INTERNATIONAL STANDARD

ISO 13856-3

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Safety of machinery — Pressure-sensitive protective devices —

Part 3: General principles for the 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

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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*.

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 the design and testing of pressure-sensitive edges and pressure-sensitive bars*

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

Introduction

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

The safeguarding of machinery (see ISO 12100-1:2003, 3.20) can be achieved by many different means. These means include guards which prevent access to the hazard zone by means of a physical barrier (e.g. fixed guards according to ISO 14120, or interlocking guards according to ISO 14119), protective devices (e.g. electro-sensitive protective equipment according to IEC 61496) and pressure-sensitive protective devices according to this part of ISO 13856.

Type-C standards makers and designers of machinery/installations (see below for an explanation of the different types of machinery safety standards) need to 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 14121). The best solution may combine several of these different means. It is advisable, too, that the machinery/installation supplier and the user examine together carefully the existing constraints before making their decision on the choice of safeguarding means.

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

The forces specified in this part of ISO 13856 should not be considered as those which will always avoid injury or fatal accidents. This depends upon several criteria which include the sensor, the actuating speed, the contact area, the material used and the part of the body affected.

The forces specified in this part of ISO 13856 are primarily intended for the purpose of assessing the performance of the pressure-sensitive protective devices. These forces are under further investigation.

Each type of application of pressure-sensitive protective devices can present particular hazards. It is not the intention of this document to identify those hazards nor to recommend specific applications to particular equipment. Particular applications may also necessitate special requirements which are not included in this document.

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

- type-A standards (basic safety standards) giving basic concepts, principles for design, and general aspects that can be applied to all machinery;
- 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);
- type-C standards (machine safety standards) dealing with detailed safety requirements for a particular machine or group of machines.

This part of ISO 13856 is a type-B2 standard as stated in ISO 12100-1.

When provisions of a type-C standard are different from those which are stated in type-A or -B standards, the provisions of the type-C standard take precedence over the provisions of the other standards, for machines that have been designed and built according to the provisions of the type-C standard.

ISO/TC 199 has a mandate in this area to produce type-A and type-B standards, which will allow verification of conformity with the essential safety requirements.

ISO 13856-3 is based on EN 1760-3:2004, published by the European Committee for Standardization (CEN).

Safety of machinery — Pressure-sensitive protective devices —

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

1 Scope

This part of ISO 13856 gives basic requirements for 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, the majority of which are produced for specific applications and are not available as off-the-shelf items. It also gives specific requirements for the following devices:

— pressure-sensitive bumpers;

— pressure-sensitive plates;

— pressure-sensitive wires (trip wires).

Its purpose relates primarily to safety and reliability rather than suitability (for the relationship between safety and reliability, see ISO 13849-1:1999, Annex D). It does not specify the dimensions of pressure-sensitive protective devices in relation to any particular application. Specific requirements for particular applications are intended to be set forth in relevant type-C standards (see ISO 12100-1 and the Introduction).

This part of ISO 13856 does not cover stopping devices used only for the regular operation (including emergency stopping) of machinery. Nor does it apply to use in locations accessible to elderly or disabled persons or children, where special additional requirements can be necessary.

NOTE Some requirements of this part of ISO 13856 are made with respect to electromagnetic compatibility (EMC). These are intended to meet only the requirements of Council Directive 98/37/EC ("Machinery Directive") [1] and not those of Council Directive 89/336/EC ("EMC Directive") [2] of the European Union.

2 Normative references

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

ISO 4413, *Hydraulic fluid power — General rules relating to systems*

ISO 4414, *Pneumatic fluid power — General rules relating to systems*

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

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

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

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

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

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

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

IEC 60068-2-29, *Environmental testing — Part 2: Tests — Test Eb and guidance: Bump*

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

IEC 60204-1:1997, *Safety of machinery — Electrical equipment of machines — Part 1: General requirements*

IEC 60439-1:1999, *Low-voltage switchgear and controlgear assemblies — Part 1: Type-tested and partially type-tested assemblies*

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

IEC 60664-1:1992, *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 measurement techniques — Electrostatic discharge immunity test*

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

IEC 61000-4-4, *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*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 12100-1:2003 and the following apply.

3.1
pressure-sensitive protective device
safety device of the "mechanically actuated trip type" which can also act as an impeding device as defined in ISO 12100-1:2003, 3.27, intended to detect the touch of a person or part of a person

NOTE 1 It consists of

— a sensor(s) 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 Pressure-sensitive protective devices can be used as tripping devices as well as presence-sensing devices as defined in ISO 12100-1:2003, 3.26.5.

3.1.1
pressure-sensitive bumper
pressure-sensitive protective device with a sensor 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 that is deformed locally or that can move as a whole

3.1.2
pressure-sensitive plate
pressure-sensitive protective device with a sensor whose characteristics are

— an effective sensing surface 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

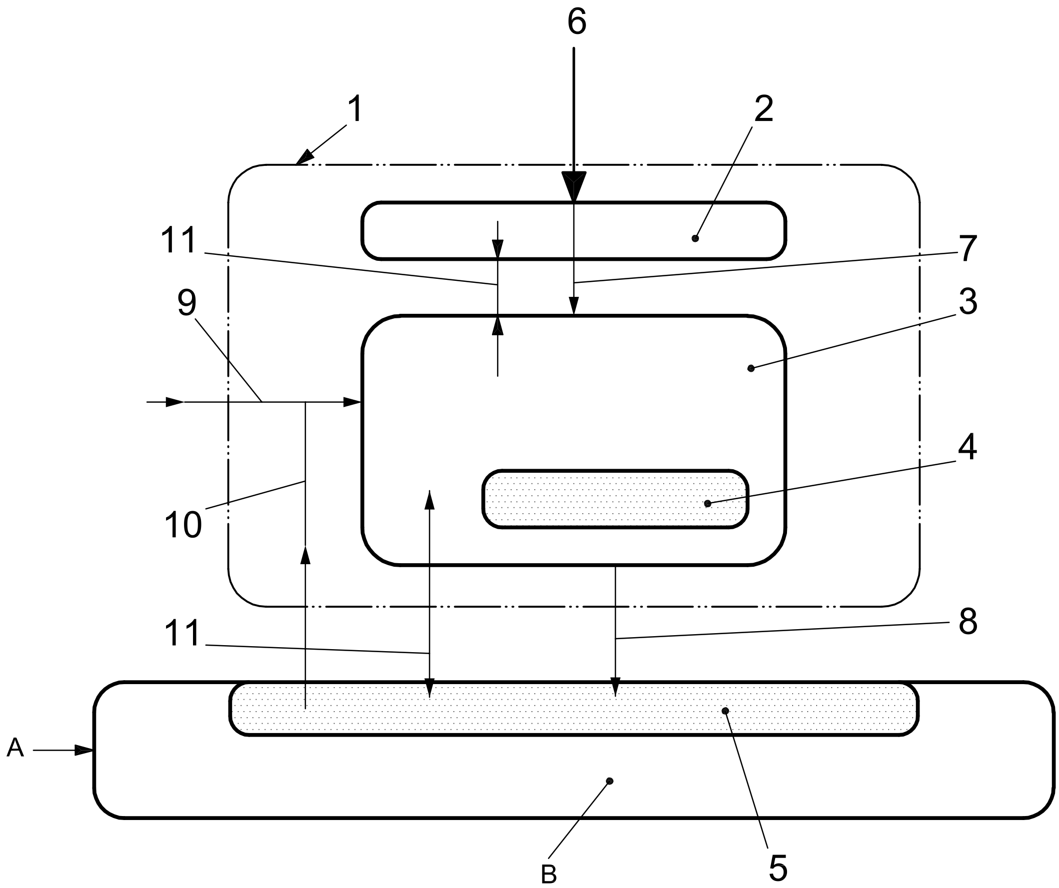
3.1.3
pressure-sensitive wire
pressure-sensitive protective device with a sensor whose characteristics are

— 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
sensor
that part of the pressure-sensitive protective device which generates a signal in response to sufficient pressure applied to part of its surface

NOTE This definition together with that of **control unit** (3.3) cover 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).



Key

A manual reset signal to the machine control system [a]

B machine control system(s)

1 pressure-sensitive protective device

2 sensor(s)

3 control unit [b]

4 output signal switching device

5 part of machine control system for pressure-sensitive protective device output signal processing

6 actuating force

7 sensor output signal

8 ON state/OFF state signal

9 manual reset signal [c]

10 reset signal from machine control system (where appropriate)

11 monitoring signals (optional)

[a] Where appropriate, this may be used as an alternative to 9.

[b] Can be located within the machine control system or as part of the machine control system, e.g. as a logic block.

[c] Where appropriate, this may be used as an alternative to A.

Figure 1 — Pressure-sensitive protective device as applied to machines

3.3
control unit
that part of the pressure-sensitive protective device which responds to the condition of the sensor and generates output signals to the machine control system

NOTE This definition together with that of **sensor** (3.2) cover 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
output signal switching device
part of the control unit of a pressure-sensitive protective device which is connected into the machine control system and transmits safety output signal(s)

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

3.6
OFF state
state an output switching device in which the output circuit(s) is broken and interrupts the flow of current or fluid

3.7
actuating force
any force applied to the sensor which causes the output signal switching device to go to the OFF state

3.8
approach speed
relative speed at which contact is made between the surface of the sensor and a part of the body

3.9
effective sensing surface
that part of the surface of the sensor or a combination of sensors, as stated by the manufacturer, where the application of an actuating force creates an OFF state in the output signal switching device

3.10
effective sensing direction(s)
direction(s) of the actuating force from which the sensor will be actuated

3.11
dead surface
part of the surface area of the sensor outside the effective sensing surface

3.12
actuating travel
distance travelled by a specified object, moving in the direction of the applied actuating force, and measured from the point where this object touches the effective sensing surface to the point where the output signal switching device changes to an OFF state under specified conditions

