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ECONOMIC ZONE

Guidelines for Machine Guarding

INTERNAL

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1. Introduction

1.1. Concept of machine guarding



Fig 1

It is crucial to understand why machine and equipment safeguards are to be used on machines. An operator or maintenance worker must be informed as to the location of the safeguards on the machines, and should also be provided with information on why safeguards protect them and what hazards they protect them from. (Figure 1 below illustrates the concept of machine guarding).

1.2. Machine guarding training



Operators or maintenance workers also should be trained on how to remove machine and equipment safeguards from the machines and also to understand in what circumstances guards can be removed. Workers need to be trained to follow the proper procedures if they notice guards are damaged, missing, or inadequate. (Figure 2 below illustrates machine guarding training).

An operator or maintenance worker should be provided with a dress code. For example, no loose-fitting clothing (Figure 3A below) or jewelry (Figure 3B and Figure 3C below). These items could easily be caught in the equipment or machines. From the simplest hand tool to the most complex machinery operational safety hazards exist with any equipment.



Fig 3A



Fig 3B



Fig 3C

The trend of accident statistics in the industry shows that the majority of accidents in manufacturing and service industries are due to machinery whether it is moved by power or operated manually. To safeguard workers operating and maintaining machines, it is necessary to make the machine safe.

2. Scope

This guideline aims to promote the safe use of machines that are used in the industry and are primarily equipped with moving parts. This guideline defines, identifies, and describes methods of safeguarding that may be applied to dangerous parts of machinery and indicates the criteria to be observed in the design, construction, and application of such safeguards.

3. Definitions

- Machinery (Machine) – An assembly of linked parts or components, at least one of which moves, with the appropriate machine actuators, control and power circuits, etc., joined together for a specific application, in particular for the processing, treatment, moving, or packaging of a material. The term machinery also covers an assembly of machines, which, in order to achieve a common function or deliver a product, are arranged and controlled so that they function as an integral whole. This definition of machinery is taken from the European standard EN 292-1: Safety of machinery – Basic concepts, general principles for design.

- Guard – A machinery guard is a barrier (Figure 3.1) or device to prevent employees or their clothing from coming in contact with the dangerous parts of machinery. In the first instant, guards shall be provided by the manufacturers of machines failing which the occupier/employer shall provide necessary safeguards for use in factories.



Fig 4: Robotic safety guard fence

4. Guidelines

4.1. Main types of hazards associated with machines operations

The principal hazards of machines can be classified as either safety or health hazards. Safety hazards can cause immediate injury to workers. See (Table 1) which displays examples of safety hazards associated with working near or on machinery these hazards vary depending on the exact machine used but can include exposure to:



Fig 5

A crushing hazard through being trapped between a moving part of a machine and a fixed structure, such as a wall or any material in a machine.



Fig 6

A shearing hazard that traps part of the body, typically a hand or fingers, between moving and fixed parts of the machine.



Fig 7

A cutting or severing hazard through contact with a cutting edge, such as a band saw or rotating cutting disc.



Fig 8

An entanglement hazard with the machinery which grips loose clothing, hair, or working material, such as emery paper, around revolving exposed parts of the machinery. The smaller the diameter of the revolving part the easier it is to get a wrap or entanglement.



Fig 9

A drawing-in or trapping hazard such as between in-running gear wheels or rollers or between belts and pulley drives.



Fig 10

An impact hazard when a moving part directly strikes a person, such as with the accidental movement of a robot's working arm when maintenance is taking place.



A stabbing or puncture hazard through the ejection of particles from a machine or a sharp operating component like a needle on a sewing machine.

Fig 11



Contact with a friction or abrasion hazard, for example, on grinding wheels or sanding machines; a high-pressure fluid injection (ejection hazard), for example, from a hydraulic system leak.

Fig 12

Table 1: Illustration of safety hazards associated with machine operation

See (Figure13) below for another example of an unguarded machine hazard.



Fig 13: Un-guarded machine hazard and control measure

This guideline primarily focuses on machine guarding (safety hazards) only.

4.2. Safety hazards

Point of operation:

The point of operation (Figure 14 and Figure 14A) is the place where work is performed on the material. This is where the material/stock is cut, shaped, pressed, bored, or formed. Most woodworking machines use a cutting and/or shearing action.



