INTERNATIONAL STANDARD

ISO 14119

First edition
1998-05-01

Safety of machinery — Interlocking devices associated with guards — Principles for design and selection

Sécurité des machines — Dispositifs de verrouillage associés à des protecteurs — Principes de conception et de choix

Reference number
ISO 14119:1998(E)

Contents

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X.400 c=ch; a=400net; p=iso; o=isocs; s=central

Printed in Switzerland

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.

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.

International Standard ISO 14119 was prepared by Technical Committee ISO/TC 199, *Safety of machinery.* ISO 14119 has been published by the European Committee on Standardization (CEN) as EN 1088.

Annexes A to P of this International Standard are for information only.

Introduction

This International Standard has been prepared to give guidance to machinery designers and writers of product safety standards on how to design or to select interlocking devices associated with guards. It may also be used as guidance in controlling the risk where there is no product safety standard for a particular machine.

Relevant sections of this International Standard, used alone or in conjunction with provisions from other standards, can be used as a basis for verification procedures for the suitability of a device for interlocking duties.

A statement by a manufacturer that an interlocking device complies with this International Standard, without reference to specific clauses, has no meaning.

Annexes A to N contain only examples complying with the principles set out in this International Standard, and the application of which has been validated by experience. Other solutions may be adopted, provided that they comply with the same principles.

Safety of machinery — Interlocking devices associated with guards — Principles for design and selection

1 Scope

This International Standard specifies principles for the design and selection, independent of the nature of the energy source, of interlocking devices associated with guards (as defined in 3.23.1 "interlocking device [interlock]", 3.22.4 "interlocking guard" and 3.22.5 "interlocking guard with guard locking" of ISO/TR 12100-1:1992).

It also provides requirements specifically intended for electrical interlocking devices (see clause 6).

This International Standard covers the parts of guards which actuate interlocking devices.

NOTE Requirements for guards are given in prEN 953. The processing of the signal from the interlocking device to stop and immobilize the machine is dealt with in ISO 13849-1.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO/TR 12100-1:1992, *Safety of machinery - Basic concepts, general principles for design - Part 1: Basic terminology, methodology*

ISO/TR 12100-2:1992, *Safety of machinery - Basic concepts, general principles for design - Part 2: Technical principles and specifications*

ISO 13849-1:–[1)], *Safety of machinery - Safety-related parts of control systems - Part 1: General principles for design*

ISO 13852:1996, *Safety of machinery - Safety distances to prevent danger zones being reached by the upper limbs*

ISO 14118:–[1)], *Safety of machinery - Prevention of unexpected start-up*

ISO 14121:–[1)], *Safety of machinery - Principles for risk assessment*

IEC 60204-1:1992, *Safety of machinery - Electrical equipment of industrial machines - Part 1: General requirements*

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1) To be published.

IEC 60947-5-1:1990, *Low-voltage switchgear and controlgear - Part 5: Control circuit devices and switching elements - Section 1: Electromechanical control circuit devices*

prEN 953, *Safety of machinery - General requirements for the design and construction of guards (fixed, movable)*

prEN 999, *Safety of machinery - The positioning of protective equipment in respect of approach speed of parts of the human body*

3 Definitions

For the purposes of this International Standard the following definitions apply :

3.1 interlocking device; interlock
Mechanical, electrical or other type of device, the purpose of which is to prevent the operation of machine elements under specified conditions (generally as long as a guard is not closed).

[ISO/TR 12100-1:1992]

3.2 interlocking guard
Guard associated with an interlocking device, so that :

— the hazardous machine functions "covered" by the guard cannot operate until the guard is closed ;

— if the guard is opened while the hazardous machine functions are operating, a stop instruction is given ;

— when the guard is closed, the hazardous machine functions "covered" by the guard can operate, but the closure of the guard does not by itself initiate their operation.

[ISO/TR 12100-1:1992]

NOTE In English "stop signal" and "stop command" are synonyms for "stop instruction". In German "Stop-Signal" and "Stop-Befehl" are synonyms for "Halt-Befehl". In French "ordre d'arrêt" is an all-encompassing term.

3.3 interlocking guard with guard locking
Guard associated with an interlocking device and a guard locking device so that :

a) the hazardous machine functions "covered" by the guard cannot operate until the guard is closed and locked ;

b) the guard remains closed and locked until the risk of injury from the hazardous machine functions has passed ;

c) when the guard is closed and locked, the hazardous machine functions "covered" by the guard can operate, but the closure and locking of the guard do not by themselves initiate their operation.

[ISO/TR 12100-1:1992]

3.4 guard locking device
Device intended to lock a guard in the closed position and linked to the control system so that :

a) the machine cannot operate until the guard is closed and locked ;

b) the guard remains locked until the risk has passed.

3.5 automatic monitoring
A back-up safety function which ensures that a safety measure is initiated if the ability of a component or an element to perform its function is diminished, or if the process conditions are changed in such a way that hazards are generated.

NOTE There are two categories of automatic monitoring :

a) "continuous" automatic monitoring, whereby a safety measure is immediately initiated when a failure occurs ;

b) "discontinuous" automatic monitoring, whereby a safety measure is initiated during a following machine cycle, if a failure has occurred.

[ISO/TR 12100-1:1992]

3.6 positive mode actuation

If a moving mechanical component inevitably moves another component along with it, either by direct contact or via rigid elements, the second component is said to be actuated in the positive mode (or positively) by the first one.

[based on ISO/TR 12100-2:1992]

3.7 positive opening operation of a contact element

The achievement of contact separation as the direct result of a specified movement of the switch actuator through non-resilient members (e.g. not dependent upon springs).

[IEC 60947-5-1:1991]

NOTE For fluid power, the equivalent concept may be called "positive mode interruption".

3.8 stopping time; time for hazard elimination

The period between the point at which the interlocking device initiates the stop command and the point at which the risk from hazardous machine functions has passed.

3.9 access time; time for access to a danger zone

The time taken to access the hazardous machine parts after initiation of the stop command by the interlocking device, as calculated on the basis of an approach speed whose value may be chosen, for each particular case, taking into account the parameters given in prEN 999.

4 Operating principles and typical forms of interlocking devices associated with guards

NOTE Reference is made to the relevant annexes where it is considered useful for clearer understanding.

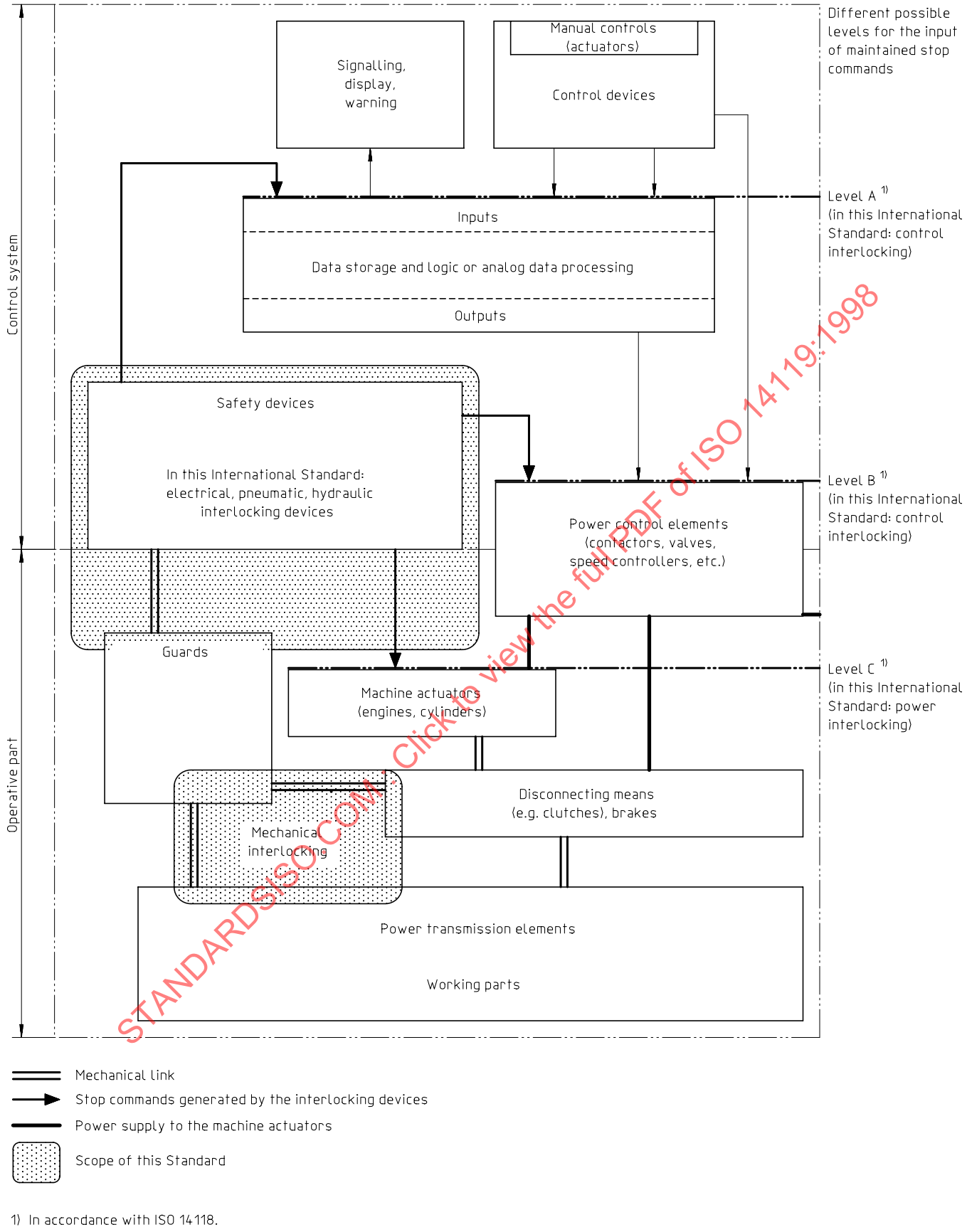
4.1 Interlocking principles

4.1.1 Control interlocking

The stop command from the interlocking device is introduced into the control system so that interruption of the energy supply to the machine actuators – or mechanical disconnection of moving parts from the machine actuators – is triggered by the control system (indirect interruption: levels A and B in figure 1).

