SAFEGUARDING & COMPLEMENTARY PROTECTIVE MEASURES

SICK
Sensor Intelligence.

Otto Görnemann

SICK AG / R&D

2023-09-24

WE ARE ONE OF THE WORLD'S LEADING COMPANIES

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WE DEVELOP SENSOR SOLUTIONS FOR CUSTOMERS AROUND THE GLOBE

- Over 50 subsidiaries worldwide
- Around EUR 2 billion sales in 2021
- More than 12,000 employees

- Your speaker : Otto Görnemann
- Since 1995 employee of SICK AG
- Functional Safety Expert
  (TÜV Rheinland, #263/16, Machinery)
- Functional Safety Trainer
  CFSA E-T Trainer (SGS - TÜV Saar #13)
- **Chairperson of ISO/TC199 – Safety of Machinery**
- **Chairperson of CEN/TC114 – Safety of Machinery**
- Nominated Expert at ISO/TC299-WG3 (Industrial Robots)
- Nominated Expert at ISO/TC110-SC10 (Safety of Industrial Trucks)
- Nominated Expert at ISO/TC039-SC2 (Safety of Tooling Machines)

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1955 - First protective device worldwide

PROTECTIVE DEVICES
TYPICAL EXAMPLES

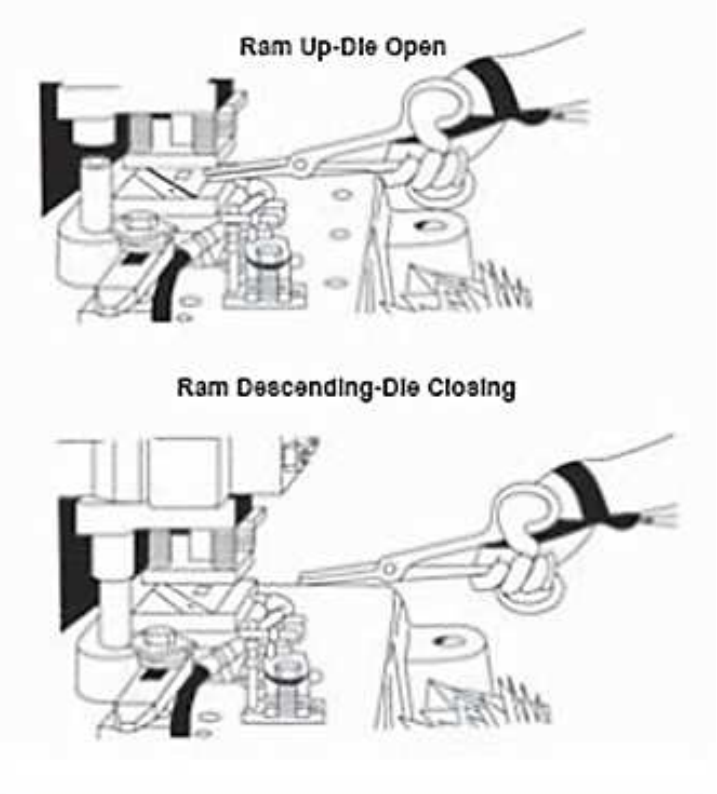
Interlocking of movable guards

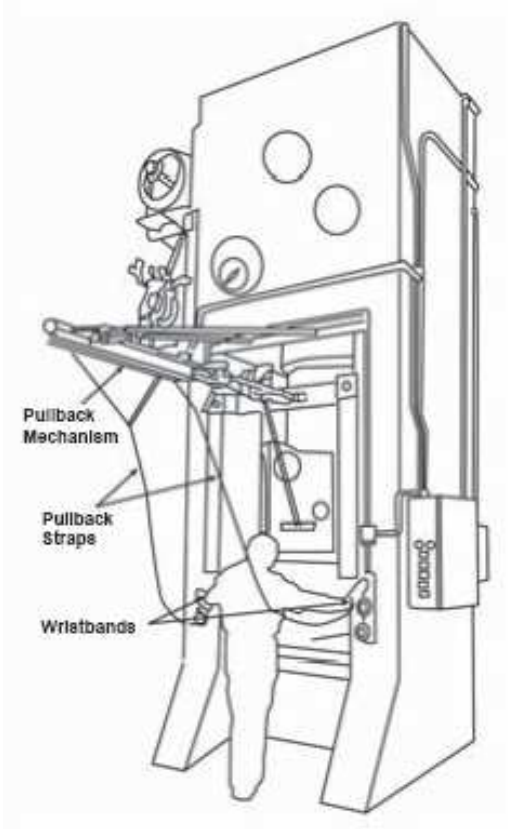
- Doors
- Gates
- Covers
- Barriers
- ...

Electro-sensitive protective equipment

- Light curtains
- Through beam photo-cells
- Laser scanners
- Vision based protective equipment
- Radar based protective devices
- ...

PULLBACK MECHANISM
IMPEDING MEASURE ?





No ! This is not a safeguarding measure according to ISO 12100

WHAT SHOULD ESPE DETECT

SAFEGUARDING TYPE & DETECTION CAPABILITY

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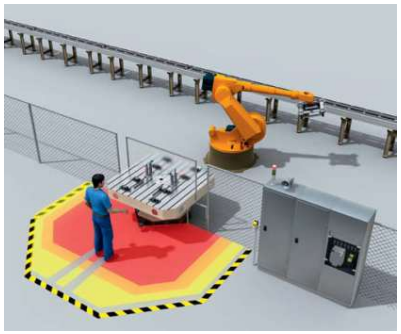
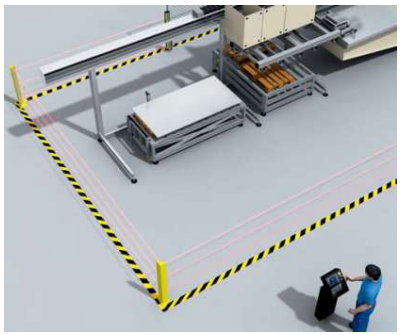
Point-of-operation protection

☑ Finger or hand detection



Hazardous area protection

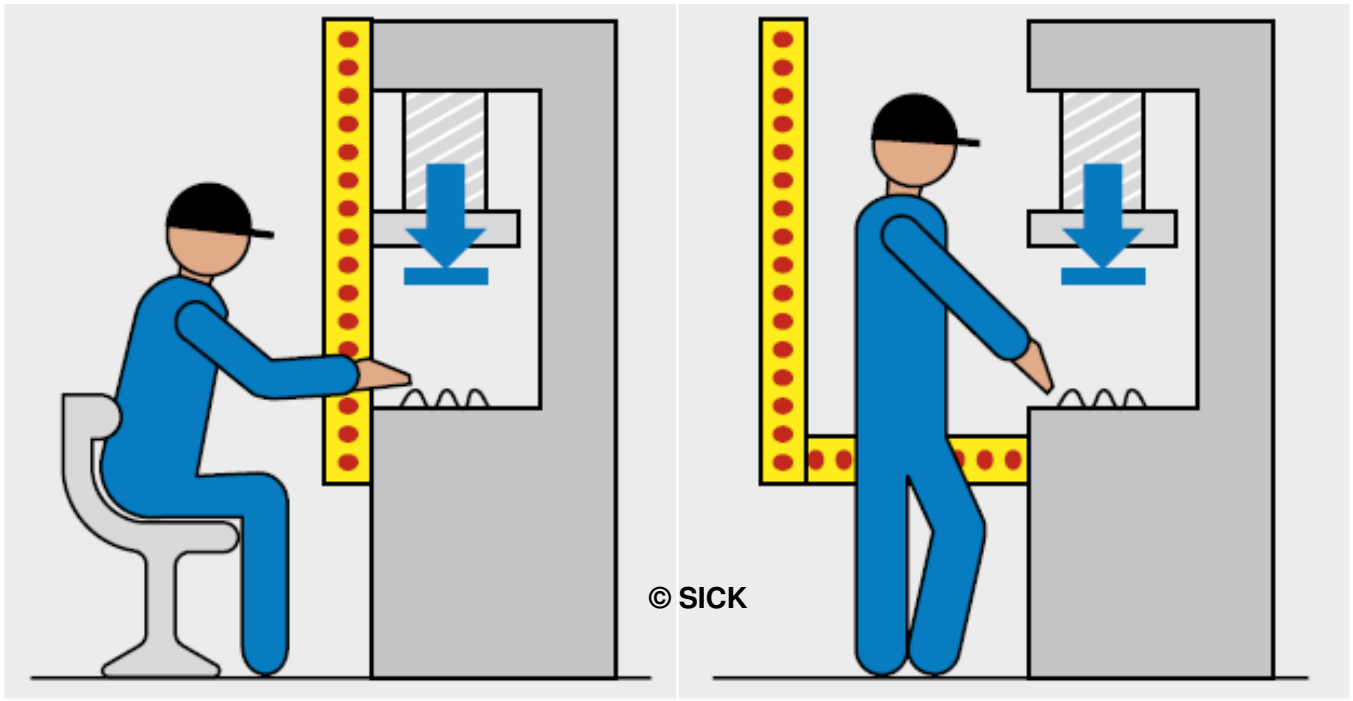
☑ Detection of the presence of a person in the hazardous area

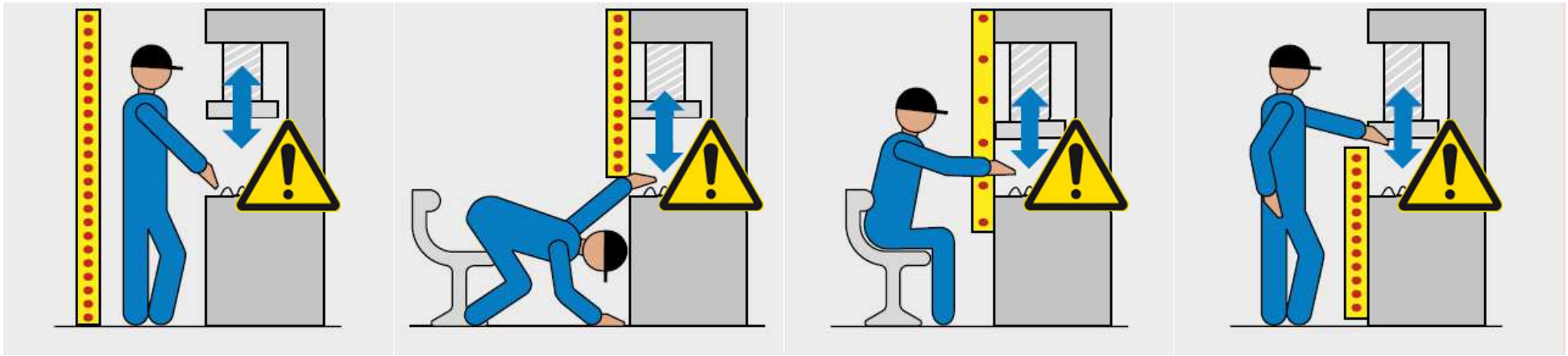


Access protection (perimeter guarding)

☑ Detection of a person on access to the hazardous area

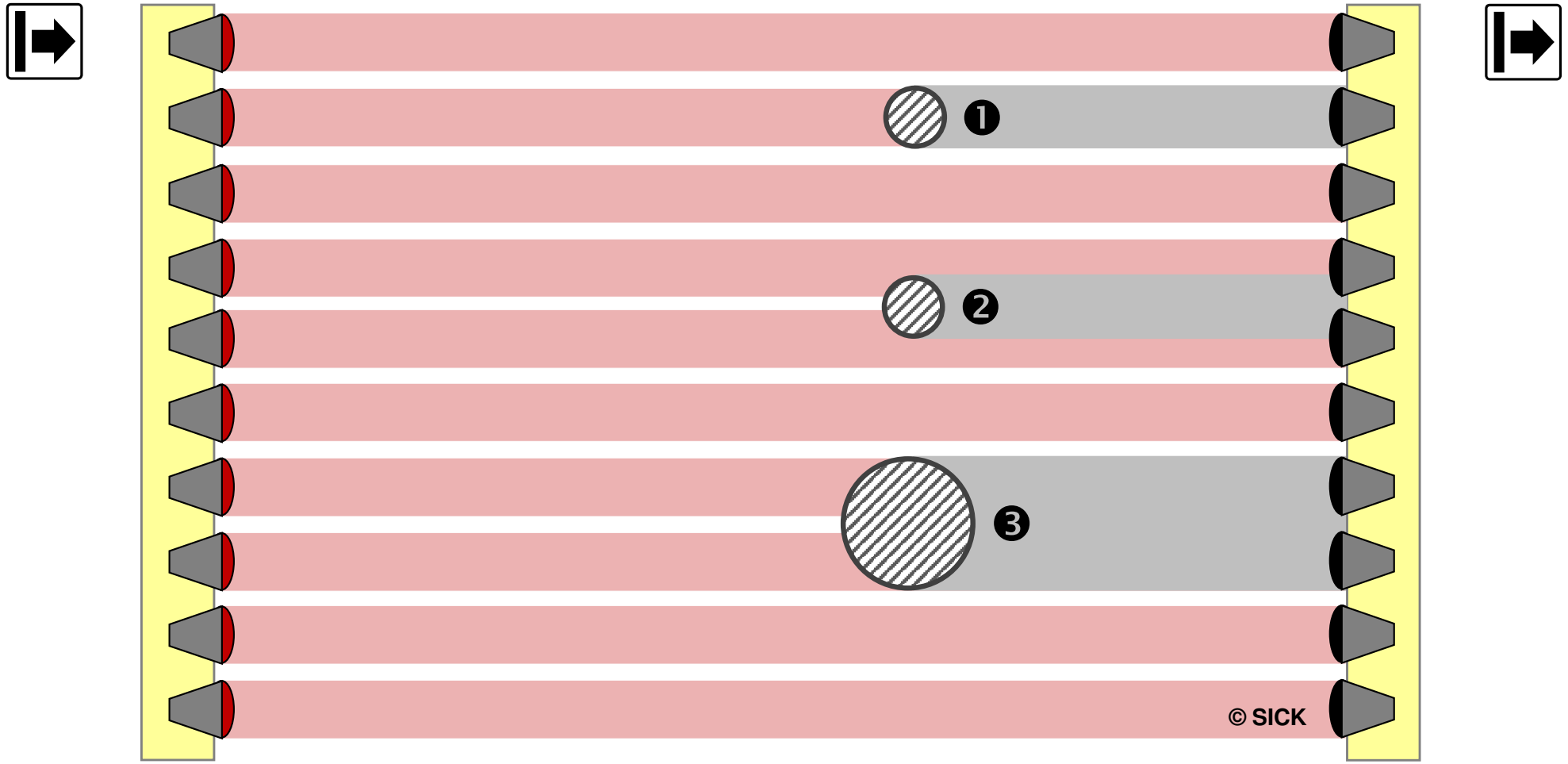
POSITIONING OF AOPD
MOUNTING





DETECTION CAPABILITY - EXAMPLE

CONSIDERATION OF EFFECTIVE BEAM SECTION (ONLY FOR PARALLEL BEAMS)



❶	**Object detection**	test piece covers one beam section completely
❷	**Undefined object detection**	test piece covers only parts of the beam sections
❸	**Reliable object detection**	test piece covers two beam sections completely

POSITIONING OF SAFEGUARDS

ISO 13855:2010

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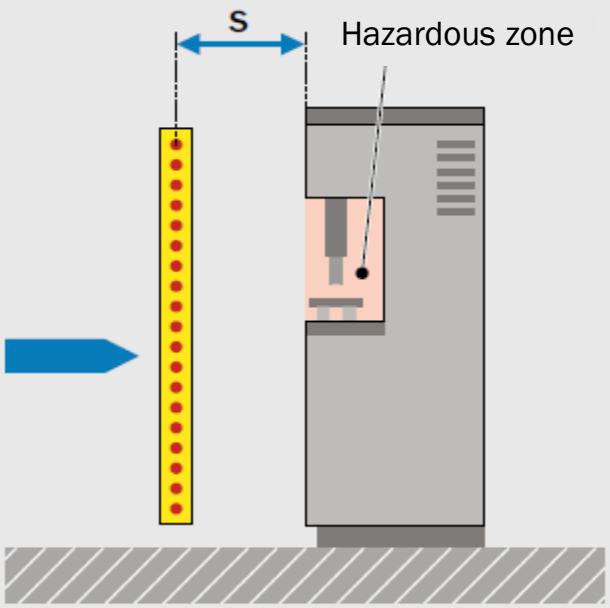
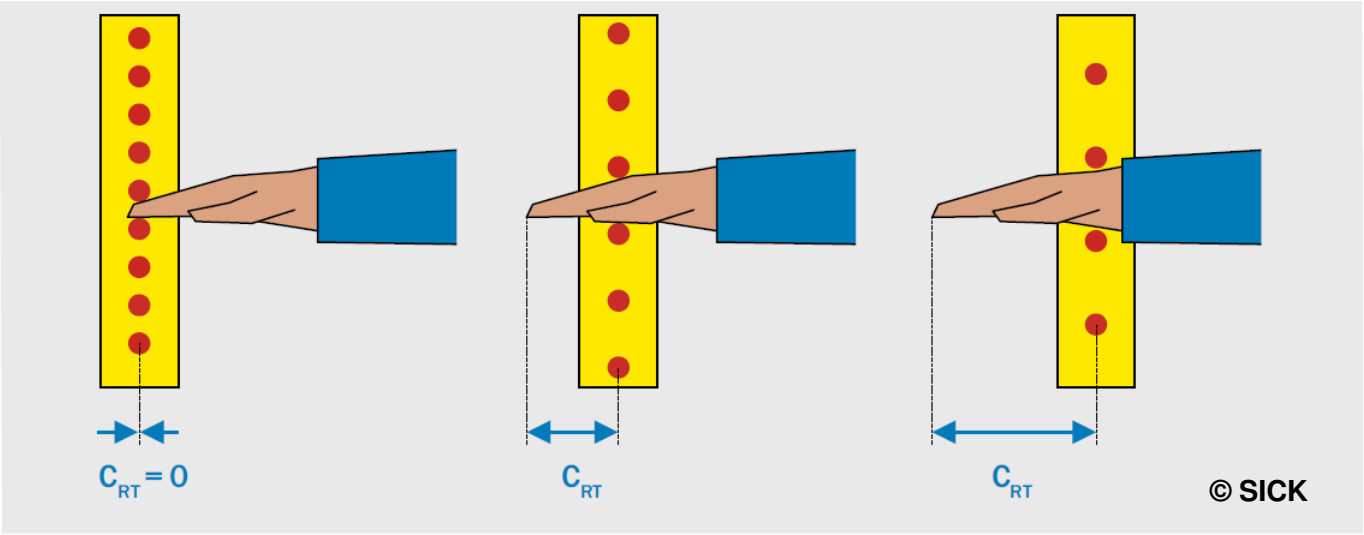
$$S = (K \times T) + C$$