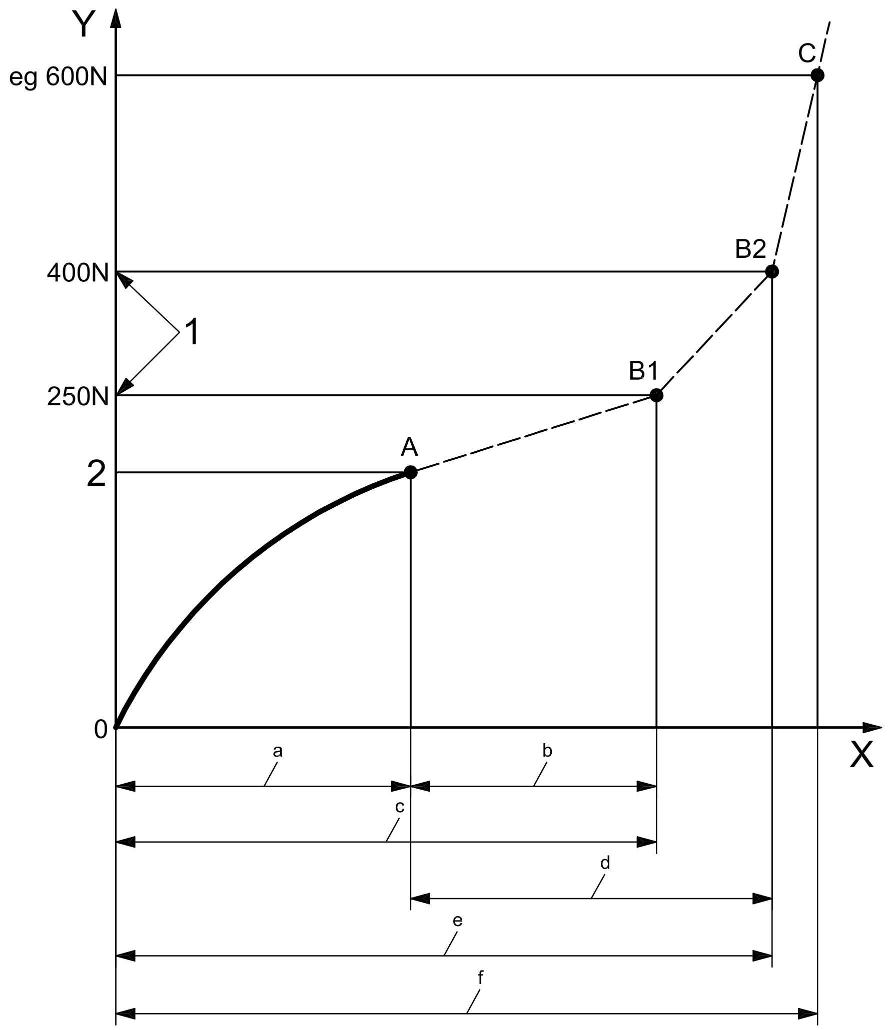
See Figure 2.

NOTE Actuating travel can differ from *pre-travel*, a term relating to an edge or 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.

3.13
working travel
distance travelled by a specified object, moving in the direction of the applied actuating force, and measured from the point where this object touches the effective sensing surface, under specified conditions, to where a specified force is exerted on the object

See Figure 2.

NOTE See also Annex B.



Key

X travel, mm

Y force, N

1 stated limit force

2 lowest actuating force

Force–travel point A is the actuating point and the point of maximum operating speed.

Force travel points B1 and B2 occur at a force of 250 N or 400 N and at an operating speed of ⩽ 10 mm/s.

Force–travel point C occurs at, in this example, 600 N and at an operating speed of ⩽ 10 mm/s.

NOTE Test piece 1 (see Table 1) is used to apply the forces.

[a] Actuating travel.

[b] Overtravel at 250 N.

[c] Working travel at 250 N.

[d] Overtravel at 400 N.

[e] Working travel at 400 N.

[f] Total travel.

Figure 2 — Example of force–travel diagram

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

See Figure 2.

3.15
force–travel relationship
relationship between the force applied and the distance travelled by a pressure-sensitive protective device in operation

See Figure 2.

3.16
reset
function which permits an ON state in the output signal switching device, provided that certain conditions are met

3.17
mounting orientations
position in space of the sensor

3.18
presence-sensing device
PSD
device that creates a sensing field, area or plane for detecting the presence of a part or the whole of a person

NOTE Pressure-sensitive protective devices can be used as tripping devices as well as presence-sensing devices as defined in ISO 12100-1:2003, 3.26.5.

3.19
total travel
movement or deformation of the effective sensing surface of a pressure-sensitive protective device, measured in the direction of the actuating force from the point of contact to the point where no further significant deformation of the effective sensing surface occurs

4 Requirements

4.1 General

The majority of 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 requirements in accordance with the risk assessment and specify the essential force–travel data for the application.

The 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 dangerous situation or a danger zone.

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

a) The device is used to stop the dangerous 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.3.2.

b) The sensor is mounted on the dangerous 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.2.10.

The following basic requirements apply to all the devices covered by this part of ISO 13856. Additional specific requirements are given for pressure-sensitive bumpers, pressure-sensitive plates and pressure-sensitive wires. The 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

NOTE 1 See 7.1.1 and 7.1.5 for verification.

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 1 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, or

— over the temperature range,

which the manufacturer of the device has specified or have been agreed upon by the manufacturer of the device and the machine builder(s).

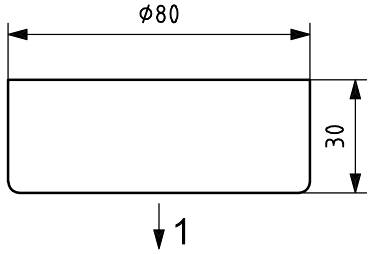
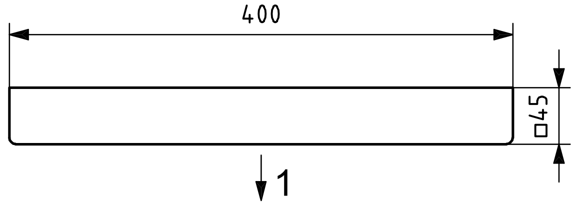
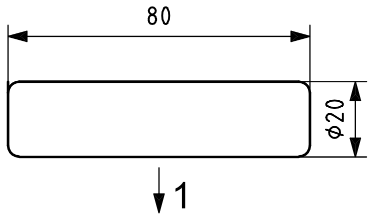
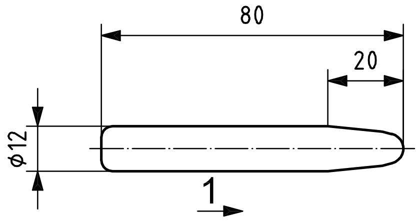
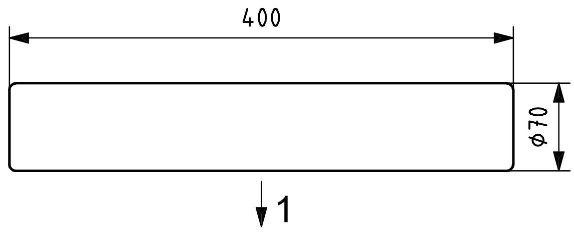
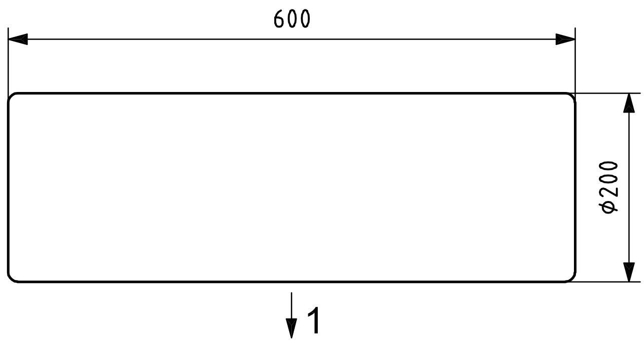
The lowest actuating force could need to be less than that stated in Table 1 for specific applications and designs of sensor. See, for example, 4.5.3 for the lowest actuating force necessary to cause the control unit for pressure-sensitive wires to go to the OFF state.

NOTE 2 The risk assessment will show which part(s) of the body are to be considered for a particular application, enabling the relevant test piece(s) to be used.

NOTE 3 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 be considered as safe forces (see Annex C and ISO 14120:2002, 5.2.5.2, for guidance).

NOTE 4 Certain applications, e.g. protecting the neck, may require a higher sensitivity device, i.e. actuating forces lower than those shown in Table 1.

Table 1 — Test pieces, actuating forces and test directions

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)	
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	

4.2.2 Actuating travel

NOTE See 7.1.1 and 7.1.6 for verification.

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

4.2.3 Overtravel

NOTE See 7.1.1 and 7.1.7 for verification.

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

4.2.4 Approach speed

NOTE See 7.1.1, 7.1.5, 7.1.6 and 7.1.7 for verification.

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 device. For devices manufactured for a specific application, the approach speed shall be appropriate for the application.

4.2.5 Number of operations

NOTE See 7.1.1 and 7.1.8 for verification.

The 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

NOTE See 7.1.1 and 7.1.9 for verification.

The sensor output shall change state when the actuating force has been applied to its sensing surface, causing the output signal switching 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 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

NOTE See 7.1.1 and 7.1.9 for verification.

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

For some devices, additional measures are required: see Annex A (Figure A.4), C.2.6 and C.2.7.

4.2.6.3 Reset function

NOTE See 7.1.1 and 7.1.10 for verification.

The reset function of a pressure-sensitive protective device shall fulfil the general requirements of ISO 13849-1:1999, 5.4, 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 Annex A (see Figures A.1 and A.2) and ISO 13849-1:1999, 5.4.

4.2.7 Environmental conditions

4.2.7.1 Requirement for normal operation

NOTE See 7.1.1 and 7.1.11 for verification.

The pressure-sensitive protective device shall continue in normal operation in the environmental conditions stated by the manufacturer. 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

NOTE See 7.1.1 and 7.1.11.3 for verification.

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 meet this requirement over the stated temperature range.

4.2.7.3 Humidity

NOTE See 7.1.1 and 7.1.11.4 for verification.

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

NOTE See 7.1.1 and 7.1.11.5 for verification.

Where relevant, the pressure-sensitive protective device shall continue in normal operation under the conditions given in IEC 61000-6-2 and in Table 5. The manufacturer may state a higher level(s) for which the pressure-sensitive protective device shall continue in normal operation.

4.2.7.5 Vibration

NOTE See 7.1.1 and 7.1.11.6 for verification.

The pressure-sensitive protective device shall continue in normal operation without changing the state under the following vibration conditions in accordance with IEC 60068-2-6:

— frequency range: 10 Hz to 55 Hz;

— displacement: 0,15 mm;

— cycles per axis: 10;

— sweep rate: one octave per min.

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

4.2.8 Power supply variation

4.2.8.1 General

NOTE See 7.1.1 and 7.1.12 for verification.

The pressure-sensitive protective device shall continue in normal operation as defined in 4.2.7 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 variation

NOTE See 7.1.1 and 7.1.12.2 for verification.

The pressure-sensitive protective device shall meet the electrical power supply variation requirements of IEC 60204-1:1997, 4.3.

4.2.8.3 Non-electrical power supply variations

NOTE See 7.1.1 and 7.1.12.3 for verification.

The pressure-sensitive protective device shall continue in normal operation as defined in 4.2.7 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 reduce the safety performance of the device.

Power supply variations outside the stated range shall not reduce the safety performance of the device.

