SICK AG WHITE PAPER

PROTECTING AUTOMATED LOADING AND UNLOADING POINTS

MUTING, DIFFERENTIATION BETWEEN HUMANS AND MACHINE, LOCK APPLICATION, BLANKING – EUROPEAN VERSION

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SUMMARY

Efficient protection of loading and unloading stations shall prevent unauthorized entry into the hazardous area. This is the prerequisite for highly automated production facilities and unrestricted productivity. It is clear that not every technology and principle is suitable for every possible automated loading and unloading station. Making the wrong selection can impair the necessary safety or productivity of the equipment. Therefore, for every application, careful consideration must be given to the type of protection and the selection of the protective device. A combination of different sensors may be the best possible solution. Protective devices should be integrated as early as possible in the machine design process. They are fundamental prerequisites for achieving safe loading and unloading of machines cost-effectively and with high machine productivity.

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CONTENT

Introduction

Modern factories are based on highly automated production facilities in which productivity plays a decisive role. Therefore, the automated production processes in these facilities require continuous and uninterrupted material handling. Protecting access to hazardous areas around machines while at the same time maintaining the flow of materials is a particular challenge for the safety concept. Reliable access protection requires either differentiation between humans and materials that are being transported automatically, or other protective devices must be considered. Safe and unhindered automated handling of materials into and out of the hazardous area is possible if you select the right protective device.

Using the right type of protection for automated loading and unloading points both increases machine productivity and maintains safety. The results are high productivity with short downtimes and a more efficient process.

This white paper identifies and compares the various technologies and principles for protecting people at automated loading and unloading points. It cites the requirements of standards and recommendations that have proven successful in practice, as well as looking at possible misapplications. The various technologies and protection principles are compared on the basis of the advantages and disadvantages described.

Assumptions about the examples

One of the most important criteria for selecting the respective technologies and protection principles is the minimum distance of protective devices according to ISO 13855 or safety distance of protective structures according to ISO 13857.

The general formula for calculating the minimum distance is $S = (K \times T) + C$. **For better comparability, a stopping/run-down time for the overall system T of 0.5 s is assumed in this white paper. This results in an approach speed K of 1,600 mm/s.** This white paper describes how the minimum or safety distances of the various technologies and protection principles can be differentiated neutrally on the basis of the penetration distance C (mm). For the sake of simplicity, other product-specific and application-specific parameters are not taken into account.

The values in the examples are based on assumptions; they will need to be adapted before being transferred to practical applications.

This white paper does not claim to be exhaustive. Please also be aware that additional or supplementary protective devices may be necessary and that the requirements of existing machine-specific type-C standards must be taken into account.

Provision must be made to ensure that the triggers for restart signals comply with the requirements of applicable safety standards and regulations.

1. Physical guards

On an automated loading and unloading station, automated material handling is facilitated by an opening in the physical guard. This opening must also fully protect access to the hazardous area. A physical guard provides the necessary distance between persons and the hazardous area, thus preventing anyone from accessing the hazardous point. Uninterrupted material handling is possible up to a specific size of material. In practice, tunnels are the most commonly used physical guards to protect automated loading and unloading stations.

The safety distance between the opening of physical guards and the hazardous machine function changes depending on the size and shape of the material being transported. In the ISO 13857 standard, the safety distances to the hazardous area are set based on the openings required in the physical guards and thus the sizes of the materials.

Fig. 1.1 Tunnel as a physical guard.

Safety distance

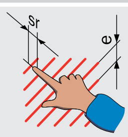
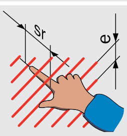
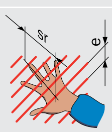
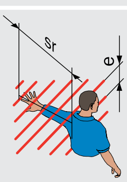
Part of the body		Opening e (mm)	Safety distance (mm)		
			Slot	Square	Circle
Fingertip		e ≤ 4	≥ 2	≥ 2	≥ 2
		4 < e ≤ 6	≥ 10	≥ 5	≥ 5
Finger up to wrist		6 < e ≤ 8	≥ 20	≥ 15	≥ 5
		8 < e ≤ 10	≥ 80	≥ 25	≥ 20
		10 < e ≤ 12	≥ 100	≥ 80	≥ 80
		12 < e ≤ 20	≥ 120	≥ 120	≥ 120
		20 < e ≤ 30	≥ 850	≥ 120	≥ 120
Arm up to shoulder		30 < e ≤ 40	≥ 850	≥ 200	≥ 120
		40 < e ≤ 120	≥ 850	≥ 850	≥ 850

Fig. 1.2 Safety distance as a function of the openings on physical guards according to ISO 13857.

The table shows how the safety distance is dependent on the opening in the physical guard for the material being transported. If the material being transported is very small, only a small opening is necessary in the physical guard. This opening only requires a short distance to the hazardous area. The bigger the material, the bigger the opening in the physical guard and thus the safety distance must be. If the diameter of the material being transported is greater than 550 mm, a physical guard without additional technical safety measures is not sufficient, because a person can get into the hazardous area through the opening.

Requirements

- Crushing and shearing points must be avoided, e.g., between fixed parts of the equipment and the transport unit (ISO 13854 includes safety distances to avoid crushing and shearing points)
- Sufficient space for the physical guard
- Sufficient safety distance
- Knowledge of the maximum size and shape of the material being transported
- Maximum diameter of the material being transported of 550 mm

Hazards and misapplications

- Distance between the material being transported and the fixed part of the equipment is too short (crushing hazard)
- Safety distance is too short
- Size of the opening in the physical guard is greater than 550 mm on the diagonal or greater than 550 mm x 300 mm
- Shape of material does not fit opening in physical guard

Fig. 1.3 Small opening size for physical guard.

Advantages

- Can be used in difficult ambient conditions without problems, including outdoors
- Not dependent on direction – materials can be transported in both directions
- Riding on materials or material carriers with an opening of compliant size is not possible in the physical guard
- Materials of different shapes and sizes are possible up to a certain size
- There can be gaps in the material flow
- Highest safety level

Disadvantages

- Additional crushing and shearing points are very probable so additional measures (e.g., interlocks) may be necessary
- Long safety distance required
- Even small openings for the transportation of material measuring 20 mm or larger require a safety distance greater than or equalto 850 mm (depending on the size of the material, this method requires the most space)
- Large items cannot be transported
- Limited flexibility with regard to the shape and size of items being transported
- No protection if safety distance is too short

2. Lock application

Fig. 2.1 Lock application with one lock and lift truck table.

A lock application is a special method to protect automated loading and unloading stations in which larger quantities of material are loaded or unloaded manually with the aid of material carriers like pallets or racks.

A lock application consists of at least one loading or unloading area whose inputs and outputs are protected by opto-electronic protective devices (usually safety light curtains) with vertical detection zones. Various types and sizes of material can be loaded or unloaded depending on the size of the lock opening. A separate manual reset is required for each protective device. The elements for actuating a reset must be located in a safe position outside the hazardous area. Both the hazardous area and the lock area must be visible from this position and it must not be possible to access the elements for actuating the reset from within the hazardous area (see EN ISO 13849-1). In a lock application, loading and unloading is usually done manually and further processing of the material is automated.

The external protective device protects access when the machine or equipment is in automated operation. During this time the internal protective device is deactivated (ineffective) so that material can be removed from or fed into the machine or equipment. So that the lock can be loaded or unloaded, a manual command is sent to deactivate the external protective device. The internal protective device is activated in order to limit and protect access to the hazardous area. Automated operation of the machine or equipment can continue during this time. Once loading or unloading is complete and the external protective device has been reset, automated operation of the machine or equipment can resume.

Minimum distance:

The penetration distance C is dependent upon the detection capability d of the opto-electronic protective device and the possibility of reaching over.

If the detection capability d ≤ 40 mm, the penetration distance C is calculated with the formula $C = 8 \times (d - 14)$ mm and varies between 0 and 208 mm. At and above a detection capability of 40 mm, the penetration distance C is 850 mm.

If it is possible to reach over the opto-electronic protective device, the penetration distance C can increase to a maximum of 1,200 mm.

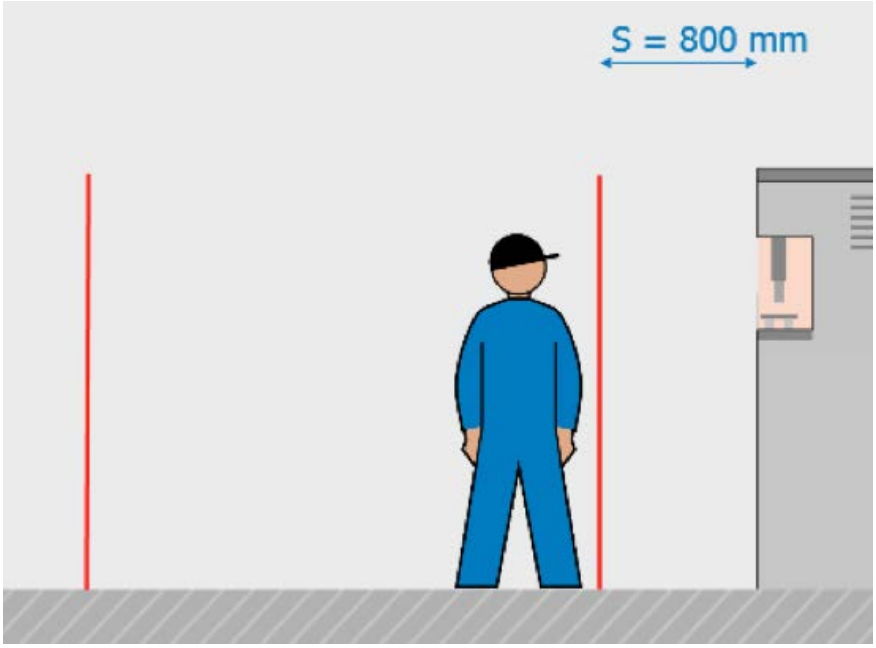


Fig. 2.2 Example minimum distance calculation for the lock application.