C_{RT} = depends on detection capability

ISO 13855 – MINIMUM DISTANCES

POINT OF OPERATION SAFEGUARDING – HAZARDOUS POINT PROTECTION

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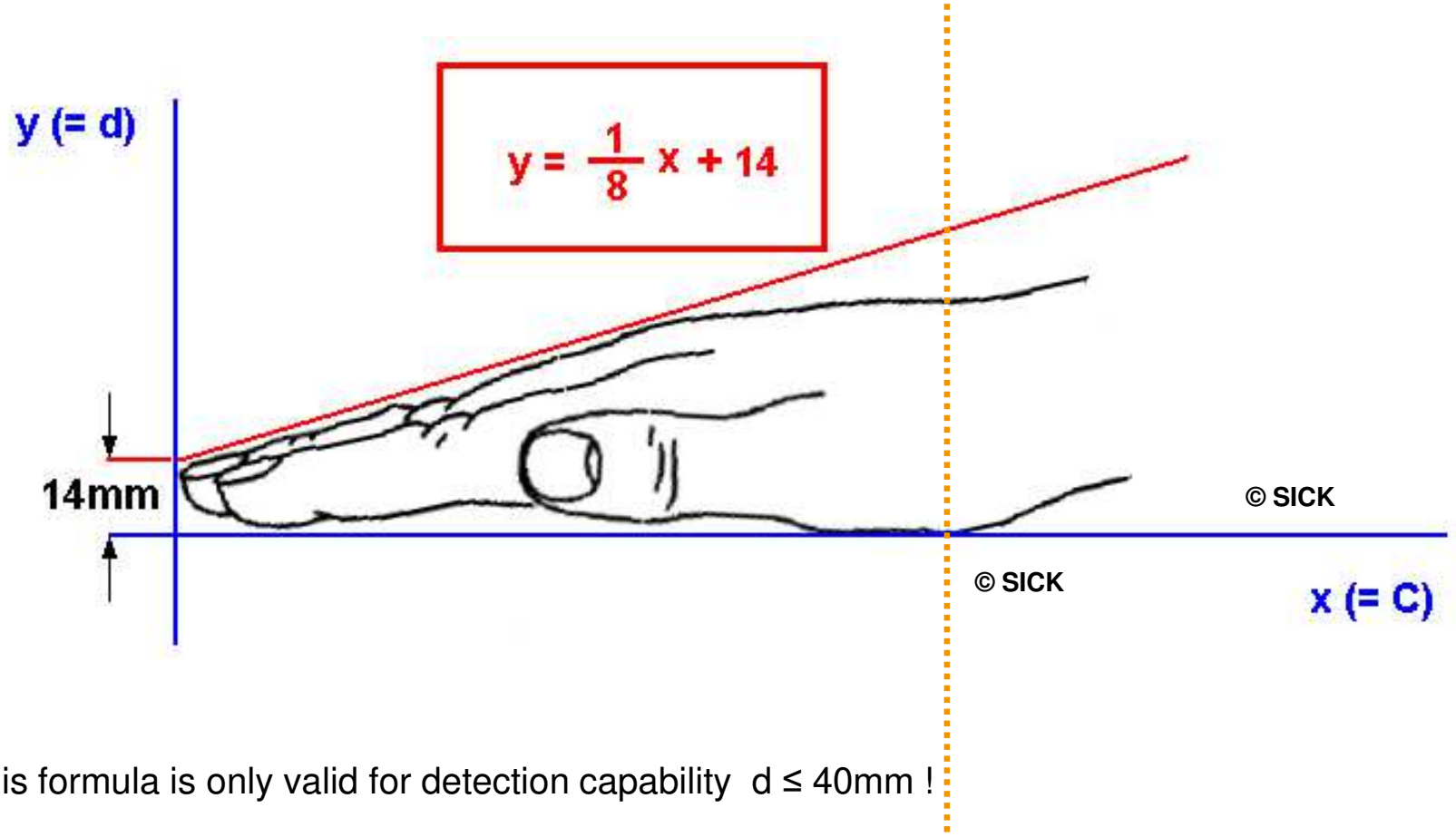
S = K x T + 8 x (d-14mm)

- S = Minimum / Safety distance [mm]
- K = Approach speed [2000 mm/s] for S ≤ 500mm
- K = Approach speed [1600 mm/s] for S > 500mm
- T = Response / stopping time [s]
- C = Additional distance [8 x (d-14mm)]
- d = Detection capability [mm]
- S always ≥ 100mm
- The formula is only valid for d ≤ 40mm & adults ! In future up to 55 mm with a different C
- Formula applies for any approach directions orthogonal to the detection plane [ß > 30°]

ISO 13855 – MINIMUM DISTANCES

POINT OF OPERATION SAFEGUARDING – INTRUSION COEFFICIENT "C"

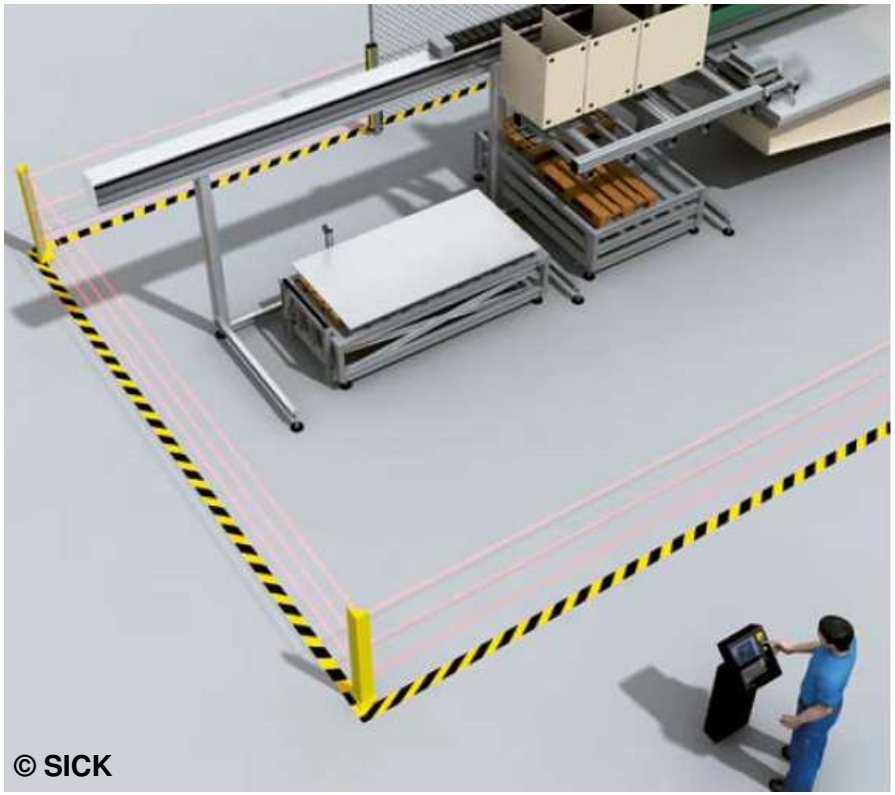
why C = 8 x (d-14mm) . . . ?



This formula is only valid for detection capability d ≤ 40mm !

ISO 13855 – MINIMUM DISTANCES

PERIMETER SAFEGUARDING – ACCESS PROTECTION



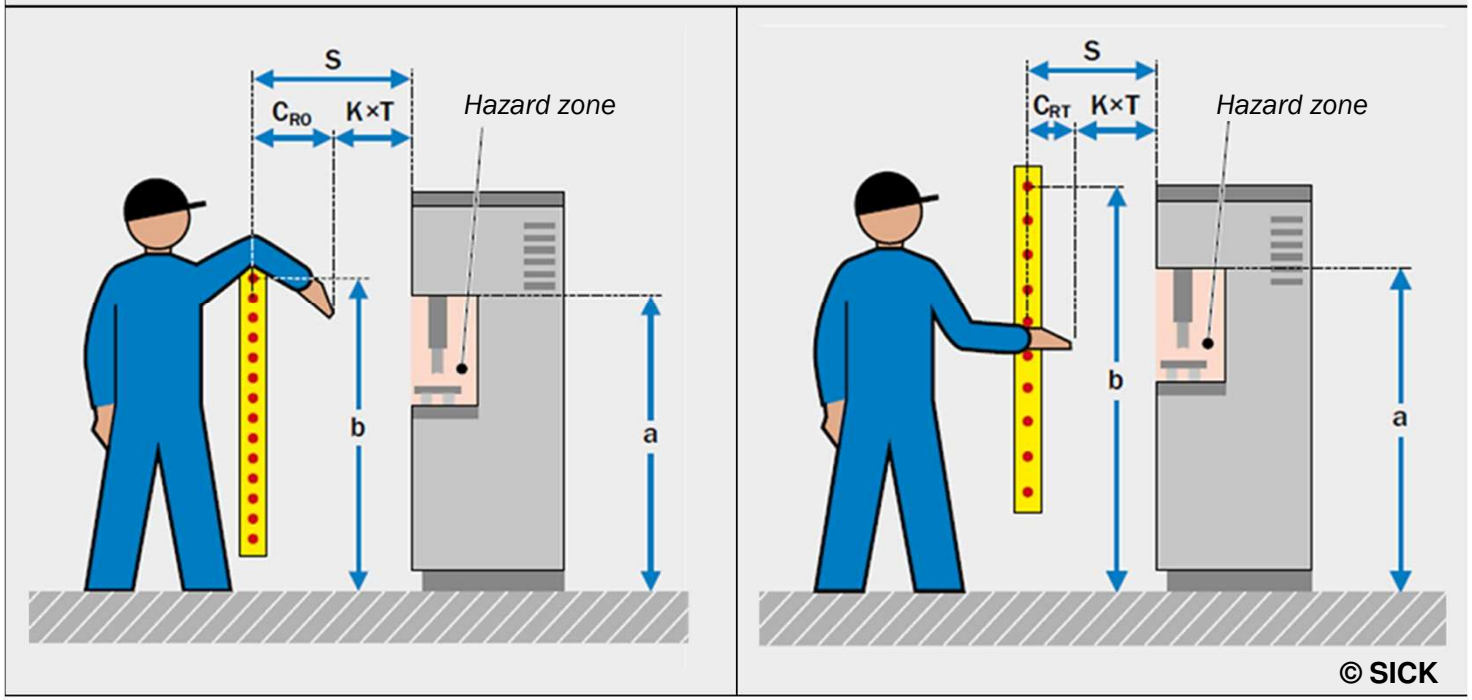
$$S = K \times T + C$$

- S = Minimum / Safety distance [mm]
- K = Approach speed [1600 mm/s]
- T = Response / stopping time [s]
- C = Additional distance = 850 mm
  if reaching over the ESPE is not possible
- C = Additional distance see Table 1
  if reaching over the ESPE is possible
- C not less than 850 mm (length of the human arm)
  The formula is valid for devices with d > 40mm !
- Formula applies for any approach directions
  orthogonal to the detection plane [ß > 30°]

INTRUSION DISTANCE
REACHING THROUGH / REACHING OVER

C distance that a part of the body (usually a hand) can move past the safeguard towards the hazard zone prior to actuation of the safeguard

$$C = \max(C_{RO}, C_{RT})$$



ESPE APPLICATION
PREVENTION OF UNDETECTED PRESENCE & REACHING OVER

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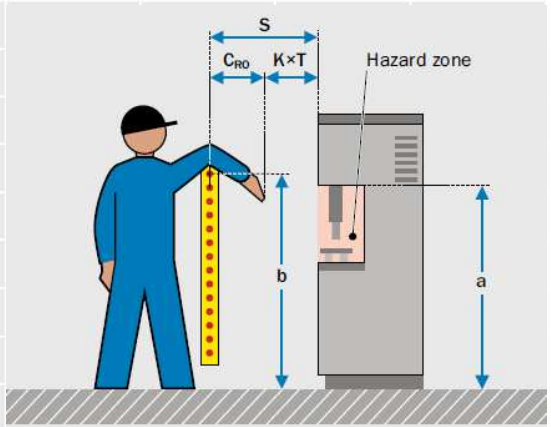
- If it is possible to access hazardous areas by reaching over the ESPE, then the height „b“ of the top edge of the detection field shall be selected according to the table so that :

$$C \geq C_{RO} \geq C_{RT}$$

C_{RO} = Intrusion factor due to reaching over the detection field, C_{RT} = Intrusion factor due to reaching through the detection field

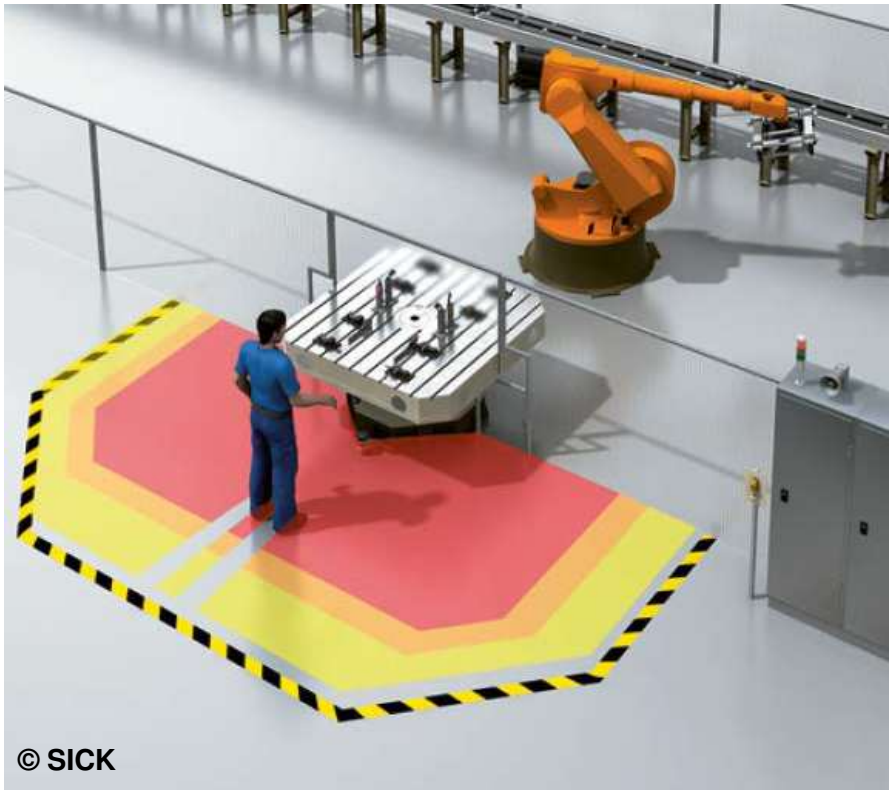
Height a of the hazard zone (mm)	Additional horizontal distance C to the hazard zone (mm)											© SICK
2600	0	0	0	0	0	0	0	0	0	0	0	0
2500	400	400	350	300	300	300	300	300	250	150	100	0
2400	550	550	550	500	450	450	400	400	300	250	100	0
2200	800	750	750	700	650	650	600	550	400	250	0	0
2000	950	950	850	850	800	750	700	550	400	0	0	0
1800	1100	1100	950	950	850	800	750	550	0	0	0	0
1600	1150	1150	1100	1000	900	850	750	450				
1400	1200	1200	1100	1000	900	850	650	0				
1200	1200	1200	1100	1000	850	800	0	0				
1000	1200	1150	1050	950	750	700	0	0				
800	1150	1050	950	800	500	450	0	0				
600	1050	950	750	550	0	0	0	0				
400	900	700	0	0	0	0	0	0				
200	600	0	0	0	0	0	0	0				
0	0	0	0	0	0	0	0	0				
	Height b of the top edge of the protective field (mm)											
	900	1000	1100	1200	1300	1400	1600	1800	2000	2200	2400	2600