4.2.9 Electrical equipment

4.2.9.1 General

NOTE See 7.1.1 and 7.1.13.1 for verification.

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 60204-1:1997, 6.1, 6.2, and 6.3.

4.2.9.3 Protection against overcurrent

Overcurrent protection shall be provided in accordance with IEC 60204-1:1997, 7.2.1, 7.2.2, 7.2.4, 7.2.8, 7.2.9 and 7.2.10.

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 60439-1:1999, 6.1.2.3.

4.2.9.6 Clearance, creepage distances and isolating distances

The electrical equipment shall be designed and constructed in accordance with IEC 60439-1:1999, 7.1.2.

4.2.9.7 Wiring

The electrical equipment shall be wired in accordance with IEC 60439-1:1999, 7.8.3.

4.2.10 Pneumatic equipment

NOTE See 7.1.1 and 7.1.13.2 for verification.

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

4.2.11 Hydraulic equipment

NOTE See 7.1.1 and 7.1.13.3 for verification.

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

4.2.12 Mechanical equipment

NOTE See 7.1.1 and 7.1.13.4 for verification.

Mechanical equipment shall meet the relevant requirements of pressure-sensitive protective devices according to ISO 12100-2:2003, 5.3 and ISO 13849-2.

4.2.13 Enclosure

NOTE See 7.1.1 and 7.1.14 for verification.

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. The manufacturer shall state the time and depth of immersion.

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

NOTE See 7.1.1 and 7.1.15 for verification.

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 Categories according to ISO 13849-1

NOTE 1 See 7.1.1 and 7.1.16 for verification.

Pressure-sensitive protective devices shall meet the requirements of the categories as stated by the manufacturer. For pressure-sensitive protective devices, the categories are as follows:

— the sensor shall meet the requirements of category 1 or, in association with the other parts of the pressure-sensitive protective device, categories 2, 3 or 4;

— the control unit and the output signal switching device shall meet the requirements of category 2 or 3 or 4.

NOTE 2 A pressure-sensitive protective device is an example of a system made up of a combination of safety-related parts. Consequently the categories of the parts of the device could differ one from another.

NOTE 3 At the time of writing, the majority of known sensors are based on the requirements of category 1. The sensor will be considered to meet the requirements of category 1 if it meets the requirements of this document and the requirements of ISO 13849-1. It might be possible for an air pulse system to fulfil the requirements of category 2 when the safety function is checked (see Figure A.4 and C.2.6).

NOTE 4 Type C standards can set out other requirements relevant to their application to achieve a relevant level of safety.

NOTE 5 It is not possible at the time of writing for the majority of sensors to meet all the requirements specified for the categories 3 or 4, in particular when considering mechanical damage and long-term deterioration.

4.2.16 Adjustments

NOTE See 7.1.1 and 7.1.17 for verification.

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 the standard 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

NOTE See 7.1.1 and 7.1.18 for verification.

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

NOTE See 7.1.1 and 7.1.19 for verification.

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 reduce the safety performance of the device.

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

NOTE See 7.1.1 and 7.1.20 for verification.

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 edges, sharp corners rough surfaces and trapping

NOTE See 7.1.1 and 7.1.21 for verification.

Exposed parts of pressure-sensitive protective devices shall have no sharp corners, edges, rough surfaces, etc., which can cause injury to persons who can come into contact with the device(s) (see ISO 12100-2:2003, 4.2.1).

4.2.21 Bump

NOTE 1 See 7.1.1 and 7.1.22 for verification.

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

NOTE 2 The effect of bumps 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)

NOTE See 7.1.1 and 7.2.1 for verification.

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

NOTE See 7.1.1 and 7.2.2 for verification.

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

4.3.3 Recovery after deformation

NOTE See 7.1.1 and 7.2.3 for verification.

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 2.

Table 2 — Recovery after deformation

Recovery time	Change in height % working travel at 10 mm/s 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 a period longer than 24 h, then the sensor shall recover according to Table 2 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

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 Additional requirements for pressure-sensitive plates

4.4.1 Bump

NOTE See 7.1.1 and 7.3.1 for verification.

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 60068-2-29:

— 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: approx. 1 Hz.

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

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

4.4.2 Recovery after actuation

If there is a delay of more than 30 s in recovery after actuation, then the requirements of 4.3.3 shall be taken into account.

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

4.5.1 Electrical switches

NOTE See 7.1.1 for verification.

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

4.5.2 Breaking or disengagement of wire

NOTE See 7.1.1 and 7.4.1 for verification.

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.8).

4.5.3 Actuating force

NOTE See 7.1.1 and 7.4.2 for verification.

The force necessary to apply to the 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. The effective sensing surface of a pressure-sensitive wire shall be stated by the manufacturer.

4.5.4 Tensile strength of sensor

NOTE See 7.1.1 and 7.4.3 for verification.

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

4.5.5 Actuating deflection of wire

NOTE See 7.1.1 and 7.4.4 for verification.

The displacement of the wire needed to generate an OFF state shall be less than 150 mm in all the stated actuating directions, see Figure C.8. For special applications, a displacement of more than 150 mm can be acceptable when indicated by the risk assessment.

5 Marking

5.1 General

Pressure-sensitive protective devices which are placed on the market separately shall be marked in accordance with ISO 12100-2:2003, 6.4 a), and, as a minimum for electrical equipment, with the rated voltage and current. See also IEC 60204-1:1997, 17.4.

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.

5.3 Reference numbers

All pressure-sensitive protective devices and every part that can be replaced in accordance with the instruction manual shall be marked with a type reference or part number in accordance with the manual and a traceability code.

6 Information for selection and use

6.1 General

Information and guidance regarding application, commissioning and regular inspection is given in Annexes D and E. The information to be supplied, and the manner in which it is presented, shall comply with ISO 12100-2:2003, Clause 6. It shall be clearly identified with the pressure-sensitive protective device.

6.2 Essential data for selection of suitable 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:

- whether the pressure-sensitive protective device is suitable for the trip function only or also for the combined trip and presence sensing function;
- the limits as to the configuration, number and length of sensors connected to one control unit;
- the limits as to the length and specifications of connections between sensor(s) and control unit(s);
- the mounting orientation(s) at which the sensor can be used;
- the means of fixing the sensor and control unit;
- the force(s) which the installed sensor is able to withstand and the direction(s) in which they are applied;
- the dimensions which specify the effective sensing surface;
- the maximum dimensions of the sensor;
- the weight of the sensor per metre length and the weight of the control unit;
- the sensor’s additional covering details (where applicable);
- the force–travel relationship(s) showing the actuating travel and overtravel in the form of a table or diagram according to Figure 2;
- the specified force after overtravel;
- the stated number of operations;
- chemical resistance table for the sensor;
- the operating temperature range;
- the power supply requirements;
- the control unit enclosure specification(s) according to IEC 60529;
- the sensor enclosure specification(s) according to IEC 60529;
- the category or categories according to ISO 13849-1;
- the selection procedure according to D.1;
- the critical lengths of connections between individual components;

- the deformation behaviour over time;
- the output signal switching device switching capability according to IEC 60947-5-1;
- application guidance;
- the output signal switching device contact configuration(s);
- the suitability or lack thereof for detecting fingers;
- the minimum operating speed (if applicable), e.g. for pneumatic systems.

6.3 Information for use

6.3.1 Information for application and commissioning

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

a) Information relating to the device:

   - detailed description of the device;
   - the limits as to the configuration, number and length of sensors connected to one control unit;
   - the limits as to the length and specifications of connections between sensor(s) and control unit(s);
   - the procedure for determining the overtravel for the pressure-sensitive protective device, which shall be included with examples (see Annex B);
   - range of applications and conditions for which the device is intended or approved, including the category according to ISO 13849-1;
   - circuit diagrams providing schematic representation of the safety functions and examples of machine control interface;
   - additional safety measures according to 4.2.6.2, necessary to achieve the required level of safety for specific applications;
   - the rating, characteristics and location of all input/output terminals (e.g. maximum rating of fuses, or setting of an overcurrent protective device);
   - type and frequency of automatic check system, where applicable;
   - guidance regarding environmental resistance (chemical, physical, e.g. resistance to solvents, allowable loading, temperature range, allowable power supply variation);
   - guidance regarding use of the device in alternative mounting orientations;
   - whether the device is designed with or without external reset 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 device, including

   - dimensions,
   - mass,

- description of packaging and methods of unpacking to prevent damage to the device,
- transportation and handling methods for preventing damage or personal injury, and
- storage requirements, e.g. whether to be laid flat, straight or in coils, temperature range.

c) Information relating to the installation and commissioning of the device, including the following:

- a warning that the information for use should be read in full before any installation work is attempted;
- requirements regarding the surface on which the sensor will be mounted;
- methods of installation, including required tooling;
- 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);
- 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;
- warning that the overall safety of the machine and its safety device depends on the quality, reliability and correct installation of the interface between them;
- the category or categories according to ISO 13849-1 required for the device, which shall comply with those established by the risk assessment;
- a 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 device

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 device, including

- purpose and method of operation of the control unit and indicators,
- information regarding limits of use, and
- instructions for fault identification and for restarting after an intervention.

b) Information for maintenance, including the following:

- a warning that the maintenance instructions should be read before any maintenance is attempted;
- nature and frequency of testing, inspection and maintenance;
- instruction for allowable setting, adjustment and cleaning;
- actions which require a definite technical knowledge and/or particular skills and hence should be carried out exclusively by skilled persons suitably trained;
- information, e.g. drawings and circuit diagrams, enabling trained personnel to carry out fault-finding tasks;
- details of tests required after replacement of parts to establish that the device functions correctly;

- warning that all parts, e.g. covers, clips, edging strips, fastenings, removed during maintenance should be replaced after maintenance and that if such parts are not correctly refitted the performance of the device could be impaired;
- list of user-replaceable parts;
- 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;
- name and address of manufacturer and/or competent service organization.

NOTE Further advice for drafting and editing the instructions is provided in ISO 12100-2:2003, 6.5.1, 6.5.2 and 6.5.3.

7 Verification

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 device. Some of the tests can also be required for variations in the design of the 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 or when testing is a more practicable option. In all cases, the manufacturer shall provide information showing how the requirements have been met.

For many applications, 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 parts of the body 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, as specified by the manufacturer. Unless otherwise specified, these tests shall be carried out at 20 °C. The following tolerances shall apply:

- temperature: ± 5 °C
- test speed: ± 10 %

If for a particular test it is evident that 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.

NOTE The following parameters can affect the performance:

- dimensions (length) of the sensor;
- material of the sensor;
- top or covering material of the effective sensing surface;

— combination of sensors;

— type and length of the interconnecting cables or tubes;

— the sensor mounting orientations.

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 number 1 — Safety-related data for selection, installation, commissioning, operation and maintenance of suitable device

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

NOTE See 6.3.1 and 6.3.2.