Fig 14: Shows a lathe machine point of operation



Fig 14A: Shows a circular saw machine point of operation

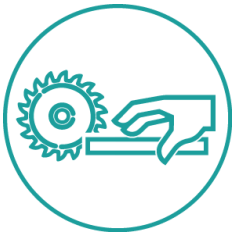
 Fig 15	Employees can be injured if their hands get too close to the blade, particularly when working on small pieces of stock. The size of the piece dictates that the operator's hand be close to the blade. Accidents can occur when stock unexpectedly moves or when a worker's hand slips.	 Fig 15A	Stock can get stuck in a blade and actually pull the operator's hands into the machine.
 Fig 15B	Employees can be injured if the machine or its guard is not properly adjusted or maintained. An improperly adjusted radial saw, for example, might not return to its starting position after making a cut.	 Fig 15C	Contact also can occur during machine repair or cleaning if care is not taken to de-energise the machine - that is, if lockout/tagout procedures are not followed.

Table 2: Lists examples of how injuries can occur at the point of operation

Power transmission:

All mechanical components including gears, cams, shafts, pulleys, and belts transmit energy and motion from the source of power (i.e.belt drives, gear drives, shafts, pulleys, etc).

Rotating and reciprocating movements:



Fig 16: Illustration of reciprocating motion

All machines operate by rotating or reciprocating motion or by a combination of these motions. For example, rotary cutting and shearing mechanisms, rotating wood stock, flywheels, shaft ends, and spindles all rotate. Rotating action is hazardous regardless of the speed, size, or surface finish of the moving part. Rotating parts and shafts, such as stock projecting from the chuck of a lathe, can catch hair or clothing and draw the operator in. This can seriously mangle or crush the operator.

Reciprocating movement is a back-and-forth or up-and-down motion. Operators can be caught and crushed by reciprocating movement when the moving part approaches or crosses a fixed part of the machine.



Fig 17: In-running nip points

In-running nip points: In-running nip points (Figure 17), also known as "pinch points", develop when two parts move together and at least one moves in a rotary or circular motion. In-running nip points occur whenever machine parts move toward each other or when one part moves past a stationary object. Typical nip points include gears, rollers, belt drives, and pulleys. The nip points in this figure are located where the belts or chains approach the pulleys or gears, or where the rotating parts approach the stationary components.

4.3. Risk-reduction hierarchy/controls available to employees from machine hazards

A hierarchical approach is recommended when first approaching the safeguarding of a machine or operation:

Hierarchy of safeguarding controls		
Most effective	Eliminate the hazard or exposure to the hazard.	• Eliminate human interference in the process • Design/redesign the operation to remove exposure (i.e.automatic feeding/ejection) • Locate the hazard where it is not accessible due to its location or distance • Reduce energy • Implement machine control techniques/systems (i.e.monitoring, redundancy, reliability)
	Install fixed guarding.	• Interlocked or fastened barrier guarding to prevent intentional or unintentional exposure, not removable or adjustable by unauthorised persons (i.e. metal or plastic enclosures, fixed screens, adjustable guarding, and self-adjustable guarding).
	Install interlock guards or other appropriate guards.	• Devices that require adjustment and/or actuation by the operator (i.e. presence-sensing devices, gates, two-hand controls, pullback, restraints)
	Use administrative controls and aids to supplement engineering controls.	• Reduce the occurrence of the task • Information (i.e. manuals) and warnings (i.e. signs, lights, alarms, awareness barriers) • Hands-on training (qualification) and safe work practices (i.e. job hazard analyses)
Least effective	Use personal protective equipment.	• Safety eyewear • Face shield

Table 3: Hierarchy of machine safeguarding controls

A more general hierarchy of hazards control is depicted in (Figure 18) below:

