports. Earth ports	10 V (r.m.s.) according to test severity level 3 of IEC 61000-4-6

4.3.2.6.2 Additional requirements

A type 3 ESPE and a type 4 ESPE shall not fail to danger when subjected to conducted radio-frequency disturbances in accordance with IEC 61000-4-6:

Ports for signal lines, etc. with a length of 1 m to 10 m	10 V (r.m.s.) according to test severity level 3 of IEC 61000-4-6
Ports for signal lines with a length exceeding 10 m Power ports. Earth ports	30 V (r.m.s.) according to test severity level X of IEC 61000-4-6

4.3.2.7 Electrostatic discharge

4.3.2.7.1 General requirements

The ESPE shall continue in normal operation when subjected to an electrostatic discharge in accordance with IEC 61000-4-2:

6 kV contact or 8 kV air discharge,
according to test severity level 3 of IEC 61000-4-2.

4.3.2.7.2 Additional requirements

A type 3 ESPE and a type 4 ESPE shall not fail to danger when subjected to an electrostatic discharge in accordance with IEC 61000-4-2:

8 kV contact or 15 kV air discharge,
to test severity level 4 of IEC 61000-4-2.

4.3.3 Mechanical environment

4.3.3.1 Vibration

The ESPE shall be capable of continuing in normal operation during the vibration tests of 5.4.4.1.

4.3.3.2 Bump

The ESPE shall be capable of continuing in normal operation during the bump tests of 5.4.4.2.

4.3.4 Enclosures

The ESPE shall have its own enclosure(s).

All enclosures of the ESPE, including those mounted remotely, shall provide a degree of protection of at least IP54 (see IEC 60529), when mounted as specified by the supplier. However, when mounted in a machine controlgear enclosure having a degree of protection of at least IP54, the ESPE enclosure shall have a degree of protection of at least IP20.

NOTE Protection against mechanical damage can be achieved by:

– a suitable location;

– the use of suitable materials and form of construction providing adequate strength; or

– the use of a protective barrier.

The method of cable entry for incoming cables shall not impair the degree of protection.

Sealing compounds which adhere to the two surfaces being joined, such that the environmental protection is degraded when the joint is separated, shall not be used to seal covers which might be removed for service access.

Enclosures shall be free from sharp edges or corners capable of causing damage to cable insulation. Compliance shall be checked by inspection.

Enclosures shall provide adequate access to enable any necessary adjustments and maintenance work to be carried out safely and effectively. The covers enabling such access shall have captive fasteners.

5 Testing

5.1 General

5.1.1 Type tests

5.1.1.1 Test samples

In so far as it is practicable, all parts of an ESPE shall be tested together. Where this is not practicable, parts of the ESPE may be tested separately. Examples of such situations include integrated ESPEs (ESPEs integrated in, and normally not separable from machinery) in the case of environmental tests. In such cases:

– any input signals necessary for the operation of the ESPE shall be simulated;

– these exceptions and any omissions of tests shall be stated in the test report.

Where a particular test would be destructive and identical results could be obtained by testing part of the ESPE in isolation, a sample of that part may be used instead of the whole equipment sample for the purpose of obtaining the results of the test.

Where the ESPE is designed for operation at a number of different supply voltages (for example for differing applications), more than one sample may be required.

When the ESPE is designed to be supplied from an external dedicated power supply, the ESPE shall undergo testing with the specified dedicated power supply (see 6.2).

5.1.1.2 Operating condition

Unless otherwise stated in the test procedure, the tests shall be carried out with the test sample operating within the conditions specified in the accompanying documents.

For the purposes of electrical disturbance immunity tests, the equipment shall be in as near its final operating configuration as is possible (i.e. with all peripheral devices and covers attached, connected to the power supply and, where applicable, connected to the external protective conductor and/or the external functional bonding conductor (see IEC 60204-1:2009)).

5.1.1.2DV D2 *Modification of the 2nd paragraph Clause 5.1.1.2 by replacing with the following:*

For the purposes of electrical disturbance immunity tests, the equipment shall be in as near its final operating configuration as is possible (i.e. with all peripheral devices and

covers attached, connected to the power supply and, where applicable, connected to the external protective conductor and/or the external functional bonding conductor.

When several mounting positions are specified, the least favourable mounting position shall be used.

