PRACTICAL GUIDE

Safe Machinery

with opto-electronic protection

Safety and
flexibility.
Realising the
future.

SICK

This guide is aimed at machinery designers and users who have to specify and install machinery guarding systems.
In the following pages we will introduce you to the possibilities of how to guard machinery using SICK protective devices by taking into consideration relevant rules and regulations, guidelines and standards. In this way an introduction into the use of opto-electronic guarding has been produced. Extensive and well presented. The examples shown are the result of many years practical experience and are valid as typical applications. No responsibility whatsoever is accepted for further use of the information contained in this guide as each machine will require a specific guarding solution based upon National, International Regulations and Standards.

This guide would not have been possible without the advice, help and support of our partners.

Monitoring of an automatic filling station with SICK laser scanner PLS. The horizontal protection field is marked in the picture. At the same time the PLS measures the type and the position of the car.

The fast moving demands of automation have changed more and more the requirements of machinery guarding.

In the past the guarding systems that were available were more often than not a hindrance to the work process and as a consequence were removed.

Today an increase in the numbers of accidents is a thing of the past due to reliable ergonomic guarding systems.

Modern opto-electronic know-how from SICK opens the possibility of unlimited applications. Due to the very large reduction in size and flexibility the possibility of new applications has been considerably increased.

Consequently, today SICK can offer guarding systems that make their use possible, pleasant, ergonomic and effective. And all that without effecting in the smallest way the work process.

Safeguarding of a welding station. Vertical protection field with SICK light curtain FGS inclined to the front. This setup protects the hand and does not allow the presence of a person between machine and light curtain.

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Regulatory framework

I.1 European Directives, objectives, procedures

For the European ideal to become a reality through the free circulation of goods, services and people, the member states of the European Union have drawn up common rules in many areas, such as fiscal regulations and technical standards.

In the latter area, which is of great relevance to the safety of operators of machinery and equipment, harmonisation has progressed at a rapid rate. Directives have been passed and standards have been issued. In this chapter we will briefly explain:

- The Machinery Directive, which relates to new working equipment (or used equipment imported from a third country outside the European Union e.g. from the USA or Japan).

- The Use of Work Equipment by Workers at Work Directive which relates to existing working equipment (or used equipment originating from a country within the European Union).

- The relevant standards, in their present form.

I.1.1 The Machinery Directive

The Machinery Directive (original directive 89/392/EEC of 14 June 1989 and first and second amendments - 91/368/EEC and 93/44/EEC is intended for the designers of new machines.
It defines the objectives in terms of the essential safety and health requirements to be satisfied by new machines, in order that they may be sold and freely circulated within the member states of the European Union, guaranteeing operators a high degree of protection.

The standards define ways and means of putting these objectives into practice. However,
the standards are not obligatory; rather, the Directive defines objectives with an obligation to achieve certain results.
On the other hand, a machine built in accordance with the harmonised standards is assumed to satisfy the essential requirements of the Directive.

As required by European law, the Directive and its amendments have to be implemented in each member country. The Directive came into full force for machinery on the 1st January 1995 and for safety components on the 1st January 1997.

Access guarding on three sides with SICK light switches WSU/WEU using corner mirrors.

What do manufacturers of new machinery have to do?

The complete procedure is set forth in Annex VI of The Machinery Directive. Briefly, however, a distinction is made between two categories of working equipment:

Equipment considered to be dangerous, which is subject to special procedures. Annex IV of The Machinery Directive provides an exhaustive list of the equipment concerned, of which safety devices form an integral part.

Other working equipment is subject to simpler procedures.

Conformity declaration procedures:

To certify the conformity of the equipment, the manufacturer is obliged to affix ”CE” marking on each machine and ensure that it is accompanied by a ”CE” declaration of conformity.

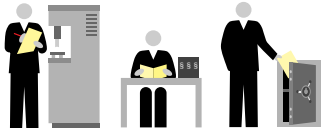
If the equipment is not included in the list of Annex IV, the ”CE” declaration of conformity is provided on the basis of self-certification, for which the manufacturer is liable. However, a technical file must be compiled, and presented to the national authorities on request.

If the equipment is included in the list in Annex IV, one of two situations may arise:

- Harmonised standards exist for the working equipment, covering the whole range of applicable requirements. Three cases are possible:

1) The manufacturer sends the technical file (cf. Annex VI of the Directive) to a notified body, which acknowledges receipt and places the file in its archives. This is a self-certification procedure which constitutes an undertaking by the manufacturer to design the equipment or safety device in compliance with the standards.

2) The manufacturer asks the notified body to examine his technical file to check that the harmonised standards are complied with. If this is the case, the body issues the manufacturer with a certificate of compliance.



3) The manufacturer requests EC type approval testing by a notified body for this purpose.

- There are no harmonised standards for the working equipment or the machine or parts of the machine are not in line with the standards.

The manufacturer must submit his machine and the technical dossier for EC type approval testing by a notified body. This body verifies conformity with the Directives and issues an EC type certificate, which sets out the results of the tests and for which it is liable.

I.1.2 The Use of Work Equipment by Workers at Work Directive

The aim of this Directive is to improve the level of safety of working equipment used in the European Union and of used equipment originating from the European Union, ensuring that they conform to the minimum requirements defined.

Each item of equipment is examined to determine its state of conformity and the date it was originally put into service.

Equipment which is in use or sold second-hand which does not conform must comply with the technical requirements by 1 January 1997. These are concerned with, amongst other things, control and stopping devices, warning and signalling devices and organisational procedures.

This Directive and the enacted legislation does not require a level of safety identical to that of new machines; it simply imposes minimum safety requirements in order to limit, or even eliminate, the principal risks.

Each member country is allowed to add its own National requirements: service/maintenance intervals, use of gloves etc.

I.2 Bodies

I.2.1 Safety advisory bodies

Companies wishing to verify that their equipment complies with European regulations can obtain help from safety advisory bodies.

I.2.2 Accredited bodies

Certain of these advisory bodies are accredited and intervene after a notice has been served by the Inspectorate, to verify conformity of the working equipment. Each EU member state is responsible for overseeing accreditation in its own country.
The accredited bodies have the powers and resources needed to perform a variety of tasks: inspection, control, analysis, technical assistance, audits, tests, measurements etc.

I.2.3 Notified bodies

Every EU member state is obliged to nominate notified bodies (cf. Annex) according to the
minimum criteria defined in the Directive, and to communicate this list to Brussels.
Only these bodies have the power to issue type approval certificates for the hazardous machines and safety devices mentioned in Annex IV of the Directive.
It should be noted that, in practice, these bodies have their own specialist fields.

I.3 European Safety Standards

I.3.1 Harmonised European Standards

A harmonised standard is a standard which has been produced upon the mandate of the Commission of the European Communities. A harmonised standard is a series of technical specifications drawn up to satisfy the essential safety requirements of the Directive. Once it has been adopted by the CEN (the European Committee for Standardisation) or CENELEC (the European Committee for Electrotechnical Standardisation), the standard is translated and published in the Official Journal of the European Communities.

This type of standard serves as a reference and replaces all national standards dealing with the same subject. The conformity of a safety device or machine with a harmonised standard gives rise to presumption of conformity with the essential safety and health requirements defined in The Machinery Directive (Article 5 of Directive 89/392/EEC).

The status of the standard is indicated by different prefixes:

- A standard prefixed EN... has been approved and is applicable.
- A standard prefixed pr EN... is in the process of being approved.