Hierarchy of hazards control

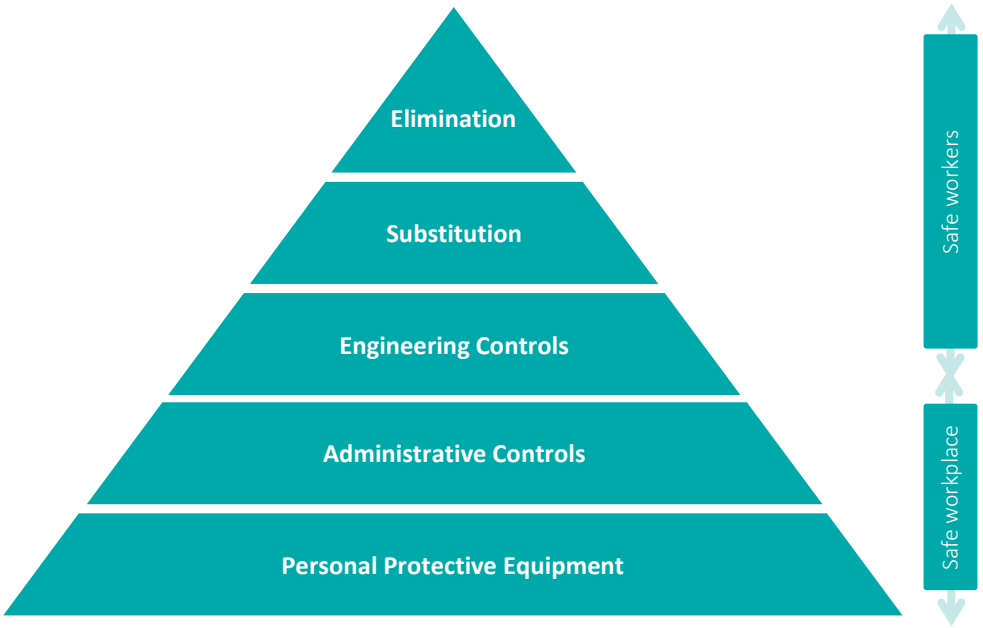


Fig 18: Hierarchy of hazards control

4.4. Main types of guards

Guards are barriers that prevent access to dangerous areas. Guards usually are preferable to other control methods because they are physical barriers that enclose dangerous machine parts and prevent employee contact with them. There are four general types of guards:

Fixed guard

As its name implies, a fixed guard is a permanent part of the machine. It is not dependent upon moving parts to function. It may be constructed of sheet metal, screen, wire cloth, bars, plastic, or any other material that is substantial enough to withstand whatever impact it may receive and to endure prolonged use. This guard is usually preferable to all other types because of its relative simplicity.

Safeguarding action	Advantages	Limitations	Examples
Provides a barrier	• Can be constructed to suit many specific applications • In-plant construction is always possible • Can provide maximum protection • Usually requires minimum maintenance	• May interfere with visibility. • Can be limited to specific operations • Machine adjustment and repair often require its removal, thereby necessitating other means of protection for maintenance personnel	Use on: • In-running rolls • Belts and pulleys (Figure19, 19A and 19B) • Power transmission apparatus • Cutting heads of planers and other automatic-feed equipment (Figure 19C)

Table 4: Outlines of fixed guards



Fig 19



Fig 19A: Fixed guard on rotating shaft/coupling



Fig 19B: Typical guard for tail section of a conveyor



Fig 19C: Planer guard

Interlocked guard

When this type of guard is opened or removed, the tripping mechanism and/or power automatically shuts off or disengages, the moving parts of the machine are stopped, and the machine cannot cycle or be started until the guard is back in place. An interlocked guard may use electrical. mechanical, hydraulic, or pneumatic power or any combination of these. Interlocks should not prevent "inching" by remote control if required. Replacing the guard should not automatically restart the machine. To be effective, all removable guards should be interlocked to prevent occupational hazards.

Safeguarding action	Advantages	Limitations	Examples
Shuts off or disengages power, stops the moving parts, and prevents starting of the machine when the guard is open; should require the machine to be stopped before the worker can reach the danger area.	• Can provide maximum protection • Allows access to the machine for removing jams without the time-consuming removal of fixed guards	• Requires careful adjustment and maintenance • May be easy to disengage or bypass	• Trip guards are presence-sensing and stop the machine when a person gets into a position where they are liable to be injured. Photoelectric curtains, laser scanners, and pressure mats are examples of this type of guard (Figures 20 and 20A). • The CNC machine is fully enclosed and equipped with an automatic

			interlocked guard/door (Figure 20B & 20C)

Table 5: Outlines of interlocked guards



Fig 20



Fig 20A

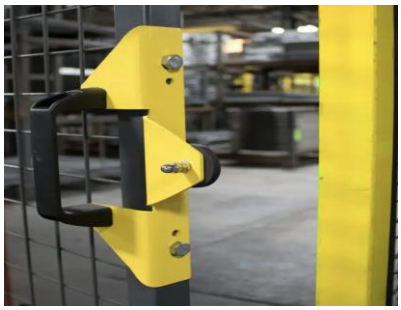


Fig 20B



Fig 20C: Photoelectric light curtain used as trip guard

Adjustable guards:

Guards are useful because they allow flexibility in accommodating various sizes of stock. The barrier moves according to the size of the stock entering point of operation. The guard is in place when the machine is at rest and pushes away when the stock enters the point of operation.

