भारतीय मानक **IS/ISO TS 19837 : 2018**

Indian Standard

मशीनरी की सुरक्षा — फंसे हुए कुंजी इंटरलॉकिंग उपकरण — डिज़ाइन और चयन के लिए सिद्धांत

Safety of Machinery — Trapped Key Interlocking Devices — Principles for Design and Selection

ICS 13.110

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Safety of Machinery Sectional Committee, MED 40

NATIONAL FOREWORD

This Indian Standard which is identical to ISO/TS 19837 : 2018 ‘Safety of machinery — Trapped key interlocking devices — Principles for design and selection’ issued by the International Organization for Standardization (ISO) was adopted by the Bureau of Indian Standards on recommendation of the Safety of Machinery Sectional Committee and approval of the Mechanical Engineering Divisional Council.

The text of ISO standard has been approved as suitable for publication as an Indian Standard without deviations. Certain conventions are, however, not identical to those used in Indian Standards. Attention is particularly drawn to the following:

a) Wherever the words ‘International Standard’ appears referring to this standard, they should be read as ‘Indian Standard’; and

b) Comma (,) has been used as a decimal marker while in Indian Standards, the current practice is to use a point (.) as the decimal marker.

In this adopted standard, reference appears to certain International Standards for which Indian Standards also exist. The corresponding Indian Standards, which are to be substituted in their respective places, are listed below along with their degree of equivalence for the editions indicated:

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
ISO 14119 : 2013, Safety of machinery — Interlocking devices associated with guards — Principles for design and selection	IS 16812 : 2018/ISO 14119 : 2013 Safety of machinery — Interlocking devices associated with guards — Principles for design and selection	Identical
ISO 13849-1, Safety of machinery — Safety-related parts of control systems — Part 1: General principles for design	IS 16810 (Part 1) : 2018/ISO 13849-1 : 2015 Safety of machinery — Safety related parts of control systems: Part 1 General principles for design	Identical
ISO 13849-2, Safety of machinery — Safety-related parts of control systems — Part 2: Validation	IS 16810 (Part 2) : 2018/ISO 13849-2 : 2012 Safety of machinery — Safety related parts of control systems: Part 2 Validation	Identical

The Committee has reviewed the provision of the following International Standard referred in this adopted standard and has decided that it is acceptable for use in conjunction with this standard:

International Standard	*Title*
IEC 60947-1 : 2008	Low-voltage switchgear and controlgear — Part 1: General rules

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 2022 ‘Rules for rounding off numerical values (*second revision*)’. The number of significant places retained in the rounded-off value should be the same as that of the specified value in this standard.

Contents

Page

Indian Standard

SAFETY OF MACHINERY — TRAPPED KEY INTERLOCKING DEVICES — PRINCIPLES FOR DESIGN AND SELECTION

1 Scope

This document specifies principles for the design, selection and application of trapped key interlocking devices and systems for machinery applications, independent of the type of energy used to control them or that they control.

The requirements of this document apply to the safety related aspects of trapped key interlocking devices and systems. ISO 14119 always applies unless an exception is given in this document.

This document is intended to be used in conjunction with ISO 14119.

This document does not provide testing requirements.

NOTE Documents addressing testing requirements can be found in the Bibliography.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 14119:2013, *Safety of machinery — Interlocking devices associated with guards — Principles for design and selection*

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

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

IEC 60947-1:2008, *Low-voltage switchgear and controlgear — Part 1: General rules*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
trapped key interlocking system
system fulfilling safety function(s) or part of safety function(s) and comprising of at least two trapped key interlocking devices which work together through the transfer of a key

3.2
key
element used to operate a trapped key interlocking device with matched coding

3.3
trapped key interlocking device
device, part of a trapped key interlocking system, which fulfils a function by trapping or releasing a key in a given system

EXAMPLE Door locks, key operated switches, key exchange units.

3.4
bolt lock
trapped key interlocking device that extends a bolt to lock an object

EXAMPLE Disconnector switches, valves or sliding doors.

3.5
access lock
trapped key interlocking device used to lock movable guards

Note 1 to entry: Access locks can also be used for locking in position of objects other than guards, e.g. isolators, valves or barriers.

3.6
timed delay device
trapped key interlocking device that releases a key after a pre-determined period of time has elapsed

3.7
key exchange device
trapped key interlocking device in which the insertion of one or more keys releases one or more keys with a different coding, trapping the inserted keys

3.8
key operated switch
trapped key interlocking device comprising a switch which can only be operated by means of a key

3.9
solenoid-controlled switch
trapped key interlocking device comprising a key operated switch which can be mechanically locked by the operation of a solenoid

3.10
valve lock
trapped key interlocking device used to lock a valve in the open position (locked open), in the closed position (locked closed) or in both positions by different keys (LO/LC)

3.11
actuator
separate part of an access lock which transmits the state of the guard (closed or not closed) to the actuating system

Note 1 to entry: Access locks can also be used for locking in position of objects other than guards, e.g. an isolator, valve or barrier.

Note 2 to entry: A Key is not covered by this definition, see 3.1.2.

[SOURCE: ISO 14119:2013, 3.12, modified — “interlocking device” has been changed to “access lock”.]

3.12
switch-disconnector
switch which, in the open position, satisfies the isolating requirements specified for a disconnector

[SOURCE: IEC 60947-1:2007, 2.2.10]

3.13
personnel key
key which is released from a trapped key interlocking device (typically a access lock used in conjunction with whole body access) and retained by a person to prevent a hazardous situation, e.g. unexpected start-up

3.14
control interlocking
function which allows access to hazardous machine functions if the energy supply is interrupted using indirect means

Note 1 to entry: Examples of indirect means can include a combination of relay modules, standstill monitoring devices, PLCs or other control devices/systems.

3.15
power interlocking
interlocking which directly interrupts the energy supply to the machine actuators or disconnects moving parts from the machine actuators

[SOURCE: ISO 14119:2013, 3.31, modified — The Note 1 to entry has been deleted.]

3.16
locked open
LO
valve locked by a trapped key interlocking device in the open position

3.17
locked closed
LC
valve locked by a trapped key interlocking device in the closed position

3.18
key transfer plan
drawing depicting the trapped key interlock system with its individual devices and the sequence(s) in which they are to be operated

3.19
key trapped
key which is locked until an external input releases it

EXAMPLE A solenoid or the insertion of an actuator releases the trapped key.

3.20
key releasable
key which is not locked and so can be (turned and) removed at any time causing a change of state of the device

EXAMPLE Change of state of the device releases or traps another key or changes contact state.

3.21
master key
key which can open multiple locks of different coding

3.22
isolation control
sub function of a trapped key interlocking system to achieve and maintain a safe state of power or movement

3.23
intermediate transfer
sub function of a trapped key interlocking system that allows the transfer of keys between isolation control and access control, subject to the designated conditions

3.24
access control
sub function of a trapped key interlocking system that controls the access to safeguarded areas or access to machine operating modes and functions

3.25
category 3 behaviour
<for the mechanical parts of trapped key systems> no single fault results in a loss of the safety function

Note 1 to entry: Category 3 behaviour is characterized by (see ISO 13849-1:2015, 6.2.6):

— continued performance of the safety function in the presence of a single fault;

— detection of some, but not all, faults;

— possible loss of the safety function due to accumulation of undetected faults.

3.26
category 4 behaviour
<for the mechanical parts of trapped key systems> no accumulation of faults results in a loss of the safety function

Note 1 to entry: Category 4 behaviour is characterized by (see ISO 13849-1:2015, 6.2.7):

— continued performance of the safety function in the presence of a single fault;

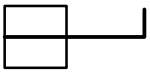
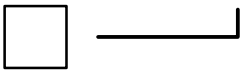
— detection of faults in time to prevent the loss of the safety function;

— the accumulation of undetected faults is taken into account;

— the consideration of an accumulation of two faults is sufficient (unless an accumulation of 3 or more faults is foreseeable).

4 Symbols and abbreviated terms

o.r	Symbol	Function	Definition
1		key	3.2
2		key path	
3		key trapped	3.19
4		key releasable	3.20
5		key inserted and removable	
6		key removed	
7		actuator *locked*	

o.r	Symbol	Function	Definition
8		actuator *unlocked*	
9		actuator removed	
10		timed delay function	3.6

NOTE The figures in this document show general function principles without claiming any PL or SIL for the associated safety functions. Therefore the corresponding links between contacts are shown in dashed lines, independently if the contacts used are mechanically linked, mirror, or normal auxiliary contacts.

