



Safety of machinery

Part 2802: Application of protective equipment to detect the presence of persons



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 - Australian Manufacturing Workers Union
 - Australian Packaging and Processing Machinery Association
 - Department of Industry, Skills and Regional Development, NSW
 - Engineers Australia
 - Human Factors and Ergonomics Society of Australia
 - Institute of Instrumentation, Control and Automation, Australia
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Australian Standard®

Safety of machinery

Part 2802: Application of protective equipment to detect the presence of persons

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PREFACE

This Standard was prepared by the Standards Australia Committee SF-041. Safety of Machinery.

The objective of this Standard is to specify the 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 Standard is identical with, and has been reproduced from IEC TS 62046:2008, *Safety of machinery—Application of protective equipment to detect the presence of persons*.

As this Standard is reproduced from an International Technical Specification, the following applies:

- (a) In the source text ‘this Technical Specification’ should read ‘this Australian Standard’.
- (b) A full point substitutes for a comma when referring to a decimal marker.

None of the normative references in the source document have been adopted as Australian or Australian/New Zealand Standards.

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

This second edition cancels and replaces the first edition issued in 2004. This second edition constitutes a general technical revision of the first edition, and includes further examples of interfacing and muting techniques.

The text of this technical specification is based on the following documents:

Enquiry draft	Report on voting
44/534/DTS	44/552B/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 the maintenance result 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

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- withdrawn,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

INTRODUCTION

This Technical Specification provides information on 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.

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.