7.1.5 Test number 2 — Actuating force and approach speed

7.1.5.1 General

NOTE For requirements, see 4.2.1.

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 as stated in Table 1.

7.1.5.2 Test locations on 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 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,

b) after the sensor has reached the particular temperature equilibrium.

7.1.5.4 Test pieces to be used

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

a) as stated by the manufacturer of the 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 may be carried out using these test pieces only.

Test pieces are illustrated in Figures 3 and 4 and in Table 1.

7.1.6 Test number 3 — Actuating travel

NOTE For requirements, see 4.2.2.

The test shall be carried out with test piece 1 or with the test piece(s) for the part(s) of the body relevant to the application (see Table 1). The test piece shall be applied to the sensor at the maximum approach speed or that as stated by the manufacturer 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 devices manufactured for a specific application, the actuating travel shall be appropriate for the application.

7.1.7 Test number 4 — Overtravel

NOTE For requirements, see 4.2.3.

The test shall be carried out with test piece 1 or with the test piece(s) for the part(s) of the body relevant to the application (see Table 1). The test piece shall be applied to the sensor at a speed $\leqslant$ 10 mm/s 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 device. For devices manufactured for a specific application, the overtravel shall be appropriate for the application.

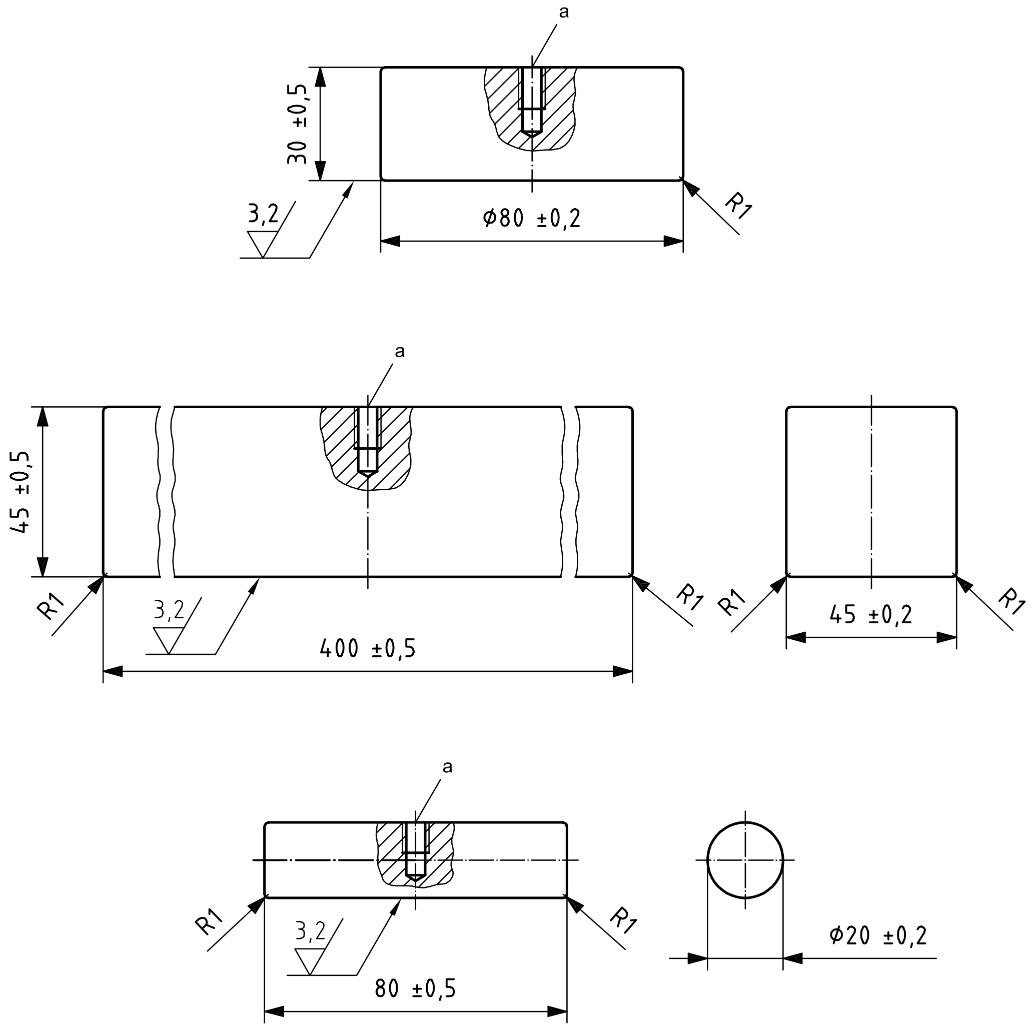
7.1.8 Test number 5 — Number of operations

NOTE For requirements, see 4.2.5.

Testing shall be carried out by applying test piece 1 at the stated approach speed 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. Test piece 1 (or the test piece(s) relevant to the part(s) of the body 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 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.

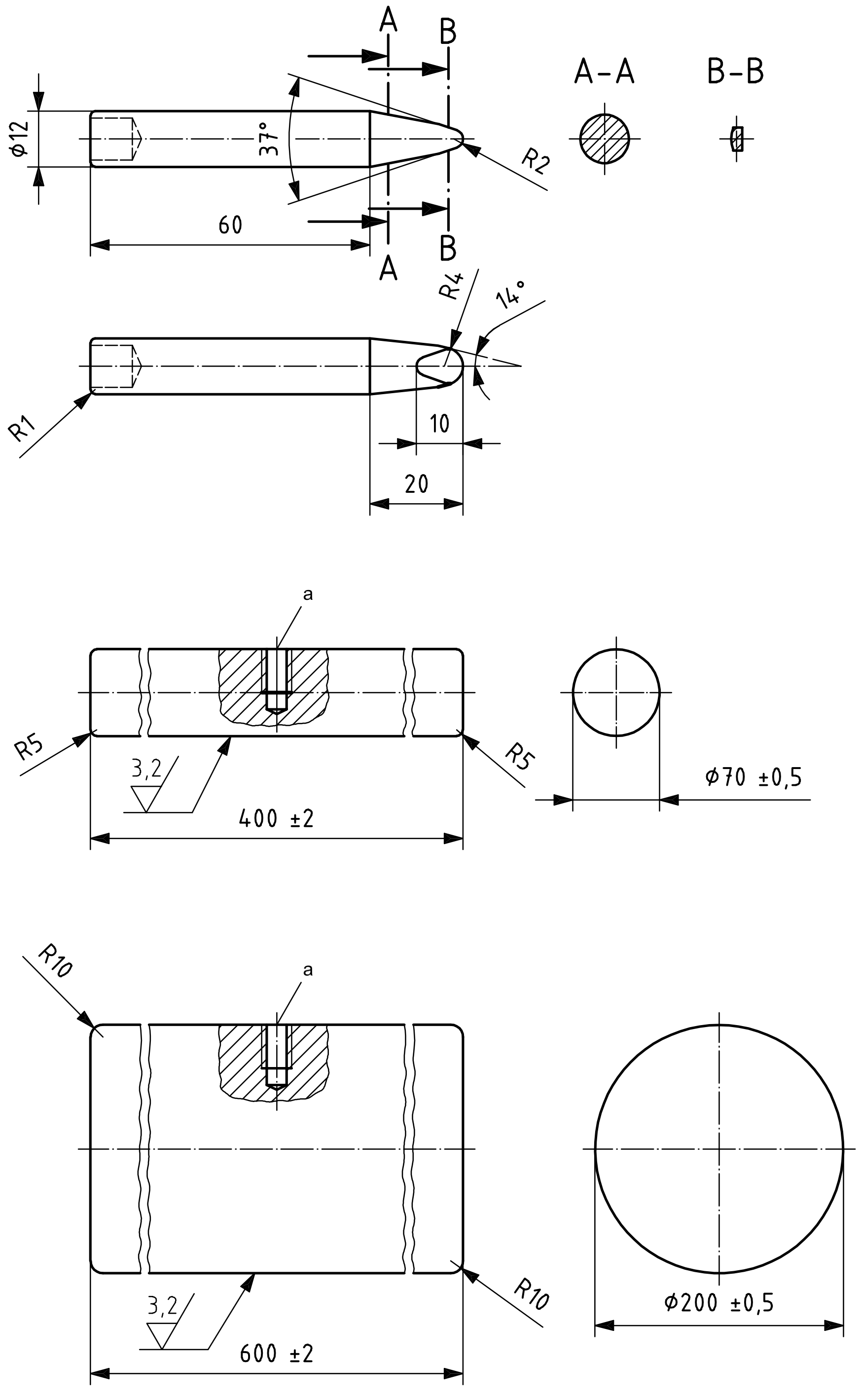
Dimensions in millimetres
Tolerances on radii: ± 0,2



a Mounting proposal only.

Figure 3 — Test pieces 1 to 3

Dimensions in millimetres
Tolerances on radii: ± 0,2



a Mounting proposal only.

Figure 4 — Test pieces 4 to 6

7.1.9 Test number 6 — Output state of sensor and output signal switching device

NOTE For requirements, see 4.2.6.1 and 4.2.6.2.

An actuating force shall be applied at a random location in the effective sensing surface in the reference direction through test piece 1 for a period of 10 min. While this force is applied, the state of 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 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 state of the sensor shall be checked in accordance with Figures A.1, A.2 and A.3.

7.1.10 Test number 7 — Response of output signal switching device to actuating force, reset and state of power supply

NOTE For requirements, see 4.2.6.3.

The interaction of separate functions as shown in Figures A.1, A.2, A.3 and A.4 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 number 8 — Environmental tests

7.1.11.1 General

NOTE For requirements, see 4.2.7.

The environmental requirements 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 following tests (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

— perpendicularly to the effective sensing surface,

— with the corresponding actuating force given in Table 1,

— 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 number 8.1 — Operating temperature range

NOTE For 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 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 1. The test piece shall be applied perpendicularly to the effective sensing surface at (10 ± 1) mm/s 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 number 8.2 — Humidity

NOTE For 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 Ca.	Pressure-sensitive protective device is not connected to the power supply. After this test, a high voltage test according to IEC 60664-1:1992, Tables 1 and 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 number 8.3 — Electromagnetic compatibility

NOTE For 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 procedures
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 field level 3	IEC 61000-4-3
Conducted disturbances, induced by radio frequency fields level 3	IEC 61000-4-6

7.1.11.6 Test number 9 — Vibration

NOTE For 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 number 10 — Power supply variation

7.1.12.1 General

NOTE For requirements, see 4.2.8.

Pressure-sensitive protective devices shall be subjected to the following analysis, inspection or tests.

7.1.12.2 Test number 10.1 — Electrical power supply variation

NOTE For requirements, see 4.2.8.2.