Safeguarding action	Advantages	Limitations	Examples

Provides a barrier that may be adjusted to facilitate a variety of production operations.	• Can be constructed to suit many specific applications • Can be adjusted to admit varying sizes of stock	• Hands may enter dangerous areas - protection may not be complete at all times • May require frequent maintenance and/or adjustment • The guard may be made ineffective by the operator • May interfere with the visibility	Used on woodworking machinery, such as: • Table saws (Figure21) • Routers • Shapers • Band saws (Figure22)

Table 6: Outline of adjustable guards



Fig 21: Table saw



Fig 22: Band saw

Self-adjusting:

The openings of these barriers are determined by the movement of the stock. As the operator moves the stock into the danger area, the guard is pushed away, providing an opening that is only large enough to admit the stock. After the stock is removed, the guard returns to the rest position. This guard protects the operator by placing a barrier between the danger area and the operator. The guards may be constructed of plastic, metal, or other substantial material. Self-adjusting guards offer different degrees of protection.

Safeguarding action	Advantages	Limitations	Examples
Provides a barrier that moves according to the size of the stock entering the danger area.	• Off-the-shelf guards are often commercially available.	• Does not always provide maximum protection. • May interfere with visibility. • May require frequent maintenance and adjustment.	Used on woodworking machinery, such as: • Table saws (Figure 23) • Radial saws • Band saws • Jointers (Figure 24)

Table 7: Outlines of self-adjusting guards

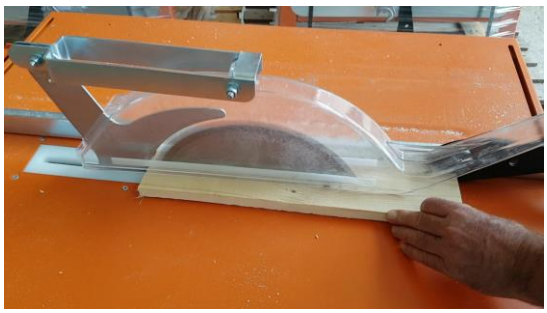


Fig 23: Circular table saw



Fig 24: Band saw

4.5. Other means of safeguarding machines

Additional methods for safeguarding machines include guarding by location or distance, feeding methods, and appropriate placement of controls. None of these methods should replace machine guards, however. It is always important to provide a guard or barrier that prevents access to the danger area. (Table 8) below describes other safeguarding methods.

Method	Safeguarding principle	Examples	Comments
Location/distance	Dangerous parts of machinery are positioned so that they are not accessible to workers during normal operation.	• Does not always provide maximum protection • May interfere with the visibility • May require frequent maintenance and adjustment	Not always feasible, particularly on non-automatic machines. (Figure 25)
Automatic feeding and ejection methods	The operator is not required to place his or her hands in the danger area.	• Power press with an automatic feed • Sanders • Lathes	Malfunctioning can create a hazard. Controls should be set at a distance. (Figure 26)
Prevent accidental startup	Controls shrouded or recessed.	Standard on many machines.	The off switch should be easily accessible, and the operator should be able to operate the machine with ease. (Figure 30-foot paddle guard)
Miscellaneous	The hazardous part of the machine is automatically retracted after the operation is complete.	Counterweight/stroking mechanisms that return the blade to rest after the stock has been cut on the overhead swing and radial saws.	Improperly adjusted counterweights can create a hazard. The blade may travel in the wrong direction or may fail to retract.