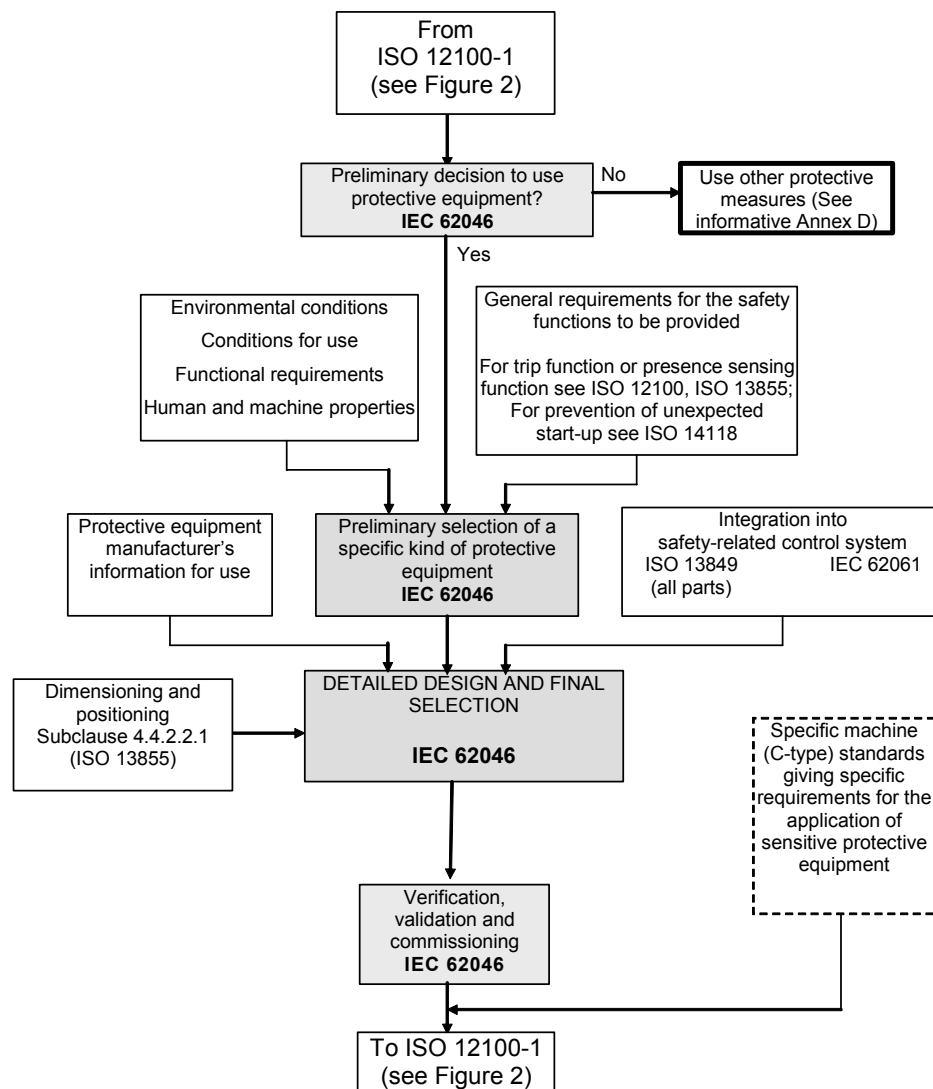


Figure 1 – Relationship of this Technical Specification to other standards

(see also Figure 2)

AUSTRALIAN STANDARD

Safety of machinery**Part 2802:****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 standard 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.

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 (all parts), *Safety of Machinery – Safety-related parts of control systems*

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 14121 (all parts), *Safety of machinery – Risk assessment*

3 Terms, definitions and abbreviations

3.1 Terms and definitions

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

3.1.1

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]

3.1.2

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]

3.1.3

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)

[IEC 61496-1, 3.1]

3.1.4

detection capability

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

[IEC 61496-1, 3.3, modified]

3.1.5

detection zone

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

[IEC 61496-1, 3.4]

NOTE ISO 13856-1 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.

3.1.6

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]

3.1.7**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.

[ISO 13856-1, modified]

3.1.8**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

[IEC 61496-1, 3.6]

3.1.9**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]

3.1.10**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]

3.1.11**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 IEC 61496-1, whereas the French term "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 3.1.9) are often used synonymously.

3.1.12**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

[IEC 61496-1, 3.10]

3.1.13**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.

3.1.14**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]

3.1.15**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).

3.1.16**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

3.1.17**light beam device**

either a single light beam device or a multiple light beam device

- **single light beam device:** active opto-electronic protective device (AOPD) comprising one emitting element and one receiving element, where a detection zone is not specified by the supplier
- **multiple light beam device:** active opto-electronic protective device (AOPD) comprising multiple emitting elements and corresponding receiving elements, and where a detection zone is not specified by the supplier

[IEC 61496-2, 3.205, modified]

3.1.18**light curtain**

active opto-electronic protective device (AOPD) comprising an integrated assembly of one or more emitting element(s) and one or more receiving element(s) forming a detection zone with a detection capability specified by the supplier

NOTE A light curtain with a large detection capability is sometimes referred to as a light grid.

[IEC 61496-2, 3.206, modified]

3.1.19**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]

3.1.20

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]

3.1.21

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]

3.1.22

mute dependent override function

function that allows manual operation of the machine when the detection zone of the ESPE is interrupted to allow the evacuation of the pallet or of the material from the muting area

NOTE This function can be necessary in case of a fault in the muting sequence(s) or when a blockage occurs in the transport system or when a pallet is already present in front of the muting sensors at "power on".

3.1.23

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.

3.1.24

muting area

area between the detection zones of the first and last muting sensors, including the detection zone of the ESPE

3.1.25

muting sensor

device used to initiate and/or terminate muting

3.1.26

OFF-state

state in which the output circuit is interrupted and does not permit the flow of current

[IEC 61496-1, 3.17]

3.1.27

ON-state

state in which the output circuit is complete and permits the flow of current

[IEC 61496-1, 3.18]

3.1.28

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

[IEC 61496-1, 3.19]

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]

3.1.29

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, modified]

3.1.30

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

3.1.31

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.

3.1.32

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.

3.1.33

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

3.1.34**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**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]

3.1.36**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]

3.1.37**(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]

3.1.38**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.

3.1.39**risk**

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

[ISO 12100-1, 3.11]

3.1.40**risk assessment**

overall process comprising a risk analysis and a risk evaluation

[ISO 12100-1, 3.13]

3.1.41

safety-related part of a control system

SRCS

part or subpart(s) of a control system which respond(s) 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]

3.1.42

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)

[IEC 61496-1, 3.24]

3.1.43

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]

3.1.44

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]

3.1.45

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, 3.27]

3.1.46

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)

3.1.47

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]

3.2 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 of protective measures

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

This procedure 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.

