Safety with AOPD - Active Optoelectronic Protective Devices

Specification & application

Revision date - 8 April 2020

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INTRODUCTION

This document serves as an introduction to a very detailed process, the selection and application of AOPD (Active Optoelectronic Protective Devices) and ESPE (Electro-Sensitive Protective Equipment). It serves, when first considering ESPE for safety-related applications, as a list of questions to consider. It then provides a brief discussion of some of those considerations and provides some references for further investigation.

CONSIDERATIONS FOR SELECTING AN APPROPRIATE AOPD

There are a number of criteria and options involved in the selection of an appropriate AOPD and ESPE. A risk assessment of the entire system must be completed to accurately define the safety-related requirements. This document is a summary of some features of AOPD, there are many other requirements and features of a complete risk assessment and mitigation project. An AOPD may or may not be appropriate for any specific application; use these criteria as part of that determination.

WHAT IS THE SAFETY FUNCTION?

A safety function must first be defined. A safety function's definition is its purpose, e.g., 'if a person approaches the machine, the machine must stop moving within 2 seconds'. An AOPD is a detection element of a proposed safety function circuit.

The safety function must also be accurately described. There are two primary methods to safeguard a machine; guards and safeguarding devices. Guards provide a physical barrier that prevents contact with the hazard. Safeguarding devices either prevent contact or detect a person and stop hazardous motions before contact occurs. ESPE are safeguarding devices. The decision to use guards, safeguarding devices or a combination will influence the safety function description. For example, this safety function description, 'a person is detected by the light curtain SLC01, this signal is processed by safety controller PLC01 and contactors C1 and C2 are opened' includes light curtains. AOPD applications can be described in one of two broad categories:

- **Point of Operation Control (POC)**: light curtains used in these applications protect on a small scale. Specifically, they help protect hands, fingers and arms that are going to be operating the machinery. These light curtains are generally located very close to the machine, directly where the worker will be interacting with it.
- **Perimeter Access Control (PAC):** light curtains used in these applications differ from the POC variety in that this style offers full body protection. They essentially create a fence around machines that don't require up-close usage by workers, and are designed to detect people or objects when they intrude into the light barrier.

WHAT IS THE REQUIRED SAFETY DISTANCE?

The time necessary to stop hazardous motions is partly a function of the response time of the detection elements. There are published equations used to help calculate this distance. See the REFERENCES section below for links. The safety distance, as defined in ANSI B11.19-2010 is: 'The distance a safeguard is installed from a hazard such that individuals are not exposed to the hazard.' Annex D of B11.19-2010 explains how to calculate the safety distance in more detail. Also consider reaching around, through or over a barrier guard or safeguard. Charts and formulas in several standards can help define these required distances.

LIGHT CURTAIN RESOLUTION & SAFETY DISTANCE

Electro-optical devices do not detect presence until an amount of penetration into the detection plane. That amount is known as the distance (or depth) penetration factor, called D_{PF} The light curtain resolution affects the Depth of Penetration Factor and the safety distance. Resolution, also called minimum object sensitivity or detection capability, is the minimum object diameter the light curtain will always detect within its detection zone. The application of reduced resolution (commonly called floating blanking) will also affect the required safety distance. See the respective manuals for the safety distance calculation details. Resolution is equal to:

$$RES = [BS * (N+1)] + BD$$

BS = beam spacing, centerline distance between adjacent beams

N = number of beams allowed to be blocked without turning off light curtain outputs

BD = effective beam diameter

The table below shows the available resolutions for each Banner light curtain series and the associated Depth of penetration factors.

Light curtain series	**Depth of penetration factor D_{PF} (mm)**					
Resolution (mm)	**14**	**23**	**24**	**25**	**30**	**40**
LS light curtains	24	54	-	-	-	112
LS BASIC light curtains	-	54	-	-	-	-
EZ-Screen 14/30 light curtains (see note)	24	-	-	-	78	-
EZ-Screen 14/30 Type 2 light curtains	-	-	-	-	78	-
EZ-Screen LP Low Profile light curtains (see note)	24	-	-	61	-	-
EZ-Screen LP Basic Low Profile light curtains	24			61		
SLC4 light curtains	24	-	58	-	-	-

Note: this series can be configured for Reduced Resolution, i.e., floating blanking. See the manual for how this affects the D_{PF}.

