
**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 14119:2013(E)

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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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2. www.iso.org/directives

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 199, *Safety of machinery*.

This second edition cancels and replaces the first edition (ISO 14119:1998), which has been technically revised. It also incorporates Amendment ISO 14119:1998/Amd 1:2007. The main changes from the previous edition comprise

- an improved structure as a result of the differentiation and definition of four types of interlocking devices,
- a description of their technology and their typical characteristics in annexes,
- “defeat in a reasonably foreseeable manner” defined and considered,
- the measures required to minimize defeat possibilities, and
- the consideration of new technologies and the addition of informative [Annexes G, H and I](#).

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.

This International Standard has been prepared to give guidance to machinery designers and writers of product safety standards on how to design and select interlocking devices associated with guards.

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

The informative [Annexes A](#) to [F](#) describe the technology and the typical characteristics of the defined 4 types of interlocking devices. Other solutions may be adopted, provided that they comply with the principles of this standard. The informative [Annexes G](#) to [I](#) give information on particular aspects like interlocking devices used within safety functions, risk assessment considering the motivation to defeat and static action forces. ISO/TR 24119 is under preparation and will give information on the masking of faults in series connection of interlocking devices.

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.

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

NOTE ISO 14120 specifies general requirements for the design and construction of guards provided primarily to protect persons from mechanical hazards. The processing of the signal from the interlocking device to stop and immobilize the machine is dealt with in ISO 13849-1 or IEC 62061.

This International Standard does not necessarily provide all the specific requirements for trapped key systems.

This International Standard provides measures to minimize defeat of interlocking devices in a reasonably foreseeable manner.

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 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 13849-2:2012, *Safety of machinery — Safety-related parts of control systems — Part 2: Validation*

IEC 60204-1:2009, *Safety of machinery — Electrical equipment of machines — Part 1: General requirements*

IEC 60947-5-3, *Low-voltage switchgear and controlgear — Part 5-3: Control circuit devices and switching elements — Requirements for proximity devices with defined behaviour under fault conditions (PDF)*

IEC 62061:2012, *Safety of machinery — Functional safety of safety-related electrical, electronic and programmable electronic control systems*

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

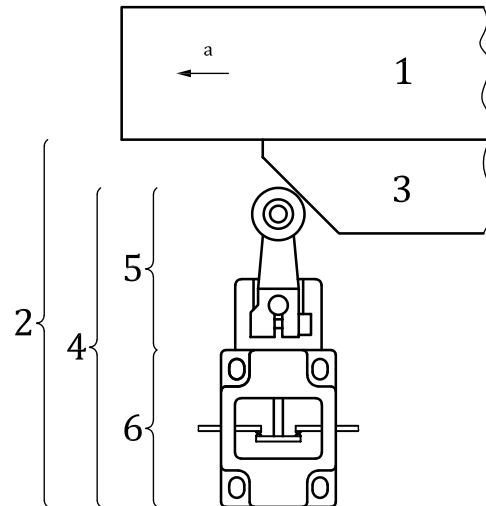
interlocking device

interlock

mechanical, electrical or other type of device, the purpose of which is to prevent the operation of hazardous machine functions under specified conditions (generally as long as a guard is not closed)

Note 1 to entry: See [Figure 1](#) and [Table 1](#).

[SOURCE: ISO 12100:2010, 3.28.1.]



Key

- | | |
|-------------------------|--------------------|
| 1 guard | 4 position switch |
| 2 interlocking device | 5 actuating system |
| 3 actuator | 6 output system |
| a Direction of opening. | |

Figure 1 — Example of an interlocking device

3.2 interlocking guard

guard associated with an interlocking device so that, together with the control system of the machine, the following functions are performed:

- the hazardous machine functions “covered” by the guard cannot operate until the guard is closed;
- if the guard is opened while hazardous machine functions are operating, a stop command is given;
- when the guard is closed, the hazardous machine functions “covered” by the guard can operate (the closure of the guard does not by itself start the hazardous machine functions)

Note 1 to entry: An interlocking guard can contain/be equipped of one or more interlocking devices. These interlocking devices can also be of different types.

[SOURCE: ISO 12100:2010, 3.27.4.]

3.3 interlocking guard with a start function

control guard

special form of an interlocking guard which, once it has reached its closed position, gives a command to initiate the hazardous machine function(s) without the use of a separate start control

Note 1 to entry: ISO 12100:2010, 6.3.3.2.5 gives detailed provisions regarding the condition of use.

[SOURCE: ISO 12100:2010, 3.27.6.]

3.4 guard locking device

device intended to lock a guard in the closed position and linked to the control system

3.5**interlocking guard with guard locking**

guard associated with an interlocking device and a guard locking device so that, together with the control system of the machine, the following functions are performed:

- the hazardous machine functions “covered” by the guard cannot operate until the guard is closed and locked;
- the guard remains closed and locked until the risk due to the hazardous machine functions “covered” by the guard has disappeared, and
- when the guard is closed and locked, the hazardous machine functions “covered” by the guard can operate (the closure and locking of the guard do not by themselves start the hazardous machine functions)

[SOURCE: ISO 12100:2010, 3.27.5.]

3.6**safety-related part of a control system****SRP/CS**

part of a control system that responds to safety-related input signals and generates safety-related output signals

Note 1 to entry: The combined safety-related parts of a control system start at the point where the safety-related input signals are initiated (including e.g. the actuating cam and the roller of the position switch) and end at the output of the power control elements (including, for example, the main contacts of a contactor).

Note 2 to entry: If monitoring systems are used for diagnostics, they are also considered as SRP/CS.

[SOURCE: ISO 13849-1:2006, 3.1.1.]

3.7**defeat**

action that makes interlocking devices inoperative or bypasses them with the result that a machine is used in a manner not intended by the designer or without the necessary safety measures

3.8**defeat in a reasonably foreseeable manner**

defeat of an interlocking device either manually or by using readily available objects

Note 1 to entry: This definition includes the removal of switches or actuators using tools that are needed for the intended use of the machine or that are readily available (screw drivers, wrenches, hexagon keys, pliers).

Note 2 to entry: Readily available objects for substitute actuation include screws, needles and sheet-metal pieces, objects in daily use such as keys, coins, adhesive tape, string and wire, spare keys for the trapped-key interlocking devices, and spare actuators.

3.9**automatic monitoring**

diagnostic function which initiates a fault reaction function 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

3.10**direct mechanical action**

positive mechanical action

movement of a mechanical component which arises inevitably from the movement of another mechanical component either by direct contact or via rigid elements

3.11

direct opening action

positive opening operation

<contact element>achievement of contact separation as a direct result of a specified movement of the switch actuator through non-resilient members (for example not dependent upon springs)

[SOURCE: IEC 60947-5-1:2003, K 2.2.]

3.12

actuator

separate part of an interlocking device which transmits the state of the guard (closed or not closed) to the actuating system

EXAMPLE Guard-mounted cam, key, shaped tongue, reflector, magnet, RFID tag.

Note 1 to entry: See also [Annexes A](#) to [E](#).

Note 2 to entry: Examples of actuators are shown in [Figure 2](#).

3.13

coded actuator

actuator which is specially designed (e.g. by shape) to actuate a certain position switch

3.13.1

low level coded actuator

coded actuator for which 1 to 9 variations in code are available

3.13.2

medium level coded actuator

coded actuator for which 10 to 1 000 variations in code are available

3.13.3

high level coded actuator

coded actuator for which more than 1 000 variations are available

3.14

actuating system

part of the interlocking device which transmits the position of the actuator and changes the state of the output system

EXAMPLE Roller plunger, cam mechanism, optical, inductive or capacitive sensor.

Note 1 to entry: Examples of actuating systems are shown in [Figure 2](#).

3.15

output system

part of the interlocking device that indicates the state of the guard to the control system

EXAMPLE Contact element (electromechanical), semiconductor output, valve.

3.16

Type 1 interlocking device

interlocking device with mechanically actuated position switch with uncoded actuator

EXAMPLE Hinged interlocking devices.

Note 1 to entry: See [Annex A](#) for detailed examples.

3.17

Type 2 interlocking device

interlocking device with mechanically actuated position switch with coded actuator

EXAMPLE Tongue-actuated position switches.

Note 1 to entry: See [Annex B](#) for detailed examples.

3.18

Type 3 interlocking device

interlocking device with non-contact actuated position switch with uncoded actuator

EXAMPLE Proximity switches.

Note 1 to entry: See [Annex C](#) for a detailed example.

3.19

Type 4 interlocking device

interlocking device with non-contact actuated position switch with coded actuator

EXAMPLE RFID tag actuated position switches.

Note 1 to entry: See [Annex D](#) for detailed examples.

3.20

stop command

signal generated by the interlocking device that causes the hazardous machine function to disappear

3.21

overall system stopping performance

time interval between the stop command given by opening the guard and the termination of the hazardous machine function

[SOURCE: ISO 13855:2010, 3.1.2, modified.]

3.22

access time

time taken by a person to reach the hazard zone after initiation of the stop command by the interlocking device, as calculated on the basis of an approach speed of the body or part of the body

Note 1 to entry: For the selection of the approach speed and the calculation, see ISO 13855.

3.23

holding force

force that a guard locking device can withstand without being damaged so that its further use will not be impaired and the guard will not leave the closed position

3.24

prevention of inadvertent locking position

feature of a guard locking device which ensures that the locking means (e.g. a locking bolt) cannot take the locking position when the guard is not closed

3.25

emergency release of guard locking

possibility to release manually without aids the guard locking from outside the safeguarded area in case of an emergency

Note 1 to entry: The guard locking with emergency release can be necessary for releasing trapped persons or fire-fighting, for example.

3.26

auxiliary release of guard locking

possibility to release manually by means of a tool or a key the guard locking from outside the safeguarded area in case of its failure

Note 1 to entry: The guard locking with auxiliary release is not suitable for emergency or escape release of guard locking.

3.27

escape release of guard locking

possibility to release manually without aids the guard locking from inside the safeguarded area to leave the area

3.28

guard locking for protection of a person

application of a guard locking device to protect a person against a hazard

3.29

guard locking for protection of the process

application of a guard locking device to protect the working process from being interrupted

3.30

tool

implement such as a key or wrench designed to operate a fastener

Note 1 to entry: An improvised implement such as a coin or a nail file cannot be considered as a tool.

[SOURCE: ISO 14120:2002, 3.9.]

3.31

power interlocking

interlocking which directly interrupts the energy supply to the machine actuators or disconnects moving parts from the machine actuators

Note 1 to entry: Resumption of the energy supply is only possible with the guard in the closed and locked position. "Directly" means that, unlike control interlocking, the control system does not play any intermediate role in the interlocking function.

3.32

safety function

function of a machine whose failure can result in an immediate increase of the risk(s)

[SOURCE: ISO 12100:2010, 3.30.]

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

4.1 General

Interlocking techniques involve a broad spectrum of technological aspects. Interlocking devices can be classified using a great variety of criteria, e.g. the nature of the link between guard and output system, or the technological type (electromechanical, pneumatic, electronic, etc.) of the output system.

Interlocking devices have a guard position monitoring function that senses whether the guard is closed or not and produce a stop command when the guard is not in the closed position. An interlocking device can also be used in the control of other functions e.g. application of a brake to stop hazardous machine functions before access is possible. Some interlocking devices also have a guard locking function to keep the guard locked while hazardous machine function is present. A guard locking device status monitoring function monitors whether the guard locking device is engaged or released and produces an appropriate output signal (see 4.3.1 a) and b)).

NOTE 1 The guard locking device (see 3.4) can be an integral part of an interlocking device, or a separate unit.

NOTE 2 See also ISO 12100:2010, 6.3.3.1 for additional information on guards.

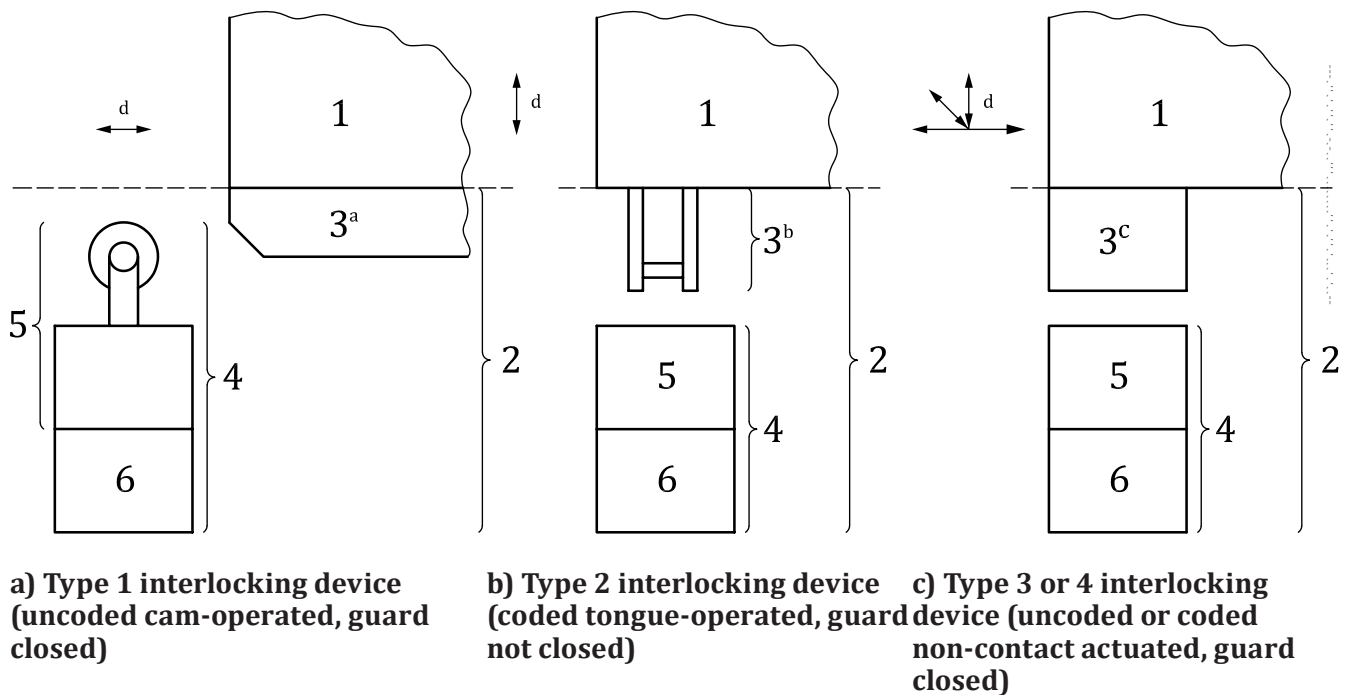
[Table 1](#) shows the actuation principles and actuators for the defined interlocking device types.

NOTE 3 The four types of interlocking device are not presented in a hierarchical order. The correct application of each type of interlocking device will be dependent on the risk assessment that should be made for the specific machine.

Table 1 — Overview of interlocking devices

Actuation principle examples		Actuator examples		Type	Examples: see Annex ^a
Mechanical	Physical contact/ force	Uncoded	Rotary cam	Type 1	A.1
			Linear cam		A.2, A.4
			Hinge		A.3
		Coded	Tongue (-shaped actuator)	Type 2	B.1
			Trapped-key		B.2
Non- contact	Inductive	Uncoded	Suitable ferric metal	Type 3	C
	Magnetic		Magnet, solenoid		
	Capacitive		Any suitable object		
	Ultrasonic		Any suitable object		
	Optic		Any suitable object		
	Magnetic	Coded	Coded magnet	Type 4	D.1
	RFID		Coded RFID tag		D.2
	Optic		Optically coded tag		—

^a Examples of other interlocking devices are given in [Annex E](#).



Key

- 1 movable guard
- 2 interlocking device
- 3 actuator:
 - a Cam.
 - b Tongue.
 - c E.g. RFID, reflector, suitable surface.
 - d Movement direction.
- 4 position switch
- 5 actuating system
- 6 output system

NOTE In some exceptional cases, the position switch can be installed on the movable guard and the actuator on the stationary part of the machine. In these cases “1” is the stationary part of the machine.

Figure 2 — Principle of Types 1, 2, 3 and 4 interlocking devices

4.2 Principles of guard interlocking without guard locking

When guard interlocking function without guard locking is used, the guard can be opened at any time regardless of the function of the machine.

If the guard is not closed, the interlocking device shall generate a stop command.

The access time shall be longer than the overall system stopping performance.

NOTE 1 For interlocking with the machine control system see [Clause 8](#).

NOTE 2 Examples of interlocking devices without guard locking are shown in [Annexes A, B, C and D](#).

NOTE 3 A functional diagram of interlocking devices without guard locking is shown in [Figure 3](#).