5 Operating principles and typical forms of trapped key interlocking system

5.1 General

A trapped key interlocking system relies upon the transfer of key(s), e.g. between a key operated switch and an access lock (see Figure 1).

Typically in trapped key interlocking systems the guard locking and the switching elements are physically separated and functionally linked by the transfer of the key.

Keys shall be coded with the intention that they can fit only into the corresponding devices.

Trapped key interlocking systems shall ensure a sequence of operation for equipment to ensure safety due to the following operating principles.

A designated safe state of the machinery results in the availability of a key. The following sequence shows an example of a simple trapped key system using a key operated switch and an access lock:

— machine in operation (see Figure 1);

— operation of the key results in a stop command (see Figure 2);

— key in transfer between devices from switch to access lock (see Figure 3);

— the key is inserted to the access lock (see Figure 4);

— operation of the key in the access lock changes its state to unlocked (see Figure 5);

— removing the actuator from the access lock traps the key (see Figure 6).

To bring the machine back into operation the sequence shall be reversed.

EXAMPLE In key operated switches, removing the key results in a change of state of the contact(s) which cannot be changed back until the key is reinserted. Typically this change of state initiates a stop command to the machine. Once the key has been removed, it is used to unlock the access lock. Removal of the actuator by opening the moveable guard results in the key becoming trapped.

NOTE

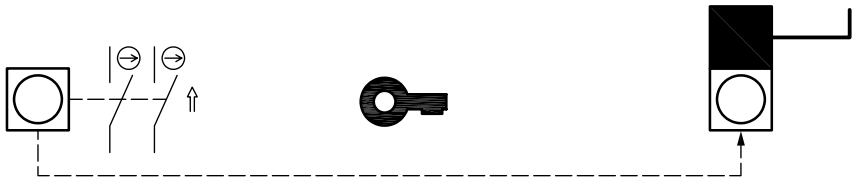
key operated switch
key releasable, contacts closed (machine on)
access lock
key removed, actuator locked

Figure 1 — Machine in operation

NOTE

key operated switch
key inserted and removable, contacts opened
access lock
key removed, actuator locked

Figure 2 — Operation of the key results in a stop command



NOTE

key operated switch
key removed, contacts opened (machine off)
key in transfer
access lock
key removed, actuator locked

Figure 3 — Key in transfer between devices from switch to access lock

NOTE

key operated switch
key removed, contacts opened (machine off)
access lock
key inserted and removable, actuator locked

Figure 4 — Key inserted to the access lock

NOTE

key operated switch — access lock

key removed, contacts opened (machine off) — key releasable, actuator unlocked

Figure 5 — Unlocked state by operation of the key in the access lock

NOTE

key operated switch — access lock

key removed, contacts opened (machine off) — key trapped, actuator removed

Figure 6 — Key trapped by removing the actuator from the access lock

Key coding shall prevent two or more devices unintentionally sharing the same key which can result in a hazard.

For example, a key that shuts down and allows safe access into machine 2 cannot be used to access or control machine 1 (see Figure 7).

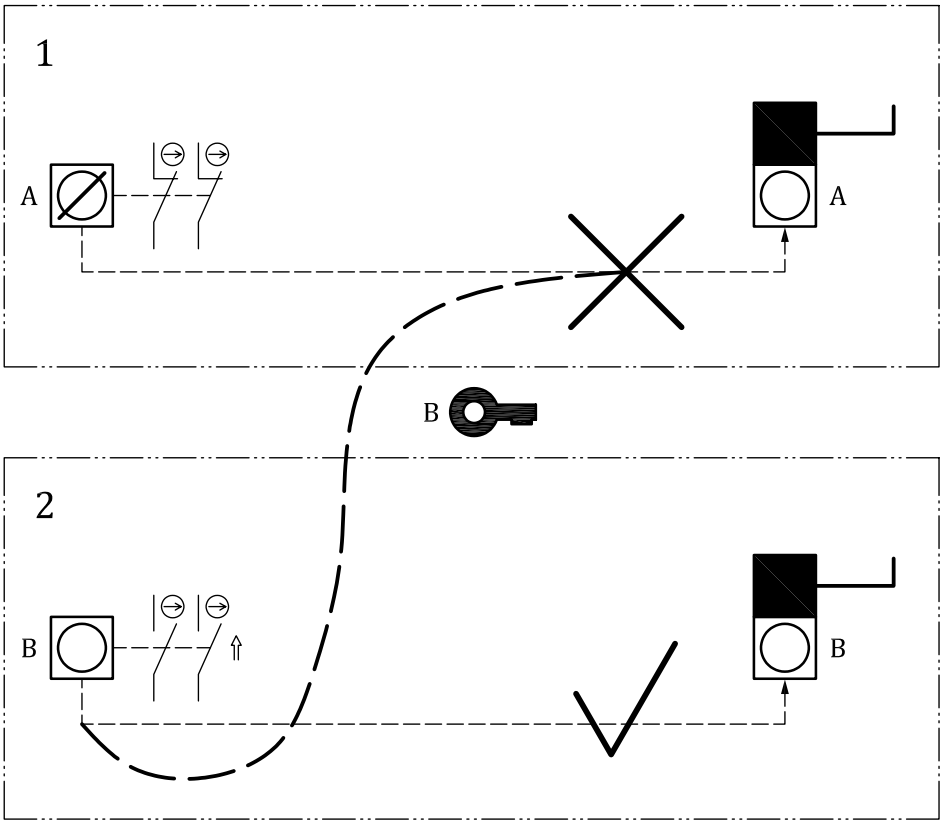
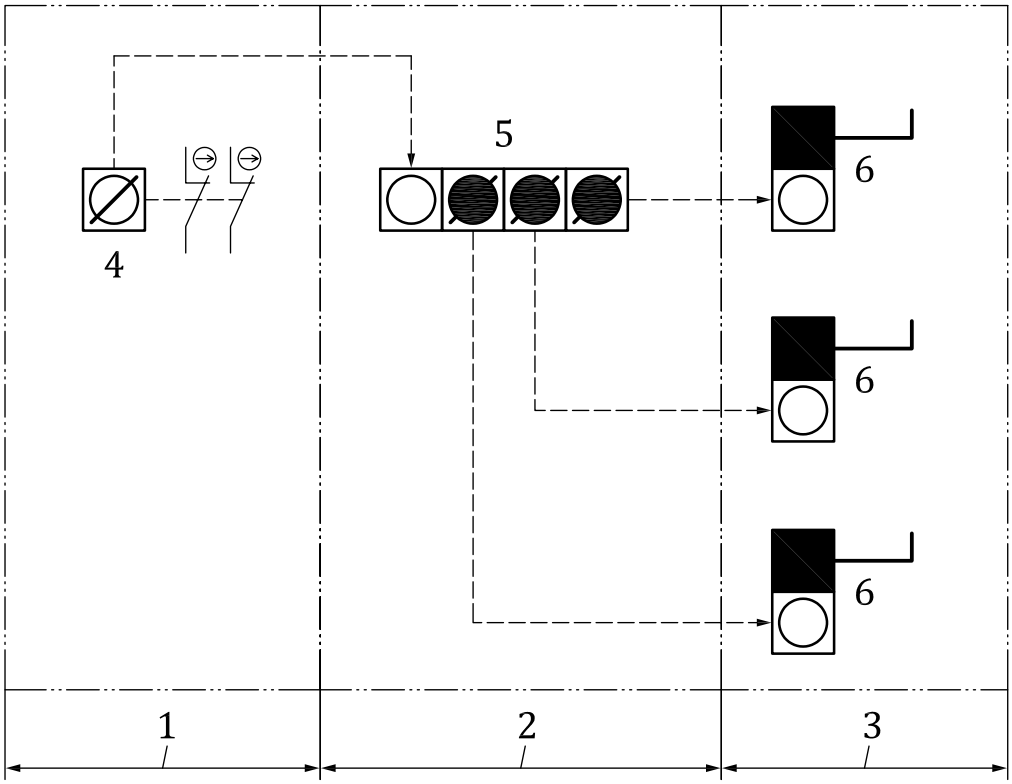


Figure 7 — Key coding

5.2 Functional decomposition of a trapped key interlocking system

A typical trapped key interlocking system comprises three sub functions:

1) isolation control (for example: key operated switch). See 5.2.1.
2) intermediate transfer (for example: key exchange device). See 5.2.2.
3) access control (for example: access lock). See 5.2.3.



