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**Safety of machinery –
Application of protective equipment
to detect the presence of persons**

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Safety of machinery – Application of protective equipment to detect the presence of persons

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SAFETY OF MACHINERY – APPLICATION OF PROTECTIVE EQUIPMENT TO DETECT THE PRESENCE OF PERSONS

FOREWORD

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Technical Specifications are subject to review within three years of publication to decide whether they can be transformed into International Standards.

IEC TS 62046, which is a Technical Specification, has been prepared by IEC technical committee 44: Safety of machinery – Electrotechnical aspects.

The text of this Technical Specification is based on the following documents:

Enquiry Draft	Report on voting
44/437/DTS	44/451/RVC

Full information on the voting for the approval of this Technical Specification 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.

The committee has decided that the contents of this publication will remain unchanged until 2006. At this date, the publication will be

- transformed into an International Standard;
- reconfirmed;
- withdrawn;
- replaced by a revised edition, or
- amended.

A bilingual edition of this Technical Specification may be issued at a later date.

INTRODUCTION

This Technical Specification addresses the application of protective equipment, which employs a sensing device(s) to detect person(s) in or approaching an area, in order to reduce or minimize a risk from hazardous parts of machinery, without providing a physical barrier. This specification provides information on the manner in which the protective equipment should be applied to the machine to achieve the targeted level of risk reduction.

The objective of this specification is to assist: standards writing committees responsible for developing machine standards ("C" Standards), machine designers, manufacturers and refurbishers, machine safety certification organizations, workplace authorities and others on the proper application of protective equipment to machinery.

Figures 1 and 2 show the general context and the intended use of this specification.

Clauses 1 to 5, 7 and 8 of this specification apply to all protective equipment included in the scope, Clause 6 contains guidance for the application of specific kinds of protective equipment.

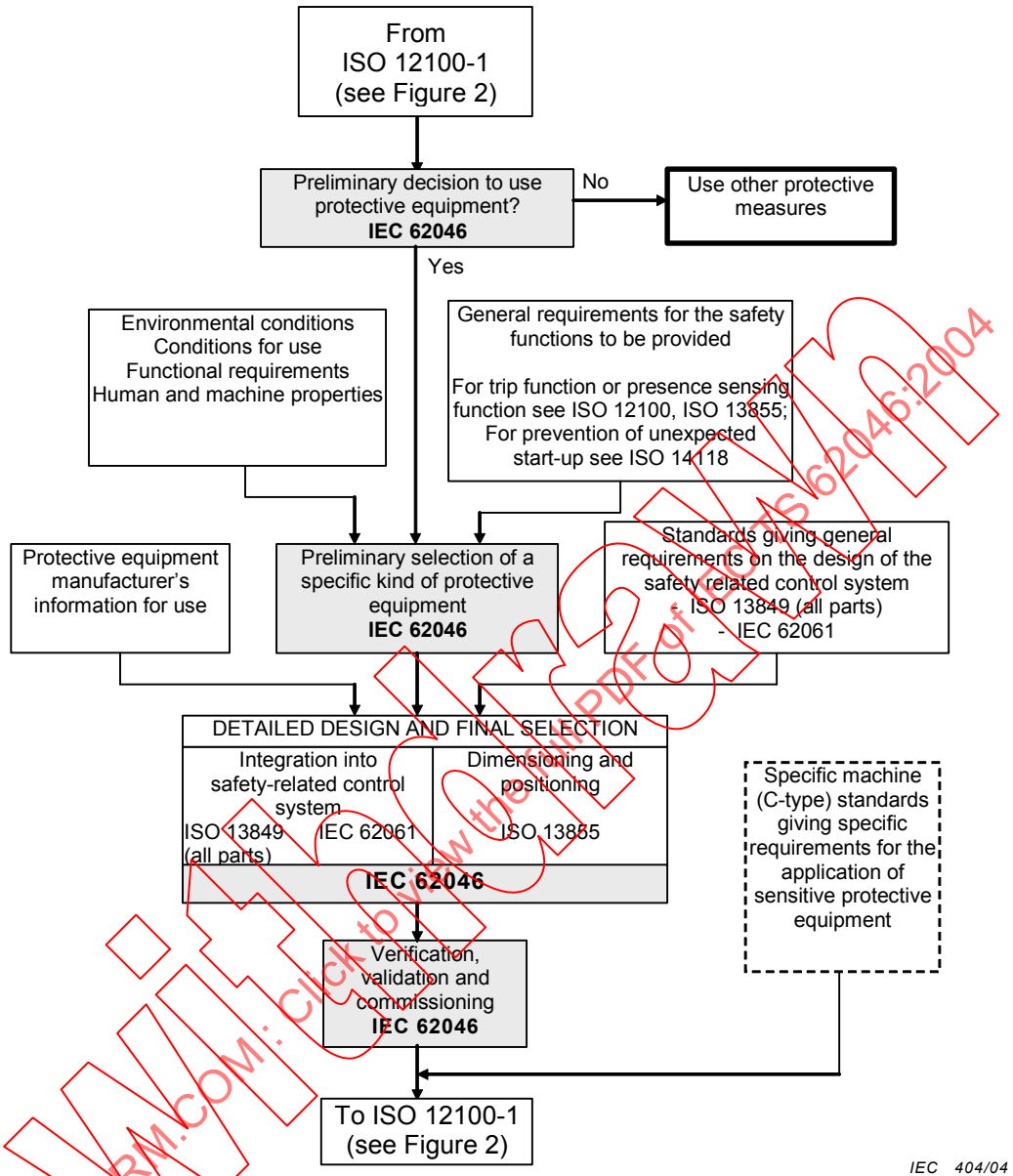

Figure 1 – Relationship of this Technical Specification to other standards

(see also Figure 2)

SAFETY OF MACHINERY – APPLICATION OF PROTECTIVE EQUIPMENT TO DETECT THE PRESENCE OF PERSONS

1 Scope

This Technical Specification specifies requirements for the selection, positioning, configuration and commissioning, of protective equipment to detect the presence of persons in order to protect those persons from dangerous part(s) of machinery in industrial applications. This specification covers the application of electro-sensitive protective equipment (ESPE) specified in IEC 61496 (all parts) and pressure sensitive mats and floors specified in ISO 13856-1.

It takes into account the characteristics of the machinery, the protective equipment, the environment and human interaction by persons of 14 years and older.

NOTE This Technical Specification may also be used for guidance in the application of other protective devices.

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.

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

IEC 61496-1:2004, *Safety of Machinery – Electro-sensitive protective equipment – General requirements and tests*

IEC 61496-2:1997, *Safety of machinery – Electro-sensitive protective equipment – Part 2: Particular requirements for equipment using active opto-electronic protective devices (AOPDs)*

IEC 61496-3:2001, *Safety of machinery – Electro-sensitive protective equipment – Particular requirements for equipment for Active Opto-Electronic Protective Devices responsive to Diffuse Reflection (AOPDDR)*

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

ISO 12100-1: 2003, *Safety of machinery – Basic concepts, general principles for design – Part 1: Basic terminology, methodology*

ISO 12100-2: 2003, *Safety of machinery – Basic concepts, general principles for design – Part 2: Technical principles*

ISO 13849-1:1999, *Safety of Machinery – Safety-related parts of control systems – Part 1: General principles for design*

ISO 13855:2002, *Safety of machinery – Positioning of protective equipment with respect to the approach speeds of parts of the human body*

ISO 13856-1:2001, *Safety of machinery – Pressure-sensitive protective devices – Part 1: General principles for design and testing of pressure-sensitive mats and pressure-sensitive floors*

ISO 14118:2000, *Safety of machinery – Prevention of unexpected start-up*

ISO 14121:1999, *Safety of machinery – Principles of risk assessment*

CLC/TS 50418: 2004, *Safety of Machinery - Electro-sensitive protective equipment - Passive infra-red protective devices (PIPDs)*

3 Terms, definitions and abbreviations

3.1 Terms and definitions

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

3.1.1
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)

3.1.2
detection capability
sensing function parameter limit specified by the supplier that will cause actuation of the protective equipment

NOTE Adapted from IEC 61496-1.

3.1.3
detection zone
zone within which a specified test piece will be detected by the electro-sensitive protective equipment

NOTE 1 ISO 13856 uses the term “effective sensing area” when describing pressure-sensitive mats and floors. In this document the terms “detection zone” and “effective sensing area” are used synonymously.

NOTE 2 Adapted from IEC 61496-1.

3.1.4
effective sensing area
part of the top surface area of the sensor or a combination of the pressure-sensitive mat or pressure-sensitive floor within which a response to an actuating force will take place

NOTE IEC 61496-1 uses the term “detection zone” when describing electro-sensitive protective equipment. In this document the terms “detection zone” and “effective sensing area” are used synonymously.

NOTE Adapted from ISO 13856-1.

3.1.5
failure (of equipment)
termination of the ability of an item to perform a required function

NOTE 1 After failure the item has a fault.

NOTE 2 "Failure" is an event, as distinguished from "fault", which is a state.

NOTE 3 This concept as defined does not apply to items consisting of software only.

[IEV-191-04-01]

3.1.6
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

[IEC 61496-1, 3.8]

3.1.7
fault
state of an item characterized by its inability to perform a required function, excluding the inability during preventive maintenance or other planned actions, or due to lack of external resources

[IEV 191-05-01]

NOTE 1 A fault is often the result of a failure of the item itself, but may exist without prior failure.

NOTE 2 In the field of machinery, the English term `fault' is commonly used in accordance with the definition in IEV 191-05-01, whereas the French item "défaut" and the German term "fehler" are used rather than the term "panne" and "fehlzustand" that appear with this definition.

NOTE 3 In practice, the terms "fault" and "failure" (see 3.1.5) are often used synonymously.

3.1.8
hazard
potential source of harm

[ISO 12100-1, 3.6]

NOTE The word "hazard" is generally used in conjunction with other words defining its origin or the nature of the expected injury or damage to health: electrical shock hazard, crushing hazard, shearing hazard, toxic hazard, etc.

