Calculating Safety Distances

Requirements for the proper placement of safety guards and presence sensing devices

Applying safeguards to equipment and machines may lead to a false sense of safety if not applied correctly. One practice which is often overlooked is determining the minimum safe distance or height at which a hard guard or protective device should be installed. Many times a hard guard will be installed which can easily be bypassed by reaching over, around or through. Also, safety devices such as light curtains are often installed too close to the hazard point where residual danger still exists once the light curtain is interrupted. Performing a safe distance calculation is crucial to ensure selected safeguarding practices will actually function as desired.

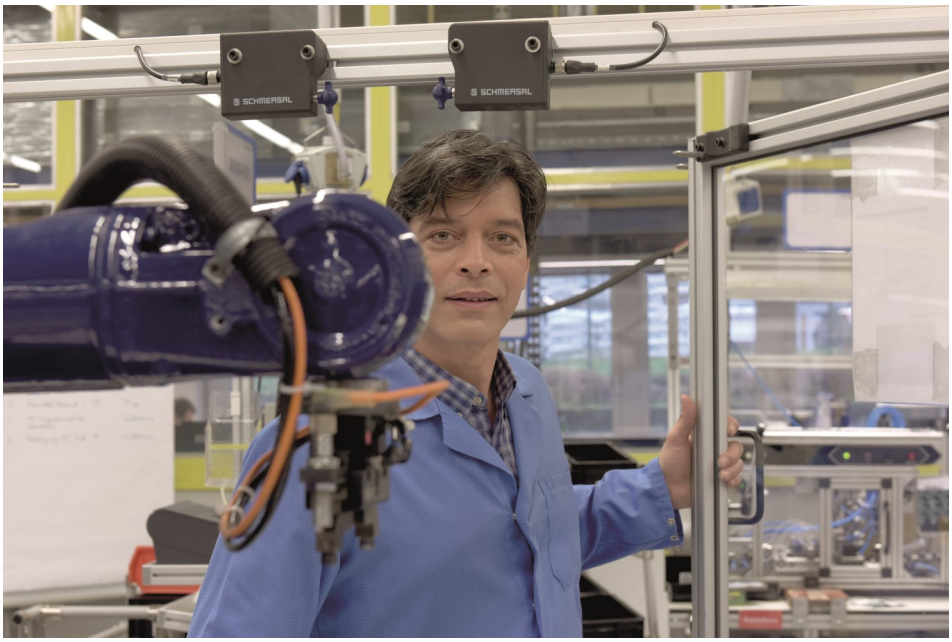


Image 1: worker enters a robot cell protected by a guard door with safety interlock switches.

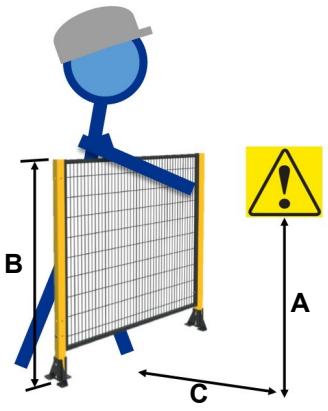
The use of hard guarding is a common practice to protect operators from hazardous conditions. If there is a danger point on a machine that an operator does not require access to, a fixed guard can be applied to separate the operator from the danger. This type of "separating guarding" should be fixed to the machine with fasteners that require a tool not common to the operator for removal. (image 2)

Safety standards such as ISO 12100 (*Safety of machinery - Basic concepts, general principles for design*) will call out this requirement for the fasteners in order to prevent the manipulation or bypassing of the fixed guard. The actual type of hard guard such as material and durability will be based on the application and environment.

The height and distance of installation however will be based on relevant safety standards such as ISO 13857 (*Safety of machinery – Safety distances to prevent hazard zones being reached by upper and lower limbs*). This international standard provides a matrix using the height of a hazard and the distance from that hazard as parameters to determine the height of the hard

Image 2: examples of various fasteners. To the left: fasteners which do not require a special tool for removal. Slotted head and thumb screws can easily be removed and should not be used to secure fixed guarding. To the right: examples of tamperproof screws, which require special tools for removal and thus can be used to secure fixed guards. Tools which are considered not common to the operator is dependent on the specific factory site.

Table 1: the guard distance matrix from ISO 13857 (*Safety of machinery – Safety distances to prevent hazard zones being reached by upper and lower limbs*). Measurements are shown in millimeters (mm)



A) Height of hazard zone (mm)	B) Height of protective structure (mm)									
	1000	1200	1400	1600	1800	2000	2200	2400	2500	2700
	C) Horizontal safety distance to hazard zone (mm)									
2700	0	0	0	0	0	0	0	0	0	0
2600	900	800	700	600	600	500	400	300	100	0
2400	1100	1000	900	800	700	600	400	300	100	0
2200	1300	12000	1000	900	800	600	400	300	0	0
2000	1400	1300	1100	900	800	600	400	0	0	0
1800	1500	1400	1100	900	800	600	0	0	0	0
1600	1500	1400	1100	900	800	500	0	0	0	0
1400	1500	1400	1100	900	800	0	0	0	0	0
1200	1500	1400	1100	900	700	0	0	0	0	0
1000	1500	1400	1000	800	0	0	0	0	0	0
800	1500	1300	900	600	0	0	0	0	0	0
600	1400	1300	800	0	0	0	0	0	0	0
400	1400	1200	400	0	0	0	0	0	0	0
200	1200	900	0	0	0	0	0	0	0	0
0	1100	500	0	0	0	0	0	0	0	0

guard, all represented in millimeters (mm). For reference when using such international standards, 1 inch is equivalent to 25.4 mm.

