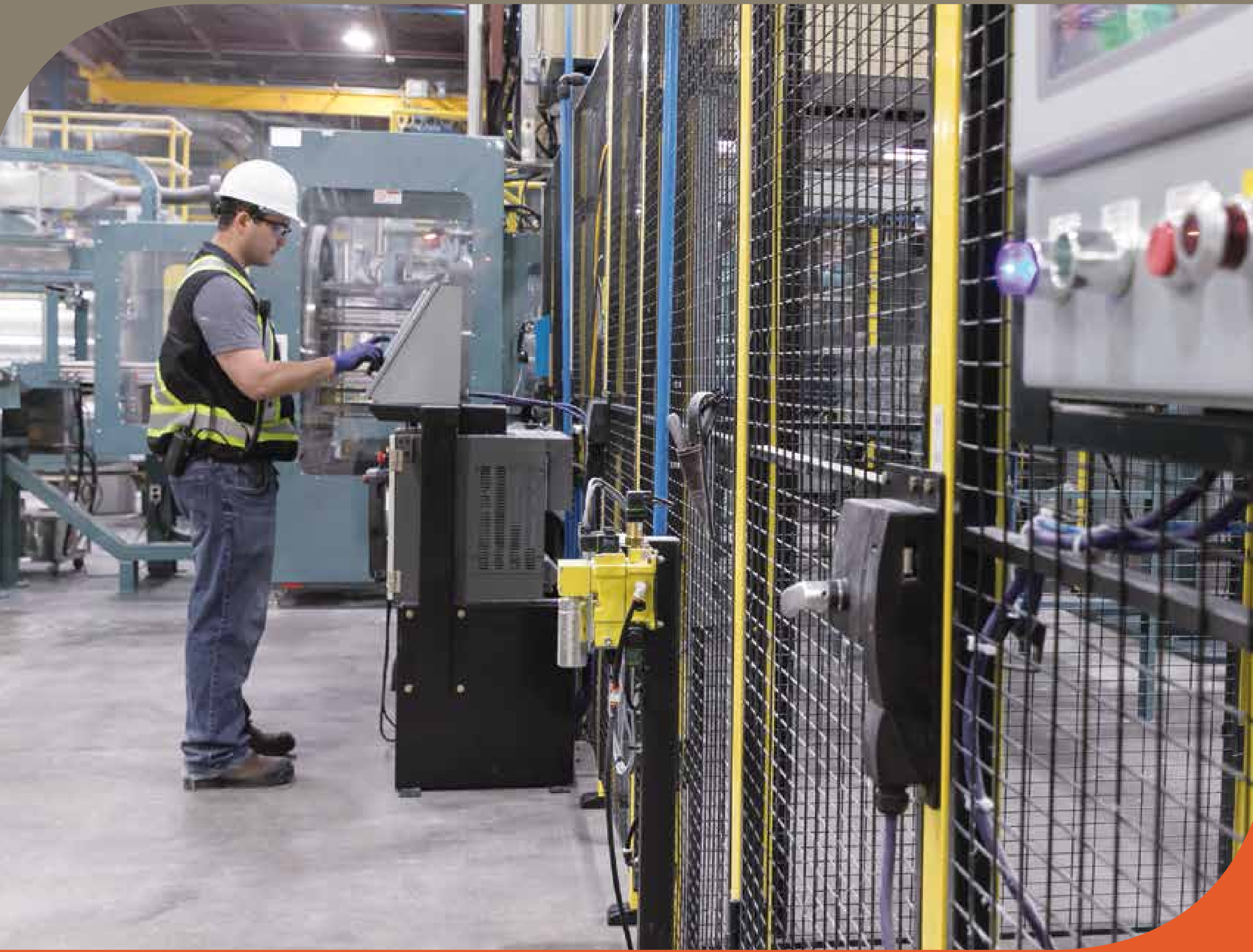
Safeguarding Machinery and Equipment



About WorkSafeBC

At WorkSafeBC, we're dedicated to promoting safe and healthy workplaces across B.C. We partner with workers and employers to save lives and prevent injury, disease, and disability. When work-related injuries or diseases occur, we provide compensation and support injured workers in their recovery, rehabilitation, and safe return to work. We also provide no-fault insurance and work diligently to sustain our workers' compensation system for today and future generations. We're honoured to serve the workers and employers in our province.

Prevention Information Line

We provide information and assistance with health and safety issues in the workplace.

Call the information line 24 hours a day, 7 days a week to report unsafe working conditions, a serious incident, or a major chemical release. Your call can be made anonymously. We can provide assistance in almost any language.

If you have questions about workplace health and safety or the Occupational Health and Safety Regulation, call during our office hours (8:05 a.m. to 4:30 p.m.) to speak to a WorkSafeBC officer.

If you're in the Lower Mainland, call 604.276.3100. Elsewhere in Canada, call toll-free at 1.888.621.7233 (621.SAFE).

Safeguarding Machinery and Equipment

Health and safety resources

You can find our health and safety resources on worksafebc.com, and many of them can be ordered from the WorkSafeBC Store at worksafebcstore.com.

In addition to books, you'll find other types of resources at the WorkSafeBC Store, including DVDs, posters, and brochures. If you have any questions about placing an order online, please contact a customer service representative at 604.232.9704, or toll-free at 1.866.319.9704.

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- Schnitzer Steel
- UBSafe Inc.

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Contents

Why is safeguarding important?

Unguarded or inadequately safeguarded machinery and equipment are hazards in any workplace that uses powered equipment. Every year, physical contact with machines and powered equipment causes a significant number of injuries, including amputations, and may also result in workplace fatalities. Most of these incidents can be prevented by effective safeguarding and lockout procedures.

It is impossible to predict what people will do around powered machinery, no matter what their level of experience or training. Effective safeguarding protects against human error, lapses in attention, inadvertent contact with moving parts, and control system disorder.

Note: In addition to safeguarding, training and supervision are essential to ensure worker safety around machinery. Training and other responsibilities of employers, workers, and supervisors are described in sections 21–23 of the *Workers Compensation Act*.

Incident examples

Incidents related to a lack of safeguarding can result in life-altering injuries, such as amputations, or even death. The following three incidents resulted from unguarded or inadequately safeguarded machinery or equipment:

- While adjusting a conveyor belt, a millwright was drawn into the unguarded tail drive of a belt conveyor and suffered fatal crushing injuries.
- A young worker feeding sheet rubber into a guillotine shear lost both hands when the machine cycled unexpectedly.
- A lumber piler cleaning up around a lumber sorting table (green chain) was strangled when loose clothing got caught on an exposed keyway at the end of a slowly rotating shaft.

Who should read this manual?

This manual is mainly for employers, although it contains information that may be useful for anyone who owns, operates, maintains, or sells powered machinery and equipment.

Employers — If you're an employer, you will find information to help you comply with the Occupational Health and Safety Regulation and Part 2 of the Act, so you can create a safe work environment for your employees.

Supervisors — If you're a supervisor, you will find information to help you assess risks to workers from harmful contact with machinery and equipment. This manual will also help you develop safeguarding solutions that satisfy the competing needs of safety, production, and quality assurance.

Workers — If you're a worker, this manual will help increase your awareness of the hazards associated with equipment operation and maintenance, and of your rights to safeguarding protection in the workplace. **Note:** In the Regulation, the word *worker* includes supervisors, managers, and other workers.

Suppliers — If you're a supplier, this manual will help you understand what you must do to provide machinery and equipment that conforms to the Act and the Regulation. This manual will also provide a quick reference to different options on how to do this.

This manual can also be used by joint health and safety committees, safety professionals, and workers involved in risk assessment, maintenance, and operations management.

Using this manual

> The information provided in this manual is for general application and is not intended to replace the contents of the Act, the Regulation, or applicable standards.

This manual provides general information that employers can use to develop safeguarding solutions for their specific machinery and equipment. It is not a complete how-to guide to safeguarding. You should evaluate each safeguarding situation on its own merits and apply the general principles described in this manual. This manual does not provide blueprint solutions or replace the need for you to consult the relevant standards and manufacturers' recommendations when faced with technically complex safeguarding problems.

Must versus *should*

In this manual, the word *must* indicates a specific requirement from the Regulation or a referenced standard. The word *should* indicates that a particular course of action will improve safety in the workplace even though it is not specified in the Regulation.

Where to find safeguarding requirements and standards

Part 12 of the Regulation specifies requirements for safeguarding machinery and equipment. Part 12 also refers to Canadian Standards Association (CSA Group) standard *Z432 Safeguarding of machinery.* Please note that the general safeguarding requirements in Part 12 always apply, even if there is also a specific code or standard covering a particular device. There are corresponding OHS Guidelines for Part 12 that will provide you with further information to help interpret and apply the regulatory requirements.

You will also find other safeguarding requirements in the Regulation in Part 4, General Conditions, and Part 27, Wood Products Manufacturing. There are also some requirements for safeguarding specific machines described in Part 19, Electrical Safety; Part 23, Oil and Gas; and Part 28, Agriculture.

Various standards organizations in North America, Europe, and elsewhere have produced written standards for almost all types of powered machinery. These publications are useful for determining how to safeguard specific types of equipment not mentioned in the Regulation. The WorkSafeBC library can help you access these publications. For a list of standards referred to in the Regulation, see Appendix 2.

> **Web resources**
>
> For more information on safeguarding, go to worksafebc.com and search for "safeguarding."

Terminology

Safeguarding versus de-energization and lockout

It is important to distinguish between safeguarding and de-energization and lockout.

Safeguarding is the first line of defence in ensuring the safety of workers operating powered machinery and equipment. Safeguarding protects workers when machinery or equipment is in operation. For more information, see Part 12 of the Regulation.

De-energization and lockout protects workers when machinery or equipment is shut down for maintenance, repair, or clearing jams. The machinery or equipment must be de-energized and locked out if it poses a risk of injury and is not effectively safeguarded. For more information, see Part 10 of the Regulation and the WorkSafeBC publication ***Lockout***.

Safeguard and guard

The terms *safeguard* and *guard* tend to be used interchangeably, but they have precise meanings in the language of machinery and equipment safety.