Other assumptions:

- Detection capability = 14 mm
- Reaching over not possible

The minimum distance of the internal protective device for the hazardous machine function is 800 mm with a detection capability of 14 mm and no possibility of reaching over, because in this example the penetration distance C is 0 mm. An additional distance to the external protective device and thus space for the lock itself must be taken into consideration, especially when hazards are permitted to enter the lock zone during normal automated operation.

Other assumptions:

- Correct selection of length and resolution of opto-electronic protective device
- Sufficient space for lock application and minimum distances
- Manual material handling
- Manual starting and stopping of the loading and unloading process
- Manual reset of protective devices necessary due to the possible presence of persons behind a protective device with exposure to a hazardous area
- The elements for actuating the reset must be located outside the hazardous area in a position from which there is clear sight of the entire hazardous area

Fig. 2.3 Lock application with two locks for low temperature conditions.

Hazards and misapplications

- Reset of a protective device while there is somebody inside the hazardous area or lock area
- Command switches (reset) do not meet requirements (can be accessed from within the hazardous area)
- Incorrect selection of opto-electronic protective devices
- Insufficient minimum distance of internal protective device
- Insufficient minimum distance of external protective device when hazards are permitted to enter the lock zone during normal automated operation
- Protective field of the opto-electronic protective device not high enough (reaching over is possible)
- Internal protective device without restart interlock
- Lower edge of the protective field of the opto-electronic protective device too high (crawling beneath is possible)
- Ambient conditions not compliant (lots of dust and dirt, outdoor equipment, etc.)

Advantages

- Access to the hazardous area is only possible through an active opto-electronic protective device
- There can be gaps in the material flow
- Flexibility with regard to materials
- Finger detection possible
- Highest safety level possible
- High productivity

Disadvantages

- The lock has to be loaded and unloaded manually
- Sufficient space for lock application necessary
- Operator bears responsibility for proper (safe) use
- Reset is activated manually by the operator
- At least two opto-electronic protective devices with manual reset are required

3. Blanking

Blanking is an alternative method to protect automated loading and unloading stations. For many safety light curtains, configuration of the detection capability and/or protective field can be designed so that the presence of one or more objects within a defined section of the protective field does not trigger the safety function (OFF state). Blanking can be used to allow objects of a specific size through the protective field.

For fixed blanking with increased size tolerance, the blanked area is precisely defined in terms of its position and maximum size. Only one object with a specific size tolerance at the defined position can move through the protective field. In the case of **floating blanking with partial object monitoring**, only the size of the blanked area is defined, not its position in the protective field. An object of a fixed size can be located and move within the protective field. An object can be present, but is not required.

With **fixed or floating blanking with complete object monitoring**, an object of a fixed size must be permanently present in the protective field; this is why these two types of blanking are not suitable for material handling.

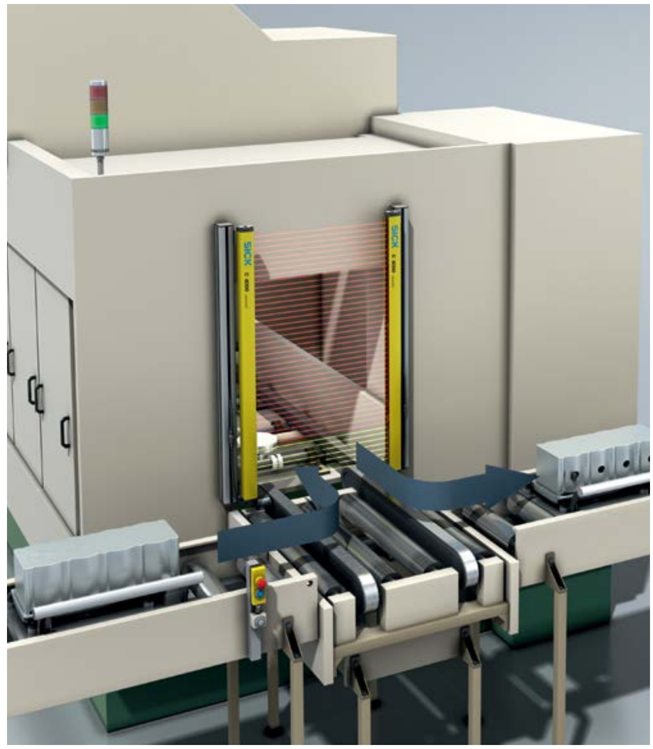


Fig. 3.1 Blanking.

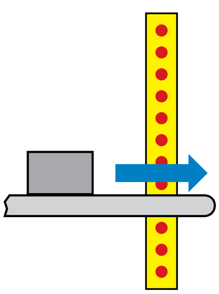
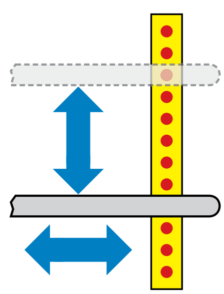
Fixed blanking with increased size tolerance	**Floating blanking with partial object monitoring**
From the operator side, an object of limited size is allowed to move through the protective field.	An object of fixed size is allowed in a specific area in the protective field. The object is allowed to move.
	

Fig. 3.2 Fixed or floating blanking

However, the first two variants of the blanking function described are suitable for protecting automated loading and unloading. All of the material must be the same size. This makes it possible to differentiate specifically between a person and the contour of the material. In some applications an additional signal may be necessary in order to reach the required safety level and counter foreseeable manipulation. To further reduce the residual risks of non-detection, the presence (or in some cases, a change in the size or position) of the material can trigger the safety function (OFF state).

Note: In the blanked area, the detection capability of the safety light curtain, and thus the minimum distance, is enlarged (deteriorates). What is known as the effective resolution takes the blanked beams (and thus the size of the blanked area during material handling) into account.

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Fig. 3.3 Special application angular blanking.

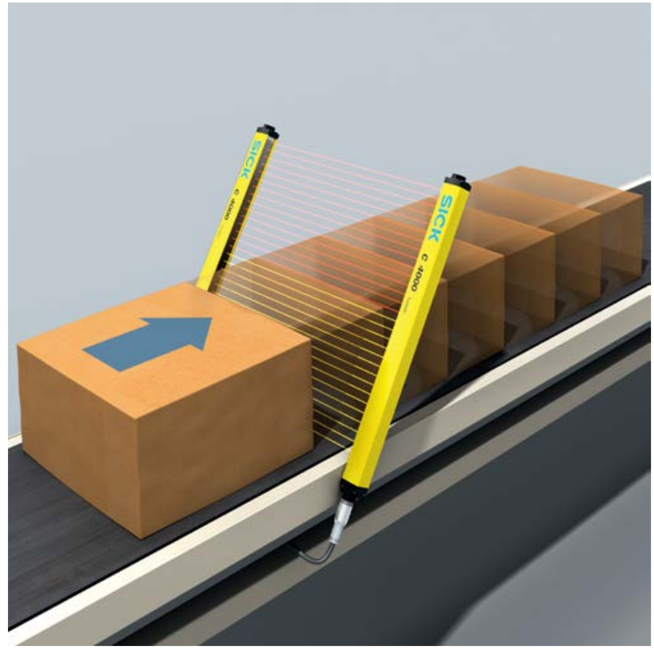


Fig. 3.4 Schematic representation of angular blanking.

Special application angular resolution (tilted blanking for objects of the same shape)

An application like this requires a safety light curtain with a resolution of between 14 and 20 mm. The safety light curtain is mounted at an angle of up to 30° in relation to the reference plane (usually the conveyor belt). If all of the material being transported is the same shape, the sensor beams can be interrupted in a defined sequence. With the blanking function, the safety light curtain is configured with a fixed start sensor beam and a maximum height of the expected material. When the material moves through the protective field of the safety light curtain, the sensor beams are interrupted in a recognized (and permitted) pattern. The blanking function cannot be triggered accidentally by a person because the sensor beams cannot be interrupted accidentally in the same sequence. Reliable differentiation between material being transported and a person is thereby assured. Normally, a human hand will interrupt more than one sensor beam. When selecting this type of protection, the sequence must be selected carefully. This special application is not affected by some of the disadvantages of conventional blanking.

Minimum distance:

The penetration distance C is dependent upon the detection capability d of the opto-electronic protective device and the possibility of reaching over.

If the effective resolution is up to and including 40 mm, the penetration distance C is calculated with the formula $C = 8 \times (d - 14)$ mm and varies between 0 and 208 mm. At and above an effective resolution of 40 mm, the penetration distance C is 850 mm.

If it is possible to reach over the opto-electronic protective device, the penetration distance C can increase to a maximum of 1,200 mm.

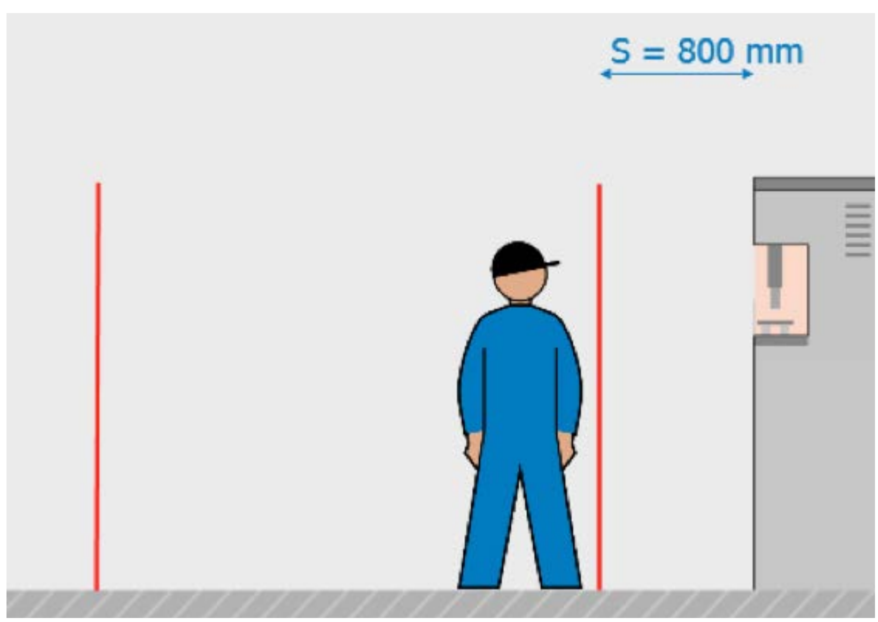


Fig. 3.5 Example minimum distance calculation for blanking.

