INTERNATIONAL STANDARD

ISO 13856-3

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Safety of machinery — Pressure-sensitive protective devices —

Part 3:
General principles for design and testing of pressure-sensitive bumpers, plates, wires and similar devices

Sécurité des machines — Dispositifs de protection sensibles à la pression —

Partie 3: Principes généraux de conception et d'essai des pare-chocs, plaques, câbles et dispositifs analogues sensibles à la pression

Reference number
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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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

ISO 13856-3 was prepared by Technical Committee ISO/TC 199, *Safety of machinery* and by Technical Committee CEN/TC 114, *Safety of machinery* in collaboration.

This second edition cancels and replaces the first edition (ISO 13856-3:2006), which has been technically revised.

ISO 13856 consists of the following parts, under the general title *Safety of machinery — Pressure-sensitive protective devices*:

— *Part 1: General principles for design and testing of pressure-sensitive mats and pressure-sensitive floors*

— *Part 2: General principles for design and testing of pressure-sensitive edges and pressure-sensitive bars*

— *Part 3: General principles for design and testing of pressure-sensitive bumpers, plates, wires and similar devices*

Introduction

The structure of safety standards in the field of machinery is as follows:

a) Type-A standards (basic safety standards) giving basic concepts, principles for design, and general aspects that can be applied to all machinery;

b) Type-B standards (generic safety standards) dealing with one safety aspect or one type of safeguard that can be used across a wide range of machinery:

— type-B1 standards on particular safety aspects (e.g. safety distances, surface temperature, noise);

— type-B2 standards on safeguards (e.g. two-hand controls, interlocking devices, pressure-sensitive devices, guards);

c) Type-C standards (machine safety standards) dealing with detailed safety requirements for a particular machine or group of machines.

This document is a type-B2 standard as stated in ISO 12100.

The requirements of this document can be supplemented or modified by a type-C standard.

For machines which are covered by the scope of a type-C standard and which have been designed and built according to the requirements of that standard, the requirements of that type-C standard take precedence.

The safeguarding of machinery (see ISO 12100:2010, 3.21) can be achieved by many different means. These means include guards which prevent access to the hazard zone by means of a physical barrier (for example, interlocking guards according to ISO 14119 or fixed guards according to ISO 14120) and protective devices (for example, electro-sensitive protective equipment according to IEC 61496-1 or pressure-sensitive protective devices according to this part of ISO 13856).

Type-C standards makers and designers of machinery/installations should consider the best way to achieve the required level of safety taking into account the intended application and the results of the risk assessment (see ISO 12100).

The required solution can also be to combine several of these different means. The machinery/installation supplier and the user examine together carefully the existing hazards and constraints before making their decision on the choice of safeguarding.

Pressure-sensitive protective devices are used in a wide range of applications with different conditions of use relating, for example, to extremes of loading or electrical, physical and chemical environments. They are interfaced with machine controls to ensure that the machine reverts to a safe condition if the sensitive protective equipment is actuated.

This part of ISO 13856 is restricted to the design of pressure-sensitive protective devices so that they can be used when the risk assessment carried out by the machine manufacturer and/or relevant type-C standard, when available, shows this to be appropriate.

This part of ISO 13856 does not specify the dimensions and the configuration of the effective sensing surface of the pressure-sensitive protective devices in relation to any particular application. However, there is a requirement for the manufacturer of any safeguard to provide sufficient information to enable the user (i.e. the machinery manufacturer and/or user of the machinery) to specify an adequate arrangement.

The forces for the activation of the pressure-sensitive protection devices specified in this part of ISO 13856 are based on the information available at the time of publication. These forces will be kept under review so that the results of further research into forces that can be applied to the human body without causing significant injury can be taken into account. While these forces provide a practical means for the design and testing of the pressure-sensitive device, they cannot prevent injury in all applications. When specifying the actuating force for a specific device or application many factors should be taken into account. These include the contact area, the contact speed, the material used and the part of the body affected.

Safety of machinery — Pressure-sensitive protective devices —

Part 3:
General principles for design and testing of pressure-sensitive bumpers, plates, wires and similar devices

1 Scope

This part of ISO 13856 establishes general principles and specifies requirements for the design and testing of those pressure-sensitive protective devices, with or without an external reset facility, that are not specified in either ISO 13856-1 or ISO 13856-2, and the majority of which are produced for specific applications and are not available as “off-the-shelf” items.

This part of ISO 13856 also gives specific requirements for the following pressure-sensitive protective devices:

a) pressure-sensitive bumpers;

b) pressure-sensitive plates;

c) pressure-sensitive wires (trip wires).

It deals with the design of a pressure-sensitive device with regard to safety and reliability rather than its suitability for particular applications.

NOTE 1 For the relationship between safety and reliability, see ISO 13849-1:2006, 4.2.

NOTE 2 The machinery manufacturer and/or user is responsible for installing appropriate types of protective device based on a risk assessment.

It is not applicable to

— specifying the dimensions of pressure-sensitive protective devices in relation to any particular application, or

— stopping devices according to IEC 60204-1 used for the normal operation, including emergency stopping of machinery.

NOTE 3 Specific requirements for particular applications are intended to be set forth in relevant type-C standards (see ISO 12100 and Introduction).

Additional requirements can be necessary where pressure-sensitive protective devices are used in locations accessible to elderly or disabled people or children.

NOTE 4 While requirements are given for the immunity of the device to electromagnetic disturbances, these are not intended to cover all aspects of electromagnetic compatibility (EMC).

2 Normative references

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

ISO 4413, *Hydraulic fluid power — General rules and safety requirements for systems and their components*

ISO 4414, *Pneumatic fluid power — General rules and safety requirements for systems and their components*

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

ISO 13849-1:2006, *Safety of machinery — Safety-related parts of control systems — Part 1: General principles for design*

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

ISO 13855:2010, *Safety of machinery — Positioning of safeguards with respect to the approach speeds of parts of the human body*

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

IEC 60068-2-14, *Environmental testing — Part 2-14: Tests — Test N: Change of temperature*

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

IEC 60068-2-78, *Environmental testing — Part 2-78: Tests — Test Cab: Damp heat, steady state*

IEC 60204-1:2005, *Safety of machinery — Electrical equipment of machines — Part 1: General requirements*

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

IEC 60664-1:2007, *Insulation coordination for equipment within low-voltage systems — Part 1: Principles, requirements and tests*

IEC 60947-5-1, *Low-voltage switchgear and controlgear — Part 5-1: Control circuit devices and switching elements — Electromechanical control circuit devices*

IEC 60947-5-5:1997, *Low-voltage switchgear and controlgear — Part 5-5: Control circuit devices and switching elements — Electrical emergency stop device with mechanical latching function*

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

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

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

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

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

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

IEC 61439-1:2009, *Low-voltage switchgear and controlgear assemblies — Part 1: General rules*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 12100 and the following apply.

3.1
pressure-sensitive protective device
sensitive protective equipment of the “mechanically activated trip” type intended to detect the touch of a person or body part of a person and which can also act as impeding device

Note 1 to entry: A pressure-sensitive protective device consists of a sensor or sensors, which generates a signal when pressure is applied to part of its outer surface, and a control unit, which responds to the signal from the sensor and generates an output signal(s) to the control system of a machine.

Note 2 to entry: Pressure-sensitive protective devices can be used as tripping devices as well as presence-sensing devices, as mentioned in ISO 12100:2010, Note to 3.28.5. For presence-sensing devices, see also 4.2.6.2.

Note 3 to entry: For the definitions of sensitive protective equipment and impeding device, see ISO 12100:2010, 3.28.5 and 3.29, respectively.

3.1.1
pressure-sensitive bumper
pressure-sensitive protective device (3.1) with a *sensor* (3.3) or sensors whose characteristics are a cross-section throughout the pressure-sensitive area that can be regular or irregular, a cross-section width usually greater than 80 mm, and an *effective sensing surface* (3.10) that is deformed locally or that can move as a whole

3.1.2
pressure-sensitive plate
pressure-sensitive protective device (3.1) with a *sensor* (3.3) or sensors whose characteristics are an *effective sensing surface* (3.10) that is normally — but not necessarily — flat, an effective sensing surface width usually greater than 80 mm, and an effective sensing surface that moves as a whole

Note 1 to entry: See Figure C.5.

3.1.3
pressure-sensitive wire
pressure-sensitive protective device (3.1) with a *sensor* (3.3) or sensors whose characteristics are a wire, cord, rope or cable held in tension, and where a change in the tension is detected to give an output signal

3.2
presence-sensing device
PSD
sensitive protective equipment that creates a sensing field, area or plane for detecting the presence of a body part or the whole of a person

Note 1 to entry: Pressure-sensitive protective devices can be used as tripping devices as well as presence-sensing devices, as mentioned in ISO 12100:2010, Note to 3.28.5.

Note 2 to entry: See also 4.2.6.2.

3.3
sensor
part of the *pressure-sensitive protective device* (3.1) which generates a signal in response to sufficient pressure applied to part of its surface

Note 1 to entry: This definition together with that of *control unit* (3.4) covers the functional components of a pressure-sensitive protective device. These functions can be integrated into a single assembly or contained in any number of separate assemblies. See Figure 1.

3.4
control unit
part of the *pressure-sensitive protective device* (3.1) which responds to the condition of the *sensor* (3.3) and generates output signals to the machine control system

Note 1 to entry: This definition together with that of *sensor* (3.3) covers the functional components of a pressure-sensitive protective device. These functions can be integrated into a single assembly or contained in any number of separate assemblies. See Figure 1.

3.5
output signal switching device
part of the *control unit* (3.4) of a *pressure-sensitive protective device* (3.1) which is connected to the machine control system and transmits output signals

3.6
ON state
state in which the output circuit(s) of an *output signal switching device* (3.5) is complete and permits the flow of current or fluid

3.7
OFF state
state in which the output circuit(s) of an *output signal switching device* (3.5) is broken and interrupts the flow of current or fluid

3.8
actuating force
any force applied to the *sensor* (3.3) which causes the *output signal switching device* (3.5) to go to the *OFF state* (3.7)

3.9
approach speed
relative speed at which contact is made between the surface of the *sensor* (3.3) and a part of the body

3.10
effective sensing surface
part of the surface of the *sensor* (3.3) or a combination of sensors, as stated by the manufacturer, where the application of an *actuating force* (3.8) creates an *OFF state* (3.7) in the *output signal switching device* (3.5)

3.11
effective sensing direction(s)
direction(s) of the *actuating force* (3.8) from which the *sensor* (3.3) will be actuated

3.12
dead surface
part of the surface area of the *sensor* (3.3) outside the *effective sensing surface* (3.10)

3.13
actuating travel
distance travelled by a specified object, moving in the direction of the applied *actuating force* (3.8), and measured from the point at which this object touches the *effective sensing surface* (3.10) to the point at which the *output signal switching device* (3.5) changes to an *OFF state* (3.7) under specified conditions

Note 1 to entry: See Figure 2.

Note 2 to entry: Actuating travel can differ from *pre-travel*, a term relating to a pressure-sensitive edge or pressure-sensitive bar (see ISO 13856-2) and signifying travel in the direction normal to the reference axis; actuating travel is in the direction of the applied force.

3.14
working travel
distance travelled by a specified object, moving in the direction of the applied *actuating force* (3.8), and measured from the point at which this object touches the *effective sensing surface* (3.10), under specified conditions, to where a specified force is exerted on the object

Note 1 to entry: See Figure 2 and Annex B.

3.15
overtravel
difference between the *working travel* (3.14) and the *actuating travel* (3.13) when both these distances are measured with the same object applied under the same conditions

Note 1 to entry: See Figure 2.

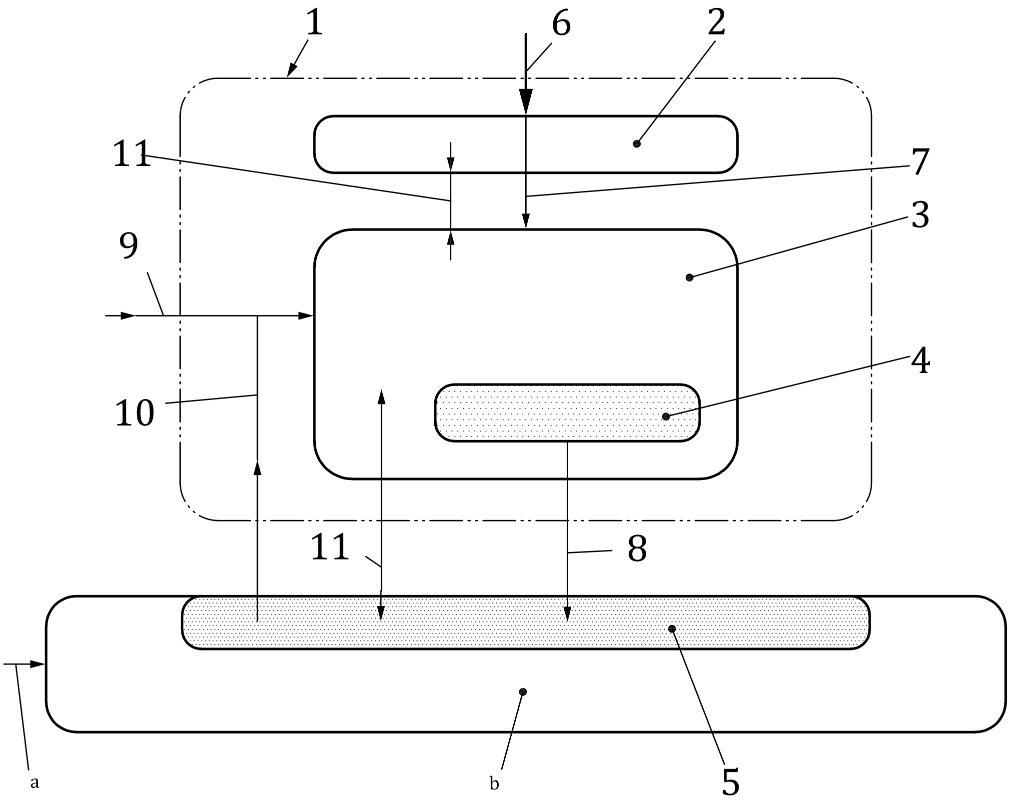
3.16
force-travel relationship
relationship between the force applied and the distance travelled by a *pressure-sensitive protective device* (3.1) in operation

Note 1 to entry: See Figure 2.

