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*Translation*

# Principles for the testing and certification of Trapped key interlocking systems

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We test for your safety.

# Introduction

By complying with the requirements of these principles of testing, which are substantially based on the technical rules listed in section 1.2, it can be assumed that the essential requirements of the German Product Safety Act (ProdSG), the 1st provision of ProdSG (1. ProdSV – Regulation on electrical equipment), the 9th provision of ProdSG (9. ProdSV – Regulation on machinery) and the law governing the electromagnetic compatibility of equipment (EMVG) have been fulfilled.

These principles of testing will become effective upon publication and are binding without a period of transition.

These principles will be revised and supplemented periodically in consideration of knowledge gained in the area of occupational safety and to keep pace with technical progress. The most recent edition will always be binding for tests carried out by the Electrical engineering testing and certification body within the Energy, textile & electrical media products department.

These principles of testing comprise the essential requirements and tests for verification that type 5 interlocking devices and trapped key interlocking systems may be introduced as safety components into the marketplace within the context of the Regulation on machinery.

**This is the English translation of the German test principle. The German original version is obligatory.**

**Changes with respect to Issue 2010-02**

– Fundamental revision
– Titles adapted to the terminology used in prEN ISO 14119.2:2022
– Text passages in blue are based on prEN ISO 14119.2:2022 (ISO/DIS 14119.2:2022)

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# 1 General

## 1.1 Scope of application

These principles of testing serve as a basis for the testing and certification of trapped key interlocking systems.

If applicable, further requirements may apply and further testing needed, depending on the technology and range of functions (e.g. in key design or signal processing).

## 1.2 Legal basis and Technical rules

The basis for these principles of testing is comprised of the EU directives, regulations, standards and specifications listed below.

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|---|---|
| 2006/42/EG | EC – Machinery directive |
| (EU) 2023/1230 | EU – Machinery regulation |
| DIN EN 894-3:2010-01 | Safety of machinery – Ergonomics requirements for the design of displays and control actuators – Part 3: Control actuators |
| DIN EN ISO 13849-1: 2023-12 | Safety of machinery; Safety-related parts of control systems – Part 1: General principles for design |
| DIN EN ISO 13849-2: 2013-02 | Safety of machinery; Safety-related parts of control systems – Part 2: Validation |
| DIN EN ISO 14119:2014-03 | Safety of machinery; Interlocking devices associated with guards – Principles for design and selection |
| prEN ISO 14119.2:2022 | Safety of machinery; Interlocking devices associated with guards – Principles for design and selection |
| DIN EN 60204-1 (VDE 0113-1):2019-06 | Safety of machinery; Electrical equipment of machines – Part 1: General requirements |
| DIN EN 60529 (VDE 0470-1):2014-09 | Degrees of protection provided by enclosures (IP code) |
| DIN EN 60695-2-10 (VDE 0471-2-10):2023-10 | Fire hazard testing – Part 2-10: Glowing/hot-wire based test methods – Glow-wire apparatus and common test procedures |

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|---|---|
| DIN EN 60695-2-11<br>(VDE 0471-2-11):2022-12 | Fire hazard testing –<br>Part 2-11: Glowing/hot-wire based test methods – Glow-wire flammability test method for end-products |
| DIN EN 60695-2-12<br>(VDE 0471-2-12):2022-11 | Fire hazard testing –<br>Part 2-12: Glowing/hot-wire based test methods – Glow-wire flammability index (GWFI) test method for materials |
| DIN EN 60695-2-13<br>(VDE 0471-2-13):2022-11 | Fire hazard testing –<br>Part 2-13: Glowing/hot-wire based test methods – Glow-wire flammability index (GWIT) test method for materials |
| DIN EN IEC 60947-1<br>(VDE 0660-100):2022-03 | Low-voltage switchgear and controlgear –<br>Part 1: General rules |
| DIN EN IEC 60947-3<br>(VDE 0660-107):2021-09 | Low-voltage switchgear and controlgear –<br>Part 3: Switches, disconnectors, switch-disconnectors and fuse-combination units |
| DIN EN 60947-5-1<br>(VDE 0660-200):2018-03 | Low-voltage switchgear –<br>Part 5-1: Control circuit devices and switching elements – Electromechanical control circuit devices |
| DIN EN 60068-2-1<br>(VDE 0468-2-1):2008-01 | Environmental testing –<br>Part 2-1: Tests – Test A: Cold |
| DIN EN 60068-2-2<br>(VDE 0468-2-2):2008-05 | Environmental testing –<br>Part 2-2: Tests – Test B: Dry heat |
| DIN EN 60068-2-6<br>(VDE 0468-2-6):2008-10 | Environmental testing –<br>Part 2-6: Tests – Test Fc: Vibration (sinusoidal) |
| DIN EN 60068-2-27<br>(VDE 0468-2-27):2010-02 | Environmental testing –<br>Part 2-27: Tests – Test Ea and guidance: Shock |
| DIN EN 60068-2-75<br>(VDE 0468-2-75):2015-08 | Environmental testing –<br>Part 2-75: Tests – Test Eh: Hammer tests |
| DIN EN 60068-2-78<br>(VDE 0468-2-78);2014-02 | Environmental testing –<br>Part 2-78: Tests – Cab test: Damp heat, steady state |
| DIN EN 61326-3-1<br>(VDE 0843-20-3-1):2018-04 | Electrical equipment for measurement, control and laboratory use – EMC requirements –<br>Part 3-1: Immunity requirements for safety-related systems and equipment intended to perform safety-related functions (functional safety) – General industrial applications |

| | |
|---|---|
| DIN EN 61000-6-7 (VDE0839-6-7):2015-12 [optional] | Electromagnetic compatibility (EMC) — Part 6-7: Generic standards – Immunity requirements for equipment intended to perform functions within a safety-related system (functional safety) in industrial locations |
| GS-ET-20:2020-04 | Supplementary requirements regarding the testing and certification of Safety relays |
| AfPS GS 2019:01 PAK 2020-04-10 | Testing and evaluation of polycyclic aromatic hydrocarbon (PAH) for the issuance of the GS-mark |

# 2 Terms

### 2.1 Trapped key interlocking system

A system fulfilling safety function(s) or part of one or more safety function(s) and comprising at least two different type 5 interlocking devices, which work together through the transfer of a key.

### 2.2 Type 5 interlocking device (interlocking device with a key transfer)

A device, which fulfils a function by trapping or releasing one or more keys in a given trapped key interlocking system.