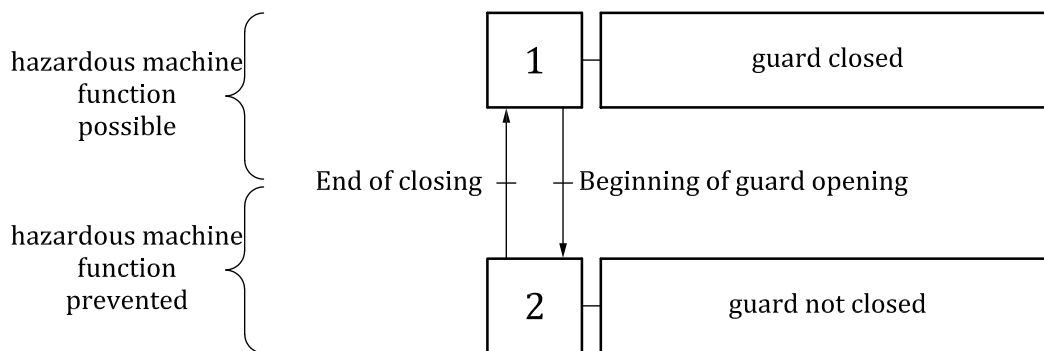


Figure 3 — Functional diagram of interlocking devices without guard locking

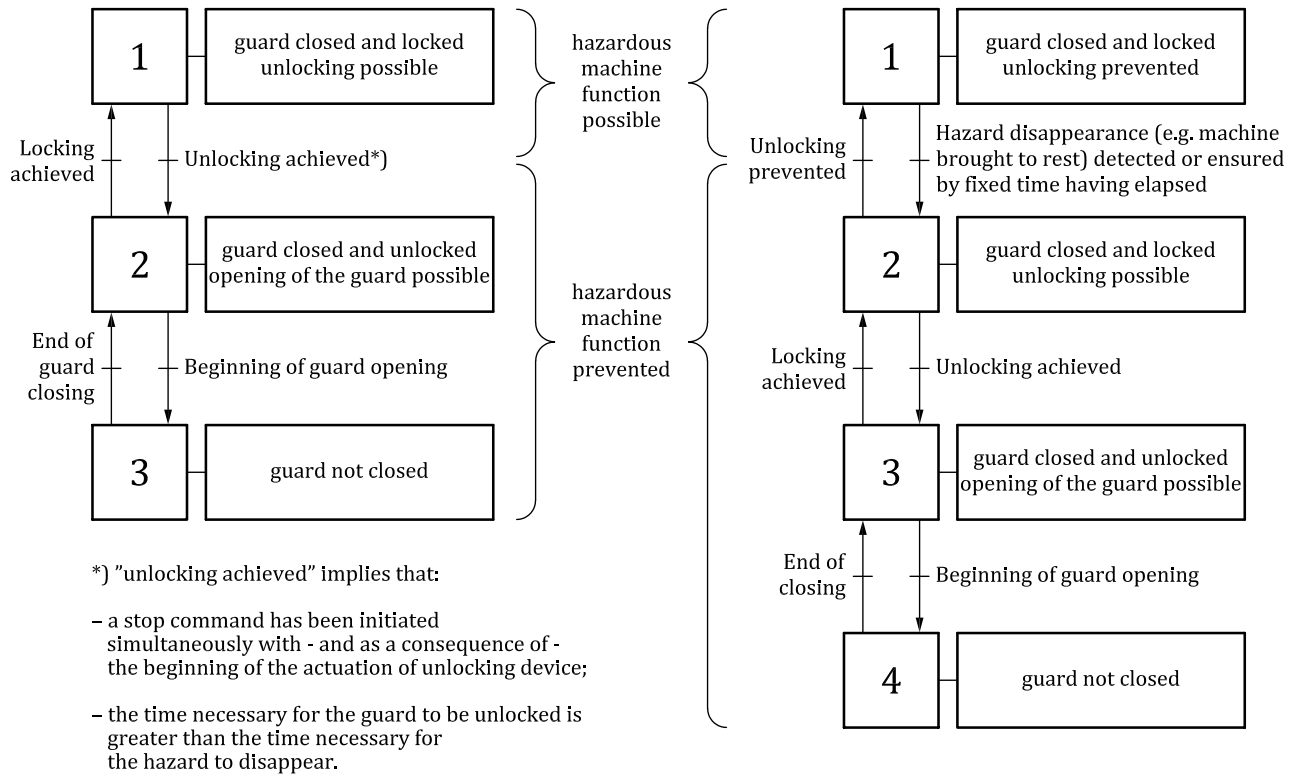
4.3 Principles of guard interlocking with guard locking

4.3.1 General

When interlocking with guard locking is applied, opening of the guard shall be prevented by a guard locking device (see [3.4](#)) unless all hazardous machine functions covered by this guard have disappeared.

There are two alternatives for the design of the guard locking function (see Figure 4).

- a) Unlocking of the guard can be initiated at any time by the operator. When unlocking is started, the guard locking device generates a stop command. This is called unconditional unlocking. The time necessary for the guard to be unlocked shall be greater than the time necessary for the hazardous machine function to disappear.
- b) Unlocking of the guard is possible only when the hazardous machine functions have disappeared. This is called conditional unlocking.



Unconditional unlocking

Conditional unlocking

NOTE In conditional locking, the change from state 2 to state 3 or from state 3 to state 2 can happen without time delay.

Figure 4 — Functional diagrams of interlocking devices with guard locking

Examples of guard locking devices are given in [Annex F](#).

4.3.2 Interlocking device with mechanically operated guard locking

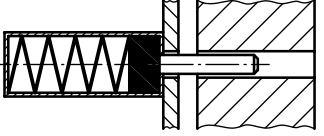
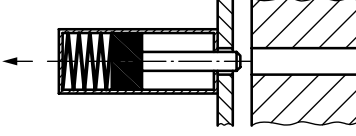
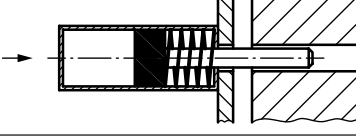
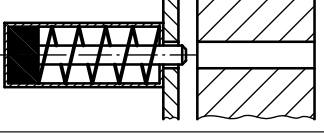
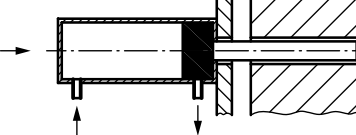
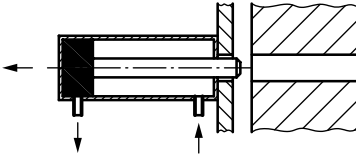
The mechanical part (e.g. bolt) which locks the interlocking guard can be

- manually applied and manually released (see [Figure F.5](#));
- spring (or similar) applied and power-ON released [see a) in [Figure 5](#)];
- power-ON applied and spring (or similar) released [see b) in [Figure 5](#)];
- power-ON applied and power-ON released [see c) in [Figure 5](#)].

Mechanically operated guard locking shall use the principle of direct mechanical blocking due to form. Friction and force alone shall not be relied upon.

4.3.3 Interlocking device with electromagnetically operated guard locking

The guard is kept closed (locked) without any mechanical locking means by an electromagnetic force (see F.4). The electromagnetic guard locking operates on the principle of power-ON applied and power-OFF released [see d) in Figure 5].

a)		Spring applied	Engaged
		Power-ON released	Released
b)		Power-ON applied	Engaged
		Spring released	Released
c)		Power-ON applied	Engaged
		Power-ON released	Released

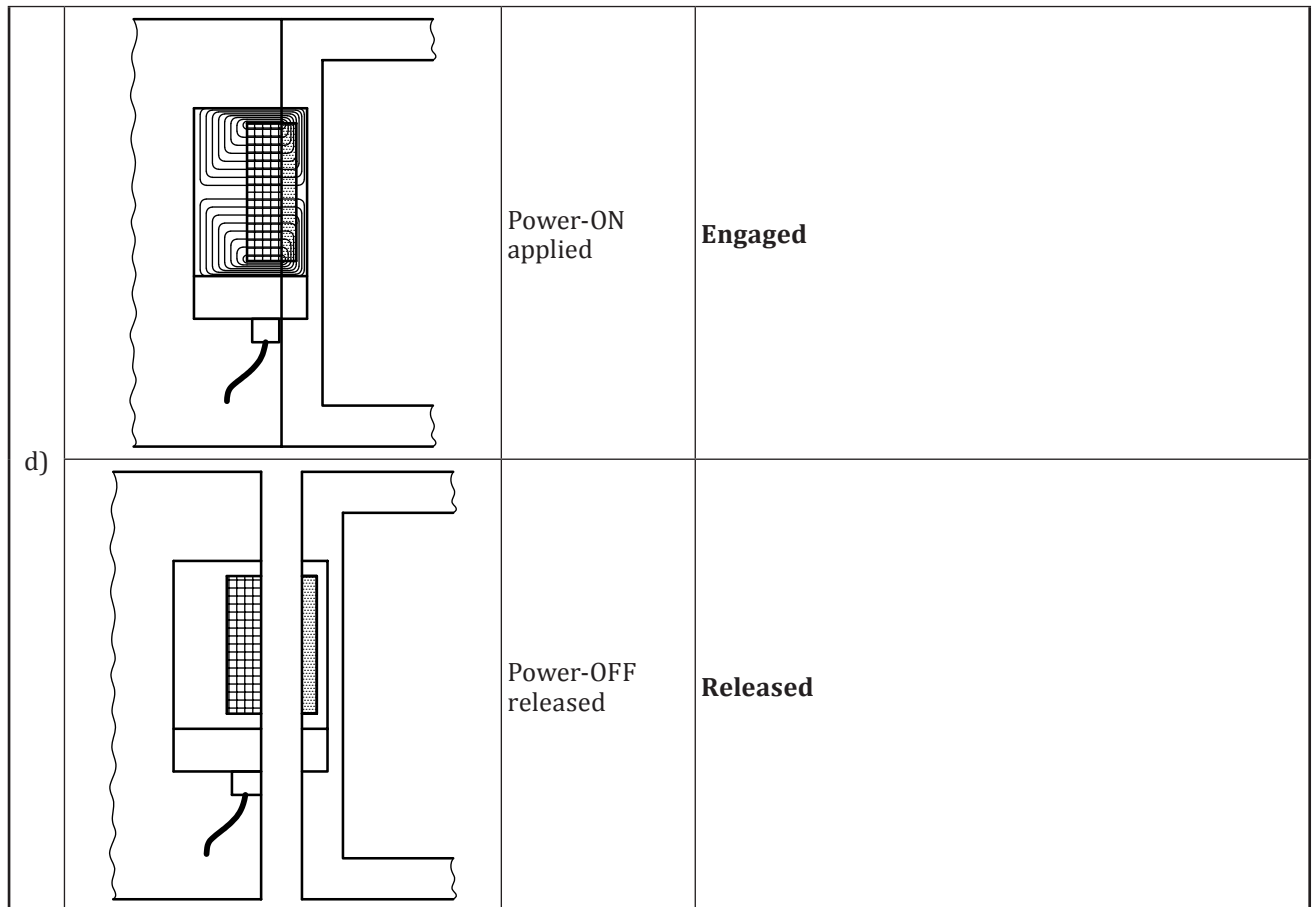


Figure 5 — Operating modes of guard locking device in power-actuated guard locking devices

5 Requirements for the design and the installation of interlocking devices with and without guard locking

5.1 General

Interlocking devices shall be installed in a suitable robust manner and in accordance with any instructions provided by the manufacturer (see [Clause 9](#)).

5.2 Arrangement and fastening of position switches

Position switches shall be arranged so that they are sufficiently protected against a change of their position. In order to achieve this, the following requirements shall be met:

- fasteners of the position switches shall be reliable and loosening them shall require a tool;
- Type 1 position switches shall have provisions for permanently fixing the location after adjustment (e.g. by means of pins or dowels);
- necessary means of access to position switches for maintenance and checking for correct operation shall be ensured. Prevention of defeat in a reasonably foreseeable manner shall also be considered when designing the access means;
- self-loosening shall be prevented;
- defeat of the position switch in a reasonably foreseeable manner shall be prevented (see [Clause 7](#));

- f) the position switch shall be located and, if necessary, protected so that damage from foreseeable external causes is avoided;
- g) the movement produced by mechanical actuation or the gap of the proximity device actuating system shall remain within the specified operating range of the position switch or actuating system specified by the switch manufacturer to ensure correct operation and/or prevent overtravel;
- h) a position switch shall not be used as a mechanical stop, unless this is the intended use of the position switch as declared by the manufacturer;
- i) misalignment of the guard that creates a gap before the position switch changes its state shall not be sufficient as to impair the protective effect of the guard (for access to hazard zones, see ISO 13855 and ISO 13857);
- j) the support and fastening for the position switches shall be sufficiently rigid to maintain correct operation of the position switch.

5.3 Arrangement and fastening of actuators

5.3.1 General

Actuators (see [Figure 2](#)) shall be so fastened to minimize the possibility that they come loose or change their intended position relative to the actuation system during the intended lifetime.

NOTE A regular check can be necessary (see [9.3.2](#)).

The following requirements shall be met:

- a) fasteners of the actuators shall be reliable and loosening them shall require a tool;
- b) self-loosening shall be prevented;
- c) the actuator shall be located and, if necessary, protected so that damage from foreseeable external causes is avoided;
- d) an actuator shall not be used as a mechanical stop, unless this is the intended use of the actuator as declared by the manufacturer;
- e) the support and fastening for the actuators shall be sufficiently rigid to maintain correct operation of the actuator.

5.3.2 Cams

Rotary and linear cams for Type 1 interlocking devices shall meet the following requirements:

- a) they are fixed by fasteners requiring a tool for loosening them;
- b) final fixing is achieved by form (e.g. spline or pin) or other methods that provide equivalent integrity of fixing;
- c) they do not damage the position switch or impair its durability.

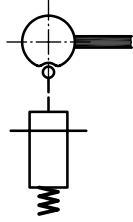
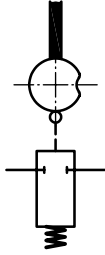
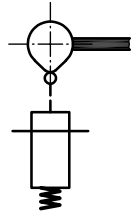
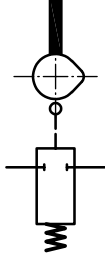
5.4 Actuation modes of interlocking devices

When a single Type 1 or Type 2 interlocking device is used to generate a stop command, it shall be actuated by direct mechanical action between guard, actuator and actuating system and the contact element shall have direct opening action (see [3.10](#), [3.11](#) and [Table 2](#)).

Non-direct mechanical action for a Type 1 interlocking device shall be used only in conjunction with a Type 1 or Type 2 interlocking device with direct mechanical action between guard, actuator and output

system. Combining one interlocking device with direct mechanical action with a second interlocking device with non-direct mechanical action avoids common cause failures (see 8.3).

Table 2 — Direct and non-direct mechanical action of Type 1 interlocking devices

Mechanical action	Guard closed	Guard not closed	Working mode	Example of behaviour in case of failure (see 8.3.2)
Direct			Plunger held depressed by cam as long as guard is not closed When guard closed, output system changes its state as result of action of return spring	Output system remains in safe state when guard is not closed even if spring breaks
Non-direct			The plunger is held depressed by a cam as long as the guard is closed. When guard not closed, output system changes state as result of action of return spring.	If spring breaks, output system can go to unsafe state even if guard not closed.

Interlocking devices shall be actuated appropriate to the actuation principle of the applied position switch.

If a Type 3 or Type 4 interlocking device is the only interlocking device it shall meet the requirements of IEC 60947-5-3.

5.5 Interface to control systems

The output system of interlocking devices shall be suitable for inclusion in a control system designed in accordance with ISO 13849-1 or IEC 62061.

5.6 Mechanical stop

If an interlocking device is declared by the manufacturer of the device to be suitable for use as a mechanical stop the maximum impact energy withstand value shall be given (see also 9.2.2 r)).

5.7 Additional requirements on guard locking devices

5.7.1 General

If the application of the guard locking function creates hazards additional measures shall be considered (see 5.7.5 and ISO 12100:2010, 6.3.5.3).

The locking element (e.g. bolt) intended to lock the guard shall be “spring applied – power-ON released” (see Figure 5 a)) or “power-ON applied – power-ON released” (see Figure 5 c)) unless the outcome of the risk assessment shows that this is not appropriate. If in a specific application other systems (e.g. Figure 5 b)) are used, they shall provide an equivalent level of safety.

NOTE When the loss of power results in the release of the locking element, the stopping time of the machine is often lengthened considerably and it can be possible to access to the hazard before the movements have been stopped (or other hazard disappeared).

The requirements of [5.7](#) apply when guard locking function is used for the protection of persons. The requirements do not apply when guard locking function is used solely for the protection of a process. Nevertheless if guard locking function and guard interlocking function are part of the same device the safety level of the guard interlocking function shall not be negatively affected by a non safety related guard locking function (i. e. guard locking function used solely for the protection of the process).

The requirements of [5.7](#) apply to both guard locking devices composed of separate components as well as to guard locking devices which form an integral part of an interlocking device with guard locking. They apply to all technologies.

The guard locking device shall allow the engaged position to be monitored by providing an output system compatible with a control system designed in accordance with ISO 13849-1 or IEC 62061.

The guard locking device shall only allow hazardous functions of the machine when the guard is closed and locked.

5.7.2 Mechanical guard locking device

5.7.2.1 General

Mechanically operating guard locking shall result from the engagement of two rigid parts (form closure, see [Figure 5 a](#)) to c)).

If it is foreseeable that access is necessary in case of emergency, for “spring applied – power-ON released” or “power-ON applied – power-ON released” systems (see [Figure 5 a](#)) and c)), a guard locking device with emergency release (see [5.7.5.3](#)) shall be provided.

[Figure 6](#) shows the functionality of such a device.

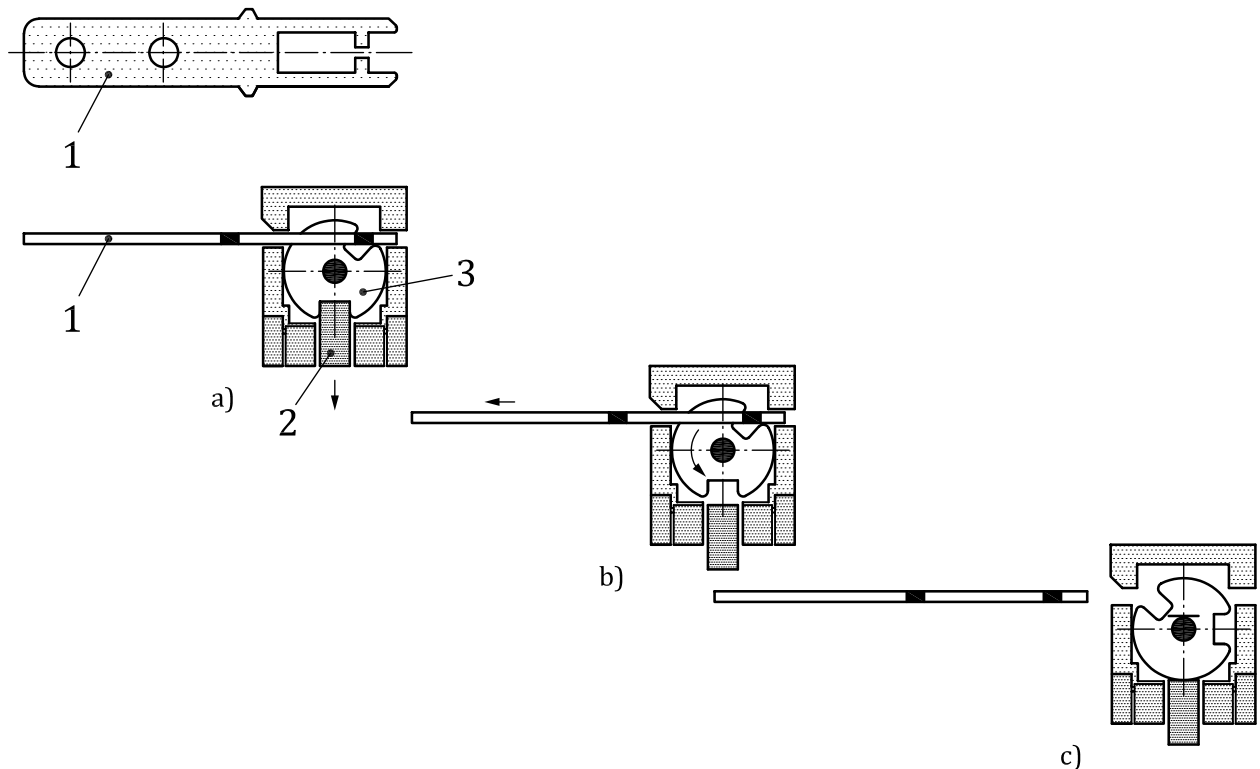
5.7.2.2 Locking monitoring

The engaged position of the locking element shall be monitored in accordance with the requirements of [5.5](#).

The hazardous function of the machine shall only be possible when the monitoring detects the closed position of the guard and the engaged position of the locking element (see [Annex F](#)).

For an effective monitoring of the guard locking device one of the following methods shall be ensured

- the locking element can only go in the engaged position if the movable guard is in the closed position (see [Figure 6](#)), in that case the closed position and the locking of the guard can be checked by the monitoring of the locking element;
- in the other case the monitoring of the locking element and additionally the monitoring of the guard position shall be used for interlocking.