The normal functioning of the pressure-sensitive protective device shall be verified according to the requirements in IEC 60204-1:1997, 4.3. Its functioning shall be checked using test piece 1 applied to the effective sensing surface with the corresponding actuating force given in Table 1, 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 10.2 — Non-electrical power supply variations

NOTE For 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 number 11 — Electrical, pneumatic, hydraulic and mechanical equipment

7.1.13.1 Test number 11.1 — Electrical equipment

NOTE For requirements, see 4.2.9.

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

7.1.13.2 Test number 11.2 — Pneumatic equipment

NOTE For requirements, see 4.2.10.

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

7.1.13.3 Test number 11.3 — Hydraulic equipment

NOTE For requirements, see 4.2.11.

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

7.1.13.4 Test number 11.4 — Mechanical equipment

NOTE For requirements, see 4.2.12.

It shall be verified by inspection, analysis and testing if necessary that the requirements of ISO 12100-2:2003, 5.3 and ISO 13849-2 are met.

7.1.14 Test number 12 — Enclosure

NOTE For requirements, see 4.2.13.

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

7.1.15 Test number 13 — Access

NOTE For requirements, see 4.2.14.

The requirements of 4.2.14 shall be verified by inspection.

7.1.16 Test number 14 — Category/Categories

NOTE For requirements, see 4.2.15.

It shall be verified that the requirements according to 4.2.15 are met.

It shall be verified by analysis (if necessary by testing and simulation) that the category of the sensor, of the control unit and of the output signal switching device (where provided) as stated by the manufacturer have been realized by reference to ISO 13849-1:1999, 6.2, and ISO 13849-2. The basis of the analysis shall include the rationale provided by the manufacturer for the categories stated (e.g. well-tried principles, fault tolerance capability, fault exclusions).

7.1.17 Test number 15 — Adjustments

NOTE For requirements see, 4.2.16.

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

7.1.18 Test number 16 — Sensor fixing and mechanical strength

NOTE For requirements see 4.2.17.

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

7.1.19 Test number 17 — Connections

NOTE For requirements, see 4.2.18.

The requirements of 4.2.18 shall be verified by inspection.

7.1.20 Test number 18 — Inhibition and blocking

NOTE For requirements see 4.2.19.

The requirements of 4.2.19 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 number 19 — Sharp edges, sharp corners, rough surfaces and trapping

NOTE For requirements see 4.2.20.

The requirements of 4.2.20 shall be verified by inspection.

7.1.22 Test number 20 — Bump

NOTE For requirements, see 4.2.21.

This shall be verified by inspection, analysis and testing, if necessary, in accordance with 7.3.1.

7.2 Verification of requirements for pressure-sensitive bumpers only

7.2.1 Test number 21 — Force–travel relationship

NOTE For requirements, see 4.3.1.

This shall be verified by inspection, analysis and testing if necessary.

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 1) to the sensor (see Figure 5) at the maximum approach speed up to point A in Figure 2. 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. The points B1, B2 and C shall be confirmed in accordance with Figure 2 by applying test piece 1 to the sensor at a speed equal to or less than 10 mm/s. 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 number 22 — Additional coverings for sensors

NOTE For requirements, see 4.3.2.

If additional coverings are specified by the manufacturer, then it shall be verified that the requirements of 4.3 have been met.

7.2.3 Test number 23 — Recovery after deformation

NOTE For requirements, see 4.3.3.

This shall be verified by inspection, analysis and test if necessary.

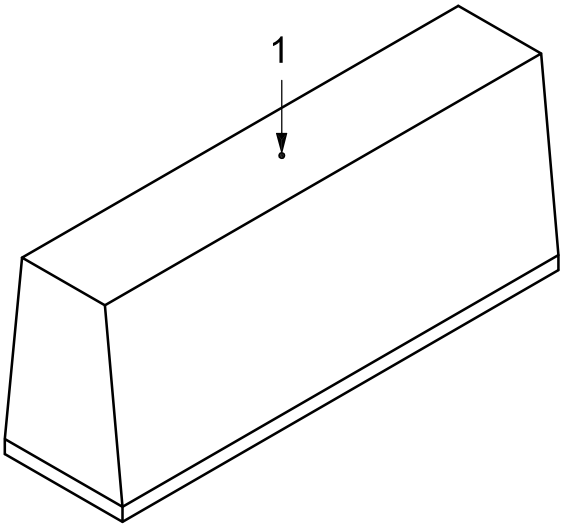
After the effective sensing surface of the sensor has been deformed or moved by the working travel using test piece 1 (see Figure 5) for 24 h, the effective sensing surface shall recover as shown in Table 2. The working travel in this instance is taken from test no. 4 with a test speed of 10 mm/s at 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 function within 30 s.

7.2.4 Test number 24 — Detection on bumpers with semi-rigid or rigid surfaces

NOTE For 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 direction on surface of pressure-sensitive bumper

7.3 Verification of requirements for pressure-sensitive plates only

7.3.1 Test number 25 — Bump

NOTE For requirements, see 4.4.1.

This shall be verified by inspection, analysis and testing if necessary.

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 — Bump

Test procedure	Test conditions
IEC 60068-2-29	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 bump test has been completed, the normal function 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

See 7.2.3.

7.4 Verification of requirements for pressure-sensitive wires

7.4.1 Test number 26 — Breaking or disengagement of wire

NOTE For requirements, see, 4.5.2.

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

7.4.2 Test number 27 — Actuating force

NOTE For requirements, see 4.5.3.

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

7.4.3 Test number 28 — Tensile strength of sensor, including any connections

NOTE For 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 number 29 — Actuating deflection of wire

NOTE For 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 number 30 — Marking

NOTE For requirements, see Clause 5.

The requirements of Claus 5 shall be verified by inspection.

7.5.2 Test number 31: Information for selection and use

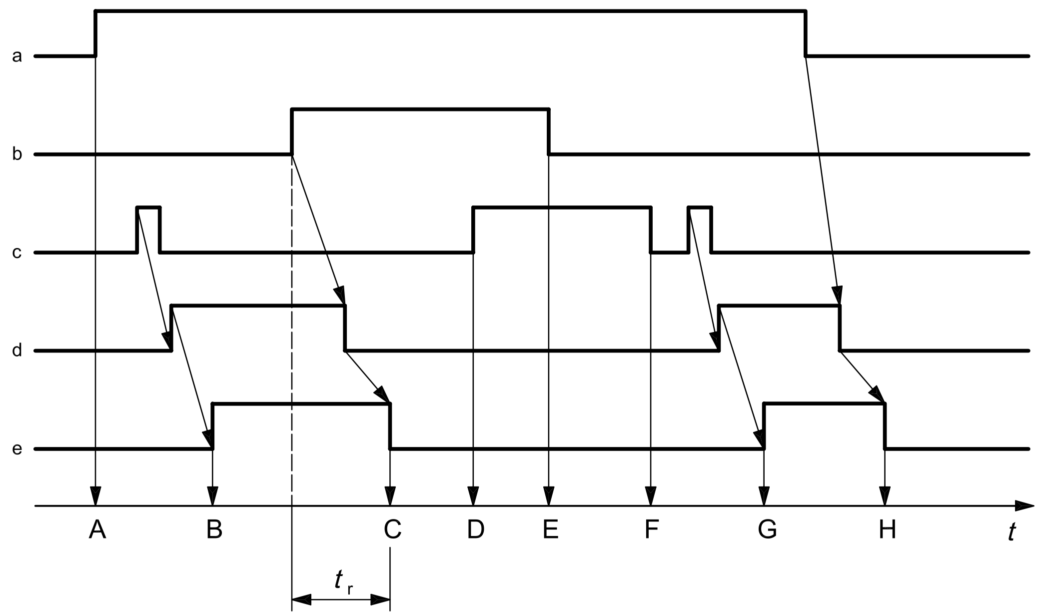
NOTE For requirements see Clause 6.

The requirements of Clause 6 shall be verified by inspection.

Annex A
(normative)

Timing diagrams

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



Key

t time

t_r response time

A Power to the device is ON; output remains in OFF state because the device has not been reset.

B Reset signal present. Output of the device is turned to ON state because sensor is turned ON due to operation of reset actuator without actuating force on the sensor.

C Output of the signal switching device is in OFF state because sensor is turned OFF due to actuating force on sensor.

D Reset signal present. Operation of reset actuator has no effect on output of the device as long as an actuating force is present on the sensor; device remains OFF.

E Actuating force removed from the sensor; the output of the device remains in OFF state even though the reset signal is still present.

F Reset signal removed. Release of reset actuator has no effect on output of the device even when the actuating force has been removed from the sensor.

G Reset signal present. Output of the device is turned to ON state because sensor is turned ON due to operation of reset actuator without actuating force on the sensor.

H Power to the device is OFF; sensor output and device output are turned to OFF state.

[a] Power to pressure-sensitive protective device.

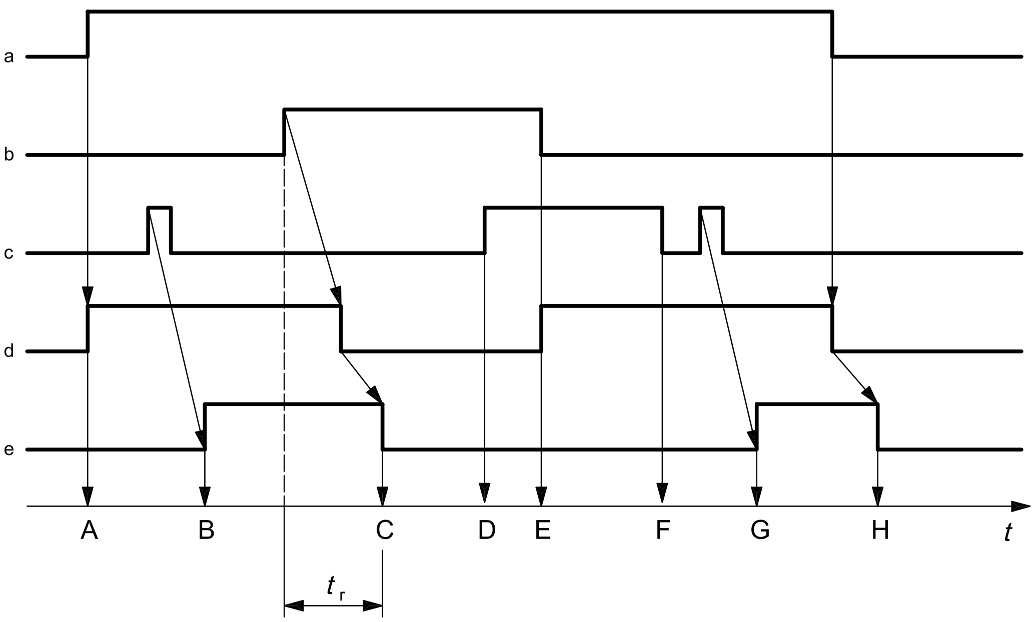
[b] Actuating force.