NOTE Type 5 interlocking devices are components within the trapped key interlocking system, such as a key-operated switch or a key exchange device).

### 2.3 Key-operated switch (key-operated switch as part of a tapped key interlocking system)

An interlocking device with key transfer comprising a switch, which can only be operated by means of a key.

### 2.4 Key-operated solenoid-controlled switch (Key-operated solenoid-controlled switch as part of a trapped key interlocking system)

An interlocking device with key transfer comprising a key-operated switch, which can be mechanically locked by the operation of a solenoid.

### 2.5 Key

The key is the element, with which the lock with matched coding can be actuated.

### 2.6 Key exchange device

An interlocking device with key transfer, in which the insertion of one or more keys releases one or more keys with a different coding, trapping the inserted keys.

### 2.7 Access lock

A device intended to lock a guard in the closed position, and is linked to the control system via the key transfer.

NOTE Access locks can also be used for locking objects in position other than guards, such as disconnectors, valves or barriers.

### 2.8 Actuator

A separate part of an interlocking device, which transmits the state of the guard (closed or not-closed) to the actuation system.

Example:
A guard-mounted cam, a shaped tongue, a reflector, a magnet or an RFID tag.

NOTE A key used in a trapped key interlocking system is not covered by this definition.

### 2.9 Blocking mechanism

A blocking mechanism is that part of the access lock, which holds an actuator in the protective position and can be released only by actuating the lock.

### 2.10 Lock bolt (locking device)

The lock bolt is that part of the Key-operated solenoid-controlled switch, which prevents actuation of the lock to release the key.

### 2.11 Control switch with direct opening action

A control switch with one or more breaker contacts, which are connected to the switch operating element via non-spring-action parts in such a manner that the breaker contact(s) is/are fully open when the operating element has travelled through the direct opening path with a force specified by the manufacturer.

### 2.12 Switch-disconnector

Switch, which, in the open position, satisfies the isolating requirements for a disconnector.

### 2.13 Direct opening action (of a contact element)

Guarantee of contact separation resulting directly from a defined movement of the switch operating element via non-spring-action parts (e.g. not dependent upon a spring).

### 2.14 Interlocking device

A mechanical. electrical or other type of device, which has the purpose of preventing the execution of hazardous machine functions under specified conditions (in general, this would mean as long as the guard is not closed).

### 2.15 Bolt lock

An interlocking device with a key transfer, which extends a bolt to lock an object.

Example:
Bolt locks can be used to lock devices, such as switch-disconnectors, valves or sliding doors.

**2.16 Timed delay key release**

An interlocking device with a key transfer, which releases a key after a pre-determined period of time has elapsed.

**2.17 Defeat (Defeat in a reasonably foreseeable manner)**

Reasonably foreseeable action, either manually or by using readily available objects, 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 protective measures.

**2.18 Mechanical service life**

The mechanical service life of a component is an indication of its resistance to wear. It is determined by the number of switching cycles without electrical loading, for which the component is designed.

**2.19 Electrical service life**

The electrical service life of a device is expressed by the number of switching cycles, which can be performed under load according to the operating conditions prescribed in DIN EN 60947-5-1, without the need for repair or replacement parts.

**2.20 Coding levels**

2.20.1 Coded actuator with a low coding level

Coded actuator, for which 1 to 9 coding options are available.

2.20.2 Coded actuator with a medium coding level

Coded actuator, for which 10 to 1,000 coding options are available.

2.20.3 Coded actuator with a high coding level

Coded actuator, for which more than 1,000 coding options are available.

**2.21 Safety-related part of a control system (SRP/CS)**

Part of a control system that responds to a safety-related input signal and generates a safety-related output signal.

**2.22 Key transfer plan**

A drawing, schematic or diagram depicting the trapped key interlocking system together with its individual type 5 interlocking devices and the sequence(s) in which they are to be operated.

# 3 Documents to be submitted

The following documents must be submitted as a minimum in support of technical testing:

- All information supplied with the trapped key interlocking system (e.g. operating instructions, installation instructions, maintenance procedures, etc.)
- Sales literature
- Block circuit diagram
- Electric circuit diagram (if necessary)
- Technical drawings
- Parts list
- Strength calculations
- Technical documentation in accordance with DIN EN ISO 13849-1, sec. 12
- Data sheets for components used
- Key transfer plan

The testing facility can request further documentation if deemed necessary.

# 4 Requirements and tests

## 4.1 General test requirements

Trapped key interlocking systems must, where applicable, fulfil all of the requirements that follow. A test object must not fail any of the tests.

Manufacturer specifications that go beyond the minimum requirements below must be verified separately.

Testing must be carried out on complete trapped key interlocking systems according to the rating data declared by the manufacturer. The test values for electrical components may deviate from the rating data as follows:

| | |
|---|---|
| Limit deviations for electrical test values: | DIN EN IEC 60947-1, table 18 |
| Limit deviations for mechanical test values: | ± 10 % |

Unless otherwise specified in the individual test instructions, proper functioning of the trapped key interlocking system must be ascertained prior to the initial test, as well as subsequent to each individual test.

## 4.2 Labels and markings

Each trapped key interlocking system must be labelled with the following discernible, clearly legible (e.g. font height = 2 mm with good contrast) and durably marked inscriptions:

Test: Visual inspection, check for completeness, correctness and consistency of information, measurement of font height, rubbing test (gently rub using two cotton cloths, one soaked in water and the other in a test fluid*) for 15 s each).

The markings must still be clearly legible following the test. It must not be possible to easily remove the marking labels, nor should they be wrinkled or creased.

*)The chemical product with the trade name “n-Hexan for analysis“, which fulfils the requirements regarding the test fluid defined in DIN EN 60335-1 and DIN EN 62368-1 shall be used as test fluid.