4.1.2 Power interlocking

The stop command from the interlocking device directly interrupts the energy supply to the machine actuators or disconnects moving parts from the machine actuators (level C in figure 1). “Directly” means that, unlike control interlocking (see 4.1.1), the control system does not play any intermediate role in the interlocking function.



1) In accordance with ISO 14118.

Figure 1 — Location of interlocking devices in machinery

[based on annex A of ISO/TR 12100-1:1992]

4.2 Typical forms of interlocking devices

4.2.1 Interlocking device (without guard locking) [see table 1 and figure 3 a)]

It is always possible to open the guard. As soon as the guard is no longer closed, the interlocking device generates a stop command. As it is possible to start opening the guard during operation of the machine (or of the hazardous machine elements), the function is that of an interlocking device, as defined in 3.22.4 of ISO/TR 12100-1:1992.

Examples of interlocking devices without guard locking are shown in annexes A, B, F, G, J, K, L.

4.2.2 Interlocking device with guard locking [see table 1 and figure 3 b)]

The guard is held closed by a guard locking device (see 3.4). There are two types of device:

— those where unlocking the guard can be initiated at any time by the operator [unconditional unlocking: see table 1 and figure 3 b1)];

— those where unlocking the guard is possible only if a condition is fulfilled, thus ensuring that the hazard has disappeared [conditional unlocking : see table 1 and figure 3 b2)].

The guard locking device (see 3.4) can be an integral part of an interlocking device, or a separate unit.

In a guard locking device, the part which is intended to lock/unlock the guard can be

— manually applied, manually released (see figure N.1 in annex N);

— spring-applied, power-released [see figure 2 a)];

— power-applied, spring-released [see figure 2 b)];

— power-applied, power-released [see figure 2 c)].

Examples of interlocking devices with guard locking are given in annexes C, D , E, H, M, N.

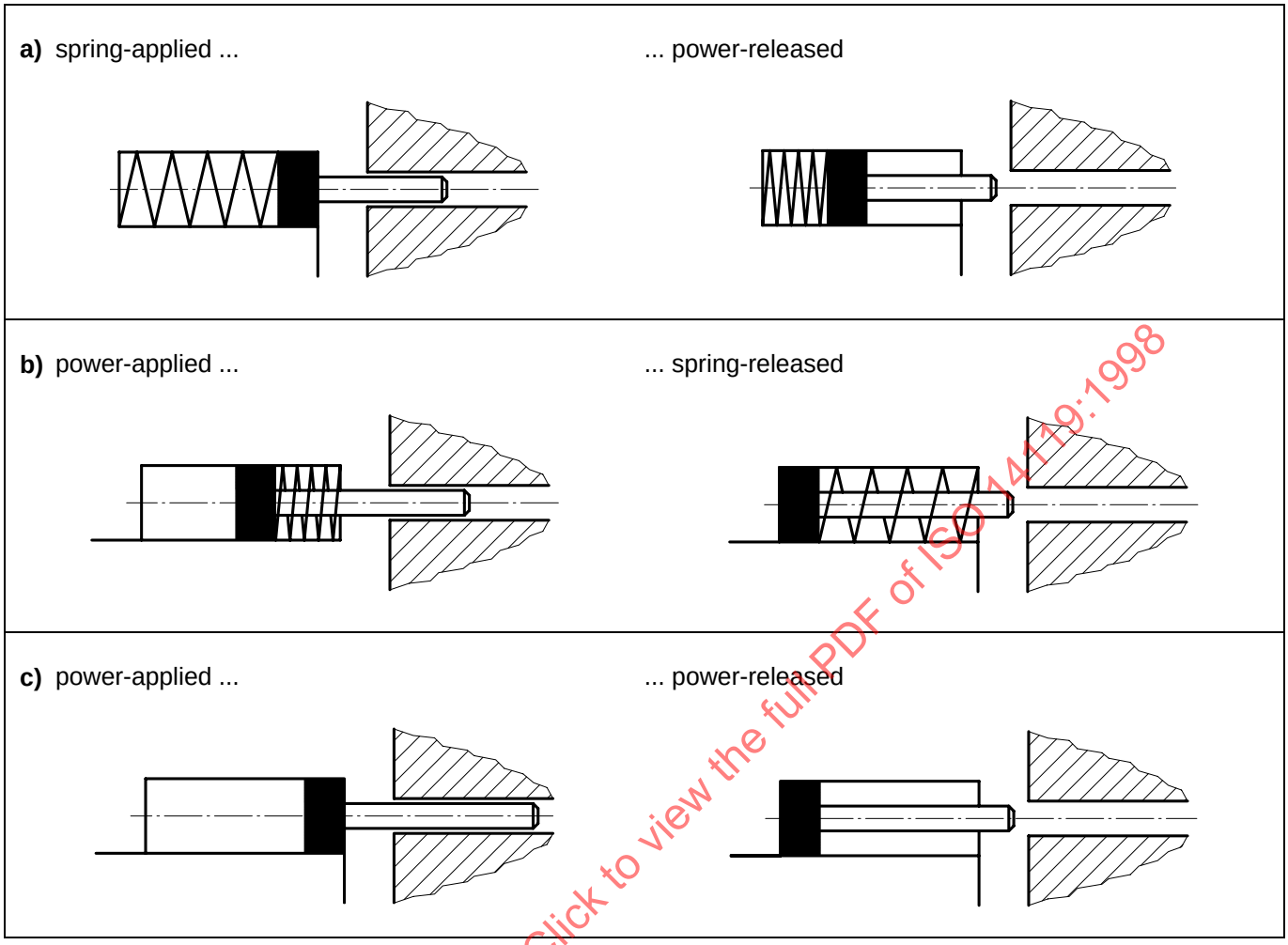
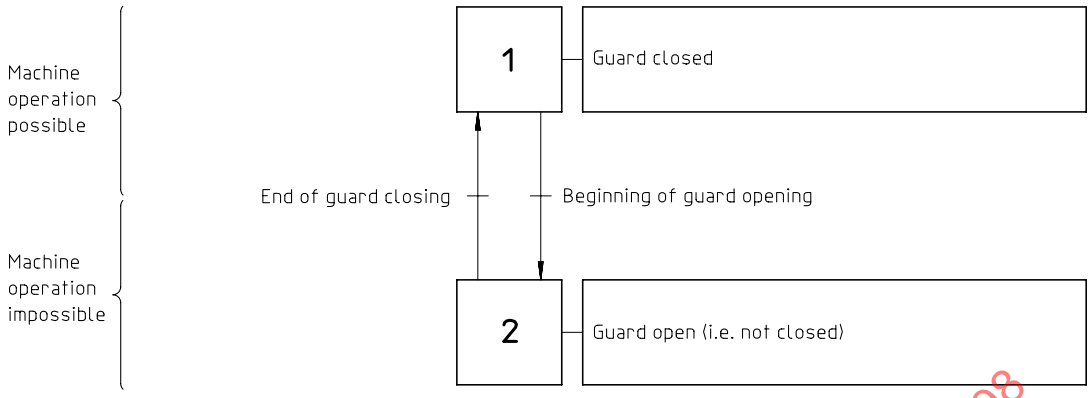
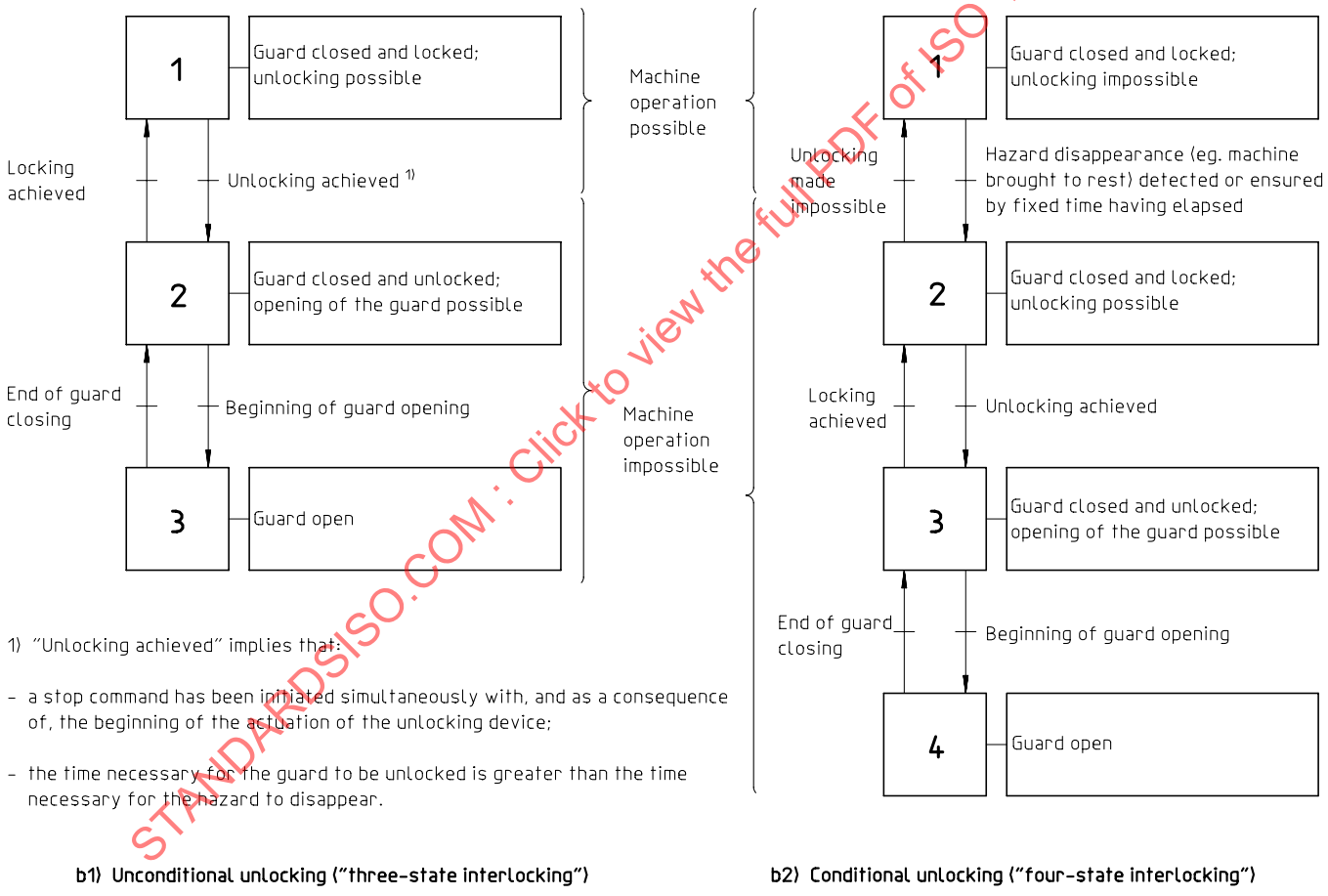