TYPES OF ESPE

The Performance Level (PL) or Safety Integrity Level (SIL) required by the safety function will influence the Type of ESPE used. Safety performance capabilities of ESPE are described by the characteristics of the 'Type'. There are three Types of ESPE, as defined in IEC 61496, and briefly described below:

- Type 2 ESPE employ a periodic test to reveal failures to danger. The test can be initiated internally or externally.
- Type 3 ESPE are designed to not fail to danger due to a single fault but can fail to danger due to an accumulation of faults.
- Type 4 ESPE are designed to not fail to danger due to a single fault or an accumulation of faults.

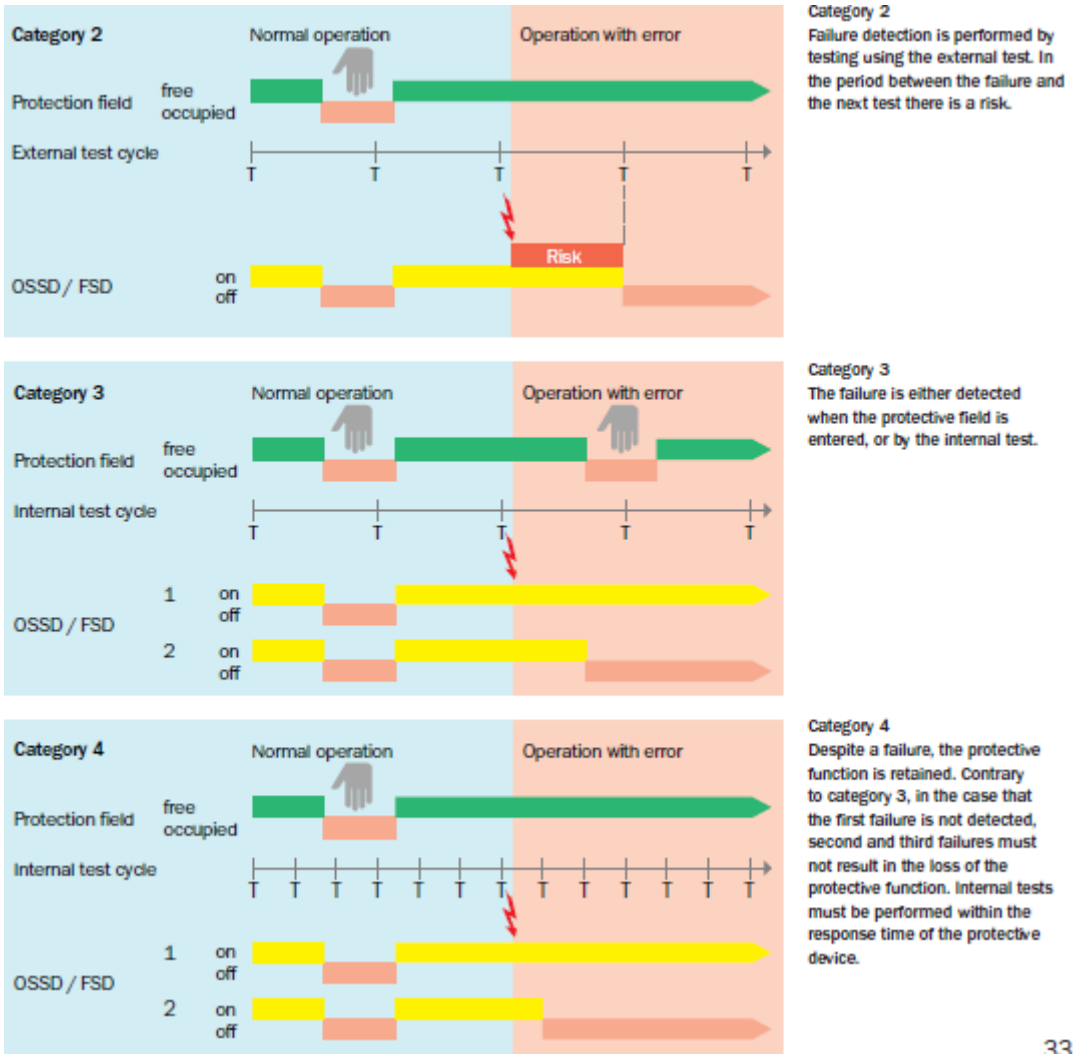


Figure 1 - ESPE Types (courtesy of SICK AG)

Banner light curtains are defined as either Type 2 or Type 4 devices. An area scanner is defined as a Type 3 device. The Type restricts the ESPE to a certain Performance Level (PL) or Safety Integrity Level (SIL) as defined. Figure 2 below is a copy of IEC 62046:2018, Table 1, showing achievable PL and SIL with each ESPE Type:

	ESPE Type	PL	SIL
For each ESPE Type, the PL or SIL that can be achieved by a safety function that includes that ESPE	2	a, b, c	1
	3	a, b, c, d	1, 2
	4	a, b, c, d, e	1, 2, 3

Figure 2 – Table 1, IEC 62046:2018

IS MUTING REQUIRED?