3.17
reset
function which permits an *ON state* (3.6) in the *output signal switching device* (3.5), provided that certain conditions are met

3.18
mounting orientation
orientation in space of the *sensor* (3.3)

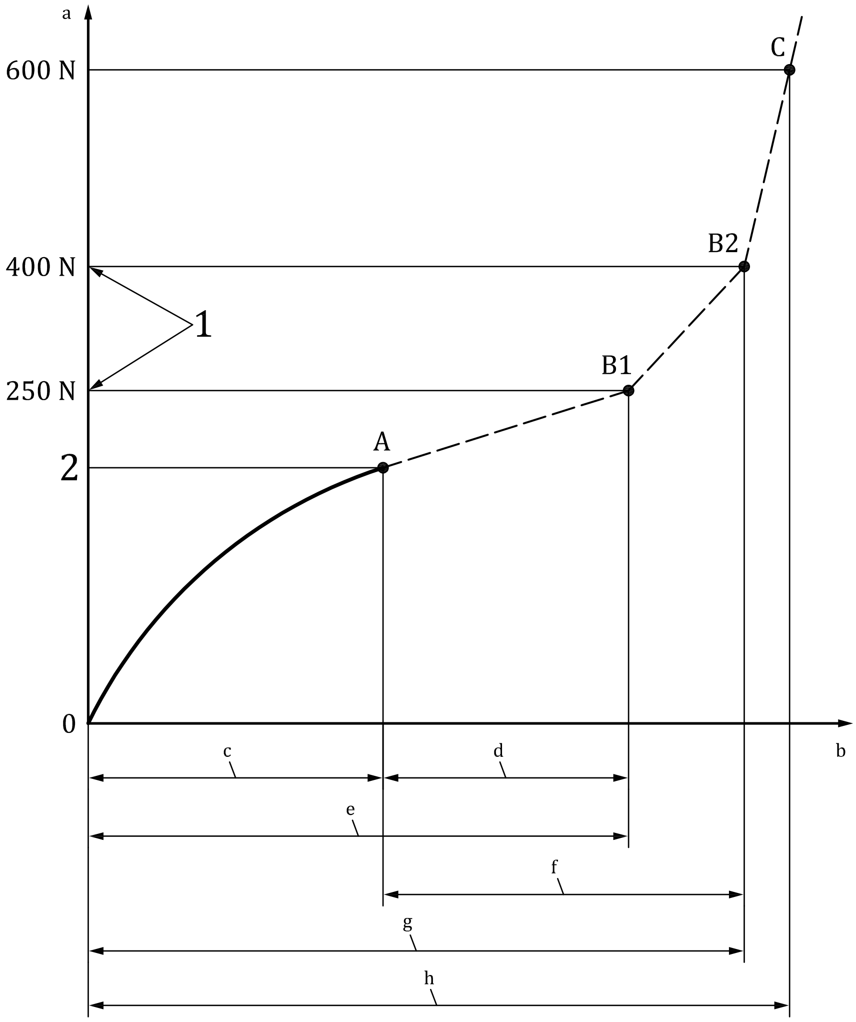
3.19
total travel
movement or deformation of the *effective sensing surface* (3.10) of a *pressure-sensitive protective device* (3.1), measured in the direction of the *actuating force* (3.8) from the point of contact to the point at which no further significant deformation of the effective sensing surface occurs



Key

1 pressure-sensitive protective device
2 sensor(s)
3 control unit*
4 output signal switching device
5 part of the machine control system for pressure-sensitive protective device output signal processing
6 actuating force
7 sensor output
8 ON state/OFF state signal
9 manual reset signal**
10 reset signal from machine control system (where appropriate)
11 monitoring signals (optional)
a manual reset signal to the machine control system***
b machine control system(s)
* Can be located within the machine control system or as part of the machine control system, e.g. as a logic block.
** Where appropriate, this may be used as an alternative to a.
*** Where appropriate, this may be used as an alternative to 9.

Figure 1 — Systematic sketch of pressure-sensitive protective device as applied to machine



Key

A actuating point and actuating force at maximum operating speed

B force-travel points occurring at force of 250 N (B1) or 400 N (B2) at operating speed of ≤ 10 mm · s−1

C force-travel point occurring, for example, at a force of 600 N at an operating speed of ≤ 10 mm · s−1

1 reference force

2 lowest actuating force

a force, N

b travel, mm

c actuating travel

d overtravel at 250 N

e working travel at 250 N

f overtravel at 400 N

g working travel at 400 N

h total travel

Figure 2 — Diagram of force-travel relationship — Example

4 Requirements for design and testing

4.1 General

The majority of pressure-sensitive protective devices covered by this part of ISO 13856 are made for specific applications. Where appropriate, the device manufacturer and the machine builder shall agree on the application specific requirements in accordance with a risk assessment and specify the essential force-travel data for the application.

The pressure-sensitive protective device shall have dimensions and be positioned such that the sensor will detect by touch the approach of a person or part of a person to a hazardous situation or a hazard zone.

In general, there are two types of application, as follows.

a) The device is used to stop the hazardous parts of machinery that are remote from the sensor. In this application, the distance between the sensor and the moving parts of the machine shall be such that the machine stops before any part of the body can reach the hazardous zone. The distance shall be calculated on the basis of the principles presented in ISO 13855. See the example given in C.4.2.

b) The sensor is mounted on the hazardous part of the machine or adjacent to it, so that the machine will stop or reverse to a safe position after the sensor is actuated and before injury can occur. See the example given in C.3.10.

The following basic requirements apply to all the pressure-sensitive protective devices covered by this part of ISO 13856. Additional specific requirements are given for pressure-sensitive bumpers, pressure-sensitive plates and pressure-sensitive wires. These specific requirements according to 4.3 to 4.5 take precedence over the basic requirements given in 4.2.

4.2 Basic requirements

4.2.1 Actuating force

For the test method, see 7.1.1 and 7.1.5.

The lowest actuating force(s) necessary to cause the output signal switching device to go to an OFF state shall not exceed those specified in Table 2, when applied

— in the reference direction(s),

— over the effective sensing surface,

— at the relevant approach speed(s),

— with the sensor in the mounting orientations,

— with the relevant test piece, and

— over the temperature range,

which the manufacturer of the pressure-sensitive protective device has specified or which have been agreed by the manufacturer of the pressure-sensitive protective device and the machine builder(s).

The lowest actuating force could need to be less than that stated in Table 2 for specific applications and designs of sensor. See 4.5.3 for the lowest actuating force necessary to cause the control unit for pressure-sensitive wires to go to the OFF state.

NOTE 1 A suitable risk assessment will show which body part(s) are to be considered for a particular application, enabling the relevant test piece(s) to be used.

NOTE 2 The forces specified in this clause are primarily intended for the purpose of assessing the pressure-sensitive performance of the device. These forces ought not to be considered as safe forces for all applications (see Introduction and Annex C for guidance).

NOTE 3 Certain applications — for example, protecting the neck — can require a device with a higher sensitivity, i.e. actuating forces lower than those shown in Table 2.

4.2.2 Actuating travel

For the test method, see 7.1.1 and 7.1.6.

The actuating travel shall be not more than that stated by the manufacturer of the pressure-sensitive protective device. For devices manufactured for a specific application, the actuating travel shall be appropriate for the application (see Annex B for advice on the force-travel relationship of specific devices).

4.2.3 Overtravel

For the test method, see 7.1.1 and 7.1.7.

The overtravel shall be not less than that stated by the manufacturer of the pressure-sensitive protective device. For devices manufactured for a specific application, the overtravel shall be appropriate for the application (see Annex B for advice on the force-travel relationship of specific devices).

4.2.4 Approach speed

For the test methods, see 7.1.1, 7.1.5, 7.1.6 and 7.1.7.

The sensor shall be able to cause an OFF state in the output signal switching device when actuated with the foreseeable approach speed(s) as stated by the manufacturer of the pressure-sensitive protective device. For devices manufactured for a specific application, the approach speed shall be appropriate for the application.

4.2.5 Number of operations

For the test method, see 7.1.1 and 7.1.8.

The pressure-sensitive protective device shall continue in normal operation and the sensor shall have no visible signs of damage after the number of operations stated by the manufacturer of the device. For devices manufactured for a specific application, the number of operations shall be appropriate for that application.

4.2.6 Response of output signal switching device to actuating force

4.2.6.1 Systems where sensor output remains in changed state as long as actuating force is applied

For the test method, see 7.1.1 and 7.1.9.

When the actuating force has been applied to the sensing surface of the sensor, the sensor output shall change state, causing the output signal switching device to change from an ON state to an OFF state. The change in state of the sensor output is a direct function of the applied force and this new state of the sensor output shall remain for as long as the actuating force is applied.

The output signal switching device shall only revert to the ON state when

— for systems with reset, the actuating force is removed and a reset signal is applied (see Figures A.1 and A.2), or

— for systems without reset, the actuating force is removed (see Figure A.3).

4.2.6.2 Systems where sensor output does not remain in changed state while actuating force is maintained

For the test method, see 7.1.1 and 7.1.9.

The sensor shall give a signal when the actuating force has been applied to its sensing surface, causing the output signal switching device to change from an ON to an OFF state. The output signal switching device shall only revert to the ON state when a reset signal is applied or when additional protective measures are taken to ensure that there is no hazard, e.g. automatic reversal of hazardous movement. Such additional protective measures shall be stated in information for use, see 6.3.1 a).

For some devices, additional protective measures are required. See Figure A.4, C.3.6 and C.3.7.

Some devices, e.g. air-pulse sensors, which are not regarded as well-tried components, shall comply with the requirements of category 2 according to ISO 13849-1:2006.

4.2.6.3 Reset function

For the test method, see 7.1.1 and 7.1.10.

The reset function of a pressure-sensitive protective device shall fulfil the general requirements of ISO 13849-1:2006, 6.2.2, and the functional requirements of Annex A of this part of ISO 13856.

To reset a start interlock or a restart interlock of a pressure-sensitive protective device, the reset signal shall be applied either

— directly to the control unit of the pressure-sensitive protective device, or

— via the machine control system.

When manual reset is provided, it shall function according to Figures A.1 and A.2 and ISO 13849-1:2006, 5.2.

4.2.7 Environmental conditions

4.2.7.1 Requirements for normal operation

For the test method, see 7.1.1 and 7.1.11.

The pressure-sensitive protective device shall continue in normal operation in the environmental conditions stated by the manufacturer in accordance with the requirements given in 4.2.7. Under these conditions, normal operation is achieved when

— the output signal switching device remains in the ON state as long as no actuating force is applied, and

— the ON state changes to an OFF state when the actuating force is applied.

4.2.7.2 Temperature

For the test method, see 7.1.1 and 7.1.11.3.

The system shall continue in normal operation over a minimum temperature range of 5 °C to 40 °C. If the manufacturer states that the pressure-sensitive protective device is suitable for a wider temperature range, then it shall continue in normal operation over the stated temperature range.

4.2.7.3 Humidity

For the test method, see 7.1.1 and 7.1.11.4.

All equipment shall meet the requirements for humidity specified by the manufacturer.

For electrical equipment only, the system shall continue in normal operation and the integrity of the electrical insulation shall be maintained following storage at a relative humidity of 93 % and at a temperature of 40 °C, for four days.

4.2.7.4 Electromagnetic compatibility

For the test method, see 7.1.1 and 7.1.11.5.

Where the pressure-sensitive protective device can be affected by electromagnetic emissions, it shall continue in normal operation under the conditions given in IEC 61000-6-2 and in Table 5. The manufacturer may design to, and subsequently state, a higher level(s) for which the pressure-sensitive protective device is required to continue in normal operation. A higher level of protection shall be provided when this is required to maintain safe operation of the pressure-sensitive protective device in a specific application.

4.2.7.5 Vibration

For the test method, see 7.1.1 and 7.1.11.6.

The pressure-sensitive protective device shall continue to operate without being actuated under the following vibration conditions in accordance with IEC 60068-2-6:

— frequency range: 10 Hz to 55 Hz;

— displacement: 0,15 mm;

— 10 cycles per axis;

— sweep rate: 1 octave per minute.

After this vibration test, the pressure-sensitive protective device shall continue in normal operation.

4.2.8 Power supply variation

4.2.8.1 General

For the test method, see 7.1.1 and 7.1.12.

The pressure-sensitive protective device shall continue in normal operation as defined in 4.2.7.1 when subjected to the power supply variations according to 4.2.8.2 and 4.2.8.3.

4.2.8.2 Electrical power supply variations

For the test method, see 7.1.1 and 7.1.12.2.

The pressure-sensitive protective device shall meet the electrical power supply variation requirements of IEC 60204-1:2005, 4.3.

4.2.8.3 Non-electrical power supply variations

For the test method, see 7.1.1 and 7.1.12.3.

The pressure-sensitive protective device shall continue in normal operation as defined in 4.2.7.1 when subjected to non-electrical power supply variations as stated by the manufacturer and in accordance with the relevant requirements of ISO 4413, for hydraulic systems, and ISO 4414, for pneumatic systems.

Where overpressure protective devices for this power supply are not incorporated, overpressure variations outside the stated range shall not result in a failure to danger.

Power supply variations outside the stated range shall not result in a failure to danger.

4.2.9 Electrical equipment

4.2.9.1 General

For the test method, see 7.1.1 and 7.1.13.1.

The electrical equipment (components) of pressure-sensitive protective devices shall

— conform to International Standards where these exist,

— be suitable for the intended use, and

— be operated within their specified ratings.

4.2.9.2 Protection against electric shock

Protection against electric shock shall be provided in accordance with IEC 60204-1:2005, 6.1, 6.2 and 6.3.

4.2.9.3 Protection against over-current

Protection against over-current shall be provided in accordance with IEC 60204-1:2005, 7.2.1, 7.2.3, 7.2.7, 7.2.8 and 7.2.9.

4.2.9.4 Electromechanical devices

Electromechanical control units and output signal switching devices shall meet the relevant requirements of IEC 60947-5-1.

4.2.9.5 Pollution degree

The electrical equipment shall be suitable for pollution degree 2 in accordance with IEC 61439-1:2009, 7.1.3.

4.2.9.6 Clearance, creepage distances

The electrical equipment shall be designed and constructed in accordance with IEC 61439-1:2009, 8.3 and 10.4.

4.2.9.7 Wiring

The electrical equipment shall be wired in accordance with IEC 61439-1:2009, 11.10.

4.2.10 Hydraulic equipment

For the test method, see 7.1.1 and 7.1.13.2.

Hydraulic equipment shall meet the relevant requirements of ISO 4413 and ISO 13849-2.

4.2.11 Pneumatic equipment

For the test method, see 7.1.1 and 7.1.13.3.

Pneumatic equipment shall meet the relevant requirements of ISO 4414 and ISO 13849-2.

4.2.12 Mechanical equipment

For the test method, see 7.1.1 and 7.1.13.4.

Mechanical equipment shall meet the relevant requirements for pressure-sensitive protective devices of ISO 12100:2010, 6.3.3 and ISO 13849-2.

4.2.13 Enclosure

For the test method, see 7.1.1 and 7.1.14.

4.2.13.1 Sensor

The sensor shall be suitable for its particular environment, e.g. wet or dusty conditions. The sensor shall be specified in accordance with the degree of protection according to IEC 60529. Those parts of the sensor containing electrical components shall have an enclosure which meets the requirements of IP 54 as a minimum. If the manufacturer specifies that the sensor may be immersed in water, the sensor enclosure shall meet the requirements of IP 67 as a minimum.

4.2.13.2 Control unit and output signal switching device

The control unit and any external output signal switching device enclosure shall meet the requirements of IP 54 as a minimum. Where the control unit and output signal switching device are designed for mounting in another control equipment enclosure, this enclosure shall meet the requirements of the standard of protection relevant to that application. In these circumstances, the control unit and output signal switching device shall meet the requirements of IP 2X as a minimum.

4.2.14 Access

For the test method, see 7.1.1 and 7.1.15.

Where access is required to the interior of any part of the pressure-sensitive protective device, it shall only be possible by means of a key or tool.

4.2.15 Performance levels and categories for safety-related parts of control systems in accordance with ISO 13849-1

4.2.15.1 Pressure-sensitive protective devices according to this part of ISO 13856 shall meet the requirements of the performance level (PL) and category for which they are specified and marked. The performance levels and categories are specified in ISO 13849-1.

For the test method, see 7.1.1 and 7.1.16.

4.2.15.2 Pressure-sensitive protective devices according to this part of ISO 13856 shall meet at least the requirements of performance level c according to ISO 13849-1 and the requirements of this part of ISO 13856.

Mechanical damages of the sensor surface that do not affect the safety function (e.g. scratches by swarf) are not treated as failures.

4.2.15.3 B_{10d} values for the sensor shall be determined by means of testing. The test results shall be documented by means of test protocols. These should comprise at least the following information:

— type of sensor;

— measurement points;

— temperature (of the environment);

— operating voltage and operating current;

— switching frequency;

— test location;

— test loading;

— actuating speed;

— number of operations;

— B_{10d} values;

— types of failure;

— test person, test laboratory, date and signature.

NOTE The determination of the B_{10d} values is undertaken by the manufacturer.

4.2.15.4 If a pressure-sensitive protective device complies with category 3, its architecture may deviate from the designated architecture according to ISO 13849-1:2006, 6.2.

Fault exclusions shall be listed and explained in the instructions for use. Fault exclusions which are not tolerable due to a reasonably foreseeable misuse of the pressure-sensitive protective device shall not be made.

If fault exclusion is used for the determination of the PL, the diagnostic coverage does not need to be calculated and will not be included when determining the performance level. Under these conditions a high expectation of the mean time to dangerous failure ($MTTF_d$) shall be present to reach performance level d.

4.2.16 Adjustments

For the test method, see 7.1.1 and 7.1.17.

Pressure-sensitive protective devices shall have no means of manual adjustment. If it is necessary to make adjustments during commissioning or during maintenance, the manufacturer shall supply instructions to enable the adjustments to be made so that the requirements of this part of ISO 13856 can be met. There shall be arrangements for checking that such adjustments have been made correctly. The adjustable elements shall only be accessible by means of a key, security code or tool.

