INTERNATIONAL STANDARD

ISO 13856-2

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Safety of machinery — Pressure-sensitive protective devices —

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

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

Partie 2: Principes généraux de conception et d'essai des bords et barres sensibles à la pression

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ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

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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 13856-2 was prepared by Technical Committee ISO/TC 199, *Safety of machinery* and by Technical Committee CEN/TC 114, *Safety of machinery* in collaboration.

This second edition cancels and replaces the first edition (ISO 13856-2:2005), which has been technically revised.

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

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

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

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

Introduction

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

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

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

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

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

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

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

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

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

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

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

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

Pressure-sensitive edges and pressure-sensitive bars are safeguards of the *mechanically-actuated trip device* type. General requirements for these safeguards (as well as others) are given in ISO 12100:2010, 6.3.1 and 6.3.2.

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

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

Pressure-sensitive edges and pressure-sensitive bars can be fitted to a fixed or moving part of a machine or an obstacle to prevent trapping or crushing hazards from another part of a machine. Pressure-sensitive edges and pressure-sensitive bars are designed, selected, installed and/or interfaced with the control system of the machine so that the force/pressure applied to a person or parts of the body do not exceed certain limits.

Pressure-sensitive edges, pressure-sensitive bars, pressure-sensitive bumpers and similar devices have many similarities. Table 1 summarizes the differences which generally apply between the two types of

pressure-sensitive protective devices covered by this part of ISO 13856 and pressure-sensitive bumpers (covered by ISO 13856-3 and gives guidance for their application).

Table 1 — Characteristic features of pressure-sensitive edges, pressure-sensitive bars and pressure-sensitive bumpers

Cross-section	Pressure-sensitive edge	Pressure-sensitive bar	Pressure-sensitive bumper
	Regular	Regular	Regular/irregular
Length/width ratio	>1	Any ratio	Any ratio
Effective sensing surface	Deforms locally	Moves as a whole	Deforms locally and/or moves as a whole
Body part(s) intended to be detected	Finger	Finger	—
	Hand	Hand	Hand
	Arm	Arm	Arm
	Leg	Leg	Leg
	Head	Head	Head
	Torso	Torso	Torso

Safety of machinery — Pressure-sensitive protective devices —

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

1 Scope

This part of ISO 13856 establishes general principles and specifies requirements for the design and testing of pressure-sensitive edges and pressure-sensitive bars used as safeguards and not as actuating devices for normal operation.

This part of ISO 13856 is applicable to pressure-sensitive edges and pressure-sensitive bars, with or without an external reset facility, used to detect persons or body parts that can be exposed to hazards such as those caused by the moving parts of machines.

It is not applicable to

— determining the suitability of a pressure-sensitive edge or pressure-sensitive bar for a particular safeguarding application,

— selection of an appropriate performance level for safety-related parts of control systems (SRP/CSs) other than to give minimum values,

— dimensioning or configuring of the effective sensing area of pressure-sensitive edges or pressure-sensitive bars in relation to any particular application,

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

Requirements for the information to be provided by the manufacturer are given to assist in the selection of a suitable pressure-sensitive edge or pressure-sensitive bar and its application.

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

2 Normative references

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

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

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

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

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

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

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

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

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

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

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

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

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

IEC 60947-5-1:2003, *Low-voltage switchgear and controlgear — Part 5-1: Control circuit devices and switching elements — Electromechanical control circuit devices*

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

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

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

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

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

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

IEC 61439-1:2011, *Low-voltage switchgear and controlgear assemblies — Part 1: General rules*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 12100, ISO 13849-1 and the following apply.

3.1
pressure-sensitive edge
sensitive protective equipment of the "mechanically activated trip" type comprising a *sensor* (3.3) or sensors and a control unit and one or more *output signal switching devices* (3.5) intended to detect contact with a person or body part of a person and where the *effective sensing surface* (3.9) is deformed locally to actuate the sensor(s)

Note 1 to entry: The sensor or sensors generate(s) a signal when pressure is applied to part of its surface. The control unit responds to the signal from the sensor and generates an output signal(s) to the control system of a machine.

Note 2 to entry: The length of the sensor(s) is greater than the width. The cross-section throughout the pressure-sensitive area is constant and its width is usually within the range from 8 mm to 80 mm.

Note 3 to entry: For the definition of sensitive protective equipment see ISO 12100:2010, 3.28.5.

3.2
pressure-sensitive bar
sensitive protective equipment of the "mechanically activated trip" type comprising a *sensor* (3.3) or sensors and a control unit and one or more *output signal switching devices* (3.5) intended to detect contact with a person or body part of a person and where the *effective sensing surface* (3.9) moves as a whole to actuate the sensor(s)

Note 1 to entry: The sensor or sensors generate(s) a signal when pressure is applied to part of its surface. The control unit responds to the signal from the sensor and generates an output signal(s) to the control system of a machine.

Note 2 to entry: The length of the sensor(s) is greater than the width. The cross-section throughout the pressure-sensitive area is constant and its width is usually within the range from 8 mm to 80 mm.

Note 3 to entry: For the definition of sensitive protective equipment see ISO 12100:2010, 3.28.5.

3.3
sensor
part of the *pressure-sensitive edge* (3.1) or *pressure-sensitive bar* (3.2) which generates a signal in response to sufficient pressure applied to part of its surface

Note 1 to entry: 3.3 to 3.5 define the functional components of a pressure-sensitive edge or pressure-sensitive bar. These functions can be integrated into a single assembly or can be contained in any number of separate assemblies (see Figure 1). For example, a simple pressure-sensitive edge or pressure-sensitive bar actuating a position switch can be considered to be the sensor, the control unit, and the output signal switching device.

3.4
control unit
part of the *pressure-sensitive edge* (3.1) or *pressure-sensitive bar* (3.2) which responds to the condition of the *sensor* (3.3) and generates output signals to the machine control system

Note 1 to entry: 3.3 to 3.5 define the functional components of a pressure-sensitive edge or pressure-sensitive bar. These functions can be integrated into a single assembly or can be contained in any number of separate assemblies (see Figure 1). For example, a simple pressure-sensitive edge or pressure-sensitive bar actuating a position switch can be considered to be the sensor, the control unit, and the output signal switching device.

3.5
output signal switching device
part of the control unit of a *pressure-sensitive edge* (3.1) or *pressure-sensitive bar* (3.2) which is connected to the machine control system and transmits output signals

Note 1 to entry: 3.3 to 3.5 define the functional components of a pressure-sensitive edge or pressure-sensitive bar. These functions can be integrated into a single assembly or can be contained in any number of separate assemblies (see Figure 1). For example, a simple pressure-sensitive edge or pressure-sensitive bar actuating a position switch can be considered to be the sensor, the control unit, and the output signal switching device.

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

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

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

3.9
effective sensing surface
part of the surface of the *sensor* (3.3) or a combination of sensors within the *effective sensing angle* (3.12) and the *effective sensing length* (3.10) where the application of an *actuating force* (3.8) creates an *OFF state* (3.7) in the *output signal switching device* (3.5)

Note 1 to entry: See, for example, Figures 2 and 3.

3.10
effective sensing length
length of the *effective sensing surface* (3.9)

3.11
reference axis
line in the direction of the length of the *sensor* (3.3), whose position in the cross-sectional view of the sensor is used to define the *effective sensing surface* (3.9)

Note 1 to entry: See Figures 2 and 3.

3.12
effective sensing angle
angle around the *reference axis* (3.11) which limits the *effective sensing surface* (3.9) along the *effective sensing length* (3.10)

Note 1 to entry: See Figures 2 and 3.

3.13
reference direction
direction of actuation, from a point on the *effective sensing surface* (3.9) towards the *reference axis* (3.11), which bisects the *effective sensing angle* (3.12) and is perpendicular to the reference axis

Note 1 to entry: See Figures 2 and 3.

3.14
dead surface
part of the surface area of the *sensor* (3.3) outside the *effective sensing surface* (3.9)

Note 1 to entry: See Figures 2 and 3.

3.15
pre-travel
distance travelled by an object moving in a direction perpendicular to the *reference axis* (3.11) and in the axis of the applied *actuating force* (3.8), measured from where this object touches the *effective sensing surface* (3.9) to where the *output signal switching device*(s) (3.5) changes to an *OFF state* (3.7) under specified conditions

Note 1 to entry: See Figure 4.

3.16
working travel
distance travelled by an object, moving in a direction perpendicular to the *reference axis* (3.11), from where this object touches the *effective sensing surface* (3.9), under specified conditions, to where a stated limit force is exerted on the object

Note 1 to entry: See Figure 4.

3.17
overtravel
difference between the *working travel* (3.16) and the *pre-travel* (3.15) when both are measured with the same object applied under the same conditions

Note 1 to entry: See Figure 4.

3.18
force–travel relationship
relationship between force applied perpendicular to the *reference axis* (3.11) and the distance travelled by a specified object perpendicular to the reference axis under specified conditions

Note 1 to entry: See Figure 4.

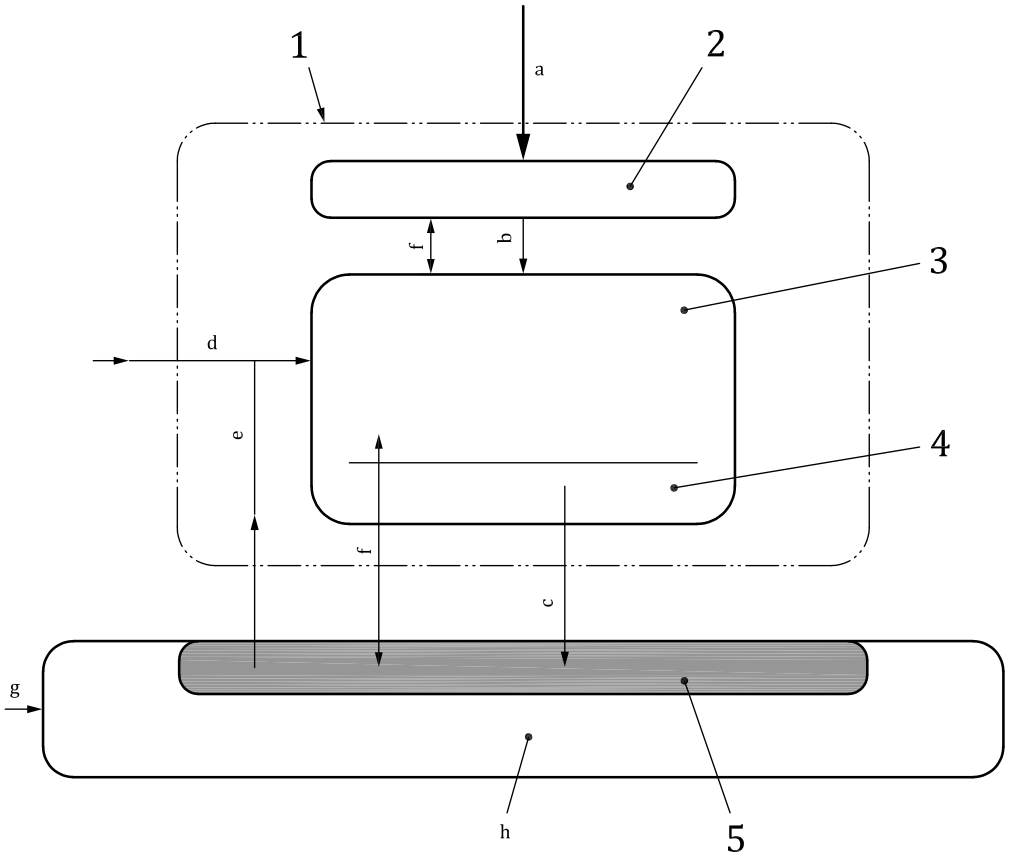
3.19
reset
function which permits an *ON state* (3.6) in an *output signal switching device* (3.5) provided that certain conditions are met

Note 1 to entry: See Annex A.

3.20
total travel
movement or deformation of the *effective sensing surface* (3.9) of a *pressure-sensitive edge* (3.1) or *pressure-sensitive bar* (3.2) which is measured in the direction of the *actuating force* (3.8) from the point of contact to the point at which no further significant deformation of the effective sensing surface occurs (e.g. at a force of 600 N)

3.21
start interlock
means which prevents the start of an automatic machine when power (e.g. the electrical supply) is switched on to the *pressure-sensitive edge* (3.1) or *pressure-sensitive bar* (3.2), or is interrupted and restored

3.22
operating speed
any speed at which an object is pressed against the *sensor* (3.3) and which causes the *output signal switching device* (3.5) to go to the *OFF state* (3.7)



Key

1 pressure-sensitive edge or pressure-sensitive bar
2 sensor(s)
3 control unit*
4 output signal switching device(s)*
5 part of the machine control system for pressure-sensitive edge or pressure-sensitive bar output signal processing
a Actuating force.
b Sensor output signal.
c ON state/OFF state signal.
d Manual reset signal**.
e Reset signal from machine control system (where appropriate).
f Monitoring signals (optional).
g Manual reset signal to machine control system***.
h Machine control system(s).
* Can be located within the machine control system or as part of the machine control system.
** Where appropriate, this may be used as an alternative to g.
*** Where appropriate, this may be used as an alternative to d.