Where a safety-related data interface is used in place of an OSSD(s), the ESPE shall be connected to a communication system in accordance with the supplier's instructions that has a means of monitoring the ESPE status.

5.1.1.3 Simulated intrusion into detection zone

In the following tests, introduction of the test piece (as defined in the relevant part of this standard) into the detection zone may be simulated if the method can be shown to be equivalent.

5.1.2 Test conditions

5.1.2.1 Test environment

Except where otherwise specified in 5.4, the tests shall be carried out with the ESPE

operated under the following conditions:

– rated voltage (or a voltage within the rated voltage range);

– rated frequency (or a frequency within the rated frequency range);

– ambient temperature: 20 °C ± 5 °C;

– relative humidity: 25 % to 75 %;

– barometric pressure: 86 kPa to 106 kPa.

NOTE Values stated in the marking and in the accompanying documents are considered as rated values.

5.1.2.2 Measurement accuracy

The errors of measurement shall not exceed:

– for measurement of ESPE response time: ±1 ms;

– for temperature measurements: ±3 °C;

– for electrical measurements: ±1 %, where technically possible and/or appropriate;

– for relative humidity (RH) measurements: ±3 % RH;

– for linear measurements: ±1 mm or ±1 %, whichever is the greater.

All measurements shall be made after stable temperature conditions have been achieved. This is considered to be fulfilled when the rate of temperature rise or fall is less than 2 K/h.

5.1.2.3 Environmental test conditions for an ESPE intended to be used with a safety-related communication interface

The ESPE and the safety-related communication interface shall be tested together (see Figure 2). Due to the fact that the safety-related communication interface does not show a static output signal, it is necessary to use a data receiver. The test setup consists of the equipment under test and a data receiver (for example, a PLC or monitoring device) which indicates the status of the sensing device or ESPE.

When testing for susceptibility to electrical disturbances, an appropriate test adapter which isolates the ESPE under test from the communication bus may be required.

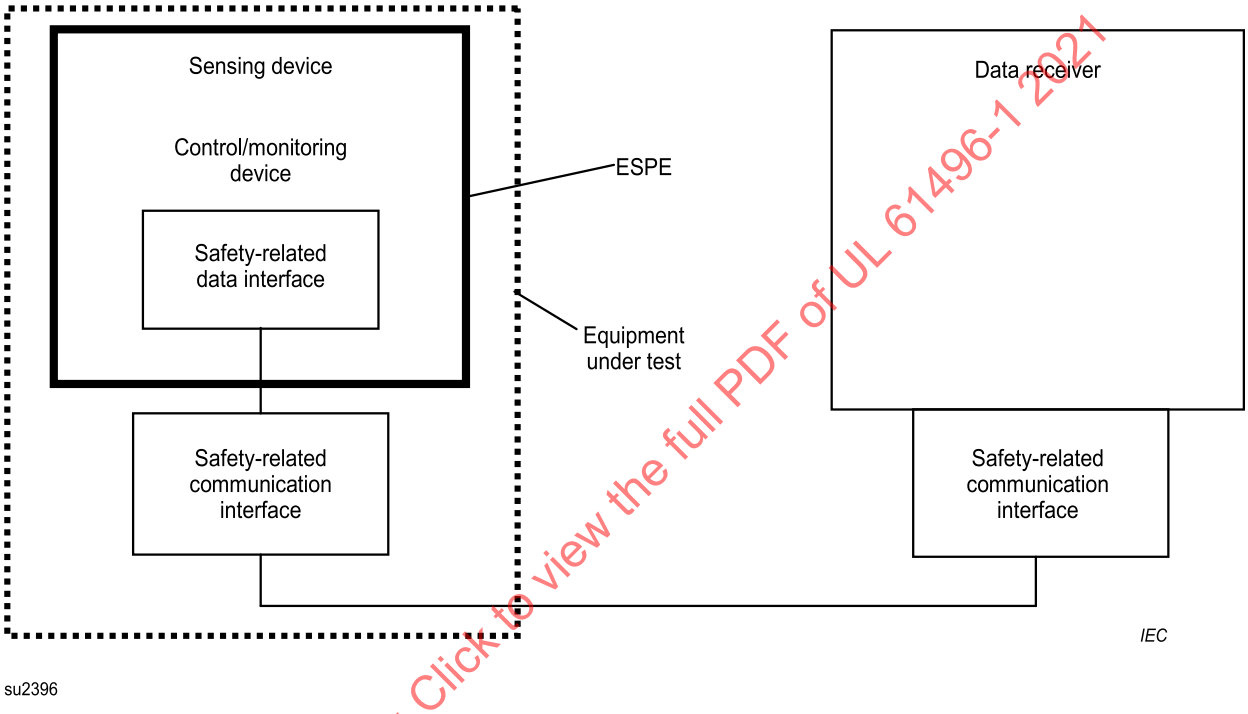

Figure 2

Test setup for the EMC test of ESPEs with safety-related communication interfaces