Figure 2 — Operating modes of the guard locking device in power-actuated guard locking devices



a) Interlocking device without guard locking ("two-state interlocking")



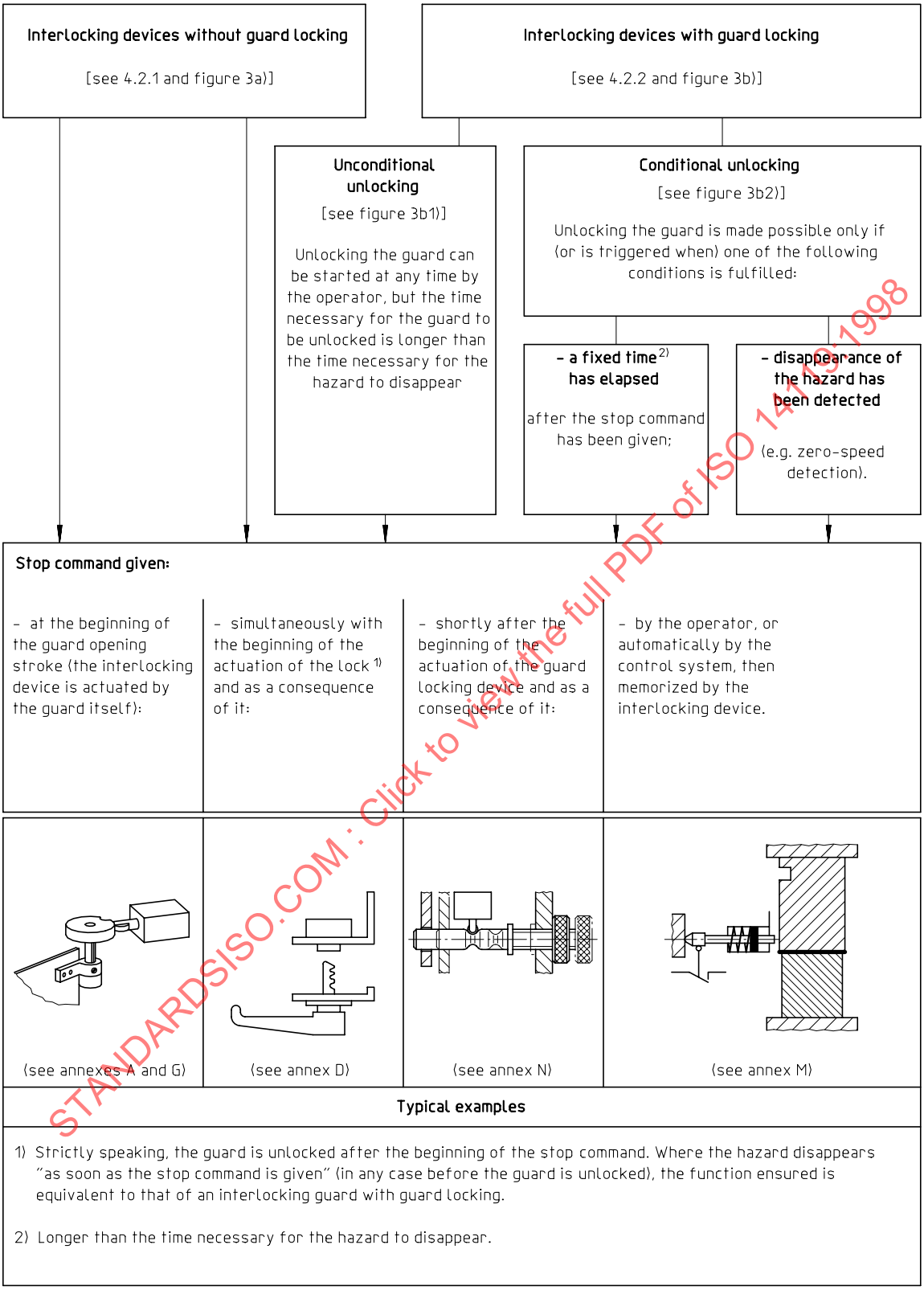
b1) Unconditional unlocking ("three-state interlocking")

b2) Conditional unlocking ("four-state interlocking")

b) Interlocking devices with guard locking

Figure 3 — Functional diagrams of the different types of interlocking devices

Table 1 — Various aspects of the interlocking devices with and without guard locking



1) Strictly speaking, the guard is unlocked after the beginning of the stop command. Where the hazard disappears "as soon as the stop command is given" (in any case before the guard is unlocked), the function ensured is equivalent to that of an interlocking guard with guard locking.

2) Longer than the time necessary for the hazard to disappear.

4.3 Technological forms of interlocking device

Interlocking techniques involve a broad spectrum of technological aspects. As such, interlocking devices can be classified using a great variety of criteria, e.g. the nature of the link between guard and circuit-opening elements, or the technological type (electromechanical, pneumatic, electronic, etc.) of the circuit-opening elements.

Table 2 establishes the link between the main technological forms of interlocking device and the elements of this International Standard which deal with them.

Table 2 — Technological forms of interlocking device

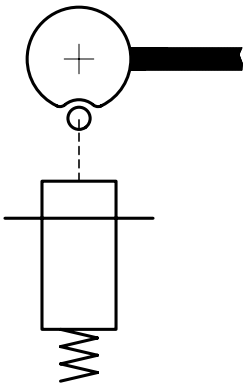
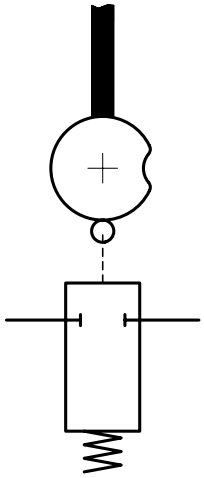
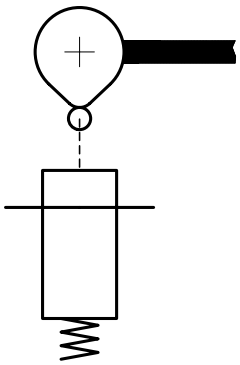
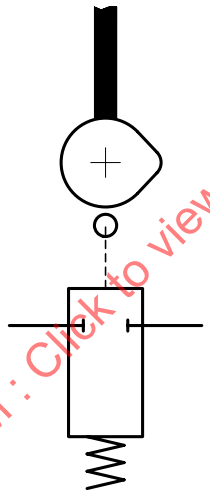
Technological forms	Provisions in subclauses	Examples in annexes
Interlocking devices with mechanically actuated detectors :	5.1 to 5.4, 5.7.2, 6.2	
- with cam-operated detectors	5.7.2.1	A, G, L, M
- with tongue-operated detectors	5.7.2.2	B
Interlocking devices with non-mechanically actuated detectors :		
- with magnetically actuated switches	5.7.3 – 6.3	J
- with electronic proximity switches	5.7.3 – 6.3	K
Systems incorporating keys :		
- captive-key systems;		D
- trapped-key systems.		E
Plug and socket systems	5.7.4	F
Mechanical interlocking between guard and movable parts		H

5 Provisions for the design of interlocking devices (independent of the nature of the energy source)

5.1 Actuation modes of mechanically actuated position detectors

When a single detector is used to generate a stop command, it shall be actuated in the positive mode (see table 3 and 3.6). Non-positive mode actuation is only allowed in conjunction with a detector with positive mode actuation, notably to avoid common-cause failures (see 5.4.1). The design of the actuator should be as simple as possible, since this may reduce the probability of failure.

Table 3 — Actuation of position detectors in the positive mode and in the non-positive mode

Mode of actuation	Guard closed	Guard open	Working mode
Positive mode			The detector stem (actuator) is held depressed by a cam as long as the guard is **open.** When the guard is **closed**, the detector changes its state as the result of the action of a return spring.
Non-positive mode			The detector stem (actuator) is held depressed by a cam as long as the guard **is closed**. When the guard is **opened**, the detector changes its state as the result of the action of a return spring.