4.2.1 On each type 5 interlocking device in the system:

- Manufacturer's/authorised representative's company name and complete address
- Designation of the safety component (e.g. Key-operated switch)
- CE markings
- Design series or type designation
- Serial number, as appropriate
- Year of manufacture
- IP-Protection class (for electrical/electronic components)

4.2.2 On an arbitrary type 5 interlocking device in the system:

- Designation of the system (e.g. trapped key interlocking system)

4.2.3 Direct opening control switch

- Marking in accordance with DIN EN 60947-5-1

4.2.4 Switch-disconnector

- Marking in accordance with DIN EN IEC 60947-3

4.2.5 Key

- Company name or mark of origin
- Marking for key assignment (e.g. inscription)

4.2.6 Access lock

In addition to sec. 4.2.1, if applicable:

- Symbol for direct opening [IEC 60617-S00226(2001-07)]
-  Symbol for monitoring of the access lock (marking of direct opening contacts used for locking device monitoring)
  NOTE As an alternative, the symbol can be included in the Operating instructions (DIN EN ISO 14119, fig. 13).
- Symbol for Protection class II or III
- IEC 60947-5-1 or DIN EN 60947-5-1, if the manufacturer claims conformity with this standard, as well as applicable markings in accordance with DIN EN 60947-5-1
- Locking force F (preferred value: ≥ 1000 N)
- The prescribed locking force F must be ≤ the force $F_{ZH}$ as determined by testing! (refer also to sec. 4.10)
  NOTE This information can also be provided exclusively in the Operating instructions
- Changeover contact elements must be marked with the relevant symbols for the Za- or Zb-mode in accordance with DIN EN 60947-5-1, fig. 4.
- For access locks with emergency release: A notice that the emergency release is only to be used in the event of an emergency
  NOTE As an alternative, this notice can be provided by the User (refer to Sec. 4.3).

4.2.7 Other electric/ electronic type 5 interlocking devices (e.g. timed delay key release, bolt lock with monitoring, key-operated solenoid-controlled switch)

In addition to sec. 4.2.1, if applicable:

- Symbol for Protection class II or III
-  Symbol or monitoring of the locking device (marking of direct opening contacts used for monitoring the locking device)
  NOTE As an alternative, the symbol can be included in the operating instructions (DIN EN ISO 14119, fig. 13).
- Symbol for direct opening [IEC 60617-S00226(2001-07)]
- IEC 60947-5-1 or DIN EN 60947-5-1 if the manufacturer claims conformity with this standard, as well as applicable markings in accordance with DIN EN 60947-5-1
- Changeover contact elements must be marked with the relevant symbols for the Za- or Zb-mode in accordance with DIN EN 60947-5-1, fig. 4

## 4.3 Operating instructions

The trapped key interlocking system shall be accompanied by the information required for proper connection and commissioning.

Safety-related information must be provided in a language acceptable in the country, in which the trapped key interlocking system is to be installed.

If the operating instructions are not in German, a German translation must be provided. Testing will be carried out with reference to the German translation.

The operating instructions supplied with the trapped key interlocking system must contain the following characteristic features of that system, where applicable:

- Annotation: “Original operating instructions“ or “Translation“
- Manufacturer's/authorised representative's company name and complete address
- Design series or type designation
- Nomenclature of the safety component
- Declaration of conformity or a rendering of the content found in the Declaration of conformity (except for serial number and signature)
- General description and intended use, instructions for assembly and for installation
- Maintenance procedures and setting instructions (if necessary)
- Description of fault characteristics (if necessary)
- Information regarding conductor type, as well as the largest and smallest conductor cross-sections for which the connecting clamps are suitable
- Scope of actuation system coverage. For example, the minimum actuating radius for curved or pre-stressed actuators and, if applicable, the maximum actuating radius
- For delay mechanisms: Specification of time-delay
- Locking force F (preferred value: ≥ 1000 N; also refer to sec. 4.10), as well as for other movement directions, if applicable
- Coding level (low, medium, high in accordance with DIN EN ISO 14119) for individually coded actuators
- Specification of the $B_{10d}$ value
- The following specifications in accordance with DIN EN ISO 13849-1:
  – Category
  – PL
  – $MTTF_D$ or PFH or $PFH_D$
- Terminal connection diagram/circuit diagram
- Exemplary applications
- Key transfer plan, additional functional description, if applicable
- Warning notice related to foreseeable misuse
- Warning notice related to coding allocations, if necessary (refer to sec. 4.6.6.1)
- Specification of the safety function(s)
- Notice regarding integration of delay mechanisms related to time response
- Information regarding residual risks
- IP-Protection class
- Notice to the user that the overall concept, into which the trapped key interlocking system is to be integrated, must be validated in accordance with DIN EN ISO 13849-2, as well as with an exemplary calculation for determining the PL for the overall concept

- Information regarding the framework conditions, under which the PL has been determined (incl. explanation of fault exclusions); refer to the Notice in sec. 4.15 of these Principles of testing
- Information regarding the environmental conditions, within which the trapped key interlocking system may be deployed
- Notice that, if, as a result of the risk assessment, it cannot be discounted that persons can become trapped inside a danger area, then guard-locks with supplemental keys requiring removal (personal keys) must be used, or comparable measures must be taken
- The information listed in DIN EN 60947-5-1, sec. 5.1 and K.5.4, or in DIN EN IEC 60947-3, sec. 6.1 may also be included in the product documentation that accompanies the operating instructions
- Notice regarding repairs
- Notice regarding functional testing prior to initial commissioning, as well as recurrent testing
- Notice signifying that the requirements stipulated in prEN ISO 14119.2; in particular those in sec. 8 "Design to minimize the motivation to defeat" must be considered during installation and operation
- Notice regarding potential constraints on the operating location, in particular with respect to anticipated functional disruptions when the device is used in heavily contaminated environments
- Notice regarding potential constraints on the scope of application; in particular with respect to influences related to contamination (e.g. by swarf, dust, moisture).
- Notice regarding the proper attachment and fixing of the access lock according to manufacturer specifications, incl. actuator, and the bolt lock.
- Notice signifying that the access lock, incl. actuator, and the bolt lock, must be configured (and protected in necessary) in such a manner that a failure due to foreseeable external influences (e.g. mechanical impact) is prevented
- Notice signifying that, following assembly, the access point to the auxiliary release must be sealed in a tamper-proof manner in order to prevent its use for normal operational purposes
- For access locks with an escape release: Notice signifying that the control actuator must be configured in such a manner that actuation is possible only from the escape side (danger area)
- For access locks with an emergency release: Notice signifying that the emergency release is to be installed and/or protected in such a manner that unintentional opening of the access lock is prevented
- For access locks with an emergency release **and** where application of this notice on the enclosure is not practicable (refer to sec. 5.2.1): Notice to the user that, when an emergency release is provided, it must be clearly marked to indicate that it be used only in the event of an emergency. This notice can be annotated on a separate placard affixed in close proximity to the emergency release.
- Notice signifying that the availability of spare actuators and keys makes it possible to easily defeat the safety devices. For this reason, it must also be noted that their availability will be controlled through organizational measures. The same applies to the keys used for resetting the emergency or the escape releases.