It is possible to mute many safeguarding devices. Muting, as defined in IEC 62046:2018, is 'temporary automatic suspension of a safety function(s) by safety-related parts of the control system'. Muting is distinct and has different requirements than blanking. The requirements for muting are detailed in many standards; some are listed in the References section at the end of this document.

If muting of an ESPE is necessary, there are a number of installation considerations necessary.

POSITIONING SENSORS FOR LIGHT CURTAIN MUTING

Here considered are four different configurations of photoelectric sensors for light curtain muting.

- Two beams with timing control. Used for entry and exit applications and named 'T configuration with timing control'. The T configuration is shown schematically with the relevant distances in Figure D.17 of IEC 62046:

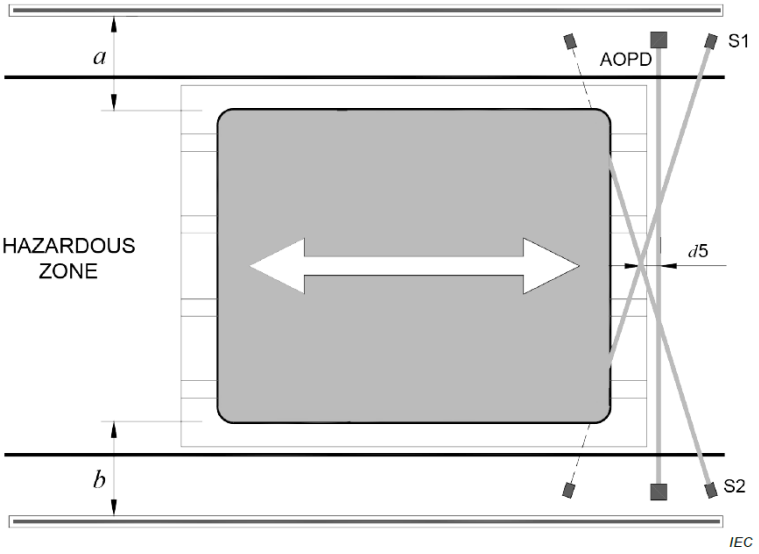


Figure D.17 – Two sensors – Crossed beams

The distance d5 is measured between the optical axis of the ESPE and the intersection of the two muting sensors light beams. This intersection should be on the hazardous side of the ESPE and should be as short as practicable to prevent persons to enter the hazardous zone by following the transported object. It is recommended that d5 be no more than 200 mm.

The distances 'a' and 'b' between the edges of the transported object and the fencing should be such that a person cannot pass undetected alongside the object.

The opening through which the pallet enters should also be configured as shown in Figure D.18 of IEC 62046, shown below:

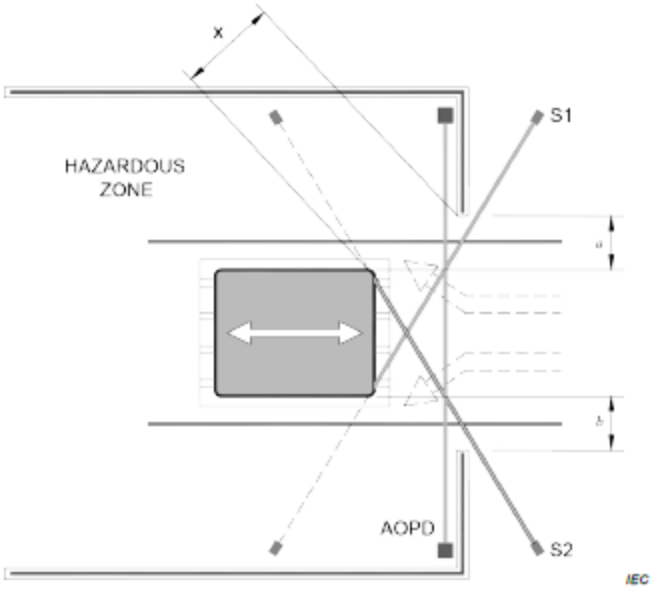


Figure D.18 – Two sensors – Crossed beams
(risk of entering the hazardous zone without detection when x >200 mm)

The distance 'x', the distance between the opening and the nearest point of the pallet as it leaves the muting sensors, should be less than 200 mm.