Key

1 isolation control
2 intermediate transfer
3 access control
4 key operated switch
5 key exchange device
6 access lock devices

Figure 8 — Sub functions of a typical trapped key interlocking system

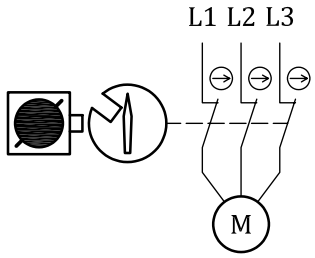
5.2.1 Isolation control

5.2.1.1 General

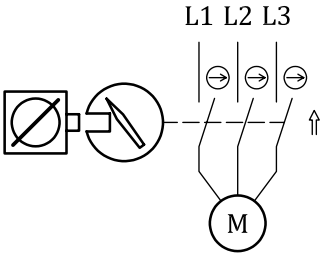
This sub function of a trapped key interlocking system is to achieve and maintain a safe state of power or movement. With the key removed the power and or movement is held in a safe state. Only when the key is returned and put into a key releasable or key trapped position can power and or movement be resumed. Examples of isolation control trapped key interlock devices include, bolt lock (operating on a valve or isolator switch), key operated switch, solenoid controlled switch, valve lock or mechanical movement prevention device linked to an access lock.

5.2.1.2 Isolation control through direct mechanical action (Power Interlocking)

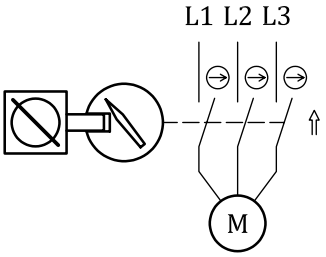
In a trapped key power interlocking system the power supply shall be locked off directly by a trapped key interlock. This is typically achieved through the use of a switch-disconnector in conjunction with a bolt lock (see Figure 9) or through a key operated switch where the switching element is the disconnector. Switch-disconnectors shall conform to the requirements of IEC 60947-3. The key can only be removed from trapped key interlocking device once the power source has been isolated and locked in the off position.



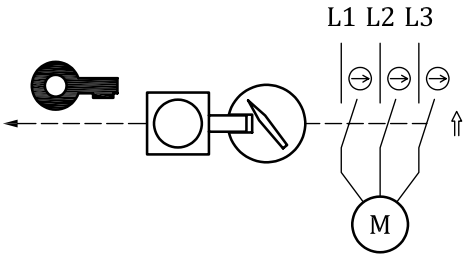
a) Supply connected, key trapped



b) Supply disconnected, key releasable



c) Supply disconnected and locked through bolt lock, key inserted and removable

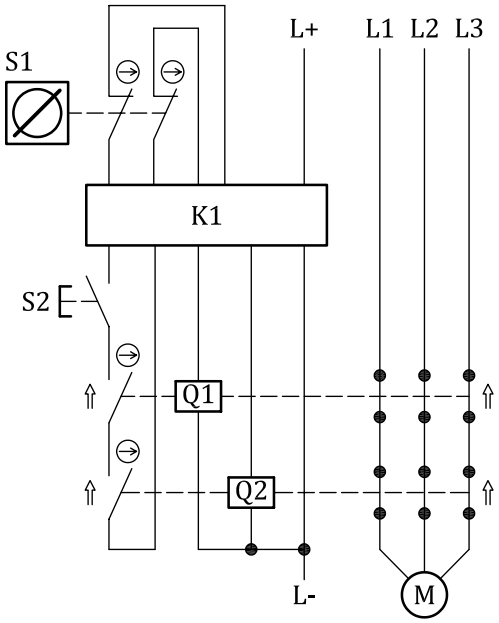


d) Supply disconnected and locked through bolt lock, key removed

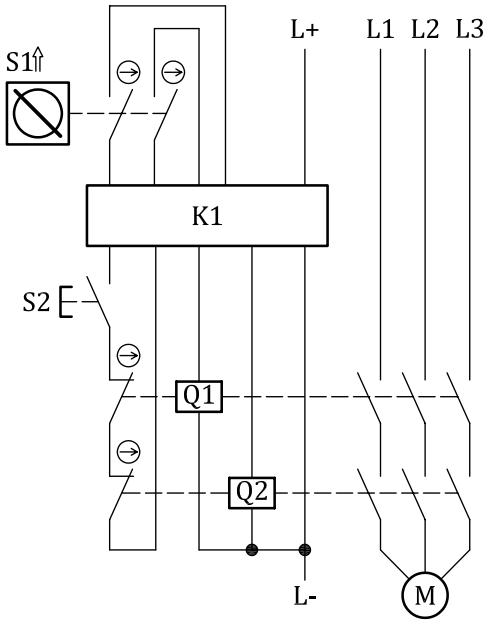
Figure 9 — Example of power interlocking sequence

5.2.1.3 Isolation control through non-direct mechanical action (Control Interlocking)

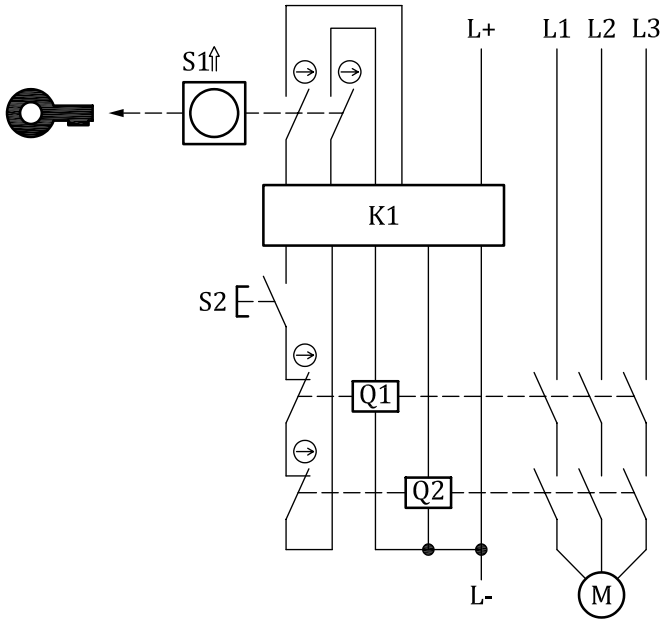
In a trapped key control interlocking system, the power supply is locked off indirectly by a trapped key interlock via a control circuit (see Figure 10). Typically, switching elements controlled by the trapped key interlock can be contactors or solenoid operated pneumatic valves. Because control is by indirect means, monitoring is normally employed.



a) Supply connected, key releasable



b) Supply disconnected, key inserted and removable



c) Supply disconnected, key removed

Key

Q1 power contactor
Q2 power contactor
S1 key operated switch
S2 reset device
K1 logic unit