Test: Visual inspection and check for completeness, correctness and consistency

### 4.4 Sales literature

Sales literature, in which the safety component is described, must not contradict the operating instructions with respect to its usage. Sales literature must contain all necessary information for selecting the trapped key interlocking system, including the specifications of the safety-relevant function(s)

Test: Visual inspection and check for completeness, correctness and consistency

### 4.5 Requirements regarding switch construction and characteristics

Only direct opening control switches or load break switches may be used within the trapped key interlocking system for integration into safety circuitry.
Other switches may also be used for reporting purposes.

4.5.1 Direct opening control switches in accordance with DIN EN 60947-5-1

Direct opening control switches must conform to the requirements stipulated in DIN EN 60947-5-1, incl. annex K.

Test: Testing in accordance with DIN EN 60947-5-1, incl. annex K

4.5.1.1 Types of contact elements on control switches

The requirements of DIN EN 60947-5-1, sec. K7.1.4.6.1 are supplemented as follows:

If the switching element is configured with C- or Za-mode changeover contacts, and the break-contact is used for a safety function, then the make-contact must not be occupied (not connected/clamped). The operating instructions must contain an appropriate notice to this effect.

Test: Visual inspection of the switch contacts and review of the technical documentation

4.5.2 Load break switches in accordance with DIN EN IEC 60947-3

Load break switches must conform to the requirements stipulated in DIN EN IEC 60947-3.

Test: Visual inspection of the technical documentation; testing in accordance with DIN EN IEC 60947-3

### 4.6. Provisions for the design of Trapped-key interlocking systems

4.6.1 Configuration and mounting of switches with safety applications

4.6.1.1 Load break switch

The following requirements apply:

- The switch enclosure must be form-fitted to the lock casing. The force transmission between the lock and the switch must be realized in a positive manner. The connection and transmission elements must be able to withstand a tensile force of 250 N (linear key) or a torque force of 5 Nm (rotary key) accordingly without damage.

- The switch must be mounted in such a manner that its actuation shaft and lock attachment are aligned along a central axis and the shaft will not be exposed to bending loads.
  Linear actuators may be subject to additional requirements.

- All connections must be protected against self-loosening.

Test: a) Visual inspection, functional check, review of the drawings, parts lists and strength calculations
b) Torque or tensile testing (load increase max. 1 Nm/s or 50 N/s accordingly) without permanent deformation of a component
c) If system behaviour should attain to category 3 or 4 (refer to sec. 4.15), then test validation shall be confirmed with 2 or 4 times the load values.

4.6.1.2 Control switch with direct opening action

The switch must:

- have a clearly defined position
- require a tool for release
- be protected against self-loosening
- ossess sufficient strength in order to warrant fault-free operation.

Test: Visual inspection, functional check, review of the drawings and parts lists

4.6.2 Control cam configuration and mounting

The control cam must:

- require a tool for release
- be protected against self-loosening
- neither damage nor impair the service life of the direct opening control switch or the locking device.

Test: Visual inspection, functional check, review of the drawings and parts lists

4.6.3 Access lock/Bolt lock

The access lock actuator must initiate the guard-locking function through the positive engagement of a rigid part.

All parts of the guard-locking mechanism intended for blocking the actuator must be positive locking.

The mounting elements for the bolt lock and access lock, incl. actuator, must function reliably.

If the bolt lock/access lock is configured with provisions for component position adjustment (e.g. elongated holes), then additional measures must be provided to warrant the positive fixing in position (e.g. boreholes in combination with non-removable mounting elements, bolts or dowel pins).

An elongated hole must not be used as the sole point of attachment for either the bolt lock or the access lock.

Self-loosening of the access lock, incl. actuator, and the bolt lock must be prevented.

On a rotary actuator, all parts foreseen for blocking the actuator must be able to withstand a torque of 5 Nm applied to the actuator.

NOTE 1 The torque test must be carried out on a new prototype.

NOTE 2 On linear actuators, the strength of the blocking mechanism shall be verified solely with reference to sec. 4.10 of these principles of testing.

Test: Visual inspection, review of the drawings, parts lists and strength calculations and, if necessary Torque test: If system behaviour should attain to category 3 or 4 (refer to sec. 4.15), then test validation shall be confirmed with 2- or 4-times the load values.

### 4.6.4 Delay mechanism

#### 4.6.4.1 Delay time

The prescribed delay time for delay mechanisms must not be exceeded.

Test: Functional test, time measurement

### 4.6.5 Key-operated solenoid-controlled switch

#### 4.6.5.1 Requirements regarding the locking mechanism

##### 4.6.5.1.1 Spring-operated locking mechanisms

The locking mechanism must function in a positive manner through the engagement of a rigid part.

The lock bolt (locking device) must be held in the locked position by spring force.
Springs used to hold the lock bolt in the locked position must be tried and tested springs in the context of DIN EN ISO 13849-2, annex A, table A.2.
The lock bolt must be designed in such a manner that it will withstand the forces anticipated during normal operation of the key-operated solenoid-controlled switch.

Test: Visual inspection, review of the data sheets, testing within the framework of sec. 4.17 of these principles of testing and, if necessary, simulation of spring breakage

##### 4.6.5.1.2 Electromagnetic actuation of the locking mechanism

Electromagnetic actuation of the locking mechanism must function as intended, even with fluctuation of the rated operating voltage.

Test: Review of the data sheet and operation of the locking mechanism at 85% and 110% of the rated operating voltage

4.6.5.1.3 Position monitoring of the lock bolt (locking device)

Switch-On commands for hazardous situations may be rendered effective only when the key is in the key-operated solenoid-controlled switch lock, the switch is in the ON-position and the lock bolt is in the locked position. This requires position monitoring of the lock bolt, such as with at least one direct opening control switch in accordance with DIN EN 60947-5-1, annex K.

Test: Visual inspection, review of the data sheets and functional testing

4.6.5.2 Optional components for the key-operated solenoid-controlled switch

If standstill monitors or safety relays with drop-out delay contacts are integral to the key-operated solenoid-controlled switch, then these must conform to the requirements of GS-ET-20.