The positioning of the muting sensors shall be such that a cylindrical object of diameter 500 mm, with its axis parallel to the protected area cannot activate the muting function when moved in any point of the opening at any speed up to 1.6 meter/second. This is shown in Figure D.19 of IEC 62046, shown below:

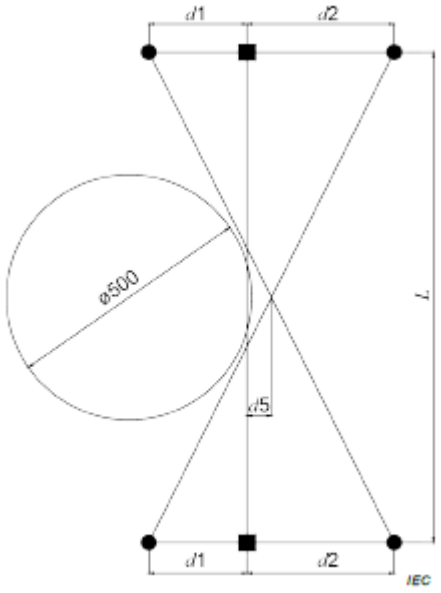


Figure D.19 – Positioning of the muting sensors

Consult the C&E Safety Specialist for assistance in calculating required distances. There is some geometry and trigonometry to be calculated. A more detailed evaluation of this Figure is found in the References section.

- Two beams with timing control. Used for exit applications only and named ‘L configuration with timing control. The L configuration is shown below copied from Figure D.28 of IEC 62046:

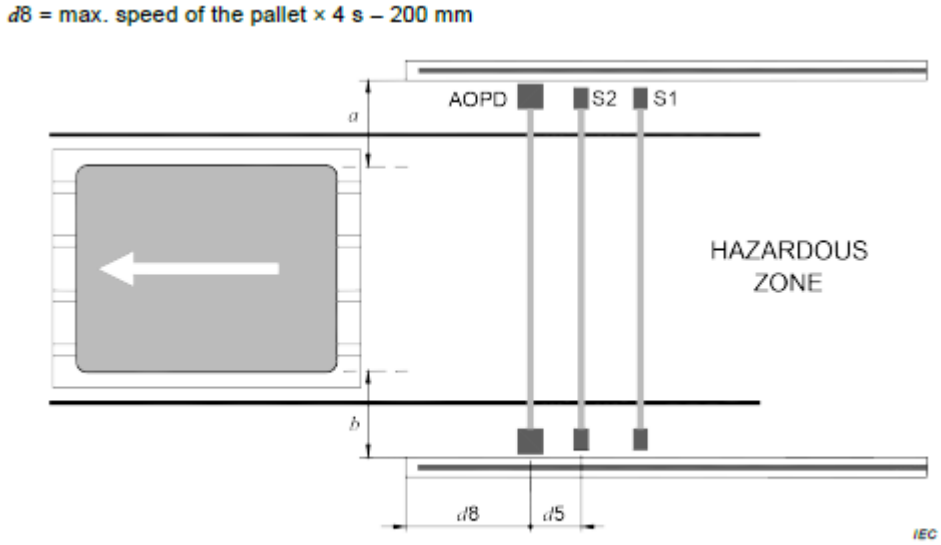


Figure D.28 – Two muting sensor beams – exit only

Termination of the muting function occurs either when the AOPD becomes clear or within 4 seconds, whichever occurs first. If the termination is performed only by the 4 second timer, the mechanical barriers should be extended by the distance d8 shown in the above Figure. Distance d8 = (maximum speed of the pallet x 4 seconds) – 200 mm.