Placement of controls	Place controls sufficiently far from the point of operation to prevent reaching into point of operation.	Two hand controls sit at a distance from the point of operation.	The stopping time of the machine is a factor in calculating the distance. (Figures 27 and 27A)

Table 8: Explaining other safeguarding methods

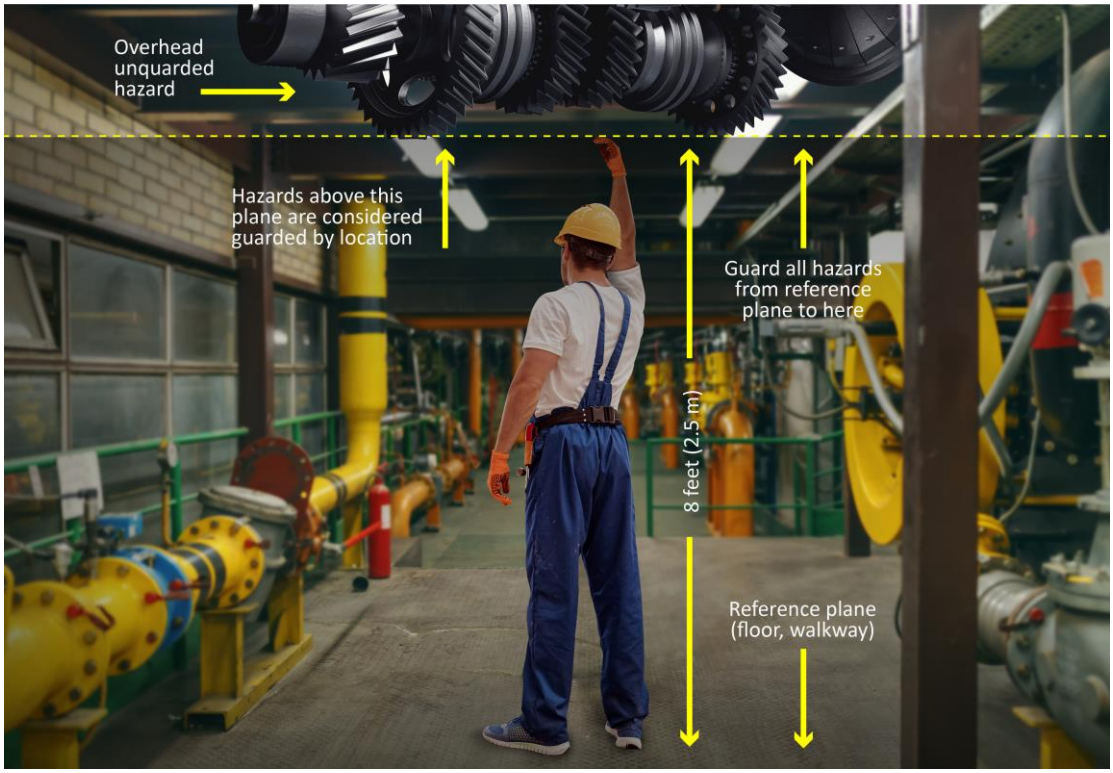


Fig 25: Safeguarding by location and distance



Fig 26: Power press with an automatic feed



Fig 27



Fig 27A

A typical example of a lathe machine with a plastic cover for avoiding flying chips

Severe injuries and death can occur primarily from being caught in or struck by rotating parts. An operator can be pulled into the lathe from working perilously close (i.e. polishing a slotted shaft with emery cloth) and/or wearing gloves, loose clothing, hair, jewelry, etc. Projected parts or materials such as chuck keys or unsecured workpieces can also strike nearby operators. Flying chips and coolant also present hazards to the operator. (Figure 28)

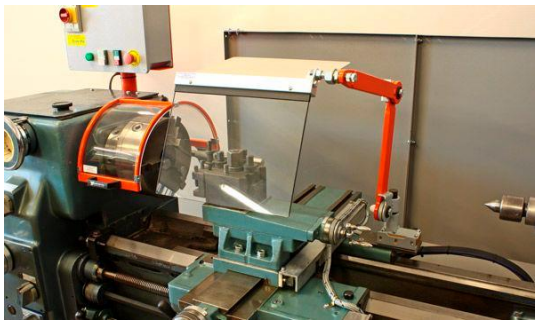


Fig 28: Lathe machine protection with plastic cover to avoid flying chips



Fig 29: Grinding machine protection with plastic or metal cover to avoid flying chips