Test: In accordance with GS-ET-20

4.6.6 Protection against defeating

Trapped key interlocking systems must be designed in such a manner that the safety function cannot be defeated by reasonably foreseeable means.

The general requirements stipulated in prEN ISO 14119.2, sec. 8.3 and 8.4 for the protection against defeating must be taken into consideration.

Special consideration must be given to the following elements:

- Keys
- Locks
- Blocking mechanisms
- Actuators

General provisions for conducting the tests:

Testing will be carried out without a deep understanding of the functional principle of the components, by hand or with the use of readily available objects in accordance with DIN EN ISO 14119.

The use of two similar objects is permissible, if their design provides an obvious potential for defeating with the two objects.

Examples of readily available objects are:

- Screws, needles, sheet-metal blanks
- Everyday items, such as keys, coins, adhesive tape, packing twine and wire
- Tools (e.g. screwdrivers, wrenches, hexagonal spanners and pliers)
- Objects that can be easily assembled by hand without the use of other tools or appliances (e.g. hand-formed wire or sheet metal, folded paper)

Objects designed especially for defeating and fabricated only with tools or appliances requiring more than one work-step are not considered readily available objects.

4.6.6.1 Keys

- must fit only into their individually corresponding lock (coding).
- must be removable only from the position assigned to the defined safety function
- must not be duplicable (e.g. by a locksmith (This means a special person/service only for making keys) or with hand tools)

Test: a) Analysis of the coding system/process
b) Test by using keys with different codes

4.6.6.2 Locks

Lock actuation must only be possible with its corresponding key.

Test: Attempt to defeat using readily available objects

4.6.6.3 Blocking mechanisms

- Removal of the access lock key must only be possible when its corresponding actuator is in the protective position.
- It must not be possible to defeat the blocking mechanism with readily available objects that simulate the actuator.
- It must not be possible to loosen the mounting elements for the blocking mechanism enclosure by hand and it shall be protected against removal.

Test: In accordance with sec. 4.6.6 of these principles of testing

4.6.6.4 Actuators

It must not be possible to loosen the mounting elements for the actuator by hand and it shall be protected against removal.

If the manufacturer provides mounting screws for the actuator, these must be either one-way screws or screws with a comparable protective function.

It must not be possible to tamper with the actuator assembly with the goal of defeating it using readily available objects.

The coding process must be suitable for realizing the coding levels as prescribed in the operating instructions.

The number of possible codes must agree with the prescribed coding level.

If applicable, when products of any coding level are delivered, it must be ensured that a sufficient statistical mix of differing codes is available.

Test: a) Visual inspection of the mounting screws, if supplied
b) In accordance with sec. 4.6.6 of these principles of testing
c) Plausibility check based on the coding process as described and four differently coded test specimens
d) Plausibility check of the description of the measures prescribed for achieving a sufficient statistical mix

NOTE The requirements/tests prescribed for a sufficient mix of differing codes are dependent upon the number of different codes. These requirements are not applicable if only one code is realized.

## 4.7 Mechanical strength

The components comprised in the trapped key interlocking system must possess sufficient mechanical strength with respect to the stress loads anticipated with proper usage, such as jolting, shock or impact.

Test: Individual testing in accordance with sect. 4.7.1 and 4.7.2 of these principles of testing

General evaluation criteria following each individual test:

1. It must not be possible to physically touch active electrical components.
2. No components should have loosened or become detached.
3. No safety-relevant damage must have occurred
4. The proper function must still be fulfilled.

| **Component test** | |
|---|---|
| I.<br>Continuous vibration:<br><br>Test standard<br>Frequency range<br>Amplitude<br><br>Frequency cycle count<br>Throughput speed | <br><br><br>DIN EN 60068-2-6<br>10–100 Hz<br>(0,35 mm /5g) ± 15 %<br><br>at the reference point 20<br>1 octave/min |
| II.<br>Individual shock:<br><br>Test standard<br>Type of shock<br>Shock amplitude<br>Shock duration<br>Number of shocks | <br><br><br>DIN EN 60068-2-27<br>Half-sine wave<br>30 g<br>1 ms<br>3 per axis (3 shocks each in both directions per axis) |

| Component test | |
|---|---|
| III.<br>Continuous shock: | |
| Test standard | DIN EN 60068-2-27 |
| Type of shock | Half-sine wave |
| Shock amplitude | 10 g |
| Shock duration | 16 ms |
| Shock cycle | (1–3)/s |
| Number of shocks | 1000 ± 10 (in both directions per axis) |

**Table 1:** Test parameters for vibration and shock loading

4.7.1 Test of resistance to vibration and shock

All components comprised in the trapped key interlocking system shall be subjected to stress loading on all three axes in accordance with table 1. A change in contact behaviour must not occur during testing. The components are to be tested as follows:

a) Key-operated switch

With the key removed

The monitoring equipment must be capable of detecting any closing or opening of the electrical contacts exceeding 0.2 ms in duration.

When testing is completed, the evaluation criteria must have been fulfilled in accordance with sec. 4.7 of these principles of testing.

b) Access lock, Bolt lock

With the key removed

Monitor the electrical contacts, if these are present.
The monitoring equipment must be capable of detecting any closing or opening of the electrical contacts exceeding 0.2 ms in duration.

When testing is completed, the evaluation criteria must have been fulfilled in accordance with sec. 4.7 of these principles of testing.

c) Key exchange device

With the releasing key removed; the releasable key inserted.

When testing is complete, the evaluation criteria must have been fulfilled in accordance with sec. 4.7 of these Principles of testing.

d) Key-operated solenoid-controlled switch

With the key removed

The monitoring equipment must be capable of detecting any closing or opening of the electrical contacts exceeding 0.2 ms in duration.

When testing is completed, the evaluation criteria must have been fulfilled in accordance with sec. 4.7 of these principles of testing.

e) Delay mechanism

With the releasing key removed; the releasable key inserted.

When testing is completed, the evaluation criteria must have been fulfilled in accordance with sec. 4.7 of these principles of testing.

4.7.2 Test of resistance to impact

Each component in the trapped key interlocking system shall be subjected to three blows of 1 J (Nm) at an accessible location when installed and at a point considered most critical, using an impact testing device in accordance with DIN EN 60068-2-75, sec. 6. Particular attention should be paid to the insulating materials used to shroud or enclose live components.

Test: In accordance with DIN EN 60068-2-75 – Test Ehb, with a spring hammer

Testing is carried out after 2 hours of storage at the manufacturer's specified minimum operating temperature.