- Four parallel beams with timing control. Used for entry and exit applications.
- Four parallel beams with sequence control. Used for both entry and exit applications. The four beam configurations have the same hardware arrangement. These configurations are shown below copied from Figure D.4 of IEC 62046:

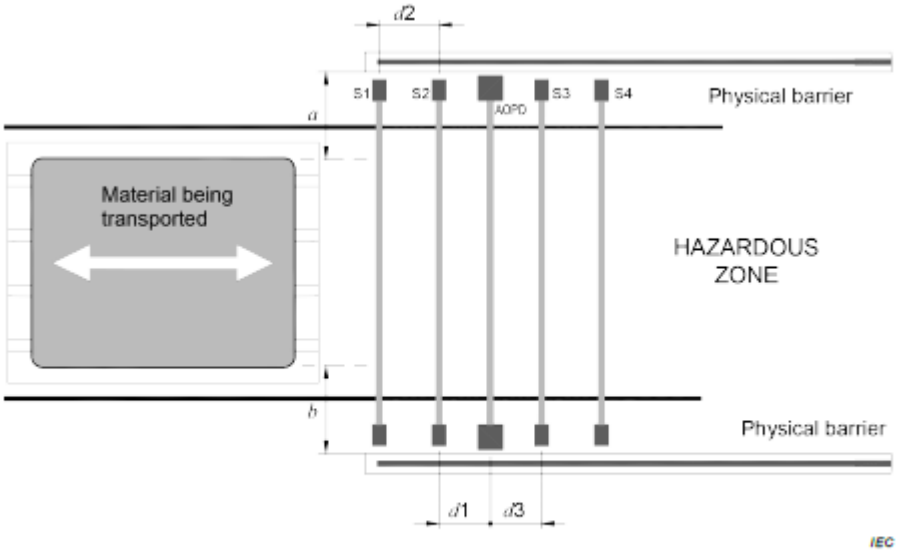


Figure D.4 – Four parallel beams with timing control

The distance between S1 and S4 should not be less than 500 mm to prevent a person to sustain the muting function with his body. Should this not be possible, a four parallel beam configuration is not suitable. Confirm the sensor spacing by ensuring that a cylindrical object with diameter of 500 mm cannot sustain the muting function when it is moved in any part of the opening at any speed up to 1.6 meter/second.

The distance between any two muting sensors should be at least 250 mm, to ensure that they cannot be simultaneously actuated by a person's leg.

VERTICAL MOUNTING OF MUTING SENSORS

- The height of the muting sensors should be such to detect the load being conveyed and not the transport pallet.
- In two-beam applications, the crossing point of the two beams should be at the same height, or higher than, the lowest beam of the ESPE. This will ensure that a person cannot place a foot under the ESPE and actuate the muting sensors without breaking the light curtain.

BANNER ENGINEERING SAFETY LIGHT CURTAIN SELECTION CRITERIA

If you have chosen a safety light curtain as the protective device consider each of these attributes to refine the hardware selection. Details of each series of Banner Engineering light curtains can be found online. There is a link to the instruction manual for each light curtain series in the References section.

RANGE

RANGE is the maximum distance between the emitter and its mated receiver. This is reduced by the inclusion of mirrors or enclosures. Below is a summary of the maximum ranges of all the Banner safety light curtains:

Light curtain series	Maximum range (meters)
LS light curtains	0.1 – 12
LS BASIC light curtains	0.1 – 8
EZ-Screen 14/30 light curtains (14mm resolution)	0.1 – 6
EZ-Screen 14/30 light curtains (30mm resolution)	0.1 – 18
EZ-Screen 14/30 Type 2 light curtains	0.2 – 15
EZ-Screen LP Low Profile light curtains	0.1 – 7
EZ-Screen LP Basic Low Profile light curtains	0.1 - 4
SLC4 light curtains	0.1 - 2

PROTECTED HEIGHT

Also referred to as the 'detection zone'.

Light curtain series	Protected height range (mm)
LS light curtains	280 – 1820 in 70mm increments
LS BASIC light curtains	10 heights between 350 and 1820mm
EZ-Screen 14/30 light curtains (14mm resolution)	150 – 1800 in 150mm increments
EZ-Screen 14/30 light curtains (30mm resolution)	150 – 2400 in 150mm increments
EZ-Screen 14/30 Type 2 light curtains	150 – 1800 in 150mm increments

EZ-Screen LP Low Profile light curtains	270 – 1810 in 140mm increments
EZ-Screen LP Basic Low Profile light curtains	270, 410, 550, or 690
SLC4 light curtains	160, 240, or 320

RESOLUTION

Refer to the section on Safety Distance to see the available resolutions and whether reduced resolution can be achieved.

