EXECUTIVE SUMMARY

Minimum Distances for Safety Control Measures

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APRIL 24, 2024

KEY TAKEAWAYS

- The Hierarchy of Controls applies throughout the machine's life cycle.
- Separating guarding places a physical barrier between personnel and the hazard.
- There is no physical barrier between personnel and the hazard when using non-separating guarding.
- Stop time analysis is critical when implementing non-separating guarding.

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OVERVIEW

Fixed guards and presence-sensing safety devices are often used as control measures for risk reductions. One important aspect to consider when implementing such solutions is their physical placement in relation to the hazard. Following industry requirements for safe minimum distances ensures compliance and an effective safe solution for these specific control measures.

Schmersal is focused on machine safety devices and safety engineering services, to safeguard machines in compliance with current safety standards without compromising productivity. The Schmersal tec.nicum group offers product- and manufacturer-neutral consultation on important matters relating to machine safety and work protection, while the TÜV Certified Functional Safety Engineers for Machinery can plan and realize complex solutions for safety in close collaboration with clients.

CONTEXT

Devin Murray discussed the types of engineering controls used to safeguard machines, industry standards that apply, and how to calculate safe minimum distances.

KEY TAKEAWAYS

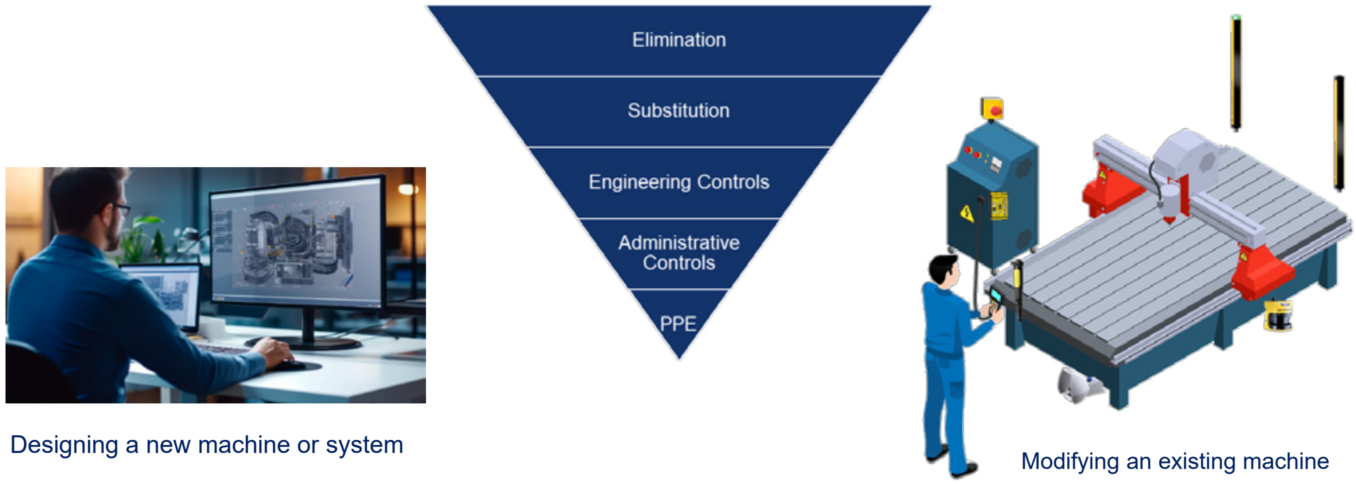
The Hierarchy of Controls applies throughout the machine's life cycle.

Whether for a new or existing machine, the approach for determining where to place hard guards and safety devices will be the same: It starts with risk assessment. Following the Hierarchy of Controls, a risk assessment involves first identifying the hazards and the risk associated with the equipment, then remediating those risks.

In this case, the risk assessment should include consideration of whether the risk can be **eliminated** using machine guarding.

- **If a risk cannot be eliminated,** the next level to explore in the Hierarchy of Controls is to determine whether it is possible to **substitute** the hazard for something less dangerous.
- **If elimination and substitution are not possible,** or if substitution leaves room for improvement, the next area to explore is **engineering controls**. Administrative controls and then PPE follow engineering controls, in that order, in the event that each level before does not produce the desired safety result.