Figure 1 — Systematic sketch of pressure-sensitive edge or pressure-sensitive bar as applied to machine

4 Requirements for design and testing

4.1 Effective sensing surface

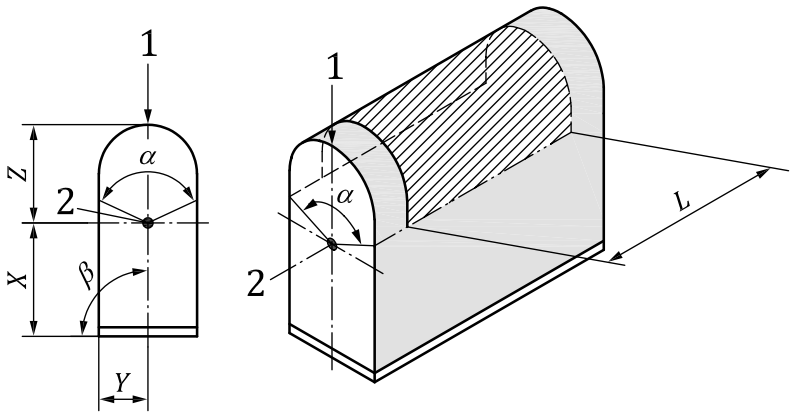
NOTE For the purposes of this part of ISO 13856, "normal operation" means compliance with the requirements of Clause 4, verified according to Clause 7.

The manufacturer of the pressure-sensitive protective device shall state the effective sensing surface by giving the dimensions X, Y, Z, the angles α and β and the effective sensing length L in accordance with Figures 2 and 3.

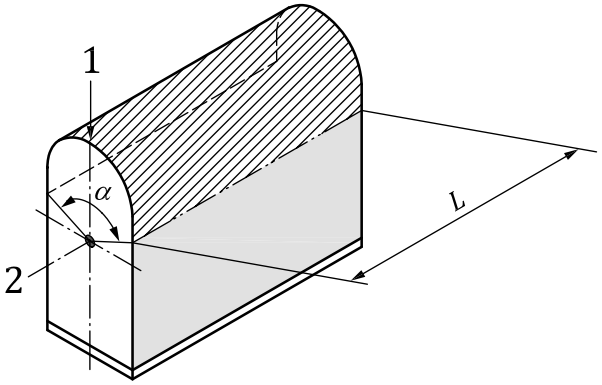
The effective sensing angle of pressure-sensitive protective devices with heights (see Figure 2) $X + Z \geq 40$ mm shall be ≥ 90°.

The effective sensing angle of pressure-sensitive protective devices with heights $X + Z < 40$ mm shall be at least 40°.

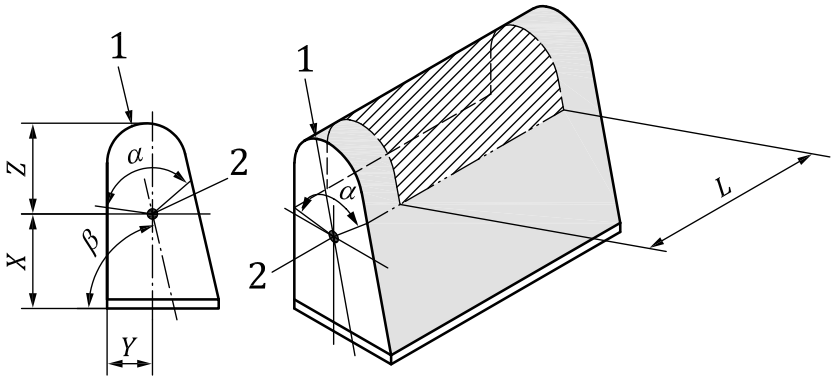
If the effective sensing angle is less than 90°, a clear warning shall be given in the information for use (see Clause 6).



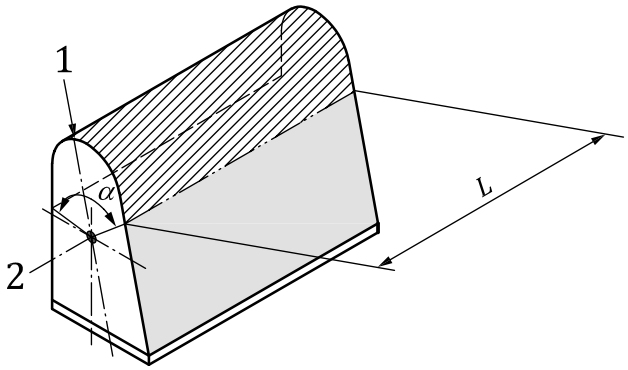
a) Symmetrical with dead surface at ends



b) Symmetrical without dead surface at ends



c) Asymmetrical with dead surface at ends

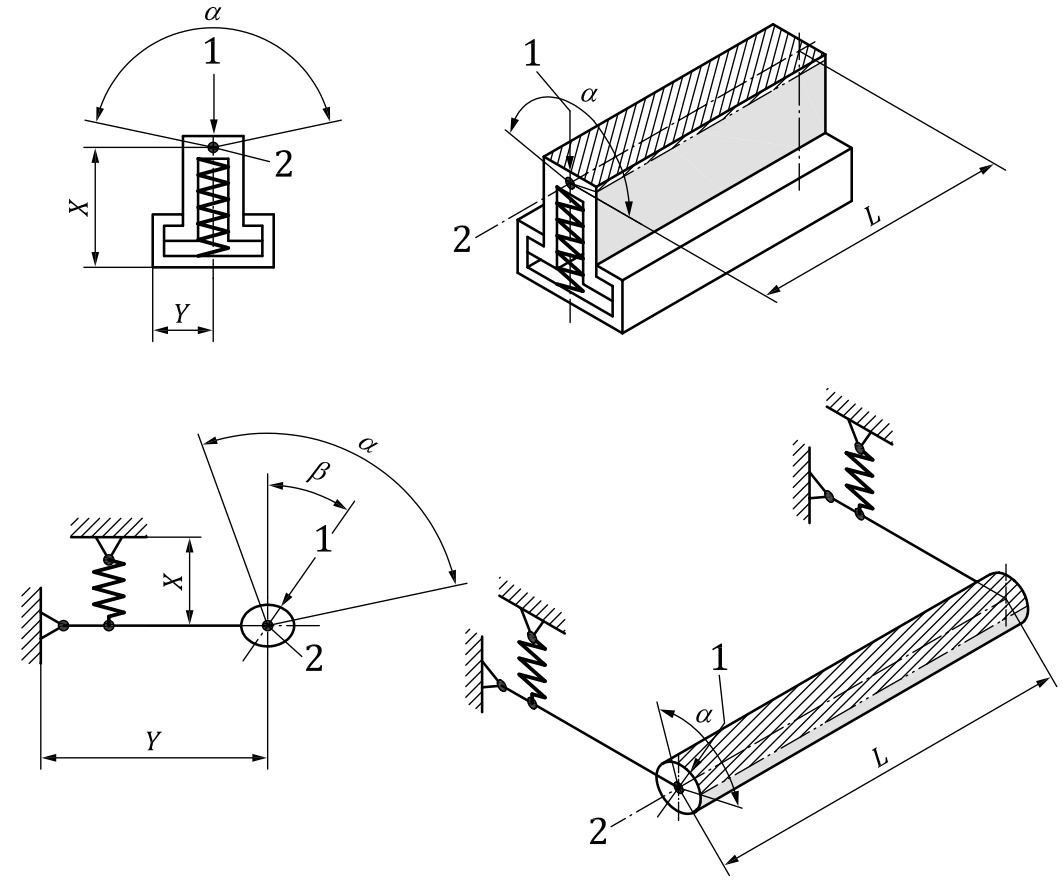


d) Asymmetrical without dead surface at ends

Key

1 reference direction
2 reference axis
L effective sensing length
α effective sensing angle
β see 7.5.2
effective sensing surface
dead surface

Figure 2 — Effective sensing surfaces of pressure-sensitive edges



Key

1	reference direction
2	reference axis
L	effective sensing length
α	effective sensing angle
β	see 7.5.2
	effective sensing surface
	dead surface

Figure 3 — Effective sensing surfaces of pressure-sensitive bars

4.2 Actuating force for testing

For the test methods, see 7.5 and 7.6.

CAUTION — The forces specified in this subclause are primarily intended for the purposes of assessing the pressure-sensitive performance of the device. These forces should not be considered as safe forces (see Annex C and ISO 14120:2002, 5.2.5.2 for guidance)**.**

The sensor of the pressure-sensitive edge or pressure-sensitive bar shall generate an output signal sufficient to cause the output signal switching device to change to the OFF state when the specified minimum actuating force(s) is applied. This requirement shall be met when the actuating force(s) is applied perpendicular to the reference axis. The actuating force shall not exceed those specified in Table 2 when applied at the test speeds (from minimum to maximum operating speeds) over the effective sensing surface and over the operating temperature range with the sensor in the mounting orientations which the manufacturer has specified are suitable for use.

Table 2 — Relationship between test pieces and actuating forces

Test piece (see Figure 5)	1	2	3
Actuating force (N)	150	600	50

Test piece 3 shall be applied only to pressure-sensitive edges or pressure-sensitive bars that are designed to detect fingers.

4.3 Pre-travel

For the test method, see 7.7.2.

The pre-travel shall not be more than that stated by the manufacturer.

4.4 Working travel

For the test method, see 7.7.3.

The working travel shall not be less than that stated by the manufacturer.

4.5 Overtravel

For the test method, see 7.7.4.

The overtravel shall not be less than that stated by the manufacturer.

4.6 Force–travel relationships

For the test method, see 7.7.1

The manufacturer of the pressure-sensitive edge or pressure-sensitive bar shall provide force–travel relationship data for a representative sample in the form of a diagram as shown in Figure 4. This data shall be determined with the force applied through test piece 1 (see Figure 5). The manufacturer shall state the temperature, the operating speed(s), the mounting orientation and the direction of operation at which the data was determined.

Each diagram shall show as a minimum:

— the actuating force and pre-travel (point A in Figure 4);

— the working travel for a reaction force of 250 N (point B1 in Figure 4, see NOTE 2) or a force as stated in the type-C standard (see NOTE 3);

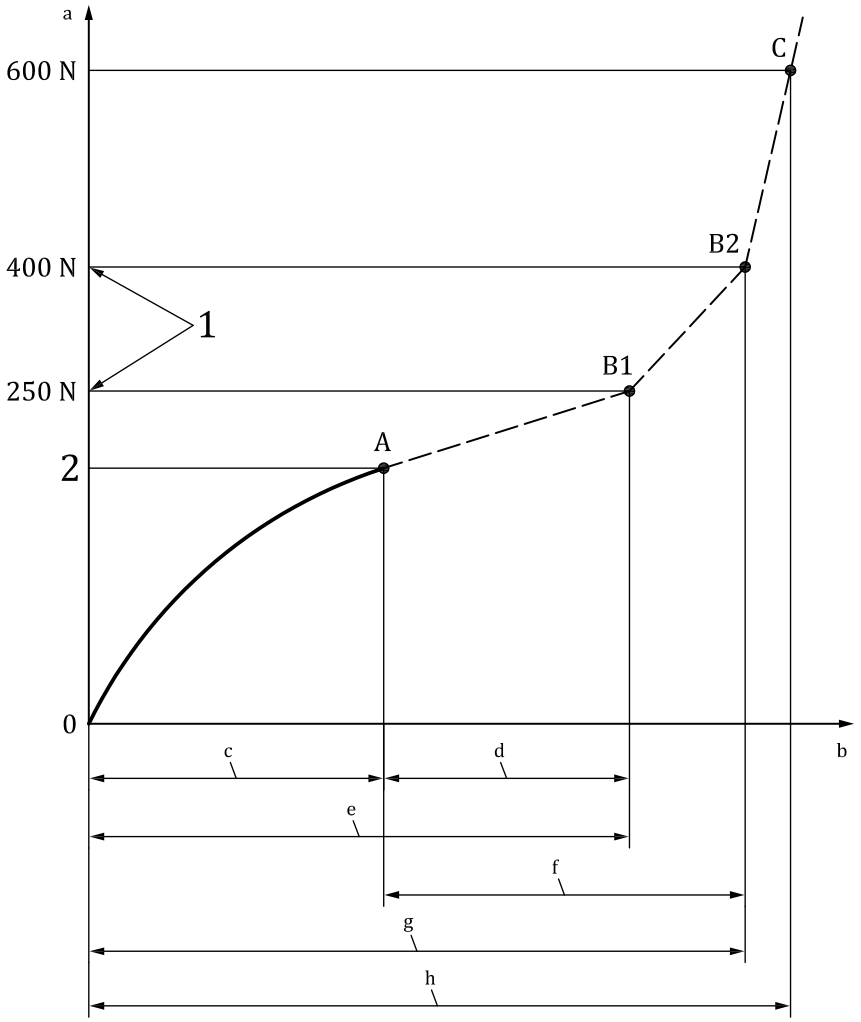
— the working travel for a reaction force of 400 N (point B2 in Figure 4, see NOTE 2) or a force as stated in the type-C standard (see NOTE 3);

— the force–travel relationship above 400 N — for example, up to 600 N (point C in Figure 4).