5.2 Arrangement and fastening of position detectors

5.2.1 Position detectors shall be arranged so that they are sufficiently protected against a change of their position. In order to meet this requirement:

a) the fasteners of the position detectors shall be reliable and loosening them shall require a tool ;

b) the use of slots shall be limited to initial adjustment ;

c) provisions shall be made for positive location after adjustment (e.g. by means of pins or dowels).

Replacement of the detectors shall be possible without any readjusting need.

5.2.2 In addition, the following requirements shall be met :

a) self-loosening or easy defeat of the detector and of its actuator shall be prevented ;

b) the support for position detectors shall be sufficiently rigid to maintain correct operation of the position detector ;

c) the movement produced by mechanical actuation shall remain within the specified operating range of the position detector to ensure correct operation and/or prevent overtravel ;

d) displacement of the guard before the position detector changes its state shall not be sufficient to impair the protective effect of the guard (for access to danger zones, see ISO 13852 and prEN 953) ;

e) the position detectors shall not be used as mechanical stops ;

f) the position detectors shall be located and, if necessary, protected so that damage from foreseeable external causes is avoided ;

g) easy access to position detectors for maintenance and checking for correct operation shall be ensured.

5.3 Arrangement and fastening of cams

Rotary and linear cams for mechanically actuating position detectors shall be designed so that :

— they are positively located, and fixed by fasteners requiring a tool for loosening them ;

— their self-loosening is prevented ;

— they can only be mounted in a correct position ;

— they do not damage the position detector or impair its durability.

NOTE These provisions exclude friction assemblies.

5.4 Reducing the possibility of common-cause failures

When switching elements have been made redundant, common-cause failures shall be avoided, e.g. by use of the measures described in 5.4.1 and/or in 5.4.2.

5.4.1 Positive and non-positive mode association of mechanically actuated position detectors (see 5.1)

Typical causes for failure of mechanically actuated position detectors are :

a) excessive wear of the actuator (e.g. plunger or roller) or of the cam attached to the guard; misalignment between cam and actuator ;

b) jamming of the actuator (plunger) making actuation by the spring impossible.

Detectors actuated in the positive mode, as D_1 (see figure 4), fail to danger in case a), but not in case b).

Detectors actuated in the non-positive mode, as D_2 (see figure 4), fail to danger in case b), but not in case a).

Thus, in the case of a failure of D_1 or D_2, breaking of the circuit is ensured by the other detector.

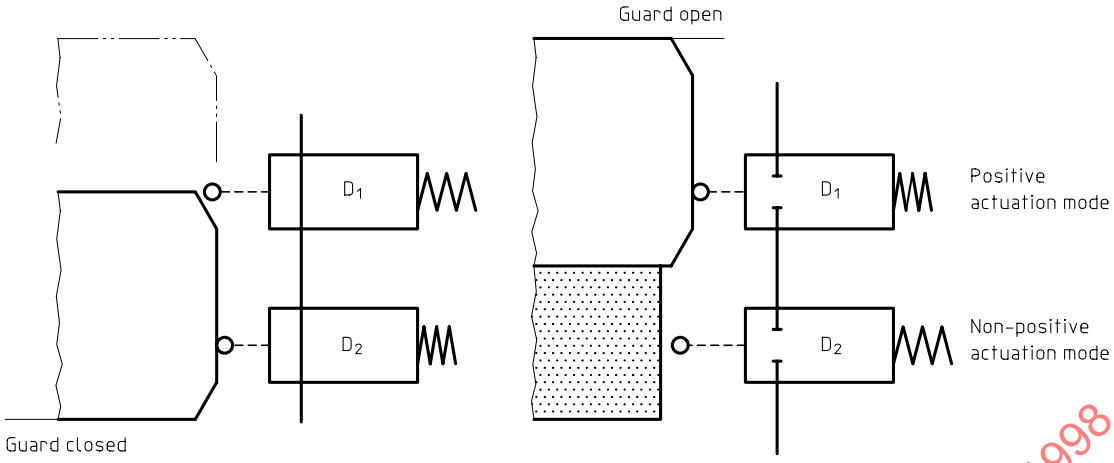


Figure 4 — Avoiding common-cause failure of two mechanically actuated position detectors by using associated positive and non-positive mode actuation

5.4.2 Power medium diversity

In order to minimize the probability of common-cause failure, two independent interlocking devices, each of which interrupts the supply from a different energy source, may be associated with a guard (see example given in figure L.3).

5.5 Guard locking device (see 3.4 and 4.2.2)

Guard locking shall result from the engagement of two rigid parts (positive location).

The part [bolt] intended to lock the guard shall be "spring-applied – power-released" [see figure 2 a)].

Other systems [e.g. figure 2 b), 2 c)] may be used if, in a specific application, they provide an equivalent level of safety.

For "spring-applied – power-released" systems [see figure 2 a)], a manual unlocking device requiring operation by a tool shall be provided. Any type C standard specifying such a guard lock should also specify the characteristics of the manual unlocking device.

The position of the bolt shall be monitored (e.g. by a detector actuated in the positive mode), so that the machine cannot be started until the bolt is in the fully engaged position (see annex M).

The bolt shall be able to withstand the forces which are to be expected during normal operation of the guard. The force which the bolt is able to withstand without damage affecting further use shall be indicated either on the guard locking device itself or in the manufacturer's instructions supplied with the device.

NOTE Guard locking devices can be used e.g. to prevent an enclosure around an automatic unit being opened before the machine/process has reached a definite state, thus preventing loss of information or material damage.

5.6 Delay devices

When a delay device [timer] is used, a failure in this device shall not decrease the delay.

5.7 Design to minimize defeat possibilities

5.7.1 General

Interlocking devices shall be designed and instructions for their installation and maintenance shall be given so that they cannot be defeated in a simple manner.

NOTE "Defeat in a simple manner" means "intended operation is achieved manually or with a readily available object". Readily available objects may be :

— screws, needles, sheet-metal pieces ;

— objects in daily use such as keys, coins, tools required by the intended use of the machine.

Provisions by which defeat may be made more difficult include :

a) provisions expressed in 5.2.2 ;

b) the use of interlocking devices or systems which are coded, e.g. mechanically, electrically, magnetically or optically ;

c) physical obstruction or shielding preventing access to the interlocking device while the guard is open [see examples in figures 5, 6 and in annex F, variant b)].

Where interlocking systems rely on special actuators or keys (coded or not), advice should be given in the instruction handbook concerning risks associated with the availability of spare actuators or keys and master keys.

5.7.2 Design to minimize defeat of mechanically actuated position detectors

5.7.2.1 Cam-operated position detectors

When a single detector is used, it shall be actuated in the positive mode (see 5.1) since, among other characteristics, this mode of actuation prevents the detector from being defeated in a simple manner.

NOTE A higher level of protection against defeat can be achieved, e.g., by enclosing the cam and detector in the same housing.

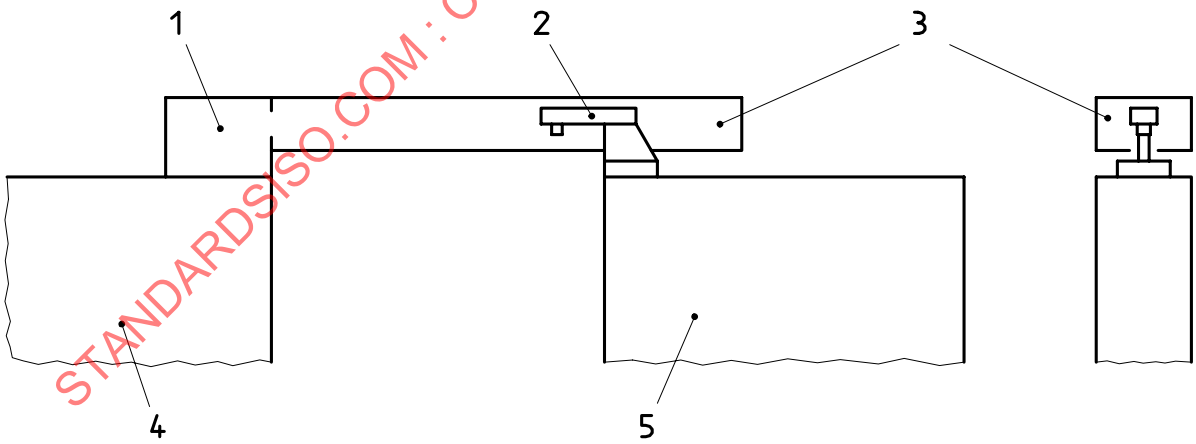
5.7.2.2 Tongue-operated switches

As the dependability of the switch relies heavily upon the design of the tongue and mechanism, the switch shall incorporate a system or systems to render it difficult to defeat by simple tools such as pliers, screwdrivers, wire, etc.

A higher level of protection against defeat can be achieved by e.g. :

— physical obstruction or shielding which prevents introduction of spare actuators (see figure 5) ;

— permanent assembly (e.g. by welding, riveting, "one-way" screw) of the tongue with the guard to render dismantling more difficult.