5.1.3 Test results

The results of the tests and analyses listed in 5.1.3 shall be documented. The test results shall be rranged in a form that shows the details of each individual test and its effects. Details of any special test procedures shall be included in the test report.

5.2 Functional tests

5.2.1 Sensing function

The sensing function and the integrity of the detection capability and zone (for example size, shape and location) of the ESPE shall be verified as specified in the relevant part of IEC 61496.

5.2.2 Response time

The response time shall be verified by systematic analysis and test.

The response time may be determined by electrical simulation of an actuation, provided that it includes the maximum time between the event triggering the actuation of the sensing device and the actuation.

Additional requirements for the measurement of the response time of the ESPE may be given in the relevant part of IEC 61496.

5.2.3 Limited functional tests

5.2.3.1 General

The following limited functional tests A, B and C shall be performed to verify that under normal environmental conditions the ESPE shall continue normal operation and that, under abnormal environmental conditions or under fault conditions, the ESPE shall not fail to danger.

When an ESPE is fitted with a restart interlock function, that function shall be bypassed or not selected during the performance of the tests. The restart interlock function shall be tested separately (see Annex A).

When using a safety-related communication interface, in the following limited functional tests, OSSDs going to the ON-state or OFF-state are replaced by a safety-related message (for example, a data telegram) indicating the corresponding status of the sensing device or ESPE.

NOTE In some situations, it can be necessary to simulate the actuation of the sensor by some means other than introducing a test piece.

5.2.3.2 Limited functional test A (A test)

With no intrusion in the detection zone, it shall be observed, for a period of at least 5 s, unless otherwise specified, that the OSSD(s) shall be in the ON-state and shall not go to OFF-state.

5.2.3.3 Limited functional test B (B test)

With no intrusion in the detection zone, it shall be observed, for a period of at least 5 s, unless otherwise specified, that the OSSD(s) shall be in the ON-state and shall not go to the OFF-state.

The test piece shall be brought into the detection zone. The OSSD(s) shall respond by going from the ON-state to the OFF-state. It shall be observed that, for a period of at least 5 s unless otherwise specified, the OSSD(s) remain(s) in the OFF-state with the test piece being present in the detection zone.

The test piece shall be removed from the detection zone or the sample shall be otherwise deactivated. The OSSD(s) shall respond by going from the OFF-state to the ON-state. It shall be observed that, for a period of at least 5 s unless otherwise specified, the OSSD(s) remain(s) in the ON-state with the test piece not being present in the detection zone.

The above tests may need to be repeated continuously depending on test requirements.

5.2.3.4 Limited functional test C (C test)

This test is the same as the limited functional test B but, where the OSSD(s) should be in the ON-state, the OSSD(s) are allowed to be in the OFF-state. No failure to danger shall occur. At the end of each of the relevant tests in 5.4, the ESPE shall continue to operate normally or shall resume normal operation following recovery from a lock-out condition.

If the ESPE cannot resume normal operation due to a permanent component failure, it is acceptable if it is verified that the failure was only in components of the communication interface and that the OSSD(s) remain in the OFF-state.

NOTE Under extreme electrical disturbances (as in the fail-to-danger tests), it is possible that some components of the communication interface will fail permanently and will not allow the ESPE to resume normal operation.

5.2.4 Periodic test

For a type 2 ESPE, the requirements of 4.2.2.3 shall be verified by analysis and measurement.

5.2.5 Indicator lights and displays

The functions and colours of indicator lights and displays shall be verified in accordance with the requirements of 4.2.5 by applying a B test.

5.2.6 Means of adjustment

The requirements of 4.1.1 and 4.1.2 shall be verified by inspection. The requirements of 4.2.6 shall be verified by inspection and by carrying out C tests as necessary.

5.2.7 Rating of components

The operation of each component within its specified ratings, throughout the entire operating range of the ESPE, shall be verified by analysis and/or inspection.