[c] Reset signal.

[d] Sensor output.

[e] Output of output signal switching device(s).

Figure A.1 — Sensor output initiated by reset function



Key

t time

t_r response time

A Power to the device is ON; output remains in OFF state because the device has not been reset; sensor is turned ON when the power is turned ON.

B Reset signal present without actuating force on sensor. Output of the device is turned to ON state due to operation of reset actuator as long as the sensor is turned ON.

C Actuating force on sensor. Output of the sensor is turned to OFF state which also turns the device OFF.

D Reset signal present. Operation of reset actuator has no effect on output of the device as long as an actuating force is present on the sensor; device remains OFF.

E Actuating force removed from sensor; the output of the sensor is turned to ON state but the device remains OFF even though the reset signal is still present.

F Reset signal removed. Release of reset actuator has no effect on the output of the sensor which remains in ON state. The device remains OFF.

G Reset signal present without actuating force on sensor. Output of the device is turned to ON state due to operation of reset actuator as long as the sensor is turned ON.

H Power to the device is OFF; sensor output and device output are turned to OFF state.

[a] Power to pressure-sensitive protective device.

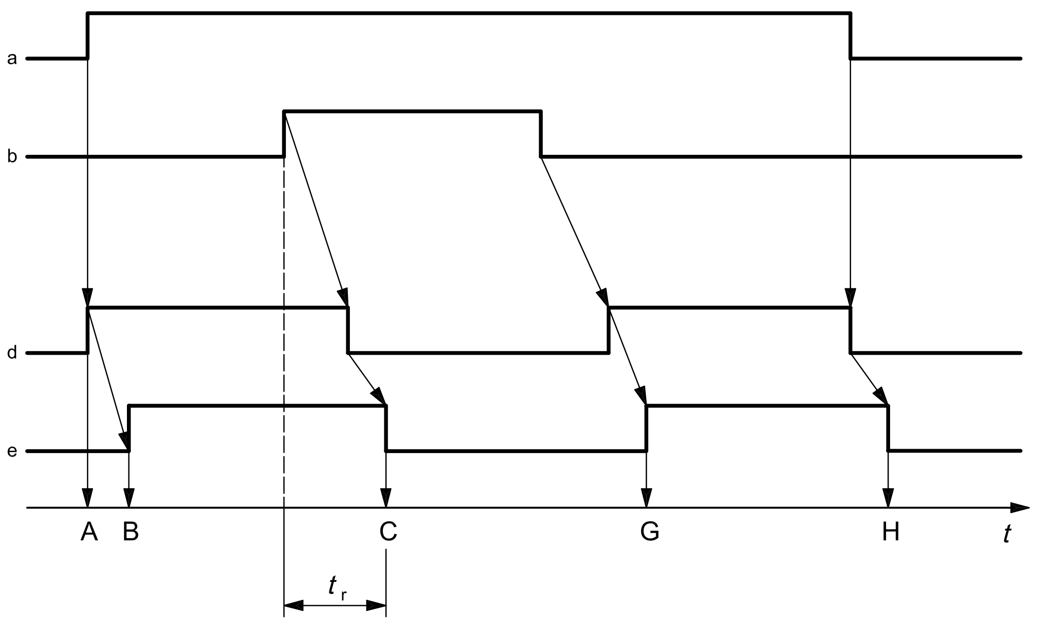
[b] Actuating force.

[c] Reset signal.

[d] Sensor output.

[e] Output of output signal switching device(s).

Figure A.2 — Sensor output independent of reset function



Key

t time

t_r response time

A Power to the device is ON; sensor is turned ON.

B Output of the device is turned to ON state because there is no actuating force on the sensor.

C Output of the device is in OFF state because sensor is OFF due to actuating force on the sensor.

G Output of the device is turned to ON state because sensor is ON due to actuating force being removed from the sensor.

H Power to the device is OFF; sensor and device output are turned to OFF state.

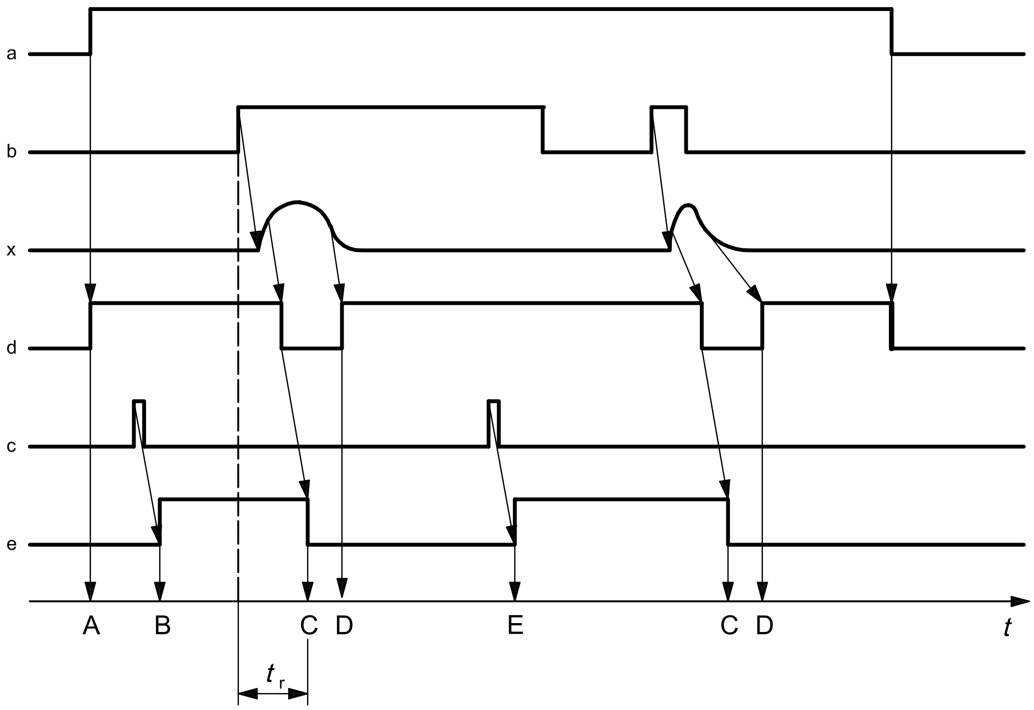
[a] Power to pressure-sensitive protective device.

[b] Actuating force.

[d] Sensor output.

[e] Output of output signal switching device(s).

Figure A.3 — Sensor output without reset function



Key

t time

t_r response time

A Power to the device is ON.

B Reset signal present. Output of the device is turned to ON state.

C Output of the device is in OFF state due to actuating force on the sensor.

D Output of the device is in ON state due to pressure decay in the sensor.

E Reset signal present. Output of the device is turned to ON state, although actuating force is still applied. This may lead to danger. This type of device shall not be used as a presence-sensing device.

It is necessary for the control system of the machine to have its own safety system to ensure that no hazardous restart occurs. For example, on powered doors, this can be in the form of automatic machine reversal or manual reset. The correct function 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, this has to be the function of the door control system.

NOTE 1 The point at which D occurs will depend on a number of factors, e.g. the level of force applied and the controlled rate of leakage of air from the system.

NOTE 2 As indicated in 4.2.15, Note 3, most air pulse systems are not considered as fulfilling the requirements of category 1 according to ISO 13849-1.

NOTE 3 See C.2.6 for additional information on air pulse systems.

[a] Power to the electrical circuits of the device.

[b] Actuating force.

[c] Reset signal.

[x] Pressure pulse in the sensor.

[d] Electrical output of the sensor.

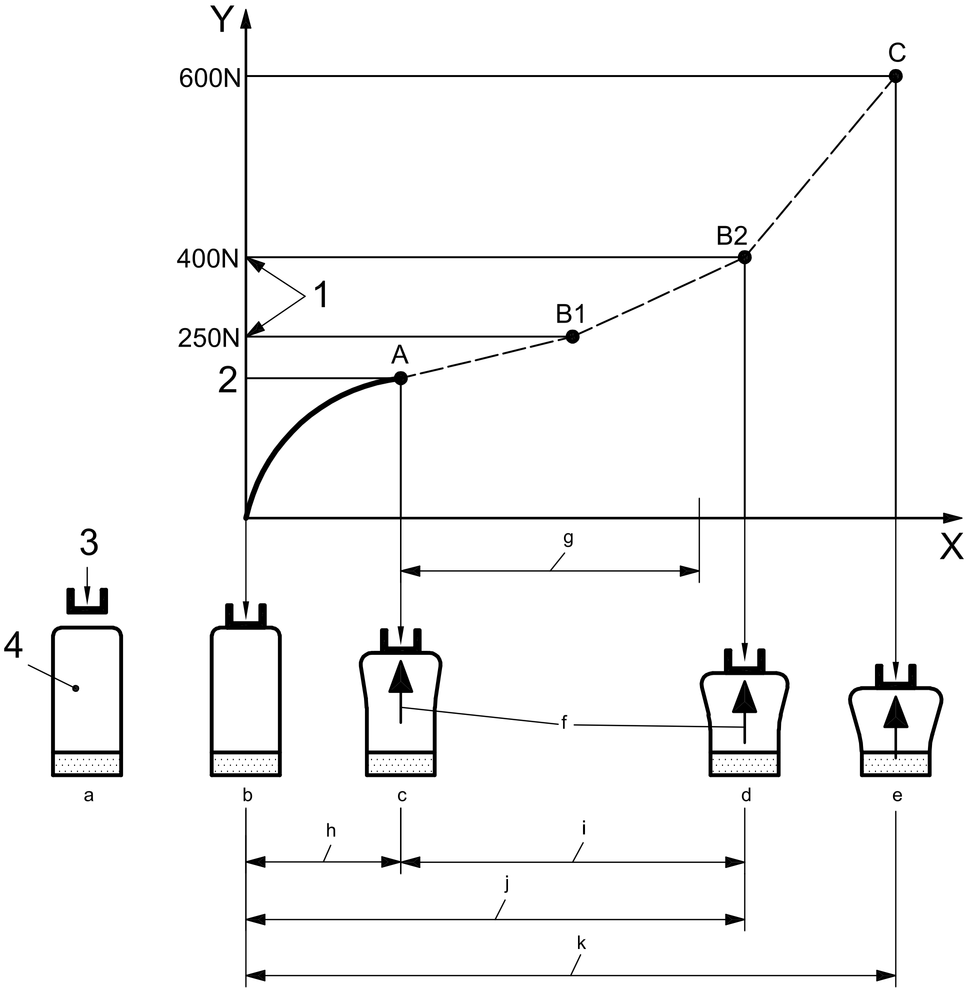
[e] Output of the output signal switching device(s).