4.2.17 Sensor fixing and mechanical strength

For the test method, see 7.1.1 and 7.1.18.

Means shall be provided for all parts of the sensor to be fixed securely in the specified mounting orientation. The fixed sensor shall have sufficient mechanical strength to withstand the maximum forces in the specified directions as stated by the manufacturer.

4.2.18 Connections

For the test method, see 7.1.1 and 7.1.19.

Where components of different configurations within the pressure-sensitive protective device are interchangeable by means of plug and socket connections, incorrect placement or exchange of these components shall not cause a failure to danger.

If a sensor is connected by a plug and socket, removal or disconnection of the sensor at the plug and socket from the control unit shall cause the output signal switching device to go to an OFF state.

4.2.19 Inhibition and blocking

For the test method, see 7.1.1 and 7.1.20.

The sensors of pressure-sensitive protective devices shall be constructed so that their operation cannot be intentionally inhibited or blocked by simple means.

4.2.20 Sharp corners, sharp edges, rough surfaces and trapping

For the test methods, see 7.1.1 and 7.1.21.

Exposed parts of pressure-sensitive protective devices shall have no sharp corners, sharp edges, rough surfaces, etc. which could cause injury to persons coming into contact with the device(s) (see ISO 12100:2010, 6.2.2.1).

4.2.21 Shock

For the test method, see 7.1.1 and 7.1.22.

The pressure-sensitive protective device shall continue to operate without being actuated under the shock conditions anticipated for the application.

NOTE The effect of shocks will vary considerably depending upon their size and direction and on the design of the sensor of the pressure-sensitive protective device. Further precise requirements are specified for pressure-sensitive plates only (see 4.4.1).

4.3 Specific requirements for pressure-sensitive bumpers

4.3.1 Force-travel relationship(s)

For the test method, see 7.1.1 and 7.2.1.

The force-travel relationship shall, as a minimum, be as stated by the manufacturer. The manufacturer shall provide the force-travel relationship data using Figure 2 as an example and shall state the conditions under which the data were determined.

4.3.2 Additional coverings for sensors

For the test method, see 7.1.1 and 7.2.2.

If additional coverings are used, the requirements of this part of ISO 13856 shall be fulfilled by the covered sensor.

4.3.3 Recovery after deformation

For the test method, see 7.1.1 and 7.2.3.

After the effective sensing surface of the sensor has been deformed or moved by the working travel for 24 h, the effective sensing surface shall recover in accordance with Table 1.

Table 1 — Recovery after deformation

Recovery time	**Change in height** percentage of working travel at 10 mm · s^{-1} at 250 N
30 s	≤ 20
5 min	≤ 10
30 min	≤ 5

If the manufacturer states that the pressure-sensitive bumper is suitable for continuous deformation for longer than 24 h, then the sensor shall recover according to Table 1 after deformation for the stated time. Alternatively, the sensor shall have sufficient overtravel to compensate for the extent of deformation for the stated time.

After the effective sensing surface of the sensor has been deformed or moved by the working travel for 24 h, the pressure-sensitive bumper shall have normal function within 30 s.

4.3.4 Detection on bumpers with semi-rigid or rigid surfaces

For the test method, see 7.1.1 and 7.2.4.

On bumpers with an open structure, e.g. as shown in Figures C.3 and C.4, it shall not be possible to stand undetected inside the structure of the bumper.

4.4 Specific requirements for pressure-sensitive plates

4.4.1 Shock

For the test method, see 7.1.1 and 7.3.1.

The pressure-sensitive plate shall continue to operate, without being actuated, under the following conditions. The requirements shall apply to the sensor of plates in the reference direction and opposite direction only and shall be in accordance with IEC 60068-2-27:

— peak acceleration: 100 m · s^{-2};

— duration of the pulse: 16 ms;

— form of the pulse: half sine;

— number of pulses per direction: 1 000;

— frequency: approximately 1 Hz.

After the shock test, the pressure-sensitive plate shall continue in normal operation.

If the manufacturer states that the pressure-sensitive plate is suitable for a wider shock range, then it shall meet this requirement over the stated shock range.

4.4.2 Deformation, inhibition and blocking

For the test method, see 7.1.1 and 7.1.20.

Deformation of the plate, prevention of the movement of the plate (wedging, blocking) and other foreseeable faults shall not lead to the loss of the safety function.

4.5 Specific requirements for pressure-sensitive wires (trip wires)

4.5.1 Electrical switches

For the test method, see 7.1.1.

Electrical switches used with pressure-sensitive wires shall meet the requirements of IEC 60947-5-5. In addition, the requirements given in 4.5.2 to 4.5.5 shall be met.

4.5.2 Breaking or disengagement of wire

For the test method, see 7.1.1 and 7.4.1.

The pressure-sensitive wire shall be designed such that, in the event of slackening, breaking or disengagement of the wire, an OFF state is generated (see Figure C.6).

4.5.3 Actuating force

For the test method, see 7.1.1 and 7.4.2.

The force necessary to apply to the pressure-sensitive wire to generate an OFF state in the control unit shall be less than 100 N when applied in the effective sensing direction(s) at 90° to, and at any point along, the effective sensing surface of the wire, using test piece 5 (see 7.1.5.1, Table 2). The effective sensing surface of the wire shall be stated by the manufacturer, taking into account the way in which the wire can be used.

4.5.4 Tensile strength of the sensor

For the test method, see 7.1.1 and 7.4.3.

The sensor (including any connections) shall resist a tension force of 1 000 N without failure.

4.5.5 Actuating deflection of the wire

For the test method, see 7.1.1 and 7.4.4.

The displacement of the pressure-sensitive wire needed to generate an OFF state shall be less than 150 mm in all the stated actuating directions (see Figure C.6). For special applications, a displacement of more than 150 mm can be acceptable when indicated by the risk assessment to be acceptable.

5 Marking

5.1 General

Pressure-sensitive protective devices which are placed on the market separately shall be marked as specified in ISO 12100:2010, 6.4.4, and, as a minimum for electrical equipment, with the rated voltage and current. See also IEC 60204-1:2005, Clause 16.

5.2 Labels

All labels shall be securely fixed and all markings shall be durable and legible for the expected lifetime of the corresponding part of the pressure-sensitive protective device to which they are attached.

5.3 Marking of the control unit

The control unit label(s) shall also contain the following information or indicate where this information can be found:

— the performance level, category and B_{10d} value according to ISO 13849-1 for the system as a whole;

— the response time for the system as a whole;

— whether designed with or without reset;

— the part number.

5.4 Marking of the sensor

The sensor label shall also contain the part number or indicate where this information can be found.

6 Information for selection and use

6.1 General

Information and guidance regarding application, commissioning and regular inspection for inclusion in the information for use is given in Annexes D and E.

The information to be supplied to the user, and the manner in which it is presented, shall comply with ISO 12100:2010, 6.4. It shall be clearly identified with the product, i. e. the pressure-sensitive protective device.

6.2 Essential data for selection of suitable pressure-sensitive protective device

The manufacturer shall make available the relevant information from the following, in order to assist in the selection of a suitable pressure-sensitive protective device:

a) suitability of the pressure-sensitive protective device for tripping function only or also for combined tripping function and presence sensing function;

b) limits as to the configuration, number and length of sensors connected to one control unit;

c) limits as to the length and specifications of connections between sensor(s) and control unit(s);

d) mounting orientation(s) at which the sensor can be used;

e) means of fixing the sensor and control unit;

f) force(s) which the installed sensor is able to withstand and the direction(s) in which they are applied;

g) dimensions which specify the effective sensing surface;

h) maximum dimensions of the sensor;

i) weight of the sensor per metre length and weight of the control unit;

j) sensor additional covering details (where applicable);

k) force-travel relationship(s), showing the actuating travel and overtravel in the form of a table or diagram according to Figure 2;

l) specified force after overtravel;

m) stated number of operations;

n) chemical resistance table for the sensor;

o) operating temperature range;

p) power supply requirements;

q) control unit enclosure specification(s) according to IEC 60529;

r) sensor enclosure specification(s) according to IEC 60529;

s) category (or categories) and performance level(s) according to ISO 13849-1;

t) selection procedure according to Annex D;

u) critical lengths of connections between individual components;

v) deformation behaviour over time;

w) output signal switching device switching capability according to IEC 60947-5-1;

x) application guidance;

y) output signal switching device contact configuration(s);

z) suitability for detecting fingers;

aa) minimum operating speed, if applicable (e.g. for pneumatic systems);

bb) indication of fault exclusions (see ISO 13849-1:2006, Clause 11);

cc) explanation on how the performance level was calculated with reference to the variable parameters' mean operation time (in hours per day and days per year) and mean time between the beginning of two successive cycles of the component considered (cycle time);

dd) statement that the user shall determine the performance level for his application by himself.

6.3 Information for use

6.3.1 Information for application and commissioning

For verification, see 7.1.4.

The manufacturer shall make available the relevant information from the following:

a) **Information relating to the pressure-sensitive protective device:**

   1) detailed description of the device;

   2) the limits as to the configuration, number and length of sensors connected to one control unit;

   3) the limits as to the length and specifications of connections between sensor(s) and control unit(s);

   4) the procedure for determining the overtravel for the pressure-sensitive protective device, which shall be included with examples (see Annex B);

   5) range of applications and conditions for which the device(s) is intended or approved, including the category, performance level and B_{10d} values according to ISO 13849-1;

   6) circuit diagrams providing schematic representation of the safety functions and examples of machine control interface;

   7) additional protective measures, according to 4.2.6.2, necessary to achieve the required level of safety for specific applications;

   8) the rating, characteristics and location of all input/output terminals (e.g. maximum rating of fuses or setting of an over-current protective device);

   9) type and frequency of automatic check system, where applicable;

   10) guidance regarding chemical, physical and environmental resistance (e.g. resistance to solvents, allowable weight loading, operating temperature range, allowable power supply variation);

   11) guidance regarding use of the device in alternative mounting orientations;

   12) indication of whether the device is designed with or without external reset function in accordance with either Figures A.1, A.2, A.3 or A.4;

b) **Information relating to packaging, transportation, handling and storage of the pressure-sensitive protective device**, including

   1) dimensions,

   2) mass,

   3) description of packaging and methods of unpacking to prevent damage to the device,

   4) transportation and handling methods to prevent damage or personal injury, and

5) storage requirements (lay flat, straight or in coils, temperature range etc.).

c) **Information relating to installation and commissioning of the pressure-sensitive protective device**, including

1) a warning that the information for use should be read in full before any installation work is attempted,

2) a warning that a reset function can be required,

3) requirements regarding the surface on which the sensor will be mounted,

4) methods of installation, including required tooling,

5) design features of the effective sensing surfaces which can influence the safety function and how the effects of dead surfaces can be minimized by installation (including drawing, where appropriate),

6) schedule of tests to be carried out after installation to establish that the device(s) are functioning and have been installed and interfaced with the machine control correctly,

7) warning that the overall safety of the machine and its safeguard depends on the quality, reliability and correct installation of the interface between them,

8) indication that the category(ies) and performance level(s) required for the device have to comply with the category(ies) and performance level(s) established by the risk assessment, and

9) record sheet which shall be completed by the installer, showing which control unit and sensor(s) are installed.

6.3.2 Information relating to operation and maintenance of the pressure-sensitive protective device

For verification see 7.1.4.

The manufacturer shall make available relevant information from the following. The machine supplier or manufacturer shall make this relevant information available to the machine user.

a) **Information relating to the use of the pressure-sensitive protective device**, including

1) purpose and method of operation of the control unit and indicators,

2) information regarding use limits,

3) instructions for fault identification and for restarting after an intervention,

4) indication of fault exclusions,

5) explanation to the calculated performance level with reference to the variable parameters, mean operation time, mean use time and cycle time, and

6) a statement that the user shall determine the performance level for his application by himself.

b) **Information for maintenance**, including the following:

1) a warning that the maintenance instructions should be read before any maintenance is attempted;

2) nature and frequency of testing, inspection and maintenance;

3) instruction for allowable setting, adjustment and cleaning;

4) actions which require a definite technical knowledge and/or particular skills and hence should be carried out exclusively by skilled persons suitably trained;

5) information (e.g. drawings and circuit diagrams) enabling trained personnel to carry out fault-finding tasks;

6) details of tests required after replacement of parts to establish that the device functions correctly;

7) warning that all parts (e.g. covers, clips, edging strips or fastenings) removed during maintenance should be replaced after the maintenance and that if such parts are not correctly refitted the performance of the device could be impaired;

8) list of user-replaceable parts;

9) warning that only those parts approved by the manufacturer may be replaced by the user and that if non-approved spares are used or non-approved modifications are made the performance of the device could be impaired;

10) name and address of manufacturer and/or competent service organization;

11) indication of the maximum test interval (e.g. a test at least every three months).

c) **Training**

Recommendations for the minimum training requirements of personnel installing the equipment to ensure that the pressure-sensitive protective device is installed to comply with this part of ISO 13856.

d) **Periodic functional tests**

The instructions for use shall contain information on how to perform the functional test at the sensor (e.g. manual deformation of the sensor surface while observing the change of signal). For this purpose, the following is required:

1) a statement that the sensor shall be tested in regular time intervals with a test piece of 80 mm diameter at optional test locations;

2) an indication that the test interval depends on the use of the pressure-sensitive protective device and that it is to be specified by the operator according to the national legislative requirements.

NOTE Further advice for production of the instruction handbook and drafting and editing the information for use is provided in ISO 12100:2010, 6.4.5.2 and 6.4.5.3.

7 Verification of requirements

7.1 Verification of requirements applicable to all pressure-sensitive protective devices covered by this part of ISO 13856

7.1.1 General

All the tests in this part of ISO 13856 shall be considered as type tests for each type of pressure-sensitive protective device.

Verification that the requirements of this part of ISO 13856 have been met shall be made by inspection and/or analysis. Tests shall be conducted where verification is not possible by inspection and analysis and when testing is a more practicable option or is a requirement of this part of ISO 13856. In all cases, the manufacturer shall provide information to show how the requirements have been met.

For many applications, pressure-sensitive protective devices are designed and manufactured as part of a machine, and such tests as are necessary can be carried out on the devices when mounted on the machine. In such cases, the test pieces, approach speeds, directions of approach and locations on the sensor(s) shall simulate the approach of the body parts intended to be detected under the worst conditions for safety.

7.1.2 Conditions during verification

The tests shall be carried out on ready-to-use pressure-sensitive protective devices under the least favourable conditions within the minimum requirements of this part of ISO 13856, with the requirements specified by the manufacturer when these are more severe or in accordance with the manufacturer's specification when not specified by this part of ISO 13856. Unless otherwise specified, these tests shall be carried out at 20 °C. The following tolerances apply:

— temperature: ± 5 °C;

— test speed: ± 10 %.

If, for a particular test, it is evident that the performance of the pressure-sensitive protective device is not influenced by temperature over the stated temperature range, then tests may be carried out at ambient temperature only.

Other relevant ambient conditions, e.g. atmospheric pressure and humidity, shall be recorded.

7.1.3 Test samples

7.1.3.1 Sensor

In order to perform the tests specified in this clause, one or more ready-to-use sensor(s) will be required.

If the pressure-sensitive protective device is designed with an effective sensing surface built up of a combination of sensors, then the sensors for connection with one control unit shall be provided. If relevant, the maximum stated number of combined sensors shall be used to verify the relevant requirements.

If the sensor dimensions influence the characteristics of the sensor output, a sensor of the least effective sensing dimension as specified by the manufacturer shall be used.

7.1.3.2 Control units with output signal switching devices

One control unit with one output signal switching device corresponding to production units shall be provided and, if necessary, one control unit with one output signal switching device specially prepared for testing under fault conditions.

7.1.4 Test No. 1 — Safety-related data for selection, installation, commissioning, operation and maintenance of suitable pressure-sensitive protective device

It shall be verified that the manufacturer's data sheet contains all safety-related data.

See 6.3.1 and 6.3.2.