3.1.9
hazardous situation
circumstance in which a person is exposed to at least one hazard. The exposure can immediately or over a period of time result in harm

[ISO 12100-1, 3.9]

3.1.10
hazard zone (danger zone)

any space within and/or around machinery in which a person can be exposed to a hazard

[ISO 12100-1, 3.10]

NOTE The hazard generating the risk envisaged in this definition:

– either is permanently present during the intended use of the machine (motion of hazardous moving elements, electric arc during a welding phase);
– or can appear unexpectedly (unintended/unexpected start-up).

3.1.11
integrator
individual or group of individuals responsible for selecting, configuring, installing and/or interfacing the protective equipment to achieve the safeguarding identified by the risk assessment

3.1.12
lock-out condition
condition, initiated by a fault, preventing normal operation of the protective equipment which is automatically attained when all output signal switching devices (OSSDs) and, where applicable, all final switching devices (FSDs) and secondary switching devices (SSD) are signalled to go to the OFF-state

[IEC 61496-1, 3.13 modified]

3.1.13
muting
temporary automatic suspension of a safety function(s) by safety-related parts of the control system

[IEC 61496-1, 3.16]

NOTE When muting is provided as part of the protective equipment and the protective equipment is muted, the OSSD(s) remain in the `ON' state upon activation of the protective equipment sensing function and safety is maintained by other means.

3.1.14
overall system stopping performance
time interval resulting from the sum of the protective equipment response time and the time to the cessation of hazardous machine operation

[IEC 61496-1, 3.20]

3.1.15
Passive Infrared Protective Device
PIPD
device whose sensing function is performed by a receiving element(s) detecting thermal radiation emitted by an object placed in, or moving within, the specified detection zone

3.1.16
periodic test
technique which stimulates or simulates the input of the protective equipment sensing device(s) to determine if the protective equipment OSSD(s) go to the off state when required to do so

NOTE The test input signal is usually produced by an external machine test input and is performed at intervals, determined by the risk assessment, which provide a reasonable degree of confidence that the intended risk reduction will be achieved.

3.1.17
protective equipment
assembly of devices using non-contact (electro-sensitive) or contact (pressure sensitive) sensing means for detection of the presence of person(s) or parts of person(s) for the purpose of controlling hazards associated with machinery and comprising as a minimum:

– a sensing device;
– control and monitoring devices;
– output signal switching devices

NOTE The safety related control system associated with the protective equipment, or the protective equipment itself, can include additional safety features such as secondary switching devices, muting function, stopping performance monitoring, etc.

3.1.18
presence sensing function
detection of the presence of a person, or a part of a person, while in a hazardous zone to enable prevention of hazardous situations such as unexpected/unintended start-up of the machine

3.1.19
protective measure
safety measure
measure intended to achieve risk reduction, implemented:

– by the designer (inherent design, safeguarding and complementary protective measures, information for use) and

– by the user (organization: safe working procedures, supervision, permit-to-work systems, additional safeguards; personal protective equipment; training)

[ISO 12100-1, 3.18]

3.1.20
reasonably foreseeable misuse
use of a machine in a way not intended by the manufacturer, but which can result from readily predictable human behaviour

[ISO/IEC Guide 51, 3.14 modified]

3.1.21
(protective equipment) response time
maximum time between the occurrence of the event leading to the actuation of the sensing device and the output signal switching device (OSSD) achieving the OFF-state

NOTE For pressure-sensitive protective devices, the event leading to the actuation of the sensing device is the application of a force within the effective sensing area

[IEC 61496-1, 3.21 modified]

3.1.22
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/or after a change in the means of start control of the machine

[IEC 61496-1, 3.22]

NOTE Modes of operation include inch, single stroke, automatic. Means of start control include foot switch, two-hand control, and single or double actuation of an electro-sensitive protective equipment (ESPE) sensing device.

3.1.23
risk
combination of the probability of occurrence of harm and the severity of that harm

[ISO 12100-1, 3.11]

3.1.24
risk assessment
overall process comprising a risk analysis and a risk evaluation

[ISO 12100-1, 3.13]

3.1.24.1
risk analysis
combination of the specification of the limits of the machine, hazard identification and risk estimation

[ISO 12100-1, 3.14]

3.1.24.2
risk evaluation
judgement, on the basis of risk analysis, of whether the risk reduction objectives have been achieved

[ISO 12100-1, 3.16]

3.1.24.3
risk estimation
defining likely severity of harm and probability of its occurrence

[ISO 12100-1, 3.15]

3.1.25
Safety-Related part of a Control System
SRCS
part or subpart(s) of a control system which responds to input signals and generate(s) safety-related output signals

NOTE 1 This also includes monitoring systems.

NOTE 2 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 Annex A of ISO 12100-1).

[IEC 61496-1, 3.23 modified]

3.1.26
start interlock
means which prevents an automatic machine start when the electrical supply to the protection equipment(s)) is switched on, or is interrupted and restored

[IEC 61496-1, 3.26 modified]

3.1.27
start test
manual or automatic test which is performed after the protective equipment has been switched on in order to test its complete safety-related control system before normal machine operation is initiated

[IEC 61946-1, 3.26 modified]

3.1.28
stopping performance monitor
SPM
monitoring means to determine whether or not the overall system stopping performance is within the preset limit(s)

[IEC 61496-1, 3.28]

3.1.29
trip function
detection of a person or a part of a person entering into a hazardous zone, to initiate a stop function (or otherwise ensure a safe condition)

3.1.30
unexpected (unintended) start-up
any start-up caused by

– a start command, which is the result of a failure in, or an external influence on, the control system;
– a start command generated by inopportune action on a start control or other parts of the machine as, for example, a sensor or a power control element;

– restoration of the power supply after an interruption;

– external/internal influences (gravity, wind, self-ignition in internal combustion engines) on parts of the machine

NOTE Automatic machine start-up during normal operation is not unintended, but can be considered to be unexpected from the point of view of the operator. Prevention of accidents in this case involves the use of safeguarding.

[ISO 12100-1, 3.29 modified]

3.1.31
Active Opto-electronic Protective Device
AOPD
device whose sensing function is performed by opto-electronic emitting and receiving elements detecting the interruption of optical radiations generated, within the device, by an opaque object present in the specified detection zone (or for a light beam device, on the axis of the light beam)

[IEC 61496-2, 3.201 modified]

3.1.32
Active Opto-electronic Protective Device responsive to Diffuse Reflection
AOPDDR
device, whose sensing function is performed by opto-electronic emitting and receiving elements, that detects the diffuse reflection of optical radiations generated within the device by an object present in a detection zone specified in two dimensions

[IEC 61496-3, 3.301]

3.1.33
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

[IEC 61496-1, 3.5]

3.1.34
pressure-sensitive mat (floor)
safety device that detects a person standing on it or who steps onto it comprising a sensor(s) that responds to the application of pressure, a control unit and one or more output signal switching device(s)

NOTE In a pressure-sensitive mat the effective sensing area is deformed locally when the sensor(s) is actuated. In a pressure-sensitive floor, the effective sensing area is moved as a whole when the sensor(s) is actuated.

[ISO 13856-1, 3.1 and 3.2]

3.1.35
External Device Monitoring
EDM
means by which the electro-sensitive protective equipment monitors the state of control devices which are external to the ESPE

[IEC 61496-1, 3.6]

3.1.36
Final Switching Device
FSD
component of the machine's safety-related control system that interrupts the circuit to the machine primary control element when the output signal switching device (OSSD) goes to the OFF-state

[IEC 61496-1, 3.10]

3.1.37
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

[IEC 61496-1, 3.14]

3.1.38
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

[IEC 61496-1, 3.15]

3.1.39
Output Signal Switching Device
OSSD
component of 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

[IEC 61496-1, 3.19 modified]

that part of the pressure-sensitive-mat or pressure-sensitive floor that, when the sensor or monitoring function means is actuated, responds by producing an OFF state

[ISO 13856-1, 3.6]

3.1.40
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)

3.2 Abbreviations

Abbreviation	Description
AGV	Automated Guided Vehicle
AOPD	Active Optoelectronic Protective Device
AOPDDR	Active Optoelectronic Protective Device responsive to Diffuse Reflection
ESPE	Electro-Sensitive Protective Equipment
EDM	External Device Monitoring
FSD	Final Switching Device
MPCE	Machine Primary Control Element

MSCE	Machine Secondary Control Element
OSSD	Output Signal Switching Device
PIPD	Passive Infrared Protective Device
PSPD	Pressure Sensitive Protective Device
SSD	Secondary Switching Device
SPM	Stopping Performance Monitor

4 Selection

4.1 Procedure (relationship with ISO 12100 (all parts))

This specification is an expansion of Step 2 “risk reduction by safeguarding” of the iterative 3-step method of risk reduction for the design of safe machinery, contained in Clause 5 of ISO 12100-1 (see Figure 2).

NOTE 1 This procedure presumes that a risk assessment has been carried out in accordance with ISO 14121, that measures have been taken to remove or reduce risks by inherently safe design and safeguarding by means of protective equipment is being considered.

The following characteristics shall be considered in the selection process when protective equipment and other protective measures as necessary are being evaluated as a risk reduction means:

– machine characteristics;
– environmental characteristics;
– human characteristics;
– protective equipment characteristics.

NOTE 2 These characteristics should be considered for both normal use and reasonably foreseeable misuse.