Car industry:
Area protection of an inlay station at a welding robot with SICK laser scanner PLS.
The protection field is marked on the floor.

I.3.2 Different types of standards

Standards - three different types:

Type A standards (fundamental safety standards) giving basic concepts, principles for design, and general aspects that can be applied to all machinery.

Type A requirements may guide the designer, in the absence of Type B and C standards.

Type B standards (group safety standards) dealing with one safety aspect or one type of safety related device that can be used across a wide range of machinery:

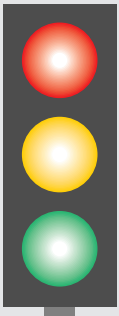
Type B1 standards on particular safety aspects (e.g. safety distances, surface temperature, noise) e.g. the electrical safety of machines (standard EN 60204), calculation of safety distances (standard pr EN 999).

Type B2 standards on safety related devices (e.g. two-hand controls, interlocking devices, pressure sensitive devices, guards, electro-sensitive protective equipment IEC 1496 parts 1 and 2 / pr EN 61496 parts 1 and 2).

Type C standards (machine safety standards) giving all detailed safety requirements for a particular machine or group of machines. Where this type of standard exists, it takes priority over Types A or B.

However, a Type C standard may refer to Type B or A standards.

Where the machine is not covered by a Type C standard, conformity is obtained on the basis of Type A or B standards.



Some examples of standards

Types of standards	Number		Title
Type A	EN 292 - 1 and 2		Safety of machinery - Basic concepts and general principles for design
	EN 1050		Risk Assessment
Type B	IEC 1496 (prEN 61496)	part 1	Electro-sensitive protective equipment General requirements and tests
		part 2	Particular requirements for equipment using AOPD
		part 4-1	Active optical area protection
	prEN 999		The positioning of protective equipment in respect of approach speeds of parts of the human body
	EN 294		Safety distances to prevent danger zones from being reached by the upper limbs
	EN 954 - 1 and -2		Safety related parts of control systems
	EN 60 204		Electrical equipment of machines
	EN 1088		Interlocking devices associated with guards
	pr EN 574		Two-hand controls
	EN 418		Emergency stop
Type C	EN 692		Mechanical presses
	pr EN 693		Hydraulic presses
	EN 617 to 620		Handling equipment
	pr EN 415-1 to 7		Packaging machinery
	EN 931		Assembling machinery
	pr EN 1010		Printing and paper converting machines
	ISO 10218 (EN 775)		Industrial robots
	EN 201		Injection moulding machines
	DIN EN ISO 11111		Textile machinery
			This list is not exhaustive

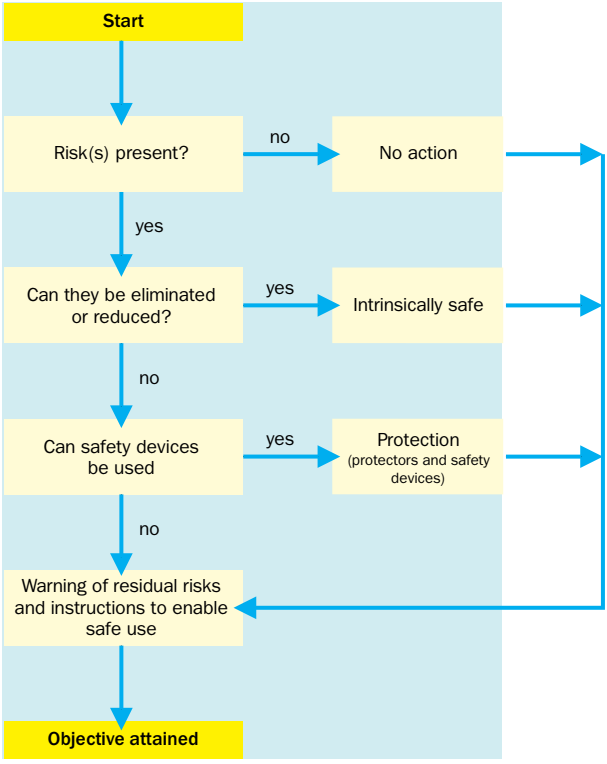
Currently there are 144 Type A/B standard projects and 537 Type C standard projects.
For more information we recommend "Standardization Programme Safety of Machinery" (ISBN 92-9097-528-8).

Safeguarding of a mobile stone setting machine using SICK laser scanner PLS.

Opto-electronic protection

II.1 General

When designing a machine, the potential risks must be analysed and where necessary, additional protection must be incorporated so as to protect operators from residual hazards (crushing, shearing, cutting, snatching, clamping, trapping, friction or abrasion, perforation or puncturing, risk of shock etc.) cf. EN 292 and pr EN 1050.



The above flowchart quickly tells us whether the use of a protective device is advisable.

The remainder of this chapter is based on the hypothesis that some risks cannot be eliminated, and that it is necessary to use a protective device.

II.2 Why opto-electronic guarding?

Generally speaking, when an operator has to use a machine frequently, and in doing so he is exposed to risk, it may be advisable to use a system of opto-electronic protection in preference to the protection offered by mechanical safety devices (fixed guarding, two-hand controls, screens etc.). This reduces access time (the operator does not have to wait for the guard to open), raises productivity (time saved in loading the machine) and improves the ergonomics of the workplace. Furthermore, it provides the operator and third parties the same protection.

Warning: An opto-electronic safety device can only be used if the operator is not exposed to any risk of being hit by splashes (e.g. molten materials) or flying materials. Also, the access time must be greater than the time needed to stop the hazard.

II.3 Choosing an opto-electronic guard

The principal criteria for choosing an opto-electronic guarding system are defined below. They are interdependent and call for an iterative approach:

- Define the zone to be guarded
- Define the safety function to be performed
  - Detection of finger or hand
  - Detection of passage of a body
  - Presence detection inside the danger zone
- Conform to the category of the parts of the safety related control system
- Calculate the safety distance

II.3.1 Defining the zone to be guarded

The work involved is mainly estimating the risk from the machine. Depending on the configuration of the installation, it is necessary to take into account the dimensions of the zone to be guarded, the different points of access and the accessible hazards, and the risk of bypassing the guard and being present in the hazardous zone undetected.

II.3.2 Defining the safety function to be performed

II.3.2.1 Detection of finger or hand

This type of detection is necessary when the operator is a short distance away from the hazardous zone. The resolution of the AOPD must in all cases be less than or equal to 14 mm.

II.3.2.2 Detection of access of an arm or body

This type of detection is suitable for access or perimeter guarding

II.3.2.3 Detection of presence of an operator in the hazardous zone

This type of guarding is suitable for machines where hazardous zones enclosed by fixed guarding are not visible from the control point.
It is also suitable for guarding the approaches to a hazardous zone, where it combines access and presence monitoring (permanent detection of personnel throughout the zone). Such guarding is also suitable for industrial trucks or construction machinery, to protect operators during movement of the trucks or when fastening these trucks to a fixed base.

II.3.3 Compliance with category of the safety related parts of the machine control system

Whereas the essential requirements of the Directive aim for a high level of safety, the resources used must nevertheless be in proportion to the risk occurring.

The guarding of an operator who manually loads and unloads piece parts inside a metal press shall not be treated in the same way as the guarding of an operator working on a machine where the maximum risk is that of pinching a finger.