Safeguard is the umbrella term for a number of control measures that provide workers with effective protection from harmful contact with hazardous moving parts or other unsafe conditions. Safeguards include guards, safety devices, shields, awareness barriers, warning signs, safe work procedures, and personal protective equipment (PPE), used on their own or in combination.

Guard refers to a specific type of safeguard. Guards are physical barriers or covers designed, constructed, and installed over moving parts to prevent any contact with them. Guards are the simple solution for protecting workers when access to moving parts, such as belts and drive chains, is not required during operation. They are reliable, cost-effective, and low maintenance when properly designed and installed.

Safeguarding devices

Safeguarding devices include a number of alternatives to guards, such as interlocks, two-hand controls, and electronic presence-sensing devices, such as light curtains and pressure-sensitive mats. These solutions are more technical than a guard but may be the only solution when access to hazardous areas is required during normal operations, such as when feeding materials into a machine for processing and a guard would interfere with this task.

Part 3 of this manual provides detailed information on the characteristics, advantages, limitations, and selection of guards and safeguarding devices.

Part 1: Identifying hazards

Mechanical hazards

Some moving machinery and equipment parts can present multiple hazards. For example, an abrasive wheel can explode and cause serious impact injuries. It can also cause minor abrasions if a worker's hand accidentally rubs against it.

The Regulation defines a *hazard* as "a thing or condition that may expose a person to a risk of injury or occupational disease."

A good way to recognize mechanical hazards is to observe how the moving parts of a machine operate and how a worker's body parts could come into harmful contact with them. Machine parts can move in a number of ways:

- Single rotating parts, such as shafts or couplings, present a risk of snagging or entanglement. Two or more parts rotating together, such as feed rolls and V-belt and pulley drives, create nip points (see figures 1.1 and 1.2).
- Parts that slide or reciprocate, such as dies in punch presses, create shearing or crushing hazards (see figure 1.4).
- Parts that can rupture or fragment, such as an abrasive wheel, may cause impact injuries (see figure 1.5).

Figures 1.1 to 1.5 illustrate some common mechanical hazards where hands, limbs, hair, clothing, and sometimes the entire body can be injured from harmful contact with unguarded moving machine parts.

Principal mechanical components of machinery

Most machines have three principal components:

- A power source (often an electrical motor)
- A power train that transfers kinetic energy (for example, washing machines or lawn mowers)
- Tooling (for example, the cutting or machining part of a lathe, planer, or drill)

The types of machine components and drives shown in figures 1.1 to 1.5 are common in most industrial operations. They are involved in many of the serious injuries that occur in industrial workplaces.

Hazards from these components generally involve the following:

- **Power transmission parts** — These are the moving parts of the power train. They usually consist of belts, pulleys, chains, sprockets, gears, shafts, and couplings. Many of the moving parts illustrated in figures 1.1 and 1.2 are power transmission parts.
- **Point of operation** — This is the hazardous area in a machine where a part is being formed or work is being done. The term *feed point* is sometimes used to describe the working area of the machine.
- **Ejected material** — This is any material ejected by the work process that could be hazardous.

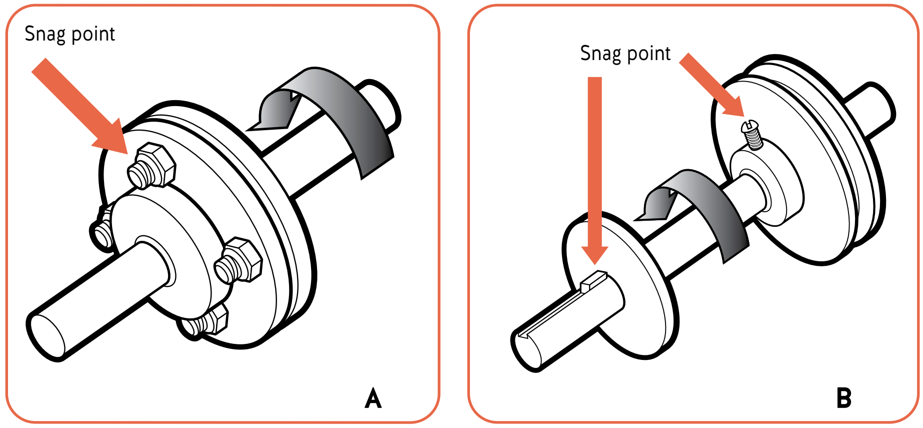

Figure 1.1. Single rotating parts presenting a snagging or entanglement hazard. (A) Snagging hazard from projecting flange bolts on rotating coupling. (B) Snagging hazard from projecting keyway and set screw on rotating shaft.

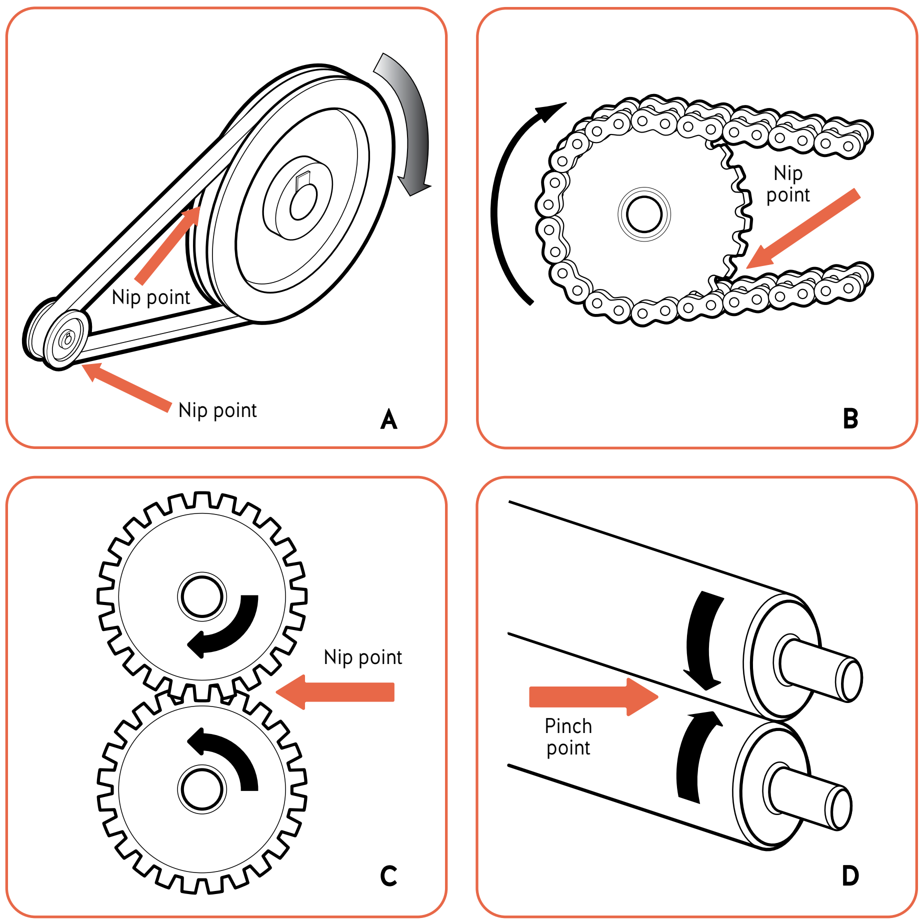

Figure 1.2. Multiple rotating parts presenting an in-running nip point hazard. (A) V-belt and pulley drive: a common source of in-running nip points on powered industrial machinery. (B) Typical chain-sprocket drive. (C) Typical exposed gears. (D) Typical feed rolls.

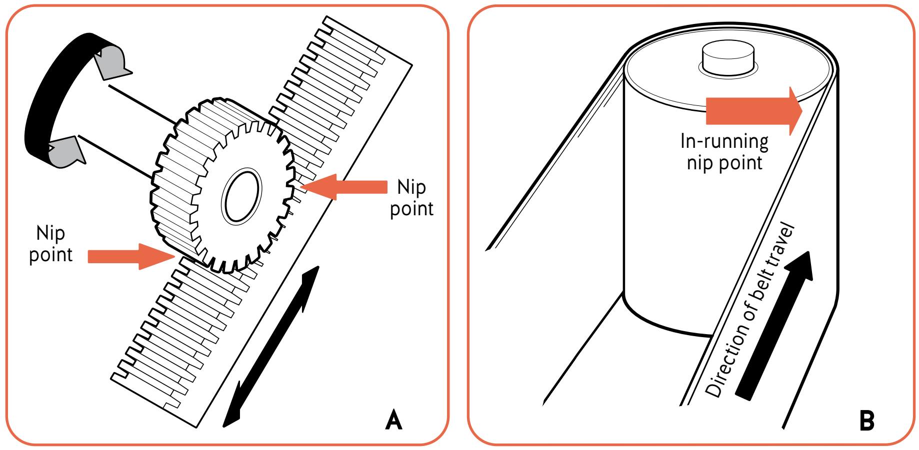

Figure 1.3. Combination of rotating and sliding parts and reversing parts, creating two in-running nip point hazards. (A) Rack and pinion gears. (B) Conveyor belt spool.