Figure 10 — Example of a control interlocking sequence

5.2.2 Intermediate transfer

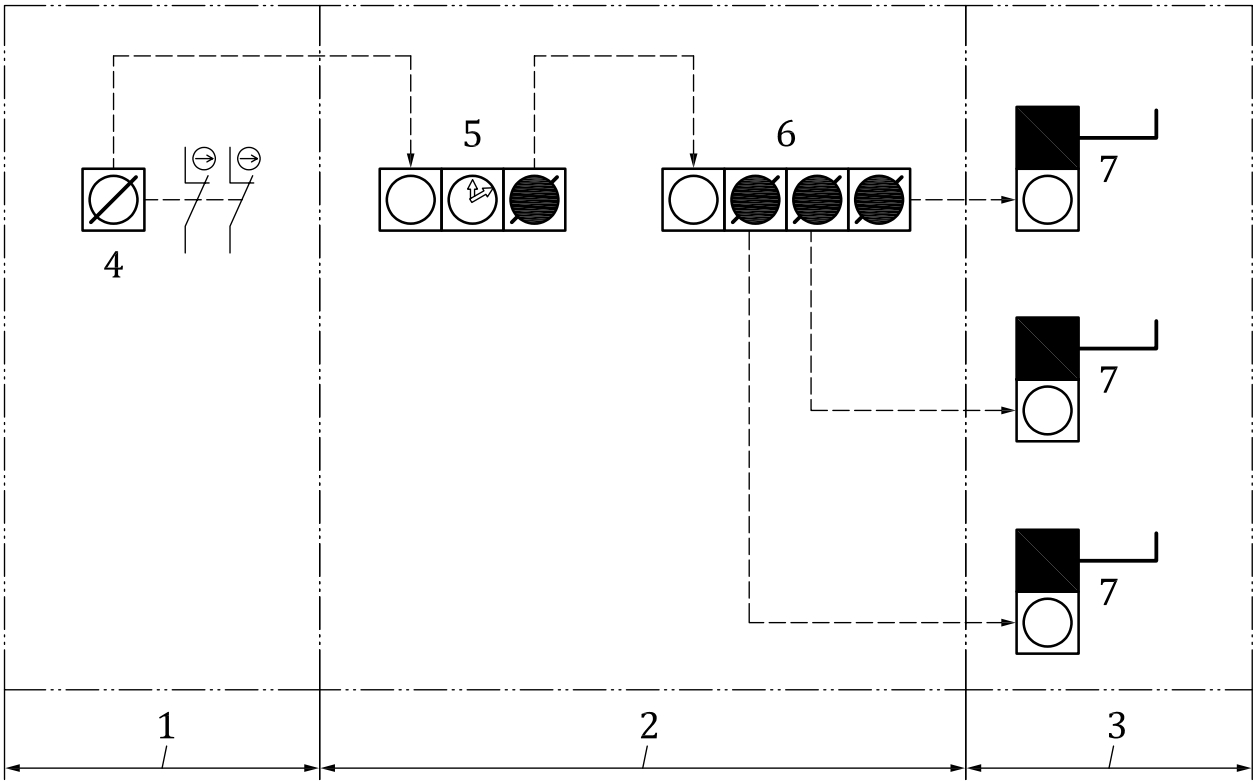
This sub-function of a trapped key interlocking system allows the transfer of keys between Isolation control and access control, subject to the designated conditions. This can be as simple as a key moving from one Isolation control device to one access control device, or allow the adding of additional functionality, such as multiple isolation control devices, multiple access control devices or timed delay. Examples of intermediate transfer include key exchange device or timed delay device (see Figure 11).

A key exchange device may be used where a number of operations need to be carried out in a defined sequence. See Figure 8 for an example of this.

The key exchange function can be stand-alone, or integral with the access control or the isolation control functions

Additional conditions for the key release can be required for example; a timed delay device may be used where a delay is required between the release of the key from the isolation control device and the operation of the access control device.

NOTE See also ISO 14119:2013, 6.2.1.



Key

1 isolation control
2 intermediate transfer
3 access control
4 key operated switch
5 timed delay device
6 key exchange devices
7 access lock devices

Figure 11 — Example of intermediate transfer

5.2.3 Access control

This sub-function of a trapped key interlocking system controls the access to safeguarded areas or access to machine operating modes and functions. Examples of access control trapped key interlocking devices include, access lock, bolt lock, valve lock or key operated switch for mode control.

6 General requirements for the design of Trapped Key interlocking device

6.1 General

A trapped key interlocking device is an interlocking device as covered by ISO 14119. The following requirements cover only the elements of trapped key interlocks that are not adequately covered by ISO 14119.

Unit components accessible by hand shall have no sharp corners or edges, or abrasive surfaces that can cause injuries.

6.2 Device architecture and positive mechanical action

A trapped key system shall be suitable for inclusion in a control system designed in accordance with ISO 13849-1.

Some trapped key interlocking devices contain dual channel mechanical structure which ensures the product does not fail, or fails to safe at or before the next demand on the safety function. In this case, the designated architectures according to ISO 13849-1 may apply.

Some trapped key interlocking devices have a single channel mechanical structure. In this case, the designated architecture according to ISO 13849-1, category 1 may apply.

If Category 3 behaviour is achieved with a single channel structure the maximum achievable Performance Level (PL) is Performance Level d (PLd).

If Category 4 behaviour is achieved with a single channel structure the maximum achievable Performance Level (PL) is Performance Level e (PLe).

The category or category behaviour shall be verified. The verification shall include an appropriate analysis methodology such as FMEA, FTA or a combination of both.

Positive mechanical action, or a principle with equivalent integrity shall be employed in single channel trapped key devices. Careful consideration shall be given to the design, endurance, systematics, key coding.

NOTE See also ISO 13849-1:2015, Clause 6.

6.3 Endurance/Strength

6.3.1 General

Careful selection of materials, dimensioning and manufacturing processes are essential to ensure adequate safety levels. In particular, the forces the device will be subject to shall be considered, such as the maximum force that can be applied to a key or actuator including foreseeable misuse (such as a spanner used to extract a key).

Wear considerations shall take into account the environment. Reasonably foreseeable systematic influences, taking into account the limits stated by the manufacturer, shall not result in a failure to danger.

Depending on the manufacturing process variability, it can be necessary to add a sample testing regime to ensure manufacturing repeatability on key components.

For Performance Level d (PLd) or Performance Level e (PLe), all failures due to endurance/strength/ manufacturing variability/systematic influences, or combination thereof shall not result in a loss of the safety function.

6.3.2 Resistance to shock and vibration

Trapped key interlocking devices shall possess sufficient mechanical strength with respect to the operational demands, such as jolting, shock or impact, which can be expected when used as intended.

6.3.3 Mechanical life

The mechanical life shall be at least 200 000 switching cycles.

6.3.4 Rotary actuators for access locks

All of the parts that are intended for blocking the rotary actuator shall be able to withstand a torque of at least 5 Nm applied to the actuator.

Furthermore, at torque values greater than 5 Nm, it shall be ensured that the actuator does not shear out of the lock resulting in a loss of the safety function (e.g. through design features such as predetermined breaking points).

NOTE This is not the same as holding force.

6.3.5 Key retention

Measures shall be taken to prevent the key from being removed from the lock in the trapped position. It shall not be possible to pull the key out of the lock with a force less than 250 N.

All of the parts that are intended for blocking the key, including the key itself, shall be able to withstand a torque of at least 5 Nm applied to the key.

Furthermore, at torque values greater than 5 Nm, it shall be ensured that the key does not shear out of the lock resulting in a loss of the safety function (e.g. through design features such as predetermined breaking points).

6.4 Systematics

See ISO 13849-1:2015, Annex G.

6.5 Safety FMEA/FTA

A safety FMEA or equivalent analysis shall be undertaken. Common cause faults shall be considered. This document is critical to determine the testing and validation required (see also IEC 60812 for FMEA and IEC 61025 for FTA).

6.6 Validating Performance Level

Trapped key interlocking systems are typically single channel mechanical structures in accordance with ISO 13849-1. This does not necessary restrict them to Performance Level c (PLc). However to achieve Performance Level d (PLd) or Performance Level e (PLe) with single channel mechanical structures, careful consideration shall be given to any fault exclusions and systematic requirements (see Annex C).

To achieve PLd with single channel mechanical structures it is necessary to meet these additional requirements above the normal interlock requirements as set out in ISO 14119 in the following areas.

The use of trapped key interlocking systems for safety functions on machines and systems requires validation according to ISO 13849-2.

The required Performance Level (PLr) shall be determined according to the actual application (see Product standard or ISO 13849-1).

Key transfer systems shall fulfil the requirements corresponding to the Performance Level (PL) for each prescribed safety function, to which they have been assigned.

If, by means of analysis (e.g. FMEA), it can be verified the faults cannot occur in the key transfer system that can lead to loss of the safety function (e.g. through fault exclusions), then a PL = d can be realized.

A fault exclusion is permissible for electromechanical components only when:

— the force is applied by positive mechanical action to a contact with direct opening action (see IEC 60947-5-1:2016, Annex K);

— measures are foreseen or are prescribed in the Instruction manual for over-current and short-circuit protection.

If all single faults that cause a loss of the safety function are excluded, Category 3 behaviour may be assumed and a diagnostic coverage (DC) is not necessary. Because there is no occurrence of faults that can lead to loss of the safety function, a maximum Performance Level (PL) = d can be assumed for the entire trapped key system.

NOTE 1 For calculation purposes a PFH_D of 1×10^{-7} for the entire trapped key system can be assumed.

Fault exclusions shall be listed and explained in the Information for use. Fault exclusions, which are not tolerable because of a foreseeable faulty application of the key transfer system, shall not be made.

For systematic failures ISO 13849-1:2015, Annex G, is applicable. In addition, requirements to avoid systematic failures relating to key coding (see 6.2) shall be followed.