ISO 13855 – MINIMUM DISTANCES

HAZARDOUS AREA PROTECTION

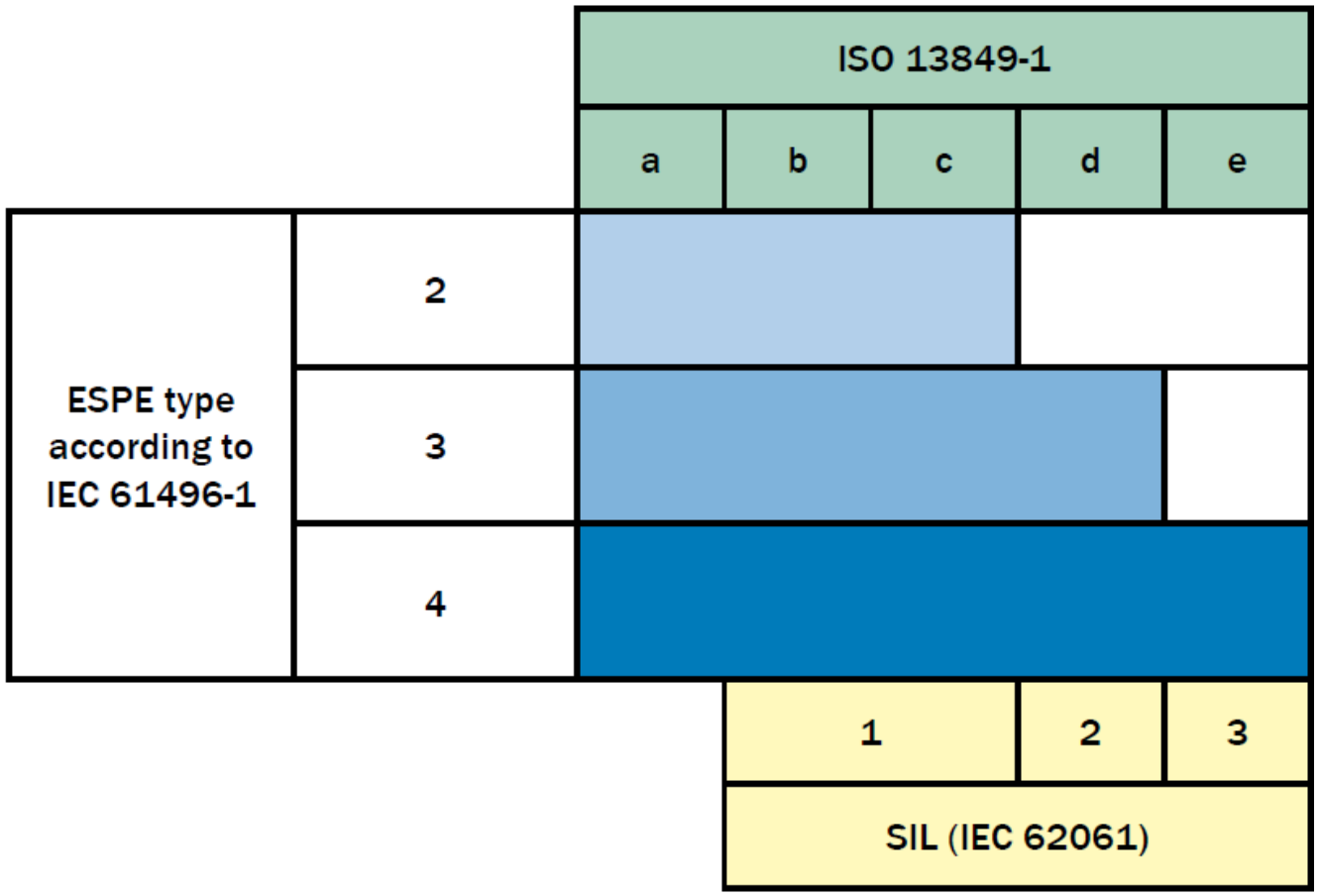
S = K x T + (1200- 0,4 x H)



- S = Minimum / Safety distance [mm]
- K = Approach speed [1600 mm/s]
- T = Response / stopping time [s]
- C = Additional distance [1200mm – 0,4H]
- H = Height of the edge of the detection zone furthest to the hazard zone but not less than 0 and not higher then 1000 mm
- d Detection capability [d ≤ (H/15) + 50mm]
- C not less than 850 mm (length of the human arm)
- In future C=1200 mm independently of height H
- The formula is only valid for devices with d ≤ 117mm !
- The formula applies for any approach directions parallel to the detection plane [ß ≤ 30°]

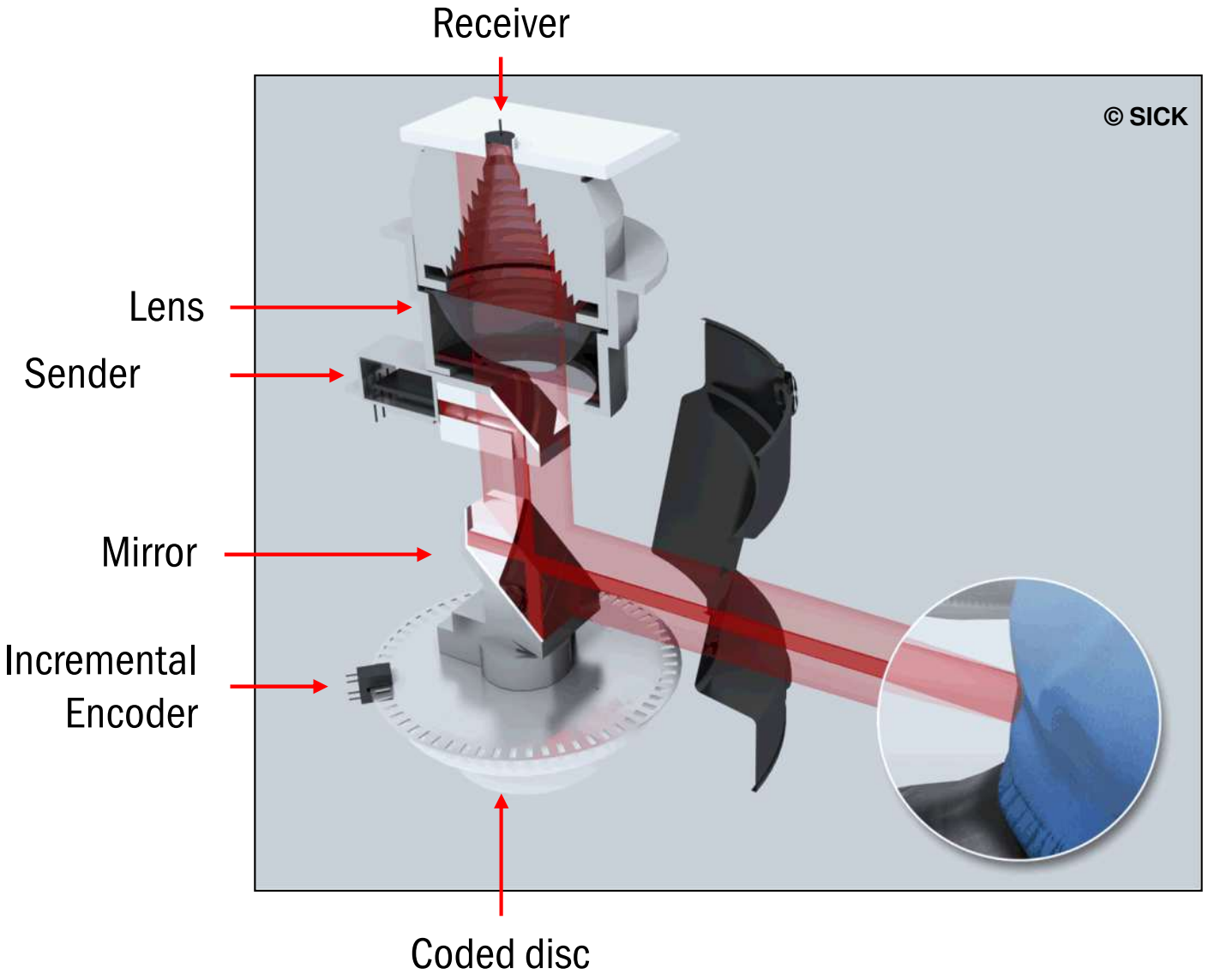
ACHIEVABLE RELIABILITY FOR ESPE TYPES

ACC. TO IEC 62046 & IEC 61496-1



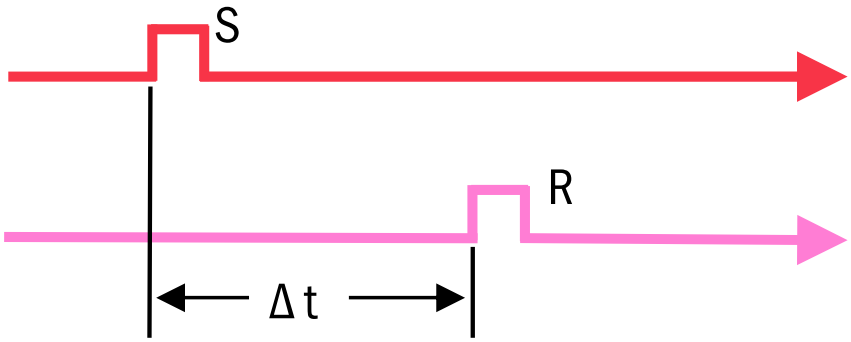
SAFETY LASER SCANNER (AOPDDR)

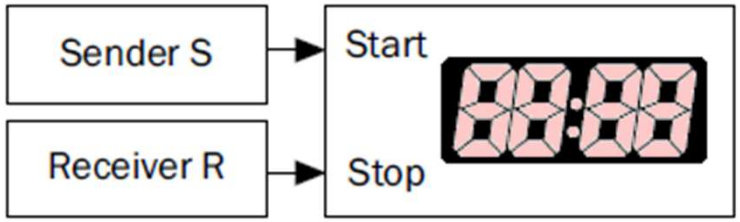
OPTICAL SCHEME

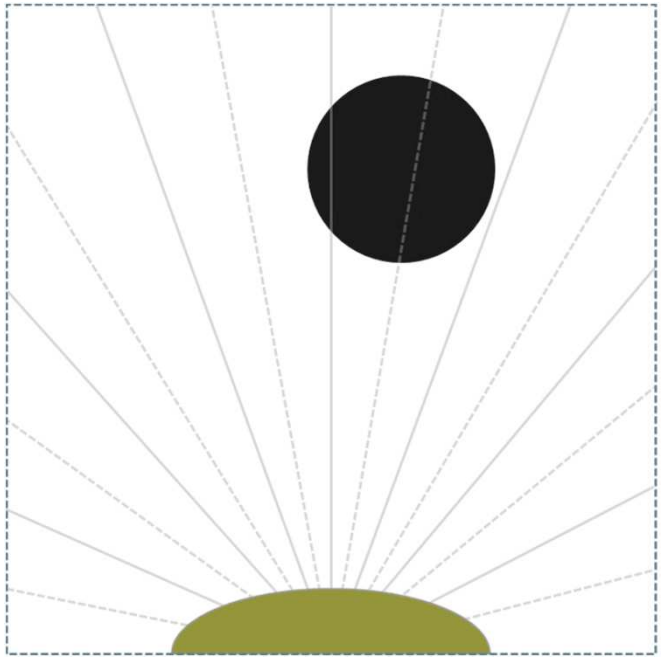


SAFETY LASER SCANNER (AOPDDR)

FUNCTIONAL PRINCIPLE – TIME OF FLIGHT MEASUREMENT

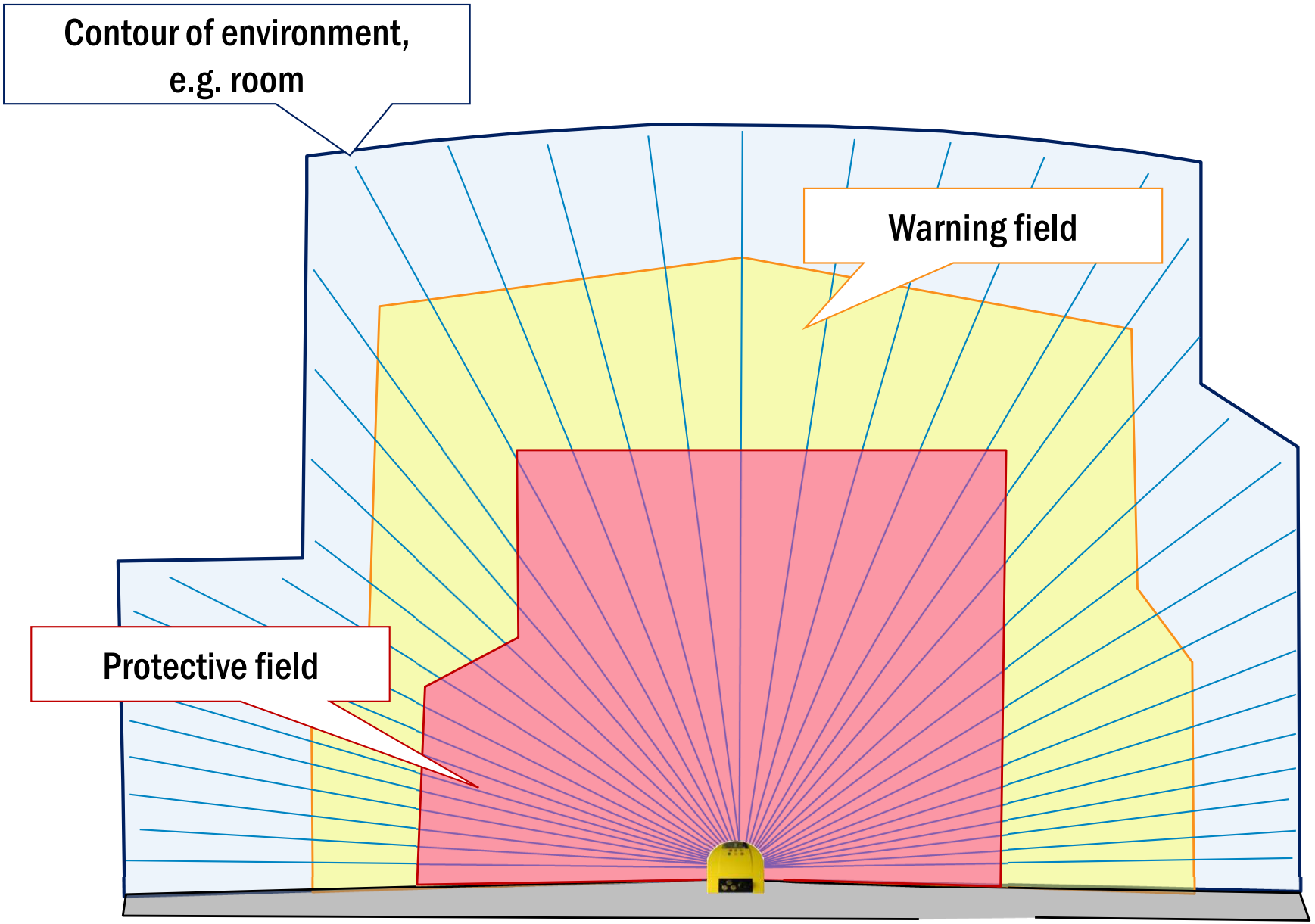






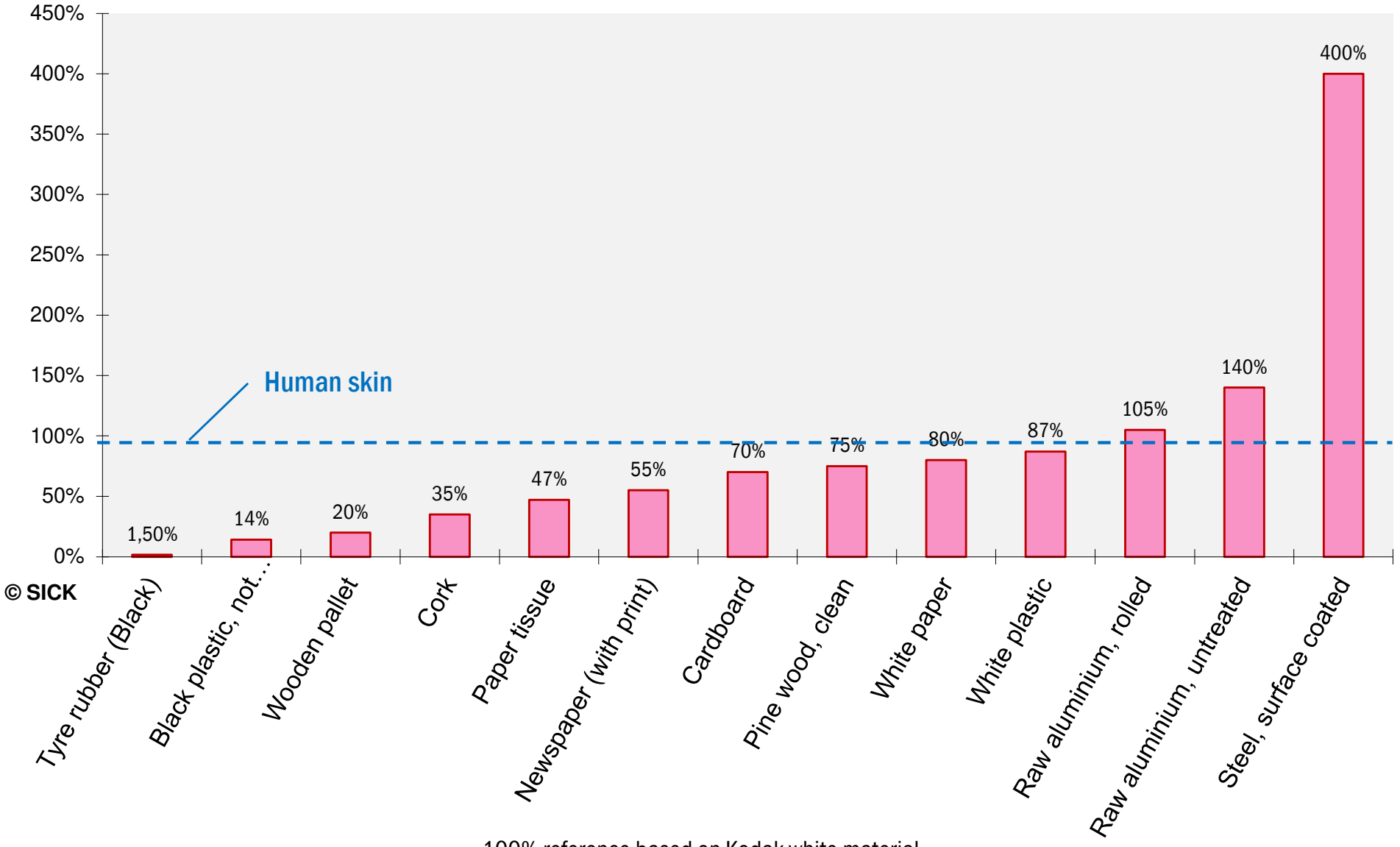
SAFETY LASER SCANNER (AOPDDR)

PROTECTIVE/WARNING FIELDS



SAFETY LASER SCANNERS (AOPDDR)