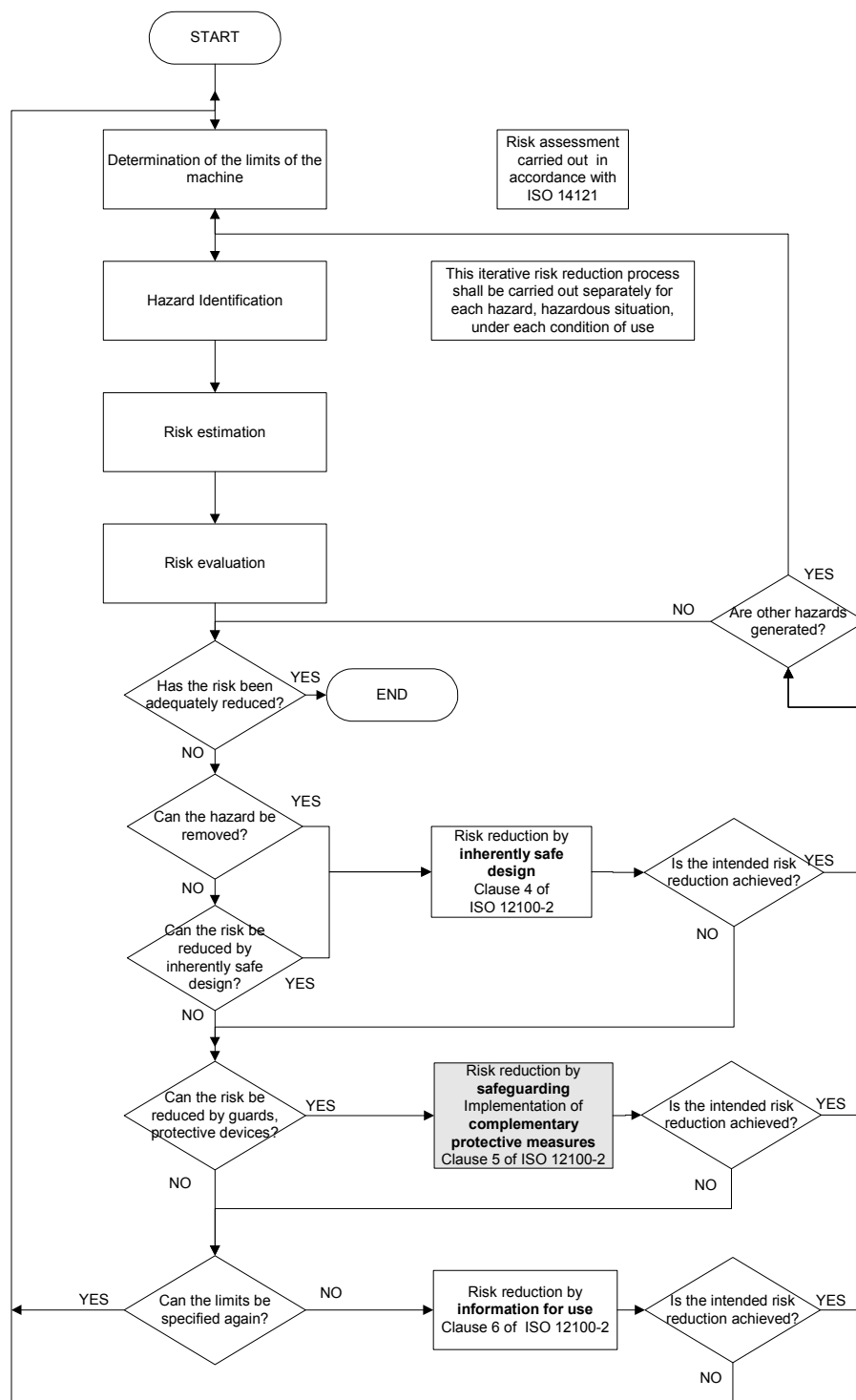


Figure 2 – Risk reduction process (simplified version of Figure 2 of ISO 12100-1)

4.2 Machine characteristics

4.2.1 Suitability of protective equipment

Protective equipment as described in this specification is typically 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 or other safety measures can be required. An example of an additional measure that can be applied in these circumstances is local guards to prevent ejection.