In addition to the permissible fault exclusions according to ISO 13849-2:2012, Annexes A, B, C, D, the presumption of breakage and deformation faults can be excluded for mechanical components (except for springs) if their strength is verified to a Safety factor of 4, unless analysis or a product standard shows otherwise. In this case, the quality assurance measures applicable to the component manufacturing processes shall be evaluated separately.

In order to achieve Performance Level e (PLe), category 4 behaviour is required. In particular an accumulation of faults does not lead to the loss of the safety function, the consideration of a fault combination of two faults is sufficient (unless 3 or more faults are foreseeable) (see Annex B for typical faults).

NOTE 2 Typically, this is achieved by insuring that if a fault occurs the device or the system is rendered inoperable and therefore preventing access to a danger area or the restart of a machine.

In cases where a single fault which, in itself, does not cause a failure to danger cannot be excluded, the tests for no failure to danger occurring shall be continued with the fault applied first and all other faults added and removed in turn. Tests shall be carried out for all non-excluded single faults. Testing for the accumulation of more than two faults need not be carried out provided that the probability of more than two faults, largely independent of each other and having to appear in a specific sequence in time, is low.

NOTE 3 The behaviour of a category does not necessarily include the designated architecture, but the definition of the category.

6.7 Design to minimize defeat

6.7.1 General

Further to ISO 14119:2013, Clause 7, which should be read in conjunction with this subclause, the following specifics apply to trapped key interlocking devices. It is important to note that none of these issues affect the Performance Level (PL) and are only of consideration in cases where motivation to defeat the interlock exist.

There is a clear distinction between the coding of keys and the coding of actuators in a trapped key system. (See 6.7.3 and 6.7.4).

6.7.2 Scheme design for ease of use

In designing a scheme, careful consideration to the ease of use for the operator should be given to prevent increasing the motivation to defeat the trapped key interlocking system.

6.7.3 Coded actuators

Should a motivation to defeat the interlock exist (see ISO 14119:2013, Annex H) and there is no way to reduce these motivation then actions shall be taken to reduce the possibilities to defeat. One possibility is the use of a medium or high coded actuator. Access to duplicate coded actuators should be minimized on one site.

Consideration should be given with regards to the processes that allow the ordering of spare medium or high coded actuators.

6.7.4 Reproduction of keys

Keys shall not be easily reproduced (for example with hand tools or at a domestic locksmith), other than by the original manufacturer.

Consideration should be given with regards to the processes that allow the ordering of spare keys.

6.8 Clearances and creepage distances

The clearances and creepage distances between adjacent electrical components shall fulfil IEC 60947-1:2008, 7.1.4, also maintained during the switching operation.

6.9 Isolation control

6.9.1 General

The mounting of the switch-disconnector to the lock shall be achieved by form. The transmission of force between the lock and switch-disconnector shall be by positive mechanical action. The connection and transmission elements shall withstand the force without damage when exposed to a torque of 5 Nm with the use of a rotary key and a tensile force of 250 N with the use of a linear key.

The switch-disconnector shall be mounted in such a manner that the actuation shaft and its seating on the lock lie on a central axis and that the shaft will not be exposed to bending loads.

All connections shall be protected against self-loosening.

6.9.2 Direct mechanical action (Power interlocking)

In addition to the requirements of this document, for power switching elements, the relevant product standards apply. For example for electrical direct mechanical power interlocking trapped key systems the requirements of IEC 60947-3 apply.

6.9.3 Solenoid controlled switch

The principles given for guard locking function of ISO 14119:2013, 5.7.1, shall apply to the release of the key(s).

The temperature rise of the electromagnetic actuating coil shall not exceed values of Table 1 during testing under the conditions set forth in IEC 60947-1:2007, 7.2.2..

Table 1 — Maximum temperature rise

Insulation class	Maximum temperature rise
Y	50 K
A	65 K
E	80 K
B	90 K
F	115 K
H	140 K

The solenoid shall operate as intended within the range from 90 % to 110 % of the rated operating voltage.

6.10 Access control

6.10.1 Escape release

Use of a personnel key normally removes the need for an escape release. However when an access lock has an escape release it shall comply with ISO 14119:2013, 5.7.5.2. In particular, the unlocking shall generate a stop command which is maintained.

6.10.2 Emergency release

When an access lock has an emergency release it shall comply with ISO 14119:2013, 5.7.5.3. In particular, the unlocking shall generate a stop command which is maintained.

6.10.3 Auxiliary release

When an access lock has an auxiliary release it shall comply with ISO 14119:2013, 5.7.5.4. In particular, the unlocking shall generate a stop command which is maintained.

7 System configuration

7.1 General

The following Figure 12 depicts a trapped key system configuration process.

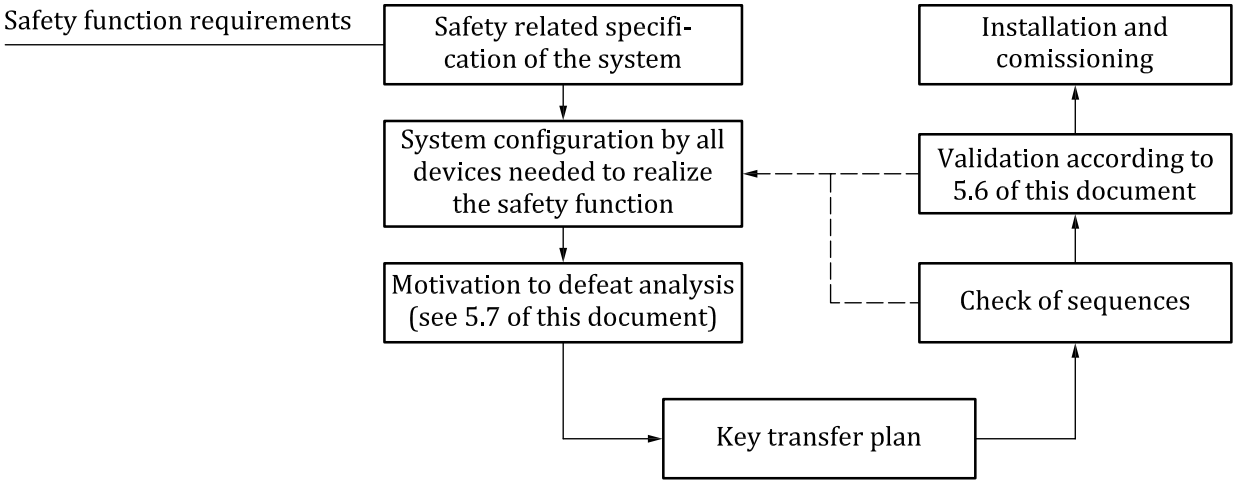


Figure 12 — Trapped key system configuration process

7.2 Key coding

There shall be means to prevent unintentional duplication of key codes.

The register or database can be controlled by the trapped key manufacturer, the machine builder or the user. Where the manufacturer or machine builder controls the register, special care shall be taken when selling through third parties (such as distributors) to ensure the final location of the lock and key is known. The key coding register shall be maintained per location and organization.

Special consideration shall be given to mobile machinery and second hand equipment to ensure the key coding is checked against and then added to the key code register.

An extremely high level of coding is no substitute for key code control, the essential requirement is that codes are not unintentionally duplicated.

It is possible through the design of lock or key to allow a lock to be operated by two differently coded keys. This can be used for a variety of purposes including for example, simplification of an interlocking scheme.

If an organization decides to keep spare or master keys then they shall be under management control and this shall be taken account of in the risk assessment. See also ISO 14119:2013, 9.2.2 u). In addition, spare keys shall only be allowed for replacement of lost or damaged keys.

7.3 Key transfer plan

A key transfer plan shall be designed for each trapped key interlock system. This transfer plan shall detail the system operation. Key coding shall be established based on the safety related specifications.

7.4 System selection

7.4.1 General

For general selection requirements refer to Figure D.1, Annex A and ISO 14119:2013, Clause 6.

7.4.2 Isolation control

Selection typically starts with:

— defining the sources of energy to be controlled;

— the type of isolation required due to the stop category, e.g. STOP 0, STOP 1, and STOP 2 according to IEC 60204-1;

— a suitable method of interlocking, e.g. control interlocking, power interlocking, valve interlocking.

7.4.3 Intermediate transfer

Devices for intermediate transfer are selected depending on:

— the requirements arising from the stop category not covered by the isolation control such as, for example, timed delay devices, standstill monitoring devices;

— the number of access points and the number of keys required, e.g. key exchange devices;

— additional components which need to be operated in sequence after the isolation control, but before the access control, such as e.g. mechanical brakes, or locking bars.