Key

- | | |
|------------------------------------|--|
| a) guard closed and locked | 1 actuator (tongue) |
| b) guard closed and not locked | 2 locking element (bolt) |
| c) guard not closed and not locked | 3 actuating system (internal rotating cam) |

NOTE In this kind of position switch the actuator has two functions: to operate the contacts (not shown in the figure) and together with the internal rotating cam and the bolt to provide the guard locking function. The bolt can be operated by external means e.g. a solenoid or pneumatic cylinder.

Figure 6 — Example of Type 2 interlocking device with guard locking

5.7.3 Electromagnetic guard locking device

5.7.3.1 General

The force required for the locking of the guard is applied by the generation of an electromagnetic field (see [Figure 5 d](#)).

5.7.3.2 Locking monitoring

The holding force shall be monitored to determine if the specified holding force has been achieved and maintained (see [6.2.2](#) and [Annex I](#)).

The hazardous function of the machine shall only be possible when the monitoring detects the closed position of the guard and the achievement of the specified holding force.

5.7.3.3 Basic measures for minimizing defeat possibilities

If an electromagnetic guard locking device is opened by force, it shall be ensured that the process cannot be immediately continued.

NOTE In contrast to a mechanical guard locking, an electromagnetic guard locking shows no damage after an opening by force.

The objective of the measure is that an opening by force results in a time expenditure which is similar to that of repair works (time delay) and comparable with the repair of a damage of an electromechanical guard locking.

This can be implemented by

- a) means of measures within the guard locking, such as e.g.
 - 1) a reset after an interruption of the hazardous machine function is only possible after a minimum of 10 min, or
 - 2) the generation of a malfunction of the guard locking, which requires replacement or repair,or
- b) means of equivalent time-consuming measures in the machine control system, such as, e.g. the following sequence:
 - 1) warning message at the machine, and
 - 2) cycle stop, and
 - 3) switching-off the production mode, and
 - 4) testing of the guard locking function, and
 - 5) switching-on the production mode, and
 - 6) restarting the next machine cycle (after a fixed time period of a minimum of 10 min).

5.7.4 Holding force

The manufacturer of the guard locking device shall ensure that in the engaged position, the guard locking device withstands at least the specified holding force F . The manufacturer shall specify a holding force which shall be less or equal than the holding force F_{Zh} , which is determined via the following test:

Test

The guard locking device is fastened onto a base as intended by the manufacturer. The guard locking device is then loaded up to the point of failure of the guard locking function, in that the locking means at its maximum operating angle is moved at a constant speed in the "open guard" direction. During this loading, the maximum force F_{1max} is measured during the course of deformation. The test shall be carried out on an unused as-new sample.

Evaluation

Based on the maximum force F_{1max} measured during the test taking into consideration the safety factor S the holding force F_{Zh} is ascertained using the following formula:

$$F_{Zh} = \frac{F_{1max}}{S}$$

with

$$S = 1,3$$

Requirements on the test device

Traction speed: constant ($10 \pm 0,25$) mm/min

Requirements on the force measurement device

Sampling rate: ≥ 10 Hz

Measurement accuracy of maximum force: $\pm 2,5$ %

NOTE For test details, see Reference [19].

5.7.5 Supplementary release of guard locking

5.7.5.1 General

Depending on the application supplementary methods of release of guard locking can be necessary (see ISO 12100:2010, 6.3.5.3). For the selection see 6.2.3. Escape and emergency releases of guard locking shall fulfil at least the requirements of Category B according to ISO 13849-1.

NOTE When one of the described release methods is used, a considerable longer stopping time than normal could be the effect which should be considered in the risk assessment.

5.7.5.2 Escape release of guard locking

When the guard locking device is provided with an escape release the following requirements shall be met:

- deliberate unlocking of the guard locking from inside of the safeguarded area shall be easily possible without auxiliary means and regardless of the operating condition;
- the unlocking means shall be manually operated and act directly on the principle of the locking mechanism;
- the unlocking shall generate a stop command;
- the unlocking means for the escape release shall only be accessible from inside the safeguarded area.

5.7.5.3 Emergency release of guard locking

When the guard locking device is provided with an emergency release the following requirements shall be met:

- deliberate unlocking of the guard locking from outside the safeguarded area shall be possible and be easily actuated without auxiliary means, regardless of the operating condition;
- the unlocking means shall be manually operated and act directly on the principle of the locking mechanism;
- the unlocking shall generate a stop command;
- the unlocking results in a blocking of the locking means in the released condition;
- the emergency guard locking release shall be clearly marked to be used only in emergency situations and shall be positioned and/or shielded to prevent accidental opening of the lock;
- the resetting of the emergency release shall be possible only by means of a tool or by other methods (e.g. change of component). This requirement can be fulfilled on a control system level. If the requirements are intended to be fulfilled on a safety control system level (not in the guard locking device), clear instructions that this needs to be achieved shall be provided in the instructions for use of the guard locking device (see 9.2.2 m)).

NOTE Provided that the emergency release meets the conditions of an escape release, the emergency release can become an escape release when it is mounted inside of the safeguarded area.

5.7.5.4 Auxiliary release of guard locking

When the guard locking device is provided with an auxiliary release the following requirements shall be met.

- Deliberate unlocking of the guard locking from outside the safeguarded area shall be possible only by the use of a tool or key(s) and regardless of the operating condition. The auxiliary release shall be protected against unintended actuation (e.g. protected by seal, protective coating) since the auxiliary release is to be used in exceptional cases only e.g. when the locking is power ON released and the power is lost and the guard locking does not have emergency release function. The instructions for use shall state that the restoring of the protection is necessary before normal operation is resumed.
- The unlocking of the auxiliary release shall generate a stop command.
- The resetting of the auxiliary release shall be possible only by means of a tool or by other methods (e.g. change of a component). This requirement can be fulfilled on a control system level. If the requirements are intended to be fulfilled on a safety control system level [not in the guard-locking device), clear instructions that this needs to be achieved shall be provided in the instructions for use of the guard locking device (see 9.2.2 m)].

5.7.6 Requirements for fastenings

The fastening of guard locking devices shall meet the requirements of [5.2](#) and shall be designed to withstand the holding forces.

6 Selection of an interlocking device

6.1 General

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

Selection shall take into account but not be limited to the following criteria:

- the conditions of use and the intended use of the machine (see 6.3, ISO 12100:2010, 3.23 and 5.3);
- the hazards present at the machine (see ISO 12100:2010, 5.4);
- the severity of the possible injury (see ISO 12100:2010, 5.5);
- the probability of failure of the interlocking device (see [Clause 8](#));
- overall system stopping performance and access time (see [6.2.1](#));
- the required Performance Level PL (see ISO 13849-1:2006) or Safety Integrity Level SIL (see IEC 62061:2012) for the safety function (see [8.1](#));
- information for use according to [9.2.2](#) provided for the interlocking device(s);
- for Type 4 interlocking devices the means to avoid that a single actuator can be taught in an unlimited manner by the operator without special knowledge and special tools.

NOTE Type 3 or Type 4 interlocking devices can be used to overcome problems arising from the use of Type 1 and Type 2 interlocking devices when a guard can be removed completely from a machine and/or when the environmental/process conditions require a high level of protection (e.g. IP69K).

6.2 Selection of a guard locking device

6.2.1 Overall system stopping performance and access time

An interlocking device with guard locking shall be used when the overall system stopping performance (see [3.21](#)) is greater than or equal to the access time taken by a person to reach the hazard zone (see [Figure 7](#)).

The access time shall be calculated by using the distance between the hazard zone and the guard together with the approach speed (see ISO 13855:2010 for typical values).

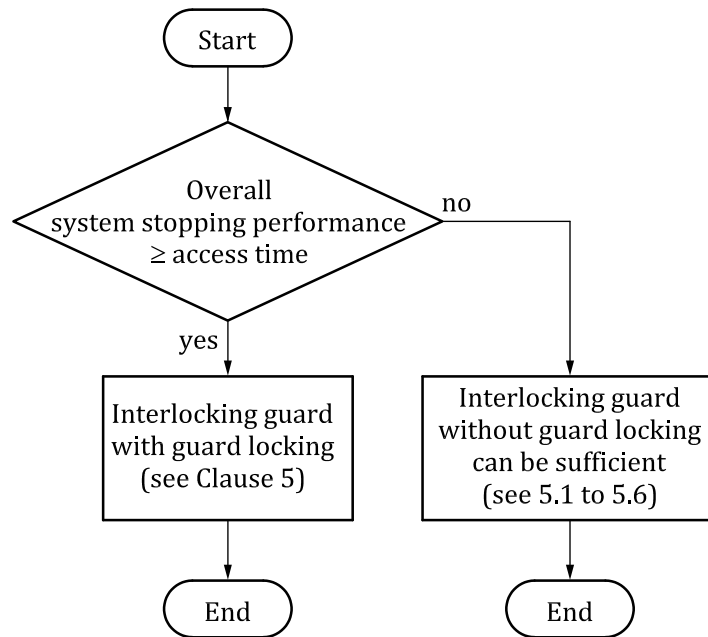


Figure 7 — Determination of the need for guard locking devices

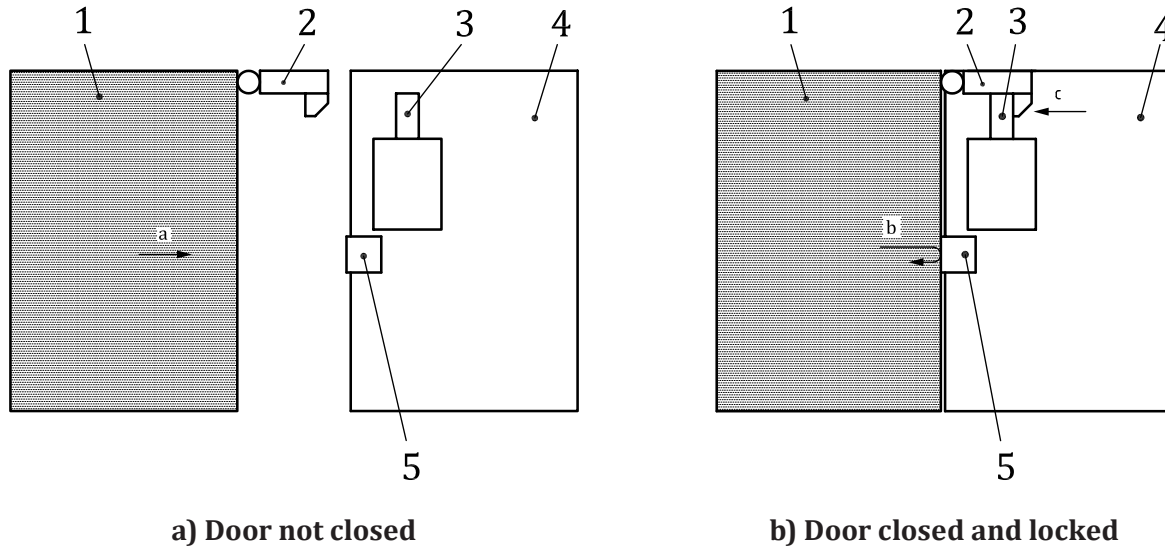
6.2.2 Specific requirements for selection of guard locking devices

The device shall be selected in order to be able to withstand the expected forces. Dynamic effects like bouncing, or chattering shall be considered as well.

If the expected impact reaction forces are higher than the forces the selected device can withstand then design measures shall be applied to reduce or avoid the forces.

NOTE 1 A dynamic force will occur, when the door is being closed and the locking mechanism is already activated, see [Figure 8](#).

When the guard locking device is intended to be activated automatically when the guard reaches the closed position, the selected guard locking device shall withstand the resulting mechanical forces.



Key

- | | | | |
|---|---------------------------------|---|--|
| 1 | movable guard | 4 | fixed part of the guard |
| 2 | actuator | 5 | guard stop |
| 3 | Guard locking mechanism (lock). | | |
| a | Direction of closing. | c | Dynamic force expended on locking mechanism. |
| b | Rebound at guard stop. | | |

Figure 8 — Example of a guard locking device affected by dynamic forces

The strength of the mechanical locking elements or the holding force of the electromagnetic locking shall be sufficient to prevent the opening of the guard from the closed position without the help of a crowbar or similar heavy tools.

The holding force needed shall be appropriate to the intended application and construction of the guard (for additional information see [Annex I](#) and ISO 14120).

NOTE 2 It is the task of the type-C standard or the machine designer to determine the appropriate holding force.

6.2.3 Selection of supplementary guard locking releases

Depending on the application supplementary methods of release can be necessary. These measures can include but are not limited to:

- an escape release of guard locking according to [5.7.5.2](#);
- an emergency release of guard locking according to [5.7.5.3](#);
- special design of the guard to allow escape;
- auxiliary release of guard locking can be necessary when it is foreseen that it is necessary to get to the safeguarded area in special situations, e.g. when the locking is power ON released and the power is lost and the guard locking does not have emergency release function..

NOTE 1 See 5.7.5, ISO 12100:2010, 6.3.5.3 and ISO 11161:2007, 8.9.

NOTE 2 An escape release can be used in combination with an emergency or auxiliary release.

6.3 Environmental conditions considerations

6.3.1 General

The technology and type of interlocking device shall be considered to ensure that it is suitable for the conditions of use (e.g. environment, hygiene) and for the intended use of the machine.

Environmental conditions shall be considered for the selection of the appropriate interlocking device. Criteria are for example:

- temperature,
- dust,
- moisture,
- vibration and shocks,
- hygiene,
- electromagnetic influences.

The interlocking device shall withstand all foreseeable influences during its expected lifetime.

NOTE 1 Failure can be induced by corrosion from salts, acids or alkalis (e.g. seawater) and the possibility of such effects, particularly over time, should be taken into account. The particular design of the interlock and type of technology used can cause it to be susceptible to the ingress of chemicals or particles. In areas where significant pollution is present, manufacturer's guidance should be sought.

NOTE 2 When combining Type 3 or Type 4 interlocking devices using reed contacts together with monitoring logic units the user should verify that possible current spikes caused by the monitoring logic unit are not exceeding the admissible limits of the switches.

6.3.2 Influence of dust on Type 2 interlocking devices

If Type 2 interlocking devices are applied, the possible pollution at the mounting location shall be considered. Type 2 interlocking devices can be unsuitable in applications where the ingress of particles, chips or dusts cannot be prevented unless suitable measures (e.g. dust protection cover) are applied.

NOTE The actuator is inserted into the position switch, therefore the position switch has an opening which allows the ingress of dust. The indicated degree of protection IPXX according IEC 60529 relates exclusively to the electrical enclosure. The pollution of the mechanical parts can result in the degradation of the mechanism and in a dangerous failure of the interlocking device.

7 Design to minimize defeat possibilities of interlocking devices

7.1 General

The machine shall be designed in such a way that it minimizes the motivation for defeating the interlocking devices (see ISO 12100:2010, 5.5.3.6).

The interlocking device shall provide the minimum possible interference with activities during operation and other phases of machine life, in order to reduce any incentive to defeat it:

- easy operation of the machine, in particular during maintenance and service operations;
- failure-free operation of functionality of a machine.

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The following procedure shall be followed in order to avoid interlocking devices being defeated in a reasonably foreseeable manner:

- a) Implement the basic measures described in [5.2](#), [5.3](#), [5.4](#), [5.7.3.3](#) and [6.2.2](#).

Type 3 interlocking devices shall not be used unless it is shown by risk assessment that in the application the device cannot be defeated in a reasonably foreseeable manner.

- b) Check whether the motivation to defeat the interlocking devices in reasonably foreseeable manner exists.

NOTE 1 Considering experience of use is helpful, see ISO 12100:2010, 5.2 c).

NOTE 2 [Table H.1](#) in [Annex H](#) can be used for guidance to evaluate and/or eliminate the motivation to defeat interlocking devices.

- c) Check whether the motivation can be eliminated or minimized by:

- design measures and/or
- alternative modes.

Implement those measures if possible.

NOTE 3 The implementation of alternative modes of operation can avoid the motivation to defeat. Alternative modes of operation can be, e.g. special modes for setting, tool changing, fault finding, maintenance or process observation. They depend highly on the type of machine and its application and cannot be dealt with comprehensively in this standard.

- d) If foreseeable motivation for defeat continues to exist, additional measures are required (see [7.2](#)).

[Figure 9](#) provides a schematic representation of the methodology for determining the possible incentive and the required measures done by the machine manufacturer.



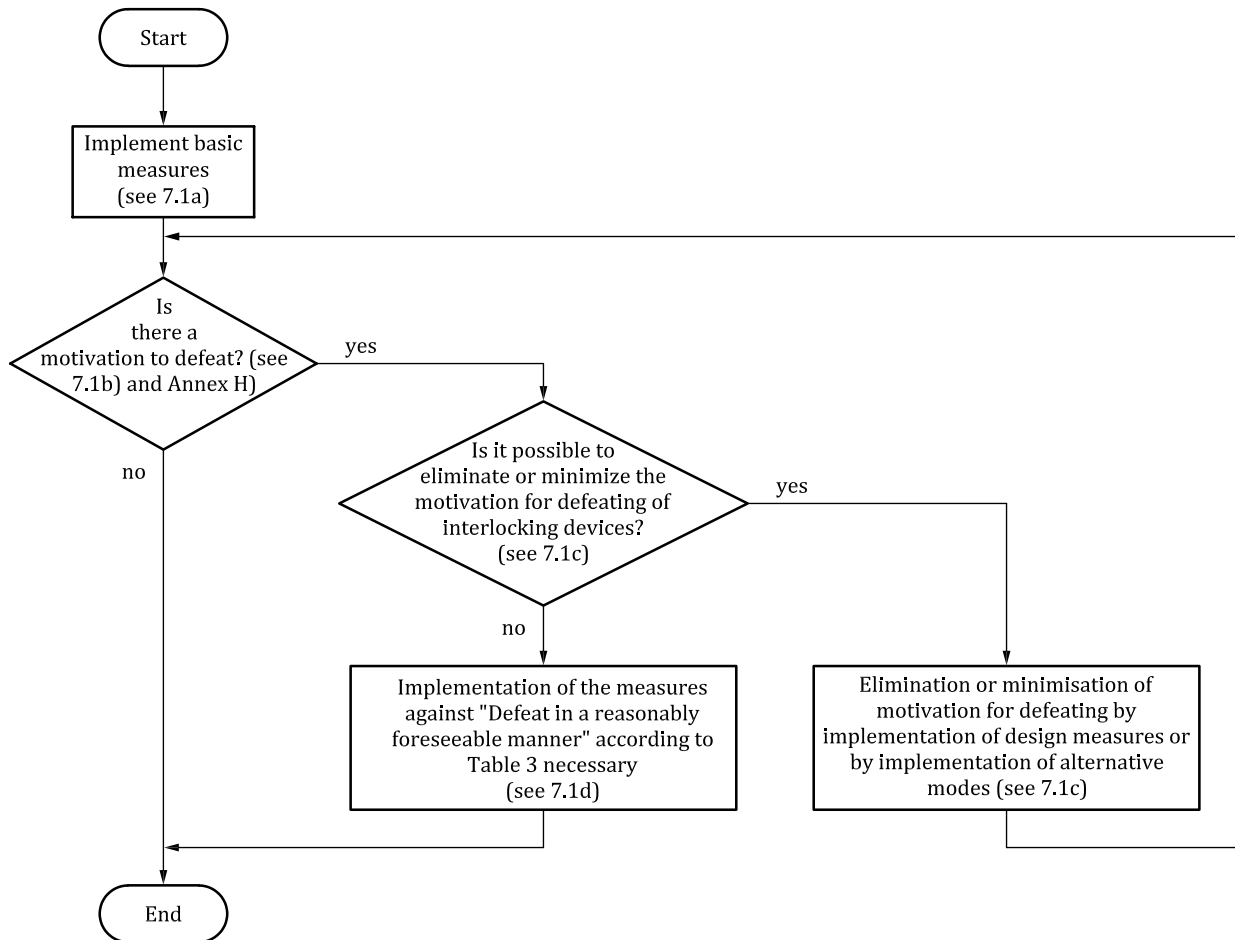


Figure 9 — Methodology for determining the possible incentive and the required measures done by the machine manufacturer

7.2 Additional measures to minimize defeat possibilities of interlocking devices

The interlocking devices shall be selected and/or installed such that defeating in a reasonably foreseeable manner is prevented.