DETECTION CAPABILITY AND RELATION TO OBJECT REFLECTANCE

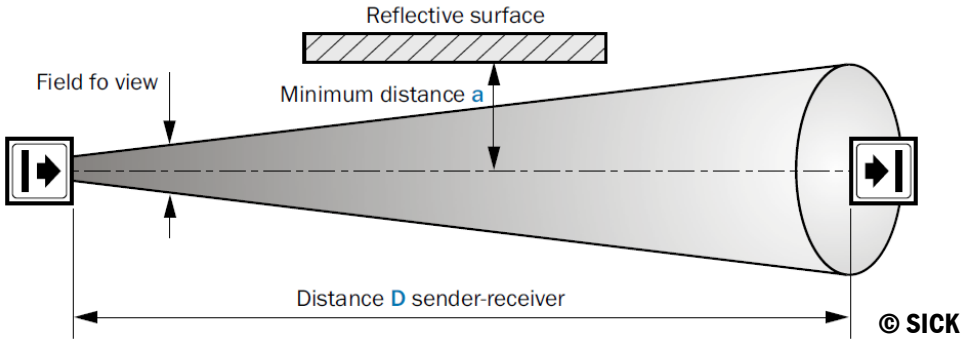


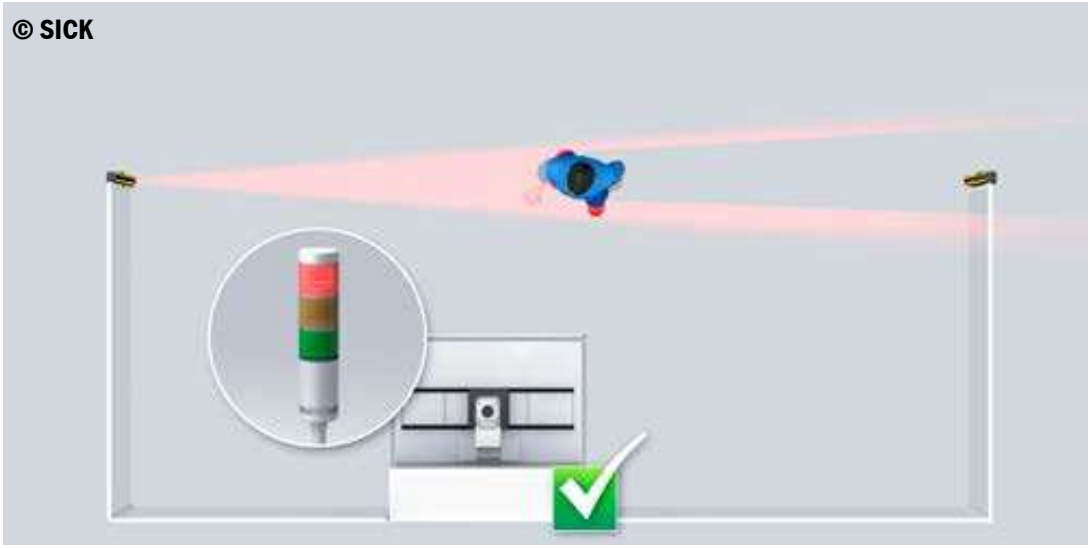
100% reference based on Kodak white material

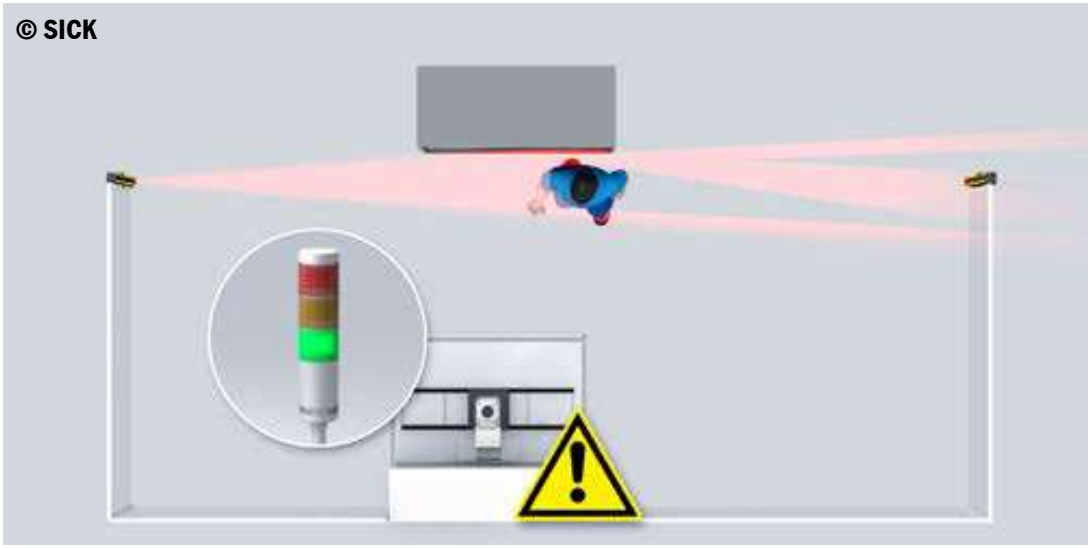
SYSTEMATIC ASPECTS – LOSS OF EFFECTIVENESS

BEAM DEFLECTION DUE TO NEAR REFLECTIVE SURFACES

- Reflective surfaces within the transmitting / receiving beam path, can cause reflections that lead to the loss of the detection.
- A minimum distance „a“ must be maintained between reflective objects and the optical axis.
- This distance depends on the distance between sender and receiver and the effective aperture angle α
- The effective aperture angle α = ± 2,5° for Type 4 devices and α = ± 5° for Type 2 devices

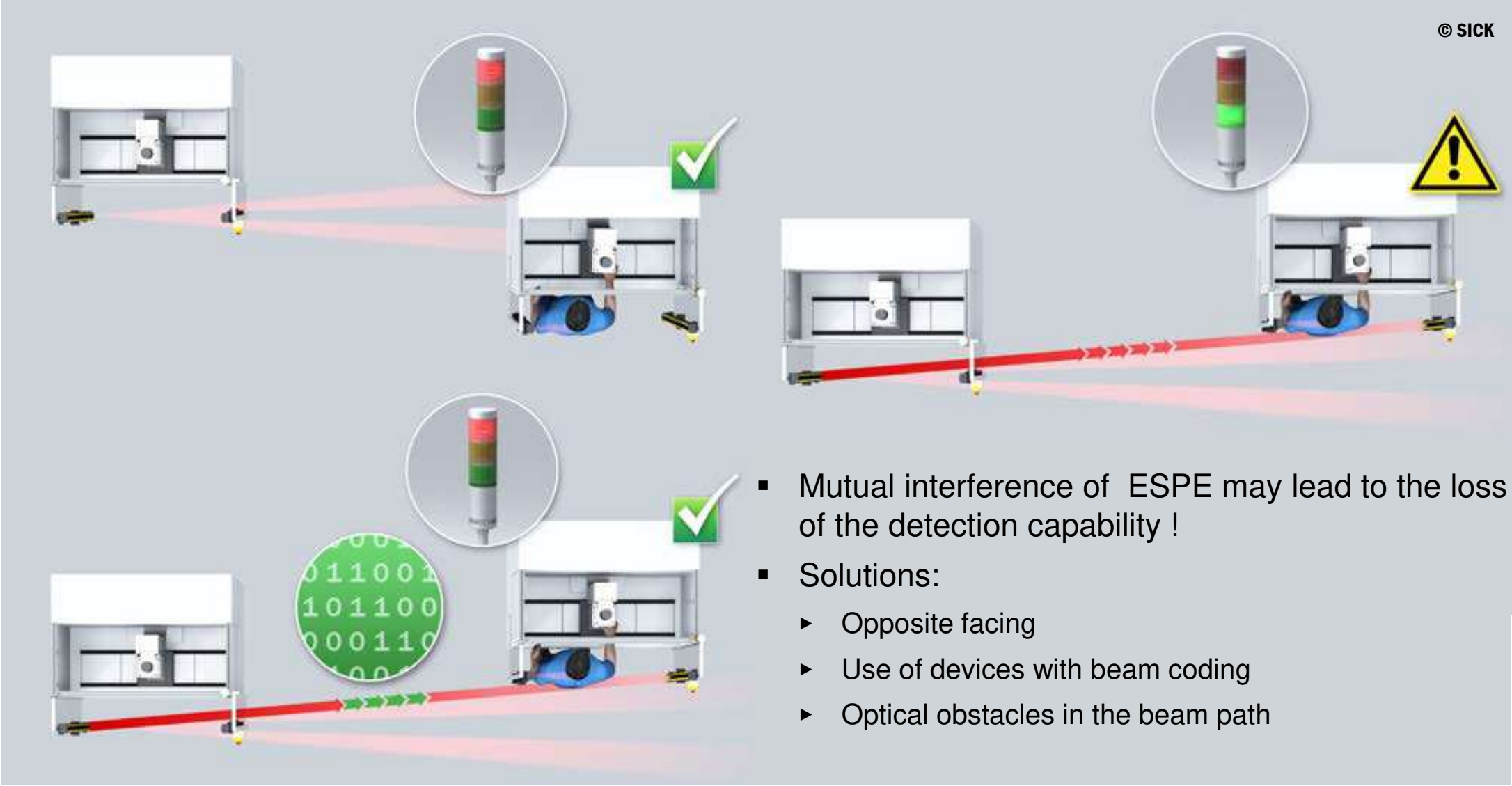






SYSTEMATIC ASPECTS – LOSS OF EFFECTIVENESS

MUTUAL INTERFERENCES



- Mutual interference of ESPE may lead to the loss of the detection capability !
- Solutions:
  - Opposite facing
  - Use of devices with beam coding
  - Optical obstacles in the beam path

ALLOWING MATERIAL PASSAGE
SUITABLE SOLUTIONS

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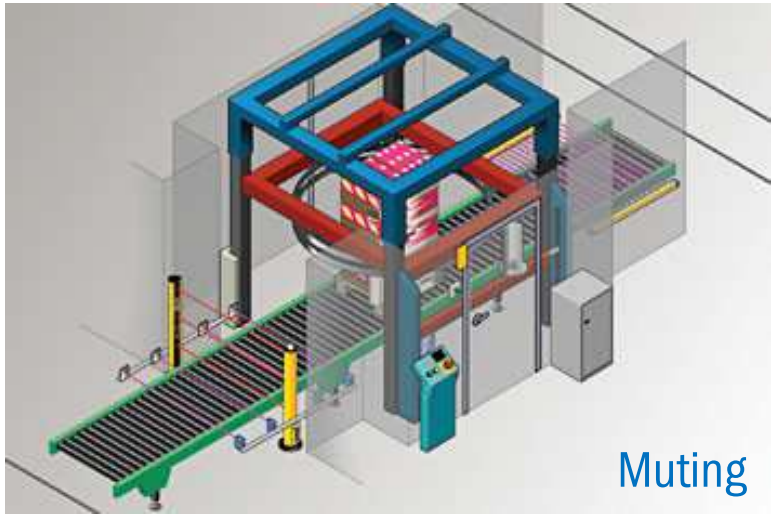
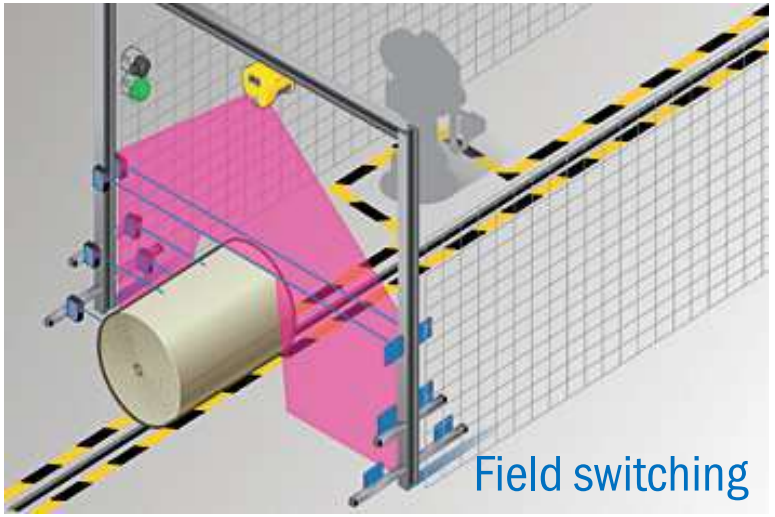
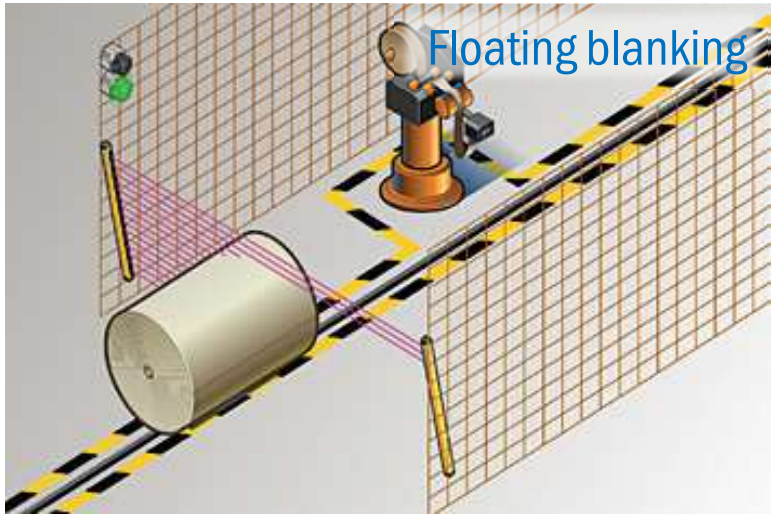
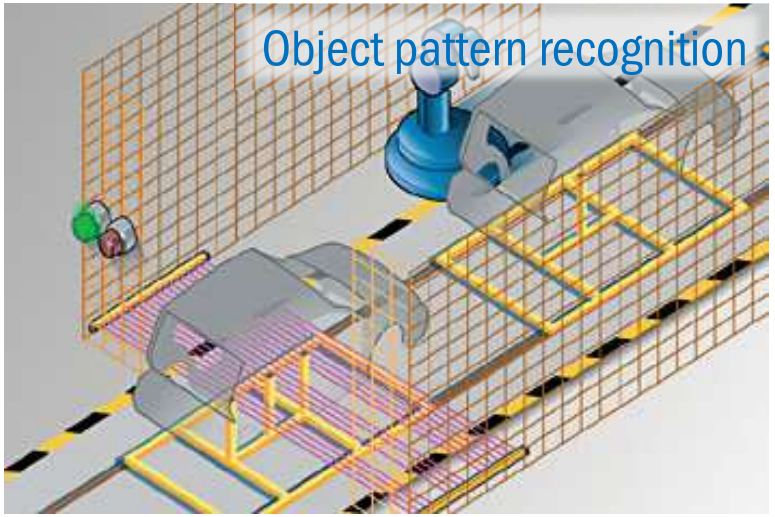
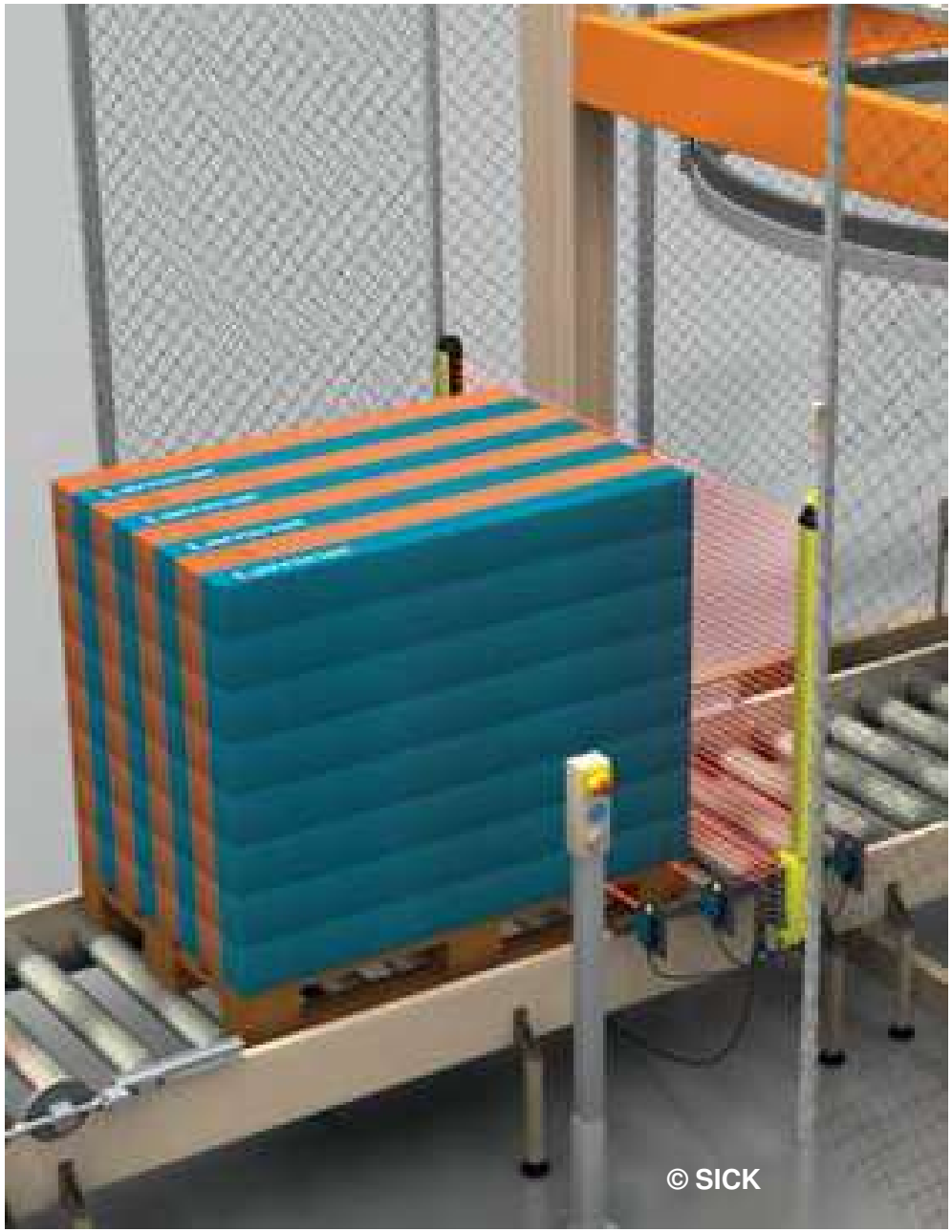