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

Annex B
(informative)

Explanatory notes concerning device characteristics

Figure B.1 gives the principle of operation only. For some devices, e.g. plates, the curve may have a different shape depending on the design.



Key

X travel, mm

Y force, N

1 stated limit forces

2 lowest actuating force

3 hazard speed

4 sensor

NOTE Forces are related to test piece 1 and are examples only.

[a] Sensor before contact.

[b] Point of contact.

[c] Point of actuation.

[d] Deformation at point B2 (400 N).

[e] Deformation at point C (e.g. 600 N).

[f] Reaction force.

[g] Established stopping travel of machine.

[h] Actuating travel.

[i] Overtravel.

[j] Working travel.

[k] Total travel.

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

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 dangerous movement. The distance travelled between these two points is called the actuating travel. This distance may vary with the approach speed and environmental conditions.

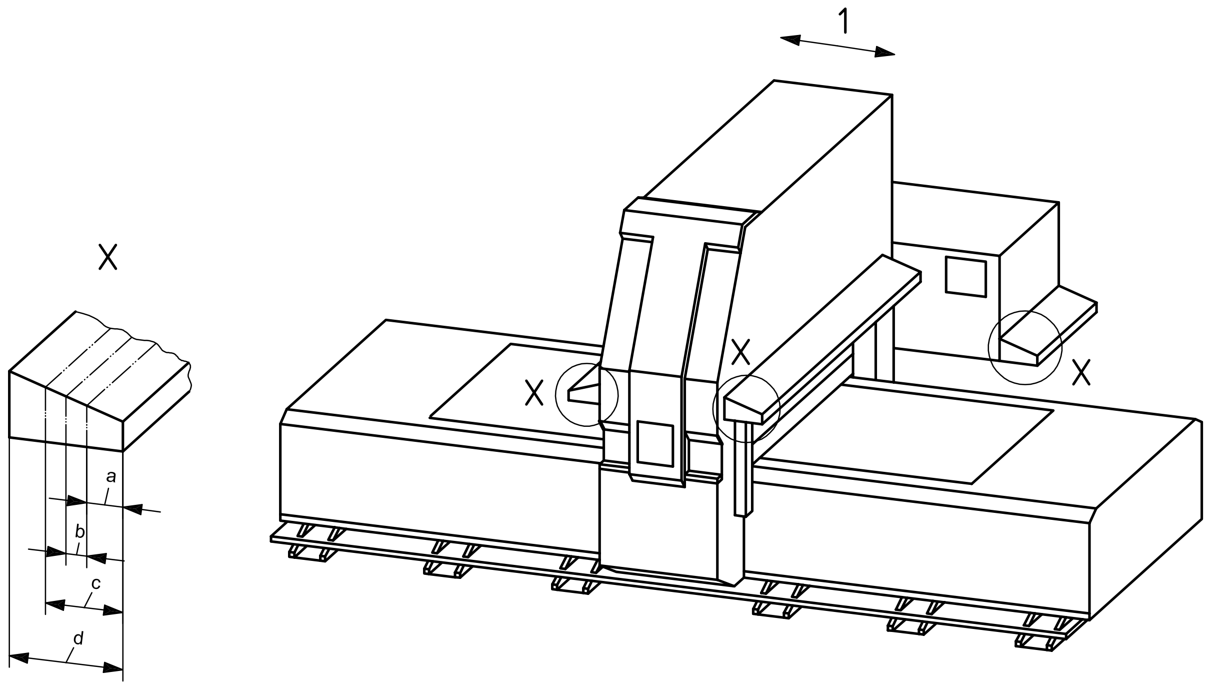
Overtravel and total travel: overtravel is the distance in which the speed decreases and the applied force increases. The maximum permissible force specified by the supplier and selected by the user for an application should be less than the limit force according to the type-C standard or the risk assessment 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 part of the body 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 parts of the body being protected. Special consideration should be given to those applications where children or elderly persons are to be protected.



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

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

Annex C
(informative)

Design notes

C.1 General

C.1.1 Purpose

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

C.1.2 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.1.3 Components

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

C.1.4 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.1.5 Profile material

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

C.1.6 Sensor sensitivity

Sensors may 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.1.7 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.1.8 Trap points

Consideration should be given to the design of pressure-sensitive protective devices having rigid sensors with respect to the prevention of trapping 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.1.9 Result of sensor actuation

After the pressure-sensitive sensor has been actuated, the control system of the machinery may 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 protective device, an automatic reset should not be possible (see Reference [1], Annex 1, 1.2.3). Restarting the machinery should be possible only after manual operation of a reset device. The reset may 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.1.10 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 and reset shall not be possible as long as the person is present.

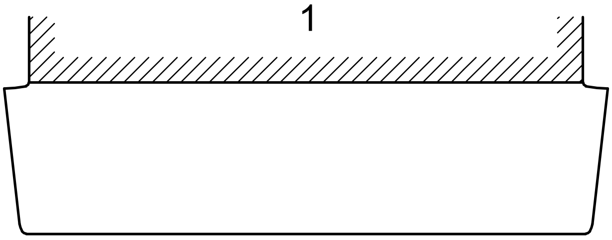
C.2 Pressure-sensitive bumpers

C.2.1 General

Bumpers are generally made in two forms: either of foam or rigid surfaces. They may 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. Equivalent bumpers with rigid surfaces are shown in Figures C.3 and C.4.

Bumpers designed in accordance with Figures C.1 or C.3 are generally used where the movement is in a straight line. See Figure B.2.

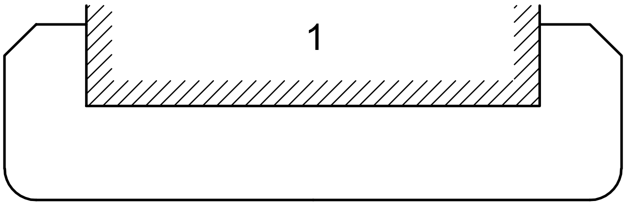
Bumpers designed in accordance with Figures C.2 or C.4 are used when the movement is multidirectional. This is the case on a vehicle turning a corner.



Key

1 mounting surface

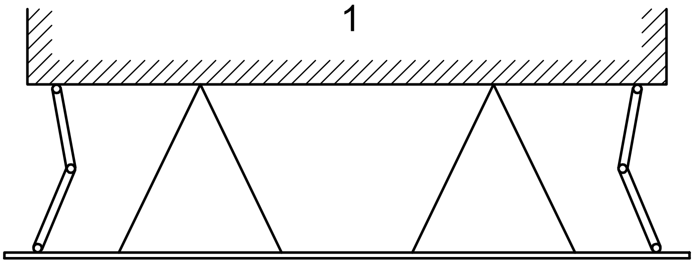
Figure C.1 — Foam bumper



Key

1 mounting surface

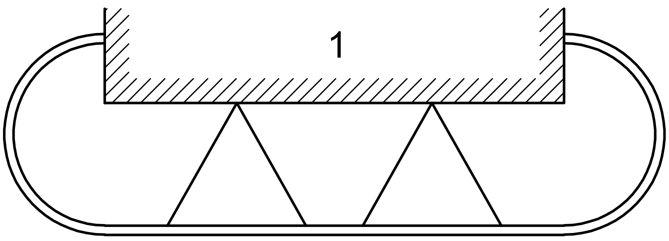
Figure C.2 — Foam bumper



Key

1 mounting surface

Figure C.3 — Rigid surface bumper



Key

1 mounting surface

Figure C.4 — Rigid surface bumper

C.2.2 Physical effects

Ingress of material (either in small or large particles), vermin or fluid which may 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 might not be possible to detect a very small hole in the surface of the flexible foam during regular inspection. However, the hole can be sufficiently large to allow fluid 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 may be desirable to ensure that fluids can escape from a pressure-sensitive bumper by or through a suitable porous area.

C.2.3 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.2.4 Pressure-sensitive bumpers with fibre optic sensors

These 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 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 fibre, e.g. after a fibre breakage.

C.2.5 Pressure-sensitive bumpers with limit switches

These normally operate on transferring the actuating force to the limit 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 limit switches.

C.2.6 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 whilst 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 reset manually 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 might not be detected.

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

— The air pressure switch might 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 may 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 device 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.2.7 Pressure-sensitive bumpers with dynamic sensors

Several technologies may 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 reset manually 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.2.8 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 should be required.

C.2.9 Pressure-sensitive bumpers with semi-rigid or rigid surfaces

NOTE See Figures C.3 and C.4.

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.2.10 Bumpers mounted on moving and stationary parts of machinery

C.2.10.1 Bumpers mounted on moving parts of machinery

The following notes apply to all applications where the bumper is mounted on the moving part of the machine, e.g. the leading edge of a power-operated door, or an automated guided vehicle.

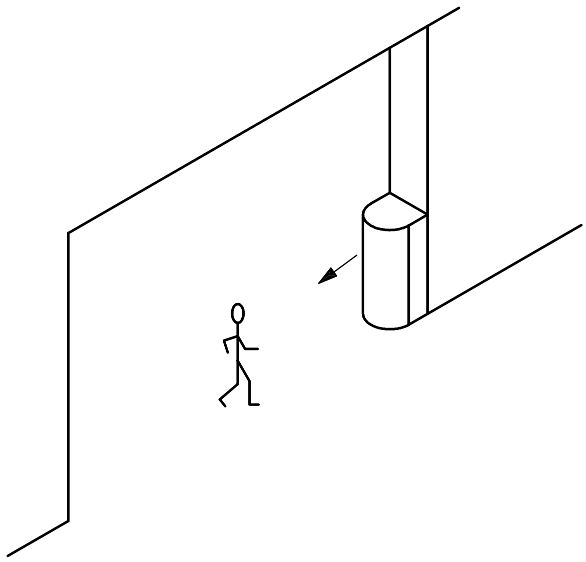


Figure C.5 — Bumper mounted on a powered door

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 is not harmful (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.2.10.2 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,

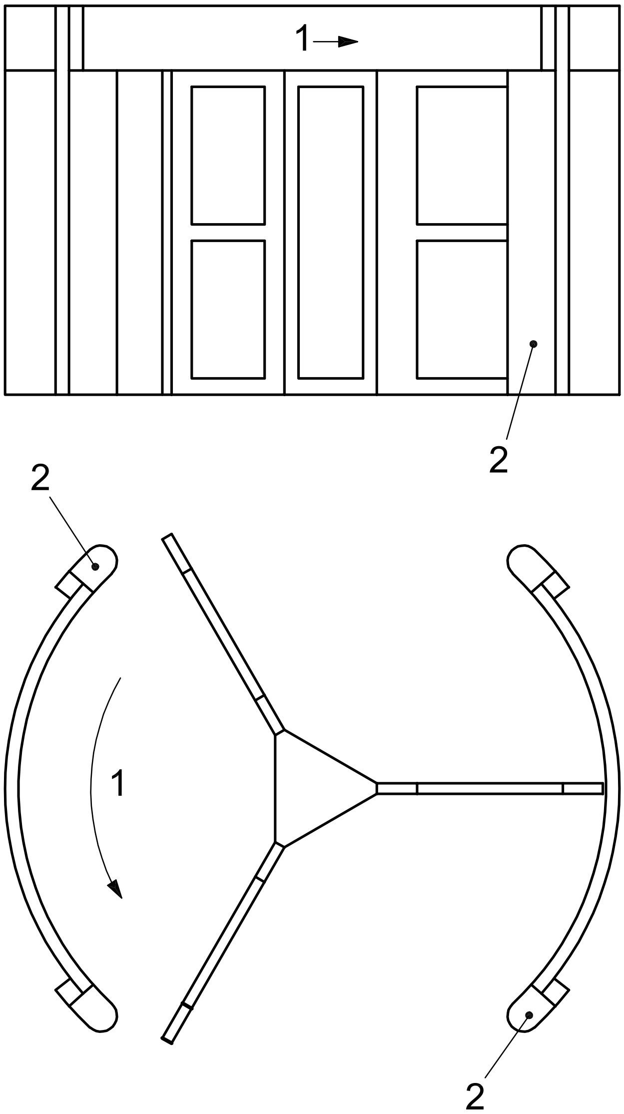
— the risk of crushing, and

— the stability of any load carried by the machine.

