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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

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Foreword

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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*

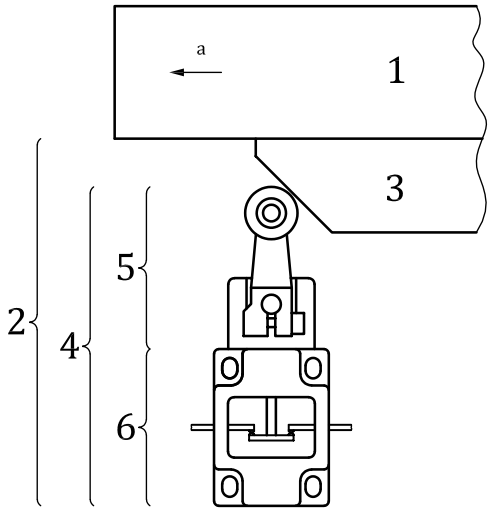
3 Terms and definitions

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
2 interlocking device
3 actuator
4 position switch
5 actuating system
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.

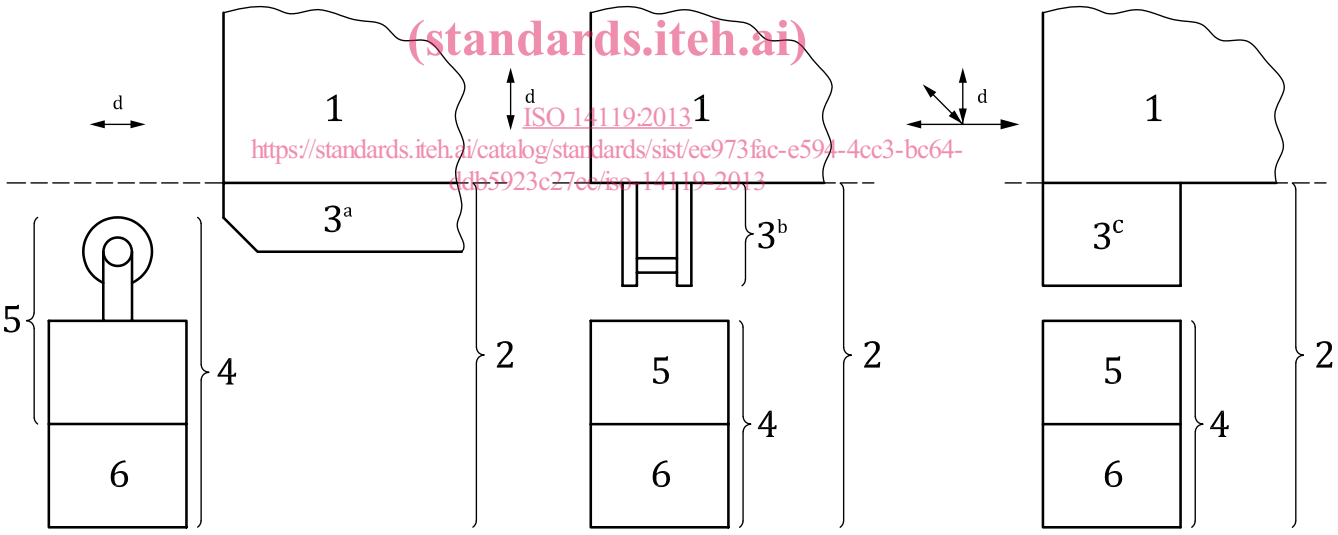
Table 1 shows the actuation principles and actuators for the defined interlocking device types.

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.



a) Type 1 interlocking device (uncoded cam-operated, guard closed)

b) Type 2 interlocking device (coded tongue-operated, guard not closed)

c) Type 3 or 4 interlocking device (uncoded or coded non-contact actuated, guard closed)

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.