The impact test must begin within 1 min after removal from the climatic exposure test cabinet.

When testing is completed, the evaluation criteria must have been fulfilled in accordance with sec. 4.7 of these Principles of testing.

## 4.8 Environmental influences

Trapped key interlocking systems must fulfil their function throughout the manufacturer's prescribed scope of application.

The following requirements must be fulfilled as a minimum:

**Indoor applications:**

Temperature range: -5 °C to + 40 °C

**Indoor and outdoor applications:**

Temperature range: -25 °C to + 70 °C

Test: Review of the data sheets for components used and assessment of proper selection

The components of the trapped key interlocking system will be stored in a test chamber for 48 hours at the lower or upper limits of the temperature range, accordingly, based on DIN EN 60068-2-1: Test Ab: Cold, or DIN EN 60068-2-2: Test Bd: Dry heat. If the manufacturer specifies different values, then the tests shall be carried out at those values.
A functional check shall be made following storage. Testing must begin within 3 minutes after removal from the test chamber.

### 4.9 Resistance to damp heat and insulation properties

Electrical components must be configured in such a manner that they are sufficiently humidity-resistant and voltage-stable.

Test: The key-operated switch will be stored in a test chamber for 48 hours at a temperature of (40 ± 2) °C and a relative humidity of (93 ± 3) % based on DIN EN 60068-2-78. If the manufacturer specifies values that exceed the minimum values specified above, then those values shall be used.

Following the storage period, an insulation test shall be carried out in accordance with DIN EN IEC 60947-1, sec. 9.3.3.4.1.

Testing must begin within 3 minutes after removal from the test chamber.

For components with Protection class II, the test voltage for double or reinforced insulation must be chosen in accordance with DIN EN 60947-5-1, sec. F.7.3.

### 4.10 Locking force

Access locks must be designed in such a manner that the forces occurring (e.g. tensile or transverse forces) will not result in failure of the locking function.

The forces, or their effective direction of exposure accordingly, which occur with intended usage and which could result in failure of the locking function must be identified. A test of the locking force shall be carried out for each of these forces and their effective direction of exposure.

NOTE This means that, in configurations where the direction of safeguard (door) opening differs from the direction of actuator movement, for example, a locking force test shall be carried out in at least both of these directions.

With respect to sec. 4.2.6 of these principles of testing, the manufacturer must indicate the locking force F on the enclosure from that effective direction, at which it is at its lowest. Locking force F must be ≤ force $F_{ZH}$, as determined by the following test:

Test: Testing must be carried out on an unused test object in as-new condition. The access lock must be properly attached to a base. It is subsequently loaded until failure of the locking function by moving the locking element at the maximum actuating angle and at a constant speed in the direction “Safeguard open“. With loading applied, the maximum force $F_{TEST}$ will be measured along the deformation pattern.

If system behaviour should attain to category 3 or 4 (refer to Sec. 4.15), then test validation shall be confirmed with 2 or 4 times the load values.

Based upon the maximum force $F_{TEST}$ measured during testing, the force $F_{ZH}$ will be determined according to the following formula with inclusion of the safety coefficient S:

$$F_{ZH} = \frac{F_{TEST}}{S}$$

**Safety coefficient:**
S = 1.3

**Requirements regarding the test equipment:**
ensile velocity: constant 10 mm/min (± 2,5 %)

**Requirements regarding the force measurement equipment:**
Sampling rate: ≥ 10 Hz
Measurement accuracy at maximum force: ± 2,5 %

## 4.11 Mechanical service life

The mechanical service life for each system component must equate to a minimum of 200,000 switching cycles, to be verified respectively on the test object.
Wearing parts must not exhibit any abrasion which could jeopardize the safety function.

### 4.11.1 Key-operated switches, Bolt locks

Test: The test of mechanical service life shall be carried out on the key-operated switch or bolt lock through intentional actuation.
When testing is completed, it must not have been possible to remove the key from the lock up to the test load (refer to sec. 4.16 of these Principles of testing). The key-operated switch must function properly subsequent to the stress loading.

Furthermore, testing shall be carried out in accordance with sec. 4.6.6 of these principles of testing (Protection against defeating by reasonably foreseeable means).

### 4.11.2 Key-operated solenoid-controlled switch

Test: The test of mechanical service life shall be carried out on the key-operated solenoid-controlled switch through intentional actuation.
When testing is completed, it must not have been possible to remove the key from the lock up to the test load (refer to sec. 4.16 of these principles of testing). The key-operated solenoid-controlled switch must function properly subsequent to the stress loading.

Furthermore, testing shall be carried out in accordance with sec. 4.6.6 of these principles of testing (Protection against defeating by reasonably foreseeable means).

4.11.3 Key exchange device

Test: The test of mechanical service life shall be carried out exclusively on those elements required for realization of the safety function.
When testing is completed, proper logical process sequencing must still be warranted.

4.11.4 Access lock

Test: The test of mechanical service life shall be carried out exclusively on those elements required for realization of the safety function.
When testing is completed, proper functioning must still be warranted.

Furthermore, testing shall be carried out in accordance with sec. 4.10 of these principles of testing.

## 4.12 Heat-filament test

DIN EN 60947-5-1, sec. 7.1.2.2, a) to c) apply.

Insulating materials used to fix current-conducting components in place must prove suitable at a test temperature of 750 °C, while all other insulating materials must prove suitable at a test temperature of 650 °C.

Test: In accordance with DIN EN 60947-5-1, sec. 8.2.1.1.1 in agreement with DIN EN 60695-2-10 to DIN EN 60695-2-13

## 4.13 Electromagnetic compatibility (EMC)

With regard to immunity to interference and in addition to the respective product standards, the components of the trapped key interlocking system must also fulfil enhanced immunity requirements. Purely mechanical components are excluded from this requirement.