7.4.4 Access control

Devices for access control are selected depending on:

— type of access, e.g. full body access, or part body access, resulting in devices equipped with functions such as e.g. personnel key(s), escape release, emergency release;

— forces expected to work on the devices, defining e.g. the locking force, F_{Zh};

— authorization accessing a danger area, e.g. devices incorporating authorization functions;

— additional diagnostic or control functions, e.g. devices incorporating monitoring of the key or actuator position.

NOTE For a general description of the process see Annex D.

8 Information for use

In addition to ISO 14119:2013, 9.2.2, the following shall be provided:

— a key transfer plan;

— all fault exclusion shall be listed and explained, see 6.6.

Annex A
(informative)

Examples of trapped key interlock devices

A.1 Key operated switch

Inserting and turning the key energizes the switching elements

Removing the key de-energizes the switching elements (see Figure A.1).

A key operated switch may be used in a power interlocking application (5.2.1.2) or a control interlocking application (5.2.1.3).

a) Key inserted and removable with switching elements open

b) Key releasable with switching elements closed

Figure A.1 — Key operated switch

A.2 Bolt lock

a) Key inserted and removable with switching elements open

b) Key trapped with switching elements closed

Figure A.2 — Bolt lock

Bolt locks (see Figure A.2) are typically used to lock energy sources “off”. Turning and removing the key extends the bolt which locates into a recess.

It is essential to ensure that when the key is inserted and turned, and the bolt withdrawn, it is not possible to remove the key and extend the bolt until the energy source has been isolated (see Figure A.4).

Bolt Locks are primarily used in Power Interlocking applications (5.2.1.2).

Where bolt locks are used the design shall ensure that the key can only be removed when intended. To ensure this a cam like arrangement shall form part of the installation to ensure the bolt can only extend as intended. See Figure A.3 for an example of this. This arrangement is often used for valves or switch-disconnectors. It is not typically used for guarding as an access lock already ensures the key can only be removed when the guard is closed.

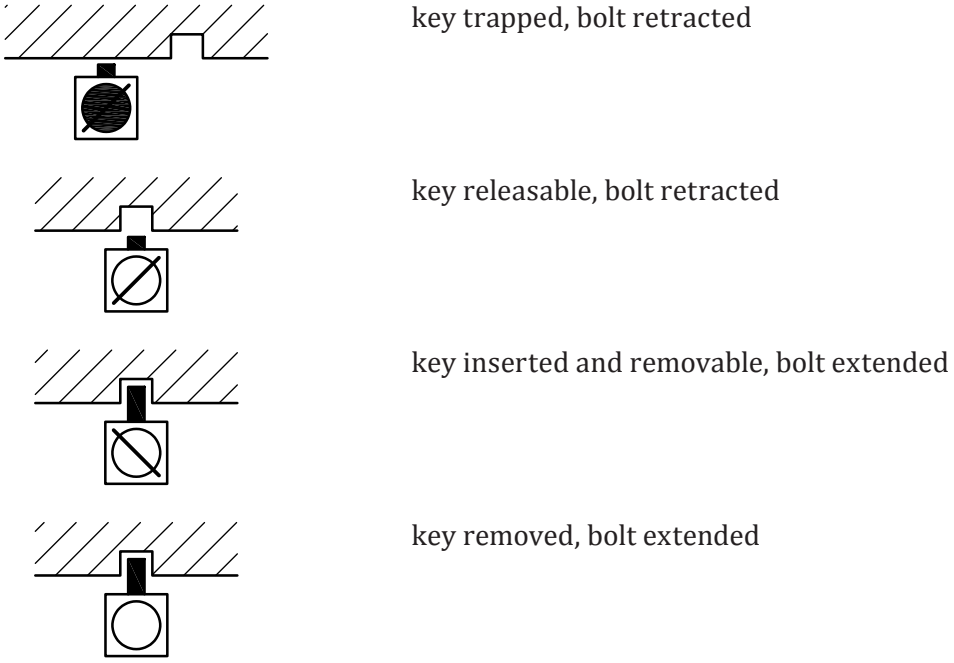
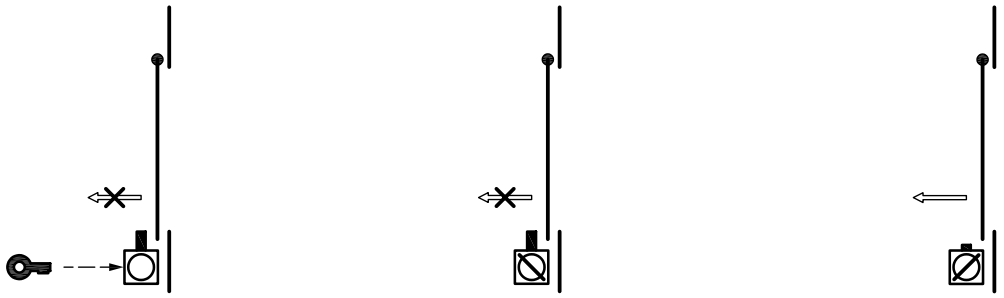


Figure A.3 — Stages of operation of a bolt lock



a)

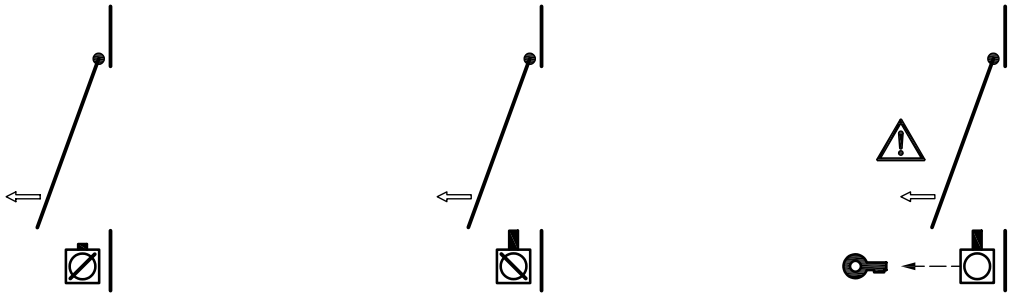
Door: closed, locked
Key removed
Bolt: extended

b)

Door: closed, locked
Key inserted and removable
Bolt: extended

c)

Door: closed, not locked
Key releasable
Bolt: retracted



d)

Door: not closed, not locked
Key releasable
Bolt: retracted

e)

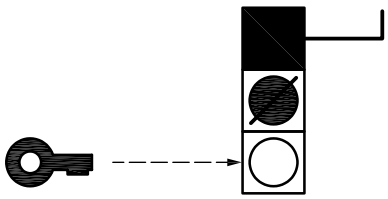
Door: not closed, not locked
Key inserted and removable
Bolt: extended

f)

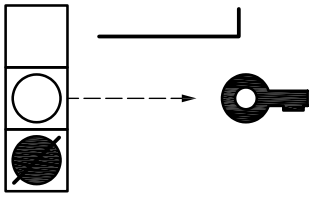
Door: not closed, not locked
Key removed
Bolt: extended
Dangerous situation

Figure A.4 — Example of the incorrect application of a bolt lock on a guard

A.3 Access lock with personnel key



a) Access key removed, Personnel key trapped, Access door locked



b) Access key trapped, Personnel key removed, Access door open

Figure A.5 — Function of an access lock with personnel key

The door cannot be opened until the key is inserted and turned in the Access Lock (see Figure A.5).

This allows the Personnel Key to be turned and removed, releasing the actuator, and allowing the access door to be opened.

While the door is open the key in the Access Lock cannot be turned and released.

The Personnel Key is taken in the safeguarded area to prevent the key in the Access Lock being turned and removed.

Reinserting the actuator, through the action of closing the access door, allows the Personnel Key to be inserted.

When the Personnel Key has been inserted and turned, the key in the Access Lock can be turned and removed.