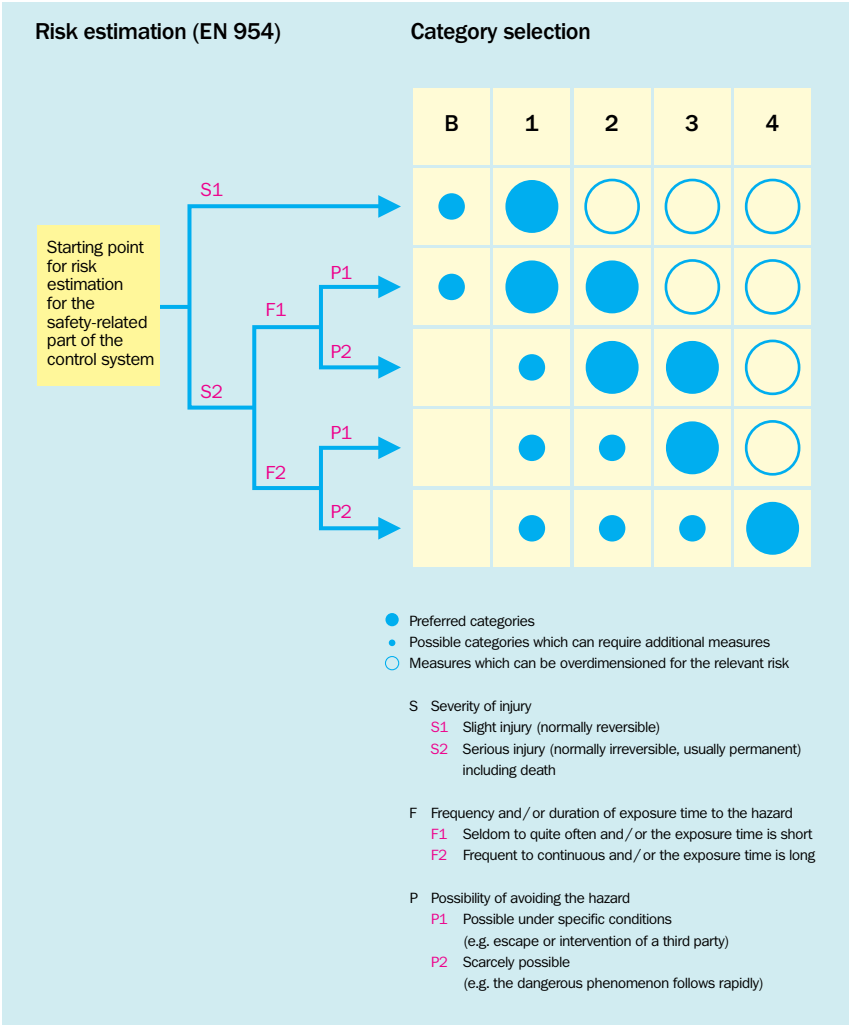
Furthermore, one and the same machine may have several points of access with varying degrees of risk. Different measures shall therefore be taken for different parts of a machine's safety related control system.

With this in mind, standard EN 954 helps the designer to define the categories of the different parts of the safety related control system on the basis of three parameters:

- The potential severity of the injury
- The frequency and/or duration of exposure to the hazard
- The possibility of avoiding the hazard

The behaviour of safety related control systems in the event of a fault is defined for each of the categories (B, 1, 2, 3, 4) (cf. table on p. 20). Assuming identical technology (pneumatic, electronic, mechanical, hydraulic etc.), these categories represent a progressive scale. For example, category 4 is higher than category 3. On the other hand, they are not intended to compare different technologies. Nevertheless, the AOPD and its interface shall meet the requirements of the category of the safety related parts of the machine control system in question, in order that the safety function shall be performed (e.g. stopping the machine and keeping it stopped).

Selection of category of the safety related parts of the control system



For examples, please refer to III.2.

Table of behaviour of system as a function of category (EN 954)

Categories	Summary of requirements	System behaviour	Principle on which safety is based
B	Safety-related parts of control systems and/or their protective equipment, as well as their components, shall be designed, constructed, selected, assembled and combined in accordance with relevant standards so that they can withstand the expected influence.	The occurrence of a fault can lead to the loss of the safety function.	mainly characterised by selection of components
1	Requirements of B shall apply. Well-tried components and well-tried safety principles shall be used.	The occurrence of a fault can lead to the loss of the safety function but the probability of occurrence is lower than for category B.	
2	Requirements of B and the use of well-tried safety principles shall apply. Safety function shall be checked at suitable intervals by the machine control system.	The occurrence of a fault may lead to loss of the safety function between the checking intervals. The loss of the safety function is detected by the check.	mainly characterised by structure
3	Requirements of B and the use of well-tried principles shall apply. Safety-related parts shall be designed, so that: - a single fault in any of these parts does not lead to the loss of the safety function, and - whenever reasonably practicable the single fault is detected.	When a single fault occurs, the safety function is still assured. Certain faults are detected but not all. An accumulation of undetected faults may lead to loss of the safety function.	
4	Requirements of B and the use of well-tried safety principles shall apply. Safety-related parts shall be designed, so that: - a single fault in any of these parts does not lead to a loss of the safety function, and - the single fault is detected at or before the next demand upon the safety function. If this is not possible, then an accumulation of faults shall not lead to a loss of the safety function.	When the faults occur, the safety function is always performed. The faults will be detected in time to prevent loss of the safety function.	

See also figures on p.31.

II.3.4 Calculating the safety distance

The calculation of the safety distance for an AOPD is described in standard pr EN 999.
If the machine comes under a specific standard (e.g. cold metal presses) or particular technical specifications (renewal of cold metal presses), these must be referred to.

Any AOPD shall be installed in such a way that access to the hazardous zone without detection by the device is impossible. Furthermore, it shall not be possible for a person to be present within the hazardous

General calculation formula given in pr EN 999

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

where

S is the minimum distance in mm from the hazardous zone to the detection point, plane or zone;

K is a parameter in mm per second, derived from data on approach speeds of the body or parts of the body;

T is the overall stopping performance in seconds;

C is the additional distance in mm, based on intrusion towards the danger zone prior to actuation of the protective equipment.

If the minimum distance calculated is acceptable from an operational, industrial and ergonomic point of view, one must nevertheless determine whether the installation and the configuration of the safety device is such that personnel can be present within the detection zone of the device and the hazardous zone without being detected.
If this is the case, the installation must be equipped with additional safety features (themselves monitored in situ if necessary).
If the minimum distance is too great and is not acceptable from an ergonomic point of view, one must determine whether it is possible either to reduce the overall response time of the machine or to improve the resolution of the protective device.

For example: With a perpendicular approach and an overall response time of 100 ms, the calculated distance will be equal to 368 mm for an AOPD with resolution of 35 mm, whereas with a resolution of 14 mm the calculated distance will be 200 mm.