A basic view of the matrix shown in Table 1 (above) is that the closer the hard guard is to the hazard, the higher the guard needs to be in order to prevent someone from reaching over. For example, a hazard point which is roughly 1200 mm from the ground will require a guard at least 1000 mm tall if installed 1500 mm away. However if we move this guard closer to the 1200 mm hazard to just 700 mm away the guard would now have to be at least 1800 mm tall.

In addition to providing guidance from reaching over guards, ISO 13857 also aids in the prevention of reaching through openings, as shown in Table 2 (below). The standard looks at the type of openings on the guard such as slotted, squared or rounded openings. The minimum distance a guard should be placed is dependent on the opening size of the particular shape. For example, a square opening of 5 mm should be placed at least 5 mm from the hazard while a slotted opening of the same size must be installed at least 10 mm away. The concept behind the distances takes into account thumbs and knuckles being used to limit the finger and hand penetration through the various shaped openings.

Part of Body	Opening	Safety distances, S_r		
		Slot	Square	Round
Fingertip	e ≤ 4	≥ 2	≥ 2	≥ 2
	4 < e ≤ 6	≥ 10	≥ 5	≥ 5
Finger up to knuckle joint	6 < e ≤ 8	≥ 20	≥ 15	≥ 5
	8 < e ≤ 10	≥ 80	≥ 25	≥ 20
	10 < e ≤12	≥ 100	≥ 80	≥ 80
Hand	12 < e ≤ 20	≥ 120	≥ 120	≥ 120
	20 < e ≤ 30	≥ 850	≥ 120	≥ 120
Arm up to junction with shoulder	30 < e ≤ 40	≥ 850	≥ 200	≥ 120
	40 < e ≤ 120	≥ 850	≥ 850	≥ 850

Table 2: The ISO13857 matrix for reaching through guards. Measurements in millimeters (mm)

Presence sensing safety devices are considered non-separating guarding as there is no physical barrier between the operator and hazard. If used as the primary safety device there will not be anything preventing someone from stepping on a safety mat, reaching or walking through a light curtain or stepping within an area covered by a scanner. Since devices such as these are relied upon to bring about a safe condition once they are triggered it is critical that they are installed at the appropriate distance. All too often non-separating guarding is installed without determining the safe

Image 3: The worker interacts with a machine protected by a safety light curtain, a non-separating guard

distance, again creating a false sense of safety.

Performing an eye test may appear that once an installed presence sensing device is trigged that the machine or equipment comes to an instant stop, however this is not the case. Reaction time of the safety device, monitoring device, output triggers, machine motor, etc. must all be taken into account even if the total is within the millisecond range. Even with passing the eye test it is very possible to be exposed to a residual hazard after triggering the safety device if it is positioned too close. Once time stop measurement have be conducted they can be used in the safe distance formula for the given safety device as called out in ISO 13855 (*Safety of machinery – Positioning of safeguards with respect to the approach speeds of parts of the human body*).

ISO 13855's general formula for the minimum safe distance is:

S = (K x T) + C

where S is the minimum distance in mm, K is the human approach speed in mm/s, T is the total stopping time in seconds and C is the intrusion distance. The different non-separating guarding device will have some variation of this general formula. For example the formula for a safety mat is S = (1600 x T) + 1200, so if a machine hazard is being guarded by a safety mat and has a total stopping time of 100 ms the minimum safe distance installation will be 1,360 mm. The light curtain formula will be dependent on vertical or horizontal mounting and its resolution (detection capability). If we take the previous machine and utilize a vertical 14mm resolution light curtain with a total stopping time of 80ms the formula will be S = (2000 x T) + C where C is calculated by 8 (d – 14) with d representing the light curtains resolution. For this setup the minimum safe distance for the light curtains will be 160 mm.

Unlike guard locking devices which keep the guard locked until a safe condition has been reached, safe distances for non-locking devices must be evaluated as the guard door can be opened at any given time. Such applications look at both ISO 13857 and ISO 13855 to determine how far the interlocked guard door must be from the hazard. Using S = (K x T) + C from ISO 13857 where K = 1600mm/s and C being the safety distance from ISO 13855 if you can reach through an opening of the hard guard.

Non-separating guarding safety devices are great for applications with high frequency interaction with a machine or piece equipment since there is no requirement to constantly open and close a guard door. Of course not every application can utilize such types of safety device and will actually require some form of hard guarding, possibly with an interlocking device if interacting with a guarded part of the machine is part of normal operation. No matter which method is decided upon, understanding how high and how far away the guard or device must be installed is essential to properly safeguard against a given hazard. Correct placement of guards and presence sensing devices helps achieve the goal of a safer working environment.

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