5.2.8 Output signal switching devices (OSSD)

5.2.8.1 General

The provision of separate output connection points (terminals) for each OSSD shall be verified by inspection.

When two OSSDs are provided, verify by inspection or test that the OSSDs are operated independently.

Verify by inspection that the OSSD(s) are protected by current limiting devices or that information for installation of current limiting devices is provided in information for use.

It shall be verified that foreseeable faults will not cause the OSSD(s) to go to or remain in the ON-state. All tests shall be carried out with the maximum inductive load and the maximum length of the connection cable specified by the manufacturer.

Foreseeable faults include:

– short circuit of the OSSD to supply voltage;

– short circuit of the OSSD to ground;

– short circuit between the OSSDs;

– open circuit at the power supply return cable;

– open circuit of the functional bonding conductor;

– open circuit of the screen of a screened cable;

– incorrect wiring.

5.2.8.2 Relay OSSDs

Verify by inspection or tests that the relays meet the requirements of 4.2.4.2.

5.2.8.3 Solid state OSSDs

The output voltage and current levels specified in 4.2.4.3 of this standard shall be verified.

5.2.8.4 Safety-related data interface and safety-related communication interface

It shall be verified by test that disconnection of components does not lead to a failure to danger.

Electrical tests specified in 5.2.8.1 (shorts, opens, improper loading) which would be applied to OSSD(s) may be excluded if not applicable.

The safety integrity of an integrated communication interface shall be verified by tests, systematic analysis and by reference to data sheets and test reports in accordance with the requirements of 4.2.4.4.

5.3 Performance testing under fault conditions

5.3.1 General

Tests for the effects of single faults selected according to 4.2.2 shall be carried out on all the relevant components of the ESPE. If further faults occur as a result of the first single fault, the first and all consequent faults shall be considered as a single fault.

A fault catalogue including all components shall be prepared recording the results of the fault considerations listed in Annex B. In order to reduce unnecessary testing according to 5.3.3, 5.3.4 and 5.3.5 where the results of a single fault or combination of faults can be predicted theoretically, an analysis statement shall be included as part of the test results statement. That statement shall be validated in accordance with 5.5.4. In such cases, only selected (sample) tests need be carried out to confirm such analysis statements.

NOTE 1 Typical methods used for the fault assessment include fault mode and effect analysis (FEMA) according to IEC 60812 and fault tree analysis (FTA) according to IEC 61025.

NOTE 2 In the case of complex circuit structures or components (for example microprocessor, complete redundancy) the review of faults is generally carried out on the structural level. See B.2 for exclusion of short circuits on assembled circuit boards and for exclusion of short circuits between adjacent terminals for external connection.

5.3.2 Type 1 ESPE

NOTE Requirements for a type 1 ESPE are not being considered at this time.

5.3.3 Type 2 ESPE

The ESPE shall be subjected to single faults to establish that a fault leading to a hazardous condition (for example loss of detection capability or increased response time) is detected by the periodic test function and results in a lock-out condition in accordance with 4.2.2.3.

Where automatic initiation of the periodic test is provided, it shall be verified that faults that lead to the loss of the monitoring function are detected and cause at least one OSSD to go to the OFF-state. If one or more OSSDs does not go to the OFF-state, a lock-out condition shall be initiated.

5.3.4 Type 3 ESPE

The ESPE shall be subjected to single faults to establish that the fault is detected by the ESPE going to a lock-out condition and that no failure to danger occurs, in accordance with 4.2.2.4.

When a single fault is not detected and the analysis specified in 5.3.1 cannot be carried out, the tests for the ESPE going to a lock-out condition and no failure to danger occurring shall be continued with that fault applied first and all other faults added and removed in turn. Tests shall be carried out for all undetected single faults.

Testing for accumulation of more than two faults need not be carried out.

5.3.5 Type 4 ESPE

The ESPE shall be subjected to single faults to establish that the fault is detected by the ESPE going to a lock-out condition and that no failure to danger occurs, in accordance with 4.2.2.5.

When a single fault is not detected and the analysis specified in 5.3.1 cannot be carried out, the tests for the ESPE going to a lock-out condition and no failure to danger occurring shall be continued with that fault applied first and all other faults added and removed in turn. Tests shall be carried out for all undetected single faults.