Other assumptions:

- Detection capability = 14 mm
- A blanked area of 45 mm – this results in an effective resolution of 60 mm
- Reaching over not possible

The penetration distance C of 850 mm results from the effective resolution of 60 mm. If there is no possibility of reaching over, the minimum distance is 1,650 mm.

Requirements

- Crushing and shearing points must be avoided, e.g., between fixed parts of the equipment and the transport unit (ISO 13854 includes minimum distances to avoid crushing and shearing points)
- Sufficient minimum distance and consideration of effective resolution
- Correct selection of length, resolution, and function of safety light curtain
- Correct configuration of the blanking function
- Knowledge of the contours of the material being transported
- Consistent material contours and sizes
- Manual reset of protective device necessary due to the possible presence of persons behind the internal protective device
- The elements for actuating the reset must be located outside the hazardous area in a position from which there is clear sight of the entire hazardous area.

Hazards and misapplications

- There is not enough distance between the material being transported and the fixed parts of the equipment (crushing hazard)
- Protective field of the safety light curtain is not high enough (reaching over is possible)
- Reset of a protective device while there is somebody inside the hazardous area or lock area
- Control switches (reset) do not meet requirements (can be accessed from within the hazardous area)
- Incorrect selection of the safety light curtain (without blanking)
- Insufficient minimum distance
- Effective resolution not taken into account
- Mounting and specifically the mounting bracket for the safety light curtain not suitable for the application
- Too many different material contours and sizes
- Ambient conditions not compliant (lots of dust and dirt, outdoor equipment, etc.)

Advantages

- Not dependent on direction (except with special application angular blanking) – materials can be transported in both directions
- Safety light curtain permanently active (increased reliability of detection of persons)
- No additional sensors for switching or muting protective fields
- No additional protection required for smaller objects (additional side protection like interlocked hinged guards)
- Highest safety level possible
- Easy configuration and installation possible
- Finger detection possible
- Probable detection of persons on the material being transported

Disadvantages

- Increased minimum distance due to blanked beams (effective resolution)
- Only small objects are possible (except with special application angular blanking)
- No flexibility with regard to material contours and sizes
- Additional signals might be necessary
- Gaps in protective field due to blanking

4. Time-limited handling

In applications to protect automated loading and unloading stations with time-limited handling, the protective field of the opto-electronic protective device is muted or adaptedfor the duration of material handling. In both cases, switching or muting of the protective field is started and stopped automatically. This can be achieved by using suitable additional sensors or in some cases with signals from a safety-related control system. The additional switching or muting sensors detect the material being transported and initiate the switching or muting signal. So that the sensors can tell the difference between the material being transported and a person, particular care must be taken when selecting and configuring these sensors (see Chapter 4.3 for more information). Other signals from the control system can specify the time at which material is to be transported in order to define the switching or muting time. These signals can be used alternatively or in addition for a higher safety level. Switching or muting protective fields is only permitted if safety is being maintained by other means. This might be a loaded material carrier, for example, which serves as a barrier during protective field switching or muting and thus prevents anyone from accessing the hazardous area.

The method for muting sensors illustrated in IEC/TS 62046 is equally recommended for switching protective fields. The procedure for selecting and positioning switching and muting sensors is, therefore, identical.

The following conditions must be met to implement a safe and standardized switching or muting function:

- During switching or muting, a safe status shall be ensured by other means; i.e., it shall not be possible to access the hazardous area (for example, The material being transported shall prevent access to the hazardous area during switching or muting of the protective field)
- Switching or muting shall be automated, i.e., not manual
- Switching or muting shall not be dependent on a single electrical signal
- Switching or muting shall not be fully dependent on software signals
- Switching or muting shall not be initiated by an earth fault or open-circuit of the signal lines or the power supply to the switching or muting sensors
- The switching or muting signals occurring during an invalid combination shall not allow any switching or muting status
- The switching or muting status shall end immediately after the material has passed through
- The material being transported shall be detected along the entire length, i.e., there must be no interruption of the output signals
- Switching or muting sensors shall be selected, positioned, and configured so that it is possible to differentiate between a person and the material being transported
- Switching or muting sensors shall be selected and positioned so that the material being transported and not the material carrier is detected (this is in order that a person riding on the material carrier, such as a pallet, will be detected)
- Switching or muting sensors shall be installed sufficiently close to the opto-electronic protective device so that when the switching or muting function is effective, persons cannot get through into the hazardous area by going immediately in front of or behind the material
- Switching or muting sensors and the opto-electronic protective device shall be positioned so that they do not pose additional hazards such as crushing or shearing points
- Switching or muting sensors shall be arranged so that a person cannot accidentally trigger unintentional muting or switching of the protective device (it shall not be possible to activate sensors mounted opposite (A) and next to (B) one another at the same time)

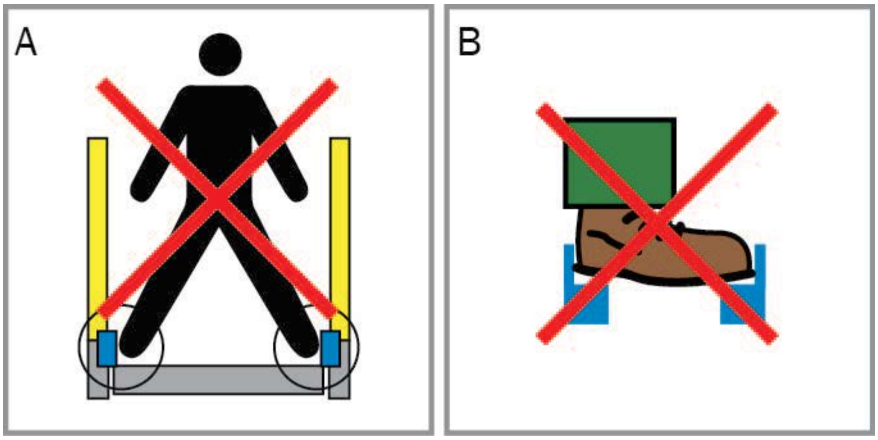


Fig. 4.1 Safety when mounting switching and muting sensors.

Additional limit values, links, or signals can improve differentiation quality, e.g.:

- Direction of movement of the material (sequence of the switching or muting signals)
- Limitation of the switching or muting duration
- Material request by the machine controller
- Operational status of the material handling elements (e.g., conveyor belt, roller conveyor)
- Material identification by additional properties (e.g., bar code, RFID)

Override function

Override is a manual triggering of protective field switching or muting after an error in the switching or muting conditions. A valid switching or muting condition is simulated briefly to switch or mute the protective device so that the system can be overridden or restored to an error-free status. Objects that have been left behind can be removed from the protective device area. This function is primarily required whenever heavy objects are being transported and the transport device is shut down by the protective device.

Errors can occur due to a response from concurrence monitoring, a response from monitoring of the switching or muting time, as well as from direction detection, sequence monitoring, or sensor gap monitoring. Even the switching or muting sensors themselves or a restart following emergency switching off or a mains voltage failure can cause an error.

Note

Faulty signals and sequences or incorrect timing of the switching or muting sensors or signals must not trigger a switching or muting status. Neither must a switching or muting status be triggered if:

- The outputs of the protective device are in the OFF state
- The protective device is interlocked
- At least one switching or muting sensor is activated (see IEC 60204-1, Clause 9.2.4)

The equipment must be in a safe status when the override function is used. The override function should only be used if the hazardous area has been visually inspected and during this function there are no persons inside or with access to the hazardous area.

4.1. Muting of the protective field

Fig. 4.1.1 Protective field muting with four sensors arranged in parallel and time monitoring

Temporary automatic suspension of the safety function (muting) is the most commonly used method in practice to protect automated loading and unloading stations. The muting function is used to deactivate the protective function of a protective device on a time limited basis. Suitable muting sensors or additional signals from the safety-related control system are used to differentiate between material and human beings.

IEC/TS 62046 defines muting as follows:
Muting is the temporary (intermittent) automatic suspension of a safety function or safety functions by safety-related parts of the control system. This is necessary when material must be moved through the detection zone of the protective device without stopping the workflow (hazardous state of the machine).

If the muting function is not activated, the protective device must detect the entry of a person and then initiate a stop command for the associated hazardous machine function(s). This is why it is necessary for a muting application to be able to tell the difference between material being transported automatically and a person. This is achieved with corresponding muting sensors or signals. Based on a logical evaluation of these external muting signals, the protective device is muted if a valid muting condition prevails so that the material being transported can pass the protective device without initiating a stop command. During muting, a safe status of the machine must be ensured by other safety devices. This means that access to the hazardous area is not possible, regardless of whether the protective device has been muted. While the protective device is muted, the material being transported shall block access to the hazardous area and serve as a barrier. If this is not possible due to the material itself or the duration of muting, additional measures are necessary. On the other hand, where protective devices preventing access (protective devices that cannot be passed) are concerned, it shall only be possible to mute the protective device if no hazardous machine functions are in progress. If the distance between the hazardous machine function and the protective device is so short that these hazards can be reached while the detection zone is muted, the hazardous machine function must be shut down safely during transport of material.

Muting lamp

A muting lamp or a muting status signal can be used to signal muting. Some type-C standards still prescribe the use of a muting lamp. The muting lamp identifies temporary muting. An external lamp (monitored/not monitored) or integrated signal lamps can be used for this purpose.