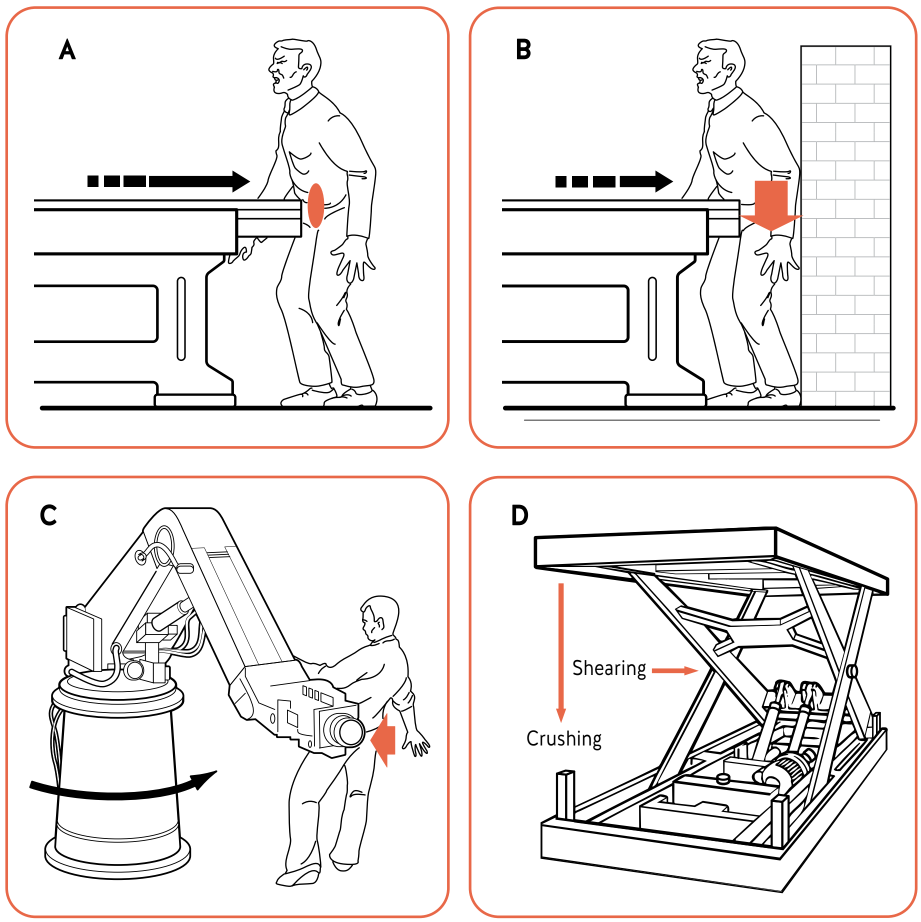

Figure 1.4. Sliding and pivoting movements creating “struck by” or crushing hazards. (A) Sliding milling table striking worker in abdomen. (B) Sliding milling table crushing worker against adjacent wall. (C) Robot arm striking worker. (D) Scissor lift creating crushing or shearing hazards.

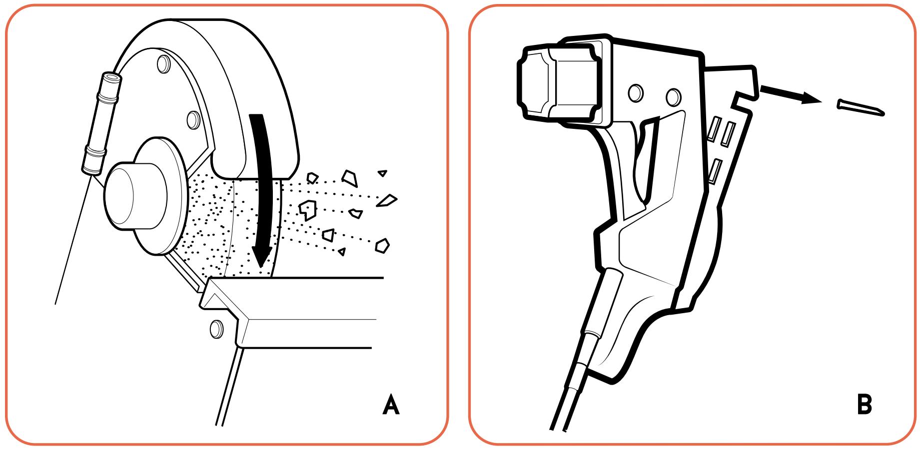

Figure 1.5. Hazards from fragments and projectiles. (A) Fragments from exploding abrasive wheel. (B) Projectile from pneumatic nail gun.

Non-mechanical hazards

Workers operating and maintaining machinery can suffer illnesses or injuries that result from hazards that don't fall under the category of mechanical hazards.

Occupational disease and injury hazards

Workers can be exposed to occupational disease hazards in a variety of ways, such as inhalation, ingestion, injection, or absorption through skin. Without adequate safeguards, PPE, and other control measures, a worker may be at risk of occupational diseases or injuries resulting from exposure to the following:

- Toxic or corrosive chemicals that can irritate, burn, or pass through the skin
- Harmful airborne substances that can be inhaled, such as gases, oil mists, metal fumes, solvents, and dusts
- Heat, noise, and vibration
- Ionizing radiation, such as X-rays and gamma rays
- Non-ionizing radiation, such as
  - Ultraviolet light (e.g., welding arcs and ultraviolet lasers)
  - Radio frequency energy and microwave radiation (e.g., cellphones)
  - Extremely low frequency radiation (e.g., high-voltage power lines)
- Biological contamination and waste
- Soft-tissue injuries resulting from repetitive motion, awkward posture, extended lifting, or pressure grips

Other hazards

Other hazards include the following:

- Slips and falls around machinery during maintenance
- Unstable equipment that is not secured against falling over or shifting unexpectedly
- Fire or explosion related to flammable or combustible materials, such as combustible dust
- Being struck by ejected materials, such as chips or swarf
- Pressure-injection injuries from the release of fluids and gases under high pressure
- Electric shocks from faulty or ungrounded electrical components

- Static electricity caused by non-conductive material moving across conveyor belt rollers
- Residual energy in capacitors because of impedance (a transmission power line)
- Burns or scalds from flames or hot objects or materials
- Vibration transmitted to the body, particularly the hands and arms
- Exposure to lasers, particularly eye exposure

Safeguarding against non-mechanical hazards

As well as being safeguarded from mechanical hazards, machines must be safeguarded to protect workers from non-mechanical hazards. Sometimes a safeguard used to eliminate or minimize a mechanical hazard can be modified to also eliminate or minimize a non-mechanical hazard, although this may require the approval of the manufacturer or a professional engineer. Examples include the following:

- A guard modified to prevent access to moving parts may also absorb noise.
- Welding curtains designed to shield against arc flash can also protect passersby against spatter and burns.
- A chuck guard and shield added to a lathe can help protect workers against projecting dogs and flying chips.
- Local exhaust ventilation systems attached to concrete grinders can reduce exposure to silica dust.

Resources

For more information on some of the non-mechanical hazards mentioned in this section, see the following resources, available at worksafebc.com:

- *Combustible Dust Explosion or Fire Outside of Primary Wood Processing*
- *Combustible Wood Dust Explosions* (video)
- *Combustible Wood Dust Management Program Development Guide*
- *Combustible Wood Dust Mitigation and Control Checklist*
- *Health Effects of Non-Ionizing Electromagnetic Radiation in the Workplace*
- *Preventing Musculoskeletal Injury (MSI): A Guide for Employers and Joint Committees*
- *Preventing Slips and Trips in Woodworking*
- *Sound Advice: A Guide to Hearing Loss Prevention Programs*
- *Supervision in Manufacturing: Slips and Falls* (video)
- *Supervision in Manufacturing: Guards and Lockout* (video)
- *Understanding the Risks of Musculoskeletal Injury (MSI): An Educational Guide for Workers on Sprains, Strains, and Other MSIs*
- *WHMIS 2015: An Overview*
- *Working Safely Around Electricity*

Types of hazardous energy

Electrical energy

Capacitors, motors, and generators are sources of electrical energy. Low-voltage and high-voltage equipment and conductors can injure or kill workers. Examples include machine power cords, motors, and capacitors.

Kinetic energy

Kinetic energy is the energy of moving equipment or materials. For example, a saw blade can rotate even after the electricity is turned off.

Potential energy

Potential energy is the energy stored in an item under tension. For instance, a spring that is compressed has stored energy that will be released in the form of movement when the spring expands.

Hydraulic energy

Hydraulic energy is the energy stored within a pressurized liquid. When under pressure, the fluid can be used to move heavy objects, machinery, or equipment. Examples include automotive lifts, injection-moulding machines, power presses, and brake systems in cars.

Pneumatic energy

Pneumatic energy is the energy stored within pressurized air. Like hydraulic energy, air under pressure can be used to move heavy objects and power equipment. Examples include spraying devices and power washers.

Chemical energy

Chemical energy is the energy released when a substance undergoes a chemical reaction. The energy is normally released as heat, but could be released in other forms, such as pressure.

A common result of a hazardous chemical reaction is fire or explosion. For example, fertilizer stored near diesel fuel is a potential source of explosion.

Thermal energy

Thermal energy is the energy in heat, which is found in steam, hot water, fire, gases, and liquefied gases. For example, a steam pipe that supplies heat or carries steam under pressure to drive a turbine has hazardous thermal energy and may take time to cool down.

Radiation

Radiation is energy from electromagnetic sources. This includes all laser, microwave, infrared, ultraviolet, and X-ray radiation. Radiation can cause negative health effects, such as skin and eye damage (from non-ionizing sources, such as lasers and UV light) or cancer (from ionizing sources, such as X-rays).

Part 2: Assessing risks

What does risk mean?

The Regulation defines *risk* as “a chance of injury or occupational disease.” CSA Group standard *Z432 - Safeguarding of machinery* identifies the three most important risk factors as severity, exposure, and avoidance (or possibility):

1. Severity — If an accident occurred, how serious would the injury be?
2. Exposure — What is the extent of workers’ exposure to the hazard?
3. Avoidance (possibility) — How likely is it that an accident will occur?

The combination of these three factors determines the level of risk. See the risk assessment tables on pages 69–82.

The safeguarding controls you implement have to match the risk levels you have identified in your risk assessment.

Risk assessments

To assess the risks of machinery and related equipment, you need to understand how the hazards of a machine can injure workers. Part 1 of this manual, which deals with hazard identification, provides some of this information.

Employers should ensure that risk assessments involve representatives from across the organization (e.g., operators, supervisors, and maintenance personnel). It's also a good idea to consult with manufacturers, safeguarding suppliers, and safety professionals. Each group sees the machine from a different perspective and can potentially provide valuable contributions.

Gathering the information necessary for a good risk assessment may require repeat observations, especially when determining what workers do when normal production flow is interrupted. The length of time that a piece of equipment is in service without causing an injury has no bearing on whether or not it is safe.