A.4 Key exchange device

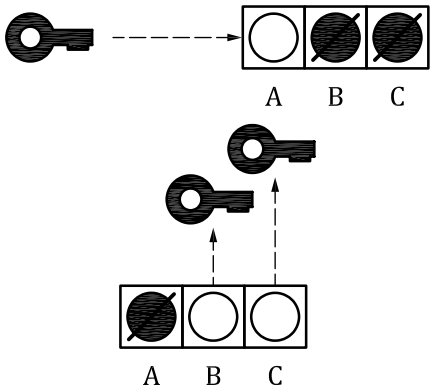


Figure A.6 — Key exchange device

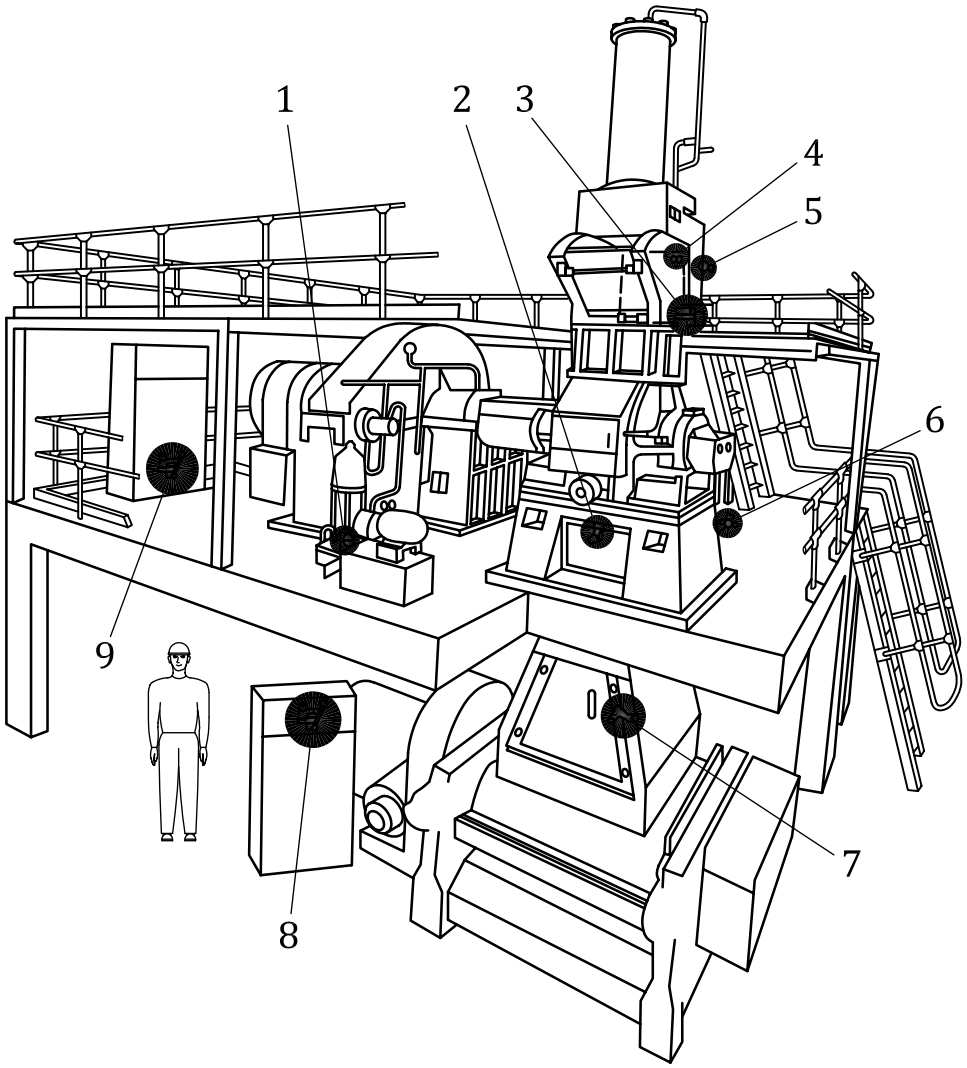
A key exchange device (see Figure A.6) allows keys to be trapped and freed in a pre-determined sequence.

In Figure A.8, Keys B and C can only be released when Key A is inserted and turned.

Key A can only be released when Keys B and C have been inserted and turned.

Key exchange devices are primarily used in applications with more than one energy source and/or more than one access door.

A.5 Mixing machinery — Trapped key system controlling multiple guards and sources of energy



Key

1 hydraulic accumulator drain valve
2 discharge guard (front and rear)
3 floating weight scotch pin
4 rear inspection door
5 compressed air three-way valve
6 drop door cam latch
7 chute access door
8 two roll mill isolator
9 isolator for main and hydraulic pump motors

Figure A.7 — Mixing machinery example

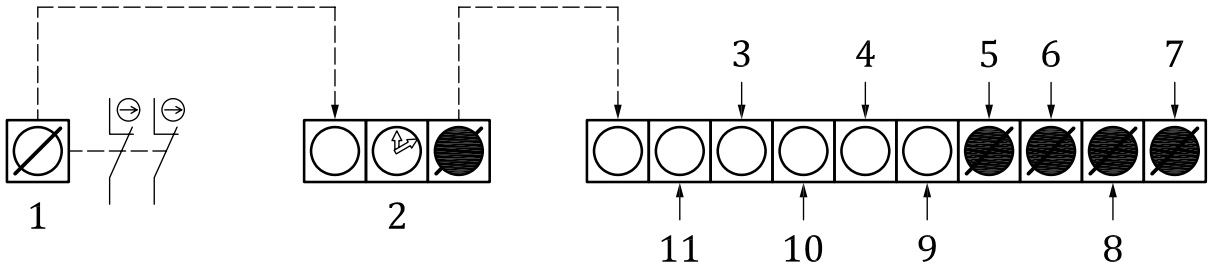
A simple trapped key interlocking system provides a practicable solution where multiple access points and multiple energy/power sources exist.

In the internal mixing machine example access to the four safeguarded areas is only possible when all sources of power are isolated, and all stored energy is dissipated. Keys are released from trapped key interlocking devices when each energy/power source is reduced to zero.

Where stored energy is present a time delay ensures the release of a key only after the energy has dissipated.

Mixing machinery example (continued)

All of the keys associated with energy sources shall be inserted into the key exchange device before the four keys are released to allow entry to the safeguarded area.



Key

1 isolator for main and hydraulic pump motors
2 timed delay device (not shown in Figure A.7)
3 three-way cock shutting off compressed air supply and discharging cylinders
4 drop door cam latch
5 rear inspector door
6 front discharge guard
7 chute access door
8 rear discharge guard
9 two-roll mill isolator
10 hydraulic accumulator drain valve
11 floating weight scotch pin

Figure A.8 — Showing the typical key transfer arrangement for mixing machinery example

Annex B
(informative)

FMEA analysis — Typical failure modes for consideration in trapped key systems

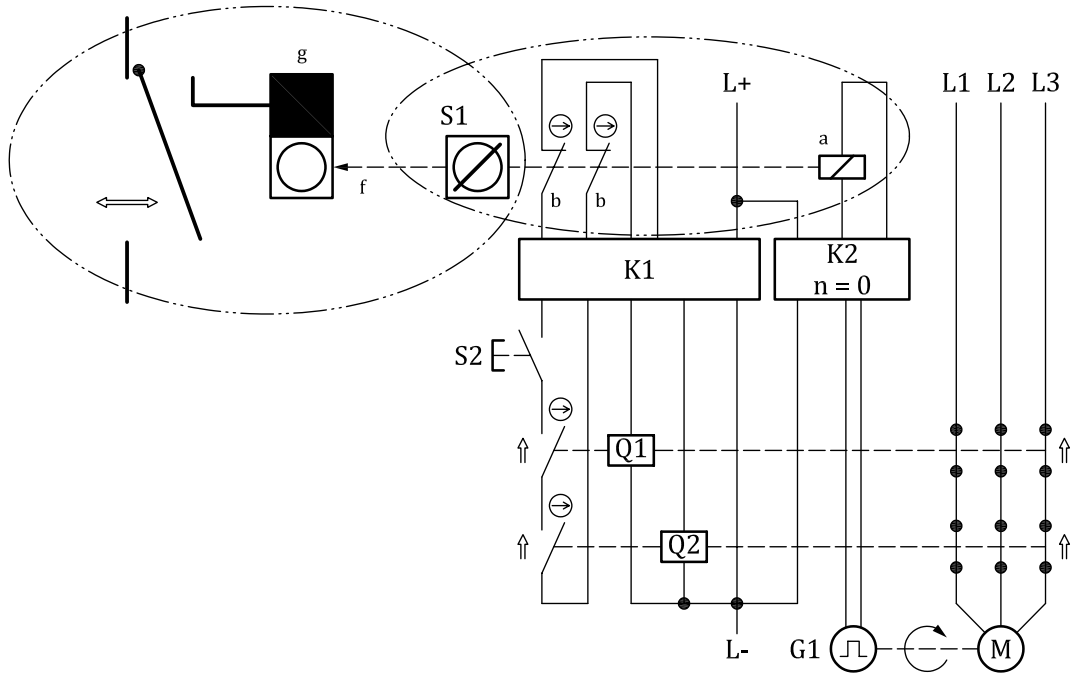
Faults to be considered include, but are not limited to, those given in ISO 13849-2:2012, Tables A.4 and A.5.