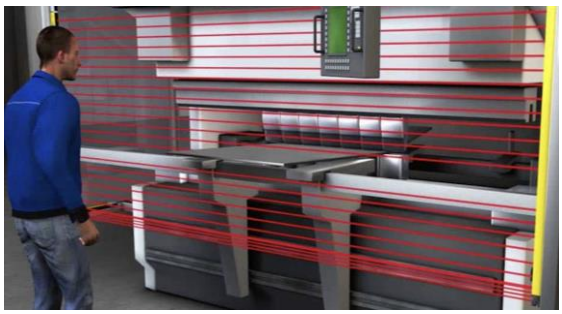


Fig 30: Power press equipped with a safety light curtain, fixed enclosure guard, two-hand activation control, and an emergency stop and shrouded foot paddle



Fig 31: Press brake installed with a laser sensing system that has transmitter and receiver mounted below the RAM to cut off the power supply to prevent hand and finger injuries

4.6. Safeguarding devices

Safeguarding devices (Figure 32) are controls or attachments that, when properly designed, applied, and used, usually prevent inadvertent access by employees to hazardous machine areas by:



Fig 32: Illustration of safeguarding devices

- Preventing hazardous machine component operation if your hand or body part is inadvertently placed in the danger area
- Restraining or withdrawing your hands from the danger area during machine operation
- Requiring the use of both of your hands-on machine controls (or the use of one hand if the control is mounted at a safe distance from the danger area) that are mounted at a predetermined safety distance; or
- Providing a barrier that is synchronised with the operating cycle in order to prevent entry to the danger area during the hazardous part of the cycle

These types of engineering controls, which either prevent the start of or stop hazardous motion, may be used in place of guards or as supplemental control measures when guards alone do not adequately enclose the hazard. In order for these safeguarding devices to accomplish this requirement, they must be properly designed and installed at a predetermined safe distance from the machine's danger area. Other safeguarding devices (probe detection and safety edge devices) that merely detect, instead of prevent, inadvertent access to a hazard are not considered primary safeguards. (Table 9 and Figures 33 through 38 for the types of safeguarding devices)

Type	Method of safeguarding	Advantages	Limitations
Pullback devices (Figure 33)	Cords connected to the operator's wrists and linked mechanically to the machine automatically withdraw the hands from the point of operation during the machine cycle.	• Allows the hands to enter the point of operation for feeding and removal • Provides protection even in the event of mechanical repeat	• Close supervision ensures proper use and adjustment. Must be inspected prior to each operator change or machine setup • Limits operator's movement and may obstruct their workspace • The operator may easily make the device ineffective by not adjusting the device properly
Restraint devices (Figure 34)	Wrists are connected by cords and secured to a fixed anchor point which limits the operator's hands from reaching the point of operation at any time.	• Simple, few moving parts; requires little maintenance • The operator cannot reach the danger area • Little risk of mechanical failure; provides protection even in the event of mechanical repeat	• Close supervision is required to ensure proper use and adjustment. Must be inspected prior to each operator change or machine setup • The operator must use hand tools to enter the point of operation • Limits the movement of the operator; may obstruct

			workspace around the operator • The operator may easily make the device ineffective by disconnecting the device
Presence-sensing devices (Figure 35)	Interlock into the machine's control system to stop operation when the sensing field (photoelectric, radio frequency, or electromagnetic) is disturbed.	• Adjusts to fit different stock sizes • Allows access to load and unload the machine • Allows access to the guarded area for maintenance and setup activities	• Restricted to machines that stop the operating cycle before the operator can reach the danger area (i.e. machines with partial revolution clutches or hydraulic machines) • Must be carefully maintained and adjusted • Does not protect the operator in the event of a mechanical failure • The operator may make the device ineffective
Presence-sensing mats (Figure 36)	Interlock into the machine's control system to stop operation when a predetermined weight is applied to the mat. A manual reset switch must be located outside the protected zone.	• Full visibility and access to the work area • Install as a perimeter guard or over an entire area • Configure for many applications	• Restricted to machines that stop the operating cycle before the operator can reach the danger area (i.e. machines with part revolution clutches or hydraulic machines) • Some chemicals can degrade the mats • Does not protect the operator during mechanical failures
Two-hand control (Figure 37)	Requires concurrent and continued use of both hands, preventing them from entering the danger area.	• The operator's hands are at a predetermined safety distance • The operator's hands are free to pick up new parts after the completion of the first part of the cycle	• Requires a partial cycle machine with a brake and anti-repeat feature • Operators may make devices without anti-tiedown ineffective • Protects the operator only
Safety trip controls (Figure 38)	Stops machine when tripped	• Simplicity of use	• Easy to defeat the body bar by going under it into the danger zone • May be difficult to activate controls because of their location • Only protects the operator