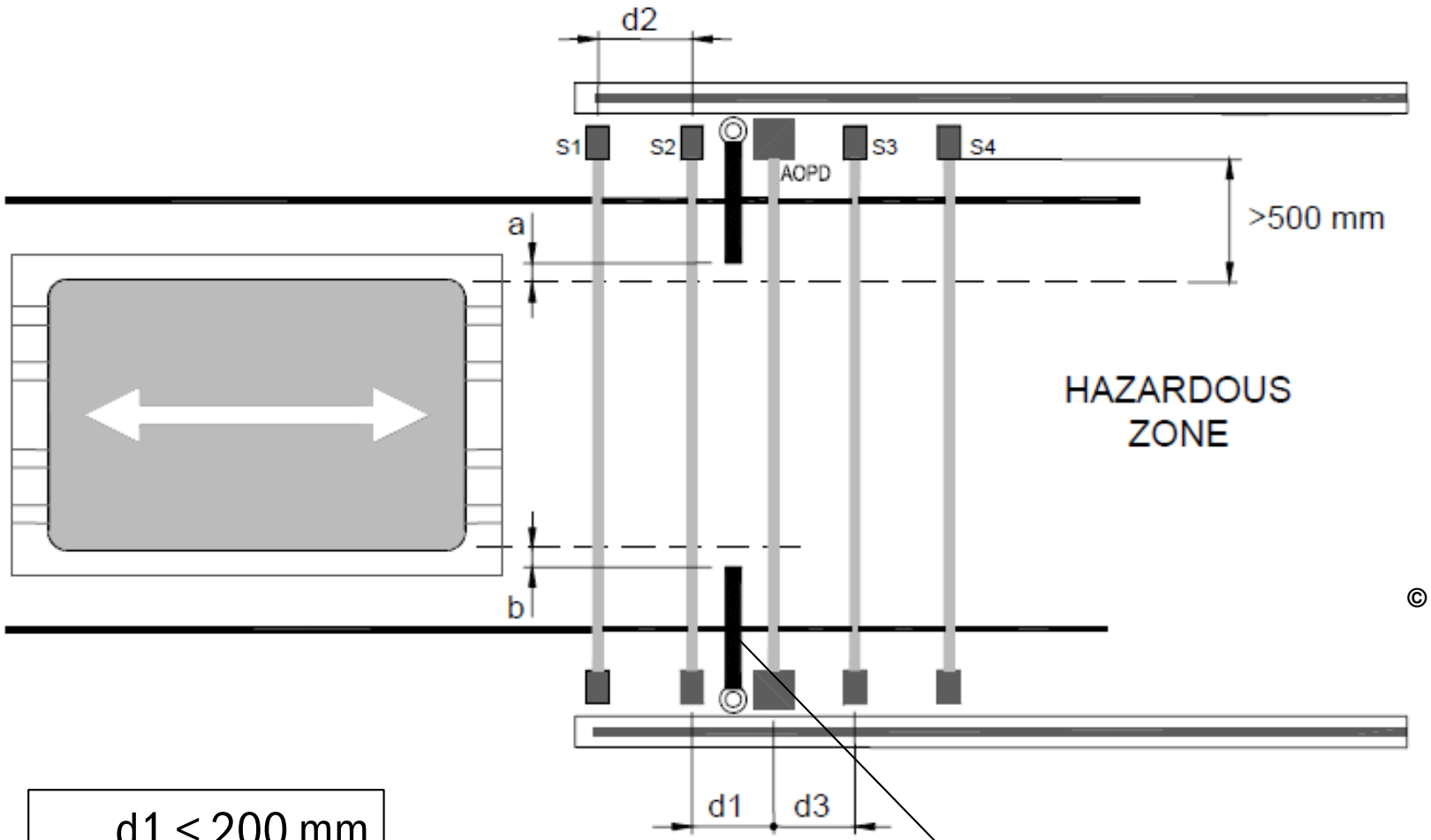
MUTING FUNCTION
REQUIREMENTS



- During muting, safety shall be ensured by other means, therefore it shall not be possible to access the hazard zone
- Muting shall be automatic, i.e. not manual
- Muting shall not depend on a single electrical signal
- Muting shall not entirely depend on software signals
- An invalid combination or sequence of muting signals shall not allow any muting state.
- The muting state shall end immediately after the material has passed through

POSITIONING OF MUTING SENSORS

APPLICATION EXAMPLE WITH FOUR THROUGH BEAM PHOTO CELLS



d1 < 200 mm

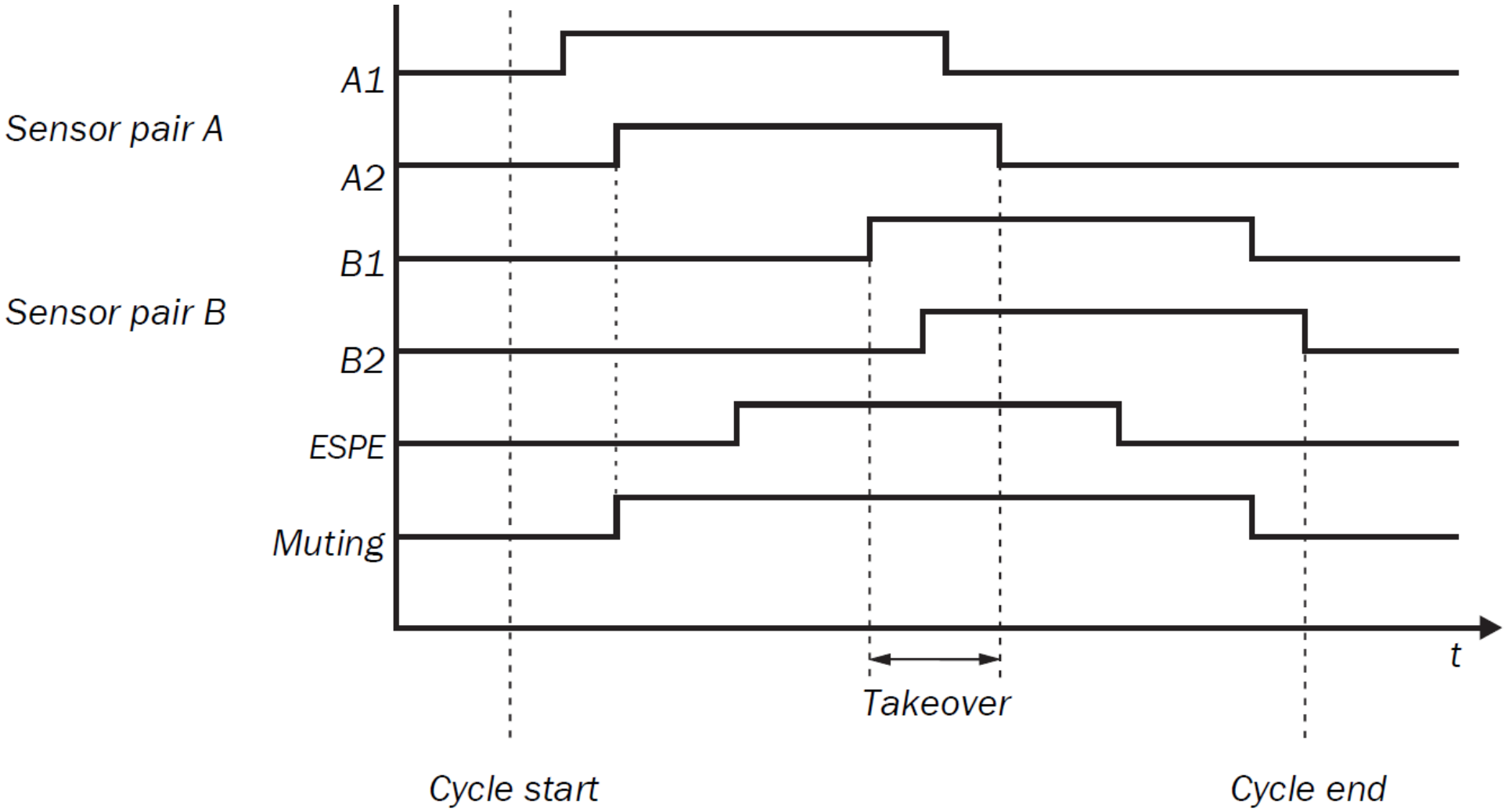
d2 > 250 mm

$\overline{S1\text{-}S4} \geq 500$ mm

optional:
additional swinging guards

SEQUENCE/TIMING DIAGRAM

EXAMPLE OF VALID MUTING SEQUENCE



ADDITIONAL SWINGING GUARDS

PREVENTION OF CRUSHING OR SHEARING RISKS

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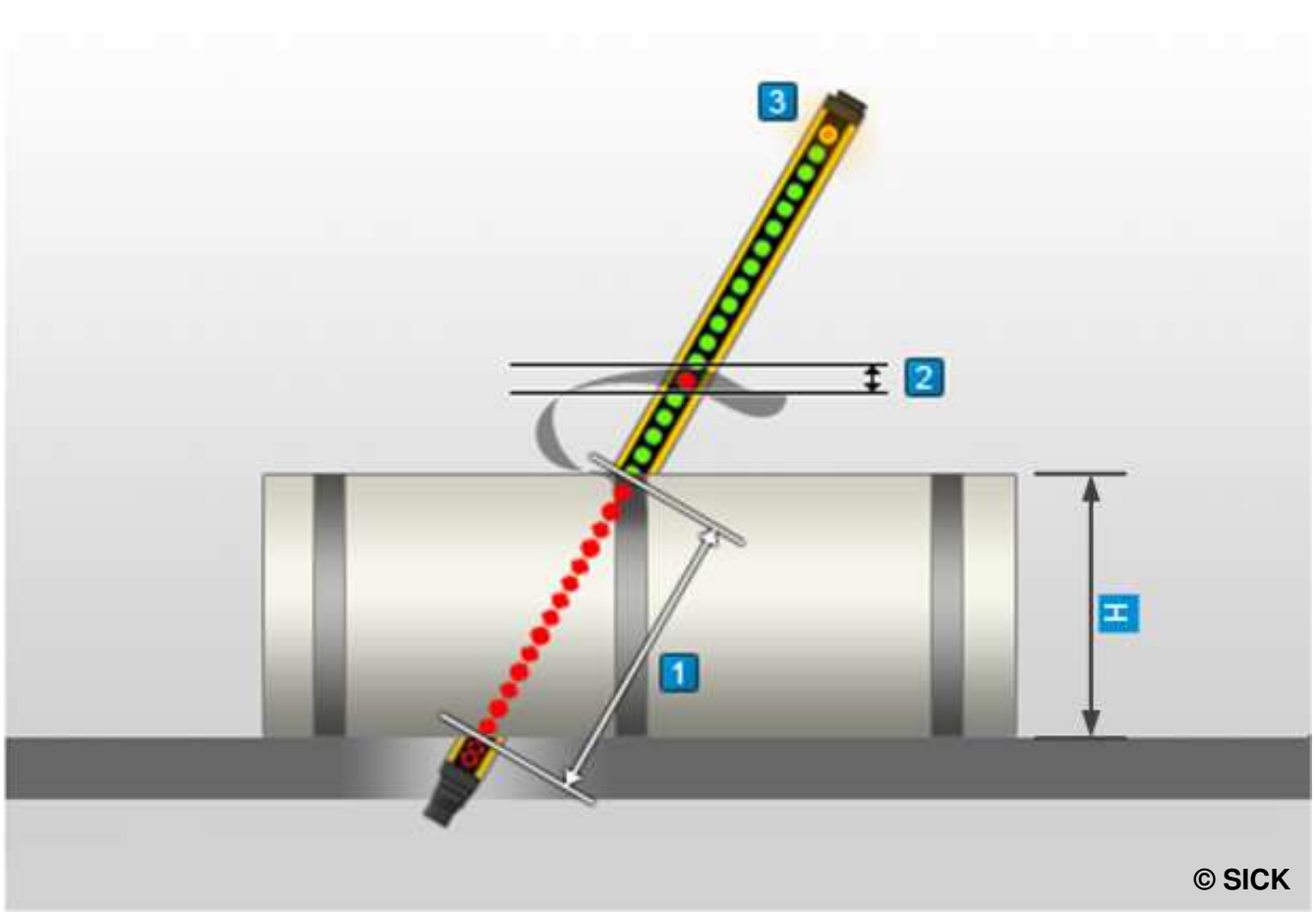
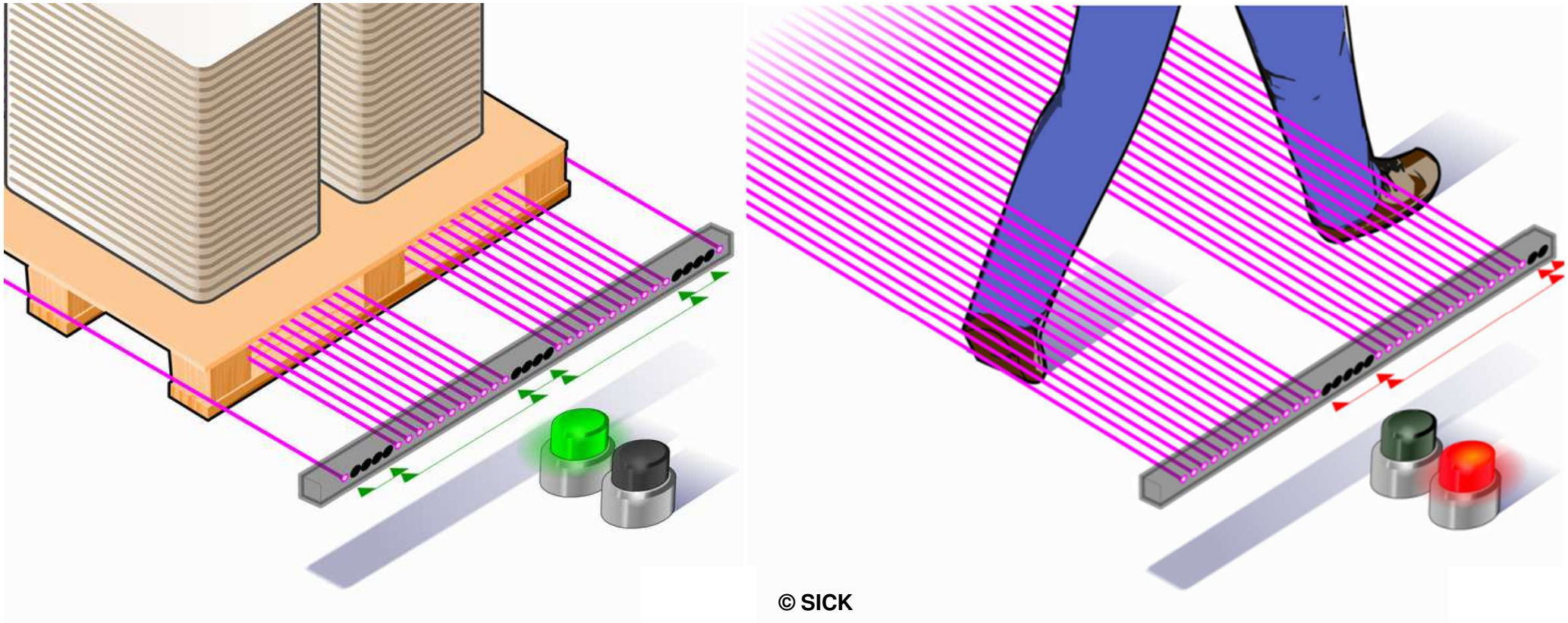
FLOATING BLANKING
APPLICATION



1. **Max. object size** [H ≤ 1.500 mm]
2. Reduced resolution
3. **Synchronization beam**