Test: Refer to the product standard and DIN EN 61326-3-1 or, as an alternative, DIN EN 61000-6-7

## 4.14 Electrical equipment

The electrical equipment used in the trapped key interlocking system must conform to the relevant requirements of DIN EN 60204-1, with specific reference to:

- Section 5 “Incoming supply conductor terminations and devices for disconnecting and switching off“
- Section 6 “Protection against electric shock“
- Section 7 “Protection of equipment“
- Section 8.2 “Protective bonding circuit“
- Section 9 “Control circuits and control functions“
- Section 10 “Operator interface and machine-mounted control devices“
- Section 11 “Controlgear: location, mounting, and enclosures“
- Section 12 “Conductors and cables“
- Section 13 “Wiring practices“
- Section 17 “Technical documentation“
- Section 18 “Verification“ – Continuity of the protective bonding circuit and insulation-resistance test

Test: Visual inspection, review of the data sheets and testing in accordance with DIN EN 60204-1, sec. 18

4.14.1 Mechanical properties of electrical connectors

4.14.1.1 Terminal connections inside enclosures or intended for such use

Terminal connections must be able to securely take up the cables prescribed by the manufacturer.

Test: In accordance with DIN EN IEC 60947-1, sec. 9.2.5.2 and 9.2.5.5 to 9.2.5.8

4.14.2 Space for cabling

The space provided for cabling must be sufficiently dimensioned. Proper connection of the conductors must be clearly possible.

Test: Visual and handling inspections

4.14.3 Air gaps and creepage distances

The air gaps and creepage distances between adjacent electrical components must be maintained, even during the switching operation.

Test: Measure the air gaps and creepage distances in accordance with DIN EN IEC 60947-1, sec. 8.1.4; compare with minimum values

4.14.4 Degree of protection

The degree of protection prescribed by the manufacturer must correspond to the environmental conditions anticipated for the intended scope of application.

The electrical components must conform to the prescribed degree of protection.

Test: Verify the protection class in accordance with DIN EN 60529

NOTE Verification of protection class must be carried out upon completion of testing according to sec. 4.7 of these principles of testing, using the same test object.

4.14.5 Temperature rise

4.14.5.1 Touchable surfaces and terminal wire connectors

The temperatures associated with touchable surfaces and terminal wire connectors during testing under the conditions set forth in DIN EN IEC 60947-1, sec. 8.2.2 must not exceed the stipulated limit values.

Test: In accordance with DIN EN 60947-5-1, sec. 8.3.3.3

4.14.5.2 Electromagnetic actuating coils

The temperatures associated with electromagnetic actuating coils during testing under the conditions set forth in DIN EN 60947-1, sec. 8.2.2.7 must not exceed the following limit values:

| Insulation class | Temperature limit |
|---|---|
| Y | 90 °C |
| A | 105 °C |
| E | 120 °C |
| B | 130 °C |
| F | 155 °C |
| H | 180 °C |

**Table 2:** Temperature limits

Test: In accordance with DIN EN IEC 60947-1, sec. 9.3.3.3.6 or in accordance with the resistance measurement method in sec. 9.3.3.3.2

## 4.15 Validation in accordance with DIN EN ISO 13849-2

The use of trapped key interlocking systems for safety functions on machines and systems requires validation in accordance with DIN EN ISO 13849-2, as well as application of the informative attachments.

Trapped key interlocking systems must fulfil the requirements corresponding to the designated Performance Level (PL) for each prescribed safety function.

In order to determine the PL, where applicable, the following information is required in accordance with DIN EN ISO 13849-1:

- Category
- for determining the $MTTF_D$ for wear-prone components in accordance with DIN EN ISO 13849-1, Annex C.4.2:
  - the mean operating time ($d_{op}$)
  - the mean usage time ($h_{op}$)
  - the cycle time ($t_{Cycle}$)
  - the $B_{10D}$ values for relevant trapped key interlocking system components
- the average diagnostic coverage ($DC_{AVG}$)

If applicable, trapped key interlocking systems must be configured with functional units for diagnosing the functionality of the stress-loaded safety function(s).

For determining diagnostic coverage (DC), it is preferable to use annex E in accordance with DIN EN ISO 13849-1.

Test: Inspection of the documentation for determining $DC/DC_{AVG}$ for the components comprised in the trapped key interlocking system, or the trapped key interlocking system with regard to the stress loading measures taken, as well as the corresponding DC for all stress-loaded safety functions being tested within the system.

**With respect to trapped key interlocking systems, categories 3 and 4 of DIN EN ISO 13849-1 must be realized through one of the following options:*

a) *through the use of two type 5 interlocking devices*

b) *through the use of single-channel type 5 interlocking devices, provided these achieve the comparable system behaviour for the category; the non-mechanical aspects of the trapped key interlocking system must conform to the requirements for the category in accordance with DIN EN ISO 13849-1.*

*NOTE 1 The system behaviour of a category does not necessarily comprise the designated architecture, but rather the definition of the category.*

*NOTE 2 If it is verified that all hazardous faults are technically improbable, then the recognition does not apply.*

*NOTE 3 If faults are technically improbable, then a "continued implementation of the safety function in the presence of an individual fault" will be assumed.*

c) *through the use of single-channel type 5 interlocking devices, provided every possible fault has been assessed and every hazardous type of fault has either been excluded or verifiably deemed technically improbable (highly unlikely), as follows:*

*When every single-fault that could lead to the loss of a safety function has been excluded, then a system behaviour of category 3 can be assumed and a diagnostic coverage (DC) rating is not required. Given that no faults occur that could lead to the loss of a safety function, then a maximum Performance Level (PL) = d can be assumed for the overall system.*

*The non-mechanical aspects of the trapped key interlocking system must conform to the requirements for the category in accordance with DIN EN ISO 13849-1.*

*For systematic failures, DIN EN ISO 13849-1, annex G is applicable, while the requirements for the avoidance of systematic failures in conjunction with key coding must be fulfilled.*

*In addition to the permissible fault exclusions according to DIN EN ISO 13849-2, annexes A, B, C and D, the presumption of breakage and deformation failure for safety-relevant mechanical components (except for springs) can be excluded if:*

1. *a safety factor of 4 with respect to the anticipated forces can be verified mathematically or through appropriate testing, or*
2. *a safety factor of 2 with respect to the anticipated forces can be verified mathematically or through appropriate testing, and if the quality of the safety-relevant mechanical components is substantiated through continuous quality assurance measures.*

*In order to achieve Performance Level e (PL e), a system behaviour of category 4 is necessary. In particular, if an accumulation of faults does not lead to a loss of the safety function and consideration is given to a fault combination of two faults, this is sufficient (unless 3 or more faults are reasonably foreseeable). In addition to the permissible fault exclusions according to DIN EN ISO 13849-2, annexes A, B, C and D, the presumption of breakage and deformation failure for safety-relevant mechanical components (except for springs) can be*