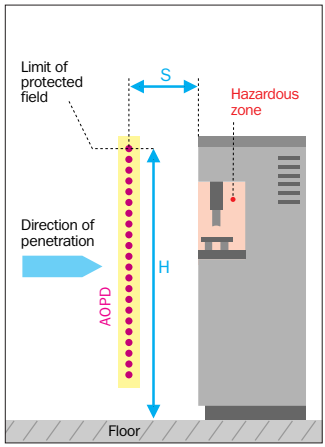
For presses according to standards EN 692 and prEN 693 the following table has to be used:

With regard to the detection capability of the AOPD, the additional distance C in the following table shall at least be used when calculating the minimum distance S (table taken

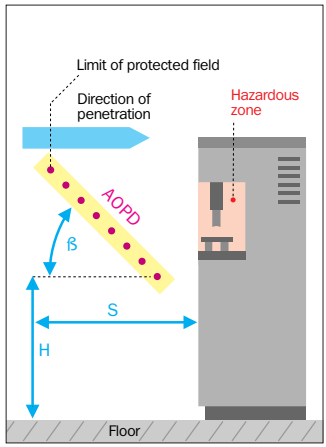
Detection capability mm	Additional distance C mm	Cycle initation by the AOPD
≤ 14 > 14 ≤ 20 > 20 ≤ 30	0 80 130	Allowed
> 30 ≤ 40 > 40	240 850	Not allowed

Generally, we can distinguish between three types of approach:

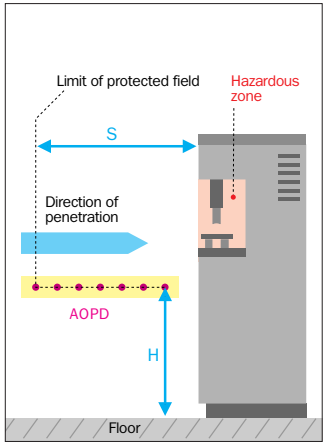
Perpendicular approach / direction of penetration perpendicular to plane of



Angular approach



Parallel approach / direction of penetration parallel to plane of protector



The following table gives the formulae for calculating the safety distance S.
Specific examples are given in the next chapter.

Perpendicular approach ß = 90° (± 5°) d = ≤ 40 mm	S = 2000T + 8 x (d - 14) where S > 100 mm where S > 500 mm take S = 1600T + 8 x (d-14) in this case S cannot be < 500 mm.	n.b. To prevent bypassing the AOPD, use EN 294. In practice, this standard is not always applicable because it regards the hand as a deformable element. In this case it is necessary to seek the advice of an accident prevention body.
40 < d ≤ 70 mm	S = 1600T + 850	Height of lowest beam ≤ 300 mm Height of highest beam ≥ 900 mm
d > 70 mm multi-beam	S = 1600T + 850	No. beams / Recommended heights 4 / 300, 600, 900, 1200 mm 3 / 300, 700, 1100 mm 2 / 400, 900 mm
single beam	S = 1600T + 1200	1 / 750 mm
Parallel approach ß = 0° (± 5°)	S = 1600T + (1200 - 0.4 x H) where 1200 - 0.4 x H > 850 mm	15 x (d-50) ≤ H ≤ 1000 mm where H ≥ 300 mm there is a risk of undetected access under the beam to be taken into account for H where d ≤ H/15 + 50
Angular approach 5° < ß < 85°	Where ß > 30°C, cf. perp. appr. Where ß < 30°C, cf. parall. appr. S then applies to the furthest beam whose height ≤ 1000 mm	d ≤ H/15 + 50 applies to the lowest beam

S: minimum distance
H: height
d: resolution
ß: angle between plane of detection and direction of penetration
T: time

II.4 Examples of machine guarding

II.4.1 Area guarding on an assembly line

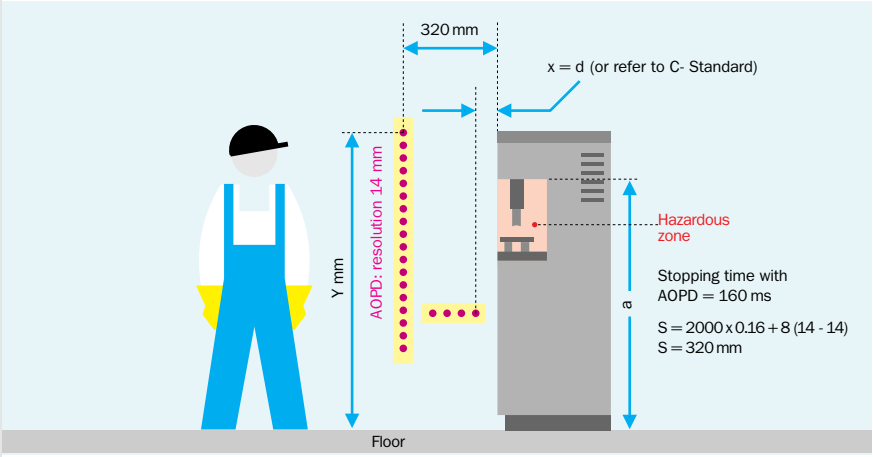
This example gives, for one and the same application (access guarding), two possible ways of installing an AOPD which takes into account both perpendicular and parallel approaches, as previously described.

It is assumed that the machine is only accessible via this access, that the risk is one of severe injury and that the operator frequently accesses the hazardous zone.

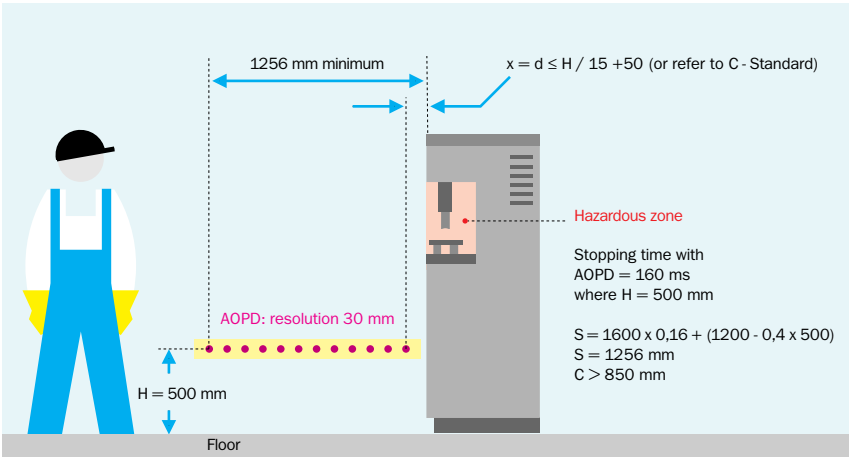
Solution no. 1:
Perpendicular approach. Point of operation guarding in combination with area guarding.

The calculation as shown in the diagram produces a value of 320 mm for the safety distance. If a reduced resolution is used (e.g. 30 mm) the safety distance increases. The safety distance shall not be less than 100 mm. To avoid the risk of being undetected, two AOPDs are used: a vertical one at safety distance (perpendicular approach) and a horizontal one to prevent being undetected behind the vertical AOPD.

According to EN 294, if the height "a" of the danger zone is
1000 mm, y = 1800 mm



x = End of the protected field up to the mechanical guarding preventing standing between.



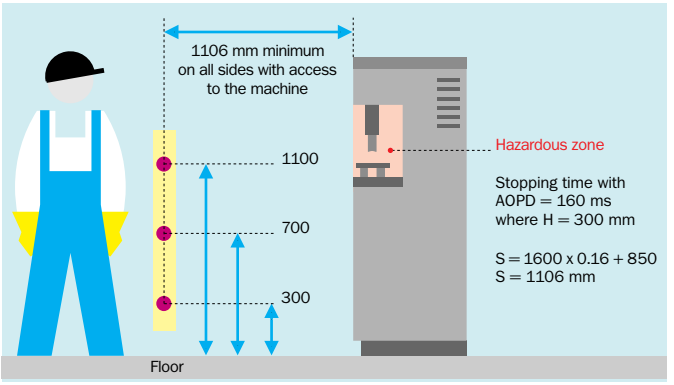
Solution no. 2:
Parallel approach.
Area guarding.