NOTE 1 The directions of operation to be considered depend upon the intended application of the pressure-sensitive edge or pressure-sensitive bar.

NOTE 2 See Introduction and Annex C concerning acceptable forces.

NOTE 3 The reaction forces 250 N, 400 N and 600 N are given as examples only. When the maximum permissible force is provided in a type-C standard, the working travel is obtained from the corresponding point on the force–travel curve shown in Figure 4.



Key

A pre-travel (actuating point and actuating force at maximum operating speed)

B working travel (e.g. force–travel points B1 and B2 occur at force of 250 N or 400 N at operating speed of ≤10 mm · s^{-1})

C total travel (e.g. occurs at 600 N at operating speed of ≤10 mm · s^{-1})

1 reference force

2 lowest actuating force

a Force, in newtons (N).

b Travel, in millimetres (mm).

c Pre-travel.

d Overtravel at 250 N.

e Working travel at 250 N.

f Overtravel at 400 N.

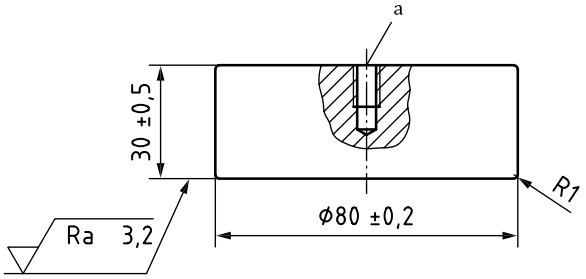
g Working travel at 400 N.

h Total travel.

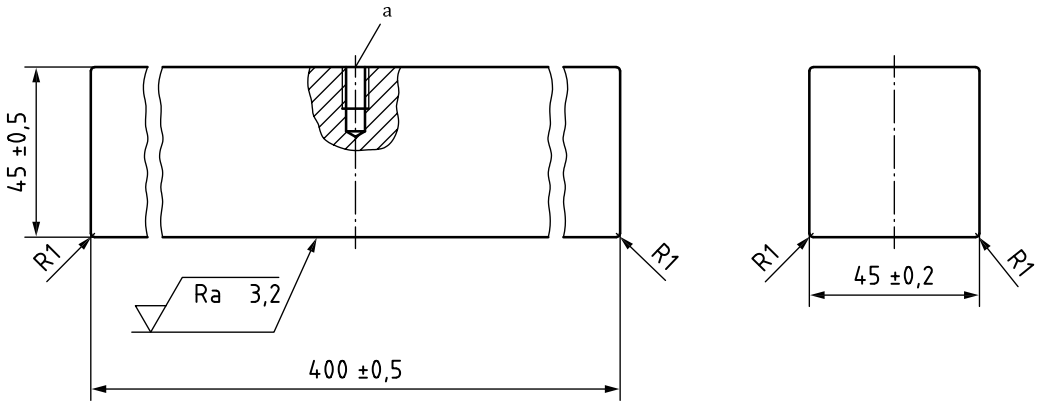
NOTE Test piece 1 according to Figure 5 is used to apply the forces.

Figure 4 — Diagram of force–travel relationship

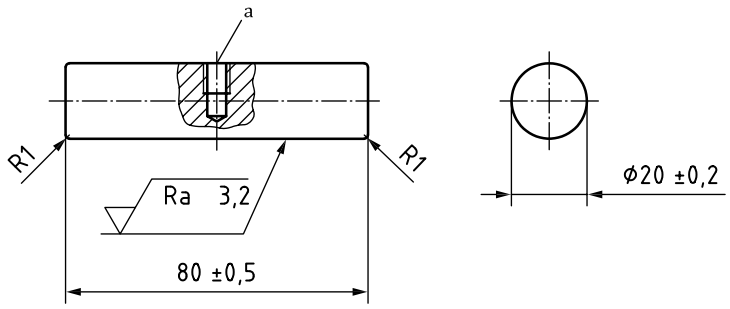
Dimensions in millimetres/Tolerance on radii ± 0,2



a) Test piece 1



b) Test piece 2



c) Test piece 3

a Mounting proposal only.

Figure 5 — Test pieces 1 to 3 (see 7.3)

4.7 Minimum operating speed

For the test method, see 7.6.

The minimum operating speed shall not exceed 10 mm · s^{-1}.

4.8 Number of operations

For the test methods, see 7.8.

4.8.1 General

The requirements for 4.8.2 and 4.8.3 apply to pressure-sensitive edges and/or pressure-sensitive bars in order for them to be accepted as well-tried components.

4.8.2 Single sensors

For the test method, see 7.8.1.

After 10 000 operations the pressure-sensitive edge or pressure-sensitive bar shall have no defects affecting the safety performance (see 7.8.3). This requirement applies to single sensors used alone or in combination (see 4.8.3).

4.8.3 Combination of sensors

For the test method, see 7.8.2.

Where the effective sensing surface comprises of more than one sensor, after a further 1 000 operations at each joint the pressure-sensitive edge or pressure-sensitive bar shall have no defects affecting the safety performance (see 7.8.3).

4.9 Sensor output

For the test method, see 7.9.

The sensor output shall have a value which causes the output signal switching device to change to the OFF state when the actuating force is applied perpendicular to the reference axis to the effective sensing surface.

4.10 Response of output signal switching device to actuating force

For the test methods, see 7.9 and 7.10.

4.10.1 Systems, where sensor output remains in OFF state for as long as actuating force is applied

When the minimum actuating force is applied perpendicular to the reference axis the output signal switching device shall change from an ON state to an OFF state and it shall remain in the OFF state at least as long as the actuating force is applied.

See Annex A.

4.10.2 Systems where sensor output does not stay in OFF state when actuating force remains

When the minimum actuating force is applied perpendicular to the reference axis, the output signal switching device shall change from an ON state to an OFF state. Since the output switching device can revert to an ON state when the actuating force remains, additional protective measures are required to ensure that there is no hazard. The output signal switching device may only revert to the ON state when a reset signal is applied (see Annex A) or when additional safety measures are taken, e.g. automatic reversal of hazardous movement. Such additional measures shall be stated in information for use, see 6.3.

See Annexes A and G for systems which are relevant to particular applications.

4.11 Reset function

For the test method, see 7.10.

The reset function of a pressure-sensitive edge or pressure-sensitive bar shall fulfil the general requirements of ISO 13849-1:2006, 5.2.2 and the functional requirements of Annex A.

To reset a start interlock or the restart interlock of a pressure-sensitive edge or pressure-sensitive bar, 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 and ISO 13849-1:2006, 5.2.2.

4.12 Environmental conditions

For the test methods, see 7.11.

4.12.1 General

The pressure-sensitive edge or pressure-sensitive bar shall continue in normal operation in the environmental conditions stated by the manufacturer. The minimum requirements are stated in 4.12.2 to 4.12.5.

4.12.2 Climatic conditions

For the test methods, see 7.11.2 and 7.11.3.

The pressure-sensitive edge or pressure-sensitive bar shall continue in normal operation under the following climatic conditions.

— The minimum temperature range shall be + 5 °C to + 40 °C. If the manufacturer states that the pressure-sensitive edge or pressure-sensitive bar is suitable for a wider temperature range, then it shall meet this requirement over the stated temperature range (see 7.11.2).

— After storage at a relative humidity of 93 % and at a temperature of 40 °C for four days, the system shall continue in normal operation (see 7.11) and the integrity of the electrical insulation shall be maintained (see 7.11.3).

4.12.3 Electromagnetic compatibility

For the test method, see 7.11.4.

The pressure-sensitive edge or pressure-sensitive bar shall continue in normal operation under the conditions given in Table 13.

NOTE The pressure-sensitive edge or pressure-sensitive bar can be designed to provide a higher immunity level.

4.12.4 Vibration

For the test method, see 7.11.5.

The pressure-sensitive edge or pressure-sensitive bar shall continue to operate without being actuated by the following vibration conditions in accordance with IEC 60068-2-6:

— frequency range 10 Hz to 55 Hz;

— displacement 0,15 mm;

— 10 cycles per axis;

— sweep rate 1 octave per minute.

After this vibration test, the pressure-sensitive edge or pressure-sensitive bar shall continue in normal operation.

4.12.5 Bump

For the test method, see 7.11.6.

The pressure-sensitive bar shall continue to operate without being actuated by the following conditions.

The requirements apply to the sensor of bars in the reference direction and opposite direction only and shall be in accordance with IEC 60068-2-27:

— peak acceleration: 100 m · s^{-2}

— duration of the pulse: 16 ms

— form of the pulse: half sine

— number of pulses per direction: 1 000

— frequency approximately: 1 Hz

The pressure-sensitive bar shall continue to operate without being actuated under the above conditions. After this bump test, the pressure-sensitive bar shall continue in normal operation.

4.13 Power supply variations

4.13.1 General

The pressure-sensitive edge or pressure-sensitive bar shall continue in normal operation when subjected to the power supply variations given in 4.13.2 and 4.13.3.

4.13.2 Electrical power supply variations

For the test method, see 7.12.2.

The pressure-sensitive edge or pressure-sensitive bar shall meet the requirements of IEC 60204-1:2005, 4.3.

4.13.3 Non-electrical power supply variations

For the test method, see 7.12.3.

The pressure-sensitive edge or pressure-sensitive bar shall continue in normal operation when subjected to power supply variations as stated by the manufacturer and in accordance with the relevant requirements of ISO 4413 for hydraulic systems and ISO 4414 for pneumatic systems.

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

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

4.14 Electrical equipment

For the test method, see 7.13.1.

4.14.1 General

The electrical equipment (components) of the pressure-sensitive edge or pressure-sensitive bar shall

— conform to the appropriate existing International Standards,

— be suitable for the intended use, and

— be operated within their specified ratings.

4.14.2 Protection against electric shock

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

4.14.3 Protection against over-current

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

4.14.4 Electromechanical devices

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

4.14.5 Pollution degree

The electrical equipment shall be suitable for pollution degree 2 in accordance with IEC 61439-1:2011, 7.1.3.

4.14.6 Clearance and creepage distances

The electrical equipment shall be designed and constructed in accordance with IEC 61439-1:2011, 8.3 and 10.4.

4.14.7 Wiring

The electrical equipment shall be wired in accordance with IEC 61439-1:2011, 11.10.

4.15 Hydraulic equipment

For the test method, see 7.13.2.

Hydraulic equipment shall meet the relevant requirements of ISO 4413.

4.16 Pneumatic equipment

For the test method, see 7.13.3.

Pneumatic equipment shall meet the relevant requirements of ISO 4414.

4.17 Enclosure

For the test method, see 7.14.

4.17.1 Sensor

The manufacturer shall specify the suitability of the sensor for the particular environment, e.g. wet or dusty conditions. This specification shall be defined as an index of protection, e.g. IP 44 according to IEC 60529. Those parts of the sensor which contain 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.

4.17.2 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 is designed for mounting in another control equipment enclosure, this enclosure shall meet the requirements of the

level 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.

4.18 Additional coverings for sensors

For the test method, see 7.15.

Where the manufacturer states that additional coverings can be used for the sensor, the requirements of this part of ISO 13856 shall still be fulfilled (see Annex D).

4.19 Access

For the test method, see 7.16.

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

4.20 Performance levels and categories for SRP/CSs in accordance with ISO 13849-1

For the test method, see 7.17.

4.20.1 Pressure-sensitive edges and pressure-sensitive bars shall meet the requirements of the performance level (PL) and category for which they are specified and marked. The performance levels and categories are specified in ISO 13849-1.

At present, air pulse systems are not considered to fulfil the requirements of category 1.

NOTE It is possible for an air pulse system to fulfil the requirements of category 2 when the safety function is checked or monitored. See also D.3.5 and G.3.

4.20.2 Pressure-sensitive edges and pressure-sensitive bars shall meet at least the requirements of performance level c according to ISO 13849-1 as well as the requirements of this part of ISO 13856.

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

4.20.3 B_{10d} values for the sensor shall be determined by means of testing.

The test results shall be documented by means of test protocols. These should comprise at least the following information:

— type of sensor;

— measurement points;

— temperature (of the environment);

— operating voltage and operating current;

— switching frequency;

— test location;

— test loading;

— actuating speed;

— number of operations;

— B_{10d} values;

— types of failure;

— test person, test laboratory, date and signature.

4.20.4 If a pressure-sensitive edge or pressure-sensitive bar complies with category 3, its architecture may deviate from the designated architecture according to ISO 13849-1:2006, 6.2.

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

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

4.21 Adjustments

For the test method, see 7.18.

If it is necessary to make adjustments during commissioning, the manufacturer shall supply instructions to enable the adjustments to be made so that the requirements of this part of ISO 13856 can be met. There shall be arrangements for checking that such adjustments have been made correctly. The adjustable elements shall only be accessible by means of a key, security code or tool.

4.22 Sensor fixing and mechanical strength

For the test method, see 7.19.

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 which are stated by the manufacturer.

4.23 Recovery after deformation

For the test method, see 7.20.

After the effective sensing surface of the sensor has been deformed or displaced by the working travel movement using test piece 1 for 24 h, the effective sensing surface shall recover as shown in Table 3. The working travel in this instance is taken from test No. 4 (see 7.7) with a test speed of 10 mm · s^{-1} at a force of 250 N.