In the following, possible measures against defeat in a reasonably foreseeable manner are mentioned. For the requirements and applicability see [Table 3](#).

a) Prevention of accessibility to the elements of the interlocking device

- 1) mounting out of reach (see [Figure 11](#)),
- 2) physical obstruction or shielding (see [Figure 10](#)),
- 3) mounting in hidden position;

b) Prevention of substitute actuation of the interlocking device by readily available objects

- 1) low level coding of actuators;
- 2) medium level coding of actuators;
- 3) high level coding of actuators;

c) Prevention of dismantling or de-positioning of the elements of the interlocking device by use of non-detachable fixing (e.g. welding, gluing, one-way screws, riveting)

NOTE 1 Use of non-detachable fixing can be an inappropriate solution in cases where a failure of the interlocking device during lifetime of the machinery can be expected and a fast change is necessary. In this case other measures, e.g. a), b) and d), should be used to provide the required level of risk reduction.

d) **Prevention of defeat**

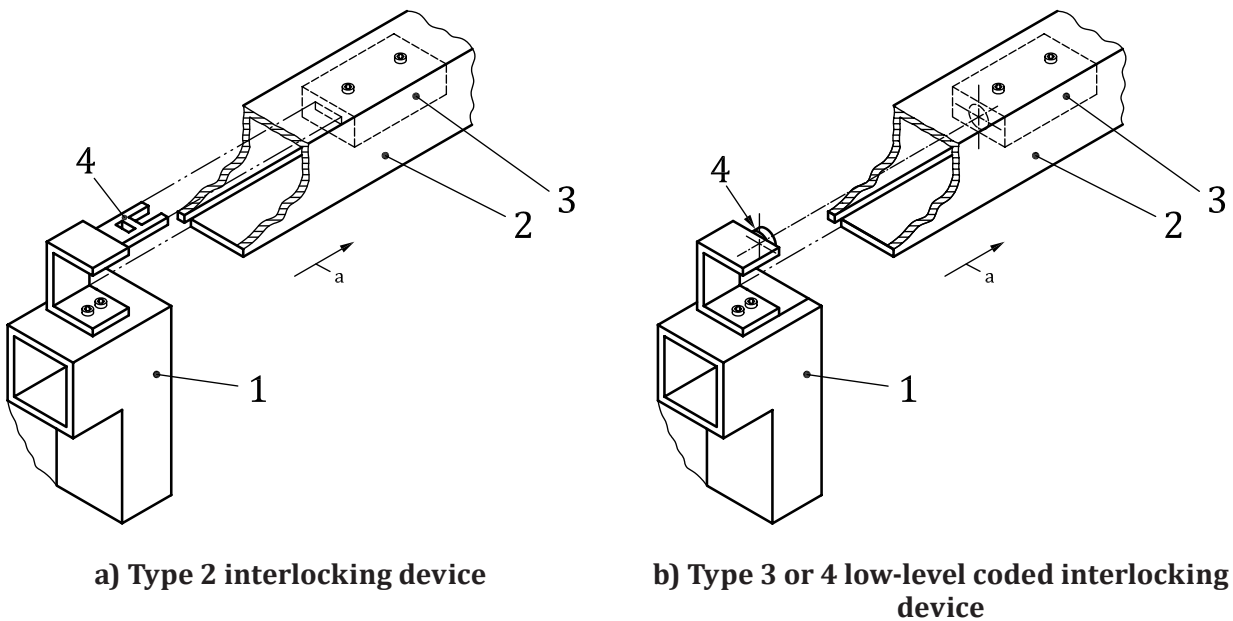
- 1) Integration of defeat monitoring in the control system by means of
 - i) status monitoring,
 - ii) cyclic testing.

NOTE 2 In i) status monitoring, plausibility testing detects during machine cycle an unusual succession of states resulting in a defeat. The system control for instance expects the opening of a door in a defined machine cycle. The absence of the control signal indicates a defeat.

NOTE 3 In ii) cyclic testing, the operator is requested by the control to actuate the safeguard. The absence of the expected control signal indicates a defeat.

- 2) Checking for plausibility using an additional interlocking device where defeat is only possible by an additional action — for example, separate mounting and wiring, or different actuation principles require an additional action for defeating.

NOTE 4 In this context, checking for plausibility means checking that both interlocking devices are reacting in a predefined manner.



Key

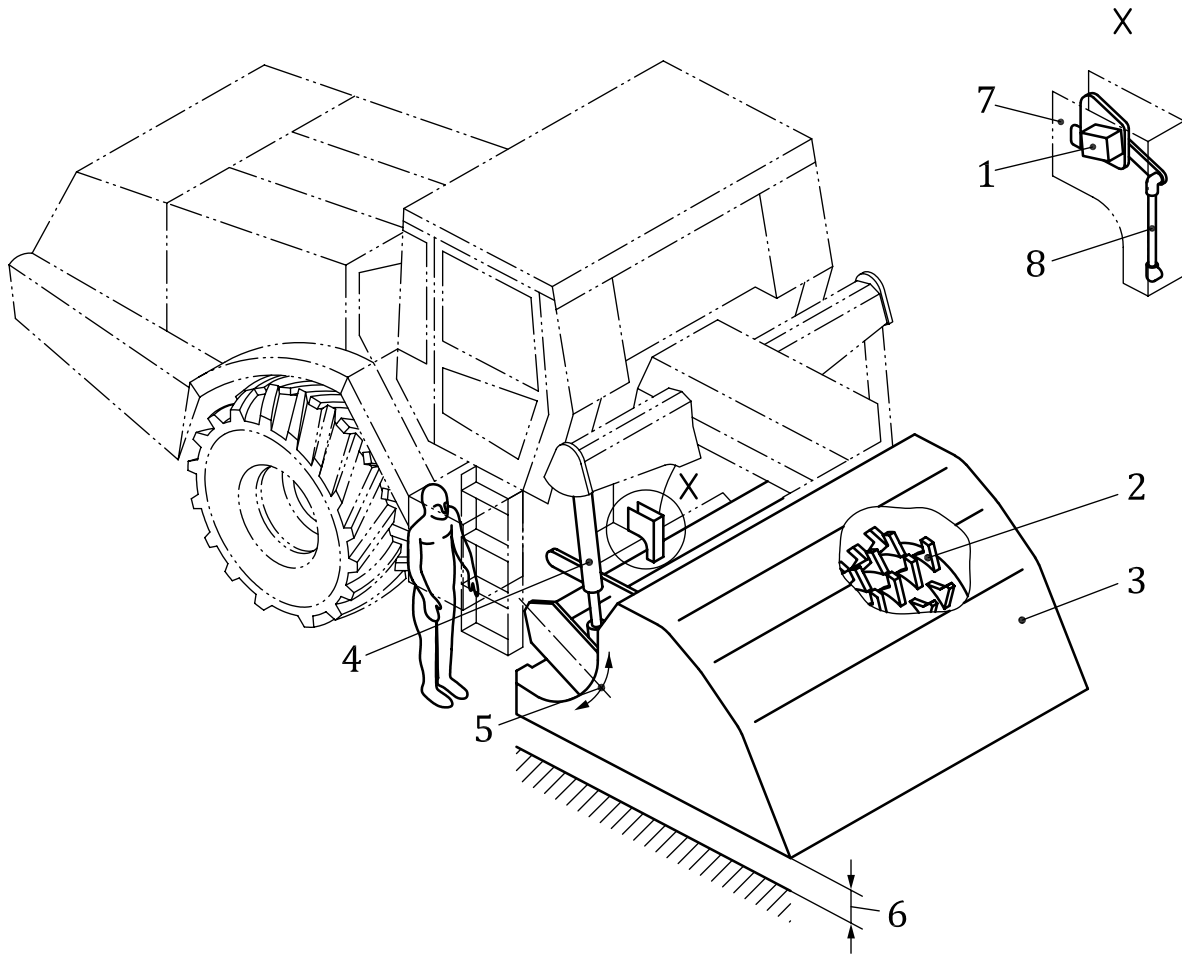
- 1 sliding guard (not closed)
- 2 cover (fixed part)
- 3 position switch
- 4 actuator
- a Direction of closing.

NOTE Defeating of the interlocking device is made difficult by the cover (2), or by the presence of the guard in front of it.

Figure 10 — Examples of protection against defeating by physical obstruction or shielding

Table 3 — Additional measures against defeating interlocking devices depending on type

Principles and measures	Type 1 interlocking device, except hinged and Type 3 interlocking devices	Type 1 interlocking device, hinged only	Types 2 and 4 interlocking devices, low or medium level coded as given in 7.2.b) 1) or 7.2.b) 2) with or without electromagnetic guard locking	Types 2 and 4 interlocking devices, high level coded as given in 7.2.b) 3) with or without electromagnetic guard locking	Trapped key systems, medium or high level coded (see Note 2)
Mounting out of reach, see 7.2.a) 1)					
Physical obstruction/ Shielding, see 7.2.a) 2)					
Mounting in hidden position, see 7.2.a) 3)	X		X		
Status monitoring or cyclic testing, see 7.2.d) 1) i) and ii)					
Non-detachable fixing of position switch and actuator, see 7.2.c)					
Non-detachable fixing of position switch, see 7.2.c)		M			M
Non-detachable fixing of actuator, see 7.2.c)		M	M	M	M
Additional interlocking device and checking for plausibility, see 7.2.d) 2)	R		R		
<p>X mandatory to apply at least one of the measures M mandatory measure R recommended measure (additionally).</p> <p>NOTE 1 Table 3 is intended to be used for the selection of appropriate measures against defeating of interlocking devices. According to the risk assessment the application of more than one of the indicated measures can be necessary.</p> <p>NOTE 2 If the number of trapped key devices used within one site is known, coded actuators can be used as a sufficient measure against reasonably foreseeable defeating under the following conditions:</p> <ul style="list-style-type: none"> — if the coding is marked on the device each interlocking device should have a different coding and — the actuator should be medium or high level coded. <p>NOTE 3: There is a clear distinction between the coding level of actuator keys and the coding of “locking bolt or catch mechanisms” in a trapped key system. This table refers solely to the coding level of actuator keys.</p> <p>NOTE 4 Measures in accordance with Table 3 provide minimum requirements.</p>					



Key

- | | | | |
|---|---------------------------|---|--------------------------------------|
| 1 | hinge position switch | 5 | moving direction of the guard |
| 2 | rotor (dangerous tool) | 6 | process dependent height over ground |
| 3 | guard | 7 | cover attached to frame |
| 4 | lifting gear of the guard | 8 | actuation coupling |

Figure 11 — Example of protection against defeating of a torsion angle operated interlocking device by mounting out of reach at a machine for road construction

8 Control requirements

8.1 General

Interlocking devices with or without guard locking are safety-related parts of the control system (SRP/CS) of a machine, (see ISO 13849-1) or a subsystem or a subsystem element of a safety-related electrical control system (SRECS) (see IEC 62061) with the purpose to prevent hazardous situations.

NOTE Examples of interlocking devices realised in several architectures are given in [Annex G](#).

8.2 Assessment of faults

For example: Where an interlocking system requires PL_r e in accordance with ISO 13849-1 or SIL 3 in accordance with IEC 62061 a minimum fault tolerance of 1 is required (e.g. by implementing two Type 1 interlocking devices). In order to achieve this it is normally not justifiable to exclude faults, such as broken actuators. However, it may be acceptable to exclude some faults, such as short circuit of wiring

within a control panel designed in accordance with relevant standards. The same requirement applies for PL_r d and SIL 2 unless a full justification is provided in accordance with ISO 13849-1 or IEC 62061.

For applications using interlocking devices with automatic monitoring to achieve the necessary diagnostic coverage for the required safety performance, a functional test (see IEC 60204-1:2009, 9.4.2.4) can be carried out every time the device changes its state, e.g. at every access. If, in such a case, there is only infrequent access, the interlocking device shall be used with additional measures, because between consecutive functional tests the probability of occurrence of an undetected fault is increased.

When a manual functional test is necessary to detect a possible accumulation of faults, it shall be made within the following test intervals:

- at least every month for PL e with Category 3 or Category 4 (according to ISO 13849-1) or SIL 3 with HFT (hardware fault tolerance) = 1 (according to IEC 62061);
- at least every 12 months for PL d with Category 3 (according to ISO 13849-1) or SIL 2 with HFT (hardware fault tolerance) = 1 (according to IEC 62061).

NOTE It is recommended that the control system of a machine demands these tests at the required intervals e.g. by visual display unit or signal lamp. The control system should monitor the tests and stop the machine if the test is omitted or fails.

8.3 Prevention of common cause failures

8.3.1 General

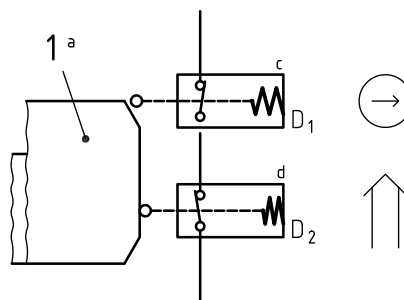
Where redundant interlocking devices are provided, common cause failures (CCF) shall be avoided.

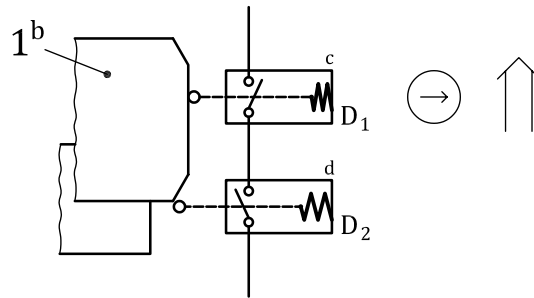
NOTE Use diversity instead of simple redundancy, e.g. by use of the measures described in 8.3.2 and/or in 8.3.3.

8.3.2 Direct and non-direct mechanical action of the position switches of Type 1 interlocking devices

The use of direct and non-direct mechanical action of the position switches of Type 1 interlocking devices is commonly used to prevent common cause failures.

Figure 12 shows the combination of direct and non-direct mechanical action of the position switches of Type 1 interlocking devices.





Key

- | | | | |
|----------------|----------------------|---|-------------------------------|
| 1 | guard | a | Closed. |
| D ₁ | position switch (NC) | b | Not closed. |
| D ₂ | position switch (NO) | c | Direct mechanical action. |
| | | d | Non-direct mechanical action. |

- ↑↑ switch actuated
- direct opening action

Figure 12 — Avoiding common cause failure of two mechanically actuated position switches by using associated direct and non-direct mechanical action

Typical causes for failure of mechanically actuated position switches are:

- a) excessive wear of the actuating system (e.g. plunger or roller) or of the actuator attached to the guard;
- b) misalignment between actuator and position switch;
- c) jamming of the actuating system (plunger) making actuation by the spring impossible.

In case of a failure of D₁ or D₂, breaking of the circuit is ensured by the other position switch. Position switches with direct mechanical action, as D₁ (see [Figure 12](#)), fail to danger in case a), but not in case c). It can fail to danger in case b) depending on the misalignment. Position switches with non-direct mechanical action, as D₂ (see [Figure 12](#)), fail to danger in case c), but not in case a). It can fail to danger in case b) depending on the misalignment.

NOTE D₂ can be a position sensing system.

If two mechanically actuated position switches using associated direct and non-direct mechanical action or one mechanically actuated position switch and one non-mechanically actuated position switch are applied, a score of 20 for diversity can be claimed for the quantification of common cause failure (CCF) according to ISO 13849-1 for this subsystem.

8.3.3 Power medium diversity

In order to minimize the probability of common cause failure CCF, two independent interlocking devices, each of which interrupts the supply from a different energy source, may be associated with a guard (see example given by [Figure A.6](#)). In this case, a score of 20 for diversity can be claimed for the quantification of CCF according to ISO 13849-1.

EXAMPLE A machine uses hydraulic components to apply the necessary forces to run the production process while the machine control is electrically/electronically driven. The opening of an interlocked movable guard initiates two independent position switches. The first position switch directly operates a hydraulic valve which interrupts the hydraulic pressure. The second position switch interrupts the control voltage which operates another valve. Either valve will cause the hazardous motion to disappear. Due to different technologies applied, there is no common cause failure possible that would cause both position switches to fail dangerously.

8.4 Release of guard locking device

For the release of a guard locking device all the devices applied

- to detect the engaged position,
- to detect the release conditions (e.g. speed or position monitoring, time delay),
- to process the logic signals, and
- to unlock the guard

are part of the SRP/CS and the appropriate safety function has to fulfil the required PL_r or SIL determined by risk assessment.

NOTE 1 If the risk assessment shows, that during the elapsed time between detection of an unintended unlocking of the guard and reaching a safe condition of the machine, a dangerous situation can occur and therefore risk reduction by a safety function for guard locking is necessary, all devices providing the (un)locking signal are part of the SRP/CS.

NOTE 2 The PL_r or SIL is dependent on the application-specific risk assessment. In most cases the PL_r or SIL of the guard locking function is lower than the PL_r or SIL of the interlocking function. The probability of the malfunction of the guard locking function at the same time as the access of a person usually is very low. For the guard locking function even in case of PL_r e fault exclusions for the mechanical parts are possible (see Annex A of ISO 13849-2:2012), Table D.8 of ISO 13849-2:2012 does not apply for guard locking devices, since D.8 is only relevant for interlocking devices.

8.5 Fault exclusion

Where fault exclusions apply, they shall be in accordance with ISO 13849-1:2006, 7.3, ISO 13849-2 and IEC 62061.

Possible faults exclusion shall be examined separately for mechanics and electronics taking into account the environmental conditions and external influences to be expected.