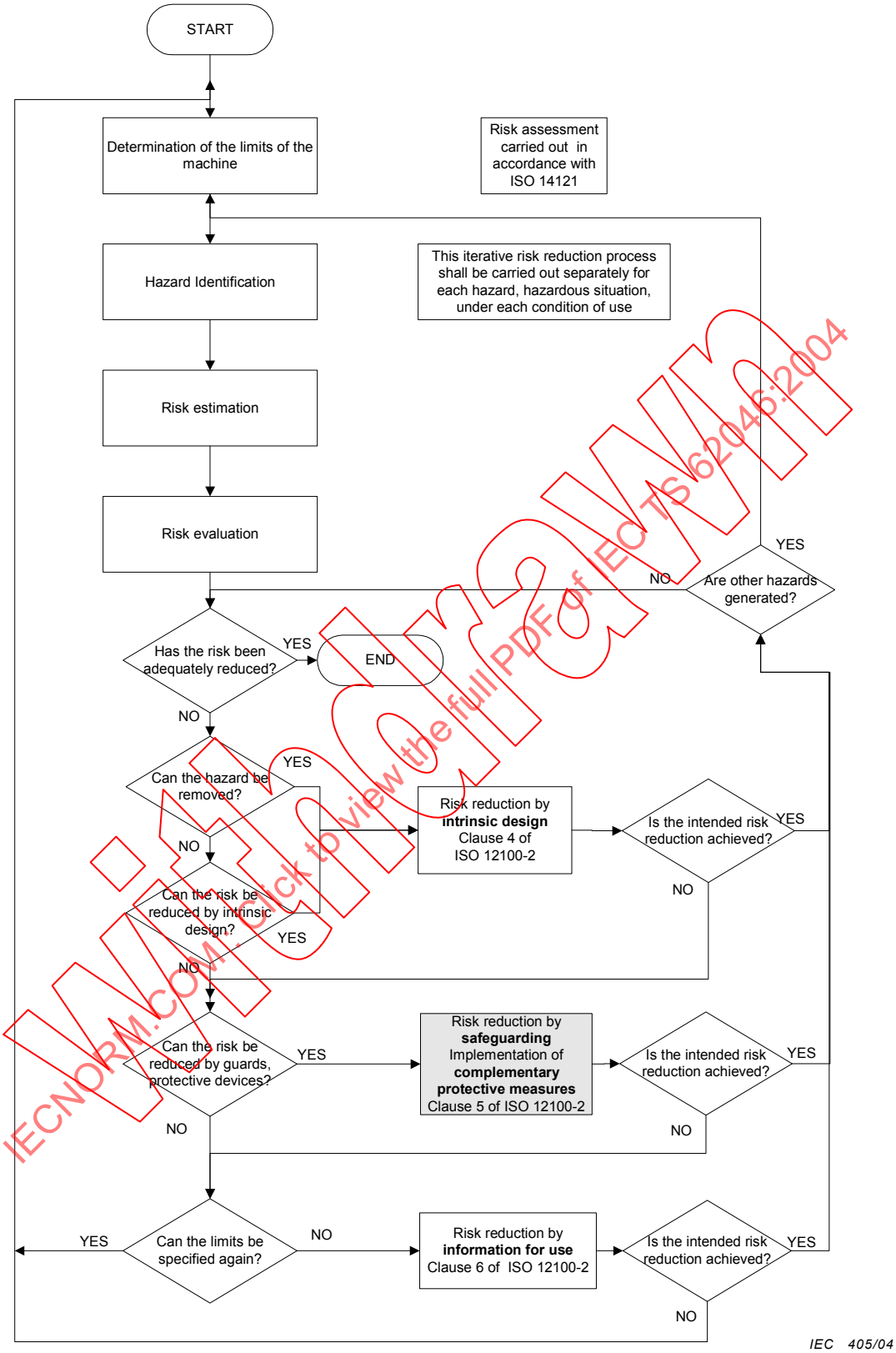

Figure 2 – Risk reduction process (Figure 2 of ISO 12100-1)

4.2 Machine characteristics

4.2.1 Suitability of protective equipment

Protective equipment as described in this specification can be selected when machine operation requires frequent access, personnel interaction with the machine, good visibility of the machine or process, or when it is difficult to provide fixed guarding. However, some characteristics of particular machines can preclude the use of protective equipment as the sole protective measure. Examples of these machine characteristics are:

a) possibility that the machinery will eject materials, swarf or component parts;

b) risk of injury from thermal or other radiation;

c) unacceptable noise levels;

d) an environment likely to adversely affect the function of the protective equipment (see 4.3); and

e) a material being processed that can influence the effectiveness of the protective measure.

Where such situations exist, additional safety measures can be required. For example, while a machine can require the use of an interlocked guard as a trip device, protective equipment may be used for presence sensing purposes inside the guard for prevention of unexpected start-up.

4.2.2 Suitability of protective equipment as a trip device

When protective equipment is used as a trip device (i.e. to detect the approach of a person or a part of a person), the machine shall stop reliably before it is possible to reach to the hazardous part(s) of the machine (for the minimum distances, see ISO 13855). However, some characteristics of particular machines can preclude the use of protective equipment as a trip device.

Protective equipment is unsuitable as a trip device or as a combined trip and presence sensing device:

a) when the stopping performance of the machine is unknown, inconsistent or inadequate due, for example, to
   - the reaction characteristics of the machinery control circuitry;
   - inadequate braking.

NOTE If a machine has variable speed, load or inertia, then the worst case should be taken into account.

b) the inability of the machine to stop part-way through a cycle due to:
   - the nature of the process, where stopping would create additional hazards;
   - the method of drive, for example positive key clutches or similar mechanisms for engaging the drive so arranged that once started, the machinery can only be stopped when the cycle is complete;
   - stored energy, for example in the form of stored pressure in pneumatic reservoirs or hydraulic accumulators.

4.3 Environmental characteristics

The functionality of protective equipment can be affected by environmental influences such as temperature, pollution, electromagnetic disturbance, radiation, etc. The degree to which environmental influences can affect the functionality of protective equipment can depend on the sensing technology used by the protective equipment. Careful evaluation of the expected environment and the sensing technology of the protective equipment should be performed during the selection process of protective equipment.

Specifiers (i.e. integrators, end users, machine builders) of protective equipment should ensure they have appropriate information to ensure that the protective equipment is suitable for the intended use under all reasonably foreseeable environments to which the protective equipment can be exposed over its entire operational lifecycle. This can take the form of information for safe use provided by the protective equipment manufacturer and/or information in the relevant product standard. Specifiers should request additional information if the intended operating environment contains particular environmental conditions that are not addressed by the information available.

Examples of environmental influences that should be considered include, but are not limited to (see also Table B.1)

- electromagnetic interference;
  - electrostatic discharge;
  - radio frequency interference, for example mobile telephones;
- vibration/shock;
- light interference;
  - ambient light;
  - infra-red, for example remote controls;
  - reflective surfaces;
  - other ESPEs that can emit interfering light;
- pollution;
  - water;
  - dust;
  - corrosive chemicals;
- temperature;
- humidity;
- weather conditions;
- radiation.

Additional and special requirements can apply to the protective equipment of machines that:

– are used in the open air (i.e. outside buildings or other protective structures);
– use, process, or produce potentially explosive material (for example paint or sawdust);
– are used in potentially explosive and/or flammable atmospheres;
– have special risks when producing or using certain materials;
– are used in mines.

The minimum values (for example operating range, immunity level, no failure to danger level, etc.) specified in the product standards are shown in Table B.1.

NOTE 1 Table B.1 provides guidance for the environmental selection criteria of protective equipment. It does not address the risk reduction contribution of the protective equipment.

NOTE 2 International product standards specify the information for safe use that is required to be provided by the supplier. Suppliers' promotional material is outside the scope of international product standards requirements and can contain insufficient information.

NOTE 3 Information specific to particular protective equipment is provided in Clause 6.

NOTE 4 Where an application is under consideration which uses a combination of protective equipment sensing techniques, the specifier should consider the relevant environmental characteristics for each protective equipment sensing technique. In addition, consideration should be given to possible cross-interference between sensing techniques.

4.4 Uses of protective equipment

4.4.1 General

A protective equipment may be used as a:

– trip device; or

– presence sensing device; or

– combination trip device and presence sensing device.

4.4.2 Trip device

4.4.2.1 Distance to the hazard

Where the protective equipment is used as a trip device, it shall be positioned at a sufficient distance from the specific machine hazard(s) to ensure the machine can stop or otherwise reach a safe condition before any part of an approaching person can reach the hazardous zone. The separation distance shall be maintained for all foreseeable directions of approach.

This distance shall take into account:

a) protective equipment detection capability in relation to human characteristics (see 4.5) including:
   – approach speed;
   – body part penetration/encroachment;
   – possibility of circumvention, and
b) the overall system stopping performance (see 3.1.14 and 4.4.2.2);
c) in the case of moving parts of machines (for example punch presses, surface grinders) or moving workpieces that can reduce the separation distance, the separation distance used shall apply from the maximum extension of the moving part towards the direction of approach.

The minimum distance of the trip device from the machine hazard (danger zone) shall be calculated by using the general formula below, which is taken from ISO 13855:

$$S = (K \times T) + C$$

where

S is the minimum distance, in millimetres, from the machine hazard (danger zone) to the detection point, line, plane or zone;

K is a parameter, in millimetres per second, derived from data on approach speeds of the body or parts of the body;

NOTE 1 ISO 13855 specifies the following values for K: walking speed; 1 600 mm/s, upper limbs; 2 000 mm/s.

NOTE 2 In some applications, it can be necessary to consider the relative speed of a person and a moving machine, for example, an AGV.

T is the overall system stopping performance in seconds (see 3.1.14 and 4.4.2.2);

C is an additional distance, in millimetres, based on intrusion of the body or part(s) of the body towards the machine hazard (danger zone) prior to actuation of the trip device (see 4.5.3).

NOTE 3 The following information is derived from ISO 13855:

Upper limbs: $C = 8(d - 14)$ where d is the detection capability and is ≤40 mm

$C = 850$ when the detection capability is >40 mm

Lower limbs: $C = 1\,200 - 0{,}4H$ where H is the height of the detection zone

$H \leq 15\,(d - 50)$ where d is the detection capability

Whole body: $C = 1\,200$ when the protective equipment is at floor level

$C = 1\,200 - 0{,}4H$ where H is the height of the detection zone at the point furthest from the hazard

The value of 1 200 mm used for C when considering ground-level trip devices includes an allowance for the first stride of a person stepping into the sensing zone of the trip device.