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 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.

- the inability of the machine to stop part-way through a cycle due, for example, 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.

When protective equipment is unsuitable for a particular application, other protective measures such as mechanical guards can be necessary; see ISO 12100 (all parts) and informative Annex D.

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 hazard zone. The minimum 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 3.1.29 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.

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 In general 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 Calculation of the minimum separation distance

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 3.1.29 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 (see also Annex C):

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

When the calculated value of C is less than zero, a value of $C =$ zero is used.

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 or response time is available, the parameters used to calculate the minimum separation distance shall be the actual settings that the application uses, or where those settings are not protected against unauthorised change, the maximum (worst case) values.

4.4.2.4 Restricted separation distance

In some applications, calculation of the minimum separation distance can give a result that cannot be accommodated in practice, i.e., the calculated minimum separation distance is too great. In such cases the following may be considered:

- Selection of protective equipment with a better detection capability or faster response time;
- Reduction of the overall stopping time, e.g. by improved braking, reduced speed or inertia;
- Reduction of the overall system response time, e.g. using hard-wired connections instead of a fieldbus, using components with a faster response time, reducing the number of interposing devices;
- Using a different configuration of approach to reduce intrusion towards the hazard, e.g. raising ground-level trip devices so that the first stride allowance is reduced.

4.4.2.5 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.

If it is possible for a person to pass through a trip device and, when behaving in a foreseeable manner, attain a position that is hidden from the location of the reset control, supplementary protective measures (for example, time-limited additional reset control inside the safeguarded area, presence sensing device, trapped-key system), shall be provided to prevent resetting the restart interlock when a person or part of a person is inside the safeguarded area.

4.4.3 Presence sensing device

Where the protective equipment is used to provide a presence sensing function (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 hazard 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 hazard zone. Examples of measures to prevent persons remaining between the detection zone and the hazard zone are:

- use of sloping surfaces to prevent standing on machine frame/feet, and
- making inside surfaces of fencing free of protrusions that can be climbed on.

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, including foreseeable misuse (see 5.3.c) of ISO 12100-1).

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 shall 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 used shall be the greater of the speed of the mobile machine or 1,6 m/s.

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 and additional protective measures, as necessary, shall be selected and installed to prevent access to the hazard zone from any direction. Additional protective measures, can include for example fixed or interlocking guards or screens or additional protective equipment.

The protective equipment shall be selected and installed with other protective measures 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 the detection zone of a presence sensing device, for example by climbing on a machine, then additional protective measures shall be provided, for example, a restart interlock or a manual reset.

4.6 Protective equipment characteristics

4.6.1 ESPEs

4.6.1.1 Types of ESPEs

This standard considers ESPEs using the following sensing technologies:

- 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.

4.6.1.2 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. This principle is illustrated in Figure 3.

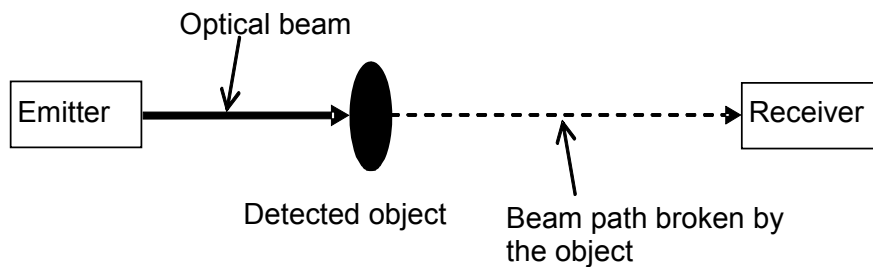


Figure 3 – Detection principle of through-beam AOPD

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 as shown in Figure 4.