NOTE 1 Frequently used fault exclusions concern electromechanical switches. The non-opening of a normally closed contact can be excluded if the contact is in accordance with IEC 60947-5-1:2003, Annex K, see ISO 13849-2:2012, Table D.8.

NOTE 2 In some cases it is possible to exclude faults of the mechanics actuating an electromechanical position switch. For justification see ISO 13849-2:2012, Annex A. It is most important to consider the expected environmental conditions.

NOTE 3 For more information see [6.3.2](#).

There should be a proper selection of the device ensuring that the holding force (F_{Zh} – see 5.7.4) of the guard locking device is sufficient to withstand static forces on the locking element (bolt) and that shearing forces on the locking element by bouncing of the movable guard are prevented (see NOTE 4). In this case the use of fault exclusion for breakage of the locking element does not necessarily limit the PL or SIL for the guard locking function.

NOTE 4 For example the design of the control system can ensure that the spring applied locking element does not move into the engaged position, before the movable guard is closed and stationary, e.g. by time delay between closing the door and cutting-off the voltage to the solenoid.

NOTE 5 The guard locking function is a different safety function to the locking monitoring function.

NOTE 6 For more information see [6.2.2](#).

8.6 Logical series connection of interlocking devices

Logical series connection of interlocking devices means for NC contacts wired in series or for NO contacts wired in parallel. When interlocking devices with redundant contacts are logically connected

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in series the detection of a single fault can be masked by the actuation of any interlocking device logically connected in series with the defective interlocking device to the safety related control system.

It is foreseeable that during the fault finding (troubleshooting) by the operator one of the guards whose interlocking devices are logically connected in series with the defective interlocking device will be actuated. In that case the fault will be masked and the effect on the diagnostic coverage value shall be considered.

For a series connection the maximum DC (see ISO 13849-1 or IEC 62061) should be considered.

NOTE ISO/TR 24119, which deals with the logical serial connection of devices, is under preparation.

8.7 Electrical and environmental conditions

8.7.1 General

Electrical interlocking devices shall comply with IEC 60204-1.

When the devices are foreseen to be used outside the environmental limits stated in IEC 60204-1, the interlocking devices shall be selected such that they meet the foreseeable environmental conditions.

8.7.2 Performance considerations

Power interlocking components shall have suitable current breaking capacity, taking into account all foreseeable situations (e.g. overload).

8.7.3 Immunity from disturbance

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

8.7.4 Electrical operating conditions

When electronic components are used in interlocking devices, necessary precautions shall be taken to prevent malfunction caused by voltage fluctuations, transient overvoltage, etc.

9 Information for use

9.1 General

An interlocking device could be

- a) designed and manufactured by the machine manufacturer using available separate components or
- b) manufactured and placed on the market as a complete device ready for use.

Therefore there are different requirements for the information for use that apply to manufacturer of the machine or the manufacturer of interlocking devices.

9.2 Information for use given by the manufacturer of interlocking devices

9.2.1 Marking

The marking shall be in accordance with ISO 12100:2010, 6.4.

Furthermore, interlocking devices designed and constructed for use in a potentially explosive atmosphere shall be marked accordingly.

Where this is not practicable due to space restrictions the full address of the manufacturer and the designation of the device type shall be stated in the instruction for use and the device shall be clearly marked with the manufacturers name or logotype.

The marking shall be sufficient to identify the document containing the information for use according to 9.2.2 or 9.3, as appropriate.

NOTE The aim of the marking is to identify the manufacturer and to show the intended functionality of the component (e.g. type or symbol for direct opening action).

The marking for locking monitoring in accordance with [5.7.1](#), [5.7.2.2](#) and [5.7.3.2](#) shall be with the symbol according [Figure 13](#).



Figure 13 — Symbol for locking monitoring of locking elements

9.2.2 Instructions

The manufacturer of the interlocking device shall indicate the following in the instructions:

- a) the business name and full address of the manufacturer and, where applicable, his authorised representative;
- b) designation of the interlocking device;
- c) designation of series or type;
- d) a general description of the interlocking device;
- e) the drawings, diagrams, descriptions and explanations necessary for the use, maintenance and repair of the interlocking device and for checking its correct functioning;
- f) a description of the intended use of interlocking device;
- g) assembly, installation and connection instructions, including drawings, diagrams and the means of attachment of the interlocking device;
- h) instructions for the putting into service and use of the interlocking device and, if necessary, instructions for the training of operators;
- i) the description of the adjustment and maintenance operations that should be carried out by the user and the preventive maintenance measures that should be observed;
- j) instructions designed to enable adjustment and maintenance to be carried out safely, including the protective measures that should be taken during these operations;
- k) any data necessary for the user to determine PL or SIL for the intended safety function(s).

In addition, where relevant, the following shall be specified:

- l) warnings relating to reasonably foreseeable misuse;
- m) warning that the device itself does not contain reset facility for emergency and auxiliary release of guard locking and that additional measures are required to achieve it (see [5.7.5.3](#) and [5.7.5.4](#));
- n) mandatory declaration;
- o) holding force F_{Zh} according [5.7.4](#);
- p) range of actuation movement;

- q) the specifications of the spare parts to be used, when these affect the health and safety of operators;
- r) the maximum impact energy withstand value, in J, if the device can be used as a mechanical stop;
- s) the maximum peak current and voltage of the output system of the position switch;
- t) information that it should not be possible to reach the manual actuator of the escape release from outside the safeguarded area or that additional measures should be taken to reduce the risk of improper activation;
- u) where interlocking systems rely on special actuators or keys (coded or not), advice shall be given in the instruction handbook concerning risks associated with the availability of spare actuators, keys and master keys and that any spare actuators or keys should be securely controlled. This also includes reset keys for emergency and escape release;
- v) the level of coding (low, medium, high) for coded interlocking devices (Type 2 or Type 4).

9.3 Information for use given by the manufacturer of the machine

9.3.1 Marking

A specific marking is not required.

9.3.2 Instructions

The manufacturer of the machine shall include the relevant information of 9.2.2 regarding the interlocking devices in the instructions for use of the machine.

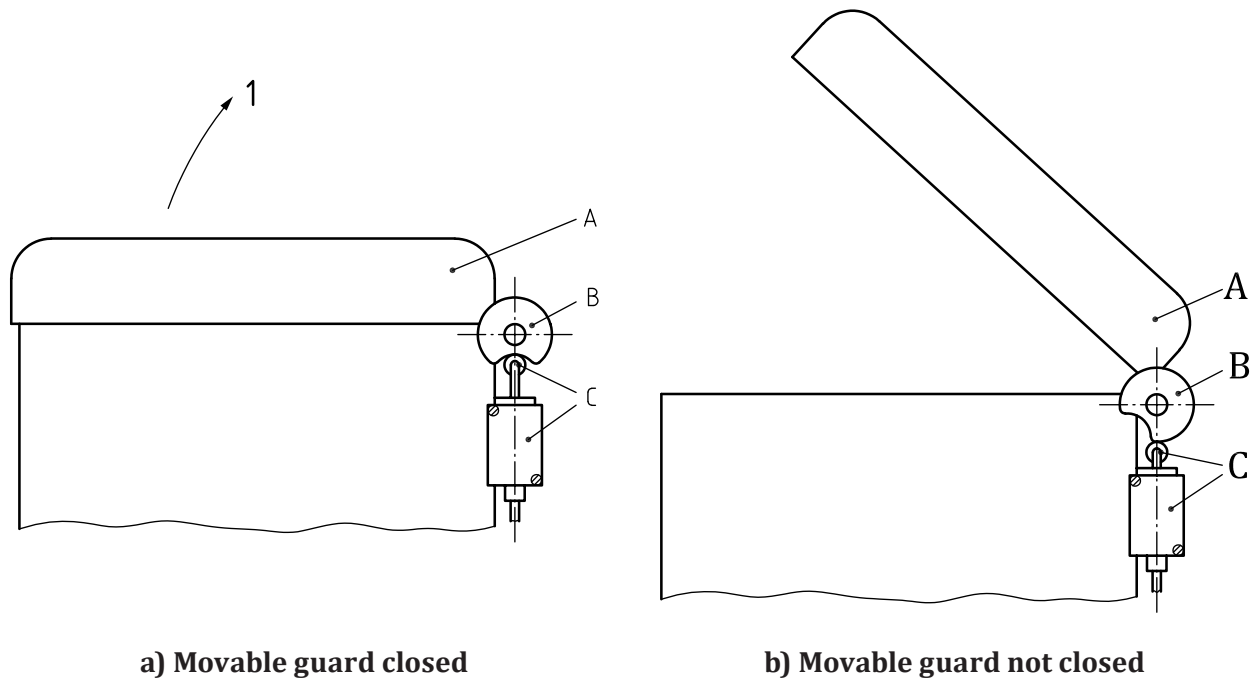
Annex A (informative)

Type 1 interlocking device — Examples

A.1 Rotary cam

A.1.1 Description

One single Type 1 interlocking device, with position switch actuated in direct mechanical action, monitors the position of the movable guard (see 5.4 and Figure A.1).



Key

A	movable guard	C	position switch
B	actuator (cam)	1	opening direction

Figure A.1 — Type 1 interlocking device with rotary cam actuated position switch

A.1.2 Typical characteristics

- direct mechanical action of the actuator (rotary cam) (B) on the actuation system of the position switch (C);
- possibility for direct opening action of the NC contact of the position switch due to direct mechanical action (see 3.11);
- impossible to defeat by manually operating the actuation system without removing rotary cam or position switch;

- Fails to danger in case of
 - failure of the mechanical link between guard and position switch (wear or breaking of the actuator),
 - misalignment between the position switch and the cam.

A.1.3 Remarks

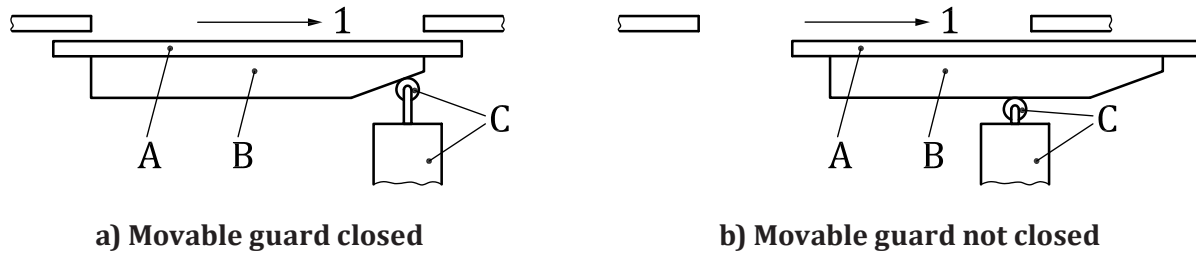
- As the absence of the movable guard is not detected, it is essential that the guard cannot be dismantled without tools;
- see also
 - 5.2,
 - 5.3.

NOTE For fault exclusion see 8.5.

A.2 Linear cam

A.2.1 Description

One single Type 1 interlocking device, with position switch actuated in direct mechanical action, monitors the position of the movable guard (see 5.4 and Figure A.2).



Key

- | | | | |
|---|----------------|---|-------------------|
| A | movable guard | C | position switch |
| B | actuator (cam) | 1 | opening direction |

Figure A.2 — Type 1 interlocking device with linear cam actuated position switch

A.2.2 Typical characteristics

- direct mechanical action of the actuator (linear cam) (B) on the actuation system of the position switch (C);
- possibility for direct opening action of the NC contact of the position switch due to direct mechanical action (see 3.11);
- impossible to defeat by manually operating the actuation system without removing linear cam or position switch;

Fails to danger in case of

- failure of the mechanical link between guard and position switch (wear or breaking of the actuator),
- misalignment between the position switch and the cam.

A.2.3 Remarks

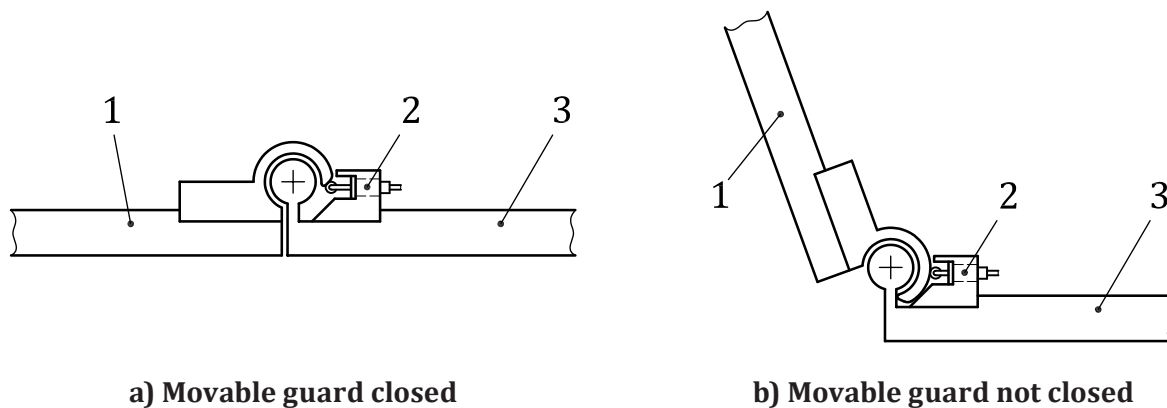
- As the absence of the movable guard and/or actuator is not detected, it is essential that the guard and/or actuator cannot be dismantled without tools;
- see also
 - [5.2](#),
 - [5.3](#).

NOTE For fault exclusion see [8.5](#).

A.3 Hinge

A.3.1 Description

One position switch mounted internally in a hinge (see [Figure A.3](#)).



Key

- | | |
|------------------------------|-----------------------|
| 1 movable guard | 3 fixed part of guard |
| 2 hinged interlocking device | |

Figure A.3 — Hinged interlocking device

A.3.2 Typical characteristics

- direct mechanical action of built-in position switch;
- impossible to defeat without dismounting;
- works as hinge for a movable part of a guard;
- adjustment of switching point has to be accurate and therefore may be unsuitable for wide movable guards;
- only usable for hinged movable guards.

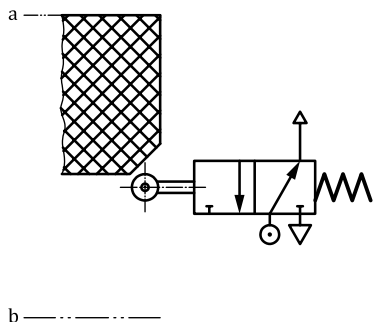
A.3.3 Remarks

As the absence of the movable guard is not detected it is essentially that the movable guard cannot be dismantled without tools.

A.4 Pneumatic/hydraulic interlocking devices

A.4.1 Examples

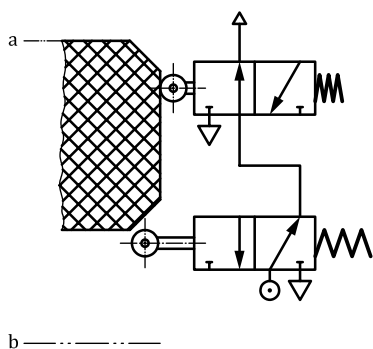
Examples of pneumatic/hydraulic interlocking devices are shown in [Figures A.4](#) to [A.6](#).



Key

- a Closed.
- b Not closed.

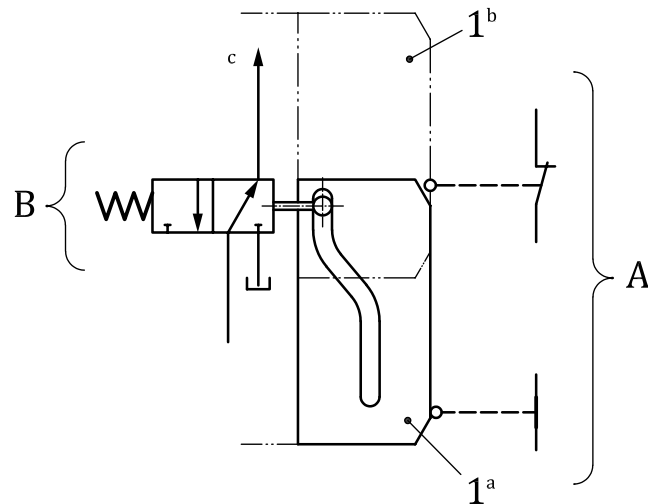
Figure A.4 — Single valve (output system) with direct-mechanical action of single valve by movable guard



Key

- a Closed.
- b Not closed.

Figure A.5 — Two valves (output system)

**Key**

- | | | | |
|---|---|---|--|
| 1 | movable guard | b | Movable guard not closed. |
| a | Movable guard closed. | c | To machine actuators. |
| A | independent interlocking device that acts on electrical control circuit (with automatic monitoring) | B | independent interlocking device that acts on hydraulic circuit (power interlocking, see 8.7.2) when direct interruption of power circuit possible |

Figure A.6 — Hybrid (electrical and hydraulic) interlocking device

A.4.2 Remarks

A hybrid interlocking device is particularly interesting in very severe environmental conditions which can induce “common cause failures” (i.e. simultaneous failures having the same cause) of components with the same technology, e.g. melting of the insulating layer of conductors on a machine working under hot conditions, or simultaneous failure of two proximity detectors under the effect of electric or electromagnetic interference.

Annex B (informative)

Type 2 interlocking device — Examples

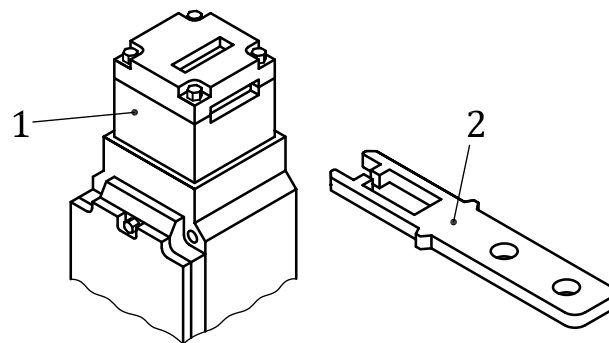
B.1 Tongue-actuated position switch

B.1.1 Description

A single Type 2 interlocking device, with position switch actuated by direct mechanical action, monitors the position of the movable guard (see [Figures B.1](#) and [B.2](#)).

B.1.2 Typical characteristics

- easy principle for integrated guard locking devices;
- especially suitable for use on the opening edge of a movable guard.
- direct mechanical action on the actuator of the position switch;
- possibility for direct opening action of the NC contact of the position switch due to direct mechanical action (see [3.11](#));
- due to low level coding additional measures against defeating can be required;
- can be damaged due to misalignment during the machine life cycle;
- can be degraded by pollution;
- impact from actuator can cause harm to persons.