Minimum distance

The penetration distance C is dependent upon the protective device selected (such as the detection capability d of an opto-electronic protective device) and the possibility of reaching over.

If the detection capability d of the opto-electronic protective device is greater than or equal to 40 mm, the penetration distance C is calculated with the formula C = 8 x (d – 14) mm and varies between 0 and 208 mm. At and above a detection capability of 40 mm, the penetration distance C is 850 mm.

If it is possible to reach over the opto-electronic protective device, the penetration distance C can increase to a maximum of 1,200 mm.

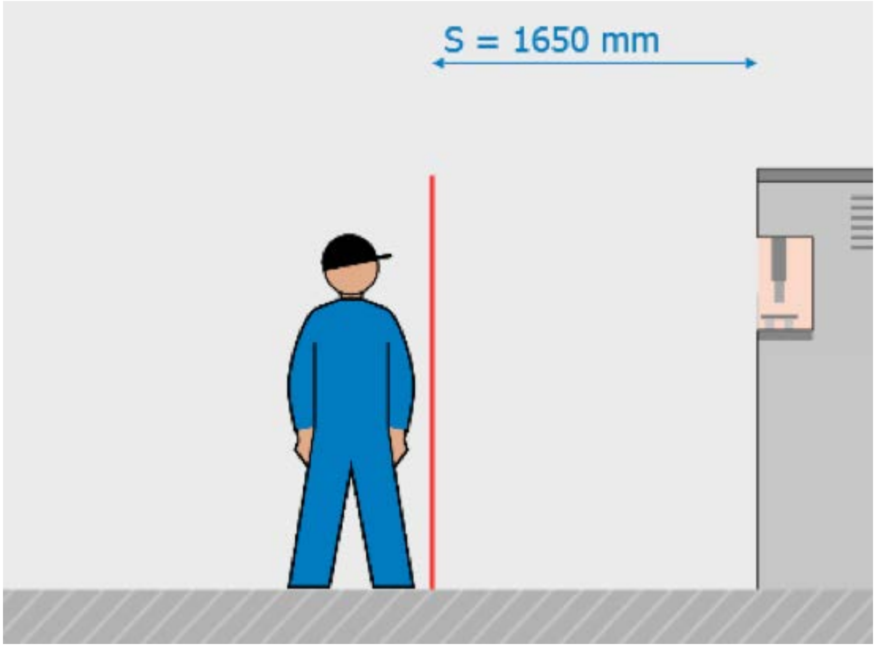


Fig. 4.1.2 Example minimum distance calculation for muting.

Other assumptions:

- Detection capability greater than 40 mm
- Reaching over not possible

The penetration distance C is 850 mm with a detection capability of > 40 mm and no possibility of reaching over.
In this example, this results in a minimum distance of 1,650 mm.

Other assumptions:

- Crushing and shearing points must be avoided, e.g., between fixed parts of the equipment and the transport unit (ISO 13854 includes minimum distances to avoid crushing and shearing points)
- Correct selection of length and resolution of protective device
- Sufficient minimum distance
- Safe and reliable differentiation between material and persons achieved by:
    - Selection of suitable muting sensors
    - Suitable positioning of muting sensors (detection of material and not material carrier)
- Muting system complying with the required safety level (PL, category)
- Blocking of access to the hazardous point by the material being transported (additional measures such as interlocked hinged guards might be necessary)
- Knowledge of the maximum material contours of the material being transported
- Detection of the material being transported (not the material carrier) No undetected riding on material carriers possible
- Manual reset of protective device necessary due to the possible presence of persons behind the internal protective device
- The elements for actuating the reset must be located outside the hazardous area in a position from which there is clear sight of the entire hazardous area

Fig. 4.1.3 Protective field muting with four sensors arranged opposite one another and additional signal

Hazards and misapplications

- Gaps between fixed and moving machine parts allow persons to ride into the hazardous area on top or along side the material
- There is not enough distance between the material being transported and the fixed parts of the equipment (crushing hazard)
- Distance between the material being transported and the fixed parts of the equipment is too long (no interlocked hinged guards)
- Protective field of the opto-electronic protective device not high enough (reaching over is possible)
- Insufficient minimum distance
- Reset of a protective device while there is somebody inside the hazardous area or lock area
- Command switches (reset) do not meet requirements (can be accessed from within the hazardous area)
- Incorrect arrangement of the muting sensors (risk of manipulation)
- Random activation of muting sensors
- Incorrect selection of muting sensors (unreliable material detection)
- Selection of unsuitable control signals (protective device always muted)
- Use of single-channel controllers in isolation for control signals (loss of safety function in the event of an error)
- Ambient conditions not compliant (lots of dust and dirt, outdoor equipment, etc.)
- No blocking of access to the hazardous area by the material being transported during protective field muting
- Detection of the material carrier instead of the material being transported

Advantages

- Comparatively inexpensive
- Short minimum distance possible
- Finger detection possible (advantageous penetration distance)
- Safe transport of many different materials of different sizes
- Flexibility with regard to material contour
- Highest safety level possible
- Not dependent on direction (depending on muting sensor arrangement selected)
  – materials can be transported in both directions

Disadvantages

- Protective device not continuously active (muted)
- Additional muting sensors or signals necessary
- Additional protection might be required (additional side protection like interlocked hinged guards)
- Unwanted triggering of the protective device due to possible gaps in the material being transported. These gaps can be initiate wrongly an end of the muting sequence.
- Risk of manipulation of protective field muting with incorrect selection and/or incorrect arrangement of muting sensors
- No detection of persons on or inside the material being transported
- No detection of persons moving alongside the material
- Possibly no detection of persons moving directly in front of or behind the material being transported
- Difficult ambient conditions can lead to the unwanted triggering of the protective device or might even exclude use
- Muting lamp might be required (might be listed as a requirement in specific regional or type-C standard)

Alternative application of protective field muting:

The muting function can also be used to optimize the workflow if allowed by certain machine states (e.g., muting the function of a safety light curtain during the non-hazardous upwards movement of a press die, making it easier for the operator to remove workpieces in a timely fashion). It is thus possible to use the muting function to provide a person or a part of a person with access to the machine for a specific period of time without the protective device switching to the OFF state. This requires that during access, the person is not exposed to a dangerous state of the machine cycle or that safety is maintained via other means. This application of protective field muting can be used to insert or remove workpieces, for example, without interrupting the machine process.

4.2. Protective field switching

Fig. 4.2.1 Protective field switching with two safety laser scanners and four sensors arranged in parallel with time monitoring.

The function of dynamic protective field switching is suitable for protecting automated loading and unloading stations. Suitable signals from switching sensors or the control system switch the protective field of the protective device for a limited time.

Safety laser scanners with vertical or slightly tilted protective fields are generally used for this application. The appropriate protective field for the material being transported at the time is activated from a series of pre-programmed protective fields by corresponding signals from the control system and suitably positioned sensors. The contour of the protective field is adapted to the object being transported so that the material passing through does not trigger the protective device. The areas that are not monitored must be contoured so any remaining gaps are small enough that a person will be detected at any time in the remaining protective field. In this case, the material itself acts as a barrier and prevents entry into the hazardous area through the area that is not being monitored. The protective field is switched again after the material has passed to the original protective field contour to once again detect the entire area. Depending on the application, it may be necessary to install two safety laser scanners in order to reduce possible blind zones to the fullest possible extent.

When safety laser scanners are used, the necessary distance between protective field and objects must be maintained in order to maintain productivity. This distance may lead to a change in the effective resolution.

Special application Safe Portal by SICK

Safe Portal is the name of a special application for protective field switching to protect automated loading and unloading stations. For this application, two safety laser scanners are mounted opposite one another vertically or horizontally. Simultaneous protective fields can be used to safely monitor multiple areas at the same time. It is important that the material carrier or the material synchronously interrupts the protective fields in advance or simultaneously. Switching sensors are not necessary for this special type of protective field switching. The method for muting sensors described in IEC/TS 62046 is, therefore, not relevant to this special application.

- With protective field switching with two safety laser scanners mounted vertically, the material carrier interrupts a previously defined sensor field in a specific position. Depending on the position of the material carrier (i.e., raised or lowered), it is possible to detect whether material is being transported on the material carrier in order to adapt the protective field contour accordingly.
- In the case of safety laser scanners that are mounted horizontally, multiple sensor fields are defined which detect the contours of the material carrier in a specific sequence. Unlike conventional protectiv field switching, this application continues to protect the hazardous area.

Fig. 4.2.2 Special type of protective field switching without switching sensors.

The advantage of this special type of protective field switching is that as well as switching sensors not being required, the protective fields are flexible for different types of material being transported, with these being differentiated based on material carrier contour or position.

Minimum distance

The penetration distance C is dependent upon the protective device selected (such as the detection capability d of an opto-electronic protective device) and the possibility of reaching over.

If the detection capability d of the opto-electronic protective device is greater than or equal to 40 mm, the penetration distance C is calculated with the formula C = 8 x (d – 14) mm and varies between 128 and 208 mm. This is because 30 mm is assumed as the lowest detection capability of a safety laser scanner. At and above a detection capability of 40 mm, the penetration distance C is 850 mm.

If it is possible to reach over the opto-electronic protective device, the penetration distance C can increase to a maximum of 1,200 mm.

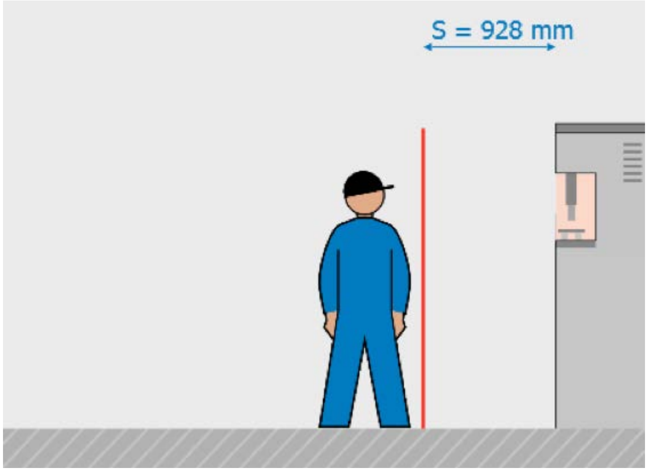


Fig. 4.2.3 Example minimum distance calculation for protective field switching.