Key:

1 Switch
2 Tongue
3 Cover
4 Fixed part
5 Sliding guard

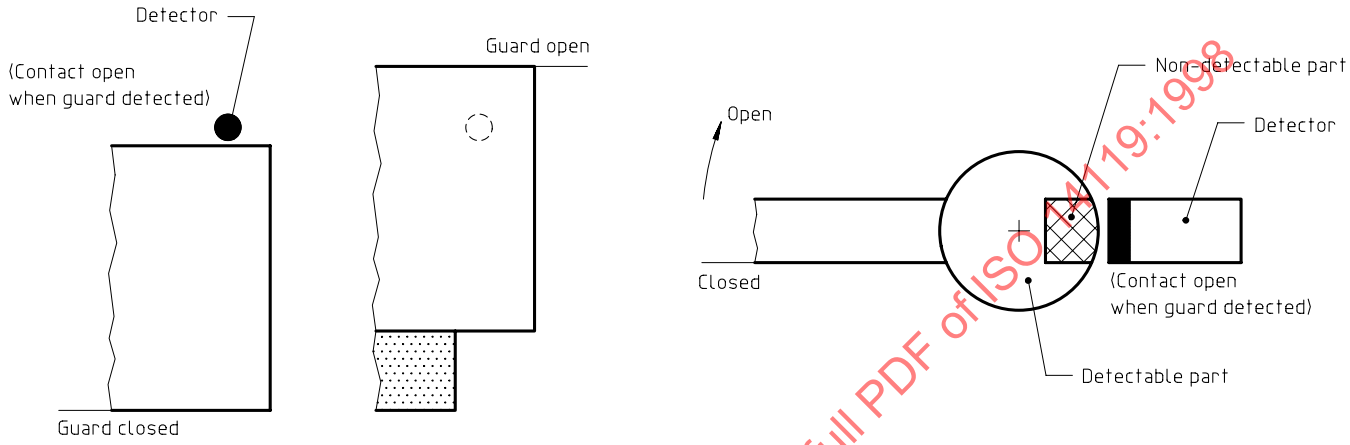
Figure 5 — Example of protection against defeat of a tongue-operated switch

5.7.3 Design to minimize defeat of proximity switches and magnetic switches

Proximity switches and magnetic switches, which rely solely on the presence or absence of detectable material or of a magnet for their actuation, can easily be defeated. Therefore, their method of mounting shall give protection against defeat (see figure 6).

NOTE See also 6.3.1 and reference [1], annex P.

Where there is a risk of a substitute actuator being used to defeat the system, an obstruction should be incorporated into the mechanical arrangement to prevent the substitute actuator being used to actuate the switch (see figure 6).



a) Sliding guard **b) Rotating guard**

NOTE Defeating the detector is made difficult by the presence of the guard in front of it

Figure 6 — Examples of protection against defeat of a proximity switch or magnetic switch

5.7.4 Design to minimize defeat of plug and socket interlocking devices

Protection against defeat can be achieved:

— by locating the socket so that access to it is prevented when the guard is open [see example in annex F, variant b)] ;

— by using a multi-pin plug and socket system the wiring of which, being hidden, makes it difficult to restore the continuity of the circuit [see example in annex F, variant a)]

— by using a plug and a socket system specifically designed for every particular application, or the spare parts of which are not readily available.

NOTE The wiring shown in figures F.1 and F.2 (designated the "ring circuit") makes it necessary to use an additional wire with a plug and a socket at its ends in order to restore the continuity of the circuit when the guard is open; this contributes to preventing defeat.

5.8 Environmental considerations

The selection of an interlocking device and/or of its components shall take into consideration the environment (e.g. temperature) in which they are intended to be used (see 3.7.3 of ISO/TR 12100-2:1992 and ISO 13849-1).

6 Additional technological requirements for electrical interlocking devices

6.1 Compliance with IEC 60204-1

Electrical interlocking devices shall comply with IEC 60204-1, with particular reference to :

— 13.3 "Degrees of protection" of IEC 60204-1:1992 for protection against ingress of solids and liquids ;

— 10.1.3 "Position sensors" of IEC 60204-1:1992 for position switches.

NOTE For the purposes of this International Standard, a "position sensor", a "position detector" and a "position switch" are considered to be the same type of device.

6.2 Interlocking devices incorporating mechanically actuated position switches

6.2.1 Interlocking devices incorporating one single mechanically actuated position switch

6.2.1.1 The position switch shall be actuated in the positive mode (see 3.5 of ISO/TR 12100-2:1992 and also 3.6 and 5.1 of this International Standard).

6.2.1.2 The break contact of the position switch shall be of the "positive opening operation" type, in accordance with clause 3 "Special requirements for control switches with positive opening operation" of IEC 60947-5-1:1990 (see also 3.7 of this International Standard).

See examples in annexes A, B.

6.2.2 Interlocking devices incorporating two mechanically actuated position switches

The position detectors should operate in opposite modes :

— one with a normally closed contact (break contact), actuated by the guard in the positive mode (see 3.5 of ISO/TR 12100-2:1992 and also 3.6 and 5.1 of this International Standard) ;

— the other with a normally open contact (make contact), actuated by the guard in the non-positive mode (see 5.1 of this International Standard).

See example in annex G.

NOTE This is a common practice. It does not exclude, when justified, the use of two switches actuated in the positive mode.

6.3 Interlocking devices incorporating non-mechanically actuated position switches (proximity switches and magnetic switches)

An interlocking device incorporating non-mechanically actuated position switches can be used, as shown in figure 6 and in annexes J and K, to overcome problems arising from the use of mechanically operated switches when a guard can be removed completely from a machine and/or when the environmental conditions require a sealed switch (or sealed switches).

6.3.1 Equivalence with mechanically actuated position switches

When non-mechanically actuated position switches are used, the safety achieved shall not be less than that obtainable with mechanically actuated position switches.

Equivalent safety may be achieved for instance by :

— minimizing the possibility of defeat (see 5.7.3) ;

— using the techniques described in 3.7 of ISO/TR 12100-2:1992, especially duplication (or redundancy) and automatic monitoring, as well as diversity of design and/or technology to avoid common-cause [common-mode] failure.

6.3.2 Immunity from disturbance

Proximity switches and magnetic switches for interlocking applications shall be selected and used so that foreseeable external fields do not impair their function.

6.3.3 Mutual influencing

Proximity switches shall be mounted so that malfunction caused by mutual influence is prevented.

6.3.4 Electrical operating conditions

When proximity switches and magnetic switches are used in interlocking devices, necessary precautions shall be taken to prevent malfunction caused by voltage fluctuations, transient overvoltage, etc.

6.3.5 Specific provisions for magnetic switches

Magnetic switches used without additional measures, such as overcurrent protection and/or redundancy and automatic monitoring, are generally not suitable for interlocking applications, principally because they can fail to danger. Malfunction by vibration shall be prevented (see 5.7.3 and annex J).

7 Selection of an interlocking device

7.1 General

The aim of this clause is to advise machine designers and type C standard makers on how to select an interlocking device suitable for a specific application in accordance with 7.2 to 7.6.

In selecting an interlocking device for a machine, it is necessary to consider all phases of the interlocking device life cycle.

The most important selection criteria are :

— the conditions of use and the intended use (see 3.12 of ISO/TR 12100-1:1992) of the machine (see 7.2) ;

— the hazards present at the machine (see clause 4 of ISO/TR 12100-1:1992 and 7.3) ;

— the severity of the possible injury (see 7.3) ;

— the probability of failure of the interlocking device (see 7.3) ;

— stopping time and access time considerations (see 7.4) ;

— the frequency of access (see 7.5 and 7.3) ;

— the duration of personnel exposure to the hazard(s) (see 7.3) ;

— performance considerations (see 7.6).

7.2 Conditions of use and intended use

All types of interlocking device technologies shall be considered to ensure that the type of device selected is suitable for the conditions of use (e.g. environment, hygiene) and for the intended use of the machine.

7.3 Risk assessment

In order to select the most appropriate interlocking device for a given machine in definite conditions of use, the designer shall carry out the risk assessment process (as described in ISO 14121), taking into account different types of interlocking device until adequate safety is achieved.

The risk to be assessed is that risk which would occur if the safety function of the interlocking device were not performed.

7.4 Stopping time and access time

An interlocking device with guard locking shall be used when the stopping time (see definition in 3.8) is greater than the time (called access time, see 3.9) taken by a person to reach the danger zone.

7.5 **Frequency of access** (frequency of opening the guard for access to the danger zone)

7.5.1 For applications requiring frequent access, the interlocking device shall be chosen to provide the least possible hindrance to the operation of the guard (taking into account the requirements of 7.2, 7.3 and 7.4).

NOTE A clear distinction should be made between the following :

— the concept of **frequent access** required by the normal operation of the machine, as e.g. once per cycle to feed raw products to the machine and remove finished products ;

— the concept of **occasional access**, e.g. to carry out adjustment or maintenance interventions, or for random corrective actions in danger zones.

Each of these concepts is associated with an order of magnitude differing greatly as to the frequency of human intervention in the danger zone (for example one hundred times per hour in the case of one access per cycle, and several times per day in the case of occasional access for adjustment or maintenance during an automatic production process).

7.5.2 For applications using interlocking devices with automatic monitoring, a functional test (see 9.4.2.4 of IEC 60204-1:1992) can be carried out every time the device changes its state, i.e. at every access. If, in such a case, there is only infrequent access, the interlocking device should be used with additional measures such as conditional guard unlocking [see figure 3 b) 2)], as between consecutive functional tests the probability of occurrence of an undetected fault is increased.

7.6 Performance considerations

Control interlocking devices are safety-related parts of the control system of a machine (see ISO 13849-1). It is therefore essential that a control interlocking device is compatible with the machine control system, to ensure that the required safety performance, which can be specified in the relevant type C standard, is achieved.

If power interlocking is used, the components shall have the suitable breaking capacity, taking into account all foreseeable situations (e.g. overload).