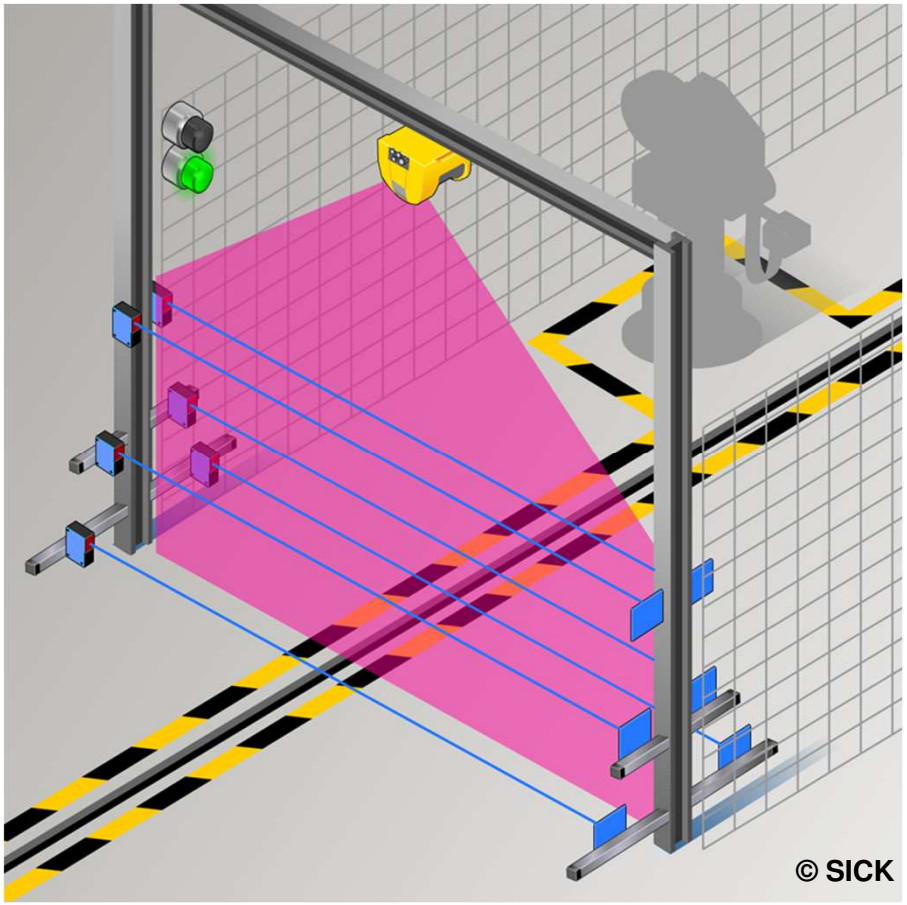
OBJECT PATTERN RECOGNITION

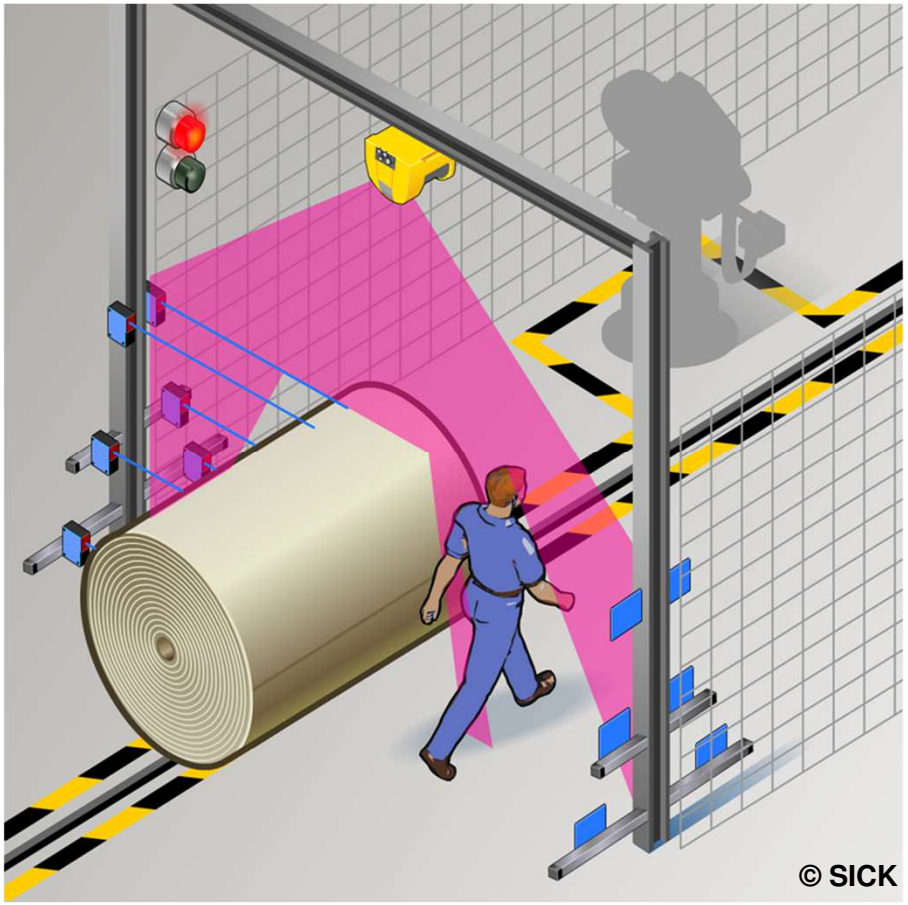
SELF-TEACHING DYNAMIC BLANKING



© SICK

VERTICAL SAFEGUARDING
MUTING ALTERNATIVE





PRESSURE-SENSITIVE PROTECTIVE DEVICES

ISO 13856:2013 SERIES

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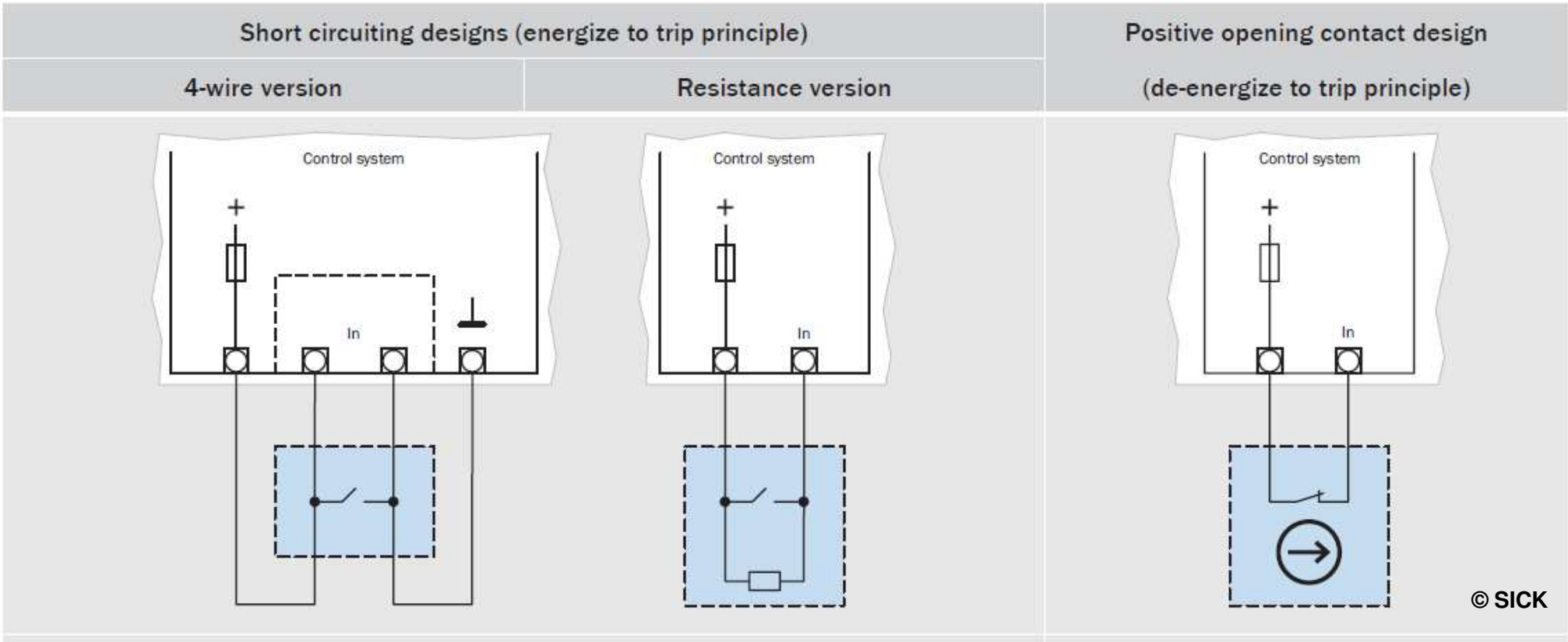
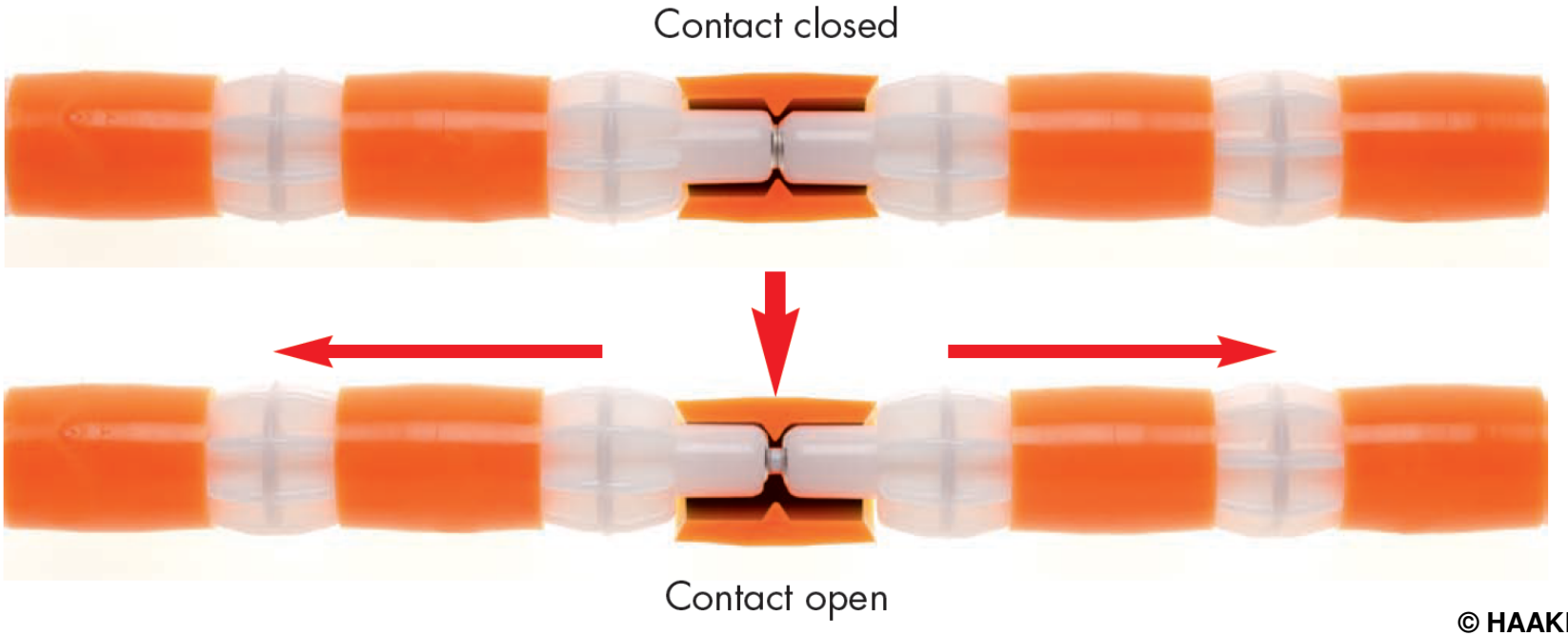


The detection of children with body weights less than 20 kg is not addressed in the product standards for pressure-sensitive mats and floors

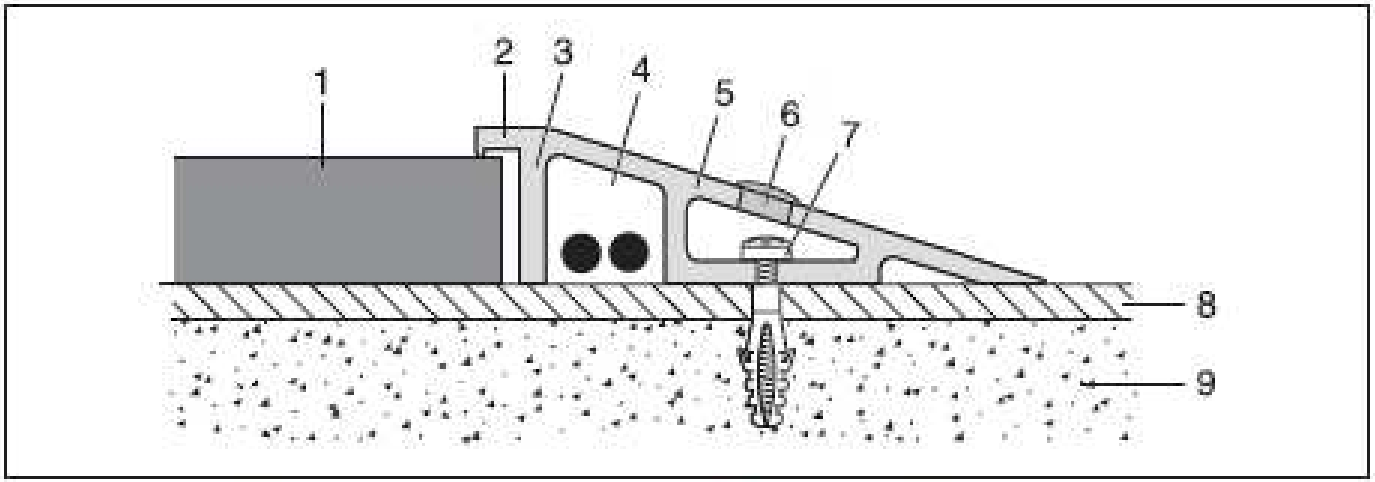
OPERATION PRINCIPLE
NORMALLY CLOSED CONTACT



© HAAKE

POSITIONING OF PRESSURE-SENSITIVE MATS

IF NOT INDICATED BY AN APPLICABLE TYPE-C STANDARD



1	Safety Mat	6	Sealing plug
2	Cover ridge	7	Fixing screw
3	Stop ridge	8	Plant floor
4	Cable conduit	9	Screed
5	Ramp Edge		

$$S = K \times T + (1.200\ mm - 0{,}4 \cdot h)$$

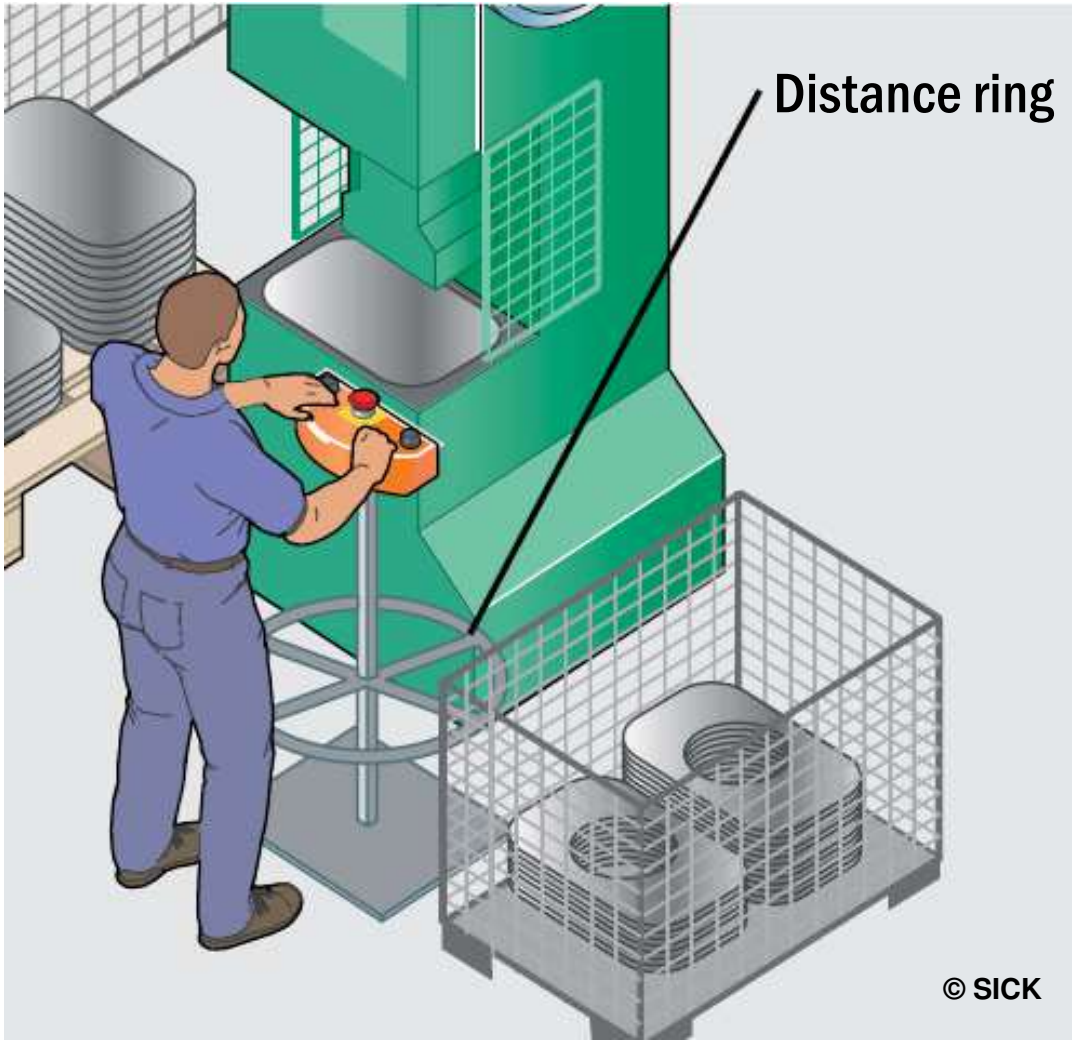
$where$

$$K = 1.600\, mm/s$$

TWO-HAND CONTROLS
ISO 13851:2019

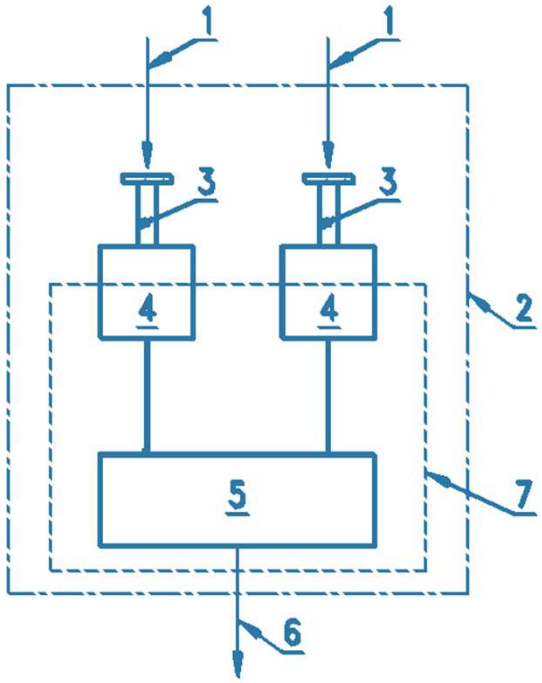
The following basic principles apply:

- It shall be ensured that both hands are used
- Releasing one of the two control actuating devices shall stop the dangerous movement
- Inadvertent actuation shall be prevented
- It shall not be possible to easily defeat the device
- It shall not be possible to take two-hand controls into the hazard zone