A horizontal AOPD is used.

The above diagram shows the calculation of the safety distance S and the positioning of the AOPD. If the installation height of the AOPD is increased beyond 300 mm the safety distance will be less but one has to allow for the risk of a person entering the hazardous zone undetected by passing under the AOPD. In such cases it will be necessary to install an additional device based on an evaluation of the risk.

Conclusion: The table below shows the results of these two solutions. Operating constraints enable us to decide between the two solutions.

Advantages	Advantages	Drawbacks
Solution no. 1 S = 320 mm	**Higher productivity** because operator is closer. The short distance between the vertical barrier and the hazardous zone makes it possible to store material close to the machine.	More expensive safety device.
Solution no. 2 S = 1336 mm	Less expensive safety device enables access to be guarded regardless of the height of hazardous zone "a".	Operator **much further** away. Difficult to store products on the ground because the barrier takes up a great deal of space. **Lower productivity.** **Higher productivity cost.**



II.4.2 Access guarding

Perimeter guarding using 3 beams (at heights of 300, 700 and 1100 mm) allows for a perpendicular approach as described in II.3.4. This solution must allow for the possibility of the operator becoming undetected between the hazardous zone and the AOPD. Consequently, additional precautions must be taken to alleviate this risk. For example, the local control shall be positioned in such a way that the whole of the hazardous zone can be seen, and it shall be beyond the reach of an operator in the hazardous zone.

II.4.3 Guarding the interior of a large press

This type of guarding is recommended for large presses where access is possible at ground level. In this particular case it is necessary to prevent the press from starting when an operator is inside. This is a secondary guarding system which shall on no account take the place of the main guarding system which shall consist of a suitable device (AOPD or two-hand control).
In this particular case:

The safety distance must be calculated for the main guarding system, the function of which is to stop the press, whereas the secondary protection system detects the presence of a person in the press and does not allow the press to be started.

Power press: combination of point of operation guarding (SICK light curtain FGS) and interior monitoring (SICK laser scanner PLS).
For starting both sensors are activated. Afterwards the SICK laser scanner PLS is muted in the down stroke.

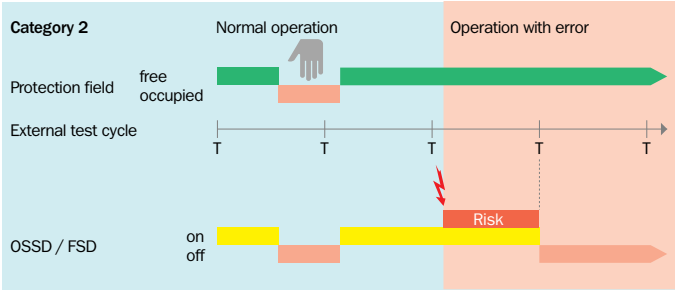
II.5 Connection to control circuit

II.5.1 Interface to the machine

Every safety device must be incorporated into the machine control system, so as to form an integral part of it. Therefore, the relevant part of the machine control circuit, the connection of the safety device to that part of the control system and the safety device itself must take into account the category, as defined at the time of estimating the risk in accordance with EN 954 and pr EN 61496.

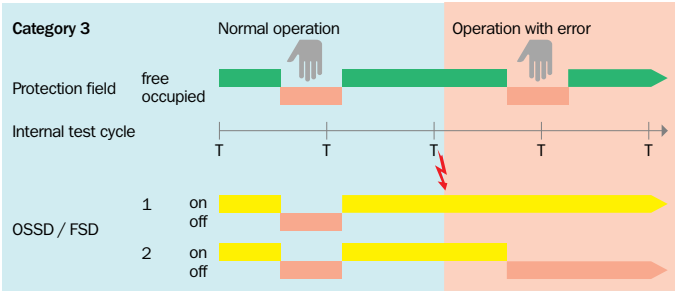
The following figures give an explanation of the safety categories in line with EN 954 suitable for an AOPD and control unit, taking into consideration the whole system including the stop valve.
How do safety devices of a particular category behave in case of a fault occurring?

If a safety device is activated under normal operating conditions, e.g. a hand enters the protected field, this always leads to a machine stop (regardless of the safety category).
Fault detection in the respective safety categories is different.

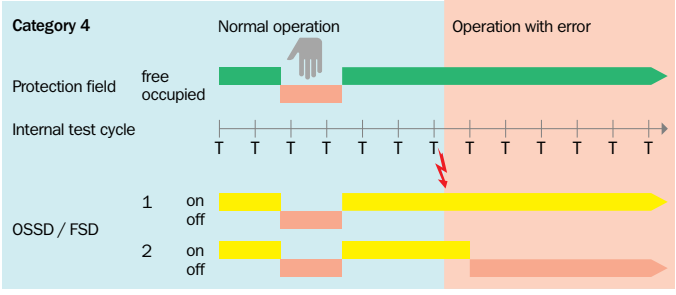


Loss of safety function between checking intervals possible.

Fault detection at time of checking through the external test.
In the period between the fault occurrence and the next test there is a risk of an accident.



A single fault assures the safety function as an output signal for stopping can still be generated (e.g. if a hand enters the protection field). The fault is detected
either when the hand enters the protection field or by internal checking.
Accumulation of faults may lead to loss of the safety function.
The system shall be designed so that a single fault in any of its parts does not lead to the loss of

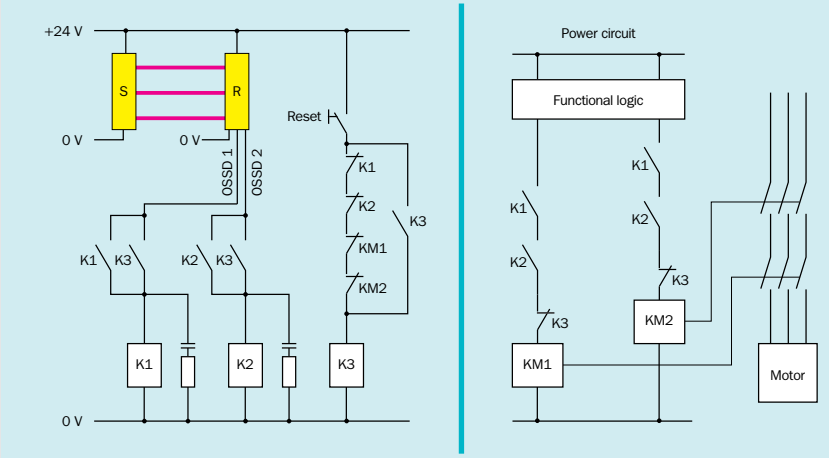


A single fault still assures the safety function. In addition to category 3 the safety function must be assured in case of an accumulation of faults. Therefore internal tests must be within the response time of the safety device.
The single fault is detected at or before the next demand on the safety function. If the detection is not possible then an accumulation of faults shall not lead to a loss of the safety function.

II.5.2 Example of connection of a type 4 device

II.5.2.1 With external reset

The diagram represents a simple machine where the AOPD resetting function also causes the machine to start.



K1, K2 and K3 are the auxiliary safety contactors. KM1 and KM2 are contactors.