Table 3 — Deformation recovery

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

If the manufacturer states that the pressure-sensitive edge or pressure-sensitive bar is suitable for continuous deformation for longer than 24 h, then the sensor shall recover according to Table 3 after deformation for the stated time.

After the effective sensing surface of the sensor has been deformed or moved by the working travel using test piece 1 for at least 24 h, the pressure-sensitive edge or pressure-sensitive bar shall have normal function (ON state) within 30 s [see C.2.1.d)].

4.24 Connections

For the test method, see 7.21.

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

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

4.25 Sharp corners, sharp edges and rough surfaces

For the test method, see 7.22.

Exposed parts of pressure-sensitive edges or pressure-sensitive bars shall not have sharp corners, edges, rough surfaces, etc. which can cause injury to persons who can come into contact with the device(s) (see ISO 12100:2010, 6.2.2.1).

4.26 Mechanical features

For the test method, see 7.23.

Pressure-sensitive edges and pressure-sensitive bars shall comply with ISO 12100:2010, 6.3.2.

For pressure-sensitive bars, see also Annex D.

4.27 Inhibition and blocking

For the test method, see 7.24.

The sensors of pressure-sensitive edges or pressure-sensitive bars shall be constructed so that their operation cannot be intentionally inhibited or blocked by simple means. See also D.3.

5 Marking

For the test method, see 7.25.

5.1 Pressure-sensitive edges and pressure-sensitive bars shall be marked in accordance with ISO 12100:2010, 6.4.4, and, for electrical equipment, with the rated voltage and current as a minimum. See also IEC 60204-1:2005, Clause 16.

5.2 All labels and markings shall be securely fixed and durable for the expected lifetime of the part of the pressure-sensitive edge or pressure-sensitive bar to which it is attached.

5.3 Every part of the pressure-sensitive edge or pressure-sensitive bar that can be replaced in accordance with the instruction manual shall be marked with a type reference or part number as listed in the manual and a traceability code.

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

— PL and category according to ISO 13849-1 for the pressure-sensitive edge or pressure-sensitive bar;

— response time for the pressure-sensitive edge or pressure-sensitive bar;

— with or without reset;

— part number.

6 Information for selection and use

6.1 General

For the test methods, see 7.4. and 7.26.

Information and guidance regarding installation, commissioning and testing is given in Annex F.

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

6.2 Essential data for the selection of suitable pressure-sensitive edge or pressure-sensitive bar

The manufacturer shall make available the relevant information from the following list so that it will assist in the selection of a suitable pressure-sensitive edge or pressure-sensitive bar:

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

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

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

— means of fixing the sensor and control unit;

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

— dimensions which specify the effective sensing surface (see Figures 2 and 3);

— maximum dimensions of the sensor;

— weight of the sensor per metre length and the weight of the control unit;

— sensor additional covering details (where applicable);

— force–travel relationship(s) showing the pre-travel and overtravel in the form of a table or diagram according to Figure 4 and an explanation of how it is used (e.g. key);

— chemical resistance table for the sensor;

— operating temperature range;

— power supply requirements;

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

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

— category(ies) and performance level(s) according to ISO 13849-1;

— selection procedure according to Annex C;

— critical lengths of connections between individual components;

— deformation behaviour over time;

— switching capability of output signal switching device(s) according to IEC 60947-5-1;

— application guidance;

— contact configuration(s) of output signal switching device(s);

— suitability for detecting fingers;

— minimum operating speed, if applicable (for example, for pneumatic systems);

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

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

— statement that the user shall determine the PL required for his application.

6.3 Information for use

6.3.1 Information for installation and commissioning

The following information for installation and commissioning of the pressure-sensitive edge or pressure-sensitive bar shall be given:

a) **Information relating to the pressure-sensitive edge or pressure-sensitive bar**, including

1) a detailed description of the pressure-sensitive edge or pressure-sensitive bar,

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

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

4) the procedure to determine the overtravel for the pressure-sensitive edge or pressure-sensitive bar, with examples (see Annex C),

5) the application range and conditions for which the pressure-sensitive edge or pressure-sensitive bar is intended or approved, including the category, performance level and B_{10d} values according to ISO 13849-1,

6) circuit diagrams providing schematic representation of the safety functions and examples of machine control interfaces,

7) additional protective measures (according to 4.10.2) which can be needed to achieve the required level of safety for specific applications,

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

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

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

11) guidance regarding use of the pressure-sensitive edge or pressure-sensitive bar in alternative mounting orientations, and

12) indication of whether the pressure-sensitive edge or pressure-sensitive bar is designed with or without external reset in accordance with Annex A.

b) **Information relating to packaging, transportation, handling and storage of the pressure-sensitive edge or pressure-sensitive bar**, including

1) dimensions,

2) mass (i.e. kilogram per meter length),

3) description of packaging and methods for unpacking to prevent damage to the pressure-sensitive edge or pressure-sensitive bar,

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

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

c) **Information relating to the installation and commissioning of the pressure-sensitive edge or pressure-sensitive bar**, including

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

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

3) methods of installation including required tooling,

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

5) schedule of tests to be carried out after installation to establish that the pressure-sensitive edge or pressure-sensitive bar is functioning and has been installed and interfaced with the machine control correctly,

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

7) an indication that the category or categories and performance level(s) declared for the pressure-sensitive edge or pressure-sensitive bar shall comply with the categories and performance levels established by the user's risk assessment, and

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

d) **Training:** recommendations for the minimum training requirements of personnel installing the equipment to ensure that the pressure-sensitive edge or pressure-sensitive bar is installed to comply with this document.

6.3.2 Information relating to operation of pressure-sensitive edge or pressure-sensitive bar

The following information relating to the operation of the pressure-sensitive edge or pressure-sensitive bar shall be given.

a) **Information relating to the use of the pressure-sensitive edge or pressure-sensitive bar**, including

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

2) information regarding use limits,

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

4) indication of fault exclusions,

5) explanation to the calculated PL with reference to the variable parameters mean operation time, mean mission time and cycle time,

6) statement that the user shall determine the PL required for his application, and

7) a warning that the machine should not be restarted if a hazard is present.

b) **Information for maintenance,** including

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

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

3) instruction for allowable setting, adjustment and cleaning,

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

5) information, for example, drawings and circuit diagrams, enabling trained personnel to carry out fault-finding tasks,

6) details of tests required after replacement of components to establish that the pressure-sensitive edge or pressure-sensitive bar functions as designed,

7) a warning that all parts (covers, clips, edging strips, fastenings, etc.) removed during maintenance must be refitted after maintenance, and that if such parts are not correctly refitted the performance of the pressure-sensitive edge or pressure-sensitive bar could be impaired,

8) list of user replaceable parts,

9) a 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 pressure-sensitive edge or pressure-sensitive bar could be impaired, and

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

c) **Training requirements:** recommendations for the minimum training requirements of the user's personnel, including operators and maintenance/inspection staff, to ensure that the pressure-sensitive edge or pressure-sensitive bar is used and maintained in accordance with this part of ISO 13856.

d) **Periodic functional tests**

The instructions for use shall contain information on the periodic testing of the sensor. For this purpose the following information is required:

1) an indication that the test interval depends on the use of the pressure-sensitive edge or pressure-sensitive bar and that it is to be specified by the operator according to the national legislative requirements;

2) an indication of the maximum test interval, for example a test at least every three months.

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

7 Verification of requirements

7.1 General

NOTE Possibly not all the tests given in this part of ISO 13856 can be carried out when the pressure-sensitive edges and pressure-sensitive bars concerned have been designed and built into the machinery by their manufacturer. In this case the tests should be carried out before a pressure-sensitive protective device is implemented in the machinery.

The following inspections, analyses or tests are to determine whether pressure-sensitive edges or pressure-sensitive bars meet the requirements of this part of ISO 13856. The tests shall be carried out on a ready-to-use pressure-sensitive edge or pressure-sensitive bar 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 other ambient conditions — for example, atmospheric pressure or relative humidity — affect test results, these should be recorded.

Except where otherwise specified, the functioning of the pressure-sensitive edge or pressure-sensitive bar shall be verified as follows: Test piece 1, with the corresponding actuating force given in Table 2, shall be applied to the effective sensing surface in the reference direction, at the maximum operating speed and at one location (so far as practicable the most unfavourable location).

For special applications, some pressure-sensitive edges or pressure-sensitive bars may be designed and manufactured as part of a machine. In this case, it could be impossible or impractical to submit these devices to all the tests set out in this clause, and so the relevant requirements may be verified by analysis. Where tests are omitted, the manufacturer shall explain why these tests have been omitted and provide information explaining how the requirements have been met.

7.2 Test samples

7.2.1 Sensor

In order to perform the test specified in this clause, sensor samples will be required as given in Table 4.

Table 4 — Test samples for particular tests

Test sample no.	**Sample length** m	**Subclause of this part of** ISO 13856
1	0,75 to 1	7.4, 7.6.2, 7.6.4, 7.7, 7.9, 7.10, 7.12, 7.14
2	0,75 to 1	7.8.1, 7.13, 7.19, 7.20
3	0,5	7.6.3, 7.6.5, 7.8.2, 7.11.2, 7.11.3, 7.11.4, 7.11.5, 7.11.6
4[a]	0,5	7.6.3, 7.6.5, 7.8.2
[a] For a combination of sensors only.		

Tests not listed in Table 4 may be carried out with test sample 1, 2 or 3.

If the pressure-sensitive edge or pressure-sensitive bar 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 combinations of sensors shall be used to verify the requirements of 4.2 to 4.7, 4.9 to 4.11, 4.13, 4.18, 4.22 and 4.27.

If the sensor length influences the characteristics of the sensor output, a sensor of the maximum effective sensing length as specified by the manufacturer (4.1) shall be used.

7.2.2 Control units and output signal switching devices

Three control units and output signal switching devices shall be provided: two units corresponding to production units and, if necessary, one specially prepared for testing under fault conditions.

7.3 Test pieces

Except where otherwise specified, the tests shall be carried out with the test pieces shown in Figure 5. The test pieces shall be manufactured from a suitable aluminium alloy.

7.4 Test No. 1 — Safety-related data for selection, installation, commissioning, operation and maintenance of suitable pressure-sensitive edges or pressure-sensitive bars

See 6.2 and 6.3.

It shall be verified that the manufacturer's data sheets contain all safety-related data.

7.5 Test No. 2 — Mounting orientations of sensors

7.5.1 General

If the manufacturer specifies different mounting orientations (see Figure 6) it shall be verified whether the mounting orientation has an influence on the safety function. This verification shall be made, firstly, by inspection and/or through practical experience and, if necessary, shall be completed by analysis or the following tests.

7.5.2 Edge sensors

7.5.2.1 If the manufacturer specifies mounting orientation A or B or A and B, as shown in Figure 6, the following tests need only be performed in orientation A or B.

7.5.2.2 If the manufacturer specifies mounting orientation C, as shown in Figure 6, then the following test shall be performed.

a) For pressure-sensitive edges, the angle β, as shown in Figure 2, shall be measured with the sensor in orientation B, at (20 ± 5) °C and at the upper operating temperature limit. Call these angles β_1 and β_2.

b) Angle β shall then be measured with the sensor in mounting orientation C at the upper operating temperature limit. Call this angle β_3.

c) If the difference between β_3 and β_1 or β_3 and β_2 is greater than 4°, then the following tests shall be performed in all specified mounting orientations. Otherwise, the tests need only be performed in orientation B.

7.5.2.3 If the manufacturer specifies mounting orientation D, as shown in Figure 6, then the following test shall be performed.

a) The angle γ, as shown in Figure 6, shall be measured with the sensor in mounting orientation B, at (20 ± 5) °C and at the upper operating temperature limit. Call these angles γ_1 and γ_2.

b) Angle γ shall then be measured with the sensor in mounting orientation D, at the upper operating temperature limit. Call this angle γ_3.

c) If the difference between γ_3 and γ_1 or γ_3 and γ_2 is greater than 4°, then the following tests shall be performed in all specified mounting orientations. Otherwise, the tests need only be performed in mounting orientation B.