TWO-HAND CONTROL DEVICE

CLAUSE 5, ISO 13851:2019



Key

1 Input signal

2 two-hand control device

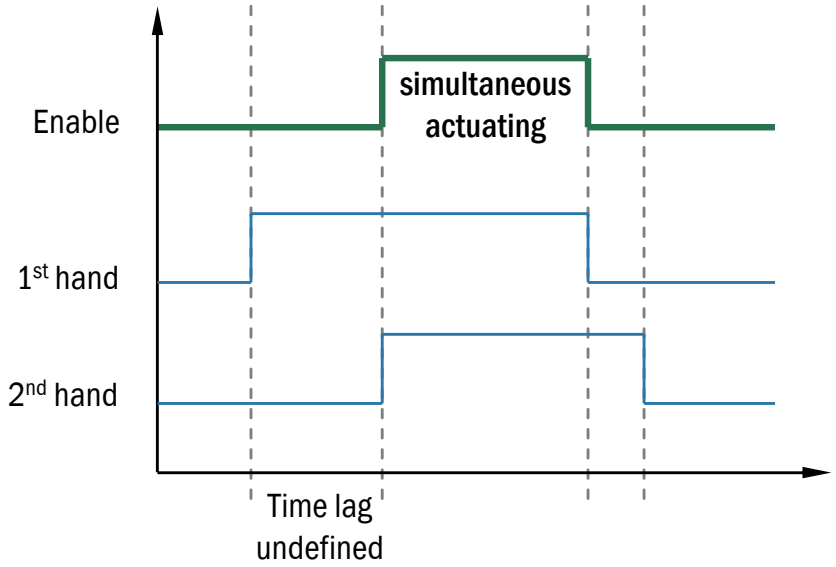
3 Control actualting device

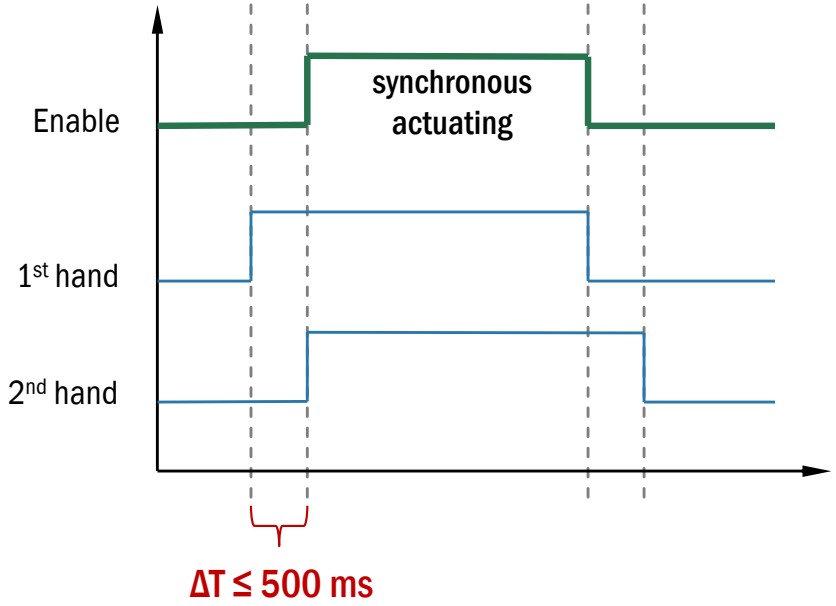
4 Signal converter(s)

5 Signal processor(s)

6 Output signal

7 Logic unit



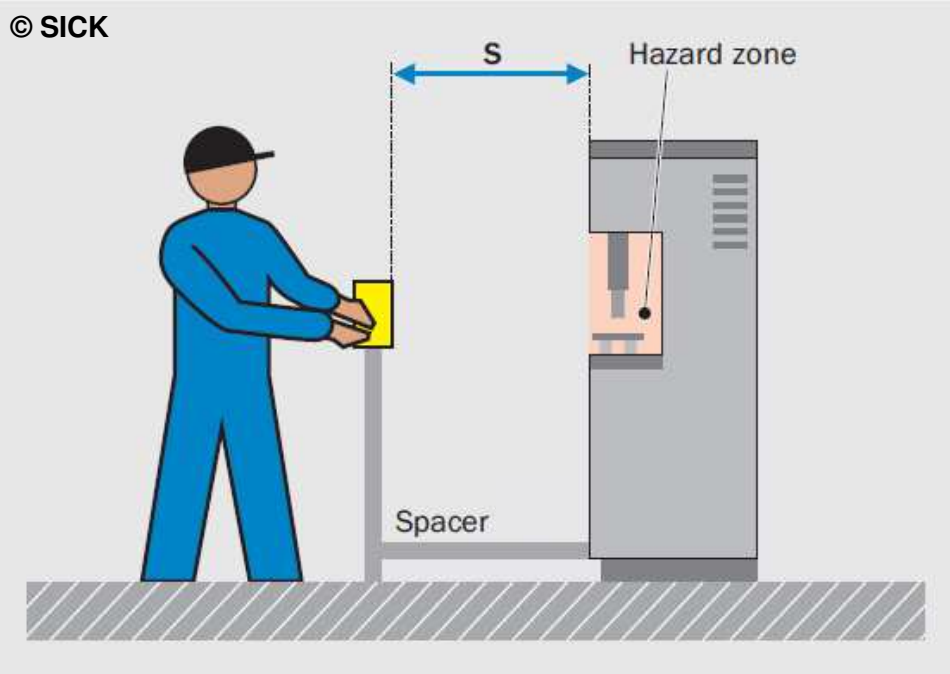


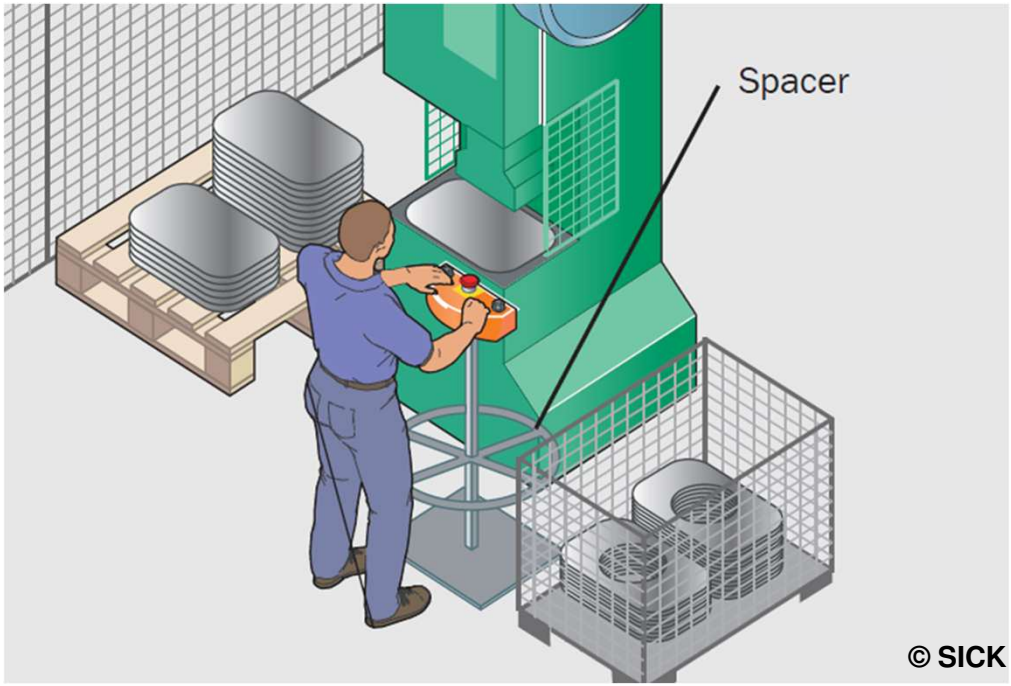
MINIMUM SAFETY REQUIREMENTS

TABLE 1, ISO 13851:2019

Requirements	Type				
	I	II	III		
			A	B	C
Use of both hands (simultaneous actuation)	●	●	●	●	●
Relationship between input signals and output signal	●	●	●	●	●
Cessation of the output signal	●	●	●	●	●
Revention of accidental operation	●	●	●	●	●
Prevention of defeat	●	●	●	●	●
Re-initiation of the output signal	□	●	●	●	●
Synchronous actuation			●	●	●
Use of category 1 (see ISO13849-1)	●		●		
Use of category 3 (see ISO13849-1)		●		●	
Use of category 4 (see ISO13849-1)					●

MINIMUM DISTANCES
FOR TWO-HAND CONTROLS





$$S = K \times T + C$$

$$C = 250\ mm$$

where

$$K = 1.600\ mm/s$$

C = 0 mm if control actuators are shrouded

ENABLING CONTROL FUNCTION

CLAUSE 9.2.3.9, IEC 60204-1:2020

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- **Manually activated** control function interlock
- When activated allows a machine operation to be initiated by a **separate** start control
- When de-activated initiates a stop function and prevents initiation of machine operation
- It shall not be possible to defeat the enabling function by simple means

THREE-POSITION ENABLING DEVICE

FIGURE C.1, ISO 10218-1:2011

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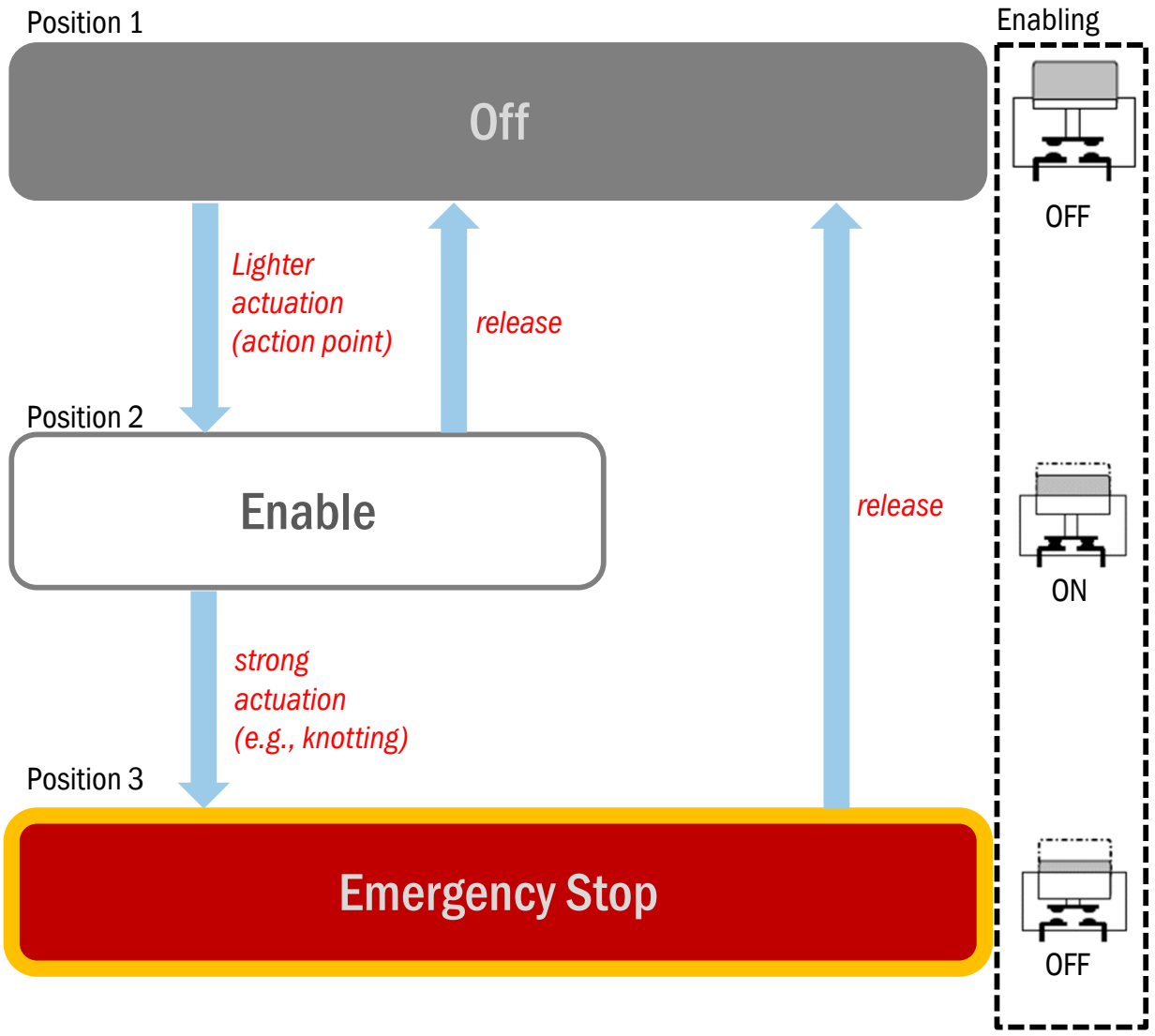

EMERGENCY STOP FUNCTION

ANNEX 1.2.4.3., DIRECTIVE 2006/42/EC [MD]

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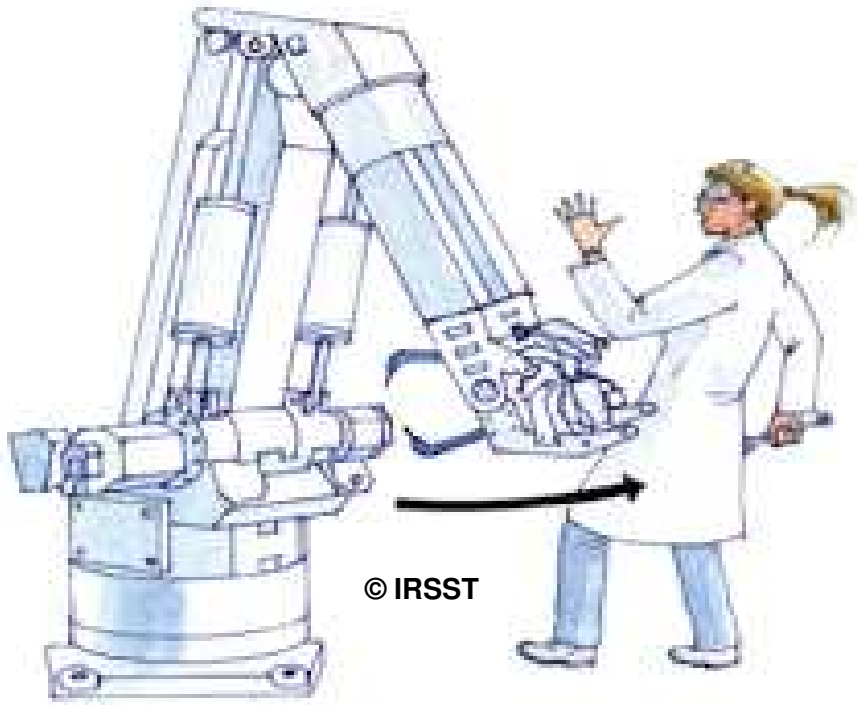
- Machinery must be fitted with one or more emergency stop devices to enable actual or impending danger to be averted.

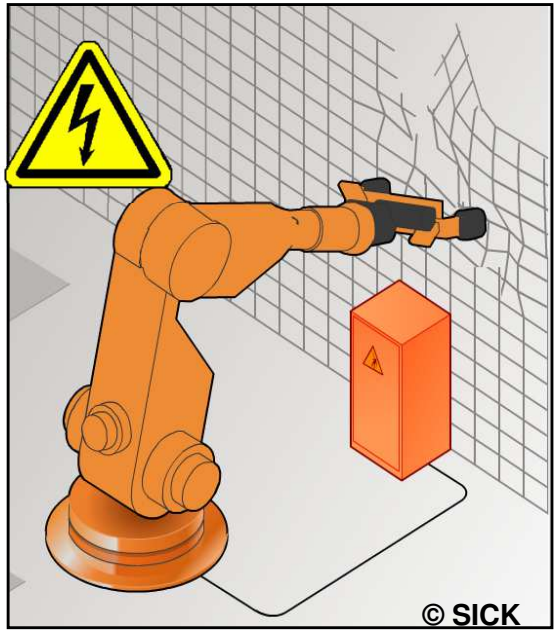
- The emergency stop function must be available and operational at all times, regardless of the operating mode.

- Emergency stop devices must be a back-up to other safeguarding measures and **not a substitute** for them.



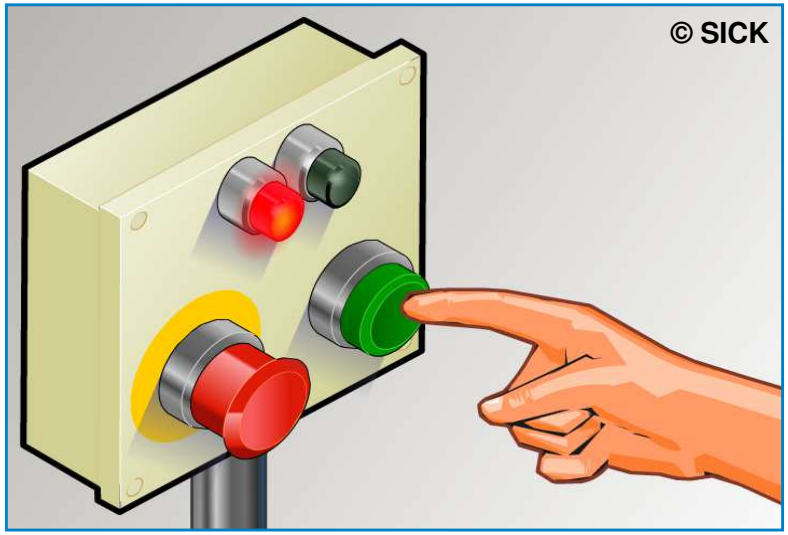
- The emergency stop function shall be so designed that, after actuation of the emergency stop actuator hazardous functions of the machine cease:
  - in an appropriate manner
  - not creating additional hazards
  - without any further intervention by any person
  - according to the risk assessment.
- An “appropriate manner” can include
  - choice of an optimal deceleration rate
  - selection of the appropriate stop category
  - use of a predetermined stopping sequence

- The emergency stop shall function in accordance with one of the following stop categories in accordance with the risk assessment.
  - Stop category 0
    - stopping by immediate removal of power
    - stopping by mechanical disconnection (declutching) from energy sources
    - if necessary, braking.
  - Stop category 1
    - A controlled stop with power available to achieve the stop and then removal of power when the stop is achieved.