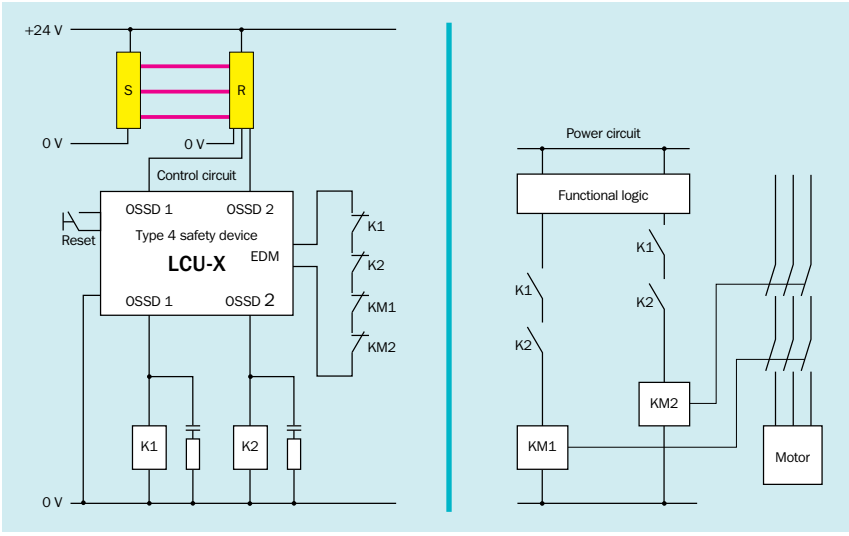
Here, redundancy is assured at all stages: At the level of the safety device, at the level of the auxiliary contactors K1 and K2 (relay technology) and to protect the coherence of the system at the level of the power contactors KM1 and KM2.

Self-monitoring of contacts is assured by preventing restarting via K3. If one of the NO contacts is stuck, its "counterpart" NC contact remains open. Consequently, the coil of K3 is not energised and will not enable coils K1 and K2 to self-hold. The control circuit therefore remains open.

K1/K2 = FSD 1/FSD 2
KM1/KM2 = MPCE 1/MPCE 2

II.5.2.2 With internal reset

Example of connection of a type 4 safety device with reset. Reset is dynamically monitored by safety devices from SICK (protection against short-circuits). Note that the wiring is simpler compared with the diagram opposite. The EDM is also dynamically monitored.



II.5.3 Muting of the AOPD

The muting of protective devices raises the problem of the safety of the installation. For example, standard pr EN 415-4 (1993) relating to packaging machines tackles the problem of palletisers/ depalletisers (machines in which all operations on the palletised load are carried out entirely and automatically by machine). At the entrance and exit of the interior zone (where a risk exists under normal operating conditions), it is necessary to mute the AOPD at the moment when the pallet passes. On the other hand, it is necessary to detect intrusion by operators. The muting system must be able to discriminate between the pallet and the operator.

The muting conditions defined in standard pr EN 415-4 state that:

a. Muting may only occur during the period of the operating cycle when the loaded pallet obstructs access to the hazardous zone.

b. Muting shall be automatic.

c. Muting shall not depend on a single electrical signal.

d. Muting shall not depend entirely on software signals.

e. The muting signals, if they occur in the course of an invalid combination, shall not allow a state of muting, or they shall ensure that the machine is locked out.

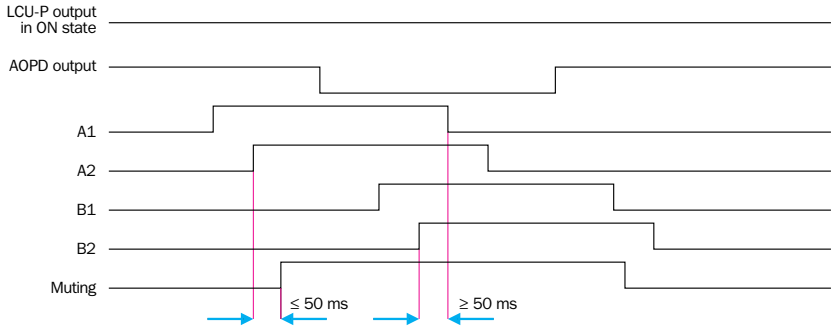
f. The state of muting must be reactivated immediately following the passage of a pallet through the detection zone of the protective device.

These six requirements can be met with the LCU-P (cf. III.1.5). This device incorporates a system of temporary muting by automatic discrimination, i.e. the device is transparent to the user, who does not have to worry about wiring this automatic, temporary muting function.

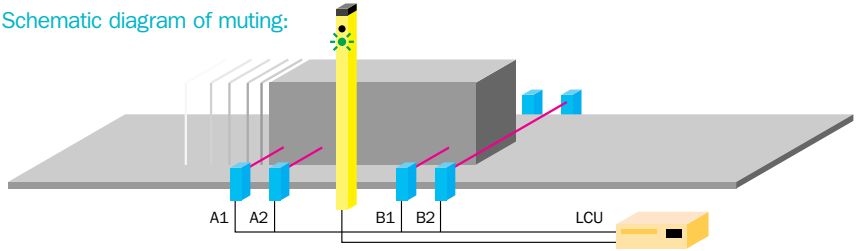
The AOPD is muted by the sensor pairs (A1, A2) and (B1, B2). (cf. fig. p. 35).

In this case the distance between A1 and B2 must be less than the length of the pallet (see timing diagram).

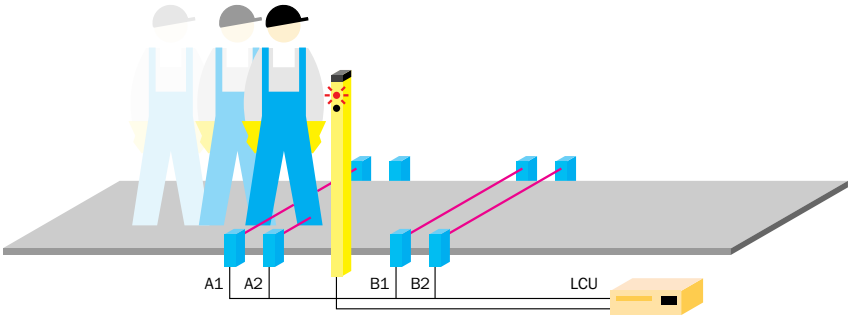
Furthermore, to prevent manipulation, with the LCU-P it is possible to define the maximum duration of muting in steps of 1 s.



Schematic diagram of muting:



The conveyed material is identified and no muting signal is sent out



Operator is identified. The LCU-P initiates an (emergency) stop.

II.5.4 Single break / double break operating mode (in US: PSDI mode)

When operating in this mode the machine cycle sequence is initiated by the protective device after it has been interrupted a predetermined number of times. This operating mode is different from auto restart. It requires a deliberate act on the part of the operator.

- Upon starting the machine
- On restarting, when the AOPD has been interrupted during a hazardous movement
- In order to restart after an interval of more than 30 seconds (cf. pr EN 61496).
- For further information please refer to EN 692.

However, it is necessary to verify that there can be no risk to the operator during the course of the work. This limits its use to small machines where the hazardous zone is not accessible at ground level, and where the operator cannot place himself between the protective device and the hazardous zone without being detected. All other sides of the machine must also be guarded by suitable means. These might, for example, cause the machine to stop and to remain stopped if they are not set up correctly.

Standard pr EN 999 also requires that opto-electronic protective devices used for restarting machines have a resolution less than or equal to 30 mm.

SICK protective devices

Safeguarding of a punching press using SICK light curtain FGS with single/double break.

III.1 The products

In the following tables the SICK range of products for different applications are presented including their most important features. It is intended as an aid to the designer or user to decide on the most appropriate solution.