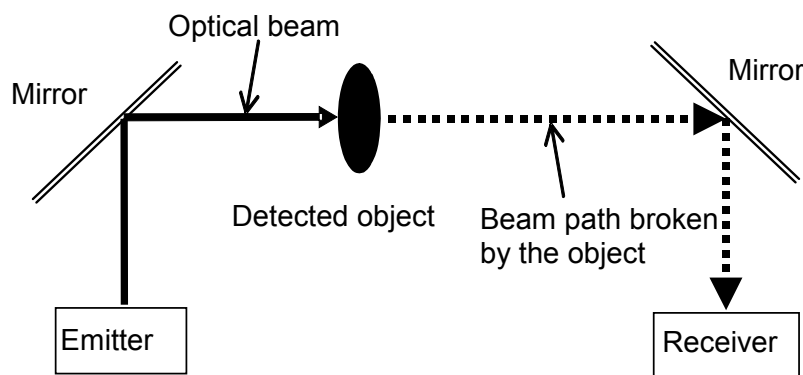


Figure 4 – Through-beam AOPD using mirrors

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 as shown in Figure 5.

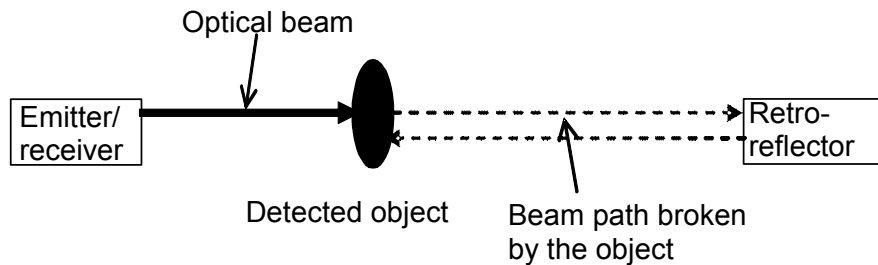


Figure 5 – Retro-reflective AOPD

4.6.1.3 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. This principle is illustrated in Figure 6.

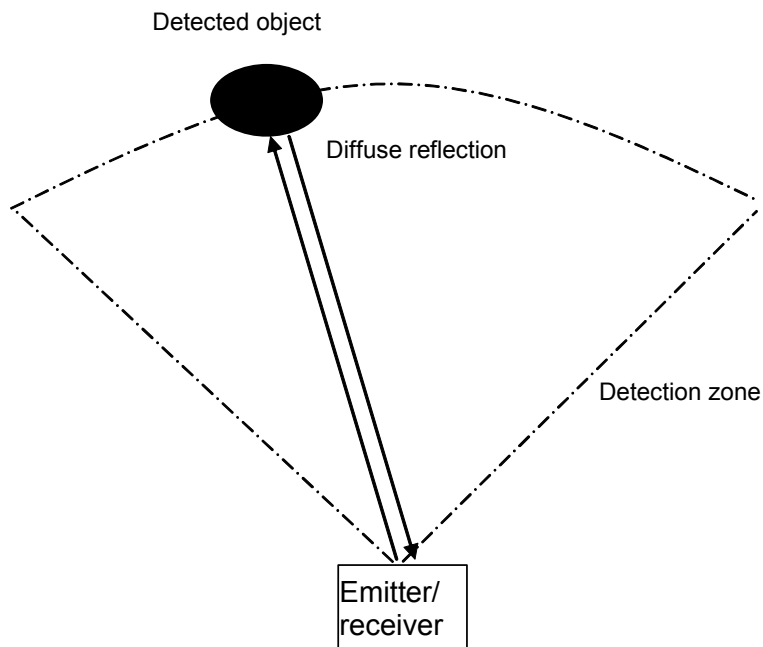


Figure 6 – Detection principle of AOPDDR

An AOPDDR receives reflected light from the object, therefore an emitter fault (no light emission) or a receiver fault leads to loss of detection. Therefore, when the emitter has a fault, the fault detection function of the AOPDDR causes a lockout condition within the specified response time.

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.

4.6.1.4 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 There is no product standard for PIPDs.

4.6.2 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. Requirements for pressure-sensitive mats and floors are given in 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 external device monitoring (EDM), stopping performance monitoring (SPM), muting, blanking, single/double break actuation, start interlock and restart interlock. These control system functions are explained in 4.7.2 to 4.7.9.

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.

NOTE Requirements for the characteristics of the stopping performance monitor are given in Clause 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 one or more 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 defined area(s) of the detection zone of an AOPD are configured such that parts of the workpiece or of the machine can project into the detection zone without generating an OFF signal.

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 External Device Monitoring (EDM)

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).