Figure 1: Machine guarding decisions should follow the Hierarchy of Controls



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Note: Post-assessments are required when implementing any control measure to ensure no additional hazards have been created.

> "What control measures can we implement to help protect against the hazard, to help minimize exposure to this hazard [through] the entire life cycle of the equipment?"
>
> *Devin Murray, tec.nicum Services Manager, Schmersal USA*

Separating guarding places a physical barrier between personnel and the hazard.

One of the first options for engineering controls is to implement hard guards. Separating guarding physically separates personnel from the hazard and does not tie into any existing controls on a machine. The required standards that apply to separating guarding are:

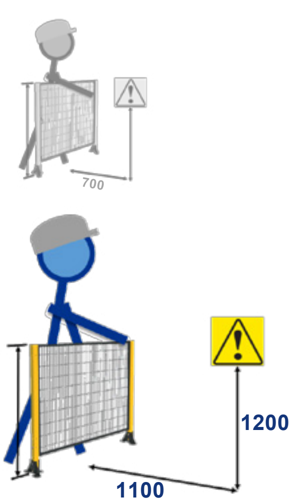
- **International.** ISO 13857 Safety of Machinery: Safety distances to prevent hazard zones being reached by upper and lower limbs—whether around, under, or through a guard.
- **U.S.** ANSI B11.19 Performance Requirements for Risk Reduction Measures: Safeguarding and other means of reducing risk.

Note: Companies should not use ISO for one machine and ANSI for another; a single standard should be selected and consistently applied.

When installing separating guarding, there are several factors to consider:

- Avoid creating a crushing hazard.
- Avoid trapping of personnel inside of an enclosed area.
- Allow access where required—even though the equipment is being safeguarded, it must still be able to be used.
- Consider ergonomic attributes and operation of the guard.
- Selection of guarding materials should be appropriate to the environment.
- Movable guards must be either monitored or secured to prevent unauthorized access.

Figure 2: The farther away from the hazard, the lower the guard can be (ISO 13857)



Height of the point of the hazard zone which is nearest to the area of upper limb reach	Height of protective structure									
	1000	1200	1400	1600	1800	2000	2200	2400	2500	2700
	Horizontal safety distance of the point of the hazard zone which is nearest to the area of upper limb reach									
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	1200	1000	900	800	600	400	0	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

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There is no physical barrier between personnel and the hazard when using non-separating guarding.

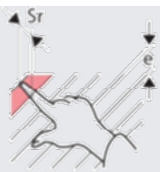
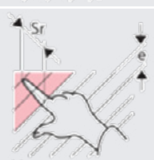
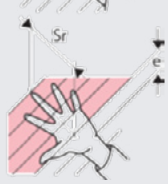
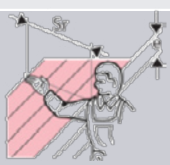
When implementing non-separating guarding as an engineering control, there is no physical barrier between personnel and the hazard. Examples include two-hand controls, light curtains, safety mats, and safety scanners. The required standards that apply to non-separating guarding are:

- **International.** ISO 13855 Safety of Machinery: Positioning of safeguards with respect to the approach speeds of parts of the human body.
- **U.S.** ANSI B11.19 Performance Requirements for Risk Reduction Measures: Safeguarding and other means of reducing risk.

Because there is no physical prevention from reaching the point of operation, the distance at which guards are placed is key. Both standards offer similar distance requirements based on the type of opening on the guard (e.g., slot, square, round) and the size of the opening to calculate the minimum distance at which to place the guard. This minimizes risk of insertion of a finger, hands, or limbs into an opening that will increase the likelihood of contact with the hazard.

Note: The standards are relative to the hazard, not the entire machine.

Figure 3: Abridged ANSI B11.19 distance requirements for non-separating guarding

Body Part	Illustration	Opening (mm) Note 2	Safety distance (mm), Sr		
			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 Note 1	≥ 120	≥ 120
Arm up to junction with shoulder		30 < e ≤ 40	≥ 850	≥ 200	≥ 120
		40 < e ≤ 120	≥ 850	≥ 850	≥ 850

Minimum Distances for Safety Control Measures

When installing non-separating guarding, there are several factors to consider:

- Application does not allow part ejections/flying debris. Otherwise, hard guards should be used.
- Hazards cannot be easily accessed by reaching under, over, around, or through protective device.
- Following safety device interruption, a safe condition is reached by the time personnel reaches the hazardous points. However, devices are too often installed without this consideration, creating a false sense of security.