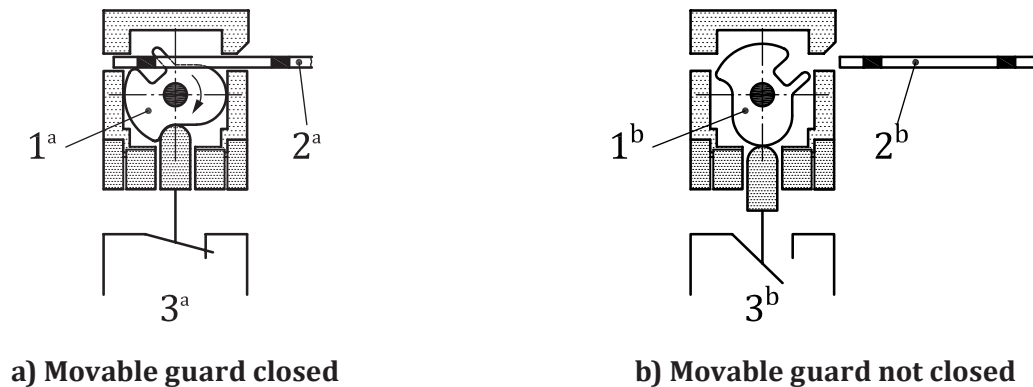


Key

1 position switch

2 actuator (shaped tongue)

Figure B.1 — Position switch with coded tongue actuator

**Key**

1 ^a	Internal rotating cam position when movable guard closed.	1 ^b	Internal rotating cam position when movable guard not closed.
2 ^a	Tongue inserted.	2 ^b	Tongue not inserted.
3 ^a	Switching element closed.	3 ^b	Switching element not closed.

Figure B.2 — Working principle of the tongue-actuated position switch

B.1.3 Remarks

For measures to minimize defeating, see [Clause 7](#).

B.2 Trapped key**B.2.1 Description**

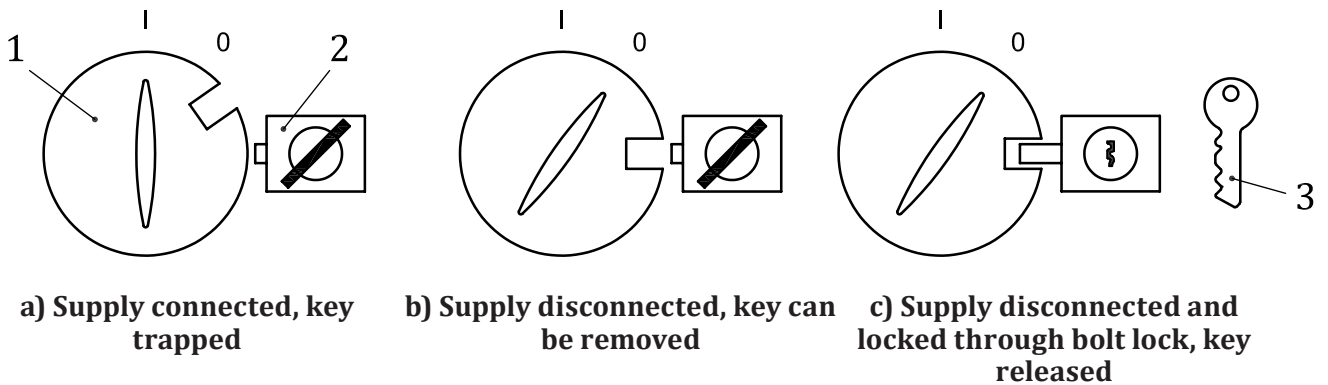
A trapped-key interlocking device is an interlocking device relying upon the transfer of keys between a control element and a lock fixed on the guard (guard lock) (see [Figure B.4](#)).

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.

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 (see [Figure B.3](#) and [B.5](#)).

If there is more than one source of power, and therefore more than one element in the output system 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 key coding, can be released for transfer to the guard lock. Where there is more than one guard, the exchange box can accommodate an equivalent number of access keys (see [Figure B.6](#)).

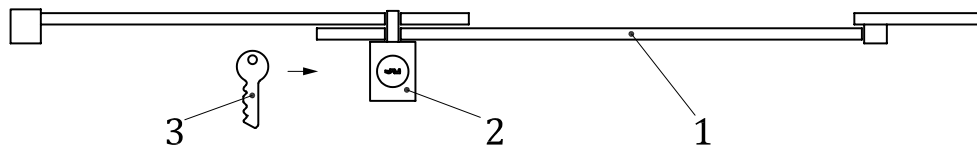
Where, for the purpose of the process or of safety, a number of operations have to be carried out in a definite sequence, then the transferable key is locked in and exchanged for a different one at each stage. The exchange box can be integral with the lock.



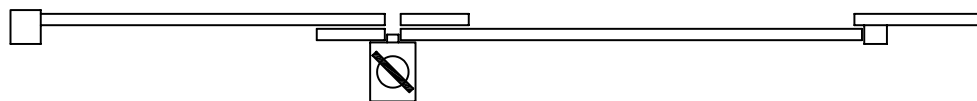
Key

- 1 switch
- 2 bolt lock
- 3 actuator (key)

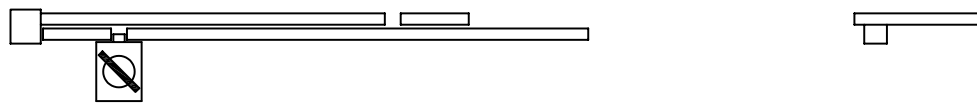
Figure B.3 — Trapped key interlocking principle — Step 1



a) Movable guard closed and locked



b) Movable guard closed, not locked, actuator key inserted, turned and trapped

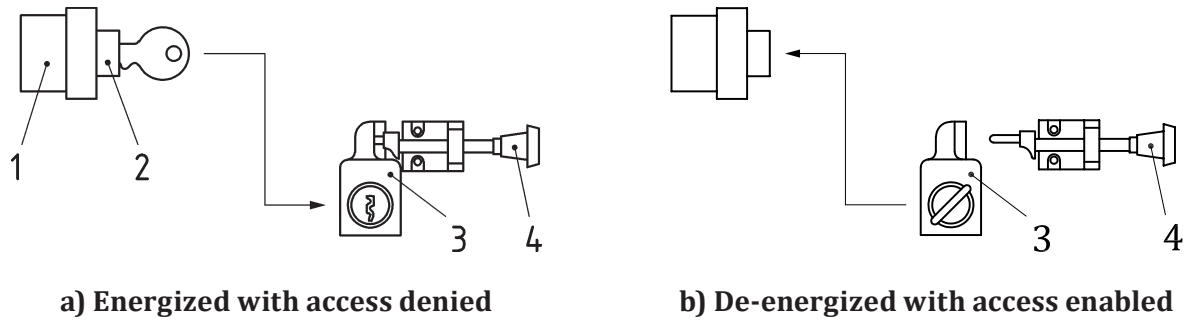


c) Movable guard not closed, bolt cannot be extended, therefore actuator key trapped

Key

- 1 movable guard
- 2 bolt lock
- 3 actuator (key)

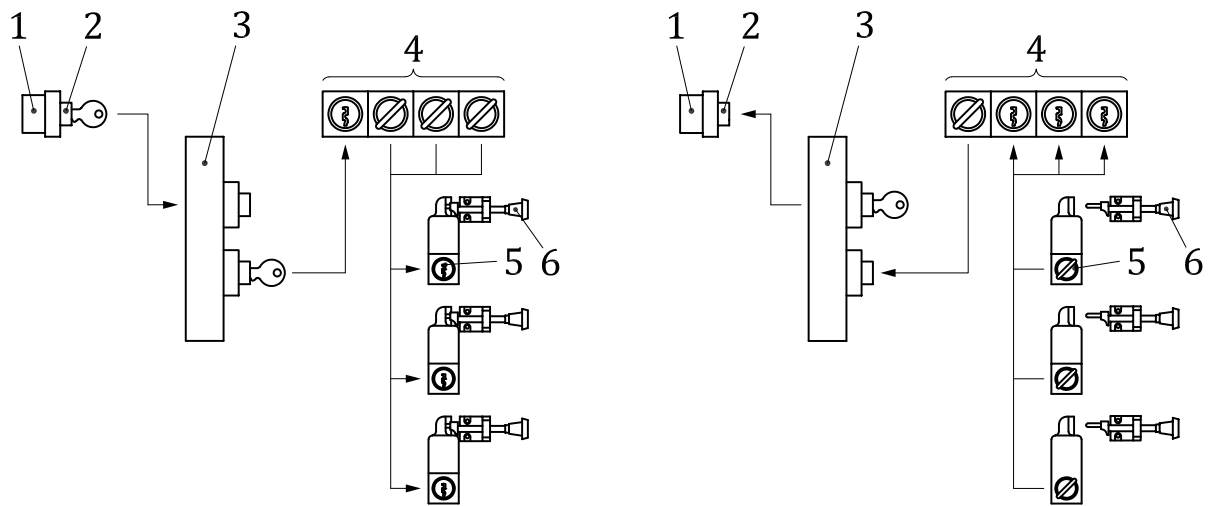
Figure B.4 — Trapped key interlocking principle using extending bolt — Step 2



Key

- | | | | |
|---|-----------------------|---|--|
| 1 | output system | 3 | lock on guard(s) |
| 2 | lock on output system | 4 | locking bolt/catch attached to movable guard |

Figure B.5 — Simple basic system



a) Time delay, exchange box and multiple entry — Energized with access denied **b) Time delay, exchange box and multiple entry — De-energized with access enabled**

Key

- | | | | |
|---|-----------------------|---|--|
| 1 | output system | 4 | key exchange box |
| 2 | lock on output system | 5 | lock(s) on guard(s) |
| 3 | time-delay device | 6 | locking bolt/catch attached to movable guard |

Figure B.6 — Complex system

B.2.2 Typical characteristics

- no reduction of integrity due to the distance between movable guard and control system;
- no need for electrical wiring to each movable guard;
- can be suitable when the movable guard is placed in hostile environment;
- can be used when the movable guard can be removed completely;

- particularly suitable when several different types of power source are present on the machine and for power interlocking;
- not suitable for applications requiring very fast access times;
- duplicate keys can become available for defeating (see [Clause 7](#));
- impact from locking bolt/catch can cause harm to persons;
- old style keys can be easy to defeat.

B.2.3 Remarks

Delay between opening of the output system and unlocking of the guard is ensured merely by key-transfer time (increased, if necessary, by a time-delay device).

Individual coding of key-access systems

Individual key coding prevents two or more interlocks unintentionally sharing the same key coding and resulting in a hazard. e.g. A factory has two machines A and B: The key that shuts down and allows safe access into machine A cannot be used to access or control machine B.

Individual key coding can be maintained per factory/site or organization, either by individual site management, or by using manufacturers of interlocks that offer a unique key coding. Keys and actuators should be unambiguously and clearly marked to avoid confusion.

NOTE *Individual coding* is where the same coding is not common to all devices. It can be achieved by medium or high level coding, see [Table 3](#).

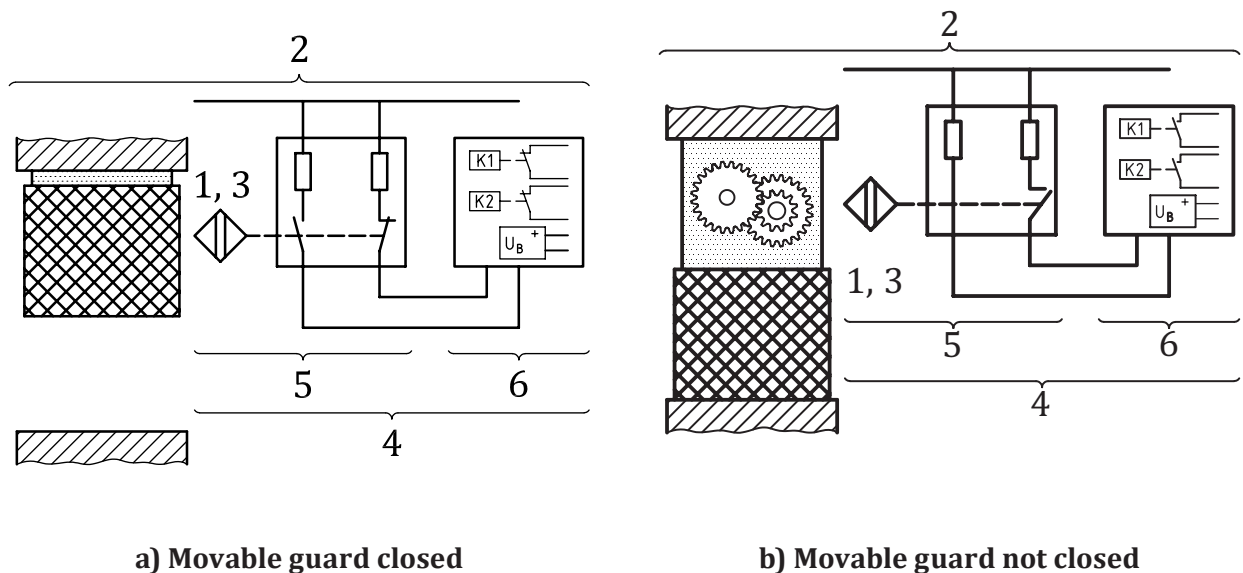
Annex C (informative)

Type 3 interlocking device — Example

C.1 Description

A Type 3 interlocking device consisting of one or more non-mechanically actuated position switch(es) (inductive, magnetic, capacitive, ultrasonic or optic proximity switch) actuated by an uncoded actuator linked to a movable guard (see [Figure C.1](#)).

To fulfil requirements for safety integrity in most cases two single position switches with monitoring will be required unless the single position switch is designed to meet the requirements of IEC 60947-5-3 (see also [5.4](#)).



Key

- | | | | |
|---|---------------------|---|------------------|
| 1 | movable guard | 4 | proximity switch |
| 2 | interlocking device | 5 | actuating system |
| 3 | actuator | 6 | output system |

Figure C.1 — Type 3 interlocking device with proximity switch actuated by uncoded actuator

C.2 Typical characteristics

- no moving parts;
- high resistance to dust, liquids;
- easily kept clean;
- due to the lack of coding additional measures against defeating are required;

— limited application possibilities.

C.3 Remarks

For measures to minimize defeating, see Clause 7.

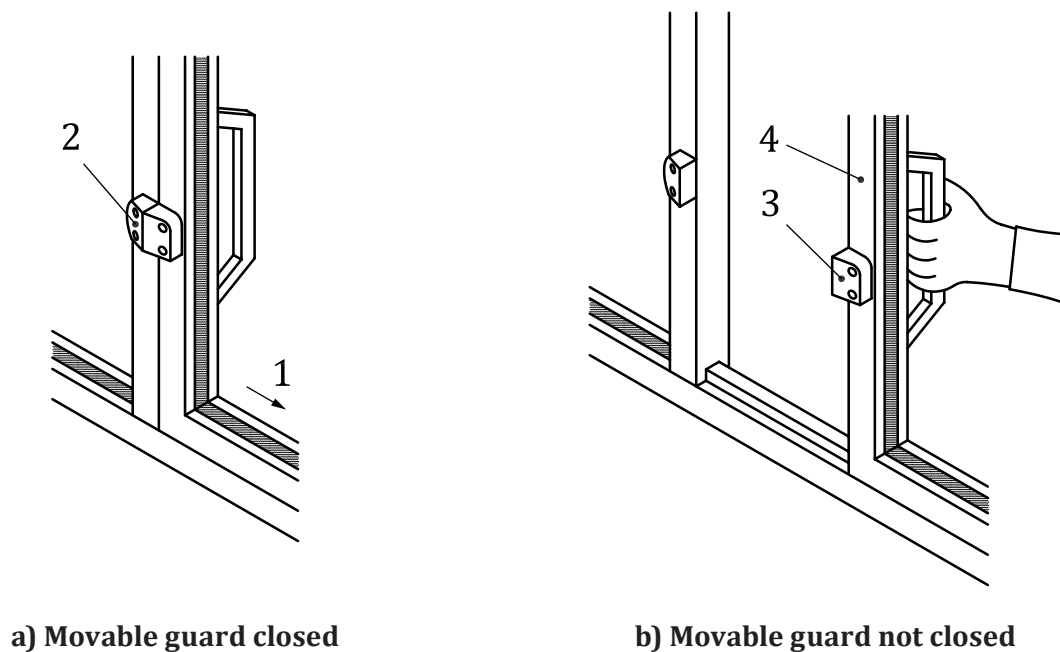
Annex D (informative)

Type 4 interlocking devices — Examples

D.1 Coded magnetic operated interlocking device

D.1.1 Description

A Type 4 interlocking device with a position switch actuated by coded magnetic actuator associated with the movable guard opens its contacts when the guard is not closed (See [Figure D.1](#)).



Key

- | | | | |
|---|----------------------------|---|-----------------------|
| 1 | opening direction | 3 | coded magnet actuator |
| 2 | Type 4 interlocking device | 4 | movable guard |

Figure D.1 — Example of Type 4 interlocking device with position switch actuated by coded magnetic actuator

D.1.2 Typical characteristics

- compact, no external moving parts;
- high resistance to dust, liquids;
- easily kept clean;
- coded;
- tolerance to guard misalignment;

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- sensitive to electromagnetic interference;
- if reed contacts are used, they are susceptible to vibrations and shocks and transient electrical effects;
- medium or high level coding not available.

D.1.3 Remarks

For measures to minimize defeating see Clause 7.

D.2 Coded RFID-operated interlocking device

D.2.1 Description

A Type 4 interlocking device with a position switch actuated by coded RFID tag actuator associated with the movable guard opens its contacts when the guard is not closed (see [Figure D.2](#)).

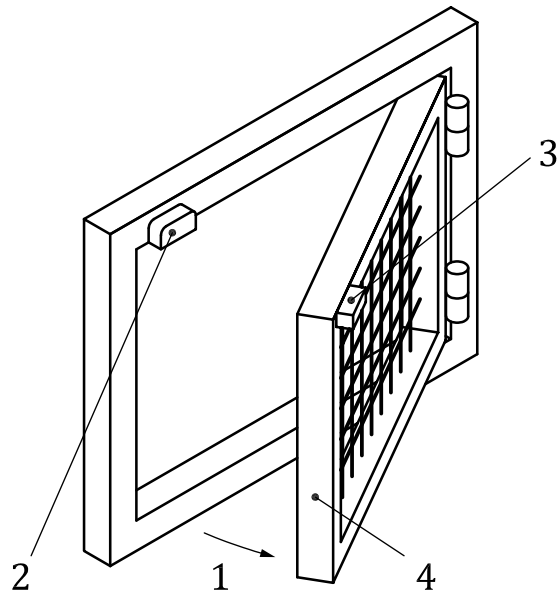
D.2.2 Typical characteristics

- compact, no external moving parts;
- high resistance to dust, liquids;
- easily kept clean;
- medium and high level coding possible;
- tolerance to guard misalignment;
- possible sensitivity to electromagnetic interference.

D.2.3 Remarks

For measures to minimize defeating, see [Clause 7](#).

.....