In addition, component movement caused by vibration or impact should be considered.

Annex C
(informative)

Safety functions and validation in accordance with ISO 13849-1 and ISO 13849-2

Using the simplified example below showing a machine with rundown time, an explanation is given how to divide the various safety functions and sub-systems.



Key

Q1	3 pole power contactor	a	solenoid
Q2	3 pole power contactor	b	solenoid monitoring contact
S1	key operated switch	f	key path
S2	reset device	g	access lock device
K1	logic unit		
M	motor		
$n = 0$	standstill monitoring logic		

Figure C.1 — Simplified diagram of the example of a guard locking trapped key application

The control system shown above depicts 2 safety functions:

1) Guard locking function. The guard cannot be unlocked until the machine is at rest.

2) Prevention of unexpected start-up (in an unlocked condition).

(For more information regarding this split in functionality, see ISO 14119:2013, 8.4)

Guard locking function

The Guard Locking safety function works as follows and is built from the following sub-systems (see Figure C.2):

The machine is switched-off through switch-disconnector Q1 or Q2, this causes the machine to run-down. When standstill is detected (n = 0), the standstill monitor enables the release of the key of the solenoid control switch. The released key can be removed and then used in the guard access lock to unlock the guard (see Figure C.3).

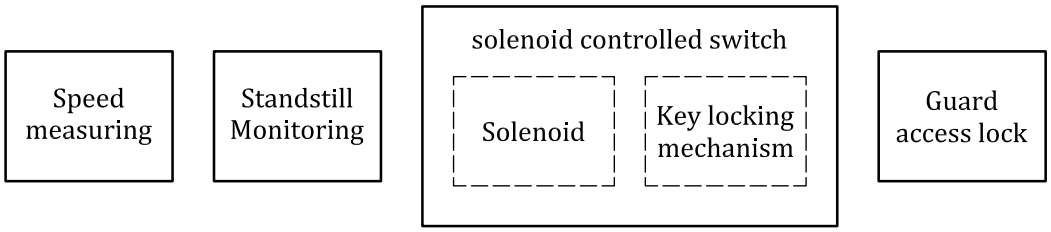


Figure C.2 — Reliability diagram for the guard locking function

Prevention of unexpected start-up (in an unlocked condition)

In the example of Figure C.1 the machine can only be started if

— the key is trapped in the solenoid controlled switch,

— Q disconnector switch is switched ON, and

— the reset actuator of the guard monitoring logic has been operated.

In the example the mechanism of the locking function of the solenoid controlled switch design, ensures that the failure of the solenoid is detected through the contacts (b) connected to the guard monitoring logic, preventing an unexpected start. The mechanical design of the solenoid controlled switch shall be such that it does not allow the locking mechanism to go to the locked position unless the key is in a trapped position.

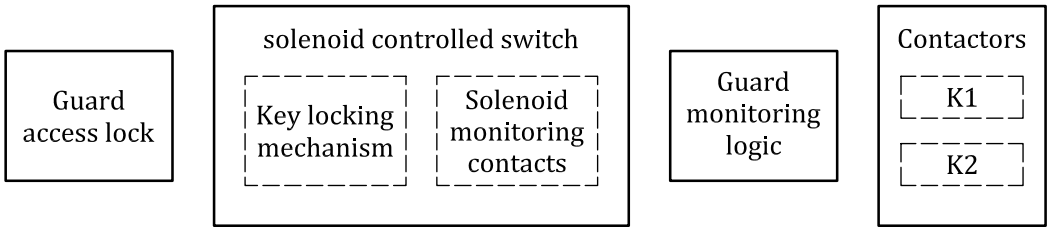


Figure C.3 — Reliability diagram for the prevention of unexpected start-up in an unlocked condition

Annex D
(informative)

Selection of trapped key interlocking devices

See Figure D.1.

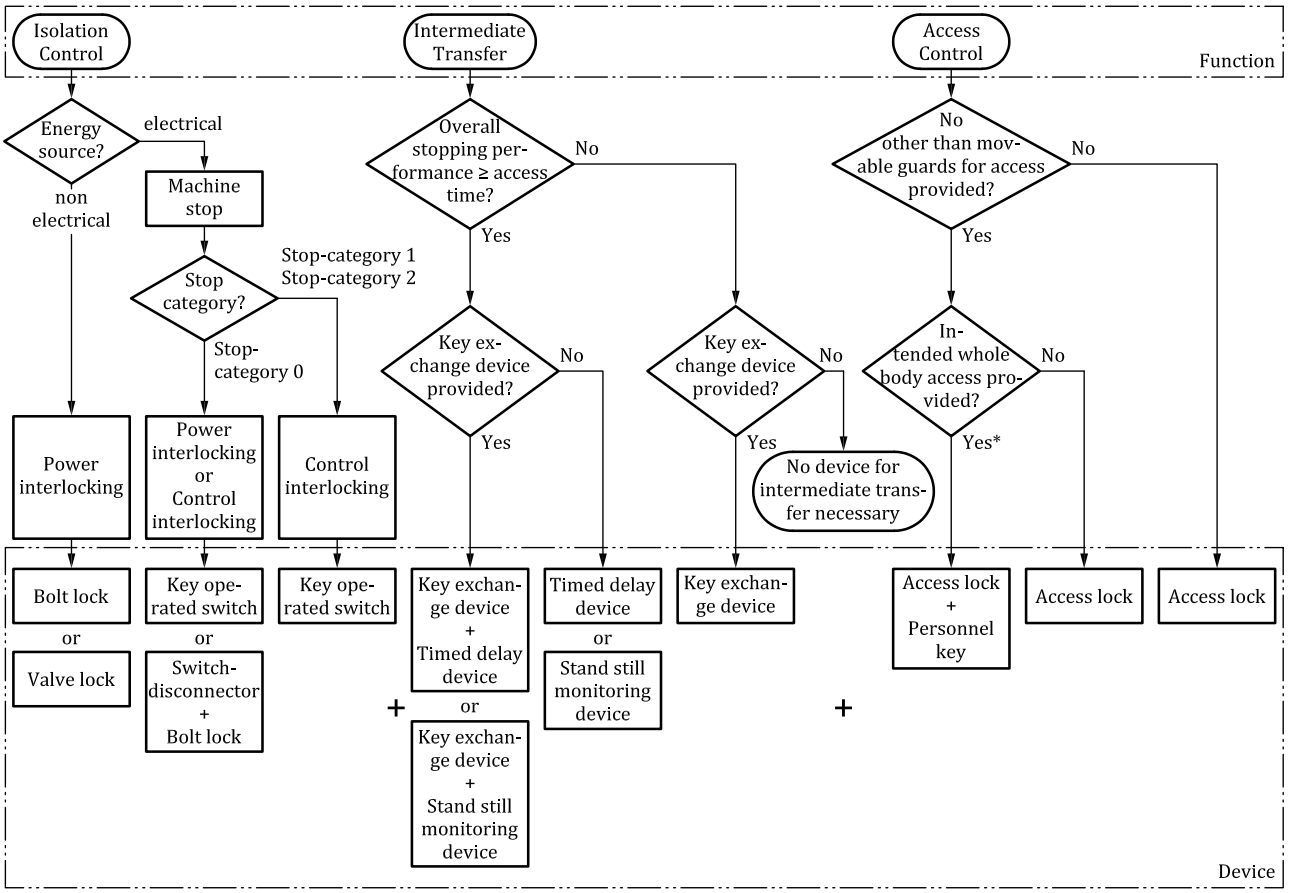


Figure D.1 — Example of a flow chart for selection of trapped key interlocking devices

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[7] GS-ET-15. *Principles of testing and certification for positively opening position switches*

[8] GS-ET-19. *Principles of testing and certification for interlocking devices with solenoid guard-locking*

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