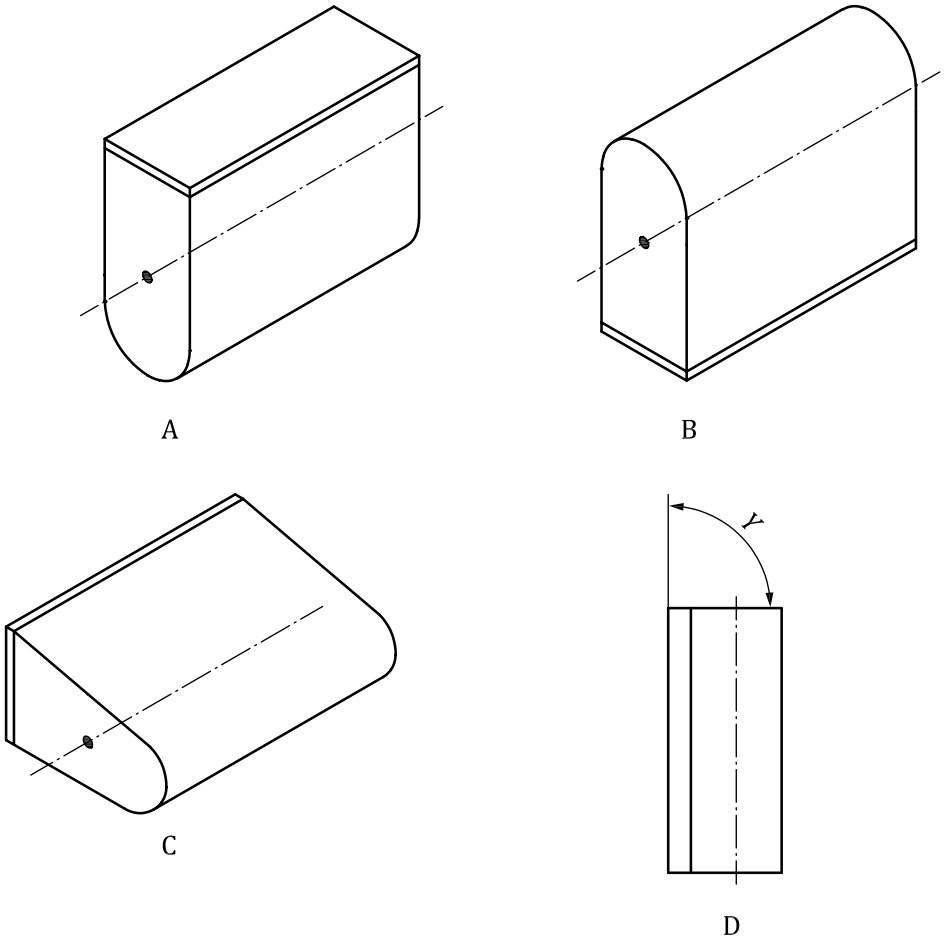


Figure 6 — Sensor mounting orientations A to D

7.5.3 Bar sensors

Pressure-sensitive bars shall be tested in the mounting orientation for which they are designed.

7.6 Test No. 3 — Actuating force

7.6.1 General

For the requirements, see 4.2.

The test shall be carried out after the sensor has reached a particular temperature equilibrium.

Test piece 3 shall be applied only to pressure-sensitive edges where the manufacturer states that the device is suitable for detecting fingers.

7.6.2 Single sensor at 20 °C

The actuating force shall be tested by applying test pieces at the test speeds and locations shown in Figure 7 and Table 5. The test pieces shall be applied perpendicularly to the reference axis and in the test direction shown in Figure 7.

For each application of a test piece, it shall be verified that the output signal switching device changes state at an actuating force lower than or equal to the value specified in Table 2.

7.6.3 Combination of sensors at 20 °C

Where two or more sensors can be combined to constitute one effective sensing surface, the test specified in 7.6.2 shall be carried out on one sensor. In addition, test pieces shall be applied at the test speeds and test locations as specified in Table 6. The test pieces shall be applied perpendicularly to the reference axis and in the test directions shown in Figure 8.

For each application of a test piece, it shall be verified that the output signal switching device changes state at an actuating force lower than or equal to the value specified in Table 2.

7.6.4 Single sensor over the operating temperature range

The actuating force shall be tested by applying the test pieces 1, 2 and 3 at the test speeds and test locations specified in Table 7 at the lower operating temperature limit, and in Table 8 at the upper operating temperature limit. The test piece shall be applied perpendicularly to the reference axis and in the test directions shown in Figure 7.

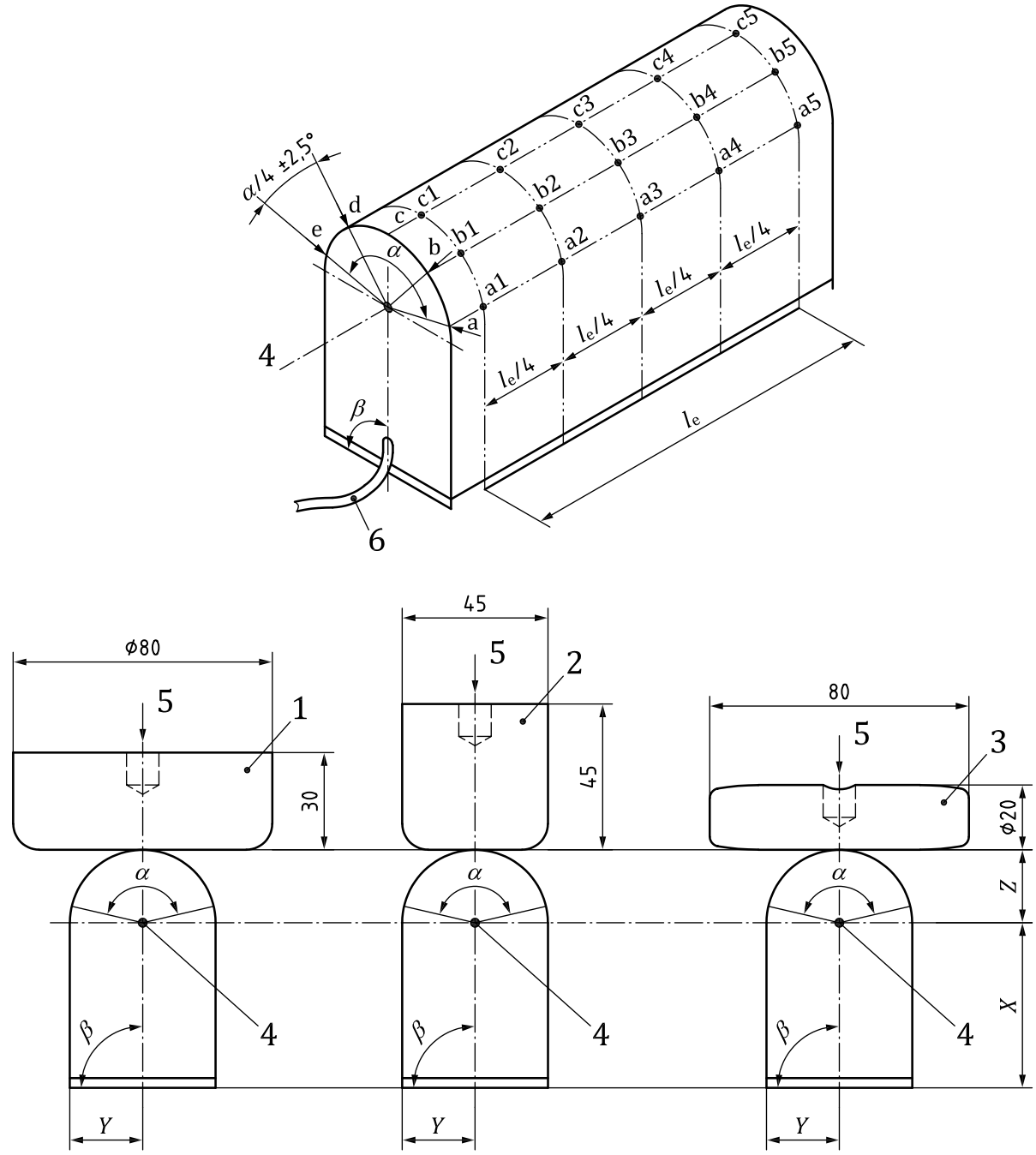
For each application of a test piece, it shall be verified that the output signal switching device changes state at an actuating force lower than or equal to the value specified in Table 2.

7.6.5 Combination of sensors over the operating temperature range

Where two or more sensors are combined to constitute one effective sensing surface, the test specified in 7.6.4 shall be carried out on one single sensor at the upper and lower operating temperature limits. In addition, test pieces 1, 2 and 3 shall be applied at the test speeds and test locations as specified in Table 9 and Table 10. The test pieces shall be applied perpendicularly to the reference axis and in the test direction shown in Figure 8.

For each application of a test piece, it shall be verified that the output signal switching device changes state at an actuating force lower than or equal to the value specified in Table 2.

Dimensions in millimetres



Key

1	test piece 1	4	reference axis
2	test piece 2	5	test direction
3	test piece 3	6	connecting cable
l_e	effective sensing length		

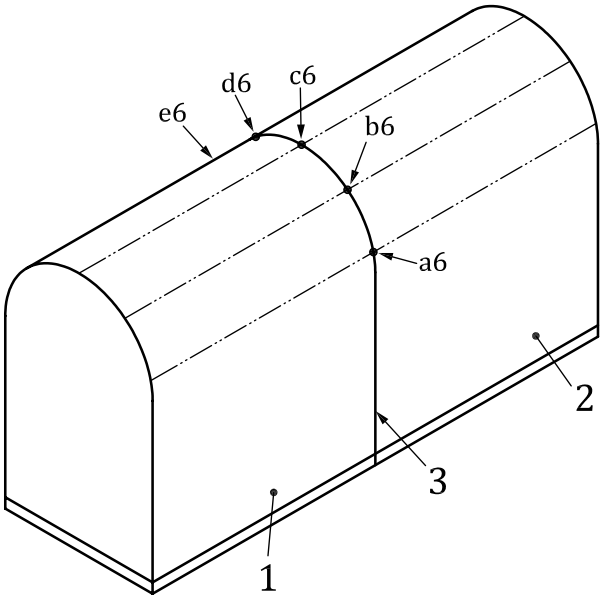
Figure 7 — Test location on effective sensing surface of single sensor

Table 5 — Test locations on effective sensing surface for test No. 3 for single sensor (see 7.6.2)

Test no.	Test piece	Test speed mm · s^{-1}	Test location
3.1	1	10	a1, a3, a5, c1, c3, c5, d1, d5, e3 and one random location
3.2	1	Maximum operating speed	a1, a3, a5. c1, c3, c5. d1, d5. e3, and one random location
3.3	1	100	Those two test locations from test number 3.2 giving the highest actuating forces and one random location
3.4	2	10	a3 and c3
3.5	2	Maximum operating speed	a3 and c3
3.6	2	100	c3
3.7	3	10	a1, a3, a5, c1, c3, c5, d1, d5, e3 and one random location
3.8	3	Maximum operating speed	a1, c1, c3, e5, and one random location
3.9	3	100	Those two test locations from test number 3.8 giving the highest actuating forces and one random location.
For maximum operating speeds ≤150 mm · s^{-1}, the tests at 100 mm · s^{-1} are not necessary. For maximum operating speeds <100 mm · s^{-1}, the tests should be carried out at 10 mm · s^{-1} and at the maximum operating speed as stated by the manufacturer.			

Table 6 — Test locations on the effective sensing surface for test No. 3 for a combination of sensors (see 7.6.3)

Test no.	Test piece	Test speed mm · s^{-1}	Test location
3.10	1	10	a6 and c6
3.11	1	Maximum operating speed	c6 and e6
3.12	1	100	c6
3.13	2	10	c6
3.14	2	Maximum operating speed	a6
3.15	2	100	c6
3.16	3	10	c6
3.17	3	Maximum operating speed	a6
3.18	3	100	c6



Key

1 sensor 1

2 sensor 2

3 joint

NOTE Test directions perpendicular to surface.

Figure 8 — Additional test locations on the effective sensing surface of combination of sensors

Table 7 — Test locations on a single sensor at the lower operating temperature limit for test No. 3 (see 7.6.4)

Test no.	Test piece	Test speed $mm \cdot s^{-1}$	Test location
3.19	1	10	Those two test locations from test number 3.1 giving the highest actuating forces and one random location
3.20	1	Maximum operating speed	Those two test locations from test number 3.2 giving the highest actuating forces and one random location
3.21	1	100	The same test locations as for test 3.3
3.22	2	10	c3
3.23	2	Maximum operating speed	c3
3.24	2	100	c3
3.25	3	10	Those two test locations from test number 3.7 giving the highest actuating forces and a random location
3.26	3	Maximum operating speed	Those two test locations from test number 3.8 giving the highest actuating forces and a random location
3.27	3	100	Those two test locations from test number 3.9 giving the highest actuating forces and a random location

Table 8 — Test locations on single sensor at upper operating temperature limit for test No. 3 (see 7.6.4)

Test no.	Test piece	Test speed mm · s^{-1}	Test location
3.28	1	10	Those two test locations from test number 3.1 giving the highest actuating forces and one random location
3.29	1	Maximum operating speed	Those two test locations from test number 3.2 giving the highest actuating forces and one random location
3.30	1	100	c3
3.31	2	10	c3
3.32	2	Maximum operating speed	c3
3.33	2	100	c3
3.34	3	10	c3
3.35	3	Maximum operating speed	c3
3.36	3	100	c3

Table 9 — Test locations for combination of sensors at lower operating temperature limit for test No. 3 (see 7.6.5)

Test no.	Test piece	Test speed mm · s^{-1}	Test location
3.37	1	10	a6 and c6
3.38	1	Maximum operating speed	c6 and e6
3.39	1	100	c6
3.40	2	10	c6
3.41	2	Maximum operating speed	a6
3.42	2	100	c6
3.43	3	10	c6
3.44	3	Maximum operating speed	a6
3.45	3	100	c6

Table 10 — Test locations for combination of sensors at upper operating temperature limit for test No. 3 (see 7.6.5)

Test no.	Test piece	Test speed mm · s^{-1}	Test location
3.46	1	10	a6 and c6
3.47	1	Maximum operating speed	c6 and e6
3.48	1	100	c6
3.49	2	10	c6
3.50	2	Maximum operating speed	a6
3.51	2	100	c6
3.52	3	10	c6
3.53	3	Maximum operating speed	a6
3.54	3	100	c6

7.7 Test No. 4 — Force–travel relationship(s)

7.7.1 General

For the requirements, see 4.6.