Key

- | | | | |
|---|----------------------------|---|-------------------------|
| 1 | opening direction | 3 | coded RFID tag actuator |
| 2 | Type 4 interlocking device | 4 | movable guard |

Figure D.2 — Example of Type 4 interlocking device with position switch actuated by coded RFID tag actuator

Annex E (informative)

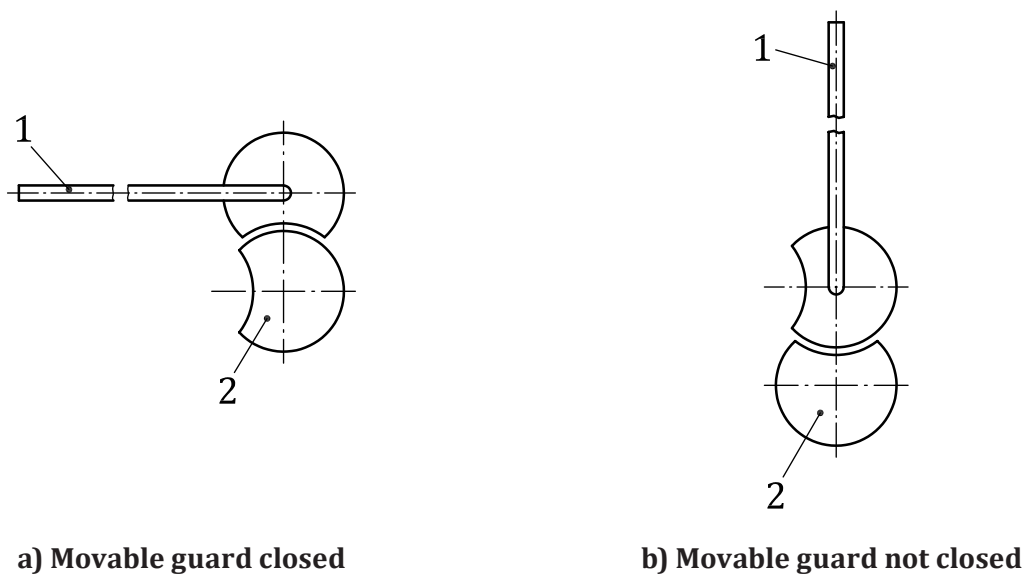
Examples of other interlocking devices

E.1 Mechanical interlocking between a movable guard and movable element

E.1.1 Description

Direct mechanical interlocking between a movable guard and a hazardous movable element (see [Figure E.1](#)).

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



Key

<p>1 movable guard</p> <p>2 movable element — free: as long as movable element not at rest, movable guard locked in closed position</p>	<p>1 movable guard</p> <p>2 movable element — blocked: as soon as movable guard no longer in closed position, movable element blocked</p>
---	---

Figure E.1 — Example for mechanical interlocking between movable guard and movable element

E.1.2 Remarks

- The application is limited to very simple mechanisms.
- Manual positioning of the movable part can be required to make it possible to open the movable guard. This should be possible without reaching the hazardous area.

Annex F (informative)

Example of guard locking devices

F.1 Example of interlocking device with separate detection of guard position and position of the locking means

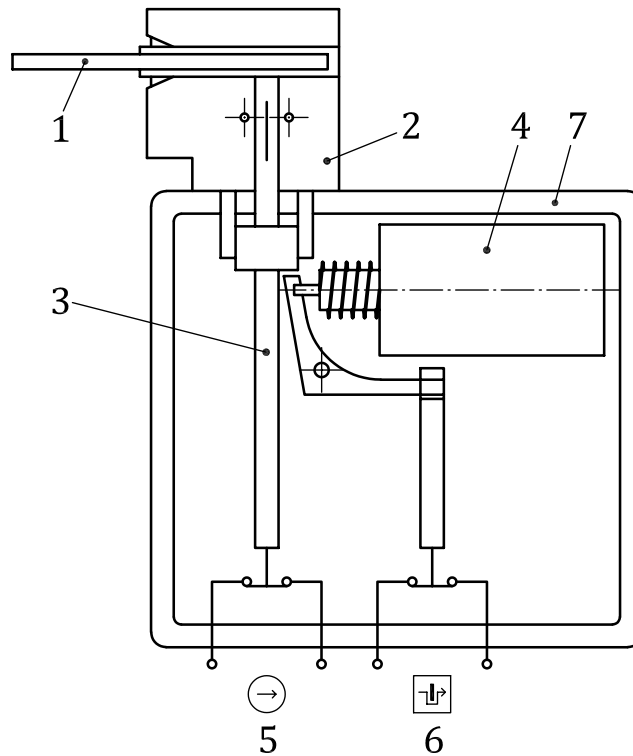
F.1.1 Description

[Figure F.1](#) shows a Type 2 interlocking device with integrated guard locking and guard locking monitoring. The actuator is shown in the closed position of the movable guard which is linked to the actuator. The guard locking solenoid is in the locking position held by the spring. If the solenoid is powered the plunger of the solenoid is moved to the right thus compressing the spring. The door monitoring contact is opened via the lever linked to the solenoid plunger. Now the interlocking plunger can be moved downwards by an opening movement of the guard and the attached actuator. In the not closed position of the guard the wide part of the interlocking plunger prevents the locking mechanism moving into the locking position (inadvertent locking prevention mechanism). By linking the interlocking plunger to a contact both interlocking and guard locking position can be monitored within one device.

F.1.2 Typical characteristic

Separate indication of the movable guard status is provided.

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Key

1	actuator	5	interlocking monitoring contact
2	actuating head	6	guard locking monitoring contact
3	interlocking plunger	7	housing
4	guard locking solenoid		

Figure F.1 — Interlocking device with spring applied/power released guard locking device

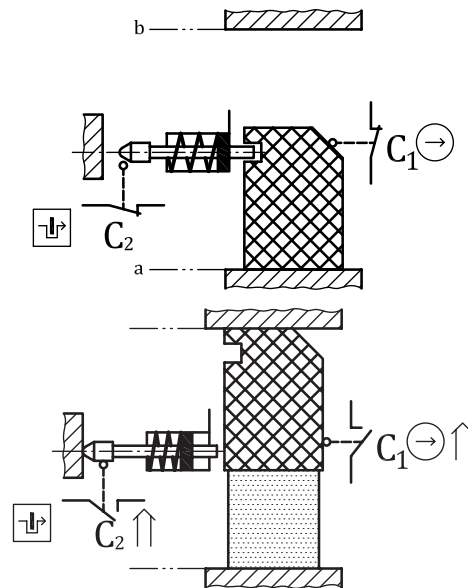
F.2 Interlocking function ensured by detecting separately guard position and position of the guard locking device

F.2.1 Description

C₁ detects the position of the movable guard. C₂ detects the position of the locking device (see [Figure F.2](#)).

F.2.2 Typical characteristic

Separate indication of the movable guard status is provided.



Key

- C₁ detects the position of the movable guard
 - C₂ detects position of locking device
- a Closed.
b Not closed.

NOTE C₁ and C₂ can be detectors of any technological type (see 4.1).

Figure F.2 — Separate detection of positions of movable guard and guard locking device

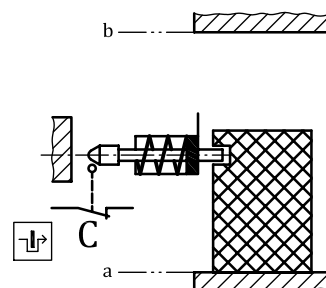
F.3 Interlocking function ensured by detecting lock position only by detecting the position of the locking device

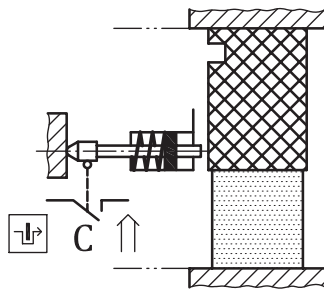
F.3.1 Description

By detecting the position of the locking device, the single detector (C) can also be used to monitor the position of the movable guard, provided that the closed position of the guard is rigorously and reliably detected due to good design and construction of the guard-locking-device-contact and movable guard assembly (see Figure F.3).

F.3.2 Typical characteristic

No separate indication of the movable guard status is provided.





Key

- | | | | |
|---|------------------------------------|---|-------------|
| C | detects position of locking device | a | Closed. |
| | | b | Not closed. |

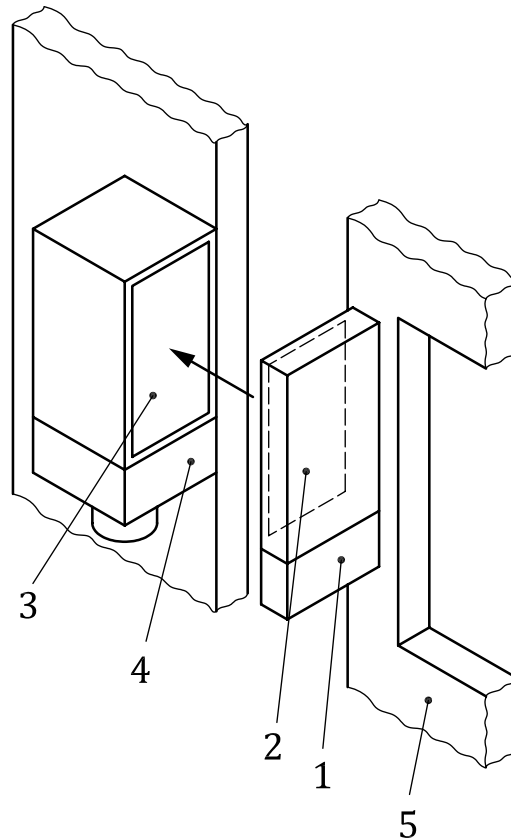
NOTE C can be a detector of any technological type (see 4.1).

Figure F.3 — Combined detection of positions of movable guard and locking device

F.4 Interlocking device with electromagnetic guard locking device

F.4.1 Description

The guard locking of the closed movable guard is done electromagnetically (electromagnetic principle of action, see [Figure F.4](#)). The interlocking function is provided by detection of the guard position. The locking function includes monitoring of the electromagnetic force. Forced opening will result in a reaction function e.g. 10 min delay until a reset is possible (see [5.7.3.3](#)).

**Key**

1	coded actuator	4	non-contact actuated position switch
2	magnetic keeper plate	5	movable guard
3	guard locking electromagnet		

Figure F.4 — Interlocking device with electromagnetic guard locking device

F.4.2 Typical characteristics

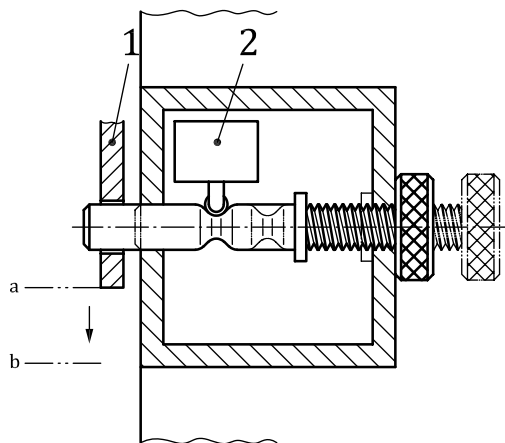
- easy to clean due to sealing;
- high resistance against dusts and fluids;
- compact, no moving parts;
- unlocking in case of power failure, depending on the design;
- very high holding force not available.

F.5 Interlocking device with guard locking, with manually operated delay device

F.5.1 Description

The threaded pin is turned by hand (unconditional unlocking, according to [Figure 4](#), see [Figure F.5](#)). The time elapsing between the switch opening and guard release is determined so that it is longer than the time taken to stop the hazardous functions.

When not closed, the movable guard prevents the pin being screwed in again, thus closing the switch contacts.



Key

- | | | | |
|---|-----------------|---|-------------|
| 1 | movable guard | a | Closed. |
| 2 | position switch | b | Not closed. |

Figure F.5 — Interlocking device with guard locking, with manually operated delay device

F.5.2 Typical characteristics

- reliability through simplicity;
- can be unlocked fast with additional means e.g. by power driven screw drivers.

F.5.3 Remarks

Only appropriate for applications with low frequency operations.

Annex G (informative)

Application examples of interlocking devices used within a safety function

G.1 General

The descriptions in this annex are limited to the appropriate categories according to ISO 13849-1 with regard to the hardware fault tolerance (architecture). To achieve the required safety related performance additional requirements (e.g. diagnostic coverage) will need to be considered.

G.2 Example 1 — Category 1

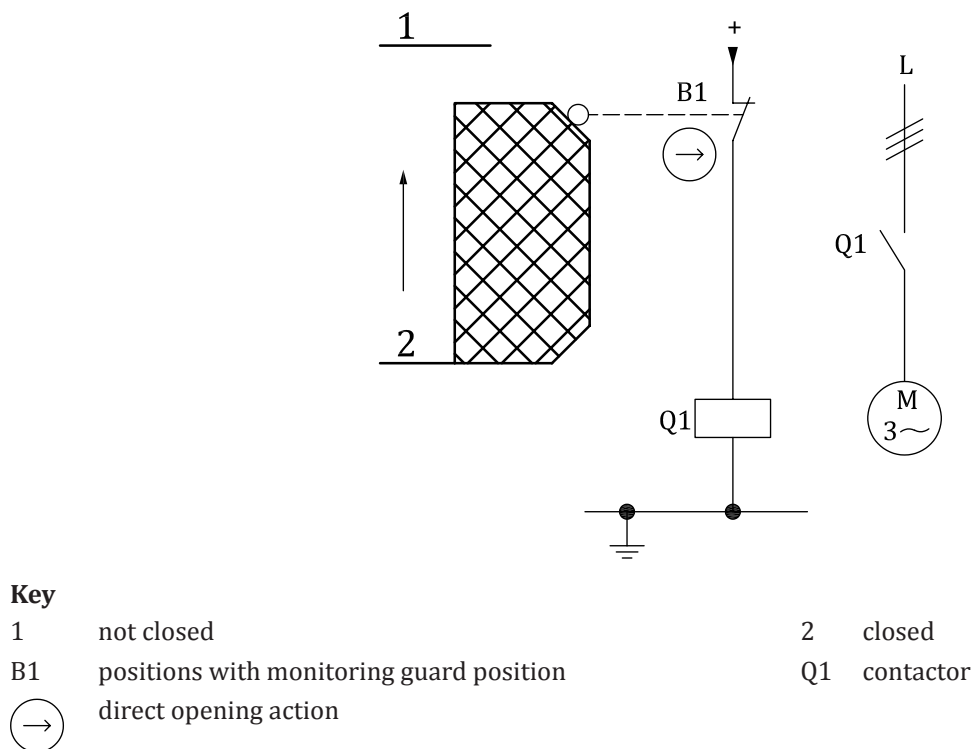


Figure G.1 — Position monitoring of movable guards for the prevention of hazardous movements

G.2.1 Safety function

- Safety-related stop function, initiated by a protective device: opening of the movable guard initiates the safety function STO – safe torque off according to IEC 61800-5-2 or stop category 0 according to IEC 60204-1.

G.2.2 Functional description

- Opening of the movable guard is detected by a position switch B1 with direct opening action. B1 de-energizes a contactor Q1 which stops the hazardous movement (see [Figure G.1](#)).

- The safety function can be lost at the occurrence of single faults and is dependent upon the reliability of the components.
- No measures for fault detection are implemented.
- Removal of the protective device is not detected.

G.2.3 Design features

To achieve Category 1 the following requirements are fulfilled:

- Basic and well-tries safety principles are implemented and the requirements of Category B are met. Protective circuits (e.g. contact protection) are implemented. The de-energization principle is used as a basic safety principle. Earthing of the control circuit is regarded as a well-tries safety principle.
- Position switch B1 has direct opening action in accordance with ISO 13849-2:2012, Table D.2 and is regarded as a well-tries component. The break contact interrupts the circuit with direct mechanical action when the movable guard is not closed.
- Contactor Q1 is a well-tries component provided that the additional conditions in accordance with ISO 13849-2:2012, Table D.3 are observed.
- The movable guard has a stable arrangement for actuation of the position switch B1. The actuating elements of the position switch B1 are protected against displacement. Only mechanical parts (no spring elements) having sufficient rigidity are employed.
- The actuating stroke for the position switch complies with the manufacturer's specification.

NOTE A detailed description including the estimation of the probability of dangerous failure per hour is available in section 8.2.5 of Reference [16].

G.3 Example 2 — Category 3

G.3.1 Safety functions

- No unlocking of the movable guard as long as the drive motor speed is greater than zero;
- Prevention of unexpected start up while the movable guard is unlocked or not closed.

G.3.2 Functional description

- Access to the hazardous movement is prevented by a movable guard which is closed and locked while the motor is powered or coasting to a standstill (see [Figure G.2](#)). The movable guard is unlocked and can be opened when the locking element (bolt) is withdrawn by energising the unlocking solenoid. The unlocking solenoid can only be energized when the motor is at a standstill. This is achieved by the standstill monitor K4.