Other assumptions:

- Detection capability = 30 mm
- Reaching over not possible

The penetration distance C is 128 mm. Taking the assumptions made into account, the minimum distance is 928 mm.

Requirements

- Crushing and shearing points must be avoided, e.g., between fixed parts of the equipment and the transport unit (ISO 13854 includes minimum distances to avoid crushing and shearing points)
- Correct selection and configuration of protective device
- Sufficient minimum distance
- Safe and reliable differentiation between material and persons achieved by:
  - Selection of suitable switching sensors
  - Suitable positioning of switching sensors
- Switching system complying with the required safety level (PL, category)
- Blocking of access to the hazardous point by the material moving through
- Total response time of the safety laser scanner with vertical installation maximum 90 ms
- Reference contour necessary for the safety laser scanner
- Knowledge of the material contours of the material being transported
- No undetected riding on material carriers possible
- Manual reset of protective device necessary due to the possible presence of persons behind the internal protective device
- The elements for actuating the reset must be located outside the hazardous area in a position from which there is clear sight of the entire hazardous area.

Hazards and misapplications

- There is not enough distance between the material being transported and the fixed parts of the equipment (crushing hazard)
- Response time of the safety laser scanner high due to configuration, thus minimum distance is increased (total less than 90 ms)
- Response time of the safety laser scanner above 90 ms due to configuration, thus vertical protection is not possible
- Protective field of the opto-electronic protective device not high enough (reaching over is possible)
- Insufficient minimum distance
- Reset of a protective device while there is somebody inside the hazardous area or lock area
- Command switches (reset) do not meet requirements (can be accessed from within the hazardous area)
- Incorrect arrangement of switching sensors (risk of manipulation)
- Random activation of switching sensors
- Incorrect selection of switching sensors (unreliable material detection)
- Selection of unsuitable control signals (protective device always switched)
- Use of single-channel controllers in isolation for control signals (loss of safety function in the event of an error)
- Ambient conditions not compliant (lots of dust and dirt, outdoor equipment, etc.)
- Blind zones in the protective field of a safety laser scanner or materials with special contour
- No blocking of access to the hazardous area by the material being transported during protective field switching

Advantages

- Flexibility with regard to size of material and field
- Safety laser scanner permanently active (increased reliability of detection of persons)
- Increased safety due to defined protective field sizes, appropriate for the material being transported
- Probable detection of persons on the material being transported
- Probable detection of persons moving alongside the material
- No additional protection required (additional side protection like interlocked hinged guards)
- Additional information about the material being transported with the assistance of the contour monitoring function
- Not dependent on direction (depending on switching sensor arrangement selected) – materials can be transported in both directions

Fig. 4.2.4 Protective field switching with one safety laser scanner and four sensors arranged in parallel with time monitoring

Disadvantages

- Switching sensors or signals necessary
- No finger detection possible
- Possible blind zones in the protective field
- Unwanted triggering of the protective device due to possible gaps in the material being transported
- Risk of manipulation of protective field switching with incorrect selection and/or incorrect arrangement of switching sensors
- Possibly no detection of persons moving directly in front of or behind the material being transported
- Difficult ambient conditions can lead to the unwanted triggering of the protective device or might even exclude use
- Total response time of the protective device must not exceed 90 ms following configuration
- In maximum Safety level PL d can be reached, if safety laser scanners are in use

4.3. Switching or muting sensors

4.3.1. Configuration

The configuration of the number, type, arrangement, and control of muting sensors are described in Appendix F of IEC/TS 62046. This procedure is also recommended for the configuration of switching sensors. Muting functions are described below, but the principle is equally applicable when used for switching functions.

There are essentially four different approaches to configuring switching or muting sensors:

1. Four sensors arranged in parallel with time monitoring – material can be transported from both sides
2. Four sensors arranged in parallel with sequence monitoring – material can be transported from both sides
3. Two sensors in T configuration with time monitoring – material can be transported from both sides
4. Two sensors in L configuration with time monitoring – material can be transported from one side

These principles can also be applied to other configurations.

The switching or muting sensors shall always be arranged so that:

- Only the material is detected, not the means of transport (pallet or vehicle)
- Material can pass through unobstructed but persons are safely detected
- When material is detected, a minimum distance is maintained between the detection zone of the protective device and the nearest hazard(s)

Switching and muting cycle

The switching and muting cycle is the defined sequence of all events that take place during switching or muting. It starts when the first switching or muting sensor is activated. It ends when the last sensor returns to the initial status (e.g., free light path in the case of optical sensors). Only at this point can the switching or muting cycle of the protective field be activated again.

Manipulation

The avoidance of manipulation must be taken into account prior to installing the switching or muting function. The following measures can be taken to reduce possible attempts at manipulation:

- Limitation of the duration (time) of the switching or muting function
- An additional enable command from the machine controller for the switching or muting function
- The selection of suitable switching or muting sensors (e.g., proximity sensors) which are installed alternately on the opposite side so that it is not easy for them to be activated by a person
- Concurrence or sequence monitoring of the switching or muting sensors

Note: The height of the switching or muting sensors in relation to the reference plane (usually the conveyor system) should be selected so that the material being transported is detected, but not the material carrier. If this is not possible, additional measures may be necessary to ensure that a person riding on the material carrier will be detected.

Additional measures such as flexible and monitored swing doors measuring at least 500 mm in width and electronic monitoring may be necessary for the following scenarios (see Fig. 4.3.1.1):

- A person has unrestricted access to the hazardous area through the openings between the material being transported and the physical guard (distances a and b)
- The material being transported and the fixed parts of the equipment represent crushing and shearing points. It is for this reason that distances a and b have to be enlarged
- Distances a and b vary on account of the different materials being transported; they are > 200 mm.

Four sensors arranged in parallel with time or sequence monitoring – material can be transported from both side

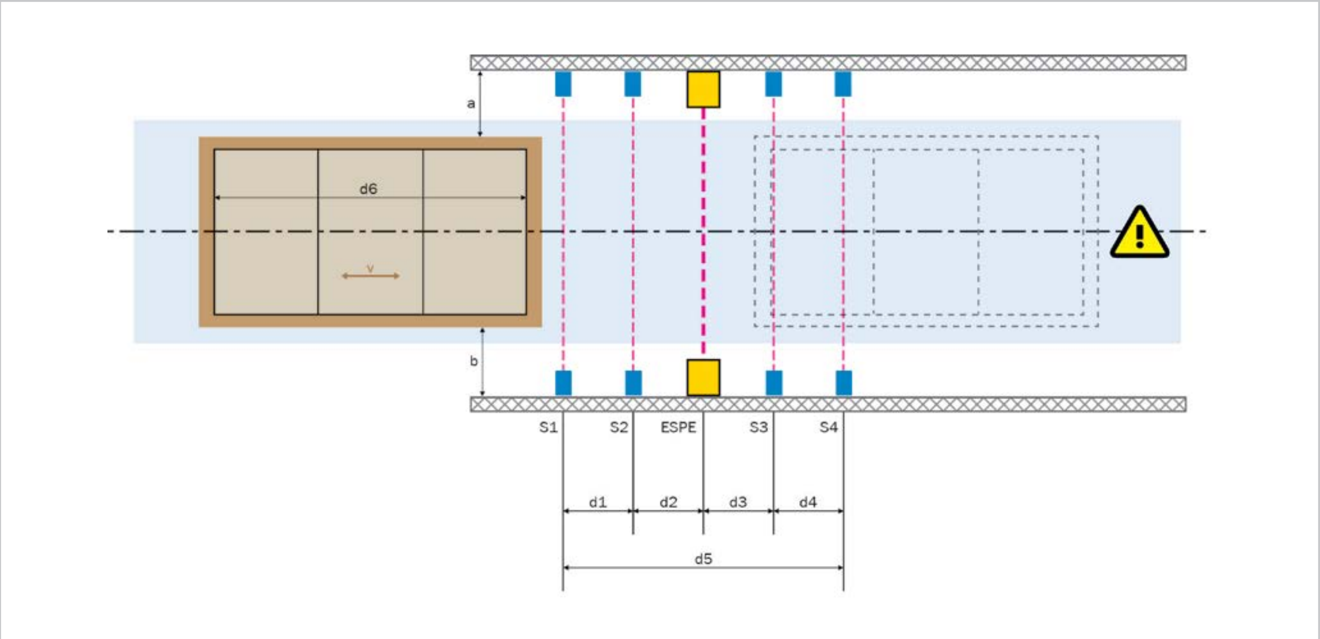


Fig. 4.3.1.1 Schematic diagram of four sensors arranged in parallel with time or sequence monitoring.

d1 = distance between sensor S1 and S2 (mm)

d2 = distance between sensor S2 and detection field of protective device (mm)

d3 = distance between detection field of protective device and sensor S3 (mm)

d4 = distance between sensor S3 and S4 (mm)

d5 = distance between sensor S1 and S4

d6 = length of the material being transported (mm)

v = transport speed (mm/s)

a and b = distance between material being transported and physical guard (mm).
The distance must be selected so that it is not possible to enter the hazardous area alongside the material being transported

Recommended distances:

d1 > 250 mm (depending on the mounting height)

d1 must not = d4

d2 < 200 mm

d3 < 200 mm

d5 > 500 mm (so that the body of a person cannot maintain the switching or muting function)

d5 < d6

d2, d3 ≥ v • response time of the protective device (including safety-related controller)

d2, d3 < 250 mm (depending on the mounting height)

The switching or muting function with four sensors arranged in parallel allows material to be transported from both sides and prevents undetected access to the hazardous area. Two sensors are arranged upstream and two downstream of the protective device. The switching or muting function is started and stopped depending on time or sequence monitoring. Virtually all types of sensor can be used in this arrangement.