7.1.5 Test No. 2 — Actuating force and approach speed

7.1.5.1 General

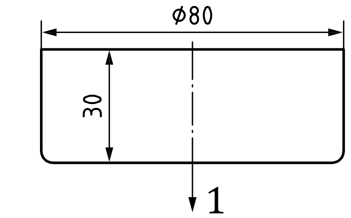
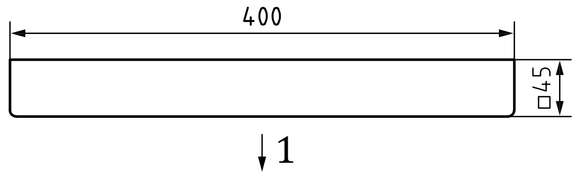
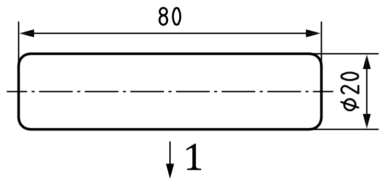
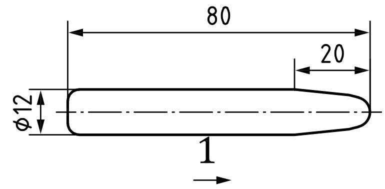
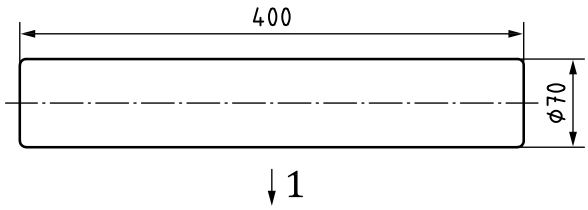
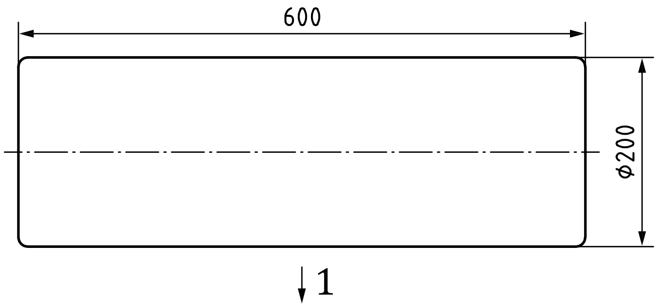
For requirements, see 4.2.1 and 4.2.4.

The actuating force shall be applied by the relevant test pieces in the relevant test direction(s) and at least at the maximum and minimum approach speeds. For each application of the test piece, it shall be verified that the output signal switching device changes to the OFF state at an actuating force less than or equal to the relevant value given in Table 2.

When determining the maximum approach speed, the combined maximum speed of the sensor as stated by the manufacturer or determined for the specific application and the foreseen approach speed of a person or part of a person, shall be used (see ISO 13855).

Table 2 — Test pieces, actuating forces and test directions

Dimensions in millimetres

Test piece 1 Actuating force: 150 N Test piece to simulate body part: Head or hand	
Test piece 2 Actuating force: 400 N Body part: Shoulder	
Test piece 3 Actuating force: 50 N Body part: Finger (knuckle)	
Test piece 4 Actuating force: 50 N Body part: Finger (tip) For dimensions see IEC 61032:1997, probe 11.	
Test piece 5 Actuating force: 250 N Body part: Arm or leg	
Test piece 6 Actuating force: 400 N Body part: Whole body	
1 test direction	

7.1.5.2 Test locations on the sensor

The tests shall be carried out at least at five different test locations on the effective sensing surface of the sensor where it is expected that the highest actuating force(s) are required to produce an OFF state in the output signal switching device. These locations may be determined by position, geometry, technology and experience. Where the pressure-sensitive protective device is made up of a combination of sensors, the junction between sensors shall be taken into account.

7.1.5.3 Sensor mounting orientation for tests

The tests shall be carried out

a) with the sensor in the least favourable of the stated mounting orientations, and

b) after the sensor has stabilized to the test temperature used.

7.1.5.4 Test pieces to be used

The tests shall be carried out with the test piece(s) relevant to the body part(s) to be detected

a) as stated by the manufacturer of the pressure-sensitive protective device, or

b) as indicated by the risk assessment for a specific application.

If it is evident that one or more of the relevant test pieces gives the least favourable result, then tests need to be carried out using these test pieces only.

Test pieces are illustrated in Figures 3 and 4 and in Table 2.

7.1.6 Test No. 3 — Actuating travel

For the requirements, see 4.2.2 and 4.2.4.

The test shall be carried out with test piece 1 or with the test piece(s) for the body part(s) relevant to the application (see Table 2). The test piece shall be applied to the sensor at the minimum and maximum approach speeds (see 7.1.5.1) at a location on the sensor where contact is normally expected for the application. The actuating travel shall be within the limits for distance as stated by the manufacturer. For pressure-sensitive protective devices manufactured for a specific application, the actuating travel shall be appropriate for the application.

7.1.7 Test No. 4 — Overtravel

For the requirements, see 4.2.3 and 4.2.4.

The test shall be carried out with test piece 1 or with the test piece(s) for the body part(s) relevant to the application (see Table 2). The test piece shall be applied to the sensor at an approach speed $\leq 10 \text{ mm} \cdot \text{s}^{-1}$ at a location on the sensor where contact is normally expected for the application. The overtravel shall be within the limits for distance and specified force as stated by the manufacturer of the pressure-sensitive protective device. For devices manufactured for a specific application, the overtravel shall be appropriate for the application.

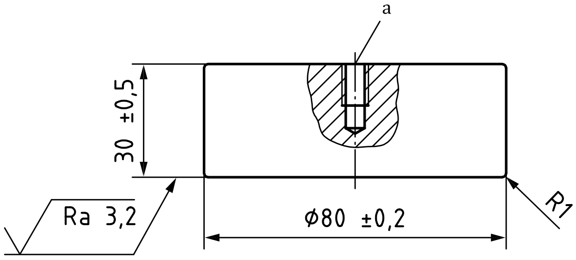
7.1.8 Test No. 5 — Number of operations

For the requirements, see 4.2.5.

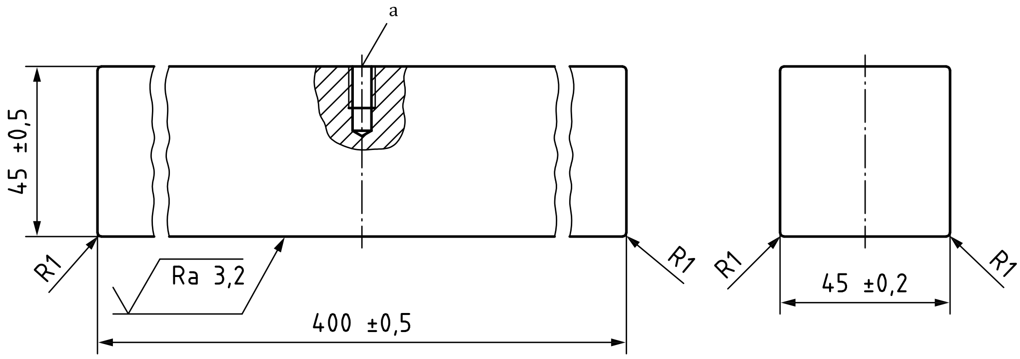
Testing shall be carried out by applying test piece 1 at the approach speed appropriate for the application and for the specified number of operations. After the tests have been completed, the tested sensor shall show no visible signs of damage and the requirements for actuating force, pre-travel and overtravel shall still be met.

The number of actuations required shall be as stated by the manufacturer or as appropriate for the application, whichever is the greater. Test piece 1 (or the test piece(s) relevant to the body part(s) to be detected) shall be applied at the location(s) on the effective sensing surface of the sensor where the most frequent applications of the actuating force are expected. Each actuation of the pressure-sensitive protective device shall cause an OFF state in the output signal switching device. The test parameters (including speed) shall be those that nearest simulate the lifetime application conditions.

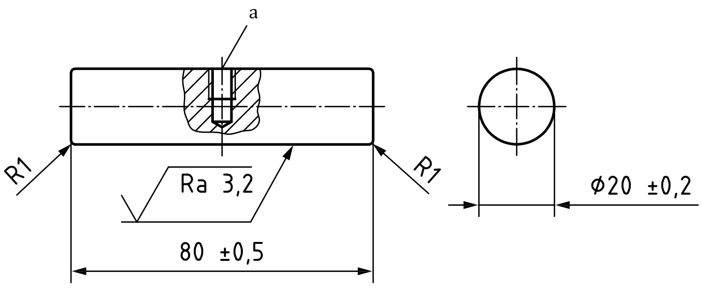
Dimensions in millimetres/Tolerances on radii: ± 0,2



a) Test piece 1



b) Test piece 2

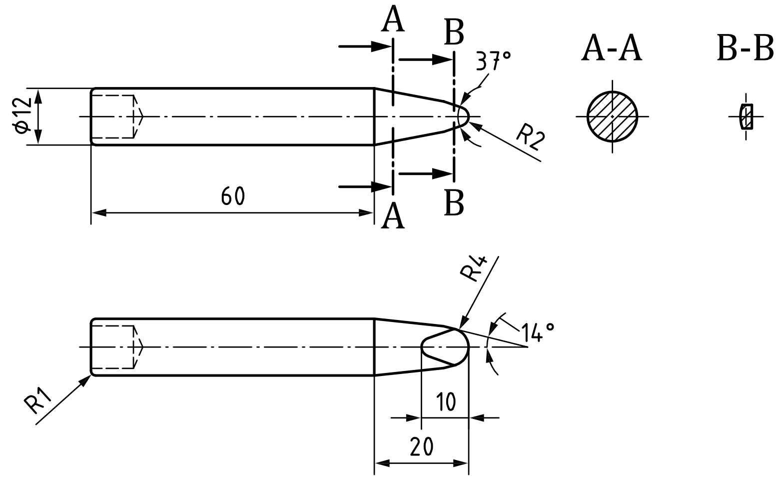


c) Test piece 3

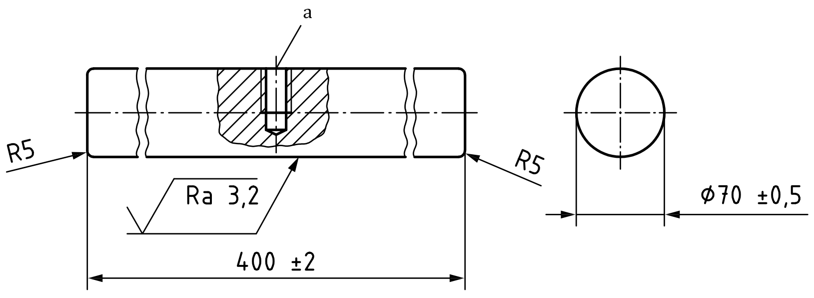
a Mounting proposal only.

Figure 3 — Test pieces 1 to 3

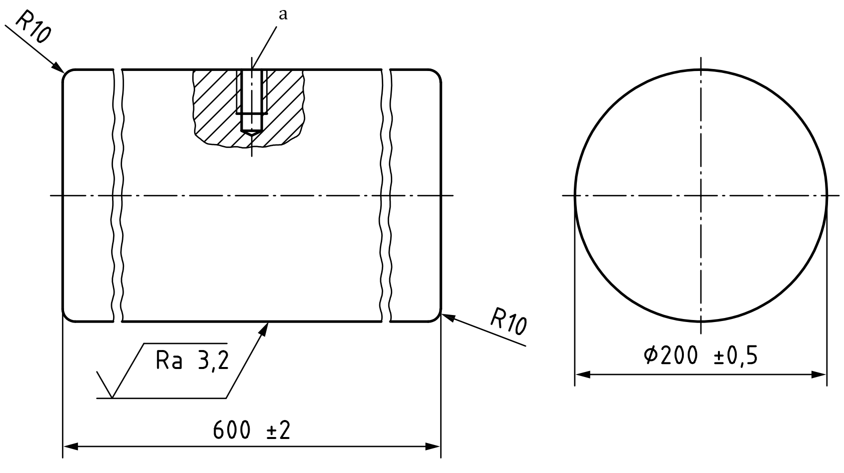
Dimensions in millimetres/Tolerances on radii: ± 0,2



a) Test piece 4



b) Test piece 5



c) Test piece 6

a Mounting proposal only.

Figure 4 — Test pieces 4 to 6

7.1.9 Test No. 6 — Output state of sensor and output signal switching device

For the requirements, see 4.2.6.1 and 4.2.6.2.

An actuating force shall be applied at a random location on the effective sensing surface in the reference direction through test piece 1 for a period of 10 min. While this force is applied, the value of the sensor output signal and the output signal switching device shall go to, and be maintained in, an OFF state, in accordance with Figures A.1, A.2, A.3 and A.4. When the force is removed, the value of the sensor output signal and the state of the output signal switching device shall change in accordance with Figures A.1, A.2, A.3 and A.4.

For systems according to 4.2.6.1, the change in the state of the sensor shall be checked in accordance with Figures A.1, A.2 and A.3.

For systems according to 4.2.6.2, the additional protective measures shall be tested and/or evaluated.

For devices such as air-pulse sensors which are not regarded as well-tried components, the compliance with the requirements of category 2 according to ISO 13849-1:2006 shall be verified.

7.1.10 Test No. 7 — Response of output signal switching device to actuating force, reset and state of power supply

For the requirements, see 4.2.6.3.

The interaction of separate functions as given in Annex A shall be tested using test piece 1 and the actuating force applied in the reference direction to the effective sensing surface at one random location.

7.1.11 Test No. 8 — Environmental conditions

7.1.11.1 General

For the requirements, see 4.2.7.

The requirements concerning the environmental conditions shall be verified by analysis. Where this is not possible, the tests according to 7.1.11.2 to 7.1.11.6 shall be performed.

7.1.11.2 Functional test

At the conclusion of each of the tests given in 7.1.11.3 to 7.1.11.6, the normal function of the pressure-sensitive protective device shall be verified using test piece 1. The test piece shall be applied as follows:

— perpendicularly to the effective sensing surface;

— with the corresponding actuating force given in Table 2;

— at the maximum operating speed;

— at one random location.

This requirement is fulfilled if an OFF state of the output signal switching device is produced.

7.1.11.3 Test No. 8.1 — Operating temperature range

For the requirements, see 4.2.7.2.

The requirements of the specified operating temperature range shall be verified by the test procedure given in Table 3.

Table 3 — Operating temperature range

Test procedure	Test conditions
IEC 60068-2-14 Test Nb	Pressure-sensitive protective device is connected to the power supply.

The rate of change of temperature shall be (0,8 ± 0,3) K · min^{-1} over the whole temperature range for heating and cooling.

At 1 min intervals during this test procedure, the function of the pressure-sensitive protective device shall be verified using test piece 1 with the corresponding actuating force, given in Table 2. The test piece shall be applied perpendicularly to the effective sensing surface at (10 ± 1) mm · s^{-1} in one random location. The application of the test piece shall produce an OFF state of the output signal switching device.

7.1.11.4 Test No. 8.2 — Humidity

For the requirements, see 4.2.7.3.

The requirements for humidity shall be verified by the test procedure given in Table 4.

Table 4 — Humidity

Test procedure	Test conditions
IEC 60068-2-78, test Cab Temperature (40 ± 2)°C Relative humidity (93 ± 3)%	Pressure-sensitive protective device is not connected to the power supply. After this test, a high voltage test according to IEC 60664-1:2007, Tables F.1 and F.5, shall be performed between circuits and exposed conductive parts or accessible surfaces of the control unit/output signal switching device.

7.1.11.5 Test No. 8.3 — Electromagnetic compatibility

For the requirements, see 4.2.7.4.

The safety-related requirements shall be verified using IEC 61000-6-2 only. Immunity shall be verified for the following states according to the test procedures, with the indicated characteristic values given in Table 5 and with the stated conditions given in 7.1.11.2:

— pressure-sensitive protective device with supply energy;

— pressure-sensitive protective device with supply energy plus applied actuating force;

— pressure-sensitive protective device with supply energy, after removal of the actuating force and prior to the execution of the reset.