In some cases it may be necessary to have a second (non-contact) safety device which will reduce the approach speed to an acceptable level before contact is made.

C.2.11 Stationary bumpers

When a stationary bumper 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.2.10 applies to stationary bumpers also.



Key

1 rotation

2 leading mullion bumper

Figure C.6 — Bumper on mullion of a powered rotating door

C.3 Pressure-sensitive plates

C.3.1 General

When a pressure-sensitive plate is used on an access opening to a danger 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;

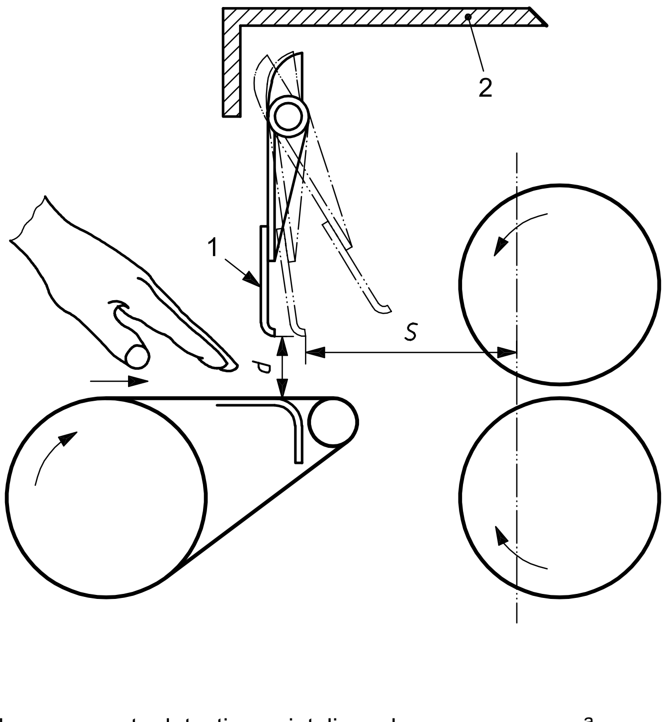
— warping/bending of the moving part of the sensor;

— 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.3.2 Minimum separation distance

See Figure C.7.



Key

S minimum distance from danger zone to detection point, line, plane or zone, mm [a]

d detection capability of device, mm [b]

1 pressure-sensitive plate

2 rigid (fixed) guard

[a] See Equation (C.1).

[b] See ISO 13855:2002, 6.1.1.

Figure C.7 — 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 danger zone to the detection point, line, plane or zone, in millimetres;

K is the approach speed of the body or parts of the body (typically 2 000 mm/s) [1];

t is the overall system stopping time (response time of the pressure-sensitive plate plus the time it takes the machine to stop), in seconds;

C is an additional distance based on intrusion towards the danger zone prior to actuation of the protective equipment (i.e. how far towards the danger zone it is possible to push the hand before it is detected by movement of the pressure-sensitive plate), in millimetres.

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 protective device is able to detect the arm. C depends on the actual opening, 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.4 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 danger zone. In addition, it is recommended that they are designed and installed such that they fulfil the relevant requirements for the emergency stop equipment (see ISO 13850:1996, Clause 4 and IEC 60947-5-5:1997, 6.4).

See Figure C.8 for an example of the principle of the operation of a pressure-sensitive wire.

1) For a detailed calculation, ISO 13855 states the following parameters for this formula:

K = 2 000 mm/s, for minimum distances of $S \leqslant$ 500 mm, while $S \geqslant$ 100 mm;

K = 1 600 mm/s, for minimum distances of $S >$ 500 mm, while $S \geqslant$ 500 mm.

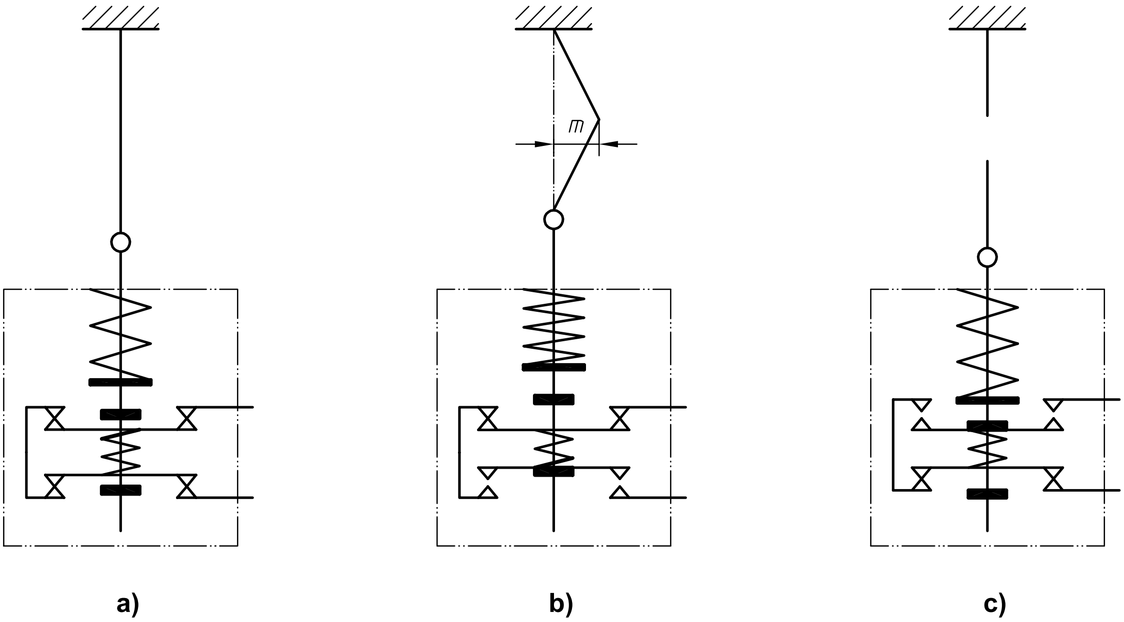


Figure C.8 — Example of a pressure-sensitive wire

In Figure C.8 a) both contacts of the interlocking device are closed and the operation of the machine is possible;

In Figure C.8 b) the wire has been deflected by the necessary amount (m). One pair of the contacts have been positively opened and a stop signal has been generated. In this case the contacts have also been latched in the open position;

In Figure C.8 c) the 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 wire is usually limited by physical means so that the switch cannot be damaged by excessive actuating deflection (m) of the wire.

Annex D
(informative)

General application notes

D.1 General

This annex gives some guidance regarding applications. The general selection criteria should include the following:

a) the relevant category according to ISO 13849-1 according to the risk assessment;

b) the approach speed;

c) the stopping travel of the hazardous parts;

d) use as a single device or in combination with other devices;

e) ability to combine sensors;

f) avoidance of “dead” surfaces;

g) frequency of operating cycles and lifetime of the system;

h) the 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 (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) the recovery time of the sensor after deformation;

y) interfacing with the machine control system.

The above list is not complete and special conditions, such as combinations of the above, may apply to particular applications.

The approach speed b) 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.

The stopping travel c) of the hazardous parts 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.

The recovery of the sensor after deformation x): 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.

D.2 Application of sensor

D.2.1 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 part of the body can reach the danger zone. See ISO 13855.

— **Application 2**

  They are mounted on the dangerous 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.2.2 Application 1

A typical application is illustrated in Figure C.7. After deciding on the 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 protective device, and the control system of the machine.

c) Determine the stopping time of the machine.

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

e) Calculate the distance between the 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.2.3 Application 2

After deciding on the 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 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 factors exist, e.g. a braking system that is subject to deterioration, a higher safety factor should be used. Refer to 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 parts of the body and the types of persons to be protected, e.g. children or elderly persons. The speed, shape, material of the sensor and maximum pressure exerted by the 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 safety 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 device with sufficient overtravel cannot be found, then it can be necessary to improve the stopping performance of the machine.

D.3 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 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.6 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.5 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 part of the body to be inserted between the sensor and the surface on which it is mounted, e.g. a moving machine with a “skirt” type sensor (see Figure C.4), or a sensing plate which can trap a hand (see Figure C.7). If this is a possibility, additional guarding should be considered.

D.4 Sensor positioning

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

D.5 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 ensures 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 The maximum permissible forces (pressures) are very different on different parts of the body. Injuries can vary also on same part of the body depending on the direction of the travel, shape and material of the obstacle (or sensor), etc. Therefore, no permissible (safe) limit forces are given in this part of ISO 13856. An indication of forces for different parts of the body is, however, given in Table 1.

Annex E
(informative)

Commissioning and inspection

E.1 General

The instructions for use should include the following notes concerning commissioning and inspection, providing guidance on the recommended commissioning and testing after installation for ensuring safe operation of the total system (see Clause 6 for documentation to be provided for information regarding selection and use).

E.2 System information

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

E.3 Commissioning

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

a) Check that the device is suitable for the environmental conditions.

b) Check that the device is fastened securely.

c) Check the rating and characteristics at all inputs/outputs, e.g. 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) 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 protective device.

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

j) Test the muting arrangements (if fitted) in accordance with ISO 13849-1:1999, 5.9.

k) Check that 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) 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 Information for regular inspection and tests

Include the information 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, the point of actuation shall be varied 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.

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