CASCADEABLE

In cascadeable light curtain systems, the number of light curtain pairs possible to cascade is a function of the protected heights and the lengths of the interconnecting cord sets. Refer to the instruction manuals for details. In a cascaded system the terminal pair can be non-cascading.

Cascadeable models have distinct part numbers, refer to the manual for all part numbers.

Light curtain series	Cascadeable	Max. number light curtain pairs in cascade
LS light curtains	Yes	4 pairs
LS BASIC light curtains	No	-
EZ-Screen 14/30 light curtains (14mm resolution)	Yes	4 pairs
EZ-Screen 14/30 light curtains (30mm resolution)	Yes	4 pairs
EZ-Screen 14/30 Type 2 light curtains	No	-
EZ-Screen LP Low Profile light curtains	Yes	4 pairs
EZ-Screen LP Basic Low Profile light curtains	No	-
SLC4 light curtains	No	-

BLANKING

Floating blanking, i.e., reduced resolution is available on some models. Refer to the safety distance section for available resolutions and reduced resolution capabilities.

Fixed blanking is a programming feature that allows a light curtain to ignore objects which will always be present at a specific location within the defined area.

Light curtain series	Fixed blanking?
LS light curtains	Remote fixed blanking on cascadeable receivers
LS BASIC light curtains	Not available
EZ-Screen 14/30 light curtains (14mm resolution)	Configured via DIP
EZ-Screen 14/30 light curtains (30mm resolution)	Configured via DIP
EZ-Screen 14/30 Type 2 light curtains	Not available
EZ-Screen LP Low Profile light curtains	Via DIP on all models, remote on cascadeable receivers
EZ-Screen LP Basic Low Profile light curtains	Not available
SLC4 light curtains	Not available

MOUNTING & INSTALLATION

Banner light curtains are supplied with two (2) end cap brackets for each emitter or receiver ordered. Units of length 910mm and longer are also supplied with a center mount bracket. When ordering light curtains of the LS Basic, LP Basic, or SLC4 series note that mounting hardware must be ordered separately and is not included with the emitters or receivers.

CONFIGURATION

	LS	**LS Basic**	**14/30**	**Type 2**	**LP**	**LP Basic**	**SLC4**
Output	Trip only	Trip only	Trip or latch via DIP	Trip or latch via part number	Trip or latch via DIP	Trip only	Trip only
EDM connection on receiver	1-ch or none via wiring (8 pin only)	1-ch or none via wiring (8 pin only)	1-ch, 2-ch or none via wiring & DIP	Power or no EDM via wiring	1-ch, 2-ch or none via wiring & DIP	None	None
Scan code (SC)	SC1 or SC2 via wiring (8 pin models)	SC1 or SC2 via wiring (8 pin models)	SC1 or SC2 via DIP	n/a	SC1 or SC2 via DIP	Selected automatically	n/a

BANNER ENGINEERING SAFETY GRID SELECTION CRITERIA

RANGE

Safety grid series	**Maximum range (meters)**
SGS emitter/receiver standard range	0.5 – 30
SGS emitter/receiver long range	6 - 60
SGS emitter/receiver with integral muting	0.5 - 30
SGS active/passive	0.5 – 6.5 or 8 depending on model
SGS active/passive with integral muting	0.5 – 6.5 or 8 depending on model

BANNER ENGINEERING SAFETY AREA SCANNER SPECIFICATION

There are some tolerances specific to safety area scanner applications that must be observed.

- A Banner SX5 laser scanner's mirror rotates every 30 msec. Another way to say this is the scanner performs 33.3 revolutions (scans) per second. Its safety outputs will switch off only after an object is detected in the Safety zone for at least two consecutive scans. Each additional scan configured increases the scanner response time by 30 msec.
- Maintain a minimum distance of 40mm between the Safety zone boundary and any wall of fixed object.
- All horizontal Safety zone applications, whether light curtains, grids, or area scanners have some additional Depth of Penetration considerations. Scanner considerations:
    - D_{PF} = 1200 mm for all horizontal applications

- Z_{SM}, Measurement Tolerance Factor, is the additional distance needed to account for distance measurement error. Z_{SM} for horizontal scanner applications = 150 mm. For vertical scanner applications with normal approach, Z_{SM} = 0.
- Z_{AMB}, Ambient Interference Factor, is the additional distance needed to account for measurement errors caused by light interference and/or the presence of highly reflective surfaces present in the scanning plane. If no ambient interference, Z_{AMB} = 0. There is a graph on page 26 of the SX5-B manual that determines this distance, based on the dust filter level.