The force–travel relationship(s) shall be confirmed in accordance with Figure 4 by applying test piece 1 (see Figure 7) to the sensor at the maximum operating speed up to point A. The reaction force of the sensor and the distance moved by the test piece shall be continuously measured from the point where the test piece touches the effective sensing surface until the actuating force is reached. Points B1, B2 and C shall be confirmed in accordance with Figure 4 by applying test piece 1 to the sensor at a speed ≤10 mm · s^{-1}. The force–travel relationship can then be shown by connecting points A, B1, B2 to C by straight lines. This test shall be carried out at test location c3 and at a temperature of 20 °C.

7.7.2 Pre-travel

For the requirements, see 4.3.

The pre-travel shall be measured. This distance shall be equal to or less than that stated by the manufacturer.

7.7.3 Working travel

For the requirements, see 4.4.

The working travel shall be measured at a force of

— 250 N, and

— 400 N.

These distances shall be greater than or equal to those stated by the manufacturer.

7.7.4 Overtravel

For the requirements, see 4.5.

The overtravel shall be measured at a force of

— 250 N, and

— 400 N.

These distances shall be greater than or equal to those stated by the manufacturer.

7.8 Test No. 5 — Number of operations

For the requirements, see 4.8.

7.8.1 A single sensor in mounting orientation B connected to the output signal switching device through the control unit shall be tested by applying test piece 1 (see Figure 5) at the maximum operating speed. The test speed shall be constant for at least 80 % of the working travel B1 (see Figure 4).

The effective sensing surface of the sensor shall be moved or deformed up to the working travel B1 (see Figure 4) 10 000 times at test location c2 (see Figure 7).

The retraction speed of the test piece shall be equal to the maximum test speed ± 20 %.

Within each test cycle the test piece shall not touch the effective sensing surface for a period of $5{,}0\ ^{+1}_{0}$ s.

7.8.2 Where two or more sensors are combined to constitute one effective sensing surface, the tests specified in 7.8.1 shall be carried out on one sensor.

In addition, test piece 1 shall be applied 1 000 times at location c6 as shown in Figure 8, under the same conditions as stated in 7.8.1.

7.8.3 When the test specified in 7.8.1 or 7.8.2 have been completed, the tested sensor(s) shall have no defects affecting the safety performance and the requirements for actuating force (see 4.2), pre-travel (see 4.3) and overtravel (see 4.5) shall still be met. This shall be tested using only test piece 1, at the maximum operating speed and at a speed of 10 mm · s^{-1}, at the locations c2 (see Figure 7) for single sensors and c2 and c6 for a combination of sensors.

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

For the requirements, see 4.9 and 4.10.

A static force of $150\ ^{0}_{-10}$ N 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. The test piece is applied at 10 mm · s^{-1}. While this force is applied, the value of the sensor output signal and the output signal switching device shall go to, and be maintained in, an OFF state, in accordance with Figures A.1, A.2, A.3 and A.4. When the force is removed, the value of the sensor output signal and the state of the output signal switching device shall change in accordance with Figures A.1, A.2, A.3 and A.4.

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

For the requirements, see 4.10 and 4.11.

The interaction of separate functions as shown in Annex A shall be tested using test piece 1 and the actuating force of $150\ ^{0}_{-10}$ N applied at (10 ± 1) mm · s^{-1} in the reference direction to the effective sensing surface at one random location.

7.11 Test No. 8 — Environmental conditions

7.11.1 Functional test

For the requirements, see 4.12.

At the end of each of the tests specified in 7.11.2 to 7.11.5, the normal function of the pressure-sensitive edge or pressure-sensitive bar shall be verified using test piece 1, applied perpendicular to the effective sensing surface with the corresponding actuating force given in Table 2, at the maximum operating speed at one random location. This requirement is fulfilled if an OFF state of the output signal switching device is produced.

7.11.2 Test No. 8.1 — Operating temperature range

For the requirements, see 4.12.2.

The requirements of the specified operating temperature range shall be verified by the test procedure given in Table 11.

Table 11 — Operating temperature range

Test procedure	Test conditions
IEC 60068-2-14 Test Nb	Pressure-sensitive edge or pressure-sensitive bar connected to the power supply.

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

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

7.11.3 Test No. 8.2 — Humidity

For the requirements, see 4.12.2.

The requirements for humidity shall be verified by the test procedure given in Table 12.

Table 12 — Humidity

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

7.11.4 Test No. 8.3 — Electromagnetic compatibility

For the requirements, see 4.12.3.

The safety-related requirements shall be verified according to 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 13 and with the stated conditions given in 7.11.1:

pressure-sensitive edges and pressure-sensitive bars with supply energy;

pressure-sensitive edges and pressure-sensitive bars with supply energy with applied actuating force;

pressure-sensitive edges and pressure-sensitive bars with supply energy, after removal of the actuating force and prior to the execution of the reset.

Table 13 — Electromagnetic compatibility

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

7.11.5 Test No. 8.4 — Vibration

For the requirements, see 4.12.4.

These requirements shall be verified in accordance with Table 14. 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 function of the pressure-sensitive edge or pressure-sensitive bar shall be verified.

Table 14 — Vibration

Test procedure	Test conditions
IEC 60068-2-6	Pressure-sensitive edge or pressure-sensitive bar is connected to the power supply. The sensor shall be tested in mounting orientation B, the control unit and the output signal switching device shall be tested in three axes perpendicular to each other.

7.11.6 Test No. 8.5 — Bump

For requirements for pressure-sensitive bars only, see 4.12.5.

During this test, it shall be verified that the output signal switching device remains in the ON state. After the bump test has been completed, the normal function of the pressure-sensitive bar shall be verified.

These requirements shall be verified in accordance with Table 15.

Table 15 — Bump

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

After the test has been completed, the pressure-sensitive bar shall be checked for mechanical damage, loose parts, etc.

7.12 Test No. 9 — Power supply variation

7.12.1 General

For the requirements, see 4.13.

Pressure-sensitive edges and pressure-sensitive bars shall be subjected to the analysis, inspection and/or tests given in 7.12.2 and 7.12.3.

7.12.2 Test No. 9.1 — Electrical power supply variation

For the requirements, see 4.13.1.

The normal function of the pressure-sensitive edge or pressure-sensitive bar shall be verified according to IEC 60204-1:2005, 4.3. The function shall be checked using test piece 1, applied to the effective sensing surface with the corresponding actuating force given in Table 2, in the reference direction, and 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.

7.12.3 Test No. 9.2 — Non-electrical power supply variations

For the requirements, see 4.13.2.

The normal function of the pressure-sensitive edge or pressure-sensitive bar shall be verified at the limits of power supply variations stated by the manufacturer. Possible power supply variations outside the stated range shall not cause the pressure-sensitive edge or pressure-sensitive bar to fail to danger.

7.13 Test No. 10 — Electrical, hydraulic and pneumatic equipment

7.13.1 Test No. 10.1 — Electrical equipment

For the requirements, see 4.14.

It shall be verified by analysis and inspection and, if necessary, by testing that the requirements of 4.14 are met.

7.13.2 Test No. 10.2 — Hydraulic equipment

For the requirements, see 4.15.

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

7.13.3 Test No. 10.3 — Pneumatic equipment

For the requirements, see 4.16.

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

7.14 Test No. 11 — Enclosure

For the requirements, see 4.17.

It shall be verified by analysis and, if necessary, by testing that the requirements of IEC 60529 are met.

7.15 Test No. 12 — Additional coverings for sensors

For the requirements, see 4.18.

If additional coverings are specified by the manufacturer, then it shall be verified that the requirement of 4.18 is met.

7.16 Test No. 13 — Access

The requirement of 4.19 shall be verified by inspection.

7.17 Test No. 14 — Performance Level (PL) according to ISO 13849-1

7.17.1 General

For the requirements, see 4.20.

The foreseen safety functions and categories shall be validated by analysis in accordance with ISO 13849-2 and the PL actually reached shall be compared with the given one.

7.17.2 B_{10d} value for the sensor

When performing the test the following conditions shall apply:

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

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

c) test speed: freely selectable;

d) working travel: until sensor changes state;

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

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

7.18 Test No. 15 — Adjustments

The requirements of 4.21 shall be verified by inspection and, if necessary, by testing.

7.19 Test No. 16 — Sensor fixing and mechanical strength

For the requirements, see 4.22.

A force of (500 ± 25) N shall be applied to the effective sensing surface of the sensor of a pressure-sensitive edge through test piece 1 (see Figure 5) at location a3 (see Figure 7) for 1 h at both the upper and lower operating temperature limits. No permanent damage shall result.

For pressure-sensitive bars the test shall be performed by applying the maximum force stated by the manufacturer through test piece 1 (see Figure 5) for 1 h in the most critical direction and location. No permanent damage shall result.

7.20 Test No. 17 — Recovery after deformation

For the requirements, see 4.23.

A static force of (250 ± 25) N shall be applied in the reference direction to the effective sensing surface of the sensor of the pressure-sensitive edge or pressure-sensitive bar through test piece 1 (see Figure 5) at test location c3. After 24 h, the force shall be removed. The deformation of the effective sensing surface by the test piece shall be measured 30 s, 5 min and 30 min after the force has been removed. The depth of the deformation measured in the reference direction from the line along location c (see Figure 7) to the deformed top surface shall not exceed the values given in Table 3.

These tests shall be carried out at the limits of the operating temperature range.

A static force of (250 ± 25) N shall be applied in the reference direction to the effective sensing surface of the sensor of the pressure-sensitive edge or pressure-sensitive bar through test piece 1 (see Figure 5) at test location c3. After 24 h the force shall be removed. Within 30 s (and after the reset is actuated, if applicable) the output signal switching device shall change to an ON state and applying the test piece 1 again to location c3 shall change the output signal switching device to an OFF state.

This test shall be carried out at the limits of the operating temperature range.

7.21 Test No. 18 — Connections

The requirements given in 4.24 shall be verified by inspection.

7.22 Test No. 19 — Sharp corners, sharp edges and rough surfaces

The requirement given in 4.25 shall be verified by inspection.

7.23 Test No. 20 — Mechanical features

The requirements given in 4.26 shall be verified by inspection.

7.24 Test No. 21 — Inhibition and blocking

The requirement given in 4.27 shall be verified by inspection and functional testing by simple means.

EXAMPLE By inserting a wire, pin, adhesive tape, wedge or magnet.

7.25 Test No. 22 — Marking

The requirements given in Clause 5 shall be verified by inspection.

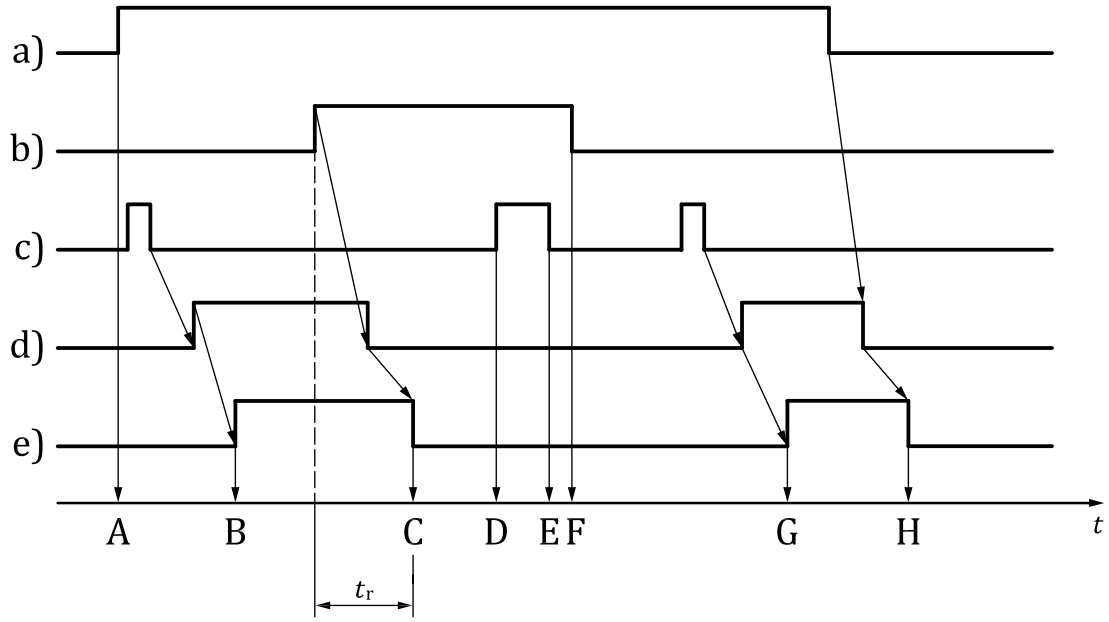
7.26 Test No. 23 — Information for selection and use

The requirements given in Clause 6 shall be verified by inspection.