Where adjustment of the detection capability is available within the protective equipment, the detection capability used to calculate the separation distance shall be the actual setting of the detection capability that the application uses, or the maximum (worst case) value.

4.4.2.2 Stopping performance

The overall system stopping performance used for calculation of the separation distance shall include:

a) the response time of the protective equipment;

b) the maximum time under worst-case conditions, for example maximum load, maximum speed, etc. for the machine to stop or otherwise reach a safe condition after receiving the output signal from the protective equipment;

c) factors which can lead to a deterioration in performance of hydraulic, pneumatic, electrical and mechanical components, for example wear, ageing, temperature;

d) an allowance for the accumulation of such factors as variations in stopping performance, installation tolerances, time measurement accuracy, SPM accuracy, etc.

NOTE The total allowance for deterioration in performance and variation in stopping performance, etc. under c) and d), should not be less than 10 %.

4.4.2.3 Supplementary protective measures

Supplementary protective measures shall be provided as necessary to ensure that:

– the hazardous zone of the machine can be approached only through the detection zone of the trip device;

– unexpected start-up of the machine is not possible after a person has passed through the detection zone of the trip device to the hazardous zone of the machine.

These supplementary protective measures can include, for example:

– barriers to ensure that a person cannot approach the machine hazard from directions not protected by the protective equipment;

– provision of a restart interlock;

– provision of a presence sensing device;

– measures to prevent a person being present between the protective equipment and the hazardous zone.

If additional measures (for example obstacles) are used to prevent a person being present between the protective equipment and the hazardous zone, and the additional means is designed to be removed, it shall be interlocked with the safety-related control system so that hazardous machine movement is not possible if the additional means is not present.

It shall not be possible to create an additional hazardous situation after any person has passed through the detection zone of a protective equipment.

4.4.3 Presence sensing device

Where the protective equipment is used as a presence sensing device (i.e. it continually senses the presence of a person or part of a person in its detection zone), it signals the machine to remain in a non-hazardous state. Upon detection, the protective equipment OSSD(s) go to the OFF-state and remain in the OFF-state until the person or part of a person is outside the detection zone and the equipment is reset.

Where a protective equipment is used only as a presence sensing device, it shall be used in conjunction with other safety measures (for example an interlocking guard) as necessary to ensure that the machine is in a non-hazardous state before access is possible.

The detection zone of presence sensing devices shall be positioned and configured so that a person or part of a person will be detected throughout the hazardous zone.

Supplementary measures can be required to ensure that the detection zone cannot be circumvented, for example by remaining between the detection zone and the hazardous zone or by reaching into the hazardous zone. Examples of measures to prevent persons remaining between the detection zone and the hazardous zone are:

- use of sloping surfaces to prevent standing on machine frame/feet, and
- making inside surfaces of fencing flush.

4.4.4 Combination trip and presence sensing device

Where the protective equipment is used as a combination trip and presence sensing device, the requirements of 4.4.2 and 4.4.3 apply.

4.5 Human characteristics

4.5.1 General

The human characteristics that shall be taken into account when selecting protective equipment are:

– approach speed and direction;

– part of human anatomy (for example finger, hand, leg, whole body) to be detected;

– human interaction with the machine.

These factors will also determine the positioning of the protective equipment. See 5.1.

4.5.2 Approach speed (K)

Approach speeds are specified in ISO 13855 as 1 600 mm/s for normal walking and 2 000 mm/s for normal unhurried reaching with upper limbs. Depending on the application, it can be necessary to take into account higher speeds (for example use of bicycles in the vicinity, foreseeable reasons for running towards the machine, etc.).

In the case of applications on mobile machines (for example AGVs), a risk assessment should be performed to determine the appropriate approach speed to be used (i.e. where the risk of collision can be avoided), but as a minimum the speed of the mobile machine shall be used.

4.5.3 Penetration/encroachment factor (C)

A protective equipment designed to detect large parts of the body can allow small parts of the body to penetrate the detection zone. This will allow smaller parts of the body to approach the hazard without detection. When calculating the minimum distance, an additional distance (C) will have to be added to take this into account.

This additional distance (C) will vary between, for example, where the protective equipment is intended to detect whole bodies but an arm can remain undetected or where the protective equipment is intended to detect hands but fingers can remain undetected. (See ISO 13855.)

Encroachment is similar to penetration; however, instead of the body part penetrating the detection zone, the body is extended over the detection zone. For example; for a protective equipment with its sensing function positioned at waist height; the body configuration of bending at the waist with an outstretched arm should be considered. In the case of a ground-level trip device, the first stride length should be considered.

NOTE The value of 1 200 mm used in ISO 13855 for C when considering ground-level trip devices includes an allowance for the first stride of a person stepping into the detection zone of the trip device.

4.5.4 Ability to circumvent protective equipment

Protective equipment shall be installed taking into account all foreseeable directions of approach by persons. Additional protective measures can be necessary, for example fixed guards.

The protective equipment shall be selected and installed so as to minimize the possibility that persons can be exposed to a hazard due for example to

– reaching over, under or around detection zones;
– bending over detection zones;
– stepping over detection zones;
– straddling ground level detection zones;
– repositioning of the protective equipment sensing device;
– deflection of the beam(s) by using reflective surfaces that cause modification of the detection zone.

When it is foreseeable that a person can circumvent a presence sensing device by leaving the detection zone, for example by climbing on a machine, then a restart interlock should be considered.

4.6 Protective equipment characteristics

4.6.1 General

The range of protective equipment covered by this specification is Electro-Sensitive Protective Equipment (ESPE) in accordance with the relevant parts of IEC 61496 and pressure sensitive mats and floors manufactured to ISO 13856-1.

4.6.2 ESPEs

4.6.2.1 Types of ESPE

Sensing technologies used by ESPEs are:

– Active Opto-electronic Protective Devices (AOPD) consisting of light curtains and single or multiple light beam devices specified in IEC 61496-2;
– Active Opto-electronic Devices operating by Diffuse Reflection (AOPDDR) specified in IEC 61496-3;
– Passive Infra-Red Protective Devices (PIPD) specified in CLC/TS 50418.

4.6.2.2 AOPD

An AOPD uses the principle of interruption of one or more light beams between its emitter and its receiver. When an opaque object (for example a person or part of a person) interrupts a light beam, the receiver no longer receives the emitted light and an output signal is generated.

Through-beam devices can be used on opposing sides of a protected opening or the path can be configured by the use of mirrors to surround an area. Retro-reflective devices have the emitter and receiver in the same housing and use a retro-reflector to reflect the emitted light back to the receiver.

4.6.2.3 AOPDDR

An AOPDDR consists of an emitter and a receiver in the same housing.

The emitted light is reflected back from an object by diffuse reflection and the AOPDDR determines the location of the object. When an object is detected within the defined detection zone, an output signal is generated.

The detection zone can usually be configured into various shapes to take into account stationary obstacles and avoid the unwanted generation of an output signal that leads to an OFF-state of the AOPDDR. AOPDDRs can be used as combined trip and presence sensing devices to stop a machine when a person approaches it and to prevent the start-up of a machine while a person is in the hazardous zone.

4.6.2.4 PIPD

Passive infrared protective devices consist of a receiver that detects the difference between the thermal radiation from a person or part of a person and the thermal radiation from the background. They have a three-dimensional detection zone.

NOTE Product requirements for PIPDs are defined in CLC/TS 50418.

4.6.3 Pressure sensitive mats and floors

Pressure sensitive mats and floors are actuated by the weight of a person on the mat or floor. They generate a signal by the use of, for example, mechanical contacts, fibre-optic sensors, pneumatic sensors. See ISO 13856-1.

4.7 Machine control system functions associated with the application of protective equipment

4.7.1 General

Machine control system functions that can be required for the application of protective equipment include stopping performance monitoring (SPM), muting, blanking, single/double break actuation, start interlock and restart interlock.

4.7.2 Stopping performance monitoring (SPM)

The SPM provides signals to the protective equipment related to the time taken by, and/or the amount of travel of, the hazardous parts of the machine in coming to rest or reverting to a safe condition. The machine safety-related control system should prevent further operation when a signal from the SPM indicates that the overall system stopping time or distance has exceeded the preset limit(s).

NOTE Requirements for the characteristics of the stopping performance monitor are given in A.3 of IEC 61496-1.

4.7.3 Muting

4.7.3.1 General

Muting is a temporary automatic suspension of a safety function by the machine safety-related control system. It can be used to allow access by persons or by materials:

– during a non-hazardous portion of the machine cycle, or

– when safety is maintained by other means.

4.7.3.2 Mute dependent override function

Mute dependent override function allows a manual operation of the machine in order to clear material in the detection zone of the protective equipment. The override function is only available when at least one muting sensor is activated. See also 9.2.4 of IEC 60204-1.

4.7.4 Reinitiation of cyclic operation by the protective equipment

In some applications, in addition to its safeguarding function, the protective equipment can be used to reinitiate cyclic operation of a machine. The following modes of reinitiation are defined in IEC 61496-1:

– single break, where an actuation and de-actuation of the sensing device reinitiates machine operation;

– double break, where two consecutive actuations and de-actuations of the sensing device reinitiate machine operation.

4.7.5 Start interlock

A start interlock is a means of preventing automatic starting of hazardous operation of a machine when the power supply is switched on, or is interrupted and restored. The start interlock is reset by a deliberate human action.

NOTE Resetting of the start interlock may be performed by a manual start actuator or other manual means.

4.7.6 Restart interlock

A restart interlock is a means of preventing automatic restarting of hazardous machine operation after any of the following:

– actuation of a safeguarding function,

– a change in operating mode of the machine,

– a change in the means of start control of the machine.

NOTE 1 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 protective equipment (ESPE) sensing device.

NOTE 2 Resetting of the restart interlock is performed by a deliberate human action, for example operation of a manual actuator.