When a sequence of two faults is not detected and the analysis specified in 5.3.1 cannot be carried out, the tests shall be continued for those two faults, applied in sequence, and all other single faults added and removed in turn. No failure to danger shall occur. Tests shall be carried out for all undetected double faults.

Testing for the accumulation of more than three faults need not be carried out provided that the probability of more than three faults, largely independent of each other and having to appear in a specific sequence in time, is low.

5.4 Environmental tests

5.4.1 Rated supply voltage

The design measures specified in 4.2.1 shall be verified by inspection.

The ESPE shall be subjected to the following sequence of tests using the relevant values specified in 4.2.1:

a) the ESPE shall be supplied with the lowest rated supply voltage. A B test shall be carried out;

b) the supply voltage shall be increased, within a period of 10 s to 20 s, to the highest rated voltage, during which time an A test shall be performed;

c) after the highest test supply voltage has been reached, a B test shall be carried out.

The requirements for frequency variation and for harmonic distortion shall be verified either by testing or by using analytical methods.

5.4.2 Ambient temperature variation and humidity

The highest ambient temperature in the tests below shall be as specified in the marking and/or the accompanying documents, but shall not be lower than +50 °C. The lowest ambient temperature in the tests below shall be as specified in the marking and/or the accompanying documents, but shall not be higher than 0 °C.

The ESPE shall be subjected to the following sequence of tests:

a) With the ESPE operating under the conditions specified in 5.1.2.1, an A test shall be performed with a duration of at least 2 h. At the end of that time, a B test shall be carried out.

b) The ambient temperature shall be increased by not more than 0,3 °C per minute up to the highest ambient temperature, during which time an A test shall be performed.

c) An A test shall be performed with a duration of at least 2 h at the highest ambient temperature. During that time, the humidity shall be increased to 95 % and held at that value for at least 1 h. Following the A test, a B test shall be carried out.

d) The ambient temperature shall be decreased by not more than 0,3 °C per minute, whilst maintaining the humidity at 95 %, until a temperature of 20 °C is reached, during which time an A test shall be performed.

e) The ambient temperature shall be decreased by not more than 0,3 °C per minute, without condensation occurring, until the lowest ambient temperature is reached, during which time an A test shall be performed.

f) An A test shall be performed with a duration of at least 2 h at the lowest ambient temperature. At the end of that time, a B test shall be carried out.

g) The ambient temperature shall then be increased by not more than 0,3 °C per minute to the value specified in 5.1.2.1, during which time an A test shall be performed.

h) An A test shall be performed with a duration of at least 2 h at the temperature specified in 5.1.2.1. At the end of that time a B test shall be carried out.

5.4.3 Effects of electrical disturbances

5.4.3.1 Supply voltage variations

The external supply voltage and each internally derived supply voltage shall in turn be varied in accordance with 4.3.2.1. During each test, a C test(s) shall be carried out as necessary to confirm that no failure to danger occurs at reduced voltage values.

5.4.3.2 Supply voltage interruptions

The tests specified in 4.3.2.2 shall be carried out with the duration of each test sufficiently long to cover at least 10 dips and to enable for each of tests 1) and 2) that a B test shall be carried out, and for test 3) that a C test shall be carried out.

5.4.3.3 Fast transient/burst

5.4.3.3.1 General requirements

The ESPE shall be subjected to fast transient/burst to the levels specified in 4.3.2.3.1 in accordance with IEC 61000-4-4:2004 (using Figure 10 of IEC 61000-4-4:2004 for coupling of d.c. and less than 50 V a.c. power and signal ports, and Figure 9 for other a.c. power ports).

During each exposure, a B test shall be carried out.

5.4.3.3.2 Additional tests

A type 3 or a type 4 ESPE shall also be subjected to fast transient/burst to the levels specified in 4.3.2.3.2 in accordance with IEC 61000-4-4:2004 (using Figure 10 of IEC 61000-4-4:2004 for coupling d.c. and less than 50 V a.c. power and signal ports, and Figure 9 for other a.c. power ports).

During each exposure, a C test shall be carried out.

5.4.3.4 Fast transient/surge

5.4.3.4.1 General requirements

The ESPE shall be subjected to fast transient/surge to the levels specified in 4.3.2.4.1 in accordance with IEC 61000-4-5:2005 (using Figures 11 to 13 or Figure 14 of IEC 61000-4-5:2005 for coupling of signal ports, Figure 8 of IEC 61000-4-5:2005 for coupling of less than 50 V a.c. and d.c. power ports, and Figures 7 and 8 of IEC 61000-4-5:2005 for other a.c. power ports).