Table 9: Types of safeguarding device



Fig 33: Pullback device



Fig 34: Restraint devices



Fig 35: Presence-sensing devices



Fig 36: Presence-sensing mats

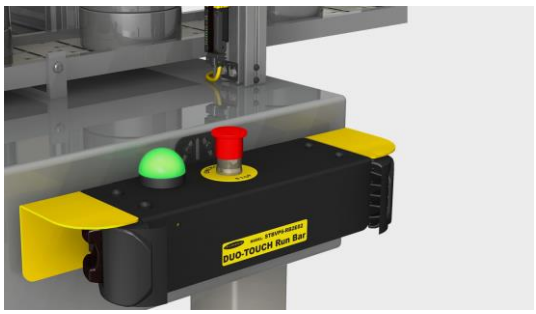


Fig 37: Two-hand control



Fig 38: Safety trip control

4.7. Industrial robots and robotic systems

The use of robots and robotic systems in manufacturing has become mainstream in large manufacturing operations such as the automotive industry, and their use in small manufacturing plants and niche operations will increase. Unauthorised entry into the working envelope of a robot exposes a worker to the potential for serious impact or crushing injuries from the unexpected movement of the robot. The safeguarding of robots requires a systems approach to safeguarding. It typically uses a combination of fixed barrier fences, interlocked gates, and presence-sensing devices such as safety mats and light curtain devices.



Fig 39: Shows a typical robot work cell safeguarding system

4.8 Procedural and administrative controls are needed to protect employees.



Keep safeguard affixed and secured to the machine before operating. Only operate the machine with guards in place. Use alternative guarding methods if needed. Do not operate the machine if guards are damaged, missing, or provide inadequate protection.



Workers should not be allowed to operate a piece of equipment if the guard or any other safety device, return device, spreader, anti-kickback fingers apparatus, guard on in-running rolls, or gauge or rip fence is not functioning properly.



Guards should always be designed and installed by technically competent and qualified persons. In addition, it is always a good idea to have the equipment manufacturer review proposed guard designs to ensure that the guard will adequately protect employees and allow the safe operation of the equipment.



Train workers on machine use and allow only trained and authorised workers to operate and maintain the equipment. Training should include hazards associated with the machine, how the safeguards protect the worker from these hazards, under what circumstances the guard may be removed (usually just for maintenance), and what to do if the guard is damaged or not functioning properly.



Frequently inspect equipment and guards. Inspect the machine to ensure that the operator and machine are equipped with the safety accessories suitable for the hazards of the job and that the machine and safety equipment are in proper working condition.



Lockout/Tagout the machine when guards need to be removed for maintenance, adjusting, or cleaning.



Provide employees with push sticks or other hand tools so that their hands are away from the point of operation when they work on small pieces of stock. Using push sticks keeps stock from tipping and prevents the operator's fingers from coming in contact with blades.



Regularly clean and maintain machines and guards, and ensure that guards are in good condition. Lubricate the machine with the guard on. If removal of the guard is needed, shut down, lock out, and keep a safe distance away.

	Never leave a machine unattended in the “ON” position. The workers shall never leave the work area while machine parts are moving or leave a machine that has been turned off but is still coasting.
	Maintain proper housekeeping and lighting. Workers have been injured by tripping and then falling onto the blades of saws. You must keep floors and aisles in good repair and free from debris, dust, protruding nails, unevenness, or other tripping hazards. Make sure you have a non-slip floor. Ensure adequate lighting on machines and around machines.
	Do not allow workers to wear loose clothing, jewelry, gloves, or long hair. Loose clothing long hair, jewellery, and gloves can be easily caught up (entanglement hazards) in rotating parts therefore should kept away from machinery.
	The preferred way to control hazards is through engineering or work practice controls. When these controls are not possible or do not provide adequate protection, personal protective equipment (PPE) must be provided as a supplement.

Table 10: Machine safeguarding controls