4.7.7 Blanking

4.7.7.1 General

Blanking is a function by which one or more area(s) of the detection zone of an ESPE are rendered inoperative, in order that parts of the workpiece or of the machine can project into the detection zone without actuating the protective equipment.

Blanking can be fixed or floating.

4.7.7.2 Fixed blanking

The locations of the blanked areas of the detection zone do not change during operation of the blanking function.

4.7.7.3 Floating blanking

The blanked area of the detection zone follows the location of a moving object during operation of the blanking function.

4.7.8 Provision of machine control functions

Those functions described in 4.7.2 to 4.7.7, and also means for monitoring the correct operation of devices external to the protective equipment (EDM) can either be provided as part of the protective equipment or can be built into the machine safety-related control system. When provided as part of an ESPE in accordance with IEC 61496-1 these functions will satisfy the relevant requirements of IEC 61496-1, Annex A. When supplied as part of the machine safety-related control system, see IEC 62061 and ISO 13849 (all parts) for requirements. See Clause 5 for application and interfacing requirements.

NOTE Care should be taken to ensure that the provision of additional switching outputs or functions external to the protective equipment (for example by external modules) does not reduce the performance of the protective equipment below that required for the risk reduction.

External Device Monitoring (EDM) can be used to detect failure of devices in the stopping/starting circuit, such as final switching devices and machine primary control elements (contactors, pneumatic valves, hydraulic valves).

5 General application requirements

5.1 Positioning and configuration of the protective equipment detection zone

The selection of the protective equipment, and its positioning and configuration with regard to the hazard is determined by the function to be performed, i.e. presence sensing function, trip function, or combined trip and presence sensing function (see 4.4).

The positioning and configuration of the protective equipment detection zone shall be determined taking into account:

– machine characteristics (see 4.2);
– environmental characteristics see 4.3);
– human characteristics (see 4.5);
– protective equipment characteristics (see 4.6);
– intended interaction of personnel.

Adjustments of the configuration of the protective equipment shall require the use of a key, keyword or tool.

5.2 Integration with the safety-related control system

The protective equipment shall be connected to the control system in accordance with the manufacturer's instructions and in the manner identified by the designer of the SRCS as meeting the risk reduction requirements specification.

NOTE The diagrams in Annex A show examples of interfacing of ESPEs to a machine.

5.3 Performance of protective equipment

5.3.1 General

The designer of the safety-related control system that performs the safety functions should establish the performance requirements for the protective equipment and select the protective equipment to achieve the required risk reduction. See ISO 13849 (all parts) and IEC 62061. Only persons with suitable experience and knowledge should select and install protective equipment.

5.3.2 Classification of protective equipment

5.3.2.1 General

ESPEs are classified in the relevant parts of IEC 61496. Pressure-sensitive mats and floors are specified in ISO 13856-1.

5.3.2.1.1 Types of ESPE

The relevant parts of IEC 61496 define 3 'types' of ESPE:

– Type 2 ESPEs (defined for AOPD) employ a periodic test to reveal failures to danger. The test can be initiated internally or externally;

– Type 3 ESPEs (defined for AOPDDR) are designed to not fail to danger due to a single fault but can fail to danger due to an accumulation of faults;

– Type 4 ESPEs (defined for AOPD) are designed to not fail to danger due to a single fault or an accumulation of faults.

NOTE 1 The types of the relevant parts of IEC 61496 contain additional requirements to the categories of ISO 13849 (all parts).

NOTE 2 There are additional differences in the performance requirements for Types 2, 3, and 4 ESPEs. See Table B.1.

5.3.2.1.2 Type 2 ESPE functional test duration

The duration of the functional test of a Type 2 ESPE shall be taken into account to ensure that it is not possible for a person to enter a hazardous zone during the functional test without being detected.

5.3.2.1.3 Classification of pressure-sensitive mats

Pressure-sensitive mats and floors are specified in ISO 13856-1. Pressure-sensitive mat systems are classified according to the categories of ISO 13849 (all parts). The mat is normally Category 1, the control module can be Category 1, 2, or 3.

Where the category of the mat system requires that a periodic functional test is performed, the duration of the functional test shall be taken into account to ensure that it is not possible for a person to enter a hazardous zone during the functional test without being detected.

NOTE The categories of ISO 13849 (all parts) are not equivalent to the types of the relevant parts of IEC 61496.

5.3.2.2 Relationship with the risk assessment

The sensing technology chosen, and the behaviour of the protective equipment in case of failure, shall be suitable for the risk reduction required by the application. See ISO 13849 (all parts), ISO 14121, and IEC 62061.

NOTE 1 The overall risk for each hazard depends on the severity of possible injury and the probability of occurrence of a hazardous condition. This probability of occurrence depends on the frequency of exposure, the duration of exposure, and the possibility of avoidance.

NOTE 2 The risk reduction contribution required from the protective equipment will depend on the overall risk, the degree of tolerable risk, and the level of risk reduction contribution by other protective measures. Reference to "low", "medium" or "high" in the following 3 paragraphs refers to the risk reduction contribution by the protective equipment.

Type 2 ESPEs and Category 2 mat systems can fail to danger as a result of a single fault between tests. For this reason, Type 2 ESPE or Category 2 mats are unlikely to be suitable for applications demanding a medium or high risk reduction.

Type 3 ESPEs and Category 3 mat systems have a greater resistance to failure to danger so can be suitable for applications demanding a medium risk reduction.

Type 4 ESPEs and Category 4 mat systems have the highest resistance to failure to danger so can be suitable for applications demanding a high risk reduction.

NOTE 3 ISO 13856-1 states that it is not possible for the majority of pressure-sensitive mats to meet all the requirements specified in Categories 2, 3 and 4, in particular when considering mechanical damage and long-term deterioration.

Where the safety performance of the protective equipment is dependent on testing, the frequency of testing should be greater than the frequency of exposure to the hazard.

5.4 Stopping performance monitoring

The provision of stopping performance monitoring shall be considered where stopping performance can be subject to deterioration (for example due to wear of friction brakes, pneumatic valves, hydraulic valves) leading to a hazardous situation (for example on cyclic hand-fed machines). Monitoring of the stopping performance should take place each time the machine stops, whether the stop is initiated by actuation of the protective equipment or by normal operation. When this cannot be achieved, the machine conditions during monitoring should be comparable to the worst-case conditions that can exist (for example similar inertia, speed, direction, load).

Stopping performance monitoring is not always necessary when:

– it has been established over an extended period that the stopping performance is consistent and not subject to deterioration;

  NOTE As a guide, unless it can be assured that under maximum load conditions that the overall system stopping performance will not deteriorate by more than 10 % over the life of the machine or over the period between thorough examinations by a competent person, stopping performance monitoring can be necessary.

– there is low frequency of demand on the stopping system (i.e. the machine stops infrequently);

– the risk assessment shows that there is no risk of serious injury even if the stopping performance deteriorates;

– the design and rating of the stopping system are adequate and an effective maintenance regime is implemented.

The stopping performance monitor shall be set so that a lock-out occurs when the overall system stopping performance exceeds that used for calculation of the separation distance.

5.5 Muting

5.5.1 General

Muting shall only be provided when it is necessary for the process being performed on the machine. It shall be ensured where practicable that a person cannot remain undetected in the hazardous zone when muting is terminated.

Depending on the risk assessment, an indicator to show when the muting function is active can be necessary. This indicator warns that the normal protective function is suspended.

The muting function shall be initiated and terminated automatically. This may be achieved by the use of appropriately selected and placed sensors or, in some cases, by signals from the safety-related control system. Incorrect signals, sequence, or timing of the muting sensors or signals shall not allow a mute condition.

NOTE When muting is performed externally to the protective equipment, the OSSDs of the protective equipment continue to operate during non-hazardous operation.

The level of performance of the circuit that performs the muting function shall not impair the level of performance of the protective equipment.

It shall not be possible to initiate the muting function when:

– the protective equipment OSSDs are in the OFF-state;
– the protective equipment is in the lock-out condition;
– the power supply is interrupted and restored.

Selection of the mode in which the muting function can be initiated shall require the use of a key, keyword, or tool.

Manual adjustment of the position or timing at which muting occurs shall require the use of a key, keyword, or tool.

When considering the application of the muting function, the following points shall be taken into account:

– initiation and termination of the muting function only at the appropriate times in the operating cycle;
– provision of alternative measures to prevent circumvention of the protective equipment;
– initiation and termination of the muting function by two or more independent muting sensors;
– use of timing and sequence control of the muting sensors to ensure correct muting operation;
– protection against mechanical damage, misalignment and foreseeable misuse;
– elimination of trapping and crushing hazards from the material being transported.

5.5.2 Muting to allow access by persons

Muting can be used to allow access by a person or part of a person:

– during a non-hazardous portion of the machine cycle (for example a non-hazardous opening stroke of a press), or
– when safety is maintained by other means (for example limitation of the working area of a robot),

in order, for example, to remove/replace a workpiece.

The inclusion of the muting function shall not reduce the performance of the relevant safety functions.

5.5.3 Muting to allow access by materials

Muting can be used to allow access by materials:

– during a non-hazardous portion of the machine cycle, or
– when safety is maintained by other means.

The following measures shall be considered:

– limiting muting to a fixed time that is only sufficient for the material to pass through the detection zone. When this time is exceeded, the muting function should be cancelled and all hazardous movements stopped. A manual control should allow the evacuation of the pallet (see 5.5.4). Restarting the installation shall only be possible by means of a deliberate action once safe operating conditions have been re-established;
– configuration of the muting sensors to distinguish a person from the material that is allowed to pass through the detection zone;

NOTE 1 The sensors should detect the load being conveyed, but not the pallet or the transport unit so that people are prevented from entering the zone by climbing onto the pallet or the transport unit.

NOTE 2 When the muting function is initiated by two photoelectric devices whose beams are crossed, the crossing point of the two light beams shall be situated behind the detection zone in the hazardous zone.