*excluded if: their respective strength values can be verified to a safety factor of 4 with respect to the anticipated forces.*

*NOTE 4 This is normally achieved in that, in the event of a fault occurrence, the device or the system is rendered inoperative and access to a danger area or the restart of a machine are prevented.*

*In those cases where the occurrence of a single fault cannot be excluded, yet the fault, itself, would not cause a hazardous failure, then testing for the non-hazardous failure shall continue, with this fault being addressed initially and all subsequent faults being added and removed sequentially. The tests must be carried out for all non-excluded single faults. Testing for the accumulation of failure can be limited to two failures in combination if:*

*– he fault occurrence is low and*
*– the faults in combination are independent of each other and*
*– the loss of the safety function arises only when the faults occur in a particular sequence.*

**) The passages in italic type in this section are contingent on the final text in standard prEN ISO 14119.*

Test: *For the requirements pursuant category 3*

a) Inspection of the documentation to at least a ‚Bottom-up'-analysis in accordance with DIN EN ISO 13849-2, sec. 5.2, or DIN EN ISO 13849-1, sec. 10.3.2 (e.g. FMEA in accordance with DIN EN 60812), accordingly.

*b) Review the safety factor verifications from 2 and the continuous quality assurance measures or the safety factor from 4.*

Test: *For the requirements pursuant category 4*

a) Inspection of the fault analysis submitted in accordance with DIN EN ISO 13849-2, sec. 5.2 or DIN EN ISO 13849-1, sec. 10.3.2 (qualitative and quantitative ‚Bottom-up- and ‚Top-down- analysis), accordingly, as well as an assessment of system behaviour pursuant category 4 in accordance with DIN EN ISO 13849-1.

*b) Review the safety factor verifications from 4.*

If, in addition to system behaviour, the structure is also to be realized pursuant category 3 in accordance with DIN EN ISO 13849-1 with $DC_{AVG}$ = mean and $MTTF_D \geq 65$ a (refer to fig. 12, or annex K in accordance with DIN EN ISO 13849-1 accordingly), then PL e can also be achieved.

Test: Inspection of the fault analysis submitted in accordance with DIN EN ISO 13849-2, sec. 5.2, or DIN EN ISO 13849-1, sec. 10.3.2 (qualitative **and** quantitative ‚Bottom-up' and, optionally, qualitative ‚Top-down-analysis), accordingly, as well as an assessment of system behaviour pursuant category 3 in accordance with DIN EN ISO 13849-1.

Fault exclusions that are subject to constraints/limits (e.g. anticipated environmental conditions, external influences and usage within the manufacturer's prescribed limits) must be listed and explained in the operating instructions. Fault exclusions that cannot be tolerated because of foreseeable misuse of the trapped key interlocking system are not permissible.

NOTE: Specific information regarding the fault exclusions can also be obtained from the manufacturer. The manufacturer is then obligated to provide this specific information upon appropriate request.

NOTE 1 If position monitoring for the locking bolt is designed with redundancy on the solenoid key's direct opening control switch, then this should function in combination with both positive and non-positive types of actuation.

NOTE 2 All components that contribute to the realization of the delay time must be tried and tested components in the context of DIN EN ISO 13849-2. When designing the delay mechanism, the fundamental and proven principles of safety must be implemented in the context of DIN EN ISO 13849-2.

Test: Testing and validation of the Performance level in accordance with DIN EN ISO 13849-1/-2

Designated safety functions and categories listed for safety-related parts of the controller should be validated by means of analysis (e.g. FMEA) or testing in accordance with DIN EN ISO 13849-1, sec. 10 or DIN EN ISO 13849-2, accordingly.

## 4.16 (Key) Removal force

Measures must be taken to prevent the key from being removed from the lock in its actuated state.

Test: A lock shall be attached to a base with the mounting elements prescribed by or provided by the manufacturer. The key is then used to set the lock to the actuated state.
A test load of up to a value of 250 N is then applied longitudinally to the key handle's central axis.

If system behaviour should attain to category 3 or 4 (refer to sec. 4.15), then test validation shall be confirmed with 2 or 4 times the load values.

**Requirements regarding the testing equipment:**

Tensile velocity: constant 10 mm/min (± 2,5 %)

**Requirements regarding the force measurement equipment:**

| | |
|---|---|
| Sampling rate: | ≥ 10 Hz |
| Measurement accuracy at maximum force: | ± 2,5 % |

NOTE The test must be carried out on a prototype in as-new condition.

### 4.17 Blocking force

In the blocked state, a key must withstand a torque force of 5 Nm or a tensile force of 250 N (with linear keys) and must not be removable, whereby proper functioning must still be warranted.

Furthermore, it must be warranted that, at torque values greater than 5 Nm or tensile forces greater than 250 N, accordingly, there will not be a loss of the safety function (e.g. due to rated break points).

Test: Testing shall be carried out on a lock from the access lock, the bolt lock, the key-operated solenoid-controlled switch and an arbitrary changeover lock from the key exchange device. The respective component shall be mounted on a base, with the key then used to set the lock to its actuated state. The actuating element is not engaged or the locking mechanism is in the locked position, accordingly. Torque force, or rather tensile force is applied subsequently to the key handle (in the unlocking direction).
The test shall be carried out with 5 Nm or 250 N, accordingly.

If system behaviour should attain to category 3 or 4 (refer to sec. 4.15), then test validation shall be confirmed with 2 or 4 times the load values.

NOTE 1 The test must be carried out on a prototype in as-new condition. The prescribed minimum value is oriented on the handling of the key with two fingers on one hand.

NOTE 2 When testing with a high degree of stress loading, the key may hold up, become jammed or maintain the safety function by means of its rated break point.

### 4.18 Lock actuation force

The actuation forces must not exceed the values prescribed in DIN EN 894-3, table 4, subject to the form and the handling of the key.

Test: Measure the actuation force on each component

### 4.19 External materials and properties

4.19.1 No parts used in the trapped key interlocking system that can be physically touched with proper usage may contain substances that could present a hazard to health.

Test: In accordance with the German AfPS GS 2019:01 PAK to examine the proportion of polycyclic aromatic hydrocarbon (PAH)

4.19.2 Where function allows, unit components that can be accessed by hand must not have sharp corners, edges or abrasive surfaces that could cause injury. Corners and edges must be deburred and surfaces must be smooth to the touch.

Test: Handling and visual inspection