III.1.1 Point of operation guarding (finger/hand)

	FGS	LGT
Description of product	Photoelectric light curtain comprising a highly compact (52 x 53 mm) multi-beam emitter and receiver. Can be connected to the LCU interface for use in numerous situations.	Extremely compact (10 x 30 mm) multi-beam photoelectric safety barrier comprising an emitter, a receiver and a control unit.
Applications	Designed to protect fingers and hands on hazardous machines (presses etc.), packaging and automatic assembly machines.	Prevents access to danger points and hazardous zones. It is therefore used on hazardous machines, machining centres, production lines, gear assemblies etc.
Protective height (mm)	300 - 1800	150 - 900
Range (m)	0.3 - 6 / 0.3 - 18	0 - 6 (8 maximum)
Resolution (mm)	14/30	30
Response time (msec)	≤ 15	≤ 50
Type according to prEN 61496-1/-2	4	2
Voltage (V) DC AC	24	24 115 / 230
Outputs	2 semi-conductor outputs, PNP	Relays, 2 NO

	PLS
Description of product	This device scans its environment in a 180° semi-circle. It has a built-in range-finder and measures the distance to all objects in its field. It is possible to define a protection zone for emergency shut-off and warning zone, to prevent unnecessary stopping. Selectable with/without restart interlock. For area guarding on stationary machines and for vehicles in mobile applications RS232 or RS 422. Notebook parametrization and diagnostics.
Applications	This equipment is designed to protect operators inside or on the peripheries of hazardous zones (robotised islands, press interior etc.) and driverless vehicles.
Range (m)	4 m radius (protection zone) / approx. 15 m radius warning zone)
Resolution (mm)	70 (at 4 m range)
Response time (msec)	≤ 80
Type according to prEN 61496-1/-4	3
Voltage (V) DC	24
Outputs	2 OSSD (PNP) 1 weak signal

For further information please refer to technical description.

III.1.3 Access or perimeter guarding (entrance/exit)

- simple safety stop, in case of access to a hazardous zone
- discriminatory safety stop with special unit which distinguishes between products and persons

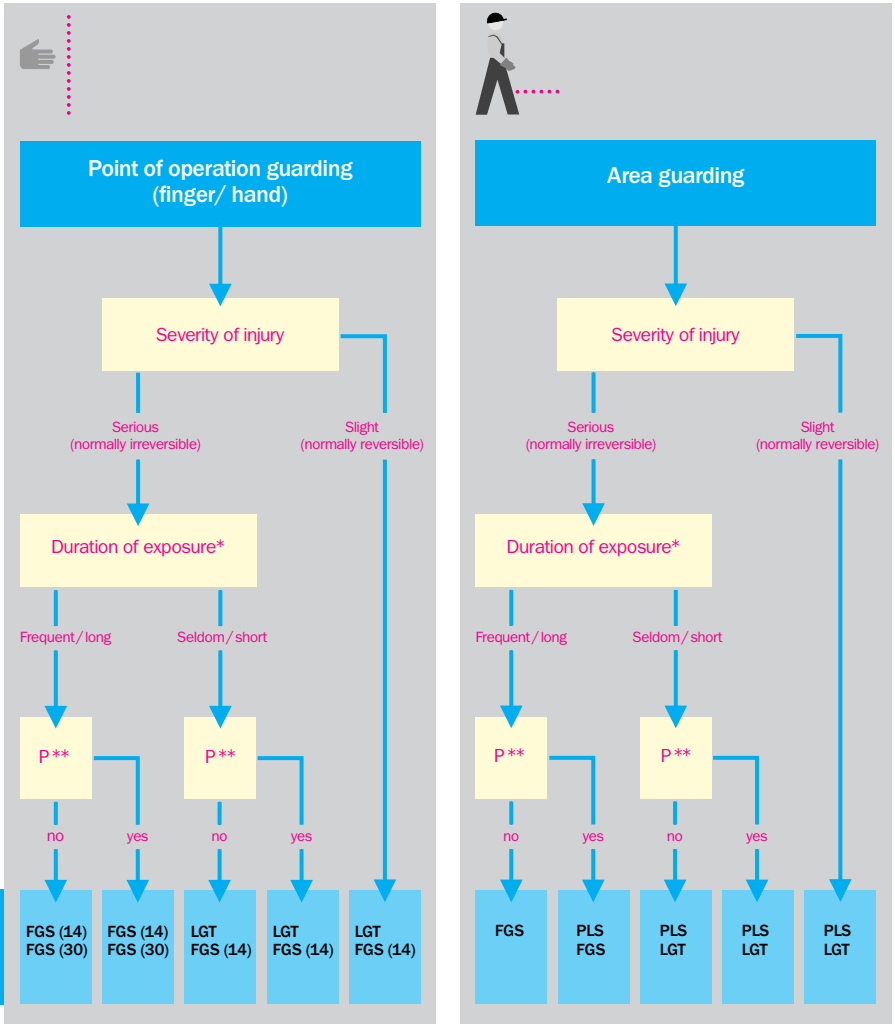
	MSL		WSU WEU 26	WS/WE 12(L)/24/27/170/260
Description of product	Photoelectric light switch with 2-12 beams comprising an emitting unit, and a receiving unit. Selectable with/without restart interlock. Selectable with/without EDM. Also available with muting module.		Single-beam photoelectric light switch, comprising an emitter and a receiver.	Single beam photoelectric switch, comprising an emitter and a receiver.
Applications	Designed to guard access to robotised zones palletisers and automatic loading / unloading machines.		Designed to monitor entrance/exit of robotised zones, palletisers, transfer paths etc.	Designed to monitor entrance/exit of palletisers, transfer paths etc.
Range (m)	0 - 20 / 15 - 70	70	0,5 - 18 / 15 - 70	0-10(60)/0-30/0-25/0-7/0-20
Number of beams	2 - 12 (MSL)	20	1	1
Response time (msec)	≤ 20		≤ 20	25
Type according to prEN 61496-1/-2	4		4	2
Voltage (V) DC AC AC	24		24 115 230	24
Outputs	2 semi-conductor outputs, PNP		2 NO / 1 NC Relays	1 PNP

	LCU-P	LCU-X	UAS 200
Description of product	Highly flexible interface whereby control circuits can be simplified. Three user modes enable customisation. Type 2 and 4 safety devices can be connected. Selectable with/without restart interlock. Selectable with/without EDM.	Interface for 1 Type 4 AOPD. Selectable with/without restart interlock. Selectable with/without EDM.	Control unit suitable for Type 2 devices.
Applications	Small presses in single and double break operating mode, person/pallet discrimination for palletisers, inhibition of a safety device etc.	All control systems of category 4 machines. LCU-X can be connected to semi-conductor or relay output safety devices.	Designed to discriminate between persons/pallets, but also to monitor access to robotised zones.
Outputs	2 semi-conductor monitored outputs PNP	2 NO / 1 NC Relays	2 NO / 1 NC Relays
Inputs	● Connection of 1 or 2 devices of type 4, 3 or 2 ● 2 or 4 auxiliary muting sensors	Connection of 1 Type 4, 3 or 2 device	Connection of 1, 2, or 3 Type 2 devices
Response time (msec)	5	15	25
Safety category according to EN 954-1	4	4	2
Voltage (V) DC	24	24	24 Control Unit AWT 1: Details available on request.