Annex A
(informative)

Guard-operated interlocking device with one cam-operated position detector (see Introduction)

A.1 Principle

One single detector, actuated in the positive mode, monitors the position of the guard (see 5.1)

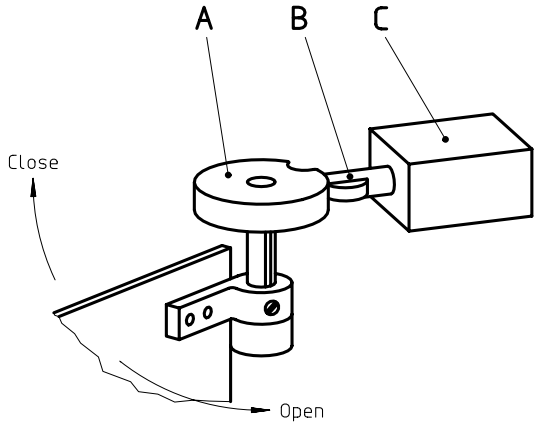


Figure A.1 — With a rotating guard

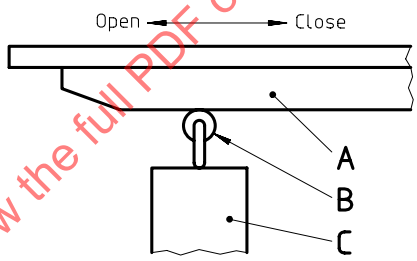


Figure A.2 — With a sliding guard

A.2 Advantages

- Positive mechanical action of the cam (A) on the actuator (B) of the position detector (C).
- Impossible to defeat by manually operating the actuator without moving cam or detector.

A.3 Disadvantage

- Fails to danger in case of :

— wear, breakage, etc. causing malfunction of the actuator;

— maladjustment between the detector and the cam.

A.4 Remarks

- As the absence of the guard is not detected, it is essential that the guard cannot be dismantled without tools.
- See also :

— 5.2 Arrangement and fastening of position detectors;

— 5.3 Arrangement and fastening of cams.

EXAMPLE : Electrical interlocking device incorporating one cam-operated switch (see 6.2.1)

Advantages

- **o** Positive mechanical action of the guard on the actuator of the switch.
- **o** Positive opening operation of the break contact of the switch (see 3.7).

Disadvantage

- **o** Fails to danger in case of :

— failure of the mechanical link between guard and switch;

— electrical by-passing of the switch.

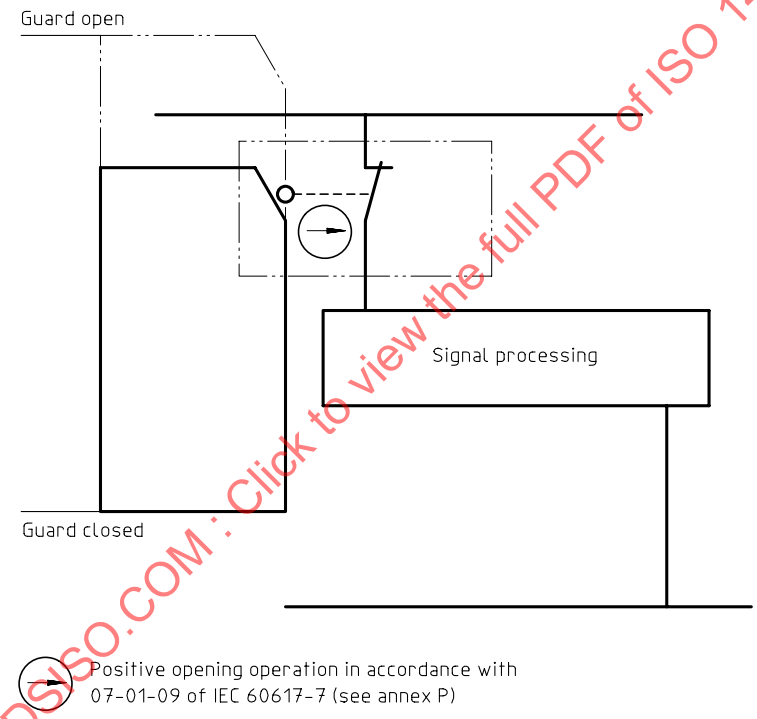


Figure A.3 — Schematic

Annex B
(informative)

Guard-operated interlocking device with tongue-operated switch (see Introduction)

B.1 Principle

The device comprises :

— a circuit-breaking element (D);

— a mechanism which, when operated, causes the circuit-breaking element to be opened and closed (for electrical devices : positive opening operation; see 3.7).

A specially shaped part (tongue) is fixed on the guard (e.g. riveted) so that this tongue cannot be easily removed.

The circuit-breaking element only ensures the continuity of the circuit when the tongue is inserted into the detector.

When the tongue is withdrawn (when opening the guard), it operates in the positive mode the mechanism which opens the circuit-breaking element.

B.2 Advantages

o Only a small displacement of the guard is needed for the detector to change its state.

o Especially suitable for use :

— on the opening edge of a guard (door);

— with guards which can be removed without the use of tools;

— with guards having neither a hinge nor a guide connecting them to the machine.

B.3 Disadvantage

o Can be defeated by using a tongue which is not attached to the guard.

B.4 Remark

For measures against defeat, see 5.7.2.2.

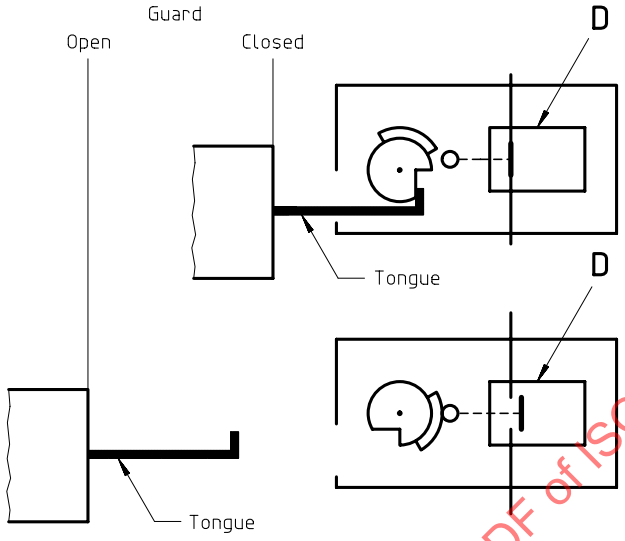


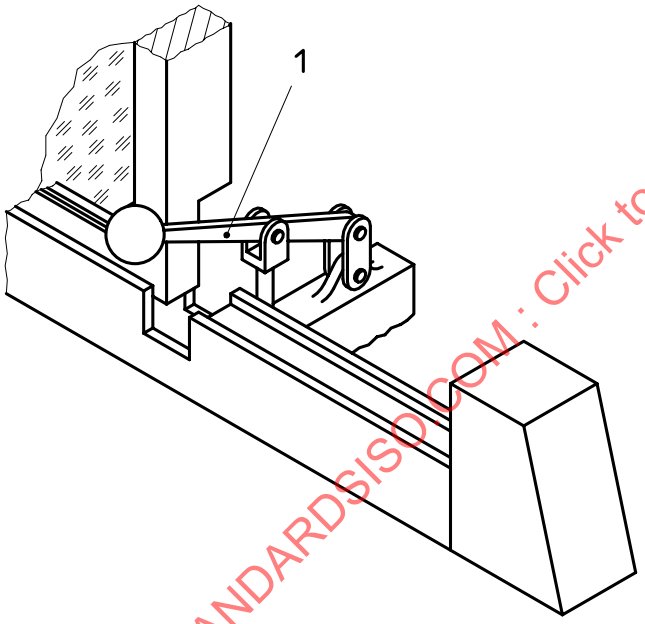
Figure B.1 — Device with tongue-operated switch

Annex C
(informative)

Direct (mechanical) interlocking between guard and start/stop manual control (see Introduction)

C.1 Principle

As long as the "start/stop" manual control (in this case a lever) is in the raised position, it prevents the guard being opened. Lowering the lever causes the device it actuates to positively interrupt circuit continuity (thus directly interrupting power to the actuator(s) if the device is part of the power circuit, or generating a stop command if it is a control device). When the lever is in the lower position, it is possible to open the guard. As long as the guard is open, it prevents the lever being lifted.

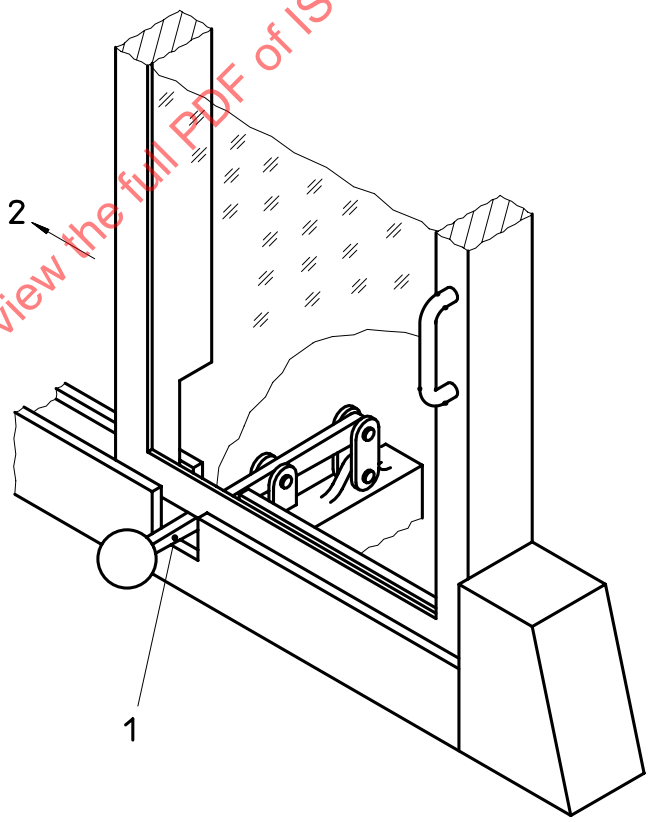


Key:

1 Lever

"Start/stop" lever prevents the guard being opened

Figure C.1 — Guard closed



Key:

1 Lever
2 To close

Guard prevents lifting "start/stop" lever, thus preventing restoration of circuit continuity

Figure C.2 — Guard open

C.2 Advantage

- Reliability through simplicity, especially when used as a power interlocking device (see 4.1.2).