During each exposure, a B test shall be carried out.

5.4.3.4.2 Additional tests

The type 3 or a type 4 ESPE shall be subjected to fast transient/surge to the levels specified in 4.3.2.4.2 in accordance with IEC 61000-4-5:2005 (using Figures 11 to 13 or Figure 14 of IEC 61000-4-5:2005 for coupling of signal ports, Figure 8 of IEC 61000-4-5:2005 for coupling of less than 50 V a.c. and d.c. power ports, and Figures 7 and 8 of IEC 61000-4-5:2005 for other a.c. power ports).

During each exposure, a C test shall be carried out.

5.4.3.5 Electromagnetic field

5.4.3.5.1 General tests

The ESPE shall be subjected to an electromagnetic field to the levels specified in 4.3.2.5.1 in accordance with IEC 61000-4-3. During the exposure to the specified levels, a B test shall be carried out.

NOTE The result of this test is dependent on the surrounding structures which may differ from when the ESPE is fitted to a machine.

5.4.3.5.2 Additional tests

A type 3 and type 4 ESPE shall also be subjected to an electromagnetic field to the levels specified in 4.3.2.5.2 in accordance with IEC 61000-4-3. During the exposure to the specified levels, a C test shall be carried out.

NOTE The result of this test is dependent on the surrounding structures which may differ from when the ESPE is fitted to a machine.

5.4.3.6 Conducted disturbances induced by radio-frequency fields

5.4.3.6.1 General tests

The ESPE shall be subjected to conducted radio-frequency disturbances to the levels specified in 4.3.2.6.1 in accordance with IEC 61000-4-6. During each exposure, a B test shall be carried out.

5.4.3.6.2 Additional tests

A type 3 or a type 4 ESPE shall also be subjected to conducted radio-frequency disturbances to the levels specified in 4.3.2.6.2 in accordance with IEC 61000-4-6.

During each exposure, a C test shall be carried out.

5.4.3.7 Electrostatic discharge

5.4.3.7.1 General tests

The ESPE shall be subjected to electrostatic discharge to the levels specified in 4.3.2.7.1 in accordance with IEC 61000-4-2. During each exposure, a B test shall be carried out.

5.4.3.7.2 Additional tests

A type 3 or a type 4 ESPE shall also be subjected to electrostatic discharge to the levels specified in 4.3.2.7.2 in accordance with IEC 61000-4-2.

During each exposure a C test shall be carried out.

5.4.4 Mechanical influences

5.4.4.1 Vibration

The test sample shall be exposed to vibration tests according to IEC 60068-2-6.

The following conditions shall apply:

Frequency range:	10 Hz to 55 Hz
Sweep rate:	1 octave/min
Amplitude:	0,35 mm ± 0,05 mm. The test shall be carried out without anti-vibration mountings
Number of sweeps:	20 for each of three mutually perpendicular axes (no delay at resonant frequencies)

The following limited functional tests shall be performed for each axis:

– an A test shall be performed during each of the first and last sweeps;

– a B test shall be carried out, so that the test piece is brought into the detection zone at the beginning of the second sweep and is removed at the end of the 19th sweep.

5.4.4.2 Bump

The test sample shall be exposed to bump tests according to IEC 60068-2-27.

The following conditions shall apply:

Acceleration:	10 g
Duration of pulse:	16 ms
Number of bumps:	1 000 ± 10 for each of three mutually perpendicular axes

The following tests shall be performed for each axis:

– an A test shall be performed during each of the first and last (100 ± 10) bumps;

– a B test shall be carried out, so that the test piece is brought into the detection zone after the first (100 ± 10) bumps.

5.4.5 Enclosures

The requirements of 4.3.4 for degrees of protection shall be tested in accordance with IEC 60529 after the tests of 5.4.4 have been completed. The remaining requirements shall be verified by inspection.

5.5 Validation of programmable or complex integrated circuits

5.5.1 General

This subclause deals with the validation of the requirements of 4.2.10 and 4.2.11, and any analysis statement included as part of the test results statement required by 5.3.1.

Validation shall be undertaken by a competent person(s) who should be independent of those responsible for any aspect of the system design, the hardware design and the software design. A written validation report shall be compiled.