Table 5 — Electromagnetic compatibility

Tests and characteristic values	Test procedure
Surge, installation class 3	IEC 61000-4-5 power, earth and input/output lines
Electrical fast transients (burst), level 3	IEC 61000-4-4 duration of test: 2 min power, earth, and input/output lines
Electrostatic discharge, level 3	IEC 61000-4-2
Radiated, radio-frequency electromagnetic fields, level 3	IEC 61000-4-3
Conducted disturbances, induced by radio frequency fields, level 3	IEC 61000-4-6

7.1.11.6 Test No. 8.4 — Vibration

For the requirements, see 4.2.7.5.

These requirements shall be verified in accordance with Table 6. During this test it shall be verified that the output signal switching device remains in the ON state. After the vibration test has been completed, the normal functioning of the pressure-sensitive protective device shall be verified.

Table 6 — Vibration

Test procedure	Test conditions
IEC 60068-2-6	Pressure-sensitive protective device is connected to the power supply. The sensor may be tested by inspection and/or analysis. The control unit and the output signal switching device shall be tested in three axes perpendicular to each other.

7.1.12 Test No. 9 — Power supply variation

7.1.12.1 General

For the requirements, see 4.2.8.

The pressure-sensitive protective device shall be subjected to the analysis, inspection and/or tests given in 7.1.12.2 and 7.1.12.3.

7.1.12.2 Test No. 9.1 — Electrical power supply variation

For the requirements, see 4.2.8.2.

The normal function of the pressure-sensitive protective device shall be verified according to the requirements given in IEC 60204-1:2005, 4.3. The function shall be checked using test piece 1 applied to the effective sensing surface with the corresponding actuating force given in Table 2, in the reference direction, at the maximum operating speed at one random location. Each requirement is fulfilled if an OFF state of the output signal switching device is produced.

7.1.12.3 Test No. 9.2 — Non-electric power supply variations

For the requirements, see 4.2.8.3.

The functioning of the pressure-sensitive protective device shall be verified at the limits of power supply variations stated by the manufacturer. Possible variations outside the stated range shall not cause the pressure-sensitive protective device to fail to danger.

7.1.13 Test No. 10 — Electrical, hydraulic, pneumatic and mechanical equipment

7.1.13.1 Test No. 10.1 — Electrical equipment

For the requirements, see 4.2.9.

It shall be verified, by inspection, analysis and, if necessary, testing, that the requirements of 4.2.9.1 to 4.2.9.7 are met.

7.1.13.2 Test No. 10.2 — Hydraulic equipment

For the requirements, see 4.2.10.

It shall be verified, by inspection, analysis and, if necessary, testing, that the requirements of ISO 4413 and ISO 13849-2 are met.

7.1.13.3 Test No. 10.3 — Pneumatic equipment

For the requirements, see 4.2.11.

It shall be verified, by inspection, analysis and, if necessary, testing that the requirements of ISO 4414 and ISO 13849-2 are met.

7.1.13.4 Test No. 10.4 — Mechanical equipment

For the requirements, see 4.2.12.

It shall be verified, by inspection, analysis and, if necessary, testing, that the requirements of ISO 12100:2010, 6.3.3 and ISO 13849-2 are met.

7.1.14 Test No. 11 — Enclosure

For the requirements, see 4.2.13.

It shall be verified, by inspection, analysis and, if necessary, testing, that the requirements of 4.2.13.1 and 4.2.13.2 are met.

7.1.15 Test No. 12 — Access

The requirement of 4.2.14 shall be verified by inspection.

7.1.16 Test No. 13 — Performance-Level (PL) according to ISO 13849-1

7.1.16.1 General

For the requirements, see 4.2.15.

The foreseen safety functions, PLs and categories shall be validated according to ISO 13849-2.

7.1.16.2 B_{10d} value for sensor

When performing the test, the following frame conditions shall apply:

a) length of test sample: at least 500 mm;

b) test piece: No. 1 according to Figure 5;

c) test speed: selectable based on the application;

d) working travel: until sensor change;

e) measurement points: one from C1 to C5, or more freely selectable points from C1 to C5;

f) minimum number of operations: 10 000 (per test location at freely selectable points).

7.1.17 Test No. 14 — Adjustments

The requirements of 4.2.16 shall be verified by inspection and, if necessary, testing.

7.1.18 Test No. 15 — Sensor fixing and mechanical strength

The requirements of 4.2.17 shall be verified by inspection and, if necessary, testing.

7.1.19 Test No. 16 — Connections

The requirements of 4.2.18 shall be verified by inspection.

7.1.20 Test No. 17 — Inhibition and blocking

The requirements of 4.2.19 and 4.4.2 shall be verified by inspection and functional testing by simple means (e.g. by inserting a wire, pin, adhesive tape, wedge or magnet).

7.1.21 Test No. 18 — Sharp corners, sharp edges, rough surfaces and trapping

The requirements of 4.2.20 shall be verified by inspection.

7.1.22 Test No. 19 — Shock

The requirements of 4.2.21 shall be verified, by inspection, analysis and, if necessary, testing, in accordance with 7.3.1.

7.2 Verification of requirements for pressure-sensitive bumpers only

7.2.1 Test No. 20 — Force-travel relationship

The requirements of 4.3.1 shall be verified by inspection, analysis and, if necessary, testing.

Where testing is necessary, the force-travel relationship(s) shall be confirmed in accordance with Figure 2 by applying test piece 1 (see Figure 3 and Table 2) to the sensor (see Figure 5) at the maximum approach speed up to point A in Figure 2. If another test piece from Figure 3 or Figure 4 is more appropriate for a particular application, it shall be used instead. The reaction force of the sensor and the distance moved by the test piece shall be continuously measured from the point where the test piece touches the effective sensing surface until the actuating force is reached. Points B1, B2 and C shall be confirmed in accordance with Figure 2 by applying test piece 1 to the sensor at a speed ≤10 mm · s^{-1}. The force-travel relationship can then be shown by connecting points A, B1, B2 to C by straight lines. This test shall be carried out at a representative location, e.g. in the centre of the effective sensing surface, and at a temperature of 20 °C.

7.2.2 Test No. 21 — Additional coverings for sensors

If additional coverings are specified by the manufacturer, then it shall be verified that the requirements of 4.3.2 have been met.

7.2.3 Test No. 22 — Recovery after deformation

The requirements of 4.3.3 shall be verified by inspection, analysis and, if necessary, testing.

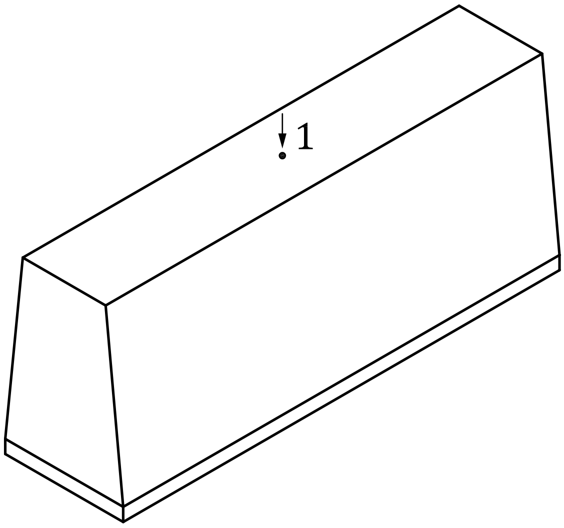
After the effective sensing surface of the sensor has been deformed or moved by the working travel using test piece 1 (see Figure 5) for 24 h, the effective sensing surface shall recover as shown in Table 1. The working travel in this instance is taken from test no. 4 with a test speed of 10 mm · s^{-1} at a force of 250 N.

After the effective sensing surface of the sensor has been deformed or moved by the working travel using test piece 1 for 24 h, the pressure-sensitive bumper shall have normal functioning within 30 s.

7.2.4 Test No. 23 — Detection on bumpers with semi-rigid or rigid surfaces

For the requirements, see 4.3.4.

It shall be verified by inspection that it is not possible to stand undetected inside the structure of the bumper (see Figures C.3 and C.4). This requirement is fulfilled if there is no opening larger than a diameter of 50 mm.



Key

1 test direction

Figure 5 — Test location and test direction on surface of pressure-sensitive bumper

7.3 Verification of requirements for pressure-sensitive plates only

7.3.1 Test No. 24 — Shock

The requirements of 4.4.1 shall be verified by inspection, analysis and, if necessary, testing.

It shall be verified that the output signal switching device remains in the ON state during the test in accordance with Table 7.

Table 7 — Shock

Test procedure	Test conditions
IEC 60068-2-27	Pressure-sensitive plate is connected to the supply. The sensor shall be tested in the relevant reference direction and in the opposite direction only.

After the shock test has been completed, the normal functioning of the pressure-sensitive plate shall be verified and the pressure-sensitive plate shall be checked for mechanical damage, loose parts, etc.

7.3.2 Recovery after deformation

The requirements of 7.2.3 apply.

7.4 Verification of requirements for pressure-sensitive wires only

7.4.1 Test No. 25 — Breaking or disengagement of the wire

For the requirements, see 4.5.2.

An OFF state shall be generated when normal tension is removed from the wire.

7.4.2 Test No. 26 — Actuating force

For the requirements, see 4.5.3.

The test shall be carried out with test piece 5 at a test speed of 10 mm · s^{-1} or less in the specified directions at the least favourable location(s) on the effective sensing surface.

7.4.3 Test No. 27 — Tensile strength of the sensor (including any connections)

For the requirements, see 4.5.4.

The test shall be carried out on a sample sensor to ensure that the sensor does not break under a tensile force of 1 000 N for at least 1 min.

7.4.4 Test No. 28 — Actuating deflection of the wire

For the requirements, see 4.5.5.

The test shall be carried out using a sample sensor with the maximum length of wire stated by the manufacturer.

7.5 Other tests

7.5.1 Test No. 29 — Marking

The requirements of Clause 5 shall be verified by inspection.

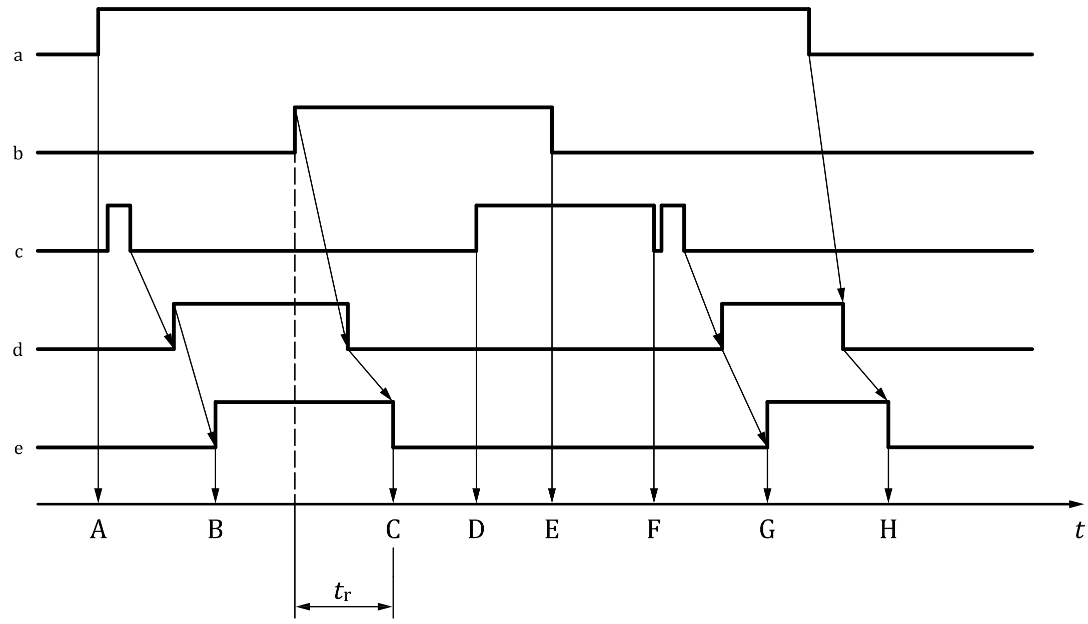
7.5.2 Test No. 30 — Information for selection and use

The requirements of Clause 6 shall be verified by inspection.

Annex A
(normative)

Timing diagrams for pressure-sensitive bumpers, plates, wires and similar devices with/without reset

Figures A.1 to A.4 shows the relationship between actuating force, reset signal and outputs of the sensor and output signal switching device (see 4.2.6).



Key

a) power to pressure-sensitive protective device

b) actuating force

c) reset signal

d) sensor output

e) output of output signal switching device(s)

t time

t_r response time

A power to pressure-sensitive protective device ON: output of output signal switching device remains in OFF state because pressure-sensitive protective device not reset

B reset achieved: output of output signal switching device turns to ON state because sensor output turned ON due to operation of reset button without actuating force on sensor

C output of output signal switching device turns to OFF state because sensor output turned OFF due to actuating force on sensor

D reset signal present: operation of reset button has no effect on output of output signal switching device as long as force present on sensor; output of output signal switching device remains in OFF state

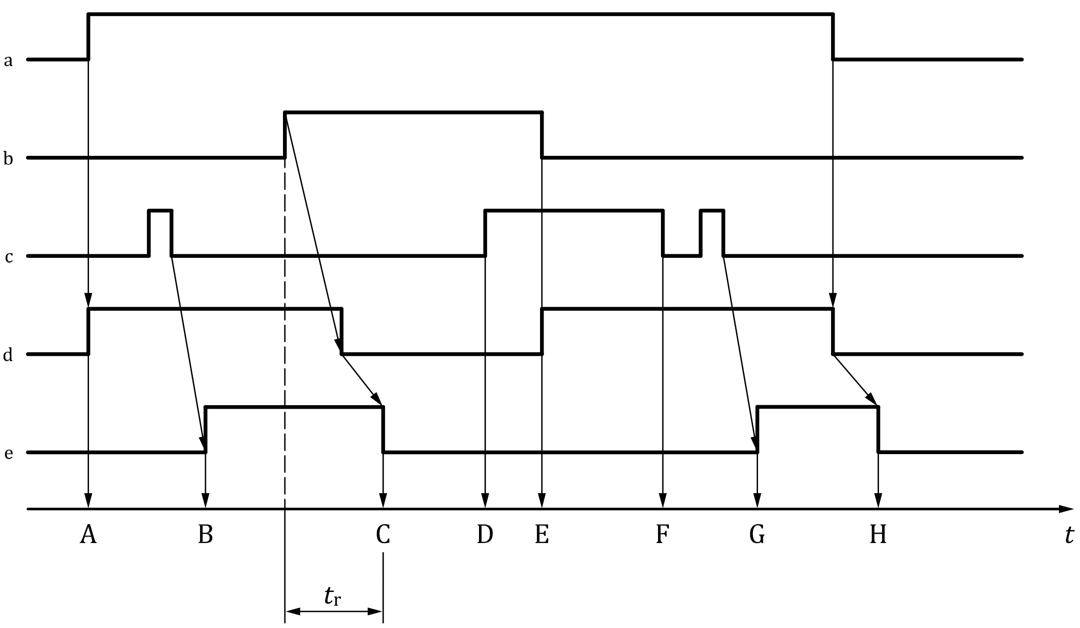
E actuating force removed from sensor: output of output signal switching device remains in OFF state even though reset signal still present

F reset signal removed: release of reset button has no effect on output of output signal switching device even when force removed from sensor

G reset achieved: output of output signal switching device turns to ON state because sensor output is turned ON due to operation of reset button without actuating force on the sensor

H power to pressure-sensitive protective device OFF: output of output signal switching device turns to OFF state because sensor output turned OFF

Figure A.1 — Sensor output initiated by reset function



Key

a) power to pressure-sensitive protective device

b) actuating force

c) reset signal

d) sensor output

e) output of output signal switching device(s)

t time

t_r response time

A power to pressure-sensitive protective device ON: output of output signal switching device remains in OFF state because pressure-sensitive protective device not reset; sensor output turned ON when power turned ON

B reset signal achieved without actuating force on sensor: output of output signal switching device turns to ON state due to operation of reset button while sensor output turned ON

C actuating force on sensor: sensor output turned OFF, turning output of output signal switching device to OFF state

D reset signal present: operation of reset button has no effect on output of output signal switching device as long as force present on sensor; output of output signal switching device remains in OFF state