Stop time analysis is critical when implementing non-separating guarding.

Not every application allows for a non-separating device. As a result, stop time analysis is important to determine whether non-separating guarding is a valid approach. Stop time analysis determines the time to stop a system in a safe condition.

Stop time analysis requires that equipment not allow a full revolution before stoppage and that the stopping time to a safe condition must be consistent. The age of the equipment should also be considered, as the stop time will change based on wear and tear on the machine, or potentially disqualify the machine from non-separating guarding.

To conduct stop time analysis, time measurements should be taken using a stopping performance device calibrated according to the manufacturer's instructions (when applicable). Using a stopwatch is not feasible.

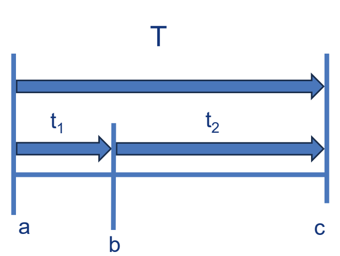
Using the stopping device, trip the safeguard solution and measure how long it takes for the machine to reach a safe condition. This must be done enough times to obtain at least 10 measurements. The highest measured value of the mean plus three standard deviations, whichever is the greater, is considered the stopping time of the machine.

Note: The stop time analysis must be documented according to detailed standards requirements.

Stop time analysis should be conducted at least annually. Depending on the age and type of machine, the analysis may need to occur more frequently.

Figure 4: Minimum safe distances stopping time

ISO 13855



a actuation of safeguard.
b Operation of safeguard (OFF signal generated).
c Termination of hazardous machine function (safe condition).

ANSI B11.19

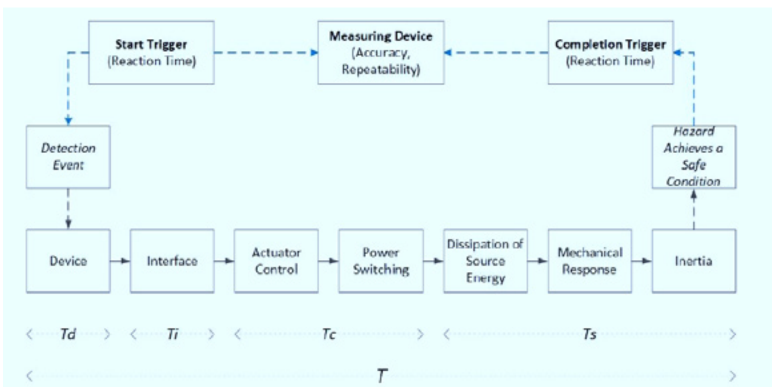


Figure H.1 – Reaction time block diagram

The ISO 13855 formula for calculating the distance from a machine at which non-separating guarding should be placed is:

$S = K * T + C$

where:

- **K** is a parameter in millimeters per second (mm/s) derived from data on approach speeds of the body or parts of the body
- **T** is the overall system stopping performance in seconds (s)
- **C** is the intrusion distance in millimeters (or, how far past the safety device can an individual reach before the device registers that it is being tripped)

The corresponding **ANSI B11.19 formula** is:

$D = K * T + d_{ds}$

where:

K is the maximum speed at which an individual can approach the hazard

T is the total time to achieve a safe condition

d_{ds} is the reaching distance associated with devices (depth penetration factor)

ADDITIONAL INFORMATION

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BIOGRAPHY

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Devin Murray is the tec.nicum Services Manager for Schmersal's engineering services group in North America. He has written many whitepapers related to safety standards and general machine guarding, conducted risk assessments and validations, and developed and reviewed the implementation of corporate safety standards. As a founding member of our tec.nicum team, Devin helped develop a curriculum of machine safety training courses and recently lead our successful efforts to be an IACET Approved Provider. He holds a Bachelor of Science in Electrical Engineering and an MBA from Alfred University and is a TÜV certified Functional Safety Engineer for Machinery.