C.3 Remark

- The lever (or its equivalent) is designed to withstand the expected forces and cannot be easily dismantled. A mechanical stop prevents overtravel of the guard.

Annex D
(informative)

Captive-key interlocking device (see Introduction)

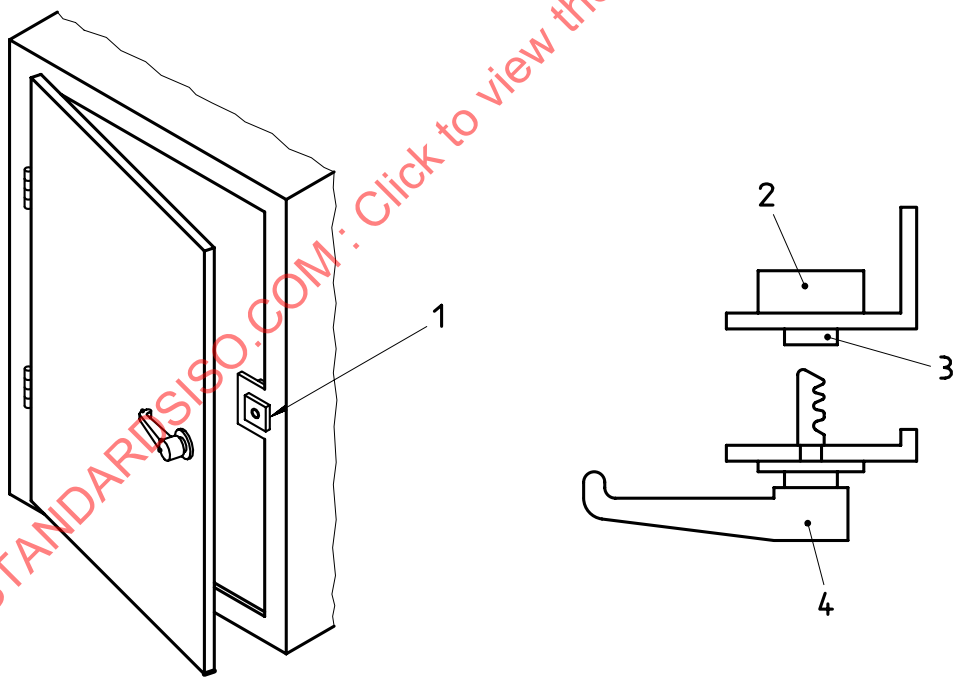
D.1 Description

A combination of a switch and a lock is secured to a fixed part of the machine. The operating key is held captive on the moving part of the guard.

D.2 Principle

The operating principle of captive-key interlocking devices is described by the sequence of operations for guard opening :

1) turn handle to switch off (stop command is given);
2) further turn to unlock guard;
3) open guard (key disengages from lock).



Key
1 Lock and switch
2 Switch
3 Lock
4 Handle containing key

Figure D.1 — Captive-key interlocking device

D.3 Advantages

- Ensures that the circuit-breaking element will be opened before the guard can be opened.
- Especially suitable when the guard is hinged or can be removed completely.

D.4 Remarks

- Can be combined with a time-delay unit. Thus, it becomes an interlocking device with guard locking with conditional unlocking [as described in figure 3 b2)].
- Alignment of the key and lock can be aided by providing a location pin or pins which engage in bushes prior to the key entering the lock.

Annex E
(informative)

Trapped-key interlocking device (see Introduction)

E.1 Principle

A trapped-key interlocking device is an interlocking device relying upon the transfer of keys between a control element and a lock fixed on the guard (guard lock).

In a trapped-key interlocking device, the guard lock and the switching element, which also incorporates a lock, are separate as opposed to being combined into a single unit as in the captive key interlocking device.

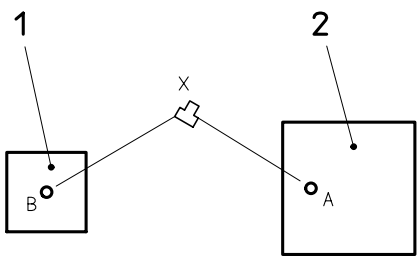
The essential feature of the system is that the removable key is trapped either in the guard lock, or in the switch lock. The lock on the guard is arranged so that the key can be released only when the guard has been closed and locked. This allows transfer of the key from the guard to the switch lock. Closing the switch traps the key, so that it cannot be removed while the switch is in the ON position.

If there is more than one source of power, and therefore more than one circuit-breaking element to be actuated, then a key-exchange box (D) is necessary, to which all keys have to be transferred and locked in before the access key, which is of a different configuration, can be released for transfer to the guard lock. Where there is more than one guard, the exchange box will accommodate an equivalent number of access keys.

Where, for the purpose of the process or of safety, a number of operations have to be carried out in a definite sequence, then the transferable key is locked in and exchanged for a different one at each stage. The exchange box can be integral with the lock.

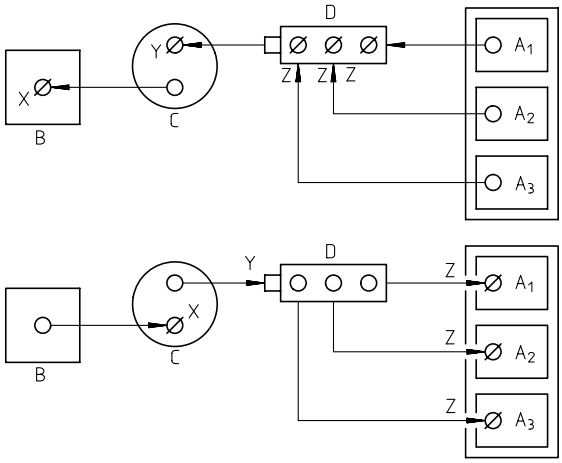
E.2 Advantages

- No reduction of integrity due to the distance between guard and control system.
- No need for electrical wiring to each guard.
- Suitable when the guard is placed in hostile environment.
- Can be used when the guard can be removed completely.
- Particularly suitable when several different types of power source are present on the machine and for power interlocking.
- Personal keys can be released for access to guarded areas where persons could become enclosed.



Key
1 Control element
2 Guard

Figure E.1 — Basic diagram



Key

A (A_1, A_2, A_3)	Lock(s) on guard(s)
B	Lock on circuit-breaking element
X, Y, Z	Keys
O	Lock without a key trapped in it
Ø	Lock with a key trapped in it

Figure E.2 — Variant with time-delay device (C) and key-exchange box[2] (D)

E.3 Disadvantages

- Not suitable for applications requiring very fast access times.
- Duplicate keys can become available for defeating (see 5.7.1).

E.4 Remark

- Delay between opening of the circuit-breaking element and unlocking of the guards is ensured merely by key-transfer time (increased, if necessary, by a time-delay device).

2) A key-exchange box is required when either a guard is interlocked with two or more machine controls, or two or more guards are interlocked with one machine control.

Annex F
(informative)

Plug and socket interlocking device (plug/socket combination) (see Introduction)

F.1 Principle

Circuit breaking by unplugging.

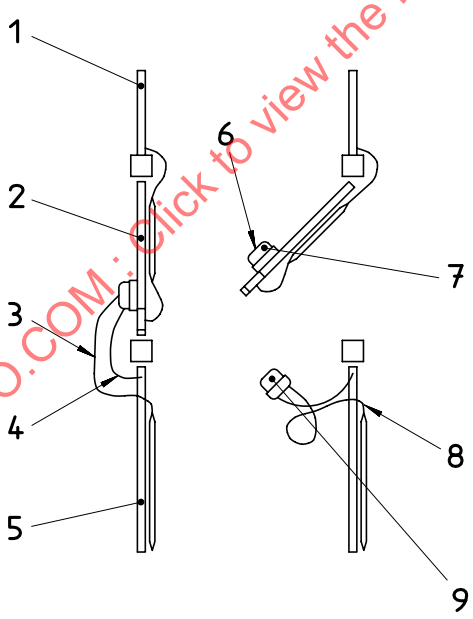
A plug and a socket (or base) are used as an interlocking device, one part mounted on the machine, the other part on the guard.

F.2 Advantage

Reliability through simplicity.

F.3 Disadvantages

Generally not suitable for applications requiring very frequent access.