EMERGENCY STOP FUNCTION
RESET

- Once the actuation of emergency stop device has ceased and an emergency stop command has followed, this command shall be sustained until it is manually reset.
- Reset shall be possible only at the location where the emergency stop command was initiated.
- Reset is necessary at each location where an emergency stop command was initiated.
- The reset of the command shall not restart the machinery but only permit restarting.



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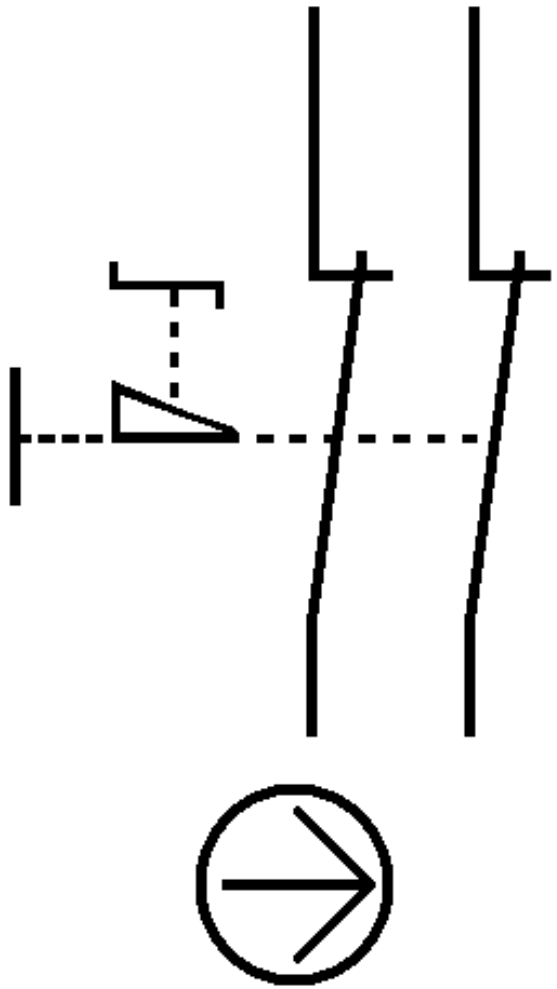
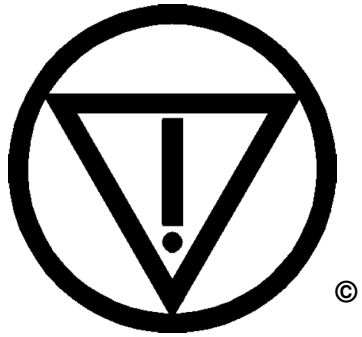
- Avoidance by design

- Detection with proper reaction



- The emergency stop device shall apply the principle of
  - Direct mechanical action
- Electrical emergency stop devices shall be in accordance with IEC 60947-5-5 and.
  - direct opening action
  - With mechanical latching.

- The emergency stop device shall be designed to be easily actuated by the operator and others who could need to actuate it.
- The types of actuators that may be used include the following:
  - mushroom-type pushbuttons
  - wires, ropes, bars
  - handles
  - foot-pedals without a protective cover (for specific applications)



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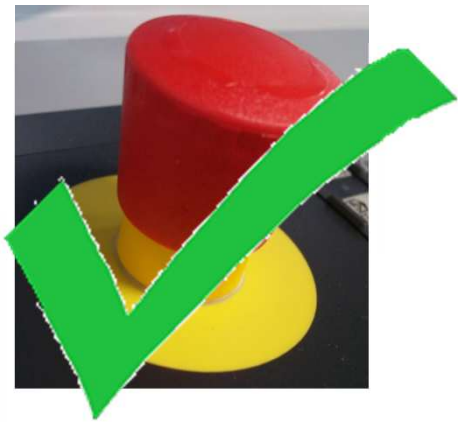
- The actuator of the emergency stop device shall be coloured **RED**
- As far as a background exists behind the actuator and as far as it is practicable, the **background shall be coloured YELLOW**.

EMERGENCY STOP FUNCTION

E-STOP DEVICE REQUIREMENTS

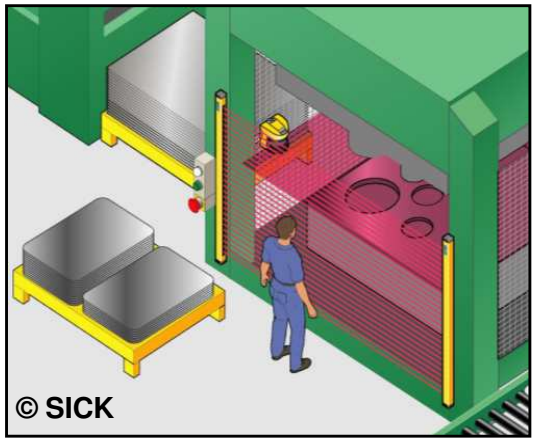
- Neither the actuator nor the background should be labelled with text or symbols. (4.3.7)
- Where a symbol is needed for clarification, the symbol from IEC 60417-5638 shall be used, see Figure 2.
- When it is necessary to identify the direction of unlatching of the actuator (button) then this identification shall have the same or nearly the same colour as the actuator (see also IEC 60947-5-5).

- NOTE The identification of unlatching (i.e. arrows) could be misinterpreted as direction of actuation.



EMERGENCY STOP FUNCTION
POSITIONING OF E-STOP DEVICES

- An emergency stop device shall be located at each operator control station (except where the risk assessment indicates that this is not necessary)
- Additional emergency stop devices shall be located at other locations, as determined by the risk assessment.
- They shall be positioned such that it is readily accessible and capable of non-hazardous actuation by the operator and others who could need to actuate it.
- Measures against inadvertent actuation should not impair its accessibility.



EMERGENCY STOP DEVICES

PREVENTION OF UNINTENDED ACTUATION - SHROUDING

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- The use of a protective shroud should be avoided, except
  when necessary to prevent unintended actuation and other measures are not practicable.

- A protective shroud shall not have any sharp corners or edges or rough surfaces which could lead to injury.

- Corners and edges shall be deburred, and surfaces shall be smooth to the touch.

- For emergency stop devices intended to be actuated by hand the measures against unintended actuation shall not impede or hinder actuation with the palm of the hand, from any foreseeable position of the machine operator and others who could need to actuate them.

EMERGENCY STOP DEVICES

UNHINDERED INTENDED ACTUATION

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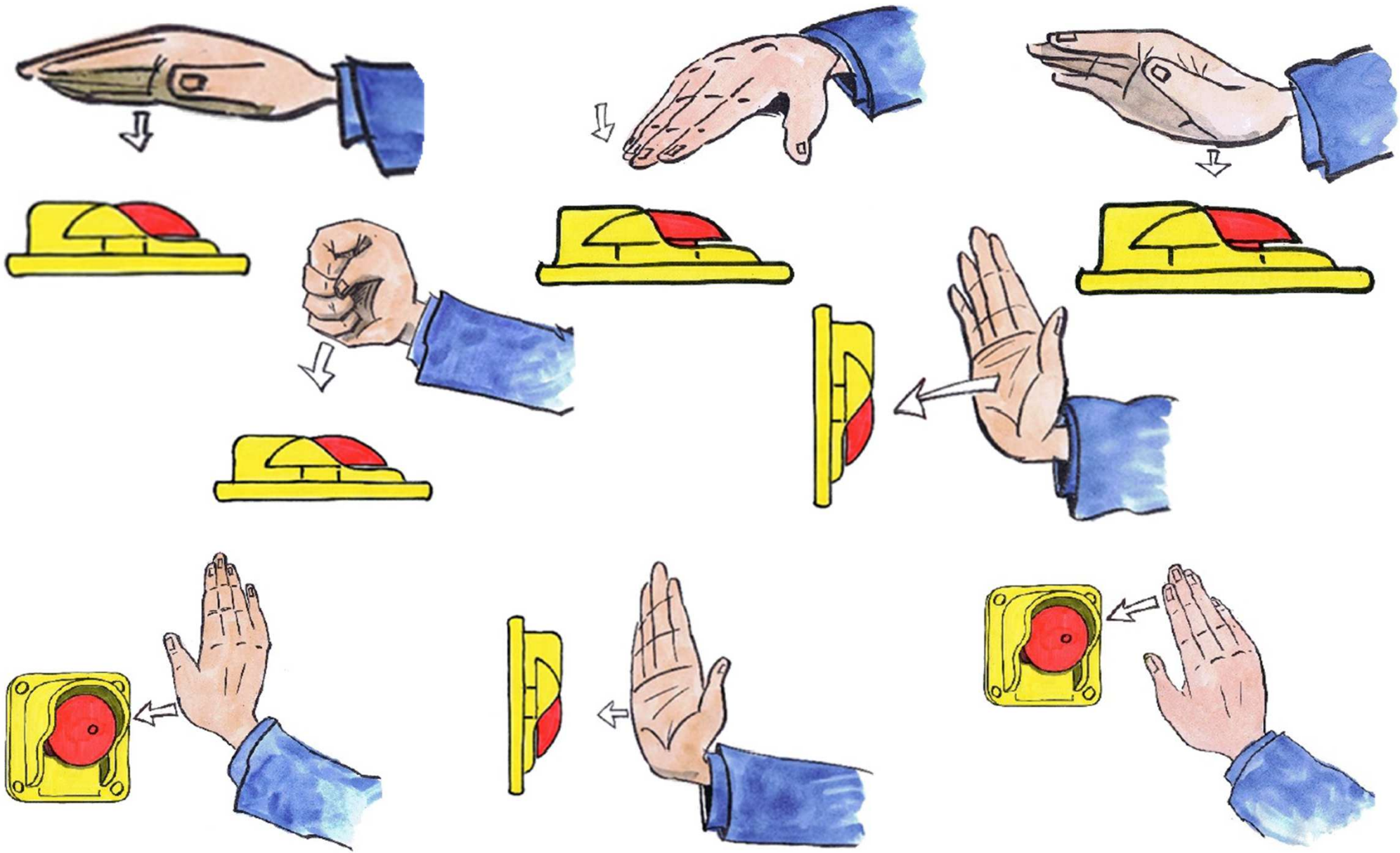
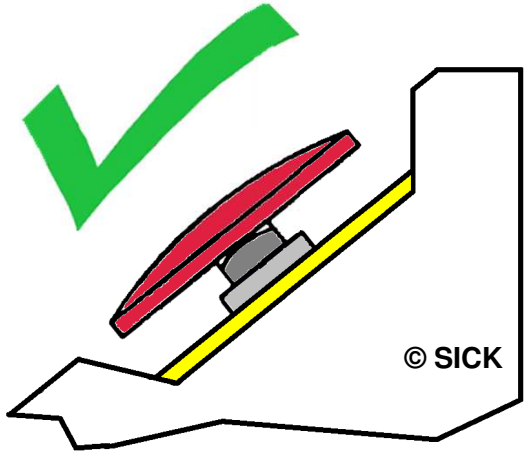


EMERGENCY STOP FUNCTION
DESIGN TO PREVENT UNINTENDED ACTUATION

- The emergency stop device shall be designed to avoid unintended actuation.
- So far as practicable, unintended actuation shall be prevented by location rather than the use of other application design measures.
- The actuation of the emergency stop device shall not be impaired. To prevent unintended actuation of the emergency-stop device some measures shall be taken



EMERGENCY STOP DEVICES
DESIGN, MOUNTING, KEY UNLATCHING

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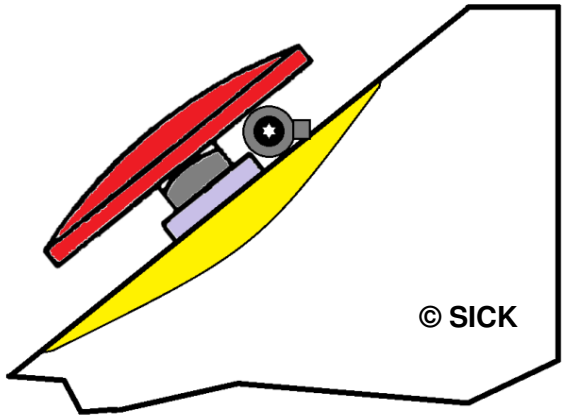
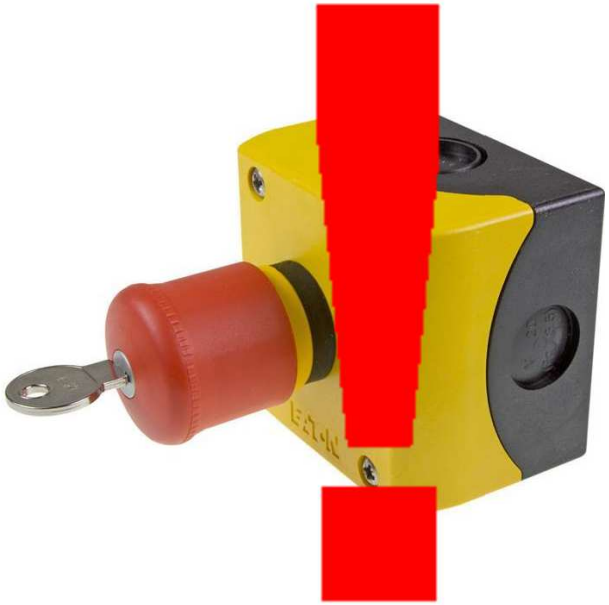
- Emergency stop devices shall be designed and mounted in such a way that the actuation cannot be easily blocked by simple means.



NOTE This can happen when objects fall beneath the actuating surface or when there is an intention of defeating.

- Emergency stop devices requiring a key on the actuator to be disengaged (unlatched) should be avoided.

- When an emergency stop actuator can only be disengaged by using a key, to avoid injuries to hands, instruction for use of the machine shall describe the correct use of the key and provide a warning that the key should only be in the actuator of the device to disengage the actuator.



TECHNOLOGY OF SAFEGUARDING

SEPARATE FROM DANGER BY MEANS OF SPACE OR TIME

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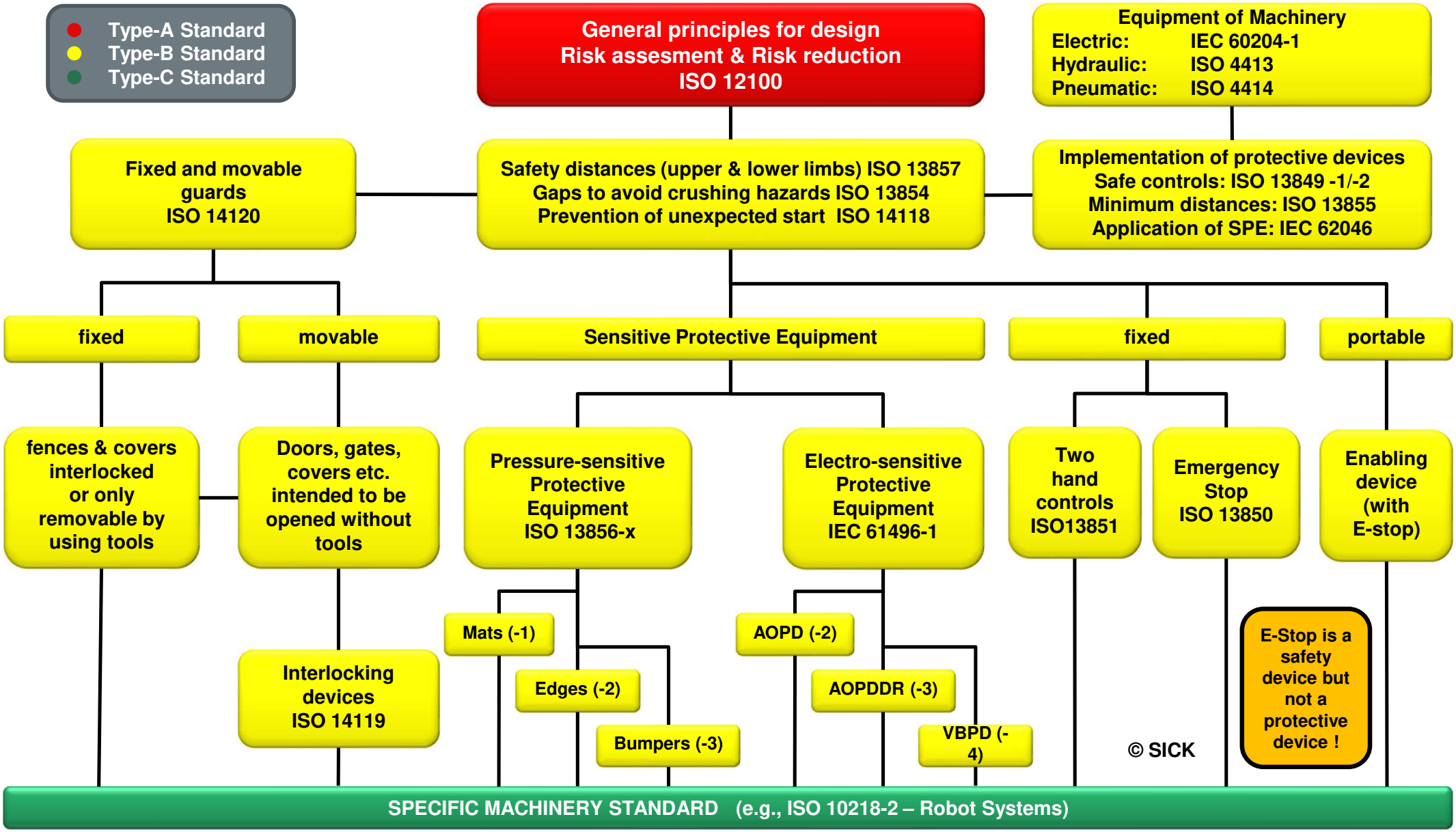

THANK YOU FOR YOUR KIND ATTENTION

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