There are a number of machinery risk assessment models. Some are highly technical (quantitative risk assessments), while others are more observation-based (qualitative risk assessments). For a series of tables you can use to help guide your risk assessments, see Appendix 3.

Baseline assessments

You must conduct baseline assessments to determine if your machinery, equipment, and processes meet legal requirements. To meet legal requirements, employers must ensure the following:

- There is a review of the appropriate regulations and, where applicable, appropriate standards.
- Safeguarding meets the general requirements and machine-specific requirements that are specified in the Regulation and required standards.
- When putting a new piece of equipment into service, a risk assessment is performed and all required safeguards are in place and functioning before the equipment is used. See "Buying and setting up machinery," pages 60–61.
- Supervisors are trained to identify hazards and are involved in performing risk assessments.
- Workers are trained to recognize hazards and are included in risk assessments.

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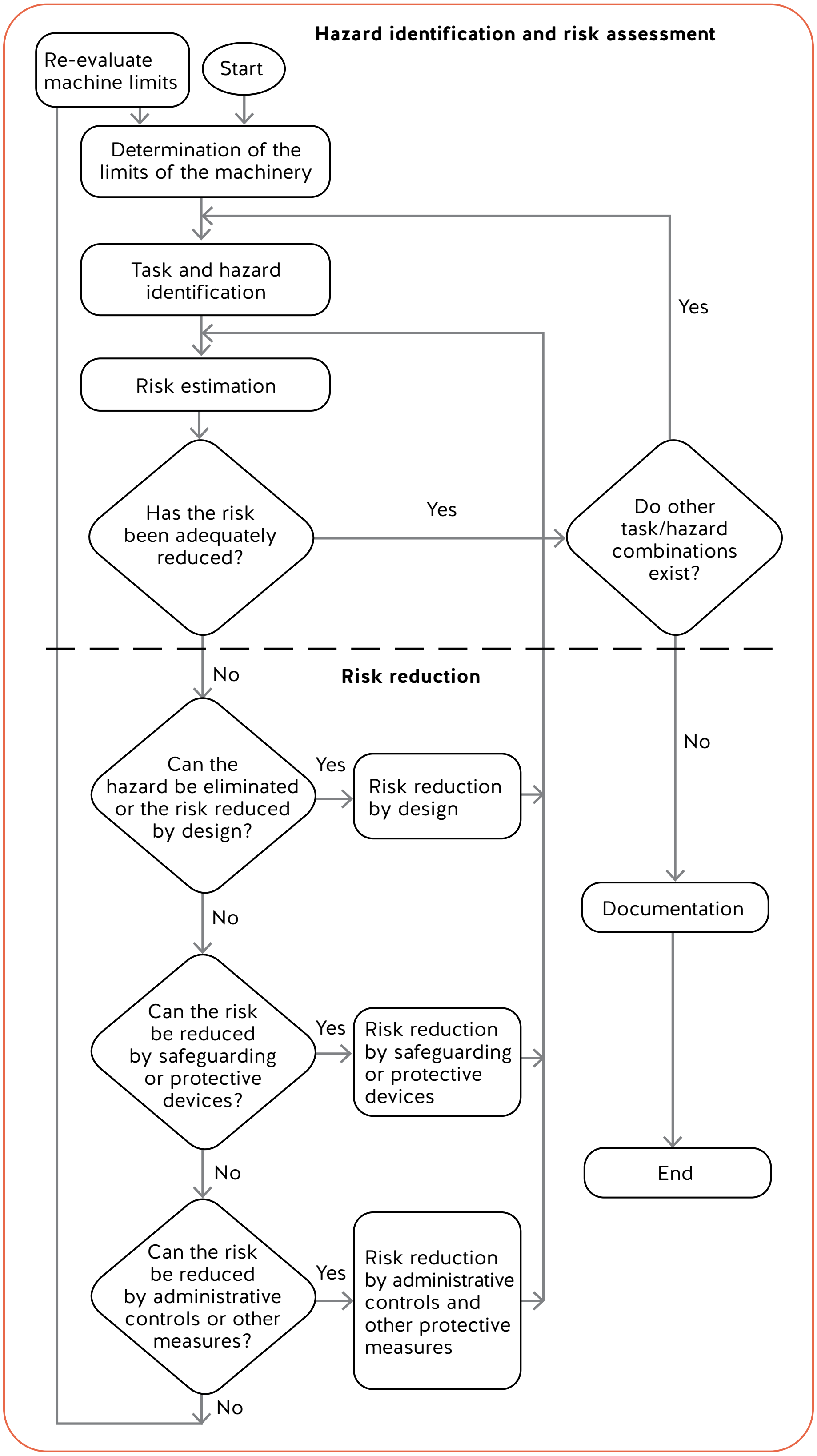
Risk assessment process



Note: This risk assessment process is adapted from CSA Group standard *Z432-04 - Safeguarding of machinery.*

Part 3: Controlling hazards (selecting and designing safeguards)

Hierarchy of controls

A safeguard is a solution or a combination of solutions that eliminates or reduces the risk of injury. Safeguards range from guards and safeguarding devices to safe work procedures and personal protective equipment (PPE).

PPE is the last line of defence and is generally used in conjunction with other controls.

Some types of safeguarding control measures are more effective than others, although it may not always be practicable to use the most effective solution. Follow the hierarchy of controls when selecting control measures:

1. Elimination
2. Substitution
3. Engineering controls
4. Awareness controls
5. Administrative controls
6. PPE

The purpose of the hierarchy of controls is to identify the most effective control or combination of controls that will eliminate or minimize the risk. When choosing controls, make sure they don't introduce any new hazards.

Hierarchy of controls from most effective to least effective

Most effective → Least effective	Control	Examples
Most effective	1. **Elimination**	• Eliminate human interaction from the process • Eliminate pinch points • Automate material handling
	2. **Substitution**	• Replace a hazardous product, process, or piece of equipment with one that is less hazardous
	3. **Engineering controls**	• Mechanical hard stops • Guards • Interlocked guards • Presence-sensing devices • Two-hand controls
	4. **Awareness controls**	• Warning signs and labels • Lights, beacons, and strobes • Computer warnings • "Restricted Space" painted on floor • Beepers • Horns and sirens
	5. **Administrative controls**	• Safe work procedures • Equipment inspections • Training • Lockout
Least effective	6. **Personal protective equipment (PPE)**	• Safety eyewear and face shields • Hearing protection • Gloves • Respirators

1. Elimination

Whenever possible, eliminate the hazard entirely so there is no risk to workers. For example, automating a process eliminates the hazard by removing the worker from the equation.

2. Substitution

If it's not practicable to eliminate a hazard, consider substitution. Substitution means replacing a hazardous product, process, or piece of equipment with a viable alternative that is less hazardous.

3. Engineering controls

Engineering controls are physical changes to the work environment, equipment, or materials that help minimize worker exposure to a hazard. Engineering controls don't eliminate hazards, but they do work by separating workers from the hazards. For example, a physical barrier such as a guard can be used to keep workers away from a hazard.

Guards

Properly designed and installed guards provide the most effective protection to workers when elimination or substitution are impracticable options and frequent access is not required. A common requirement of all guards is that they prevent a worker from reaching around, over, under, or through the guard to the hazardous area. For more information, see "Guards," pages 27–34, and refer to CSA Group standard *Z432-16 - Safeguarding of machinery.*

Other safeguarding devices

Other safeguarding devices eliminate or reduce risk by themselves or in combination with a guard. The goal of safeguarding devices is to prevent any part of the body from reaching a hazardous area. Access to feed points and ejection of formed parts is often required during normal machine operation. This may make the use of a guard or an interlocked guard impracticable. Fortunately, there are a number of safeguarding devices that can provide a high level of protection to workers. Examples include two-hand controls for a punch press or presence-sensing devices for a brake press. For more information, see "Safeguarding devices," pages 35–50, and refer to CSA Group standard *Z432-16 - Safeguarding of machinery.*

Safeguarding by location

Power transmission parts of machinery may be safeguarded by location if the distance to hazardous moving parts is greater than 2.5 m (8 ft.) from any floor, walkway, access platform, or service ladder. As part of a risk assessment, all hazards from a machine or process should be considered when determining if a machine is safeguarded by location. If the evaluated safe location of the machine is encroached, the machine must be de-energized and locked out before any work is performed on it. For more information, see "Safeguarding by location," pages 51–52.

4. Awareness controls

Awareness controls include warning devices, such as the following:

- Flashing lights, strobes, and beacons
- Audible warning devices such as beepers, horns, and sirens
- Warning signs, decals, and barrier chains
- Ropes to restrict access or painted lines on the floor to indicate hazardous areas

You will need to consider the work environment and layout to determine whether these measures will be effective.

5. Administrative controls

Administrative controls are changes to the way people work. Administrative controls include training, supervision, and safe work procedures. These types of controls are near the low end of the hierarchy because their effectiveness depends on the effectiveness of the training and supervision.

Although they are near the low end of the hierarchy, administrative controls should still be part of almost every risk control solution. Even with a fixed guard, workers have to know how to identify when the guard needs attention (e.g., if it comes loose or is damaged). Effective worker training and supervision have been shown to be major contributors to safety performance.

6. Personal protective equipment (PPE)

Personal protective equipment is considered the least effective option because it does not keep workers away from the hazard and is only effective if workers use it properly. However, sometimes PPE is the only option available. PPE may include gloves, hard hats, safety footwear, safety eyewear, respirators, and high-visibility clothing.

Workers may have to use PPE to protect against a hazard even when other forms of safeguarding are already in place. For example, even when a table saw is properly equipped with a guard over the saw blade, workers should also use safety eyewear to minimize the risk.

Assess and monitor controls

Once controls are in place, it's important to assess them to make sure they are effective. You should also monitor controls on an ongoing basis to ensure they continue to be effective as conditions in the workplace change. For example, conduct monthly audits on fixed guards and interlocks, and carry out annual interlock audits.