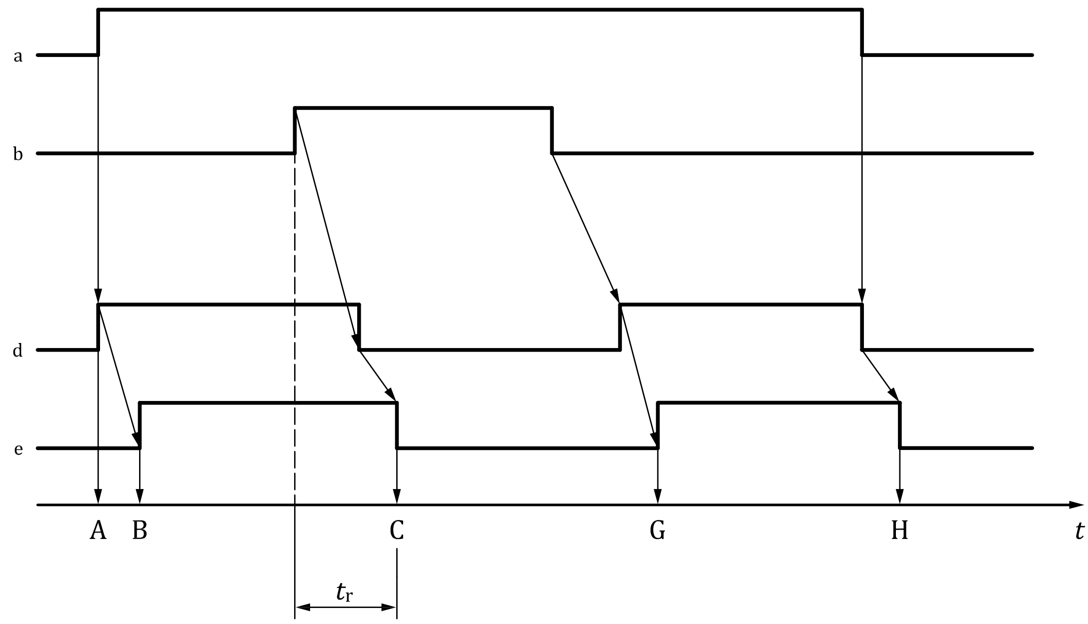
E actuating force removed from sensor: sensor output turns ON but output of output signal switching device remains in OFF state even though reset signal still present

F reset signal removed: release of reset button has no effect on output of sensor, which remains ON; output of output signal switching device remains in OFF state

G reset signal achieved without actuating force on sensor: output of output signal switching device turns to ON state due to operation of reset button while sensor output turned ON

H power to pressure-sensitive protective device OFF: output of output signal switching device turns to OFF state because sensor output turned OFF

Figure A.2 — Sensor output independent of reset function



Key

a) power to pressure-sensitive protective device

b) actuating force

c) reset signal

d) sensor output

e) output of output signal switching device(s)

t time

t_r response time

A power to pressure-sensitive protective device ON: sensor output turned ON when power turned ON

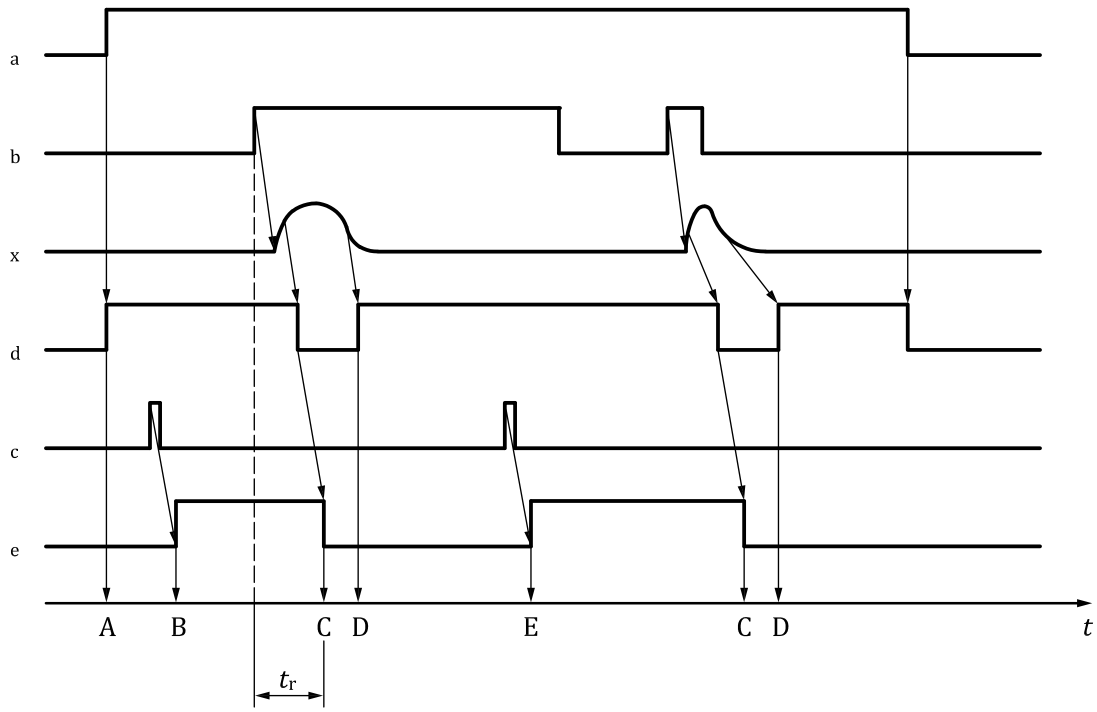
B output of output signal switching device turns to ON state because no actuating force on sensor

C actuating force on sensor: sensor output turned OFF, turning output of output signal switching device to OFF state

G output of output signal switching device turns to ON state because sensor output turned ON due to removal of actuating force from sensor

H power to pressure-sensitive protective device is OFF: output of output signal switching device turns to OFF state because sensor output turned OFF

Figure A.3 — Sensor output without reset function



Key

a) power to electrical circuits of pressure-sensitive protective device
b) actuating force
c) reset signal
d) electrical output of sensor (air-pulse switch)
e) output of output signal switching device(s)
A power to pressure-sensitive protective device ON
B reset signal present: output of output signal switching device turns to ON state
C actuating force on the sensor: electrical output of sensor turned OFF, turning output of output signal switching device to OFF state
D electrical output of sensor turns to ON state due to pressure decay in sensor
E reset signal present: output of output signal switching device turns to ON state, although actuating force is still applied —can lead to danger
x) pressure pulse in sensor
t time
t_r response time

The point at which "D" occurs will depend on a number of factors, for example the level of force applied and the controlled rate of leakage of air from the system.

As indicated in 4.2.6.2, air-pulse systems are not considered to fulfil the requirements of category 1 according to ISO 13849-1:2006. See C.3.6 for additional information on air-pulse systems.

It is necessary for the control system of the machine to have its own safety system to ensure that no hazardous restart occurs. On powered doors, for example, this can be in the form of automatic machine reversal or manual reset. The correct functioning of such controls shall be described in the relevant type-C standards.

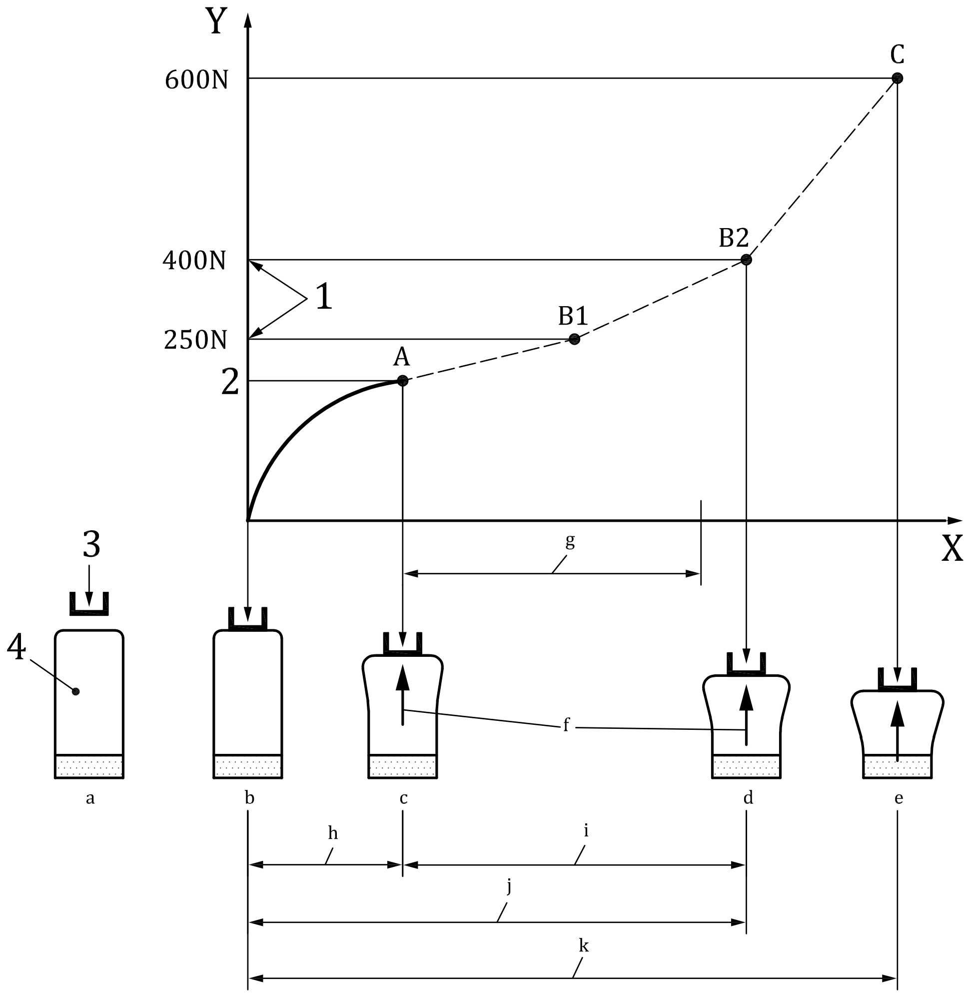
As shown, this system has no means of checking the operation of the sensor in response to a pressure impulse. On doors, in order to satisfy category 2 according to ISO 13849-1:2006, this shall be the function of the door control system.

Figure A.4 — Sensor output for trip devices where the sensor output does not remain in OFF state when actuating force is still applied (e.g. air-pulse or piezo-electric systems)

Annex B
(informative)

Device characteristics — Explanatory remarks and recommendations

Figure B.1 gives the principle of operation only. For some pressure-sensitive protective devices, such as example pressure-sensitive plates, the curve can have a different shape depending on the design.



Key

X	travel, mm	a	sensor before contact	g	established stopping travel of machine
Y	force, N	b	point of contact	h	actuating travel
1	reference forces	c	point of actuation	i	overtravel
2	lowest actuating force	d	deformation at point B2	j	working travel
3	hazard speed	e	deformation at point C	k	total travel
4	sensor	f	reaction force		

Forces are related to test piece 1 of Table 2 and are examples only.

Figure B.1 — Force-travel relationship for pressure-sensitive protective devices

a) **Actuating travel**

The force increases from the point of contact with the obstruction. At a given point, the sensor signals the control unit to go to the OFF state. A signal is then sent to the machine control system to stop the hazardous movement. The distance travelled between these two points is called the actuating travel. This distance can vary with the approach speed and environmental conditions.

b) **Overtravel and total travel**

Overtravel is the distance in which the speed decreases and the applied force increases. The maximum permissible force specified by the supplier and selected by the user for an application should be less than the reference force according to the type-C standard or the risk assessment and should occur within the overtravel. See Figure B.2.

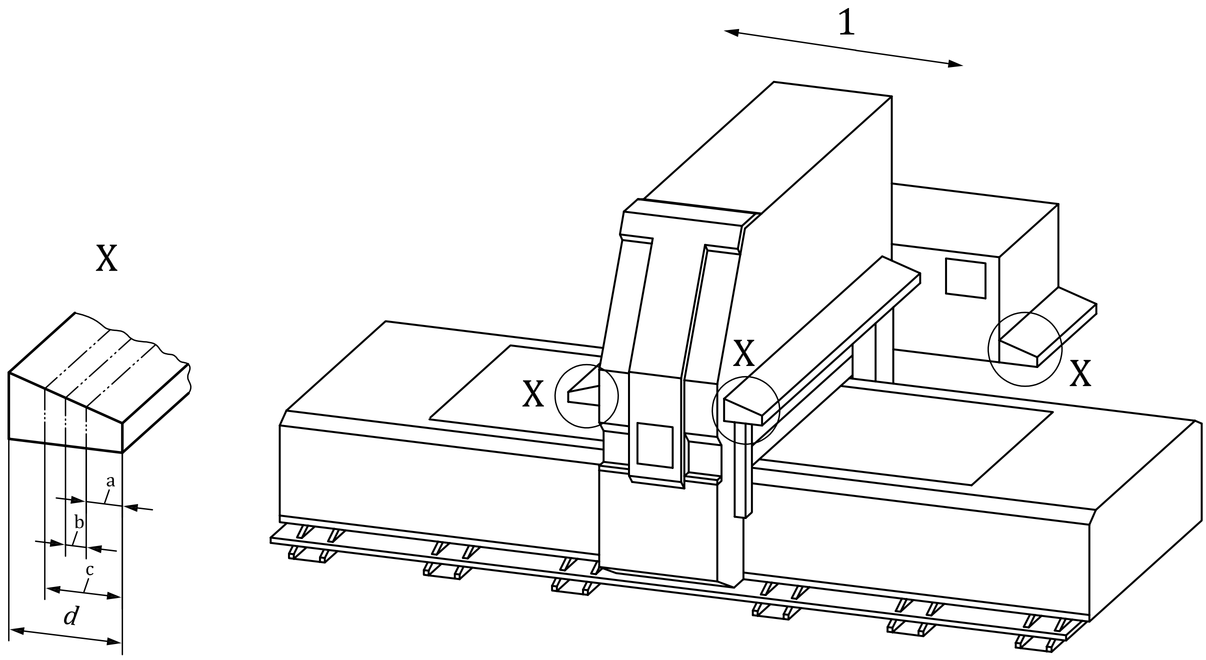
A number of factors can cause the maximum permissible force to be exceeded, any of which can lead to injury due to excessive force acting on the body part concerned when no further sensor deformation is possible.

EXAMPLE Brake deterioration (age), extended response time, mechanical wear, increased hazard speed.

Depending on the design, the overtravel for pressure-sensitive plates can be either very small (i.e. where the travel is deliberately restricted) or infinitely large (i.e. where the plate is designed to move completely out of the way).

In all applications, the force exerted on a person should be kept to a minimum. The maximum permissible force can be influenced by, e.g. the duration of application of the force, the dimensions of the sensor, the material of the sensor and the body parts being protected. Special consideration should be given to those applications where children or elderly persons are to be protected.

The moving power transmission elements and tools are protected with fixed and interlocked guards. Bumpers are used to protect a person who may enter the path of the moving enclosure.



Key

1 direction of travel

a actuating travel

b overtravel

c total travel

d overall bumper height

Figure B.2 — Example of bumper mounted on woodworking machine

Annex C
(informative)

Design guidance

C.1 Application note

This annex gives some guidance on the design of pressure-sensitive protective devices. However, ignoring this design guidance does not necessarily mean that the pressure-sensitive protective device as finally constructed will be unsafe.

C.2 General

C.2.1 Frequency of operation

Pressure-sensitive protective devices are frequently used in applications where they are not actuated for many months. However, when they are actuated, they should work safely.

Conversely, some pressure-sensitive protective devices are used on applications where they are frequently activated. This can sometimes result in a change of sensitivity over time.

C.2.2 Components

Components of pressure-sensitive protective devices should be fully protected from foreseeable damage, e.g. with protective sheaths.

C.2.3 Effects of liquid

Where components can come into contact with liquids such as oils, chemicals or water, the sensor should be made of suitable materials which will not corrode, degrade or swell, resulting in a loss of sensitivity.

C.2.4 Profile material

The profile material of the sensor should withstand the operating duty and environmental conditions.

C.2.5 Sensor sensitivity

Sensors can have certain parts of the pressure-sensing surface which are less sensitive than others and also parts which can be more easily damaged than others. Sensitivity can be reduced near the connection point with incoming cables, tubes, fibres or leads and at points where contact elements are held apart.