– installing the muting sensors sufficiently close to the ESPE so that it is not possible for persons to enter the hazardous zone undetected by immediately preceding or following the pallet or the transport system;

– designing the access to the hazardous zone so that it is not possible for persons to enter undetected while the muting function is active;

NOTE 3 Trapping and crushing hazards should be considered.

– provision of a mute dependent override function.

NOTE 4 Mute dependent override can require a separate restart interlock in some applications.

5.5.4 Mute dependent override

A manually operated, mute dependent override function can be necessary to allow blockages to be removed from the detection zone of the protective equipment. When a mute dependent override function is active, access to the hazardous zone is freely available. Safety shall then be maintained by other means.

The mute dependent override function shall:

- be activated either:
  - by the use of a spring return key operated switch or other secure hold-to-run device located so that it is not possible to enter the hazardous zone whilst maintaining the action on the hold-to-run device, or;
  - by the use of a momentary action pushbutton when the override function is automatically terminated after a correct muting signal sequence is identified and no access to the hazardous zone is possible during the override sequence;
- only be activated when at least one of the muting sensors is actuated;
- automatically terminate when all the muting sensors are de-actuated;
- automatically terminate after a pre-determined time limit has expired.

NOTE Care should be taken to prevent activation of the mute dependent override function due to a fault or inadvertent operation of the initiating device.

5.6 Reinitiation of cyclic operation by the protective equipment

The use of this function is restricted to applications using AOPDs.

Reinitiation of cyclic operation by the protective equipment shall only be considered for single-operator, hand-fed machines having repetitive, short cycle time operations.

The protective equipment shall not be the only means of initiating machine operation. Conventional machine start controls (for example pushbuttons, footpedals) and appropriate mode selection (guard-only, single actuation reinitiation, double actuation reinitiation) of the protective equipment using, for example a key operated switch shall be provided.

A start interlock and a restart interlock shall be provided.

To reduce the possibility of unexpected reinitiation, the detection capability of the protective equipment shall be a minimum of 30 mm for hand or 50 mm for leg or whole body detection.

It shall not be possible for persons to pass through the detection zone towards the hazardous zone and so cause reinitiation of machine operation. (See 4.4.2.)

NOTE 1 This can require the use of a presence sensing device.

Access to the hazardous zone shall not be possible without actuating the trip device.

NOTE 2 The possibility of actuation of the protective equipment by the workpiece should be considered.

When single actuation or double actuation is selected, the operation conditions shall be as follows:

The first cycle of the machine shall be initiated using a conventional start control. Further operations can then be actuated, depending on which actuation mode is selected, provided that:

– operation is reinitiated within a time commensurate with the cycle time of the machine, and
– when the reinitiation does not occur within the expected time, the protective equipment shall initiate a restart interlock. This time shall be as short as practicable, but shall not exceed 30 s;
– reinitiation will only occur when the duration of actuation of the protective equipment is not less than 100 ms;
– there is no actuation of the protective equipment during hazardous operation. Such actuation shall initiate a restart interlock requiring a conventional manual restart of the machine.

NOTE 3 Setting, maintenance and similar non-production operations should be performed in the guard-only mode.

NOTE 4 A test of the protective equipment function is advisable before starting to use reinitiation by single actuation or double actuation.

5.7 Start interlock

A start interlock shall be provided except where the risk assessment shows that the possibility of injury will not be reduced by a start interlock, for example when start interlock is already provided by other parts of the machine control system.

5.8 Restart interlock

A restart interlock shall be provided except where the risk assessment shows that the possibility of injury will not be reduced by a restart interlock, for example when it is not possible to be in the hazardous zone without detection.

NOTE 1 Particular care should be taken in the risk assessment for mobile machines, for example where it can be possible to fall or climb on the machine so that the protective device is not activated.

NOTE 2 Consideration should be given to the possibility of exiting and re-entering the hazardous zone without detection via the structure of the machine or by other foreseeable methods.

The provision of a restart interlock shall be considered where protective equipment is used for perimeter guarding.

5.9 Blanking

Blanking is only applicable to AOPDs. See 6.1.3.3.

6 Particular application requirements for specific protective equipment

NOTE Application examples are under consideration. See Annex C.

6.1 AOPDs

6.1.1 General

Light beam devices and light curtains depend for their activation on the interruption of one or more light beams. Reflective surfaces in the vicinity of the light beam(s) can reduce the ability of the AOPD to detect the intended object, as shown in Figure 3.

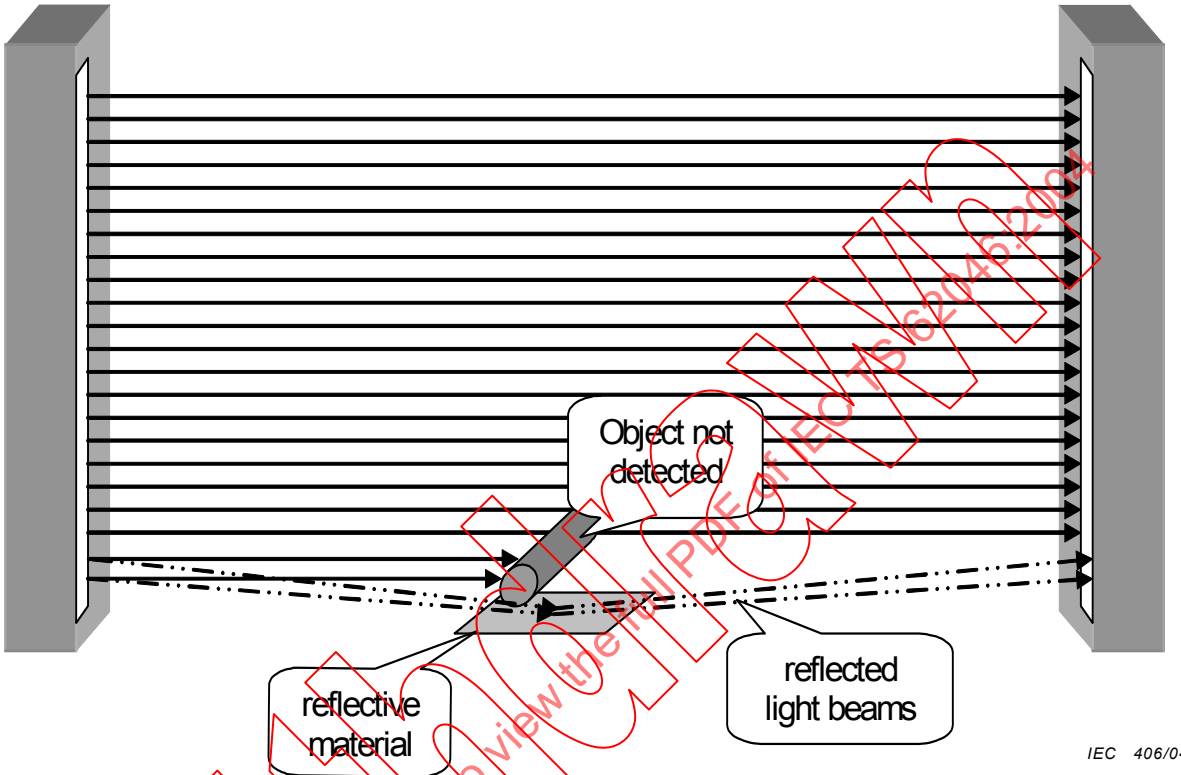

Figure 3 – Example of the effect of reflective surfaces

The AOPD manufacturer's guidance on avoiding the effect of reflective surfaces should be followed. To achieve this throughout the lifecycle of the machine, it is necessary to consider factors such as wearing of painted surfaces, changes of process material, beam divergence, etc.

6.1.2 Light beam device(s)

6.1.2.1 General

Light beam devices may consist of one or more beams. They are usually used as trip devices for whole body detection in perimeter guarding. A restart interlock or a presence-sensing device is usually necessary to prevent unexpected restarting. Because light beam devices usually have no specified detection capability but only detect interruption of the beam(s), they require careful positioning to ensure they are effective.

For the calculation of the separation distance, the response time of each beam with respect to the size and speed of the body part that will pass at each height shall be considered.

The positioning shall take into account the possibility of

– encroachment over or under the beams;
– undetected penetration of parts of the body, for example hands/arms;
– crawling under, climbing through or jumping over.

Table 1 gives recommended beam heights.

Table 1 – Beam heights for light beam devices

No. of beams	Heights above reference plane, for example floor mm
4	300, 600, 900, 1 200
3	300, 700, 1 100
2	400, 900

NOTE A greater number of beams reduces the possibility of encroachment, penetration or bypassing.

6.1.2.2 Cross-interference

Light beam devices can be subject to cross-interference between adjacent beams, or between adjacent devices. Measures shall be taken to reduce the risk of cross interference. Such measures can include:

– measures provided by the device manufacturer, for example different codes;
– secure installation and fastening;
– alternating the direction of adjacent beams;
– orientation of the beam direction;
– alignment of devices, use of light baffles and avoidance of reflective surfaces to prevent a transmitter energizing the receiver of a different light beam device.

6.1.3 Light curtains

6.1.3.1 General

Light curtains may be used as trip devices, presence sensing devices or combined devices.

They can be oriented in one of five formats (see Annex C):

– normal approach – where the detection zone is normal to the direction of approach;
– parallel approach – where the detection zone is parallel to the direction of approach;
– angled approach – where the detection zone is at some other angle to the direction of approach;
– combination – where the detection zone combines two or more of the above;
– fixed or rotating dual format – where the detection zone can be converted to a position either normal or parallel to the direction of approach. It shall not be possible to rotate the light curtain towards the dangerous parts if the separation distance cannot be maintained.

For separation distance calculations, where the angle of approach is greater than 30°, it is considered as a normal approach and where the angle of approach is less than 30°, it is considered as a parallel approach.