Monthly guarding audits

It's important to complete monthly checks when new fixed guards have been added. Verify that the guards remain in place, especially in the months immediately after they are added. The review process should include a detailed list of the new guards in a checklist format with enough information so reviewers can understand the intended function of each guard. For annual reviews, there should be enough information so reviewers understand the overall intent of the guarding and are able to identify deficient situations. Annual review checklists should be added to the existing annual guarding review, which should already be taking place for existing guards.

Annual interlock audits

Interlocks should be checked before each shift and audits should be conducted at least annually to ensure the machine and its interlocks are functioning as intended. This should include a detailed list of the interlocks and their intended function for each machine. The audit process doesn't need to occur all at once and can be completed in many different forms. For example, interlock audits can occur in the following ways:

- An annual audit of all interlocks completed in one day by a trained person
- A single machine interlock audit completed by a trained person each month as part of the monthly inspections
- Ongoing interlock checks done as a pre-start of the machine being audited

Guards

In the Regulation

Under section 12.5 of the Regulation, a fixed guard must not be modified to be readily removable without the use of tools.

Guards are the first choice of engineering control to keep workers from coming into contact with hazardous moving parts or to contain harmful fluids and projectiles, particularly when access is not normally required during operation.

Sometimes it's necessary to move a guard aside so a worker can access a point of operation during normal production work. If so, the guard should be interlocked to stop the machine and any hazardous movement of the equipment until the guard is put back in place and the safety control system is reset. Where access to the danger zone is not required during operation, a fixed guard shall be used. In other circumstances, guards need to be adjustable to allow materials of varying thickness to be fed into a machine.

Resources

For relevant WorkSafeBC publications, go to worksafebc.com, search for "machine guarding," and under Type select "Hazard alerts & safety bulletins."

Typical guards

Typical guards include the following:

- Fixed
- Distance
- Movable
- Adjustable
- Interlocked
- Self-closing

Figures 3.1 to 3.3 show examples of typical guards.

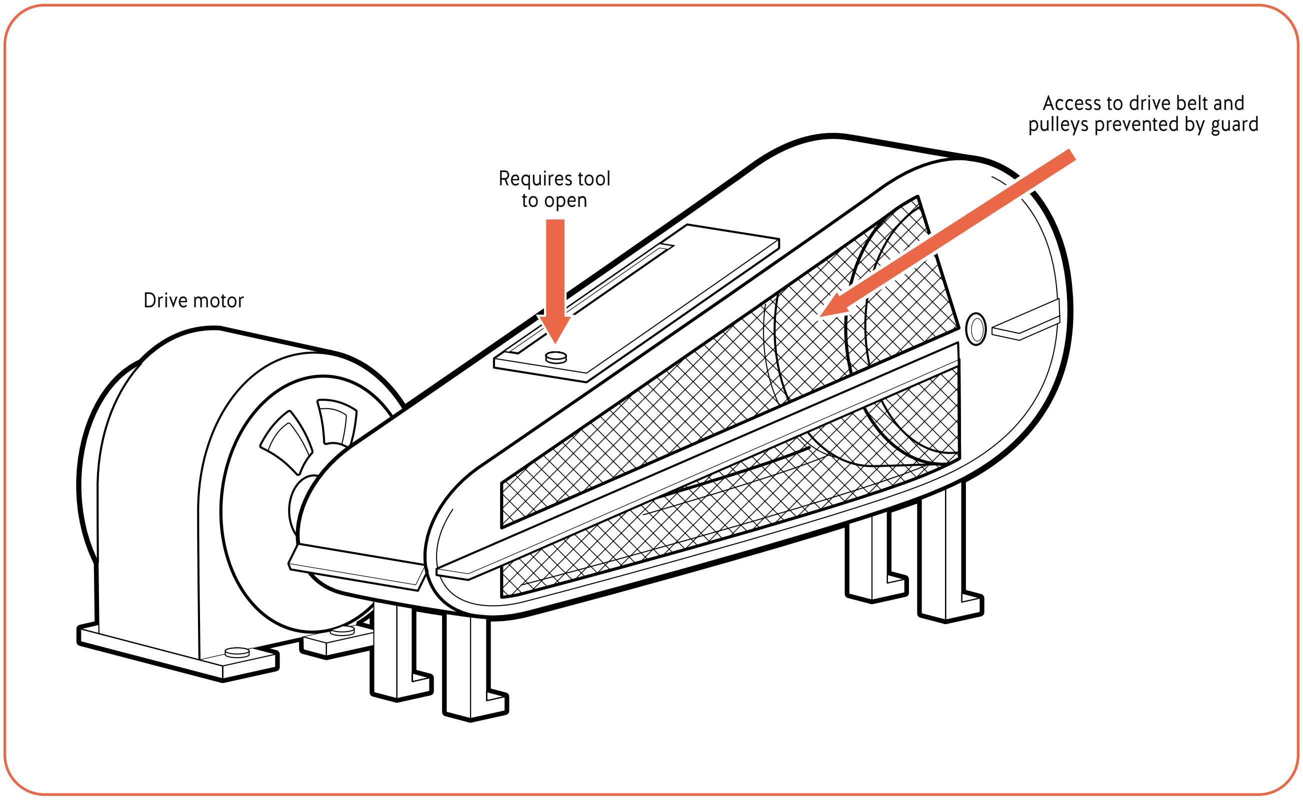
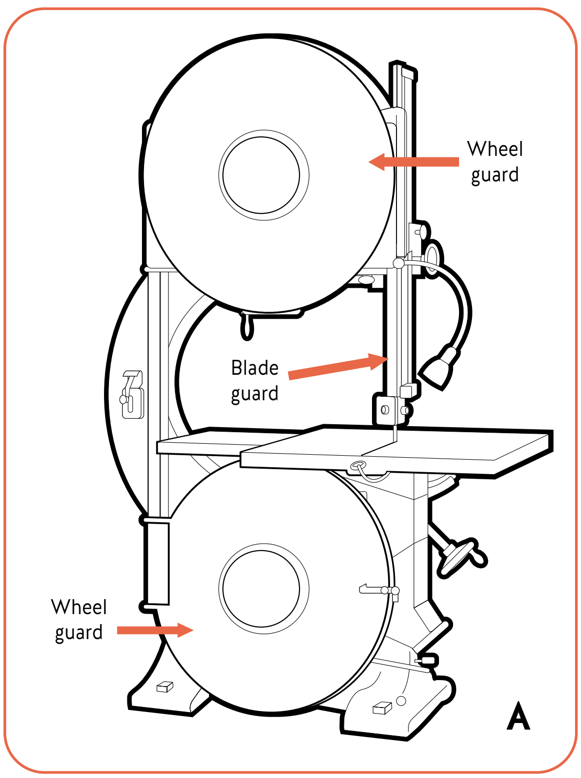


Figure 3.1. Fixed power transmission guard.



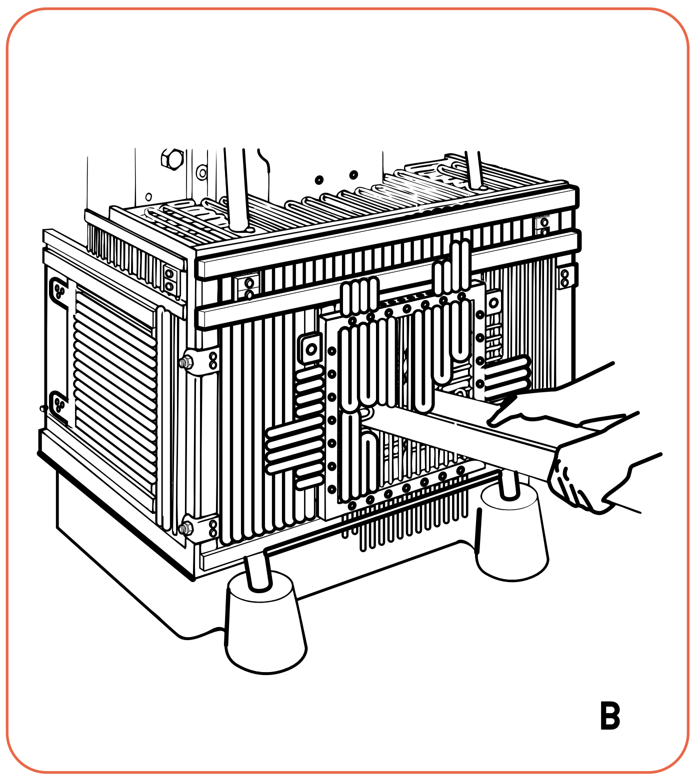


Figure 3.2. Adjustable guards. (A) Adjustable band saw guard. (B) Adjustable power press feed guard.
Note: Adjustable guards must be adjustable without the use of tools.

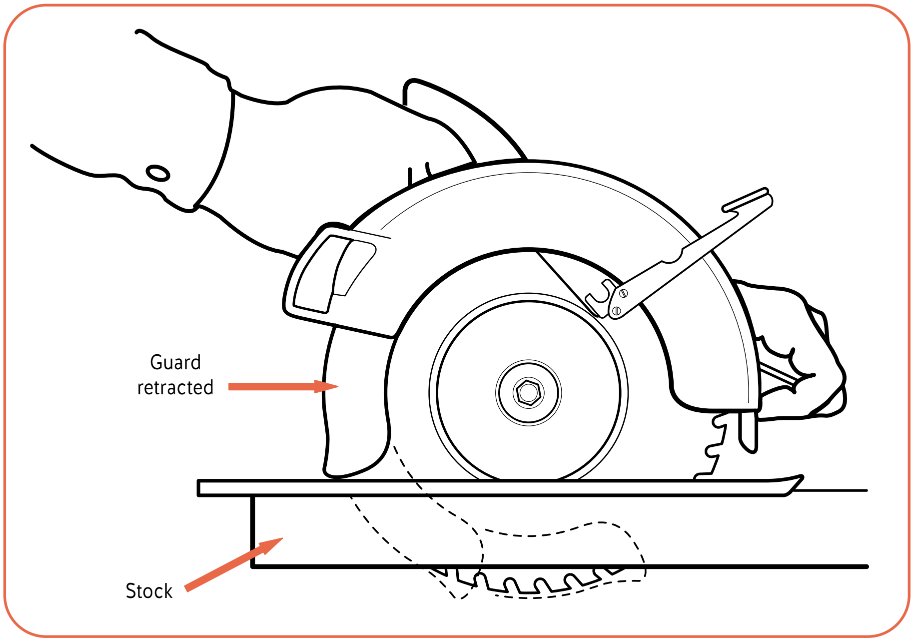


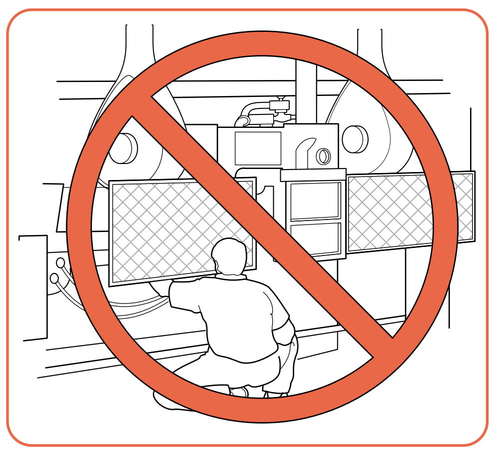
Figure 3.3. Handheld circular saw guard, an example of a self-adjusting (self-retracting) guard. Guards designed for right-handed people can sometimes cause problems for those who are left-handed. Left-handed workers often have difficulty operating handheld circular saws.