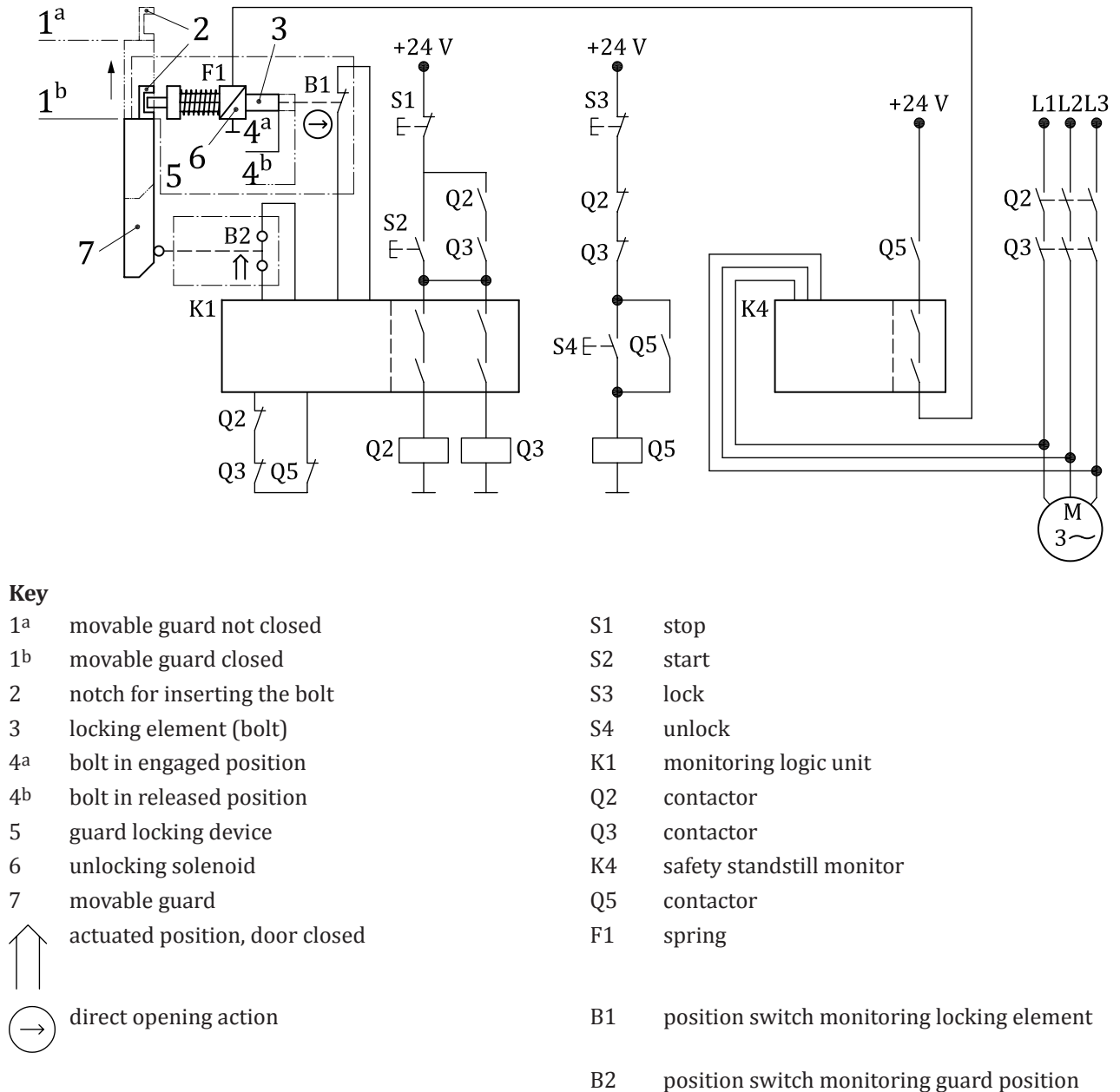


Figure G.2 — Guard locking device with safety relay and standstill monitor — Category 3

- Starting the motor by pressing the start button S2 is only possible when the movable guard is closed (B2 is closed) and locked (B1 is closed); Q2, Q3 and Q5 are de-energized, so the feedback loop of K1 is closed. When S2 is momentarily closed, Q2 and Q3 are energized and remain latched. Power supply to the motor is turned on.
- By pressing the stop button S1, Q2 and Q3 are de-energized and the motor stops.
- Opening of the movable guard during movement of the motor is prevented by a locking element (bolt). Opening is only possible if the bolt is released. The following procedure is required to release the bolt:
 - push stop switch S1; Q2 and Q3 are de-energized and their contacts change state;
 - push unlock switch S4 to request unlocking (Q5 becomes energized and latched);
 - when the motor stops, the output of standstill monitor K4 closes;

- the unlocking solenoid is energized, the locking element (bolt) moves to the unlocked position.

The unlocking request is cancelled by pushing the lock switch S3; Q5 de-energizes.

- When the movable guard is closed, the spring applied locking element (bolt) engages in the intended notch. The movable guard becomes locked and B1 and B2 are closed.
- The outputs of K1 open if one of the input circuits, B1 (monitoring locking element) or B2 (monitoring guard) is open.

G.3.3 Design features

To achieve Category 3 the following requirements are fulfilled:

- Basic and well-tried safety principles are observed and the requirements of Category B are met. Protective circuits (e.g. contact protection) are implemented.
- Faults in the wiring are considered (ISO 13849-2:2012, Table D.4). Short circuits are detected and a safe condition is initiated or the cables are routed so that fault exclusions are possible.
- The contactor relays Q2, Q3 and Q5 have mechanically linked contact elements in accordance with IEC 60947-5-1:2003, Annex L.
- To fulfil the single fault safety needed for a Category 3 system, the position switch B2 is a separate position switch (mechanically independent from actuation of B1).
- The position switch B1 has direct opening action in accordance with IEC 60947-5-1:2003, Annex K, therefore fault exclusion for non opening due to welding of the contact is permitted.
- The guard locking device with the spring applied locking element (bolt), the unlocking solenoid and the locking element monitoring position switch B1 are contained in one single enclosure. The notch for inserting the bolt is part of the movable guard.
- The spring of the guard locking device is a well-tried spring according to ISO 13849-2:2012, Table A.3. In addition, the spring is permanently fail-safe to EN 13906-1 (fault exclusion for “breaking of the spring”). The unlocking solenoid does not energize without electrical input.
- Fault exclusion for “breakage of the locking element (bolt)” due to
 - proper selection of the devices ensuring that the holding force (F_{Zh}) of the guard locking device is sufficient to withstand static forces on the locking bolt and
 - dynamic forces on the locking bolt due to rebound or bouncing of the movable guard are prevented. The design of the control system ensures that the spring applied locking element (bolt) does not move into the locked position, before the movable guard is closed and stationary, e.g. by time delay between closing the door and de-energising the solenoid (not shown in [Figure G.2](#))

The use of fault exclusion for breakage of the locking bolt does not necessarily limit the PL or SIL for the safety function.

- Due to the design arrangement, the locking element (bolt) cannot reach the locked position (guard locking position) when the movable guard is not closed (prevention of inadvertent locking position).
- K1 is a monitoring logic unit that meets at least the requirements of Category 3 in accordance with ISO 13849-1. The input circuits are monitored for shorts to earth and supply voltage. The safe state is initiated at detection of a fault. The safety relevant output can be activated only when the input circuits and the feedback loop are closed. Errors such as contact welding of Q2, Q3 or Q5 are detected by the feedback circuit of K1.
- The standstill monitor K4 meets at least the requirements of Category 3 in accordance with ISO 13849-1. It monitors the input circuits for short circuits across contacts, open wires to the motor and short circuits to the supply voltage. The safe state is initiated at detection of a fault.

- The switches B1 and B2 are also tested by the process, because the safety relevant outputs of K1 are only switched on again when B1 and B2 have been operated. This is done by opening and closing the guard.

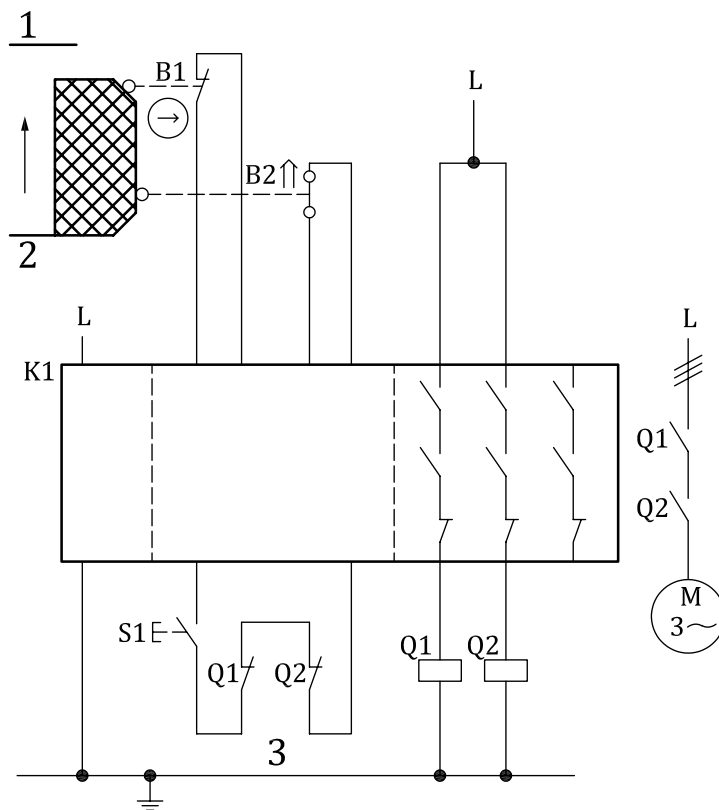
G.4 Example 3 — Category 4

G.4.1 Safety function

- Safety-related stop function, initiated by a protective device: opening of the movable guard initiates the safety function (STO, safe torque off, according to IEC 61800-5-2 or stop category 0 according to IEC 60204-1).

G.4.2 Functional description

- Hazardous movement is safeguarded by a movable guard (see [Figure G.3](#)). Opening of the movable guard is detected by two position switches B1/B2, using a NC/NO contact combination, and evaluated by a monitoring logic unit K1. K1 de-energizes two contactors, Q1 and Q2, which stop the hazardous movement.



Key

- | | | | |
|----|---|-----|-----------------------|
| 1 | not closed | S1E | start (reset) |
| 2 | closed | Q1 | contactor |
| 3 | feedback circuit | Q2 | contactor |
| B1 | position switch monitoring guard position | K1 | monitoring logic unit |
| B2 | position switch monitoring guard position | | |
| ↑ | shown in actuated position | ⊖ | direct opening action |

Figure G.3 — Position monitoring of movable guards by means of a safety module

- The position switches are monitored for plausibility in K1 for the purpose of fault detection. Faults in Q1 and Q2 are detected by external device monitoring by K1. A start command is successful only if the main contacts at Q1 and Q2 had previously opened.
- The safety function remains intact in the event of a component fault. Faults are detected during operation or at actuation (opening and closing) of the movable guard resulting in de-energization of Q1 and Q2. Energization of Q1 and Q2 is prevented until fault has been corrected.

G.4.3 Design features

To achieve Category 4 the following requirements are fulfilled:

- Basic and well-tried safety principles are observed and the requirements of Category B are met.
- A stable arrangement of the protective devices is assured for actuation of the position switches.
- Switch B1 is a position switch with direct opening action in accordance with IEC 60947-5-1:2003, Annex K.
- The supply conductors to position switches B1 and B2 are laid separately or with protection.
- The monitoring logic unit K1 satisfies all requirements for Category 4.
- The contactors Q1 and Q2 possess mechanically linked contact elements according to IEC 60947-5-1:2003, Annex L.

NOTE 1 Category 4 is observed only if several mechanical position switches for different protective devices are not connected in a series arrangement (i. e. no cascading), since faults in the switches cannot otherwise be detected.

NOTE 2 A detailed description, including the estimation of the probability of dangerous failure per hour, is available in section 8.2.34 of Reference[15].

Annex H (informative)

Motivation to defeat interlocking device

The defeating of interlocking devices can increase significantly the risk of harm and so far as practicable protective measures shall be taken to minimize the effect of such foreseeable misuse.

NOTE 1 This annex is an example for automatic machine tools. When the principles and tables presented in this annex are used for other types of machines it is recommended that the table is modified to suit the specific characteristics of the machines and the production.

The motivation for defeating interlocking devices of guards comprises several aspects, one of which is how hindering the safeguards are when a certain machining task has to be performed, another aspect is that the operator may need to monitor and fine tune the machining closely in order to avoid scrap of workpieces.

The following method supports the machine designer in identifying possible incentives for defeating the interlocking devices. Use of this method requires that all intended modes of operation and protective devices must be considered. Each individual protective device is regarded separately, and for each relevant task, a person familiar with operating the machine is asked the following question:

“What would be the benefits of defeating the protective device for work on the machine?”

[Table H.1](#) supports the execution of the procedure. The most common operator tasks are listed versus the respective benefits, when defeating the interlocking devices. The table offers some basic entries, but additional entries can be supplement, if necessary.

To follow the procedure, these four steps are performed:

- a) All modes of operation provided with the machine have to be identified, e.g. mode 1 = automatic, mode 2 = manual etc.
- b) All individual tasks applied on the machine should be collected in the table rows and marked with an “x” at the column for the corresponding mode of operation.
- c) The next two columns have to be marked with “Yes” or “No”, whether the intended task is permissible in that mode and whether it is possible in that mode without defeating. One “No” in these two columns identifies an unsafe machine. Improvement of the machine design is mandatory.
- d) Several further columns are filled with potential benefits of *working without protective devices* such as “Higher precision”. These should be checked and marked with “0” (none), “+” (minor) and “++” (substantial). The entries “++” and “+” identify operating conditions where safeguards hinder the working process. The designer should check whether improved practice-orientated safeguards are possible.

NOTE 2 Practice-oriented modes of operation are an important means of making defeating of the interlocking device unnecessary or unattractive. Restricted operating conditions (e.g. reduced speed, hold to run control in combination with an enabling device, restricted functionality) provide both, reduced residual risk and a kind of “switchback motivation” to automatic mode (lowest residual risk).

[Table H.2](#) gives an example of applying [Table H.1](#).

If the defeating incentive cannot be eliminated completely by modified or additional modes of operation, then the designer has only one element left. This is to make the defeating of interlocking devices more difficult or even impossible.

Table H.1 — Evaluation of motivation to defeat interlocking devices

Task	Mode 1 ^a	Mode 2 ^a	Mode 3 ^a	Mode 4 ^a	Mode 5 ^a	Task permissible in these modes of operation?	Task possible without defeating?	Easier/more convenient ^b	Faster, increased productivity ^b	Flexibility, e.g. for larger workpieces ^b	Higher precision ^b	Better visibility ^b	Better audibility ^b	Less physical effort ^b	Reduced travel ^b	Greater freedom of movement ^b	Improved flow of movement ^b	Avoidance of interruption ^b	...
Initial operation																			
Program test/Test run																			
Setup/adjustment conversion/tooling/																			
Machining																			
Manual intervention for swarf removal																			
Manual change of workpiece																			
Manual intervention for trouble shooting																			
Checking/random sampling																			
Manual intervention for measuring/fine tuning																			
<p>^a Modes of operation.</p> <p>Op. Mode 1:</p> <p>Op. Mode 2:</p> <p>Op. Mode 3:</p> <p>Op. Mode 4:</p> <p>Op. Mode 5:</p> <p>Modes of operation include automatic mode and manual mode, as in the example presented in Table H.2.</p> <p>^b Benefits without protective device: 0 = None; + = Minor; ++ = Substantial.</p> <p>See Reference [15].</p>																			

Table H.1 (continued)

Task	Mode 1 ^a	Mode 2 ^a	Mode 3 ^a	Mode 4 ^a	Mode 5 ^a	Task permissible in these modes of operation?	Task possible without defeating?	Easier/more convenient ^b	Faster, increased productivity ^b	Flexibility, e.g. for larger workpieces ^b	Higher precision ^b	Better visibility ^b	Better audibility ^b	Less physical effort ^b	Reduced travel ^b	Greater freedom of movement ^b	Improved flow of movement ^b	Avoidance of interruption ^b	...
Manual change of tools																			
Maintenance servicing																			
Rectification of faults machine																			
Cleaning, e.g. removal of swarf																			
...																			
...																			
^a Modes of operation.																			
Op. Mode 1:																		
Op. Mode 2:																		
Op. Mode 3:																		
Op. Mode 4:																		
Op. Mode 5:																		
Modes of operation include automatic mode and manual mode, as in the example presented in Table H.2.																			
^b Benefits without protective device: 0 = None; + = Minor; ++ = Substantial.																			
See Reference [15].																			

Table H.2 — Example of an evaluation of motivation to defeat interlocking devices on a machine

Task	Automatic ^a	Manual ^a	Task permissible in these modes of operation?	Task possible without defeating?	Easier, more convenient ^b	Faster, increased productivity ^b	Flexibility, e.g. for larger workpieces ^b	Higher precision ^b	Better visibility ^b	Better audibility ^b	Less physical effort ^b	Reduced travel ^b	Greater freedom of movement ^b	Improved flow of movement ^b	Avoidance of interruption ^b	
Initial operation		X	Yes	Yes	0	0	0	0	0	0	0	0	0	0	0	
Program test/test run		X	Yes	Yes	0	0	0	0	0	0	0	0	0	0	0	
Setup/ adjustment conversion/ tooling/	X		No	No	++	0	0	0	++	++	0	0	0	0	0	Appropriate mode of operation missing
Machining	X		Yes	Yes	0	0	0	0	0	0	0	0	0	0	0	
Manual intervention for swarf removal																
Manual change of workpiece																
Manual intervention for trouble shooting		X	Yes	Yes	++	0	0	0	0	0	0	0	0	0	0	Improvement necessary
Checking/ random sampling																
Manual intervention for measuring/																
Manual change of tools		X	Yes	Yes	0	0	0	0	0	0	0	0	0	0	0	
Maintenance/ servicing																
Rectification of faults Machine																
^a Modes of operation.																
^b Benefits without protective device: 0 = None; + = Minor; ++ = Substantial.																

Table H.2 (continued)

Task	Auto-matic ^a	Manu-al ^a	Task per-missible in these modes of operation?	Task possible without defeating?	Easier, more convenient ^b	Faster, increased productivity ^b	Flexibility, e.g. for larger work-pieces ^b	Higher precision ^b	Better visibility ^b	Better audibility ^b	Less physical effort ^b	Reduced travel ^b	Greater freedom of movement ^b	Improved flow of movement ^b	Avoidance of inter-ruption ^b
Cleaning, e.g. removal of swarf															
...															
...															
a Modes of operation.															
b Benefits without protective device: 0 = None; + = Minor; ++ = Substantial.															

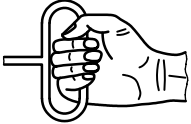
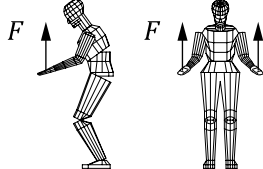
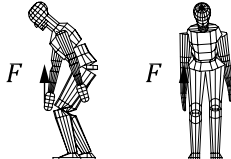
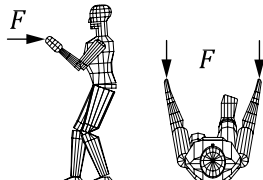
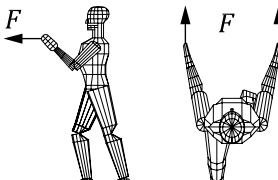
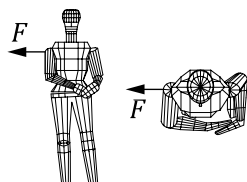
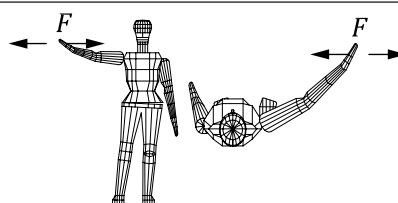
Annex I (informative)

Examples for maximum static action forces

The examples in [Table I.1](#) can give orientation for the maximum static action forces (see also Reference [\[18\]](#)).

NOTE [Table I.1](#) shows examples for static forces. For some applications dynamic forces will also have to be taken into account.

Table I.1 — Examples for maximum static action forces

Direction of force	Posture	Force application	Force value N
	Horizontal pulling (dragging)	Sitting	Single handed 600
	Vertical upward	Standing, torso and legs bent, feet parallel	Bi-manual, horizontal grips 1 400
	Vertical upward	Standing, free	Single-handed, horizontal grips 1 200
	Horizontal, parallel to body symmetry plane backward Pull	Standing upright, feet parallel, or in step posture	Bi-manual, vertical grips 1 100
	Horizontal, parallel to body symmetry plane forward Push	Standing, feet parallel, or in step posture	Bi-manual, vertical grips 1 300
	Horizontal, normal to body symmetry plane body off	Standing, torso bent sideward	Shoulder pushing on metal plate on the side 1 300
	Horizontal, normal to body symmetry plane	Standing, feet parallel	Single-handed, vertical grip 700

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1) Free download of Table H.1.

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