Annex A
(normative)

Timing diagrams for pressure-sensitive edges/bars with/ without reset

Figures A.1 to A.4 show the relationship between actuating force, reset signal and outputs of the sensor and output signal switching device (see 4.10).



Key

t	time	c)	reset signal
t_r	response time	d)	sensor output
a)	power to pressure-sensitive edge/pressure-sensitive bar	e)	output of output signal switching device(s)
b)	actuating force		

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

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

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

D starting point of reset signal: operation of reset button has no effect on output of output signal switching device because signal has not yet been terminated and actuating force still present

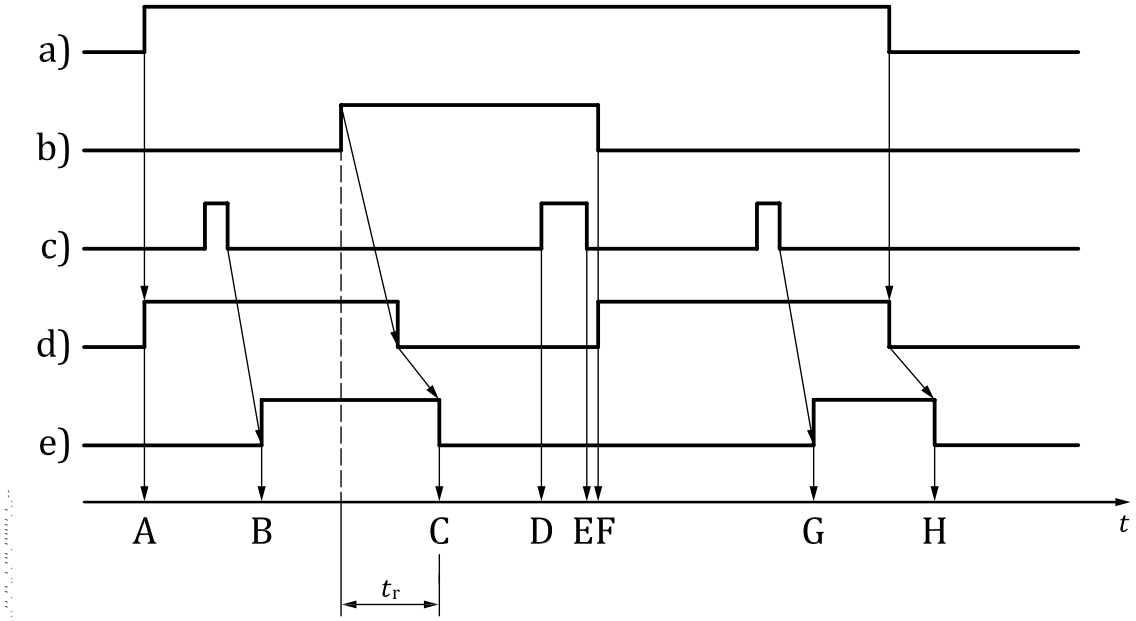
E reset signal has been present: cessation of reset signal has no effect on output of output signal switching device as long as force present on sensor; output of output signal switching device remains in OFF state

F actuating force removed from sensor: output of output signal switching device remains in OFF state because reset not applied

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

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

Figure A.1 — Sensor output initiated by reset function



Key

t time

t_r response time

a) power to pressure-sensitive edge/pressure-sensitive bar

b) actuating force

c) reset signal

d) sensor output

e) output of output signal switching device

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

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

C actuating force on sensor. sensor output turned OFF — also turns the output of the output signal switching device in OFF state

D starting point of reset signal. operation of reset button has no effect on output of output signal switching device because signal not yet terminated and actuating force still present

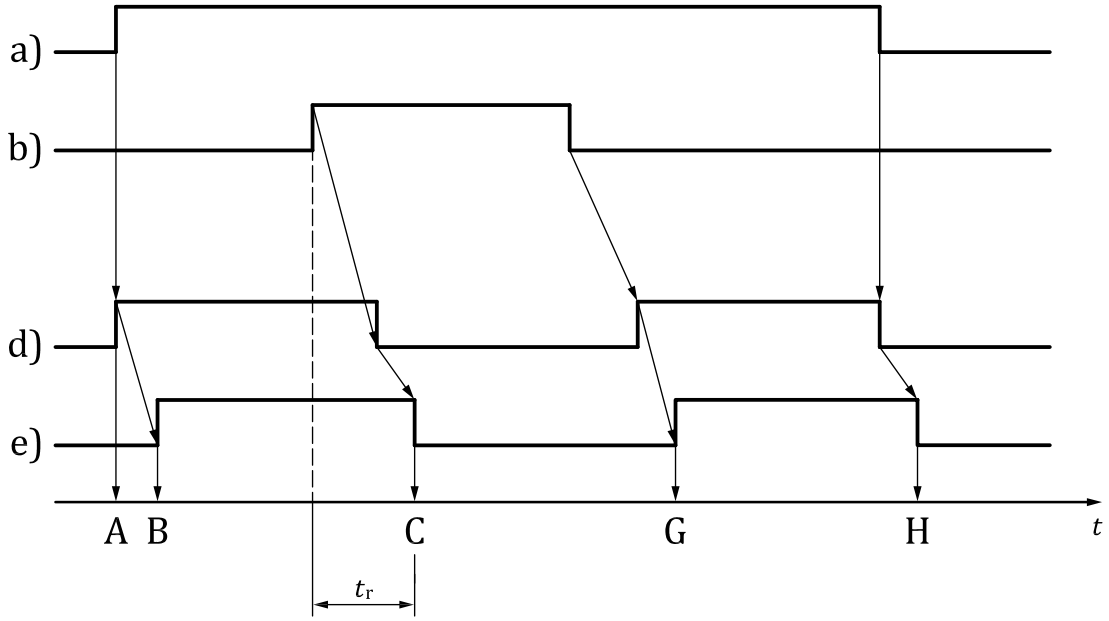
E reset signal has been present: cessation of reset signal has no effect on output of output signal switching device as long as force present on sensor; output of output signal switching device remains in OFF state

F actuating force removed from sensor: sensor output turns ON but output of output signal switching device remains in OFF state because reset not applied after removal of force

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

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

Figure A.2 — Sensor output independent of reset function



Key

t	time	b)	actuating force
t_r	response time	d)	sensor output
a)	power to pressure-sensitive edge/pressure-sensitive bar	e)	output of output signal switching device(s)

A power to pressure-sensitive edge or pressure-sensitive bar ON: sensor output turned ON when power turned ON

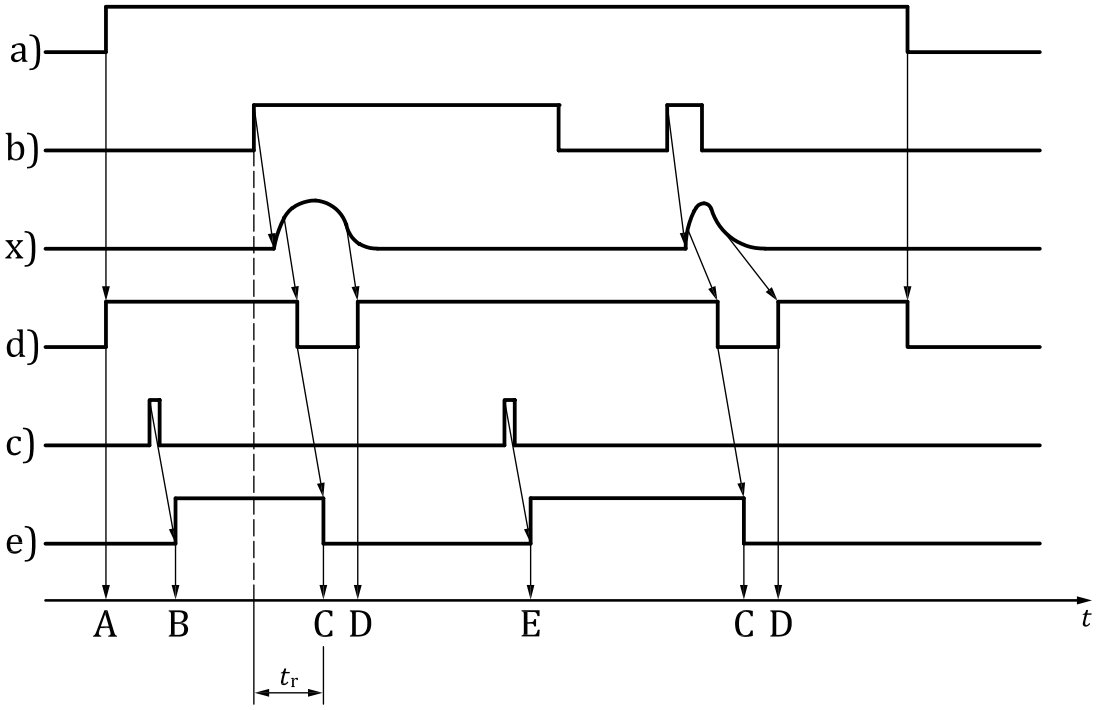
B output of output signal switching device turns to ON state because no actuating force on sensor

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

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

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

Figure A.3 — Sensor output without reset function



Key

t time

t_r response time

a) power to electrical circuits of pressure-sensitive edge/pressure-sensitive bar

b) actuating force

x) pressure pulse in sensor

d) electrical output of sensor (air-pulse switch)

c) reset signal

e) output of output signal switching device

A power to the pressure-sensitive edge or pressure-sensitive bar ON

B reset signal present: output of output signal switching device turns to ON state

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

D sensor output turns to ON state due to pressure decay in sensor

E reset signal present: output of output signal switching device turns to ON state, although actuating force still applied — can lead to hazardous situation

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 — for example, the level of force applied and the controlled rate of leakage of air from the system.

NOTE 2 Air-pulse systems are not considered to fulfil the requirements of category 1 according to ISO 13849-1. See D.3.5 for additional information on air-pulse systems.

Figure A.4 — Sensor output for systems where sensor output does not stay in OFF state when actuating force still applied (e.g. air-pulse systems)

Annex B
(informative)

Operating speed, force and travel — Explanatory remarks and recommendations

See Figure B.1 for the force–travel relationship for pressure-sensitive edges.

Pre-travel: The force increases from the point of contact with the obstruction. At a given point, the sensor signals the control unit to go to the OFF state. A signal is then sent to the machine control system to stop the hazardous movement. The distance travelled between these two points is called the pre-travel. This distance can 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 reference force according to the type-C standard or the risk assessment and should occur within the overtravel.

A number of factors can cause the maximum permissible force to be exceeded, including

— brake deterioration (age),

— extended response time,

— mechanical wear, and

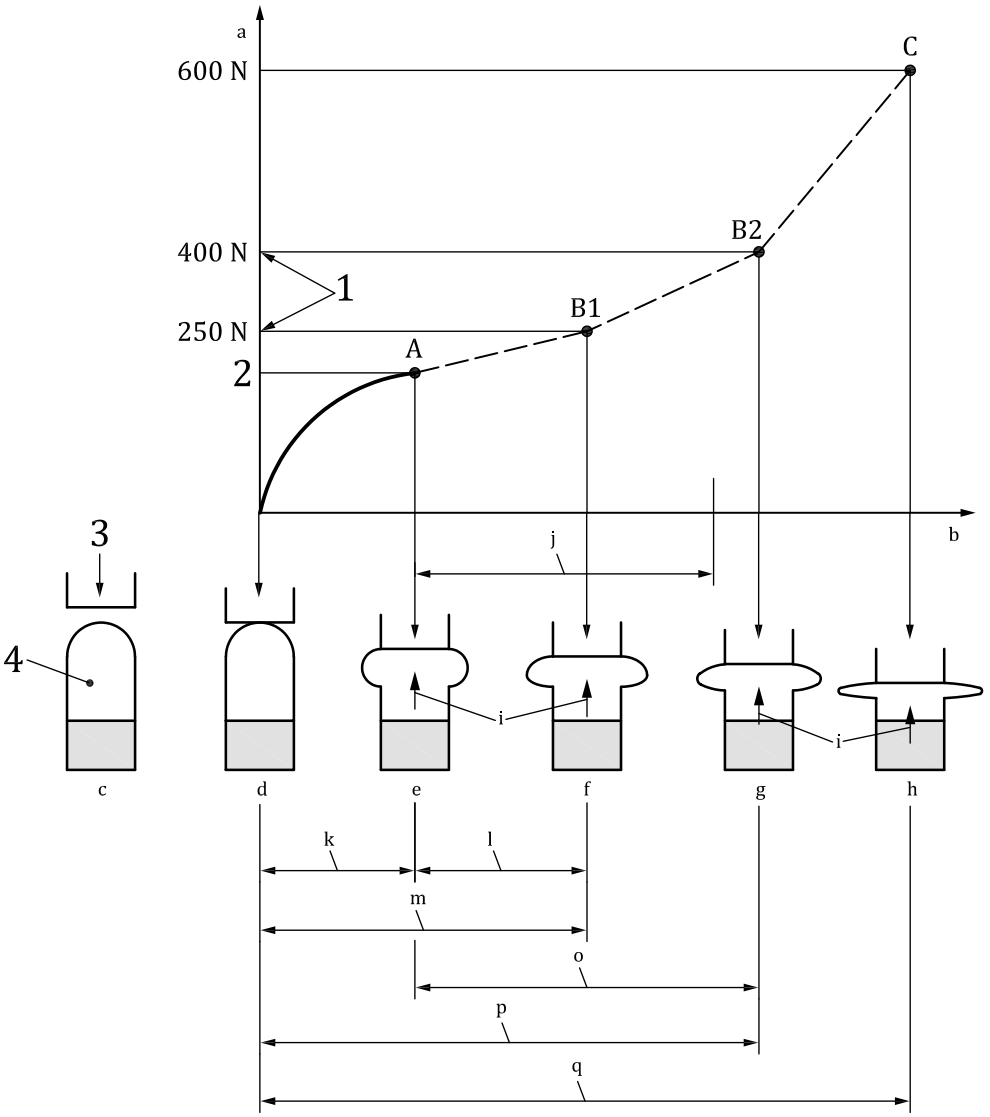
— increased hazard speed.