C.2.6 Use of position detection switches

Where position detection switches are used, e.g. as a part of the sensor of pressure-sensitive plates or pressure-sensitive bumpers, the following design characteristics should be considered:

— displacement or removal of the sensor;

— permanent deformation of the top surface due to overloading;

— sticking of position detection switches due to infrequent use;

— excessive wear or misalignment of cams on cam-operated systems;

— position detection switches becoming loose on brackets causing misalignment.

Where position detection switches are used with rigid sensors, their reliability should be considered in relation to the consequences of their failure. The use of position detection switches manufactured in accordance with IEC 60947-5-1 is recommended.

C.2.7 Trap points

Consideration should be given to the design of pressure-sensitive protective devices having rigid sensors with respect to the prevention of trap points. Where possible, gaps which close when the sensor is deflected/displaced should be eliminated at the design stage. If there is a gap which reduces when the sensor is moving or being deflected/displaced, the gap should remain large enough to avoid becoming a trapping hazard.

C.2.8 Result of sensor actuation

After the pressure-sensitive sensor has been actuated, the control system of the machinery can be designed to

— stop the machine, or

— reverse the direction of machine motion.

If the machine has been stopped through the actuation of a pressure-sensitive sensor, an automatic reset should not be possible. Restarting the machine should be possible only after manual operation of a reset device. The reset can be provided by the control system of the pressure-sensitive protective device or by the control system of the machinery.

Automatic reset may be possible, depending upon the application and the risk assessment.

C.2.9 Use of pressure-sensitive protective devices as combined trip and presence-sensing devices

When a pressure-sensitive protective device is used as a combined trip and presence-sensing device it shall perform the trip function. Reset shall not be possible as long as a person is present in the hazard zone.

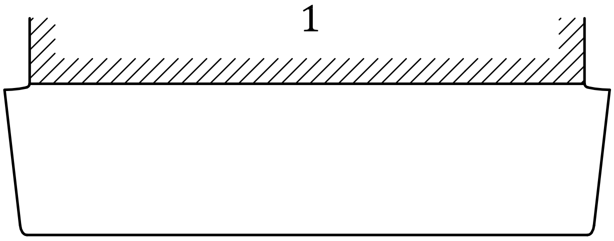
C.3 Pressure-sensitive bumpers

C.3.1 General

Bumpers are generally made in two forms: either of foam or rigid surfaces. They can be installed on the leading edge of a machine or wrapped around to include the sides. Examples of foam bumpers are shown in Figures C.1 and C.2.

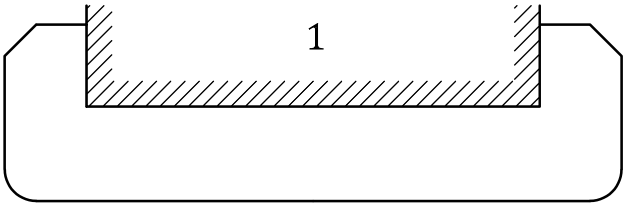
Bumpers designed in accordance with Figure C.1 are generally used where the movement is in a straight line. See Figure B.2.

Bumpers designed in accordance with Figure C.2 are used when the movement is multidirectional. This is the case on a vehicle turning a corner.



Key
1 mounting surface

Figure C.1 — Foam bumper



Key
1 mounting surface

Figure C.2 — Foam bumper

C.3.2 Physical effects

Ingress of material (either in small or large particles), vermin or fluid, which can be present in the area in which the pressure-sensitive protective device is to be used, can cause the sensor made of flexible foam to degrade or to lose its sensitivity.

It is possible that a very small hole in the surface of the flexible foam remains undetected during regular inspection. However, the hole can be sufficiently large to allow fluid penetrating into the interior of the pressure-sensitive bumper. The larger the pressure-sensitive bumper, the more fluid or dirt can get into the gap and form a barrier which prevents the sensor from being actuated. Conversely, it can be desirable to ensure that fluids can escape from a pressure-sensitive bumper by or through a suitable porous area.

C.3.3 Pressure-sensitive bumpers with electric sensors

On some designs, electric contact elements are used. The contact elements are normally separated by an air gap which is closed when pressure is applied to the surface. The air gap may be maintained by springs, insulating pads or a resilient foam. Consideration should be given to the effects of failure of these components, e.g. failure should not result from parts breaking off and moving around inside a pressure-sensitive sensor, thereby impairing sensitivity or preventing operation.

The manner of the electrical connections to the sensor should also be considered. They should be of high integrity. The leads should be connected so that any open circuit to any single sensor will be detected.

C.3.4 Pressure-sensitive bumpers with fibre optic sensors

These pressure-sensitive bumpers normally operate on a reduction of light passing through an optical fibre. Consideration should be given to the long-term changes that can occur in the light emitters and detectors and in the optical fibre. The means by which the mechanical force is translated into an optical change should be stable. There should be no possibility of light from the emitter being picked up by the detector without going through the optical fibre — for example, after a fibre breakage.

C.3.5 Pressure-sensitive bumpers with position-detection switches

These pressure-sensitive bumpers normally operate on transferring the actuating force to the position detection switch which interrupts an electric circuit. The design should ensure that mechanical failure, misalignment or other foreseeable situations will not lead to a reduction in safety level. The same conditions apply where light beams or proximity switches are used in place of position detection switches.

C.3.6 Pressure-sensitive bumpers with air-pulse sensors

A rupture/puncture, such as a tear or a hole in an air-pulse sensor or its connecting elements, can lead to the instantaneous loss of the safety function. In this case, the control unit should detect such rupture/puncture and maintain the output signal switching device in the OFF state while the rupture/puncture exists. This can be achieved with a system which regularly checks the integrity of the system. The output signal switching device should remain in the OFF state until manual reset by authorized personnel.

With some air-pulse sensors, the deformation of the sensor profile causes a pressure rise which is transmitted along a tube to an air pressure switch. If the system does not have a constantly maintained air pressure, the following faults can occur.

— Damage such as cuts or permanent deformation of the profile will not be detected.

— The connecting tube can be cut, become disconnected, or kinked without detection.

— The air pressure switch does not operate when the sensor is deformed at a low approach speed.

— The reaction time is extended when a long connecting tube is used between the sensor and the air pressure switch.

— Most air pressure switches include an air “bleed” to compensate for changing ambient conditions. If this air bleed becomes blocked, the pressure-sensitive bumper can fail to operate.

— The setting of the air bleed will depend upon the cross-section of the sensor profile, the length of the sensor, the material of the sensor and the temperature range of the application. See 4.2.16.

— If the air bleed is too large, the sensitivity of the pressure-sensitive bumper is reduced.

— If the sensor is compressed so that a large proportion of the internal air is expelled, a partial vacuum is created when the sensor is released. This vacuum can severely reduce the sensitivity of the sensor or prevent its immediate re-actuation.

C.3.7 Pressure-sensitive bumpers with dynamic sensors

Several technologies make use of dynamic sensing such as air-pulse or light-pulse monitoring. The effect is to regularly check the state of the system so that any failure results in the output signal switching device going to the OFF state. The output signal switching device should remain in the OFF state until manual reset by authorized personnel.

The system can also be used to set a pre-determined level of sensitivity which is re-set with every cycle of the machine and can vary in a pre-determined way during the cycle of the machine.

C.3.8 High impact forces

In some situations, high-impact forces (e.g. from the forks of manually operated fork lift trucks) can be applied to the sensor during service. If this is foreseeable, extra measures are required.

C.3.9 Pressure-sensitive bumpers with semi-rigid or rigid surfaces

There is a risk that movement of the semi-rigid or rigid surface of a pressure-sensitive bumper will be inhibited or blocked. This can be caused by any one of the following:

- failure by blocking or wedging;
- long term build-up of dirt;
- permanent deformation of the rigid active surface;
- seizing of the guides.

C.3.10 Pressure-sensitive bumpers mounted on moving and stationary parts of machinery

C.3.10.1 Pressure-sensitive bumpers mounted on moving parts of machinery

The following remarks apply to all applications where the pressure-sensitive bumper is mounted on the moving part of the machine, e.g. the leading edge of a power-operated door (see Figure C.3), or an automated guided vehicle.

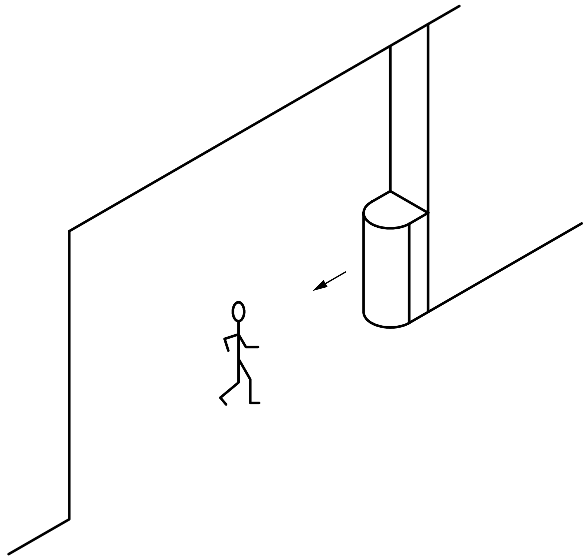


Figure C.3 — Pressure-sensitive bumper mounted on power-operated door

There are several important considerations to be taken into account in the risk assessment of the machine and in the selection, design and application of a pressure-sensitive bumper when it is mounted on moving machinery.

Since the pressure-sensitive bumper detects the person (or other obstacle) only after the person has already made contact with it, it is essential that

- the bumper reliability is appropriate for the risk assessment of the machinery,
- the pressure (force) applied to the person does not cause damage to health (i.e. the overtravel of the pressure-sensitive bumper is acceptable), and
- the stopping performance of the machinery is acceptable in all foreseeable conditions.

When assessing the stopping performance of machinery, the worst case shall be taken into account. At least the following factors shall be considered:

- worn brakes or reduced braking performance for some other reasons;

— ground conditions (floor finish, guide rails etc.);

— environmental conditions (water, ice, oil or other slippery material) on the floor;

— loss or fluctuations in energy supply.

C.3.10.2 Approach speed

The allowable approach speed will depend upon the risk assessment for the machine, which should include

— combined speed of approach of the person and the machine,

— the energy dissipated on impact,

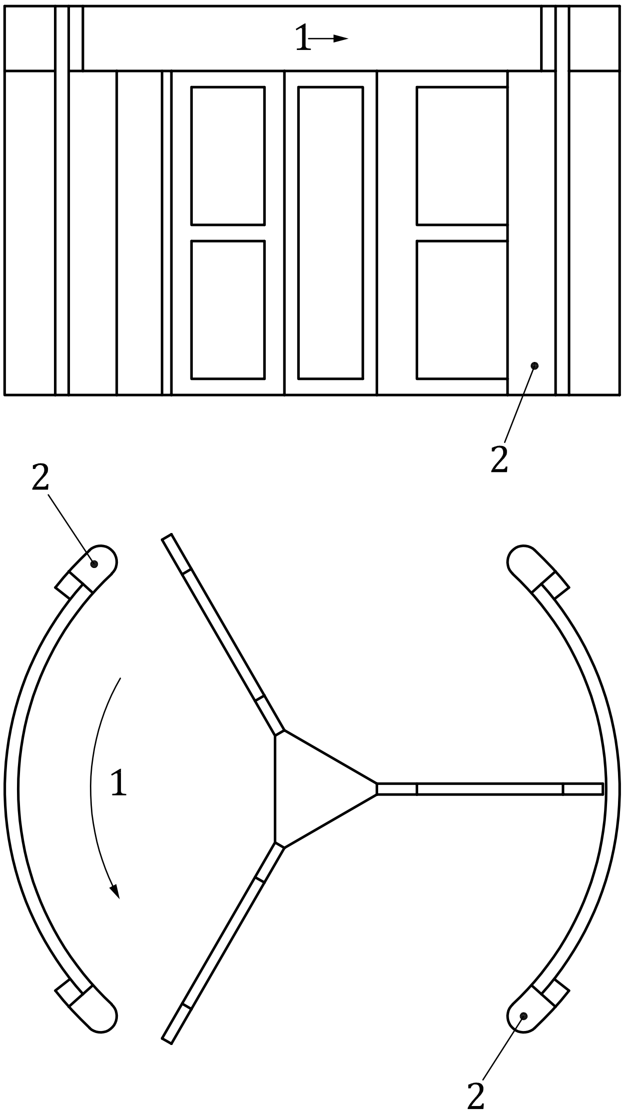
— the risk of crushing, and

— the stability of any load carried by the machine.

In some cases it is required to set a second (non-contact) safeguard aside which will reduce the approach speed to an acceptable level before contact is made.

C.3.11 Stationary pressure-sensitive bumpers

When a stationary pressure-sensitive bumper (see Figure C.4) is actuated, the machine shall arrive at a safe state before harm can be caused through contact with the moving part of the machine. If this is the case, then the guidance given in C.3.10 applies to stationary pressure-sensitive bumpers also.



Key

1 rotation

2 leading mullion pressure-sensitive bumper

Figure C.4 — Pressure-sensitive bumper on mullion of power-operated rotating door

C.4 Pressure-sensitive plates

C.4.1 General

When a pressure-sensitive plate is used on an access opening to a hazard zone, there is a risk that the moving part of the sensor can be inhibited or blocked. This can be caused by any one of the following:

— failure by blocking or wedging;

— long term build-up of dirt;

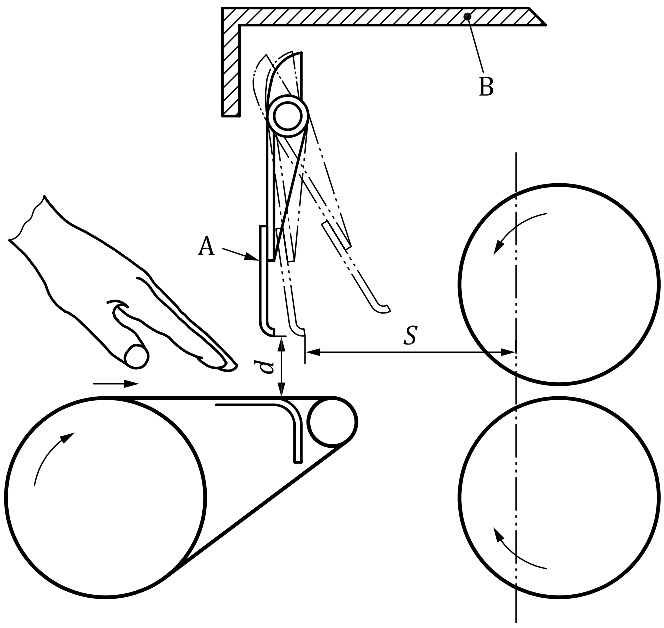
— warping/bending of the moving part of the sensor;

— seizing of the guides

The sensor will be adjusted so that it will operate with the correct amount of movement of the pressure-sensitive plate to achieve an OFF state in the output signal switching device.

C.4.2 Minimum separation distance

See Figure C.5.



Key

A pressure-sensitive plate

B fixed guard

S minimum distance from the detection zone (point, line or plane) to the hazard zone, mm [a]

d sensor detection capability of the pressure-sensitive protective device, mm [b]

[a] See Formula (C.1).

[b] See ISO 13855:2010, 6.2.3.1.

Figure C.5 — Pressure-sensitive plate

The distance and dimensions of the pressure-sensitive plate are determined on the basis of the principles presented in ISO 13855.

The basic equation is

$$S = K \times T + C \quad \text{(C.1)}$$

where

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

K is a parameter derived from data on approach speeds of the body or body parts (typically 2 000 mm · s^{-1} — see Note, below);

T is the overall system stopping performance (time interval between the actuation of the sensing function of the pressure-sensitive plate and the termination of the hazardous machine function), in seconds;

C is the intrusion distance (distance that a body part (usually a hand) can move past the safeguard towards the hazard zone prior to actuation of the safeguard, i.e. how far towards the hazard zone it is possible to push the hand before it is detected by movement of the pressure-sensitive plate), in millimetres.