6.1.3.2 Cross-interference

Light curtains can be subject to cross-interference between adjacent devices. Measures shall be taken to reduce the risk of cross interference. Such measures can include:

– measures provided by the light curtain manufacturer, for example different codes;
– secure installation and fastening;
– alternating the beam direction of adjacent devices;
– alignment of devices, use of light baffles and avoidance of reflective surfaces to prevent a transmitter energizing the receiver of a different light curtain.

6.1.3.3 Blanking

To prevent possible misuse, blanking shall not be available except when necessary for the operation of the machine.

Blanking can be used to allow the presence of parts of the workpiece or of the machine in the detection zone when safety is maintained by other measures, for example:

– the blanked area is continuously and entirely occupied by material, fixtures, fixed guards or removable interlocking guards (see Figure 4); or

– the separation distance is increased in accordance with ISO 13855 due to the modified detection capability. Information on the modified detection capability is needed from the AOPD manufacturer.

The installation shall be such as to minimize the possibility of loss of detection capability caused by reflective surfaces in the blanked zone (see also 6.1.1).

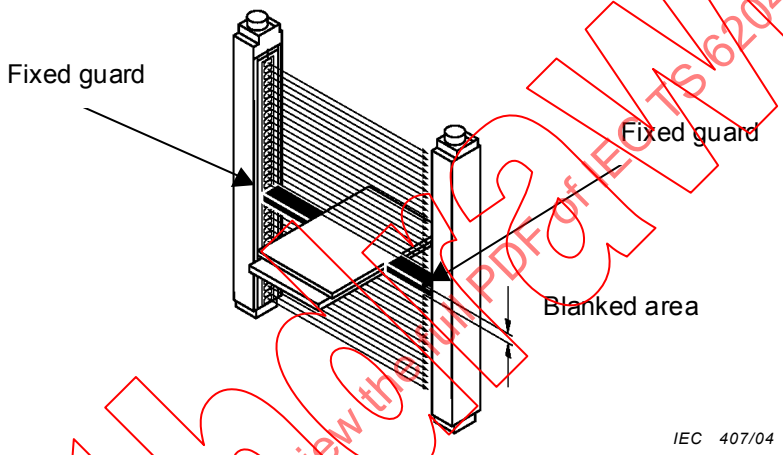

Figure 4 – Example of use of blanking

6.2 AOPDDRs

These devices are used both in static and mobile applications.

IEC 61496-3 specifies that AOPDDRs are Type 3 ESPEs.

When configuring the detection zone of an AOPDDR, care shall be taken to ensure that:

– the detection zone fully covers the hazardous zone;

– no shadow zones are created behind objects, that can allow persons to approach closer to the danger zone than the calculated minimum separation distance;

– the AOPDDR manufacturer's instructions regarding nearby reflective surfaces have been taken into account.

In mobile applications, there shall be no trapping or crushing hazards at the edge of the overall detection zone. In mobile applications, several additional factors shall be considered in order to maintain an adequate separation distance, for example:

– difficult environmental conditions;

– the physical environment (for example reflecting properties) changes as a result of the movement;

– the stopping system performance and possible deterioration;

– the hazardous zone moves together with the machine (the primary hazard is the impact or crushing caused by the moving machine);

- the direction of approach of an object can vary, for example due to changes in direction of movement of the vehicle;
- the direction of approach of a person can vary due to changes in direction of movement of the vehicle and/or the person;
- if the machine moves over uneven surfaces the effective height of the detection zone can vary from its intended position;
- different speeds of movement shall be considered, for example:
  - speed of the machine (and AOPDDR);
  - relative speed of the machine and the object to be detected, for example
    - person,
    - bicycles,
    - forklift trucks,
    - other vehicles.

6.3 PIPDs

6.3.1 General

Only PIPDs designed for safety-related applications should be used as protective equipment. PIPDs use a relatively new technology and are described in CLC/TS 50418. Until a product standard for PIPDs is published, care should be taken in the selection and use of these devices. It is recommended to consult the PIPD manufacturer and other sources of information about their application.

PIPDs can detect the difference between a person and an inanimate object, provided that the thermal radiation from the person is different from that of the background. Some PIPDs can only detect moving persons. Such PIPDs shall not be used as presence sensing devices.

PIPDs detect thermal radiation, and spurious tripping can be caused by the thermal radiation from objects other than persons, for example hot process material, space heaters.

The calculated separation distance shall be increased by a supplementary distance representing the intrusion towards the hazardous area before the actuation of the sensing element of the PIPD. This distance is an inherent characteristic of the PIPD, specified by the manufacturer of the PIPD.

6.3.2 Mobile applications

When setting the detection zone, the values of the tolerance zone and the required extension to the detection zone shall be added to the separation distance S.

If it is possible for a person to stand between the front of the vehicle and the detection zone when the vehicle is at rest, then other safety measures shall be provided to prevent injury when the vehicle starts.

A PIPD is not a means of prevention of collision between vehicles.

6.4 Pressure-sensitive mats and floors

6.4.1 Pressure sensitive floors

Pressure sensitive floors consist of moving rigid plates that actuate position sensors, for example limit switches. Pressure sensitive floors shall not be used when deformation of the plate or foreign objects under the plate can render the device unable to detect a person stepping on it.

6.4.2 Pressure sensitive mats

6.4.2.1 Selection criteria

Factors that shall be taken into account when selecting a pressure sensitive mat as a protective device include the construction of the mat, the environmental conditions, the behaviour in the presence of faults (for example category in accordance with ISO 13849 (all parts)) and the operational conditions (for example the possibility of circumvention).

6.4.2.2 Mat construction

The safety integrity of the mat depends on its reliability and fault resistance, therefore deterioration of performance (for example due to slow ingress of dust, liquids or gases) can be undetected.

Some types of pressure sensitive mat cannot detect a person already standing on the mat when the power is switched on, or is interrupted and restored. These mats shall only be considered for use as trip devices and shall not be used as presence-sensing devices.

Sensitivity can be adversely affected by static loading (for example process material resting on the surface of the mat).

Cable entry points to mats shall be such that:

– there are no tripping hazards due to connecting cables;

– any dead zone adjacent to the entry point of connecting cables is not in the area intended for the detection of persons;

– the cable is not in a position where mechanical damage is likely.

When the difference in height of adjacent horizontal surfaces is 4 mm or more, a ground-flush installation or a small ramp shall be used. If a ramp is used, its slope shall not exceed 20°.

When using a combination of mats, dead areas in the detection zone shall be avoided. For guidance, see Figures B.1 and B.2 of ISO 13856-1.

When a mat system is used as a trip device, the separation distance of the mat edge from the hazard shall take into account the worst case conditions, for example the length of a person's first stride onto the mat from any possible direction of approach.

The dimensions of the mat shall be selected to prevent a person stepping over or jumping over the mat.

6.4.2.3 Environmental conditions

Environmental conditions that shall be taken into account when considering the selection of a pressure sensitive mat as a protective device include:

– surface contamination of the mat giving rise to a slipping hazard;

– irregularities of the mat mounting surface that can impair the sensitivity of the mat;

– wheeled traffic on the mat (forklift trucks or other heavy vehicles can cause damage to the mat especially when braking, accelerating or turning);

– chemicals (for example oils, solvents, cutting fluids) that can cause changes in the properties of the mat, such as swelling or hardening of the material, resulting in a change of sensitivity;

NOTE 1 The manufacturer of the mat usually gives information in the data sheet about the permissible chemical environment. Special surface coverings may also be available.

– effects of temperature. The minimum temperature range required in ISO 13856-1 is +5 °C to +40 °C. Cold environments can make the material of the mat stiff and hot environments can make the material soft, thus changing the sensitivity of the mat;

– foreign bodies such as welding splatter, swarf or sand can wear or damage the mat. Additional protective coverings specified by the manufacturer may be used.

NOTE 2 Other additional coverings can impair the sensitivity of the mat.

6.4.2.4 Frequent actuation

The safety integrity of the mat depends on its reliability and fault resistance. The mat shall be chosen to withstand the expected number of actuations and frequency of operation.

6.4.2.5 Infrequent actuation

Where mats are infrequently actuated, it will be necessary for the user to perform periodic tests to verify the mat's integrity.

6.4.2.6 Physical properties of the mat

The physical properties of the mat can cause problems in some applications. At least the following points shall be taken into account:

– permanent deformation or hardening of the mat surface can form "bridges" over parts of the sensing field;

– in most designs there is an internal air gap inside the mat. Ingress of material (small or large particles), vermin, corrosive gases or fluid can cause the mat to fail. Small holes might not be detected during maintenance.

6.4.2.7 Mounting surface

Irregularities of the floor or other mounting surface can impair the function of the mat and shall therefore be within the limits stated by the manufacturer of the mat.

The mat shall be securely fixed in place to prevent accidental or intended movement of the mat and thus leaving unprotected access to the hazardous zone.

7 Commissioning

NOTE This Clause deals only with those aspects of commissioning specific to the protective equipment.

Commissioning shall include as a minimum, verification that:

a) the specified protective equipment has been installed;

b) the protective equipment has been selected, installed and configured in accordance with the requirements of the application and the information for use provided by the supplier:

   – access to, or presence anywhere in, the hazardous zone protected by the equipment is not possible without actuating the protective equipment;

   – adjustments of the protective equipment that can result in an unsafe condition require the use of a key, keyword or tool;

   – the separation distance complies with the recommendations of this specification for orientation, detection capability, speeds of approach, direction of approach, penetration/encroachment toward the hazard;

c) when relevant, the overall system stopping performance shall be verified by a test;

d) the protective equipment is correctly interfaced with the control system;
   - all inputs and outputs of the protective equipment shall be verified for proper connection (for example type and size of wire, screened cables when required, correct terminations) and function, including the operation of the start and restart interlocks where specified and provided by the machine control system;
   - the protective equipment is operative in all relevant modes of operation of the machine;
   - when it is possible to switch off the protective equipment, hazardous machine operation ceases within the specified response time;

e) OSSDs and, where fitted, secondary switching devices are rated adequately for their duty;

f) where functions such as muting, blanking, and/or initiation of cyclic operation are provided, safety is maintained while each function is active.