Time monitoring

The switching or muting function with four sensors arranged in parallel and time monitoring is based on a time limit between the actuation of sensors S1 and S2 and between the actuation of sensors S3 and S4. IEC/TS 62046 recommends a maximum time limit of 4 s. The switching or muting function is started by the actuation of the two sensors S1 and S2 within the time limit and maintained via the two sensors S3 and S4. All four sensors are thus actuated for a certain period of time. The switching or muting function is stopped by the deactivation of sensor S3 or S4, at which point the protective field is switched or the protective device is reactivated. When the material is exiting the hazardous area (changed direction of motion) the sensors are actuated in reverse order.

Sequence monitoring

With sequence monitoring of four sensors arranged in parallel, the triggering of the switching or muting function is dependent upon the four sensors being actuated in the correct sequence. For example, the deactivation of sensor S1 in the unswitched or unmuted status before sensor S3 is activated will stop the switching or muting function. The switched or reactivated protective field of the protective device detects transported material – or a person – in the wrong sequence and switches to the OFF state.

The additional monitoring of the interruption of the protective device within the sequence during the muting function can offer improved protection against manipulation and bypassing of the protective device.

Two sensors in T configuration with time monitoring – material can be transported on both sides (cross muting)

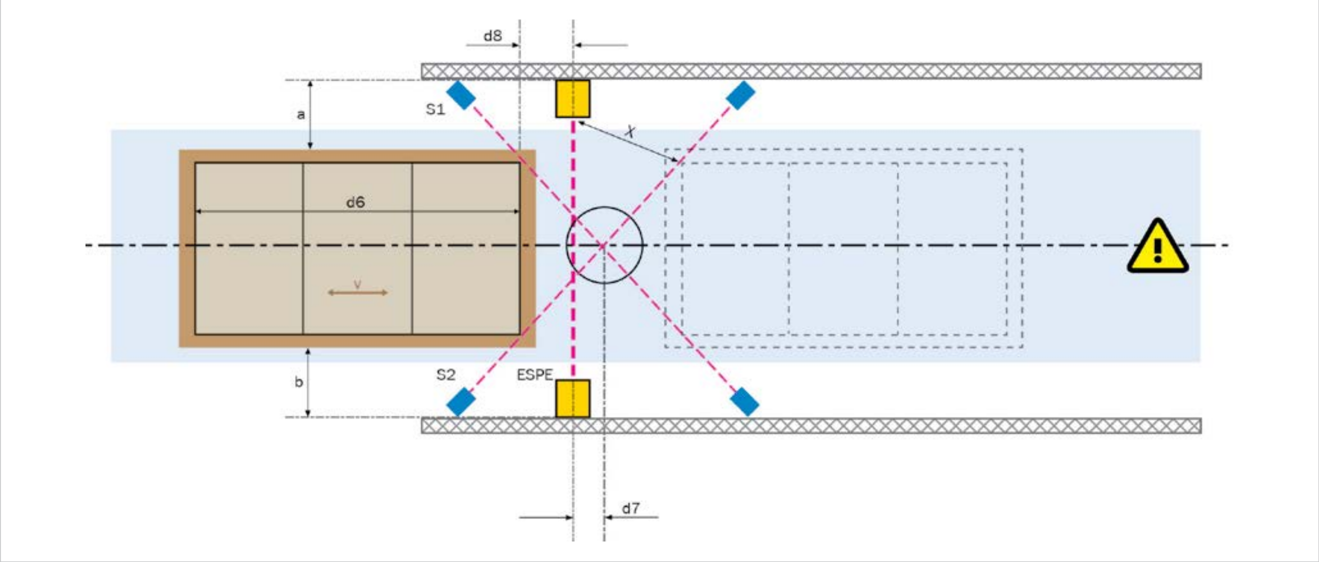


Fig. 4.3.1.2 Schematic diagram of two sensors in T configuration with time monitoring.

d6 = length of the material being transported (mm)

d7 = distance between the detection field of protective device and the crossing point between the two sensors S1 and S2 (mm)

d8 = minimum distance between the detection field of protective device and the detection of the material being transported (mm)

v = transport speed (mm/s)

x = distance between the edge of the physical guard and the edge of the material being transported

a and b= distance between material being transported and physical guard (mm).
This distance must be selected so that it is not possible to enter the hazardous area alongside the material being transported

Recommended distances:

d8 ≥ v • response time of the protective device (including safety-related controller)

d8 < 250 mm (depending on the mounting height)

d7 ≤ 200 mm

x < 200 mm

The T configuration (cross muting) with two sensors and time monitoring allows material to be transported from one side and prevents undetected access to the hazardous area. Relatively identical material dimensions are required for cross muting. The crossing point of the two sensors S1 and S2 should be past the detection zone of the protective device and inside the hazardous area to ensure protection against triggering of the switching or muting function by a person or other unexpected material. The distance between the detection zone of the protective device and the crossing point (d7) should be as short as possible in order to prevent undetected access by a person following directly behind the material being transported. The height of the crossing point of sensors S1 and S2 must be at least at the same height as or higher than the lowest edge of the detection zone of the protective device.

The distances between the material being transported and the fixed parts of the equipment (a and b) must be selected so that a person cannot enter the hazardous area undetected with the material being transported while the switching or muting function is activated. This also applies for the distance between the edge of the fixed parts of the equipment (in the figure this is the edge of the opto-electronic protective device) and the edge of the material being transported (x).

Sensors S1 and S2 must be positioned so that the switching or muting function cannot be activated by a person. This means that a person must be detected by the protective device first before he or she interrupts sensors S1 and S2. Through-beam photoelectric sensors and photoelectric retro-reflective sensors are suitable for this arrangement.

Time monitoring

With two sensors in T configuration and time monitoring, the switching or muting function requires a defined period of time in which the two sensors S1 and S2 must be actuated. According to IEC/TS 62046, this period of time must not exceed 4 s and shall be monitored, otherwise a different configuration has to be used.

If one of the two sensors S1 and S2 is no longer activated or if the defined period of time has elapsed, the switching or muting function must cease immediately.

Two sensors in L configuration with time monitoring – material can be transported from one side (exit only)

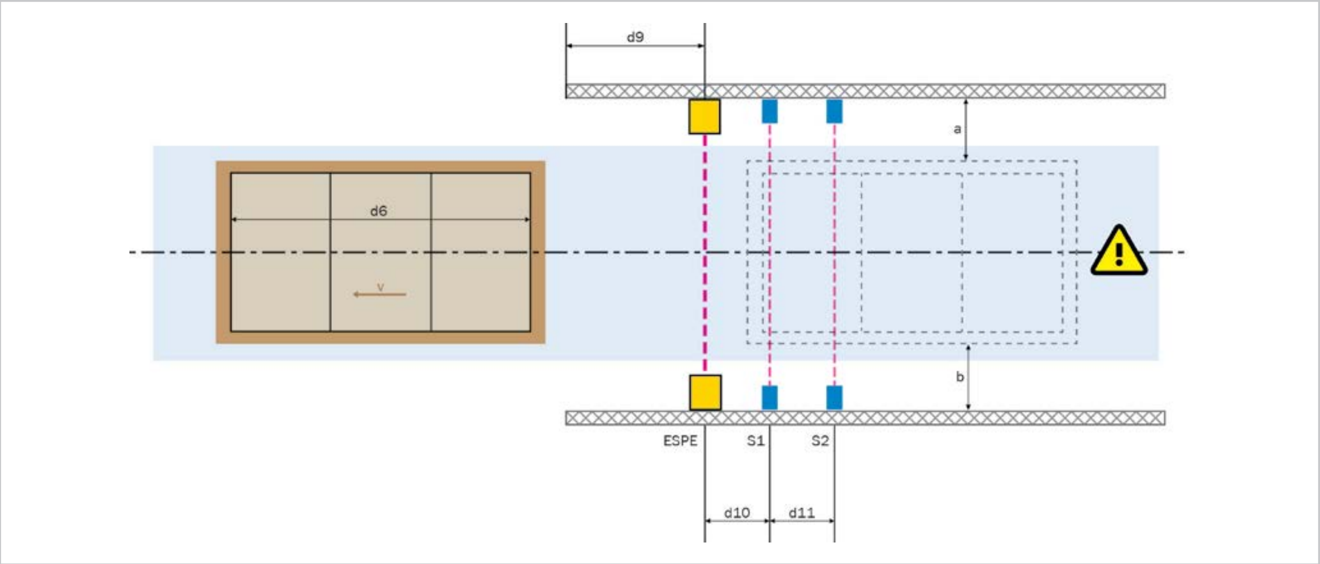


Fig. 4.3.1.3 Schematic diagram of two sensors in L configuration with time monitoring.

d9 = additional length of physical guard if the switching or muting function is stopped due to a defined period of time

d10 = distance between detection field of protective device and sensor S1 (mm)

d11 = distance between sensor S1 and S2 (mm)

v = transport speed (mm/s)

a and b= distance between material being transported and physical guard (mm)

Recommended distances:

d10 ≥ v • response time of the protective device (including safety-related controller)

d10 < 250 mm (depending on the mounting height)

d10 + d11 < d6

d9 = maximum speed of the material being transported (mm/s) • defined period of time for time monitoring (s) – 200 mm

The configuration with two sensors in L configuration and time monitoring is only suitable for transporting materials out of the hazardous area and for preventing undetected access. The two sensors S1 and S2 are positioned upstream of the protective device inside the hazardous area. The switching or muting function may only be started if the two sensors are activated within a defined period of time which is specified by IEC/TS 62046 as a maximum of 4 s.

The switching or muting function must be stopped as soon as the material to be transported is no longer detected by the protective device or the defined period of time elapses. If the switching or muting function is stopped due to the defined period of time, an additional length of the physical guard or the fixed parts of the system (d9) must be taken into account in order to prevent undetected access to the hazardous area by a person while the switching or muting function is active.