NOTE For a detailed calculation, ISO 13855 states the following parameters for this equation:

K = 2 000 mm · s^{-1}, for minimum distances of $S \leq 500$ mm, while $S \geq 100$ mm;

K = 1 600 mm · s^{-1}, for minimum distances of $S > 500$ mm, while $S \geq 500$ mm.

When the opening between the hinged plate and the fixed part is less than 40 mm at the moment when the changed position is detected, the pressure-sensitive protective device is able to detect the arm. The intrusion distance C depends on the actual opening (sensor detection capability d), in millimetres at the point of detection. C = 8 (d − 14 mm), but not less than zero.

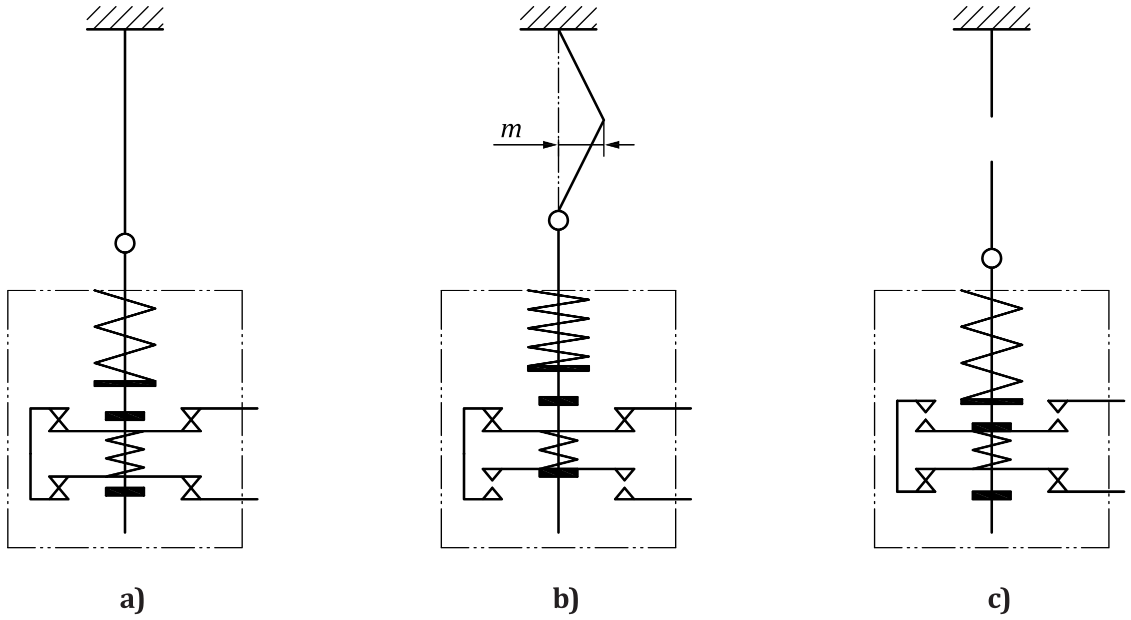
When the opening (d) is between 40 mm and 120 mm at the point of actuation the upper limb can be pushed through up to the shoulder. In this case C = 850 mm.

It shall be possible to withdraw the hand from under the plate regardless of the position of the plate.

C.5 Pressure-sensitive wires

When wires or ropes are used as pressure-sensitive protective devices, they give only partial protection because they cannot be used as the sole means of preventing access to a hazard zone. In addition, they should be designed and installed such that they fulfil the relevant requirements for emergency stops (see ISO 13850:2006, Clause 4 and IEC 60947-5-5:1997, 6.4).

See Figure C.6 for an example of the principle of the operation of a pressure-sensitive wire.



Key

m actuating deflection of pressure-sensitive wire

Figure C.6 — Example of pressure-sensitive wire

In Figure C.6 a) both contacts of the interlocking device are closed and the operation of the machine is possible;

In Figure C.6 b) the pressure-sensitive wire has been deflected by the necessary amount *m*. One pair of contacts have been directly opened and a stop signal has been generated. In this case, the contacts have also been latched in the open position;

In Figure C.6 c) the pressure-sensitive wire has been broken. The spring has forced the other pair of contacts open and a stop signal has been generated.

NOTE The linear deflection of the pressure-sensitive wire is usually limited by physical means so that the switch cannot be damaged by excessive actuating deflection of the wire.

Annex D
(informative)

Application guidance

D.1 Application note

This annex gives general guidance on the application of the pressure-sensitive protective devices covered by this part of ISO 13856.

D.2 General selection criteria

The general selection criteria should include the following.

NOTE The given list is not complete and special conditions, such as combinations of the selection criteria, can apply to particular applications.

a) Relevant category, performance level and B_{10d} values according to ISO 13849-1 and risk assessment.

b) Approach speed: This is the speed at which the hazardous surface is moving or approached by the person. Normally one surface is moving and the other is stationary. The maximum possible speed should be considered as the approach speed. If both the person and the hazardous surface are moving, or two moving surfaces form a trapping hazard, then the combined approach speed will need to be estimated.

c) Stopping travel of the hazardous parts: This is the distance travelled by the hazardous surfaces after a stop signal has been given by the output signal switching device to the machine control system. This travel depends on the hazard speed, the response time of the machine control system and the efficiency of the machine braking system. This travel can be calculated and/or measured. A suitable safety factor should be used where appropriate to account for brake deterioration, measurement tolerances, etc.

d) Use as a single protective device or in combination with other safeguards.

e) Ability to combine sensors.

f) Avoidance of “dead” surfaces.

g) Frequency of operating cycles and lifetime of the system.

h) Switching capacity of the output signal switching device.

i) Temperature and humidity outside the defined range.

j) Radiant heat.

k) Rapid variations in temperature and humidity.

l) Effects of chemicals, such as oils, solvents, cutting fluids and combinations of these.

m) Effect of foreign bodies such as swarf, dust and sand.

n) Additional covering for the sensor.

o) Stress due to vibration, shocks etc.

p) EMC.

q) Supply voltage fluctuations outside the specification (see IEC 60204).

r) Sensitivity levels which can differ from the requirements of this part of ISO 13856.

s) Need for reset and the location of the reset button.

t) Need for special wording on signs and marking.

u) Sensor fixing.

v) Variation of performance with time.

w) Indirect influences such as floor surfaces.

x) Recovery time of the sensor after deformation: On some applications, the time between successive actuations of the sensor is less than the recovery time of the sensor. In this case, a sensor should be selected which will recover normal operation within the time available.

y) Interfacing with the machine control system.

D.3 Application of sensor

D.3.1 General

In general, sensors are used on two types of application:

— **Application 1**

They are used to stop machinery which is remote from the sensor. In this instance, the sensor is mounted such that the machine will stop before any body part can reach the hazard zone. See ISO 13855.

— **Application 2**

They are mounted on the hazardous part of the machine or adjacent to it so that the machine will stop or reverse to a safe position after the sensor is actuated and before injury can occur.

D.3.2 Application 1

A typical application is illustrated in Figure C.5. After deciding on the performance level and category according to ISO 13849-1, the procedure is as follows.

a) Determine the approach speed between the hazard and the pressure-sensitive protective device according to ISO 13855.

b) Determine the response time of the pressure-sensitive protective device and the control system of the machine.

c) Determine the stopping travel of the machine.

d) Where appropriate, determine the opening required for normal operation and the distance to be allowed before the pressure-sensitive protective device is actuated.

e) Calculate the distance between the pressure-sensitive protective device and the hazardous part of the machine.

f) The distance given in e) multiplied by a suitable safety factor of at least 1,2 gives the required minimum separation distance for the application.

g) Where other circumstances exist, e.g. a braking system that is subject to deterioration, a higher safety factor should be used.

D.3.3 Application 2

After deciding on the performance level and category according to ISO 13849-1, the procedure is as follows:

a) **Determine the required operating speed and determine the maximum hazard speed.**

If the maximum hazard speed is not given, it should be measured or calculated. The point in the travel at which the maximum speed occurs will depend on the drive mechanism.

The maximum operating speed of the pressure-sensitive protective device should be greater than the maximum hazard speed.

b) **Determine the required minimum overtravel.**

Determine the stopping travel of the hazardous parts. If this is not given, it should be measured and/or calculated. The stopping travel multiplied by a suitable safety factor of at least 1,2 gives the required minimum overtravel for the application. Where other circumstances exist, e.g. a braking system that is subject to deterioration, a higher safety factor should be used. See Figure B.1.

A simple way to measure the stopping travel is to temporarily fit a position detector at a position close to where the maximum hazard speed occurs. Normally closed contacts of this position detector should be connected into the machine control stop circuit at the point where the output signal switching devices would be connected. The machine should be run several times in the worst anticipated conditions and the distance travelled beyond the actuating point of the position detector should be measured. The maximum distance measured should be regarded as the stopping travel.

c) **Determine the maximum permissible force.**

The maximum permissible force should be given in type-C standards or according to the risk assessment. The risk assessment should take into account the body parts that foreseeably can be in contact with the device and the types of persons to be protected, e.g. children or elderly persons. The contact speed, sensor shape, material of the sensor, stopping performance of the hazardous machinery and maximum pressure exerted by the pressure-sensitive protective device should also be considered. The maximum permissible force should be as low as possible.

d) **Device selection**

Using the force-travel relationship data or diagrams provided by the manufacturer, select the pressure-sensitive protective device with the required maximum operating speed which provides at least the required minimum overtravel distance before the maximum permissible force is reached.

If a pressure-sensitive protective device with sufficient overtravel cannot be found then it can be necessary to improve the stopping performance of the machine.

D.4 Sensor mounting

The mounting surface should be suitable for the sensor which will be used. If the mounting surface is not sufficiently rigid, or has large irregularities, the sensitivity and reliability of the pressure-sensitive protective device can be reduced. Where the sensor makes regular or repeated contact with a surface, sharp edges or irregularities should be avoided as they can cause damage. Connecting cables, tubes, etc. between the sensor and the control unit should be designed, positioned and fixed so that

a) they are able to withstand the design conditions,

b) they are protected from mechanical damage, and

c) they are firmly fixed, at least at each end, to prevent stress on connections.

Sensors may be mounted on either the fixed or moving part of a machine, e.g. a power-operated door. Figure C.4 shows a sensor mounted on the fixed part of the machine i.e. the door mullion. This is particularly suitable for rotating doors with a number of leaves.

Figure C.3 shows a sensor mounted to detect people only, but it could be desirable for the sensor to cover the full height of the door. It will then protect the door and obstacles such as vehicles.

It should not be possible for a body part to be inserted between the sensor and the surface on which it is mounted, e. g. a moving machine with a “skirt2 type sensor or a sensing plate which can trap a hand (see Figure C.5). If this is a possibility, additional protective measures should be provided.

D.5 Sensor positioning

The sensor should have sufficient effective sensing surface and should be mounted to ensure the most effective mounting orientation for the foreseeable direction of actuation.

D.6 Force imparted by the sensor

The sensor is frequently mounted on a moving surface which can create a collision, trapping or crushing hazard, e.g. a power-operated door. It is essential that the machinery manufacturer/user ensure that the braking or reversal of the moving parts is such that the reaction force of the compressed sensor will not exceed the maximum permissible force specified for the particular application.

The maximum force created by a person coming into contact with a moving sensor in free space will normally be lower than that created by a person being trapped between a moving sensor and a fixed obstacle.

The following aspects need to be taken into consideration when applying pressure-sensitive protective devices to prevent injury to people:

— the dimensions of the sensor;

— the stopping travel of the hazardous machine;

— the compressibility (and other properties) of the sensor material;

— the mobility and size of the person when in free space;

— the maximum force created when a person is trapped between the sensor and a fixed object.

NOTE An indication of maximum permissible forces acting on different body parts is given in Table 2. However, maximum permissible forces (pressures) are very different on different body parts. Injuries can vary also on the same body part depending on the direction of the travel, shape and material of the obstacle; (or sensor) etc. Therefore, risk assessment or a type-C standard can indicate lower values.

Annex E
(informative)

Commissioning and inspection

E.1 General

The information for use should include the following notes concerning commissioning, inspection and guidance on the recommended commissioning and testing after installation, in order to ensure the safe operation of the total system. See Clause 6 for documentation to be provided for information regarding selection and use of the pressure-sensitive protective device.

E.2 System information

The system should be installed, commissioned, tested and maintained in accordance with the information supplied by the manufacturer of the safeguard.

E.3 Commissioning

The person carrying out the commissioning should ensure that the following checks are carried out.

a) Check that the pressure-sensitive protective device is suitable for the environmental conditions.

b) Check that the pressure-sensitive protective device is fastened securely.

c) Check the rating and characteristics at all inputs/outputs, for example, rating of fuses.

d) Check that the removal of power supply from the pressure-sensitive protective device prevents further hazardous operation of the machine. The hazardous parts of the machine should not be capable of being reactivated until the safety function has been restored.

e) It should not be possible for the hazardous parts of the machine to be set in motion while an actuating force is applied to the effective sensing surface.

f) Ensure that the sensor has been installed to provide protection from all foreseeable directions of actuation and that no dead surfaces increase the risk of injury.

g) Actuation of the pressure-sensitive protective device during a hazardous phase of the operating cycle should result in the hazardous moving parts being arrested or, where appropriate, assuming an otherwise safe condition. It should not be possible for the hazardous moving parts to be set in motion again unless the safety function has been restored.

h) Check that when required a reset facility has been provided and that the hazardous function cannot be restarted after actuation of the pressure-sensitive device until the system has been reset.

i) An important feature for safety of the machine is the interface between the machine and its safeguard(s). Ensure that all parts of the machine, including the safeguard(s), the control circuit and the connections to the safeguard(s) comply with the results of the risk assessment and the categories and performance levels according to ISO 13849-1, as stated in the relevant standard(s).

j) Test the muting arrangements (if fitted) to the requirements of ISO 13849-1:2006, 5.2.

k) Check all indicator lamps are functioning correctly.

l) Check the sensitivity of the pressure-sensitive protective device over the whole effective sensing surface according to the manufacturer’s instructions.

m) Ensure that additional safeguards have been provided where necessary to prevent access to the hazardous parts of machinery from any direction not protected by the pressure-sensitive device.

n) Check that no trapping points have been created by the installation of the pressure-sensitive protective device.

NOTE In addition, other checks can be required as set out in relevant type-C standards.

E.4 Regular inspection and tests

Include the information given in E.3. In addition, the following should also be stated.

a) Test the machine control elements to ensure that they are functioning correctly and are not in need of maintenance and/or replacement.

b) Inspect the machine to ensure that there are no other mechanical or structural aspects that would prevent the machine from stopping or assuming an otherwise safe condition when stopped by the pressure-sensitive protective device.

c) Inspect the machine controls and connections to the pressure-sensitive protective device to ensure that no modifications have been made which adversely affect the system, and that suitable modifications have been properly recorded.

d) Inspect the condition of the sensor surface and its connections to ensure no damage has been caused which could prevent the system operating as designed.

e) Test the effectiveness of the pressure-sensitive protective device with power on but with the machine at rest. If relevant, vary the point of actuation to ensure that the whole of the effective sensing surface is tested over a period of time.

f) Where reset is provided, test that the machine cannot be operated until the system has been reset.

g) Inspect that all control unit enclosures are closed and in good condition and can only be opened by a key or tool. Inspect that key(s) are removed for retention by designated personnel.

E.5 Inspection and tests after maintenance

After maintenance has been undertaken, tests of the safety function appropriate to the level of maintenance should be performed following the relevant guidance given in E.3.

Bibliography

[1] ISO 13850:2006, *Safety of machinery — Emergency stop — Principles for design*

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

[3] ISO 13856-2, *Safety of machinery — Pressure-sensitive protective devices — Part 2: General principles for design and testing of pressure-sensitive edges and pressure-sensitive bars*

[4] ISO 14119, *Safety of machinery — Interlocking devices associated with guards — Principles for design and selection*

[5] ISO 14120, *Safety of machinery — Guards — General requirements for the design and construction of fixed and movable guards*

[6] IEC 61032:1997, *Protection of persons and equipment by enclosures — Probes for verification*

[7] IEC 61496 (all parts), *Safety of machinery — Electro-sensitive protective equipment*

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

[9] IEC 62061, *Safety of machinery — Functional safety of safety-related electrical, electronic and programmable electronic control systems*

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