8 Information for safe use

The integrator shall provide all necessary information for operation and maintenance.

This information shall at least contain:

— general description of the protective equipment safety system;

— identification of safety related parts;

— wiring schematics;

NOTE This requirement is not intended to include the internal circuit diagram of the protective equipment.

— overview (block) diagrams;

— where relevant, information on the parameters of muting systems, for example the position of muting sensors;

— instructions for use, including guidance for periodic inspection;

— identification of residual risks;

— maintenance instructions;

— advice on periodic inspection and testing;

— environmental limits;

— where relevant, the information for use provided by the protective equipment manufacturer;

— where relevant, details of additional mechanical protection, for example protection against overreaching.

Annex A
(informative)

Examples of interfacing ESPEs to a machine

A.1 Integration of protective equipment with the output of a machine control system

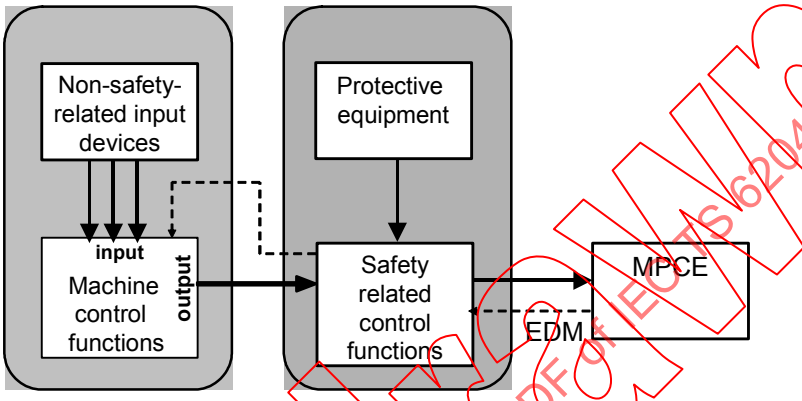

Figure A.1 – Integration with the control system

Figure A.1 shows the principle of integration of protective equipment with a safety-related control system. In this example, the machine's operational control system is not safety-related, so the operation of the protective equipment and other safety-related functions on the MPCE is independent of the operational functions of the machine control system.

A.2 Integration with a safety-related control system

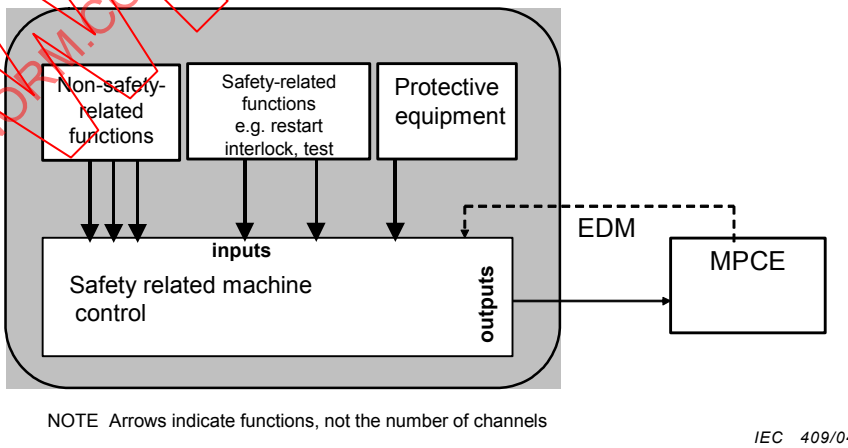

Figure A.2 – Integration with a safety-related control system

Figure A.2 shows the principle of integration of protective equipment when the machine control system is safety-related. In this example the machine's functions, including both operational control functions and safety-related functions, are performed by the safety-related system.

Annex B
(informative)

Environmental parameters of protective equipment product standards

The values (for example operating range, immunity level, no failure to danger level, etc.) shown in Table B.1 are the requirements as specified in the product standards.

NOTE Users of this specification should refer to the manufacturer's literature before the final selection of protective equipment.

Table B.1 – List of environmental considerations to assist the selection of a protective equipment

Environmental consideration		Protective device				
		AOPD		AOPDDR	PIPD	Pressure sensitive mats and floors
Product standard		IEC 61496-2	IEC 61496-2	IEC 61496-3	CLC/TS 50418	ISO 13856-1
		Type 4	Type 2	Type 3	Type 2	
Radio frequency signal lines <10m	Normal operation	3 V/m level 2	3 V/m level 2	3 V/m level 2	3 V/m level 2	NR
	No failure to danger	10 V/m level 3	NR	10 V/m level 3	NR	NR
Radio frequency signal lines >10m	Normal operation	10 V/m level 3	10 V/m level 3	10 V/m level 3	10 V/m level 3	NR
	No failure to danger	30 V/m level X	NR	30 V/m level X	NR	NR
Electrostatic	Normal operation	8 kV air	8 kV air	8 kV air	8 kV air	Level 3
	No failure to danger	15 kV air	NR	15 kV Air	NR	NR
Electromagnetic	Normal operation	10 V/m level 3	10 V/m level 3	10 V/m level 3	10 V/m level 3	Level 3
	No failure to danger	30 V/m level X	NR	30 V/m level X	NR	NR
Surge	Normal operation	Level 2 DC/level 3 AC	Level 2 DC/level 3 AC	Level 2 DC/level 3 AC	Level 2 DC/level 3 AC	NR
	No failure to danger	Level 3 DC/level 4 AC	NR	Level 3 DC/level 4 AC	NR	NR
Burst	Normal operation	Level 2 DC/level 3 AC	Level 2 DC/level 3 AC	Level 2 DC/level 3 AC	Level 2 DC/level 3 AC	Level 3
	No failure to danger	Level 3 DC/level 4 AC	NR	Level 3 DC/level 4 AC	NR	NR
Power supply interruptions	Normal operation	100 % at 10 ms	100 % at 10 ms	100 % at 10 ms	100 % at 10 ms	3 ms
	Normal operation	50 % at 20 ms	50 % at 20 ms	50 % at 20 ms	50 % at 20 ms	20 % at 20 ms
	No failure to danger	50 % at 500 ms	50 % at 500 ms	50 % at 500 ms	50 % at 500 ms	20 % at 20 ms
Power supply variation	Normal operation	85 % to 110 % VAC	85 % to 110 % VAC	85 % to 110 % VAC	85 % to 110 % VAC	90 % to 110 % VAC
	Normal operation	85 % to 115 % VDC	85 % to 115 % VDC	85 % to 115 % VDC	85 % to 115 % VDC	85 % to 115 % VDC
	No failure to danger	Nominal to 0 in 10s	Nominal to 0 in 10s	Nominal to 0 in 10s	Nominal to 0 in 10s	NR
Power supply (AC) frequency	Normal operation	± 1 % continuously	± 1 % continuously	± 1 % continuously	± 1 % continuously	± 1 % continuously
	Normal operation	± 2 % short time	± 2 % short time	± 2 % short time	± 2 % short time	± 2 % short time
Temperature range	Normal operation	(0 to 50) °C	(0 to 50) °C	(0 to 50) °C	(0 to 50) °C	(5 to 40) °C
Changing temperature	No failure to danger	(0 to 50) °C at 0,3 °C/min	(0 to 50) °C at 0,3 °C/min	(0 to 50) °C at 0,3 °C/min	(0 to 50) °C at 0,3 °C/min	0,8 °C/min
Humidity	Normal operation	95 % non-condensing	95 % non-condensing	95 % non-condensing	95 % non-condensing	IEC 60068-2-3 test
	No failure to danger	95 % at (0 to 50) °C	95 % at (0 to 50) °C	70 % at 25 °C	95 % at (0 to 50) °C	NR

Environmental consideration		Protective device				
		AOPD		AOPDDR	PIPD	Pressure sensitive mats and floors
Product standard		IEC 61496-2	IEC 61496-2	IEC 61496-3	CLC/TS 50418	ISO 13856-1
		Type 4	Type 2	Type 3	Type 2	
Vibration	Normal operation	(10 to 55) Hz at 1 octave/min 0,35 amplitude	(10 to 55) Hz at 1 octave/min 0,35 amplitude	(10 to 55) Hz at 1 octave/min 0,35 amplitude	(10 to 55) Hz at 1 octave/min 0,35 amplitude	(10 to 55) Hz at 1 octave/min 0,15 mm amplitude (control unit only)
	No failure to danger	NA	NA	NR	NR	NR
Bump	Normal operation	10 g at 16 ms pulse	10 g at 16 ms pulse	10 g at 16 ms pulse	10 g at 16 ms pulse	NR
	No failure to danger	NA	NA	NR	NR	NR
Impact	Normal operation	NR	NR	1,0 J energy	NR	NR
	No failure to danger	NR	NR	2,0 J energy	NR	NR
Ingress protection	Normal	IP54	IP54	IP65	IP54	IP54
	Minimum	IP20	IP20	IP65	IP20	IP54
Contaminants (fallen) for example fluids, corrosives, debris, etc.	Normal operation	NA	NA	30 % signal attenuation	NR	NR
	No failure to danger	NA	NA	NR	30 % signal attenuation	NR
Airborne particles for example dust, oil mist, steam, smoke, rain, snow	Normal operation	NR	NR	18 % to 22 % signal attenuation	NR	NA
	No failure to danger	NA	NA	NR	30 % signal attenuation	NA
Background changes	Normal operation	NA	NA	NR	60 °C object at 0,9 emissivity outside detection zone	NA
	No failure to danger	NA	NA	NR	60 °C object at 0,9 emissivity inside detection zone	NA
Distance to reflective surfaces	No optical bypass	<3 m range, 131 mm >3 m range, range x tan2,5°	<3 m range, 262 mm >3 m range, range x tan5°	No reflective surfaces in the detection zone	No reflective surfaces in the detection zone	NA
Misalignment	Normal operation	NA	NA	NR	NR	NA
	No failure to danger	>2,5°	>5°	NR	NR	NA