Performance requirements for guards

Guards are the preferred means of safeguarding when access is not required during normal operation.

Guards must:

- Prevent access to the hazardous area from all directions
- Not create additional pinch points or other hazards
- Safely contain broken parts (such as belts and chains)
- Allow for safe lubrication and minor adjustments without guard removal



When applying guards, ensure that they:

- Offer good visibility to feed points
- Stand up to normal wear and tear
- Meet normal production and quality needs
- Are difficult to modify or defeat

Power transmission guards and enclosures: Maximum permissible openings

Materials used for constructing power transmission guards generally consist of woven wire or expanded or perforated metal. Mesh or grid guards must be installed with sufficient clearance to prevent workers from reaching through the openings and contacting the point of operation. This is done by placing the guard at a safe distance from hazardous moving parts.

The effectiveness of a guard opening can be judged by a reach test carried out with the machinery locked out and safely at rest. The relationship between the size of the opening in the guard and the distance to the point of operation is illustrated in figure 3.4.

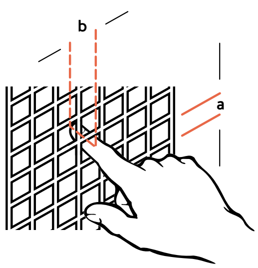
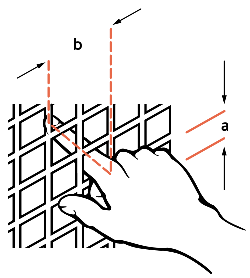
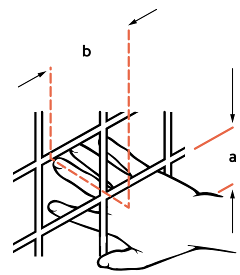
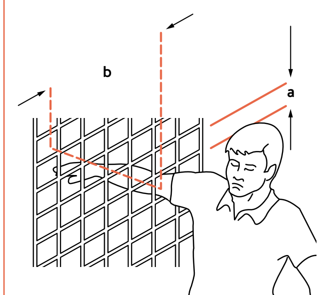
Fingertip	Finger	Hand to ball of thumb	Arm to armpit
			
If “a” is 4 to 8 mm (3/16 to ⅜ in.), then “b” must be at least 15 mm (⅝ in.).	If “a” is 8 to 12 mm (⅜ to ½ in.), then “b” must be at least 80 mm (3⅛ in.). If “a” is 12 to 20 mm (½ to ¾ in.), then “b” must be at least 120 mm (4¾ in.).	If “a” is 20 to 30 mm (¾ to 1⅛ in.), then “b” must be at least 200 mm (7⅞ in.).	If “a” is 30 to 150 mm (1⅛ to 6 in.), then “b” must be at least 850 mm (33½ in.).

Figure 3.4. Relationship between size of opening in a grid guard and distance to the point of operation.

Note: a = vertical dimension of the guard opening; b = distance from the nearest danger point inside the guard.

Point-of-operation guards: Maximum permissible openings

Point-of-operation guards (also known as *feed guards*) are often designed with horizontal members to enable the operator to insert flat stock into the machine. Figure 3.5 shows how the openings between the horizontal guarding members decrease as the worker’s fingers come closer to the pinch point.

Hand-feeding equipment usually presents the highest risk of injury to a worker. Feed guards must be carefully designed to ensure that the worker's hands cannot access the point of operation. Table 3.1 and figure 3.5 show the necessary clearances for an effective point-of-operation guard with a horizontal slotted feed opening.

Table 3.1. Maximum permissible openings in point-of-operation guards based on distance to hazard

Barrier opening size (smallest dimension)		Minimum distance from hazard	
mm	in.	Slotted opening	Square opening
6.1–11.0	¼–⅜	≥ 64.0 mm (2½ in.)	≥ 48.0 mm (2 in.)
11.1–16.0	⅜–⅝	≥ 89.0 mm (3½ in.)	≥ 66.0 mm (2⅝ in.)
16.1–32.0	⅝–1¼	≥ 166.0 mm (6½ in.)	≥ 166.0 mm (6½ in.)
32.1–49.0	1¼–2	≥ 445.0 mm (17½ in.)	≥ 445.0 mm (17½ in.)
49.1–132.0	2–5	≥ 915.0 mm (36 in.)	≥ 915.0 mm (36 in.)

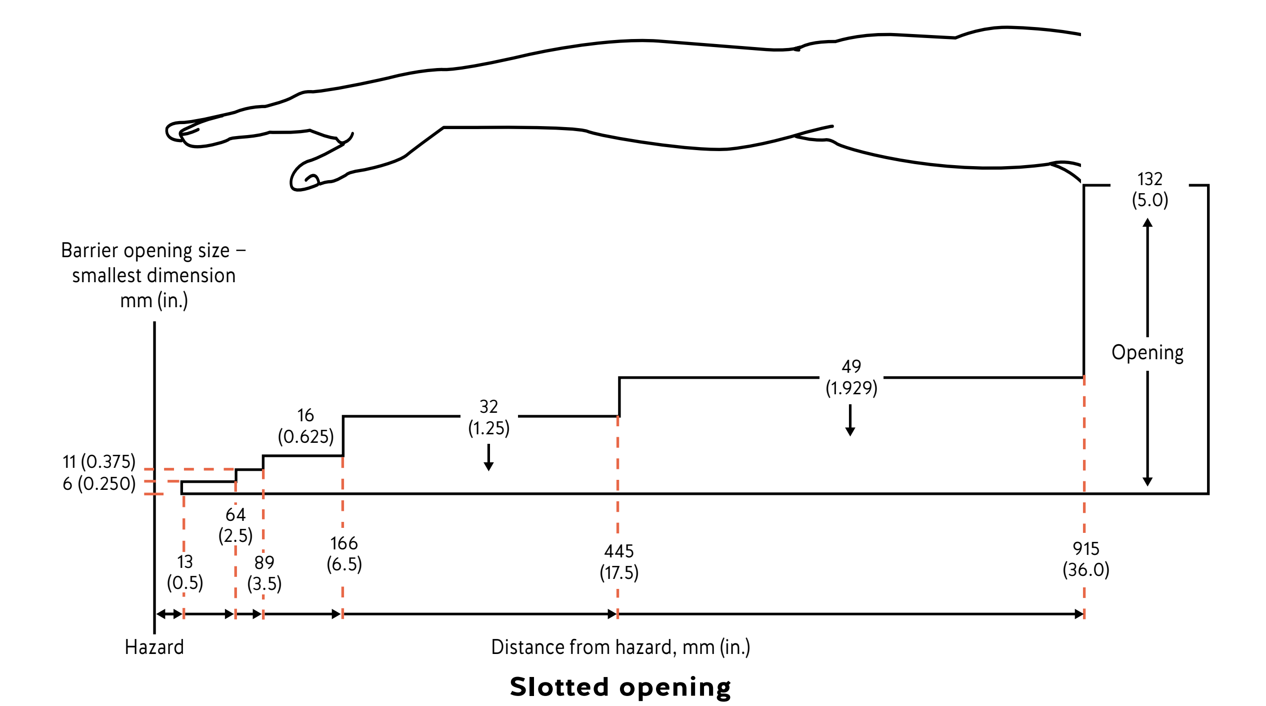


Figure 3.5. Visual representation of table showing maximum permissible openings.

Barrier or perimeter fences — reach distances to moving parts

For low- and medium-risk situations, a barrier or perimeter fence can be used to protect workers from contacting hazardous machine parts. Where possible, a barrier or perimeter fence should be at least 1.8 m (6 ft.) high.

If this is not practicable, the reach distance from the guardrail, barrier, or perimeter fence to the point of operation must be in accordance with figure 3.6 and table 3.2, at a minimum. (Table 3.2 outlines the minimum regulatory requirements. However, since higher protective barriers provide better protection, you may want to consider the stricter specifications in table 3.3.) For example, if the height of the hazardous area (A) is 1400 mm (55 in.) and its horizontal distance (C) from the proposed protective barrier is 1000 mm (40 in.), the height of the protective barrier (B) must be at least 1120 mm (44 in.). If the fence is lower than 1.8 m (6 ft.), then the reason should be documented.