Two pairs of sensors arranged in parallel (four sensors) with time monitoring – material can be transported from both sides (parallel muting)

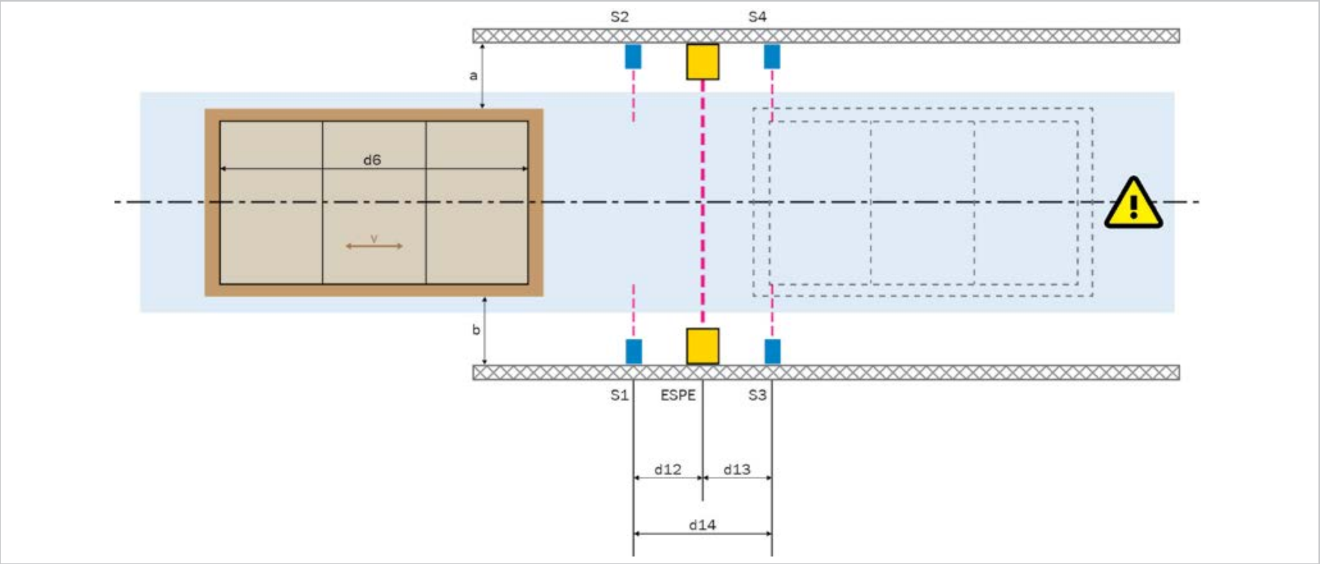


Fig. 4.3.1.4 Schematic diagram of two pairs of sensors arranged in parallel with time monitoring.

d12 = distance between pair of sensors S1 and S2 and detection field of protective device (mm)

d13 = distance between detection field of protective device and pair of sensors S3 and S4 (mm)

d14 = distance between pair of sensors S1 and S2 and pair of sensors S3 and S4 (mm)

d6 = length of the material being transported (mm)

v = transport speed (mm/s)

a and b= distance between material being transported and physical guard (mm). The distance must be selected so that it is not possible to enter the hazardous area alongside the material being transported

Recommended distances:

d14 > 500 mm (so that the body of a person cannot maintain the switching or muting function)

d14 < d6

d12, d13 ≥ v • response time of the protective device (including safety-related controller)

d12, d13 < 250 mm (depending on the mounting height)

The switching or muting function with two pairs of sensors arranged in parallel allows material to be transported from both sides and prevents undetected access to the hazardous area. One pair of sensors is arranged upstream and one downstream of the protective device. Arranging the sensors in this way helps to reduce the opportunities for manipulation and the distances inside the switching or muting system.

The switching or muting function with two pairs of sensors arranged in parallel with time monitoring is based on a time limit between the actuation of the first pair of sensors S1 and S2 and between the actuation of the second pair of sensors S3 and S4. Both pairs of sensors are thus actuated for a certain period of time. The switching or muting function ceases when the pair of sensors S3 and S4 are deactivated, therefore switching or reactivating the protective field of the protective device . When the material is exiting the hazardous area (changed direction of transport), the pairs of sensors are actuated in reverse order.

Optical and all types of non-optical proximity sensor can be used in this arrangement. Proximity sensors with background suppression should be used, as they make it possible to check the width of the permissible object. The objects must always pass the sensors with the same width, and the sensors must not cause mutual interference.

Concurrence monitoring time

The concurrence monitoring time is used to check for simultaneous activation of the switching or muting sensors. This value indicates the maximum duration for which each of the two switching or muting sensors, for which both channels are evaluated, are permitted to exhibit different values without this being classified as an error. This means that the pair of sensors S1 and S2 or the pair of sensors S3 and S4 must adopt equivalent values before the concurrence monitoring time elapses.

4.3.2. Suitability

Switching or muting sensors detect material and initiate signals which an evaluation unit requires for logical linking and the subsequent switching or muting function. Sensor signals can be generated by devices following the requirements identified above:

- Optical sensors
- Ultrasonic sensors
- Inductive, magnetic, and capacitive sensors
- Electro-mechanical switches
- Signals from the safety-oriented controller

Tactile sensors (position switches)

The use of tactile sensors as switching and muting sensors is only a suitable option for certain applications. The ease with which these sensors can be manipulated is a big weakness and explains why additional measures are necessary.

Advantages:

- Cost-effective
- Easy mounting
- Suitable for many objects

Disadvantages:

- Only for direct contact
- Cannot be cycle tested
- Easy to manipulate
- Susceptible to wear and mechanical failure (not non-contact)

Ultrasonic sensors

Ultrasonic sensors are only suitable for use as switching and muting sensors in selected applications. Although they are suitable for all materials, they require careful engineering. Therefore, the use of ultrasonic sensors is recommended as a supplement in combination with other sensors.

Advantages:

- Wide sensing distance
- Suitable for all objects
- Insensitive to dust and dirt
- Detection of transparent objects possible

Disadvantages:

- High procurement costs
- Unreliable due to blurring
- Careful engineering
- Easy to manipulate
- Sensitive to noise and moisture

Inductive proximity sensors

Since inductive proximity sensors can only detect certain metal objects, they are not suitable for all applications. However, if the right metal objects are being transported, inductive proximity sensors are a very suitable solution.

Advantages:

- Cost-effective
- Easy mounting
- Difficult to manipulate
- Very precise

Disadvantages:

- Low scanning ranges
- Short switching distances
- Only certain metal objects can be detected
- Cannot be cycle tested

Magnetic proximity sensors

Magnetic proximity sensors are very suitable for applications in which the material being transported is magnetic or marked with magnets.

Advantages:

- Cost-effective
- Easy mounting
- Almost impossible to manipulate
- Very precise

Disadvantages:

- Low scanning ranges
- Short switching distances
- Only magnetic objects or objects marked with magnets can be detected
- Cannot be cycle tested

Capacitive proximity sensors

Although capacitive proximity sensors are suitable for all materials, the scanning range is too short for most applications and they are usually too easy to manipulate.

Advantages:

- Simple mounting and adjustment
- Detection of (almost) all objects

Disadvantages:

- Low scanning ranges
- Short switching distances
- Higher procurement costs
- Cannot be cycle tested
- Easy to manipulate
- Sensitive to dirt

Through-beam photoelectric sensors

Due to the beam length, it can be difficult to differentiate between a person and materials and manipulation can be very easy in some cases. If through-beam photoelectric sensors are mounted carefully their high accuracy and vibration resistance can represent the most suitable solution for some applications.

Advantages:

- Very long scanning ranges
- Types available which can be cycle tested
- Very accurate response
- Wide variety of types
- Vibration resistance

Disadvantages:

- Mounting is more challenging as precise alignment is required
- Higher procurement costs
- Difficult to differentiate between humans and material being transported
- Easy to manipulate

Photoelectric retro-reflective sensors

Photoelectric retro-reflective sensors are very suitable for use as switching or muting sensors in many applications. Due to the beam length, it can be difficult to differentiate between a person and materials and manipulation can be very easy in some cases.

Advantages:

- Ideal scanning ranges
- Types available which can be cycle tested (object must have a reflector)

Disadvantages:

- Higher procurement costs
- Difficult to differentiate between humans and material being transported
- Easy to manipulate
- Mounting is more challenging as precise alignment is required

Photoelectric proximity sensors

Photoelectric proximity sensors are ideal for most applications but object surfaces and ambient conditions are decisive factors. Manipulation can be prevented through tests and/or background or foreground suppression. Easy mounting and an ideal scanning range offer further advantages compared with other sensors.

Advantages:

- Easy mounting
- Ideal scanning ranges
- Types that can be cycle tested
- Difficult to manipulate

Disadvantages:

- Higher procurement costs
- Very difficult to use with only two sensors, because the detection of the object is very much dependent from the lightbeam angles and the surface of the object
- Dependent on object surfaces (sensing angle)

Other sensors

Laser scanners or inductive loops, for example, can also be used as switching or muting sensors. Solutions of this type are usually ideal for special applications but they do require very good engineering and are more expensive. Other advantages and disadvantages vary significantly by sensor.

5. Differentiation between humans and materials (entry/exit)

Fig. 5.1 Differentiation between humans and materials on a bodyparts carrier.