NOTE The validation provides independent confirmation that specific requirements have been achieved. The process is intended to confirm that systematic faults in the design have been avoided, that procedures are in place to maintain safety performance during the life cycle of the product (including, for example, following modification) and that the design of the ESPE fulfils the fault detection requirements appropriate to its type.

5.5.2 Complex or programmable integrated circuits

For a Type 4 ESPE employing a complex or programmable integrated circuit(s), the

following requirements shall be validated by analysis:

a) there are a minimum of two independent decision-making channels;

b) the detection of disparity between channels, and the initiation of a lock-out condition, shall be maintained under all applicable fault conditions.

5.5.3 Software, programming, functional design of integrated circuits

Verification and validation shall be in accordance with the standard (s) selected for development (see 4.2.11.2).

5.5.4 Test results analysis statement

When analysis is employed to define the result of any test required by 5.3, the adequacy, suitability, and validity of the techniques used shall be validated. The correct implementation of the methods used shall be verified by repeating parts of the analysis selected at random.

6 Marking for identification and for safe use

6.1 General

In accordance with 6.4.4 of ISO 12100, all parts of the ESPE shall bear all markings which are necessary:

– for its unambiguous identification;

– for its safe use,

and supplementary information shall be given, as appropriate:

– permanently on the ESPE;

– in accompanying documents such as instruction handbooks;

– on the packaging.

6.1DV D2 ***Modification of the first sentence of Clause 6.1 by replacing with the following:***

All parts of the ESPE shall bear all markings which are necessary.

The enclosure of the most appropriate part of the ESPE shall carry the following permanent markings:

a) identification of the product, including name and address of the supplier, designation of series or type, serial number and year of construction;

b) parameters, for example dimensions, of the detection zone;

c) detection capability;

d) response time;

e) rated voltage(s) including number of phases and frequency where relevant;

f) rated input power (if greater than 25 W) or rated current;

g) designation of IP code;

h) for class II equipment only, symbol for classification for protection against electric shock;

i) warning sign of hazards arising from dangerous voltages;

j) type of ESPE according to 4.1.3;

k) PL and/or SIL according to 4.1.4.

6.2 ESPE supplied from a dedicated power supply

Where an ESPE is designed to be supplied from an external dedicated power supply, details of the model or type of dedicated power supply with which it has been tested shall be permanently marked on the enclosure of the most appropriate part of the ESPE and/or included in the instructions for use.

6.3 ESPE supplied from an internal electrical power source

An ESPE supplied from an internal power source shall be marked with details of the rated current of the supply fuse, if applicable, on the enclosure of the most appropriate part of the ESPE.

6.4 Adjustment

When the ESPE can be adjusted to suit different rated voltages or different inputs, a marking showing the voltage or input to which the ESPE is adjusted shall be clearly and easily discernible at the point of adjustment.

6.5 Enclosures

Any enclosure which contains electrical devices shall be marked with a warning sign in accordance with 16.2.1 of IEC 60204-1:2009.

6.5DV D2 *Modification of Clause 6.5 by replacing with the following:*

Any enclosure which contains electrical devices shall be marked with a warning sign in accordance with 16.2.1 of NFPA-79:2015.

6.6 Control devices

6.6.1 Markings for switches, indicating lamps, and other control devices shall be placed adjacent to those components; they shall not be placed on removable parts which can be replaced in such a way that the marking is misleading.

6.6.2 Functional identification of control and indicating devices shall be in accordance with 16.3 of IEC 60204-1:2009.

6.6.2DV D2 *Modification of Clause 6.6.2 by replacing with the following:*

Functional identification of control and indicating devices shall be provided.

6.6.3 The positions of any power supply switches shall be marked according to 5.3.1 of IEC 60204-1:2009.

6.6.3DV D2 *Modification of Clause 6.6.3 by replacing with the following:*

The positions of any power supply switches shall be marked.

6.6.4 Devices intended for the adjustment of a characteristic during or after installation, shall be provided with markings of the direction of adjustment to increase or decrease the value of that characteristic. See also IEC 60447.

6.6.4DV D2 *Modification of Clause 6.6.4 as follows:*

Delete the last sentence of 6.6.4.

6.7 Terminal markings

6.7.1 Terminals to which cable connections are to be made at the time of installation, or re-established after maintenance of the ESPE, shall be marked and related to a diagram.