Any of these can lead to injury due to excessive force acting on the part of the body concerned when no further sensor deformation is possible.

Stopping travel is the distance the moving part of the machine which represents the hazard travels between the point at which the signal is sent by the sensor to its control unit, and the point at which the machine comes to rest. The stopping travel of the machine is required to be within the overtravel of the pressure-sensitive edge or pressure-sensitive bar.

Total travel is the maximum possible movement or deformation of the sensor due to the applied force, e.g. 600 N.

Working travel and force: A force of 250 N or 400 N, perpendicular to the reference axis, is used as a reference to measure the working travel of the pressure-sensitive edge or pressure-sensitive bar with test piece 1 (see Figure 5). According to 4.6, the manufacturer is required to provide force–travel relationship data up to at least the reference force. However, 250 N or 400 N should not be regarded as forces which do not cause injury in all applications.



Key

1	reference forces	3	hazard speed
2	lowest actuating force	4	sensor
a	Force, in newtons (N).	i	Reaction force.
b	Travel, in millimetres (mm).	j	Established stopping travel of machine.
c	Sensor before contact.	k	Pre-travel.
d	Point of contact.	l	Overtravel B1.
e	Point of actuation.	m	Working travel B1.
f	Deformation at point B1.	o	Overtravel B2.
g	Deformation at point B2.	p	Working travel B2.
h	Deformation at 600 N.	q	Total travel.

NOTE Forces are related to test piece 1 of Figure 5 and are examples only.

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

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

It is essential that the braking or reversal of the moving parts is such that the reaction force of the activated sensor does not exceed the maximum permissible force specified by the manufacturer for the particular application.

Annex C
(informative)

Device selection guidance for machinery manufacturer/user

C.1 General

The sensor is most frequently mounted on a moving surface that can create a trapping, crushing or collision hazard, such as a power-operated door. It is essential that the machinery manufacturer/user ensure that the braking or reversal of the moving parts is such that the reaction force of the compressed sensor does not exceed the maximum permissible force specified for the particular application. See Annex B and C.2.2 c).

C.2 Selection of suitable pressure-sensitive edge or pressure-sensitive bar

C.2.1 General

The following are the four most important factors influencing the selection of a suitable pressure-sensitive edge or pressure-sensitive bar for a specific application.

a) **Category and performance level according to** ISO 13849-1 **as required for the application**

These are based on

— the risk assessment for the particular application plus the requirements given in 4.20, or

— the requirements of a relevant type-C standard.

b) **Hazard speed**

This is the speed at which the hazardous surface is moving. Normally, one surface is moving and the other is stationary. The maximum possible speed should be considered as the hazard speed. If both surfaces are moving, special consideration is required.

c) **Stopping travel of hazardous parts**

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

d) **Recovery of the sensor after deformation**

On applications where the time between successive actuations of the sensor is less than 30 s (see 4.23, a sensor should be selected which will recover sufficiently for normal operation within the time available.

C.2.2 Selection procedure

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

a) **Determine the required operating speed and 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 distance.**

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, such as a braking system that is subject to deterioration, a higher safety factor should be used. See Figure B.1.

A simple way to measure the stopping distance is to temporarily fit a position detection at a position close to where the maximum hazard speed occurs. Normally, closed contacts of this position detection should be connected into the machine control stop circuit at the point at which 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 detection measured. The maximum distance measured should be regarded as the stopping distance.

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

When available, the maximum permissible force should be taken from a type-C standard for the specific machine or be in accordance with the risk assessment. The risk assessment should take into account the body parts and types of persons to be protected, for example, children or elderly persons. The speed, shape and 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) **Select the device.**

Using the force/distance relationship data or diagrams provided by the manufacturer, select the safeguard with the required maximum operating speed which provides at least the required minimum overtravel distance before the maximum permissible force is reached.

If a pressure-sensitive edge or pressure-sensitive bar with sufficient overtravel cannot be found, it can then be necessary to improve the stopping performance of the machine.

Annex D
(informative)

Design guidance

D.1 Application note

This annex gives some guidance regarding the design of pressure-sensitive edges and pressure-sensitive bars. However, ignoring this design guidance does not necessarily mean that the product as finally constructed will be unsafe.

D.2 General

D.2.1 Frequency of operation

Pressure-sensitive edges and pressure-sensitive bars are frequently used in applications where they are not actuated for many months. When actuated, they need to work safely.

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

D.2.2 Components

Components of pressure-sensitive edges and pressure-sensitive bars should be fully protected from foreseeable damage, for example, with protective sheaths.

D.2.3 Effects of liquid

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

D.3 Pressure-sensitive edges

D.3.1 Profile material

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

D.3.2 Sensor sensitivity

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

D.3.3 Physical effects

Ingress of material (either in small or large particles), vermin or fluid, which can be present in the area in which the edge is to be used, can cause the sensor to corrode or to lose its sensitivity.

It can be possible that a very small hole in the surface of a pressure-sensitive edge cannot be detected during regular inspection. However, it can be sufficiently large to allow fluid to penetrate into the interior which can form a barrier preventing the sensor from being actuated. Conversely, it can be desirable to ensure that fluids can escape from a profile by either leaving ends open or by using a porous end cap.

D.3.4 Pressure-sensitive edges with electric sensors

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

The manner of electrical connection to the sensor should also be considered. Connections should be of high integrity. Where two leads in and two out are used, they should be connected at opposite ends of the contact element to ensure integrity through the contact elements. If leads are connected and there is an open circuit joint onto the contact element, an unsafe situation can arise.

D.3.5 Pressure-sensitive edges with air pulse sensors

Ruptures/punctures 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 system should detect the rupture/puncture and maintain the output signal switching device in the OFF state while the rupture/puncture exists. 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 cannot be detected;

— the connecting tube can be cut, become disconnected, or kinked without detection;

— the air pressure switch cannot operate when the sensor is deformed at a low approach speed;

— the reaction time can be 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, and if this air “bleed” becomes blocked, the pressure-sensitive edge can fail to operate;

— the setting of the air bleed will depend upon the cross-section of the sensor profile, the length of the sensor, the material of the sensor and the temperature range of the application, see 4.21 (adjustments), and if the air “bleed” is too large, the sensitivity of the device will be reduced;

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

It is possible to design an air-pulse system according to category 2 of ISO 13849-1 by checking the function of the pressure-sensitive edge at each cycle of the machine.

D.3.6 Pressure-sensitive edges 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 optical fibre. The means by which the mechanical force is translated into an optical change should be stable. There should be no possibility of light from the emitter being picked up by the detector without going through the optical fibre — for example, after a fibre breakage.

D.4 Pressure-sensitive bars

D.4.1 General

There is a risk that movement of the rigid surface of a pressure-sensitive bar will be inhibited or blocked. This can be due to any one of the following causes:

— failure by blocking or wedging;

— long-term build-up of dirt;

— warping of the rigid active surface;

— seizing of the guides.

D.4.2 Use of position switches

Where position switches are used in pressure-sensitive bars, the following design characteristics should be considered:

— lifting or removal of the sensor;

— warping of the top surface due to overloading;

— sticking of position switches due to infrequent use;

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

— position switches becoming loose on brackets and thereby causing misalignment.

Where position switches are used in pressure-sensitive bars, their reliability should be considered in relation to the consequences of their failure. Position switches manufactured according to IEC 60947-5-1:2003, Clause 3, should be used.

D.4.3 Trap points

Consideration should be given to the design of pressure-sensitive bars with regard to trapping points. Where possible, gaps which close when the sensor is deformed should be eliminated at the design stage. If there is a gap which reduces when the sensor is moving or being deformed, the gap should remain large enough to avoid becoming a trapping hazard.

Annex E
(informative)

Application guidance

E.1 Sensor mounting

The mounting surface should be suitable for the sensor to be used. If the mounting surface is not sufficiently rigid or has large irregularities, the sensitivity and reliability of the pressure-sensitive bar or pressure-sensitive edge 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 they are

a) able to withstand the design conditions,

b) protected from mechanical damage, and

c) firmly fixed at each end to prevent stress on connections.

E.2 Consideration of environmental influences

The following environmental factors should be considered:

— effects of hydraulic and cutting oils;

— combinations of fluids;

— liquids entering sealed systems;

— the effect of metal swarf;

— the effect of cleaning fluids;

— the effect of radiant heat, for example, when sensors are exposed to direct sunlight or nearby hot surfaces;

— the effects of changes in ambient temperatures;

— the effects of freezing;

— the possible effects of any combinations of the above.

NOTE The above list is not comprehensive and special conditions can apply to particular applications.

E.3 Sensor positioning

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

Annex F
(informative)

Guidance on commissioning and testing after installation

F.1 General

This annex provides guidance on commissioning and testing after installation for ensuring safe operation of the total system (see Clause 6 for requirements to be provided on information for selection and use).

F.2 System information

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

F.3 Commissioning

The person carrying out the commissioning should ensure that the following checks are performed:

a) that the pressure-sensitive edge or pressure-sensitive bar is suitable for the environmental conditions;

b) that the pressure-sensitive edge or pressure-sensitive bar is fastened securely;

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

d) that the removal of power supply from the pressure-sensitive edge or pressure-sensitive bar prevents further hazardous operation of the machine, and that the hazardous parts of the machine are not able to be reactivated until the safety function has been restored;

e) that it is not 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) 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) that actuation of the pressure-sensitive edge or pressure-sensitive bar during a hazardous phase of the operating cycle results in the hazardous moving parts being arrested or, where appropriate, assuming an otherwise safe condition, and that it is not possible for the hazardous moving parts to be set in motion again unless the safety function has been restored;

h) 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) as the adequate safety required for a machine is dependent on the safety integrity of the interface between the machine and its protective device(s), ensure that all parts of the machine, including the safeguard(s), the control circuit and the connections to the safeguard(s) comply with the results of the risk assessment and the categories and performance levels according to ISO 13849-1, as stated in the relevant standard(s);

j) that the muting arrangements (if fitted) are tested to the requirements of ISO 13849-1:2006, 5.2;

k) that all indicator lamps are functioning correctly.

l) that the sensitivity of the pressure-sensitive edge or pressure-sensitive bar over the whole effective sensing surface is according to the manufacturer's instructions.

m) where reset is provided, by testing that that the machine cannot be operated until the system has been reset.

NOTE Additional checks can be required by the relevant type-C standards.

F.4 Regular inspection and tests

Regular inspection and tests should be performed in accordance with the manufacturer's recommendations.

The checks set out in F.3 should be repeated. In addition, the following should also be inspected and/or tested.

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 it from stopping or assuming an otherwise safe condition when stopped by the pressure-sensitive edge or pressure-sensitive bar.

c) Inspect the machine controls and the connections to the pressure-sensitive edge or pressure-sensitive bar 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 edge or pressure-sensitive bar with power on but with the machine at rest. Vary the point of actuation to ensure that the whole of the effective sensing surface is tested over a period of time.

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

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

F.5 Inspection and testing following maintenance

After maintenance has been undertaken, tests of the safety function appropriate to the level of maintenance should be performed following the relevant guidance presented in F.2.

Annex G
(informative)

General considerations for systems meeting ISO 13849-1, category 2

G.1 General

Some systems, especially air-pulse systems, have been in use for many years. However, failures have occurred where systems are not automatically checked. Systems that are not checked automatically cannot meet the requirements of category 2. This annex gives guidance on how to ensure that a pressure-sensitive protective device complies with the requirements of category 2.

G.2 Safety function check

The safety function of the complete system should be checked with each cycle of the part of the machine on which the sensor is installed, for example, a moving door or guard fitted with a pressure-sensitive edge.

G.3 Air-pulse sensors

G.3.1 When checking an air-pulse sensor, an air pulse (sensor output) should be generated in the sensor at the end furthest away from the air-pulse switch.

G.3.2 The level of this "check" air pulse should be not greater than that generated by the minimum actuating force applied through test piece 1 at the minimum operating speed used on the application.

G.3.3 The air-pulse sensor output should cause the output signal switching device to go to the OFF state. Further operation of the machine should be allowed only after this test has been successfully completed.

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