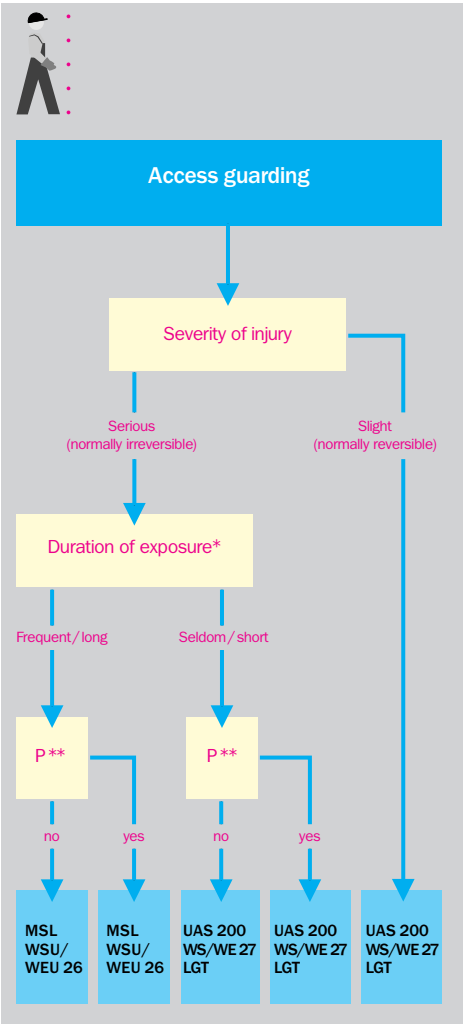
For further information please refer to technical description.

III.2 How to select a SICK protective device

(According to the principle of risk estimation described in II.3.3)



SICK products



* Duration of exposure of operator (frequency / time)
The expected duration of direct exposure must include the intervention frequency.

** Possibility of avoiding the hazard
YES: means possible under specific conditions.

Note: If the severity of injury is irreversible, we recommend the use of a Type 3 AOPD.

III.3 CE-conformity of SICK protective devices

Device	Type according to pr EN 61496	EC-Type approval number	Notified body	CE-conformity number
Point of operation guarding				
FGSS300-1800 / FGSE300-1800 14 mm	4	951010	BIA	9043794
FGSS300-1800 / FGSE300-1800 30 mm	4	951009	BIA	9043795
LGTS015-090 / LGTE015-090 30 mm	2	BB 9511317 01	TÜV Rheinland	9043792
LGTN control unit, generally needed for LGT	2	BB 9511317 02	TÜV Rheinland	9043792
Access guarding				
MSLS02-25071 / MSLE02-25011	4	96410	BG	9047305
MSLS03-22271 / MSLE03-22211	4	96410	BG	9047305
MSLS03-24071 / MSLE03-24011	4	96410	BG	9047305
with Muting:				
MSLE02-25051	4	96410	BG	9047305
MSLE03-22251	4	96410	BG	9047305
MSLE03-24051	4	96410	BG	9047305
MSLZ01-25031	4	96410	BG	9047305
with Muting: MSLZ01-25061	4	96410	BG	9047305
MSLS20-10711/MSLE20-10711	4	BB951154101	TÜV Rheinland	9045877
WSU all types also available in a pluggable version				
WSU26/2-130/WEU26/2-130 24 V / 0,5 - 18 m	4	available in March 1997	BG	available in March 1997
WSU26/2-120/WEU26/2-120 115 V / 0,5 - 18 m	4	available in March 1997	BG	available in March 1997
WSU26/2-110/WEU26/2-110 230 V / 0,5 - 18 m	4	available in March 1997	BG	available in March 1997
WSU26/2-230/WEU26/2-230 24 V / 15 - 70 m	4	available in March 1997	BG	available in March 1997
WSU26/2-220/WEU26/2-220 115 V / 15 - 70 m	4	available in March 1997	BG	available in March 1997
WSU26/2-210/WEU26/2-210 230 V / 15 - 70 m	4	available in March 1997	BG	available in March 1997

Device	Type according to pr EN 61496	EC-Type approval number	Notified body	CE-conformity number
Access guarding				
WS/WE12 / 0 - 10 m	2	70 510 0116 10 95	INRS	7008405
WS/WE12L / 0 - 60 m	2	70 510 0116 10 95	INRS	7008405
WS/WE24 / 0 - 30 m	2	70 510 0116 10 95	INRS	7008405
WS/WE27 / 0 - 25 m	2	70 510 0116 10 95	INRS	7008405
WS/WE170 / 0 - 7 m	2	available in April 1997	INRS	available in April 1997
WS/WE260 / 0 - 20 m	2	available in April 1997	INRS	available in April 1997
Area guarding				
PLS 101-112 RS232, V.3.XX	3	9508826.1	BIA	9044438
PLS 101-212 RS422, V.3.XX	3	9508826.1	BIA	9044438
Interfaces				
LCU-X	4	94538	BIA	9043790
LCU-P	4	951021	BIA	9043789
UAS 200 AP / UAS 200 BP	2	70 510 0116 10 95	INRS	7008405

For further product information, please refer to technical description.
For order details, please refer to price list.

Appendices

Annex
Bibliography
Glossary

Annex

Notified Bodies in Europe
(status 15/6/96)

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TÜV Rheinland
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IEC 1496 (prEN 61496)	part 1	Electro-sensitive protective equipment General requirements and tests
	part 2	Particular requirements for equipment using AOPD
	part 4-1	Active optical area protection
prEN 999		The positioning of protective equipment in respect of approach speeds of parts of the human body
EN 954 -1 and 2		Safety related parts of control systems
89/392 EEC and first and second amendments 91/368/EEC and 93/44/EEC		The Machinery Directive

AOAPD Active optical area protection device: an active radiation detection device using radiation in a range of 820 - 946 nm. A transmitter element emits radiation in the near infrared range. In the case of diffuse reflectance a portion of the emitted radiation will go back to the receiving element (e.g. SICK laser scanner PLS).

AOPD Active opto-electronic protective device: A device whose sensing function is performed by opto-electronic emitting and receiving elements detecting the interruption of optical radiations, generated within the device, by an opaque object present in the specified detection zone.

EDM External device monitoring: A means by which the electro-sensitive protective equipment monitors the state of control devices which are external to the electro-sensitive protective equipment.

ESPE electro-sensitive protective equipment: An assembly of devices and/or components working together for protective tripping or presence-sensing purposes and comprising as a minimum:

- a sensing function;
- a control/monitoring;
- output signal switching devices;

FSD Final switching device: The component which, when signalled by the OSSD going to the OFF-state, responds by interrupting the circuit connecting the machine control system to the machine primary control element.

Light curtain: an AOPD with a resolution between 14 mm and 40 mm, i.e protecting hand/arm.

MPCE Machine primary control element: The electrically powered element that directly controls the normal operation of a machine in such a way that it is the last element (in time) to function when machine operation is to be initiated or arrested.

Muting: A temporary automatic suspension of a safety function(s) by safety-related parts of the control system.

OSSD Output signal switching device: The component of the electro-sensitive protective equipment connected to the machine control system which, when the sensing function is actuated during normal operation, responds by going to the OFF-state.

Protection zone: The zone within which a specified test piece will be detected by the electro-sensitive protective equipment. Also referred to as detection zone (for laser scanners).

R(eceiver)

Resolution refers to the minimum size of an object for which the supplier guarantees detection by the AOPD. Also referred to as object sensitivity.

S(ender)

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