The protection of automated loading and unloading stations relies on active differentiation between humans and materials. Pattern detection with a permanently active safety sensor (as in a safety light curtain, for example) is suitable for this purpose. The possibility of evaluating each sensor beam from the safety light curtain individually is used, for example, to differentiate the interruption pattern of the material or material carrier (e.g., a pallet) from a person. The size and distances of objects are monitored continuously and taught in again for the next material carrier. As the maximum width and number of permitted objects can be programmed, different materials or material carriers can be transported into the hazardous area safely without having to change the operating mode. With the exception of the passing through of the permitted objects, every other area is active for the protective device. The protective device is not muted fully at any time. To increase productivity, gaps between materials can be ignored up to a defined size. This means that smaller objects entering the protective field (e.g., cables) will not trigger an unwanted machine stop. Self-teaching dynamic blanking, along with other differentiation criteria such as direction of movement, speed, entry and exit in the protective field, etc., allow a safety-relevant distinction to be made. In this way, undetected entry into the hazardous area by humans can be reliably prevented.

The safety light curtains use a sensor beam to synchronize senders and receivers. To avoid the protective device triggering while the material passes through the synchronization sensor beam, the first and last sensor beams are used for synchronization. The user simply has to ensure that both synchronization beams are not interrupted at the same time.

When pattern detection technology is used to differentiate between humans and materials, the following criteria will trigger an immediate stop command:

- Object is longer than permitted
- Number of permissible objects exceeded
- Distance between permissible objects does not match programmed path
- Distance between permissible objects does not maintain consistent spacing during transport
- Protective device is detecting more objects than permitted
- Object is moving too fast or too slow
- Object is moving into or out of the protective field in the wrong way
- Object does not interrupt the first sensor beam on entering the protective field
- Object does not interrupt the last sensor beam on exiting the protective field
- Too much or too little distance between the objects

Minimum distance

The penetration distance C is dependent on the height HD and is calculated using the formula C = 1,200 mm – (0.4 x HD). The penetration distance C varies between 850 and maximum 1,200 mm, because the height HD must not exceed 1,000 mm and C must be at least 850 mm. If the height HD ≥ 300 mm (200 mm in non-industrial applications), the possibility of crawling beneath must be taken into account.

Depending on the application and the functions required, an additional application-specific allowance of up to 850 mm may be required.

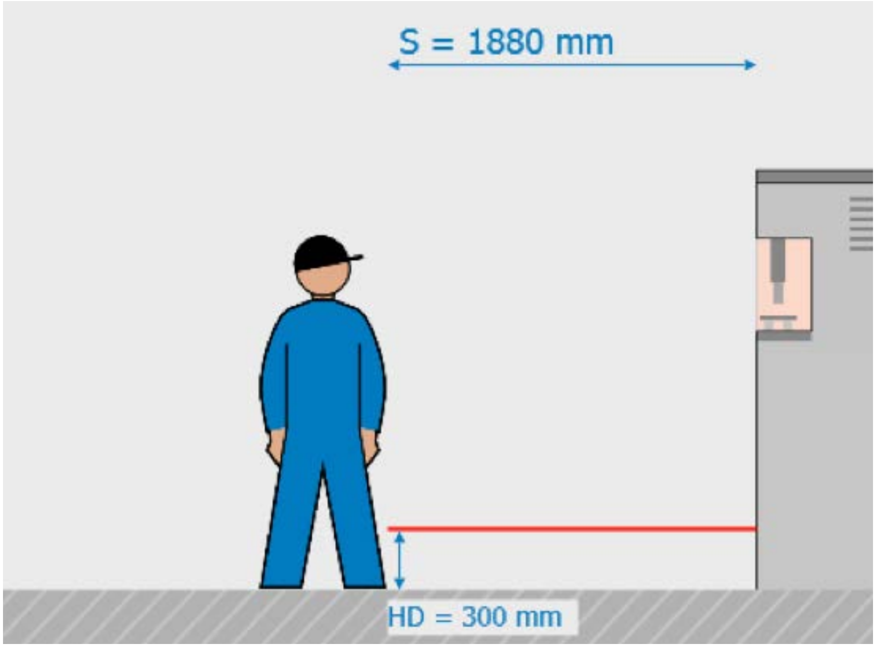


Fig 5.2 Example minimum distance calculation for differentiating between humans and materials (entry/exit).

Other assumptions:

- H_D = 300 mm

At a height H_D of 300 mm, the penetration distance C is 1,080 mm. Taking the assumptions made into account, the minimum distance is 1,880 mm. The possibility of crawling beneath the protective device must be taken into account.

Requirements

- Crushing and shearing points must be avoided, e.g., between fixed parts of the equipment and the transport unit (ISO 13854 includes minimum distances to avoid crushing and shearing points)
- Correct selection of length, resolution, and function of safety light curtain
- Sufficient minimum distance and space for horizontal mounting of the safety light curtain
- Knowledge of the contours of the material being transported or the material carrier
- No undetected riding on material carriers permitted
- Manual reset of protective device necessary due to the possible presence of persons behind the internal protective device
- The elements for actuating the reset must be located outside the hazardous area in a position from which there is clear sight of the entire hazardous area.

Hazards and misapplications

- There is not enough distance between the material being transported and the fixed parts of the equipment (crushing hazard)
- The safety light curtain is too short (stepping over is possible or material is larger than safety light curtain)
- Incorrect selection of the safety light curtain (without suitable functions)
- Material parts entering the protective field during transport are too large or too numerous
- Insufficient minimum distance
- Mounting height of the safety light curtain is too high (crawling beneath is possible)
- Physical guards at the sides of the safety light curtain are not long enough
- Reset of a protective device while there is somebody inside the hazardous area or lock area
- Command switches (reset) do not meet requirements (can be accessed from within the hazardous area)

Advantages

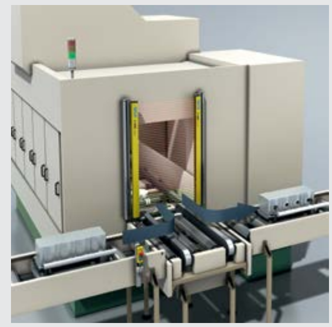
- There can be gaps in the material flow
- Means of transport can be detected
- Not dependent on direction – materials can be transported in both directions
- Safety light curtain permanently active (increased reliability of detection of persons)
- No additional sensors required
- No additional protection required (additional side protection like interlocked hinged guards)
- Highest safety level possible
- Provides the safest way to differentiate between humans and materials
- Easy configuration and installation possible
- Flexibility with regard to material contours and sizes
- Either the material being transported and the material carrier can be detected
- No gaps or blind zones in the protective field thanks to the sender/receiver principle of safety light curtains

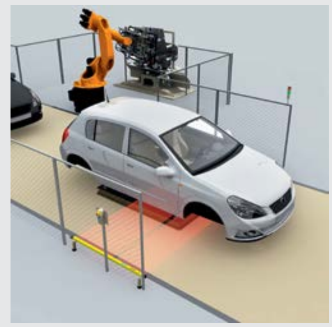
Disadvantages

- Long minimum distance required
- Higher procurement costs
- Advance knowledge of the contours of the material being transported or the material carrier
- Persons on the material being transported might not be detected
- Persons moving alongside the material might not be detected
- Materials that are too long without interruption might lead to unwanted triggering of the protective device (sender and receiver cannot be synchronized)

6. Comparison of possible solutions

Below is a comparison of a selection of advantages and disadvantages of the various possible solutions.
This overview does not claim to be exhaustive.

Physical guards		**Lock application**		**Blanking**	
					
Page 4		Page 6		Page 9	
+	–	+	–	+	–
Not influenced by ambient conditions – suitable for use outdoors	Long safety distance required	Very high productivity	Requires a lot of space	Easy configuration and installation	Additional signals might be required
Not possible for anyone to travel on or alongside the material being transported	Only possible up to a specific size of material	Access to the hazardous area is only possible through active protective device	Operator bears responsibility	Protective device permanently active	Effective resolution increases minimum distance
There can be gaps in the material flow	Additional protection might be required	There can be gaps in the material flow	Reset is activated manually	No additional sensors for switching or muting	No flexibility with regard to material contours and sizes
Highest safety level	Increased shearing and crushing hazards	Highest safety level	At least two opto-electronic protective devices are required	Highest safety level	Only small objects are possible (except with special application)
	Limited flexibility with regard to the shape and size of items being transported	Flexibility with regard to the shape and size of materials	Manual loading and unloading of the lock	Anyone traveling on the material being transported can be detected	Gaps in protective field due to blanking

Protective field muting		**Protective field switching**		**Differentiation between humans and materials (entry/exit)**	
					
Page 14		Page 17		Page 28	
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Comparatively inexpensive	Additional muting sensors or signals	No need for additional side protection	Additional switching sensors or signals	Detection of means of transport combined with flexibility with regard to size and shape of materials	Long minimum distance
Flexibility with regard to material contours and sizes	Additional protection might be required (side protection)	Flexibility with regard to size of material and field	Highest safety level not possible	Protective device permanently active	Higher procurement costs
Short minimum distance possible	Anyone traveling on or alongside the material being transported is very unlikely to be detected	Protective device permanently active	Possible blind zones in the protective field	No additional protection (side protection) and sensors	Knowledge of material contours and sizes
Highest safety level	Gaps in the material being transported will lead to unwanted triggering of the protective device	Anyone traveling on or alongside the material being transported can be detected	Gaps in the material being transported will lead to unwanted triggering of the protective device	Highest safety level	Anyone traveling on or alongside the material being transported is very unlikely to be detected
	Protective field not permanently active	Increased safety thanks to suitable protective fields	Cannot be used in difficult ambient conditions	There can be gaps in the material flow	Materials that are too long are not possible
	Risk of manipulation		Risk of manipulation	Detection of material carrier or material being transported	

REFERENCES

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EN ISO 13849-1:2015: Safety of machinery - Safety-related parts of control systems - Part 1: General principles for design
IEC/TS 62046:2008: Application of protective equipment to detect the presence of Persons
ISO 13854:1996: Safety of machinery - Minimum gaps to avoid crushing of parts of the human body
EN ISO 13855:2010: Safety of machinery - Positioning of protective devices with respect to the approach speeds of parts of the human body
EN ISO 13857:2008: Safety of machinery - Safety distances to prevent hazard zones being reached by upper and lower limbs
SICK Guide for Safe Machinery – Six steps to a safe machine

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