- There are additional specifications when safety laser scanners are applied on mobile devices. Refer to Section 3.9 of the SX5 manual and Annex B of IEC 62046.

DEFINITIONS USED IN THIS DOCUMENT

AOPD – Active Optoelectronic Protective Device

AOPDDR – Active Optoelectronic Protective Device responsive to Diffuse Reflection

ESPE – Electro-Sensitive Protective Equipment

REFERENCES

SAFETY STANDARDS USED IN THIS DOCUMENT

ANSI B11.19-2010: Performance Criteria for Safeguarding

OSHA - A link to the OSHA safety distance formula is here

IEC 62046-2018: Safety of machinery – Application of protective equipment to detect the presence of persons

ISO 13855-2010: Safety of machinery – Positioning of Safeguards With Respect to the Approach Speeds of Parts of the Human Body

ISO 13857-2019: Safety of machinery - Safety Distances to Prevent Hazard Zones Being Reached by Upper and Lower Limbs

BANNER ENGINEERING EQUIPMENT MANUALS

LS light curtain manual can be found here.

LS BASIC light curtain manual can be found here.

14/30 light curtain manual can be found here

LP light curtain manual can be found here

LP Basic light curtain manual can be found here

SLC4 light curtain manual can be found here

SGS emitter/receiver grid system manual can be found here.

SGS emitter/receiver with integral muting grid system manual can be found here.

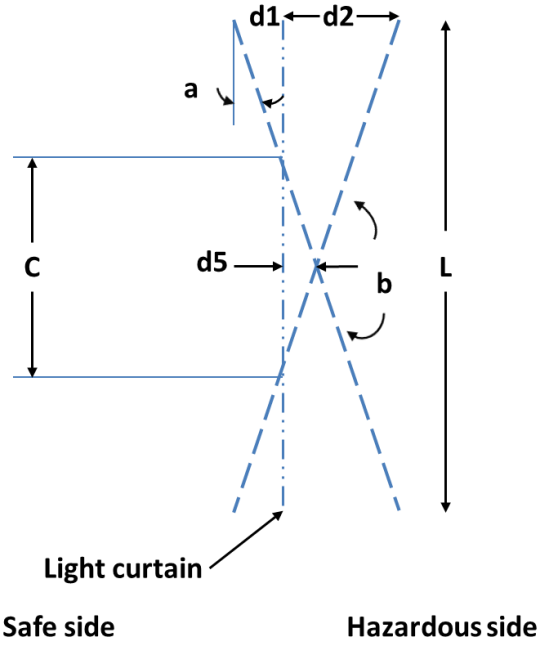
SGS active/passive grid system manual can be found here

SGS active/passive with integral muting grid system manual can be found here

SX5 safety laser scanner manual can be found here

FIGURE D.19 GEOMETRY

1. LOCATE THE LIGHT CURTAIN
2. CHOOSE SENSOR SEPARATION DISTANCE L
3. CHOOSE SENSOR LOCATION DISTANCES d1 and d2
    1. d2 is always greater than d1
4. CONFIRM LOCATIONS AND DISTANCES
    1. CALCULATE ANGLE a
        1. $\tan a = \frac{d1+d2}{L}$
    2. CALCULATE ANGLE b
        1. $b = 180 - 2a$
5. 500mm diameter test cylinder must break light curtain before breaking the muting sensors. Angle b can be no smaller than required to keep the chord C of a 500mm cylinder.
    1. $C = 2r * \sin\frac{b}{2}$
6. Calculate distance from center of cylinder to point of tangent intersection, called OY.
    1. $\frac{\sin\frac{b}{2}}{r} = \frac{\sin 90}{OY}$
    2. OY = 280 mm
7. d5 should be as small as possible to prevent someone walking in behind the conveyed product and no larger than 200mm:
    1. d5 = OY – r = 280 – 250 = 30 mm
8. The test cylinder must trip the light curtain before initiating a mute cycle at any speed up to 1600 mm/second. This may increase d5, but to no more than 200 mm.



FOR MORE INFORMATION:

For more information or to discuss the particular details of your application, please contact the C&E Advanced Technologies Safety Specialist:

Steve Wright – Safety Specialist
P.E., CSP
FS Eng (TÜV Rheinland, #5619/12, Machinery)
Office: 800-228-2790
Cell: 937-510-5918
swright@ceadvancedtech.com