For more information on protective barriers, see CSA Group standard *Z432-04 - Safeguarding of machinery, Annex C.2 - Reaching over protective structures.*

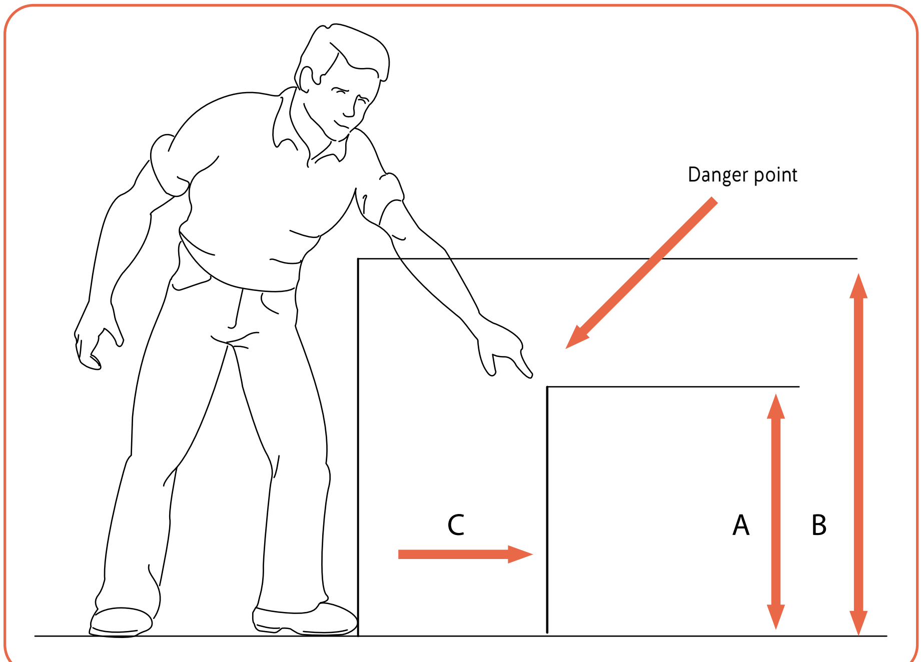


Figure 3.6. Factors to consider in designing a protective barrier:
A = height of the hazardous area, B = height of the protective barrier, and
C = horizontal distance to the hazardous area.

Table 3.2. Height of protective barriers based on distance to hazard — required specifications

	Height of fixed barrier or protective structure (B),* mm (in.)								
Height of hazardous area (A), mm (in.)	1000 (40)	1120 (44)	1400 (55)	1600 (63)	1800 (71)	2000 (78)	2200 (86)	2400 (94)	2500 (98)
	Horizontal distance to hazardous area (C), mm (in.)								
2500 (98)	—	—	—	—	—	—	—	—	—
2400 (94)	100 (4)	100 (4)	100 (4)	100 (4)	100 (4)	100 (4)	100 (4)	100 (4)	—
2200 (86)	600 (24)	600 (24)	500 (20)	500 (20)	400 (16)	350 (14)	250 (10)	—	—
2000 (78)	1100 (43)	900 (36)	700 (28)	600 (24)	500 (20)	350 (14)	—	—	—
1800 (71)	1100 (43)	1000 (40)	900 (36)	900 (36)	600 (24)	—	—	—	—
1600 (63)	1300 (51)	1000 (40)	900 (36)	900 (36)	500 (20)	—	—	—	—
1400 (55)	1300 (51)	1000 (40)	900 (36)	500 (20)	100 (4)	—	—	—	—
1200 (48)	1400 (55)	1000 (40)	900 (36)	500 (20)	—	—	—	—	—
1000 (40)	1400 (55)	1000 (40)	900 (36)	300 (20)	—	—	—	—	—
800 (32)	1300 (51)	900 (36)	600 (24)	—	—	—	—	—	—
600 (24)	1200 (48)	500 (20)	—	—	—	—	—	—	—
400 (16)	1200 (48)	300 (12)	—	—	—	—	—	—	—
200 (8)	1100 (43)	200 (8)	—	—	—	—	—	—	—
0	1100 (43)	200 (8)	—	—	—	—	—	—	—

* Barriers less than 1000 mm in height are not included because they do not sufficiently restrict movement of the body.

Table 3.3. Height of protective barriers based on distance to hazard — optional stricter specifications

	Height of fixed barrier or protective structure (B),* mm (in.)									
Height of hazardous area (A), mm (in.)	1000 (40)	1200 (47)	1400 (55)	1600 (63)	1800 (71)	2000 (78)	2200 (86)	2400 (94)	2500 (98)	2700 (106)
	Horizontal distance to hazardous area (C), mm (in.)									
2700 (106)	—	—	—	—	—	—	—	—	—	—
2600 (103)	900 (36)	800 (32)	700 (28)	600 (24)	600 (24)	500 (20)	400 (16)	300 (12)	100 (4)	—
2400 (94)	1100 (43)	1000 (40)	900 (36)	800 (32)	700 (28)	600 (24)	400 (16)	300 (12)	100 (4)	—
2200 (86)	1300 (51)	1200 (47)	1000 (40)	900 (36)	800 (32)	600 (24)	400 (16)	300 (12)	—	—
2000 (78)	1400 (55)	1300 (51)	1100 (43)	900 (36)	800 (32)	600 (24)	400 (16)	—	—	—
1800 (71)	1500 (59)	1400 (55)	1100 (43)	900 (36)	800 (32)	600 (24)	—	—	—	—
1600 (63)	1500 (59)	1400 (55)	1100 (43)	900 (36)	800 (32)	500 (20)	—	—	—	—
1400 (55)	1500 (59)	1400 (55)	1100 (43)	900 (36)	800 (32)	—	—	—	—	—
1200 (47)	1500 (59)	1400 (55)	1100 (43)	900 (36)	700 (28)	—	—	—	—	—
1000 (40)	1500 (59)	1400 (55)	1000 (40)	800 (32)	—	—	—	—	—	—
800 (32)	1500 (59)	1300 (51)	900 (36)	600 (24)	—	—	—	—	—	—
600 (24)	1400 (55)	1300 (51)	800 (32)	—	—	—	—	—	—	—
400 (16)	1400 (55)	1200 (47)	400 (16)	—	—	—	—	—	—	—
200 (8)	1200 (47)	900 (36)	—	—	—	—	—	—	—	—
0	1100 (43)	500 (20)	—	—	—	—	—	—	—	—

* Barriers less than 1000 mm in height are not included because they do not sufficiently restrict movement of the body.

Safeguarding devices

Resources

For relevant WorkSafeBC hazard alerts and safety bulletins, go to worksafebc.com, search for "machine guarding," and under Type select "Hazard alerts & safety bulletins."

Safeguarding devices may operate in one or more of the following ways:

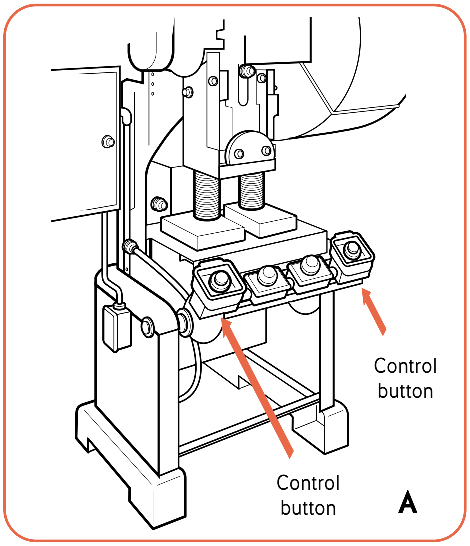
- Requiring the operator to remove his or her hands or entire body from the hazardous area before the machine can be cycled. Two-hand controls and interlocked gate guards function this way. See figure 3.7.
- Stopping the machine if the operator or another worker enters the hazardous area while the machine is cycling. Presence-sensing devices such as light curtains, photoelectric devices, and pressure-sensitive mats function this way. The effectiveness of these devices depends on a reliable braking system and associated control system.
- Physically restraining the operator from reaching into the hazardous area of the machine. This can be done through the use of a restraint device such as a pullback or holdback (tether). See figure 3.10.
- Involuntary tripping or activation of an emergency stop device if all or part of a worker's body approaches or enters the hazardous area. Examples include a crash bar or belly bar on a calender (see figure 3.11), the emergency contact bar in front of the in-running feed rolls of a flatwork ironer, or the emergency trip wire installed along a conveyor system.
- Limiting machine movement or travel to a safe range or speed. One example is operating the machine in a "jog," "inch," or "setup" mode, activated by special control buttons (printing presses). Another example is limiting die movement to 6 mm (¼ in.) or less before a piece can be inserted into the dies. A third example is an anti-repeat device that prevents a machine from performing more than one cycle (single-stroke mode).
- Locating the worker in a safe place before the machine can be started. One example is a foot control fastened to the floor a safe distance from the machine (called a *captive* or *hostage* control). Another example is positioning the activating control for an X-ray machine in an isolated room.
- Hold-to-run controls, which require the operator to keep the control activated to keep the machine operating (also known as *enabling-device* or *operator-maintained* controls).
- Captive key systems, which use a series of keys and locks to start up or shut down a hazardous operation in a prescribed and safe sequence.

Properly selected safeguarding devices can provide a high level of protection to workers during normal production, but they are not a substitute for locking out when performing maintenance activities.

Interlocking safeguarding devices must be interlocked to meet control system performance requirements defined in the risk assessment.

Typical safeguarding devices

Figures 3.7 to 3.12 show examples of typical safeguarding devices.