6.7.2 Terminals for external connections provided with, and relating to the ESPE and user replaceable components shall be marked and related to a diagram.

6.7.3 All terminals for the incoming supply connections shall be marked in accordance with IEC 60445.

6.7.3DV D2 *Modification of Clause 6.7.3 by replacing with the following:*

All terminals for the incoming supply connections shall be marked in accordance with UL 60947-1.

6.7.4 Protective conductor connection points shall be marked in accordance with 8.2.6 of IEC 60204-1:2009.

This marking shall not be placed on screws, removable washers or other parts which might be removed when conductors are being connected/disconnected.

6.7.4DV D2 *Modification of the 1st paragraph of Clause 6.7.4 by replacing with the following:*

Protective conductor connection points shall be marked using the ground in a circle symbol from IEC 60417-5019 (DB 2002-10).

6.7.5 Where an ESPE is to be connected to more than two supply conductors, it shall be provided with a connection diagram, fixed to the ESPE, unless the correct mode of connection is obvious.

6.7.6 If more than one supply is taken to an ESPE, the marking shall include a warning that all supplies shall be switched off before the terminal cover may be removed.

6.8 Marking durability

Marking shall be capable of withstanding the environmental influences of an industrial environment with respect to temperature and humidity as defined by this standard, and liquids such as water, soapy water, machine oil, benzine, etc.

Markings shall be capable of withstanding being rubbed lightly for 15 s with a piece of cloth soaked with petroleum spirits, and with a piece of cloth soaked in water.

7 Accompanying documents

The supplier of the ESPE shall provide documentation in the languages agreed between the user and the supplier.

7DV.1 D2 *Modification of Clause 7 as follows:*

Delete the first paragraph of Clause 7.

The accompanying documents shall contain the information required for the installation, use and subsequent disposal of the ESPE, including the following information where applicable:

a) a statement that other devices shall not be connected to the internally generated power supplies of the ESPE;

b) details of the included optional functions of the ESPE, as described in Annex A (including all necessary data for determining safety performance);

c) a description of facilities for connection of Stopping Performance Monitor (SPM) if provided;

d) for a type 2 ESPE, information on the means of applying an external test signal, where required (see 4.2.2.3);

e) a recommendation that security keys/special tools, if provided for adjustments, operations or access, be kept under the control of a responsible or authorized person(s);

f) the size and type of the test piece and the test procedure, or description of other methods for checking the detection capability and the operation of the visual indicator;

g) the response time.

If a safety-related communication interface is used, procedures for determining overall system response time;

h) the rated operating conditions for the ESPE including:

– temperature range;

– humidity;

– voltage range;

– range of separation distances between the subsystems, and the maximum length of interconnecting cables.

i) advice on the prevention of mutual interference of sensing functions;

j) block diagrams, functional description chart showing sequence of relay switching operations;

k) the location of all input and output terminals;

l) the ratings and characteristics of all input/output terminals;

m) the minimum and maximum voltage and current that the OSSDs (and if provided, the SSDs) are capable of switching into a resistive, capacitive or inductive load, and the maximum switching rate with this load, and the anticipated life of the switching device depending on load;

n) information to enable the user to carry out maintenance using the supplier's recommended spares;

o) special requirements regarding input cables and terminations, if applicable;

p) the total load/power requirements of the ESPE;

q) details of the space required around the equipment for removal and maintenance purposes;

r) a list of the user-replaceable parts specified by the supplier;

s) a list of colour and coding systems (see IEC 60204-1:2009);

t) the overall dimensions of the equipment;

u) operating instructions;

v) the location and dimensions of the detection zone(s) and definitions of other functional limits;

w) a schedule of checks to be carried out after installation, after maintenance, or periodically, to establish that the device is functioning correctly;

x) the method and frequency of regular testing to confirm that proper operation is maintained;

y) a statement of the IP rating of the enclosures, or where the ESPE is intended to be mounted in a machine controlgear enclosure, the minimum IP rating required of that enclosure according to 4.3.4;

z) a clear statement of any particular application for which the ESPE is intended;

aa) for a type 2 ESPE when the periodic test is externally initiated, information on selecting the required test interval; if the periodic test is internally initiated, information on the internal test interval;

bb) the installation and mounting instructions for any switches, controls and indicators remotely mounted from the ESPE that are connected to the ESPE;

cc) instructions on where parts with restart interlock should be located in relation to the danger zone;