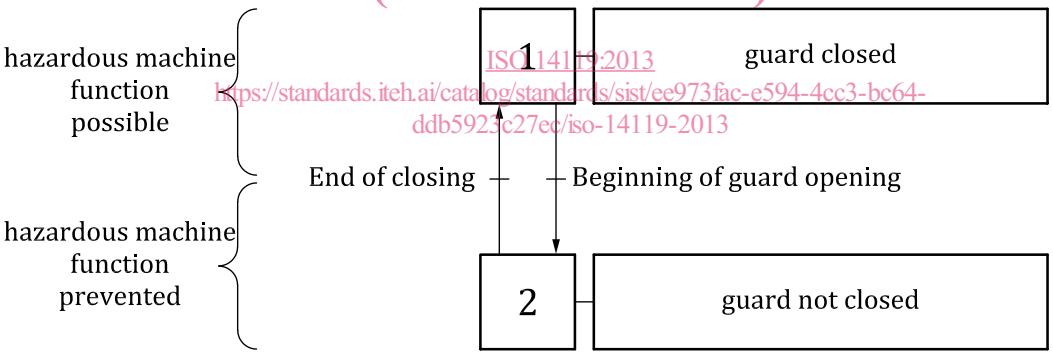


Figure 3 — Functional diagram of interlocking devices without guard locking

4.3 Principles of guard interlocking with guard locking

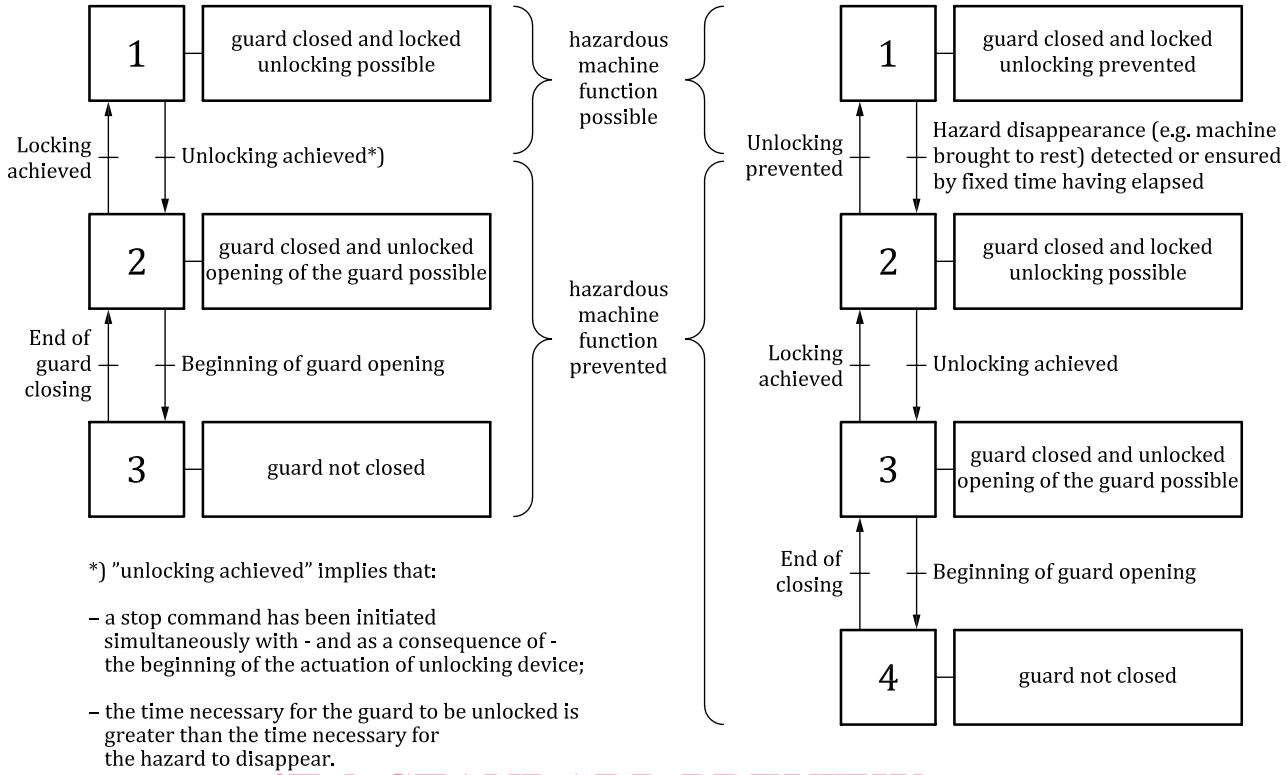
4.3.1 General

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.



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.