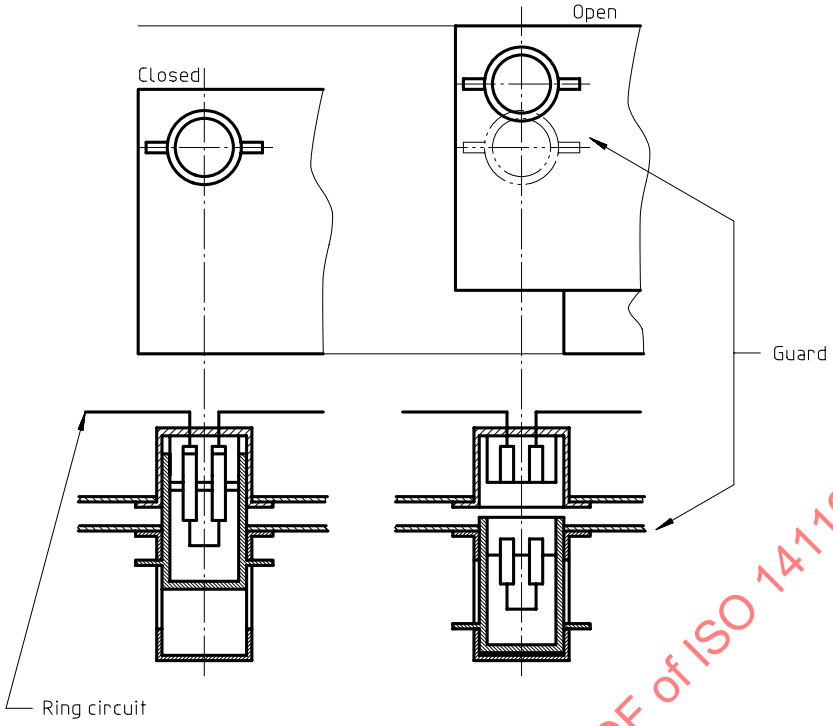
Key

1	Fixed guard	6	Multi-pin fixed connector
2	Movable guard	7	Toolproof base (spot-welded nuts or screws)
3	Shortest possible cable	8	Ring circuit
4	Chain	9	Multi-pin removable connector
5	Fixed guard		

NOTE Pins and sockets are accessible when the plug is removed from the socket. It is then easy to complete the circuit using electric lead(s) when the guard is open.

A possible measure to prevent this method of defeat is by the use of a multi-pin connector. Since the wiring arrangement is complex, it is more difficult to restore the continuity of the circuit when the guard is open.

Figure F.1 — Variant a) hinged (rotating) guard



NOTE 1 Both pins of the plug are linked to ensure that, when the guard is closed and the plug inserted into the socket, the circuit is complete.

NOTE 2 As the plug remains fixed to the guard and the guard covers the socket when open, it is not possible to restore the integrity of the circuit by inserting a bridging link into the socket.

Figure F.2 — Variant b) laterally sliding guard

Annex G
(informative)

Guard-operated interlocking device incorporating two cam-operated position detectors (see Introduction)

G.1 Principle

One detector is actuated in the positive mode. The other one is actuated in the non-positive mode (see 5.1).

G.2 Advantages

- Duplication of detectors avoids failure to danger in case of a single fault.
- Diversification of redundant components reduces the risk of common-cause failure.
- The non-positively actuated detector detects the absence of the guard.

G.3 Remark

- Without monitoring, one faulty detector remains undetected, until a fault in the second detector results in failure to danger.

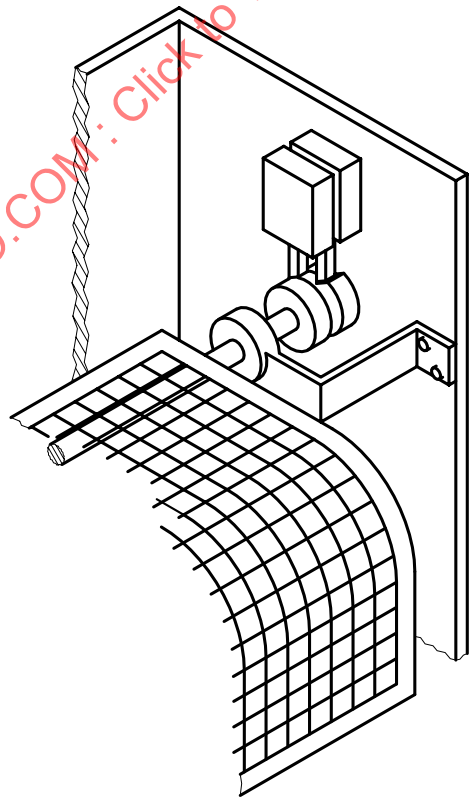


Figure G.1

EXAMPLE : Electrical interlocking device with two cam-operated switches (see 6.2.2)

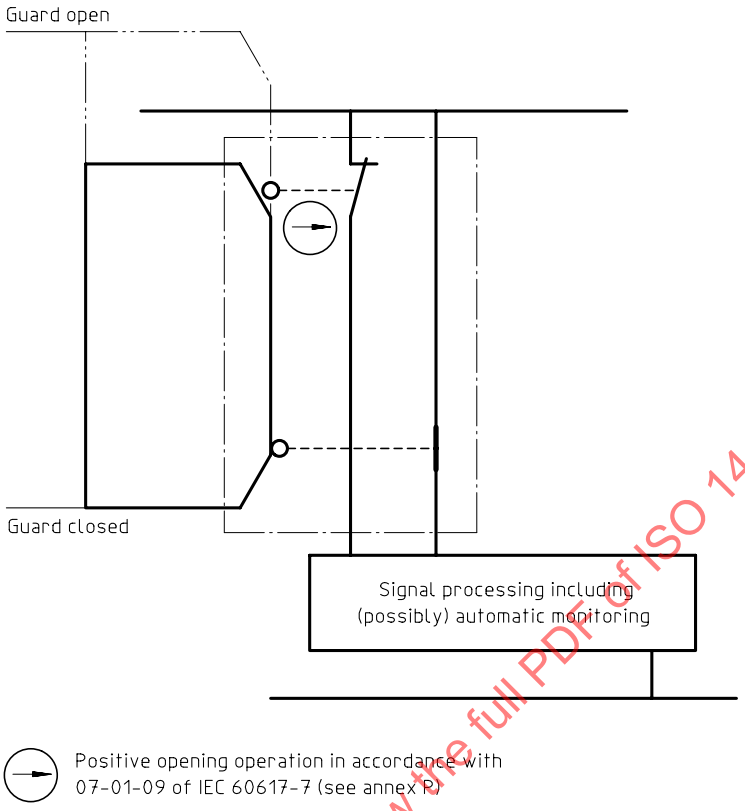


Figure G.2

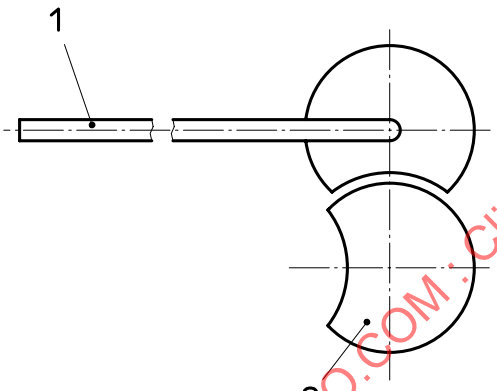
Annex H
(informative)

Mechanical interlocking between a guard and a movable element (see Introduction)

H.1 Principle

Direct mechanical interlocking between a guard and a hazardous movable element.

The function ensured is that of an interlocking guard with guard locking.

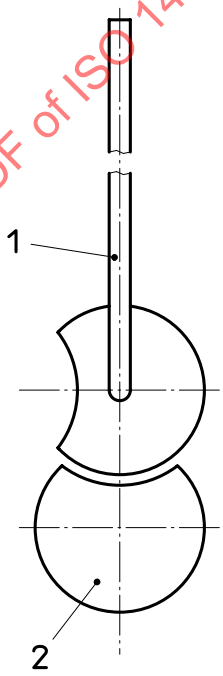


Key

1 Guard closed
2 Movable element free

As long as the movable element is not at rest, the guard is locked in the closed position

Figure H.1 — Guard closed



Key

1 Guard open
2 Movable element blocked

As soon as the guard is no longer in the closed position, the movable element is blocked

Figure H.2 — Guard open

H.2 Remarks

- The application is limited to very simple mechanisms.
- Manual positioning of the movable part may be required to make it possible to open the guard.

Annex J
(informative)

Electrical interlocking device incorporating magnetically actuated (magnetic) switches (see Introduction)

J.1 Principle

A coded magnet, fitted to the guard, actuates a normally open and a normally closed Reed switch.

J.2 Advantages

- Compact; no external moving parts.
- High resistance to dust, liquids.
- Easily kept clean.

J.3 Disadvantages

- Sensitive to electromagnetic interference.
- No positive opening of contacts.
- Possible contact welding in case of overcurrent.

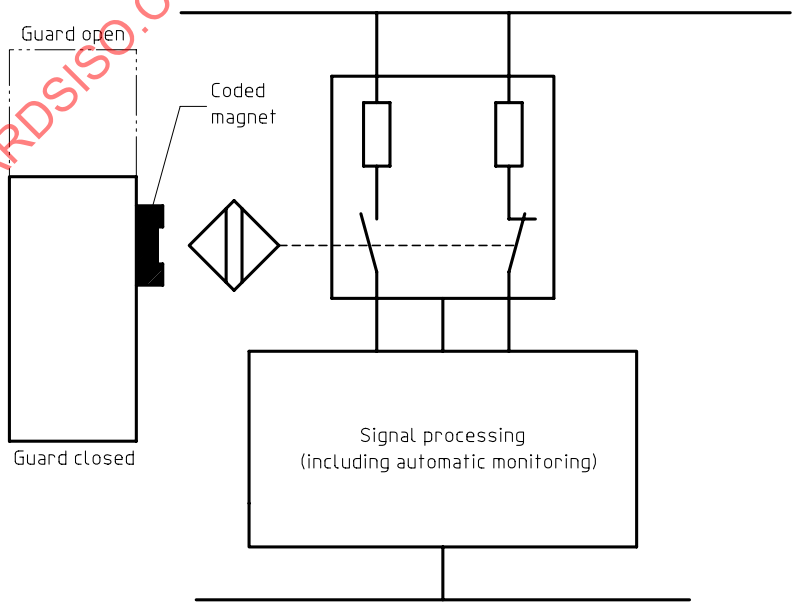


Figure J.1

J.4 Remarks

o The disadvantages quoted above make it necessary for the magnetic switches to be automatically checked at each switching cycle, and for overcurrent protection to be provided (see 6.3.5).

o The device is designed so as to require a coded magnet in order to be actuated. This prevents it being defeated in a simple manner.