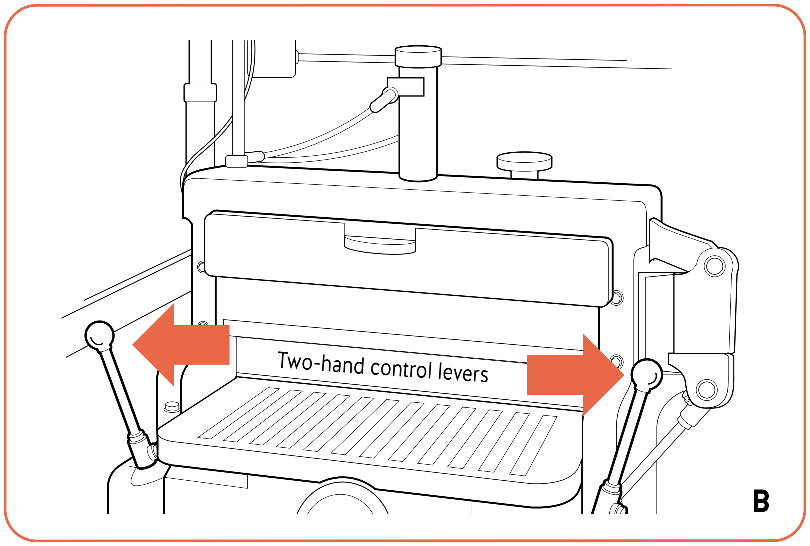
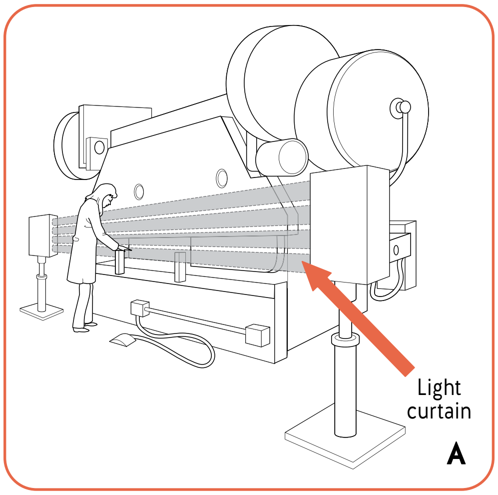


Figure 3.7. Two-hand controls. (A) Two-hand controls — power press. The press will not cycle unless both run buttons are activated using both hands within a certain amount of time. (B) Two-hand control levers — paper guillotine shear. The shear will not cycle unless both levers are activated using both hands within a certain amount of time.



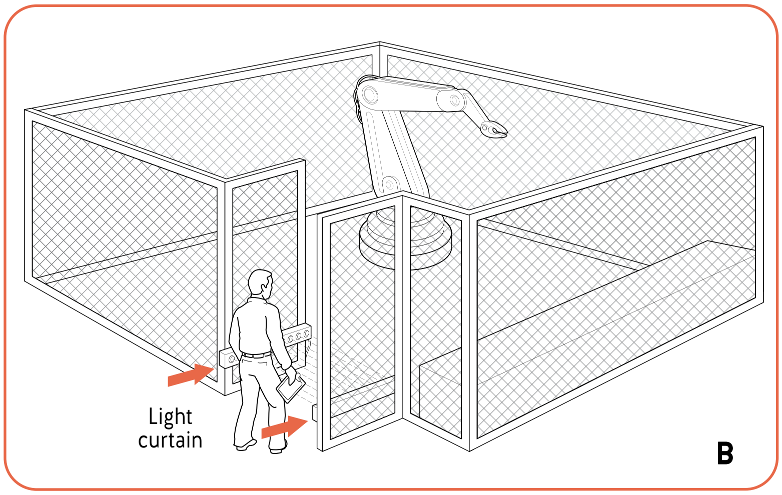


Figure 3.8. Light curtain or similar photoelectric sensing device. (A) Light curtain — brake press. The press is operated using the foot control. It will stop if hands enter the light beam-protected zone. (B) Light curtain — access to robotic cell. The robot is deactivated if a worker enters the doorway, which is protected by a light curtain safeguarding device.

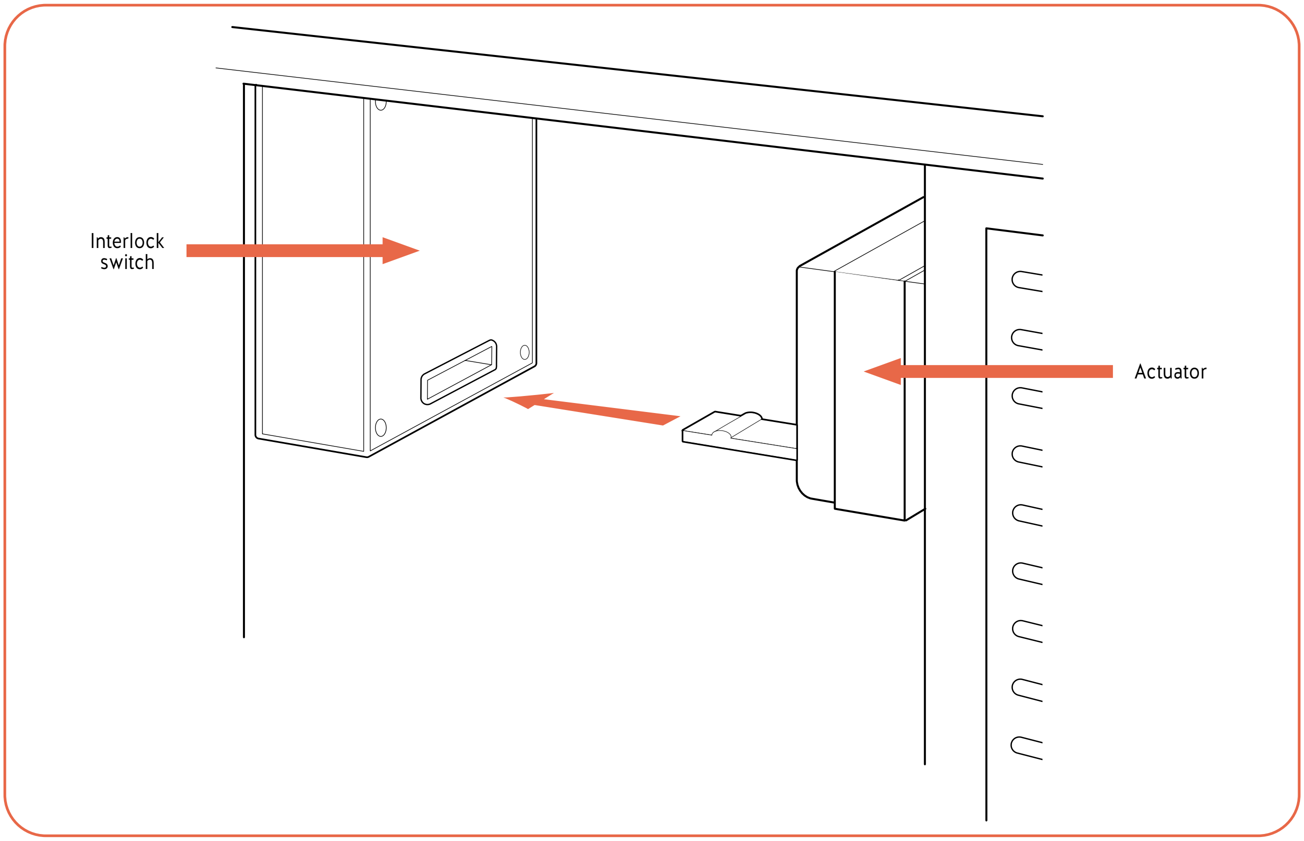
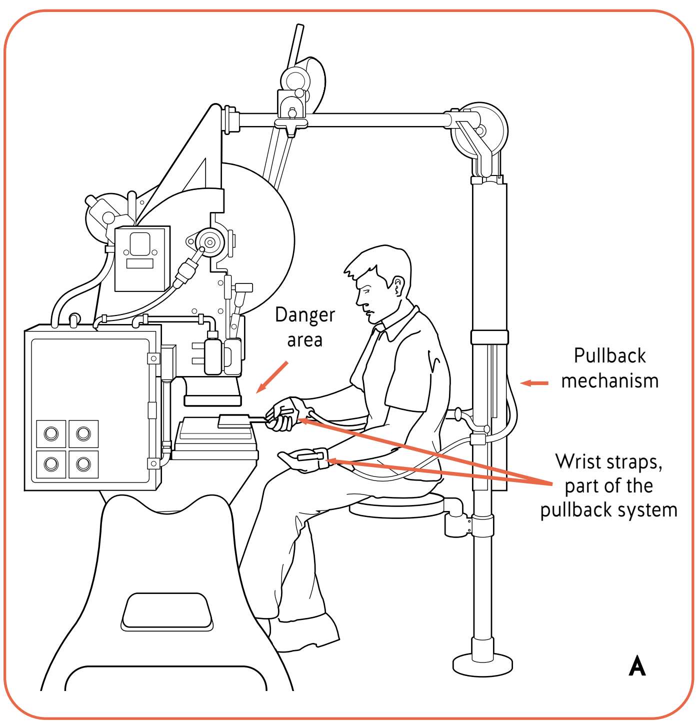


Figure 3.9. Interlocked guard. The interlocked door must be closed before the machine can be started.



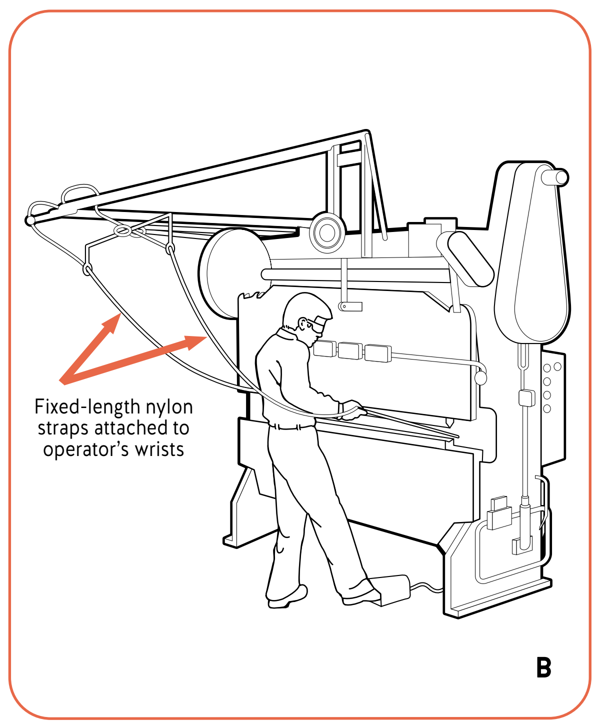


Figure 3.10. Pullback and restraint devices (not in common use). (A) Press operator using pullback devices. The operator's hands are pulled away by cables if the operator leaves them in the hazardous area.
(B) Brake press operator using fixed restraint devices. The operator's hands cannot reach the hazardous area. Hand tools are required for access.

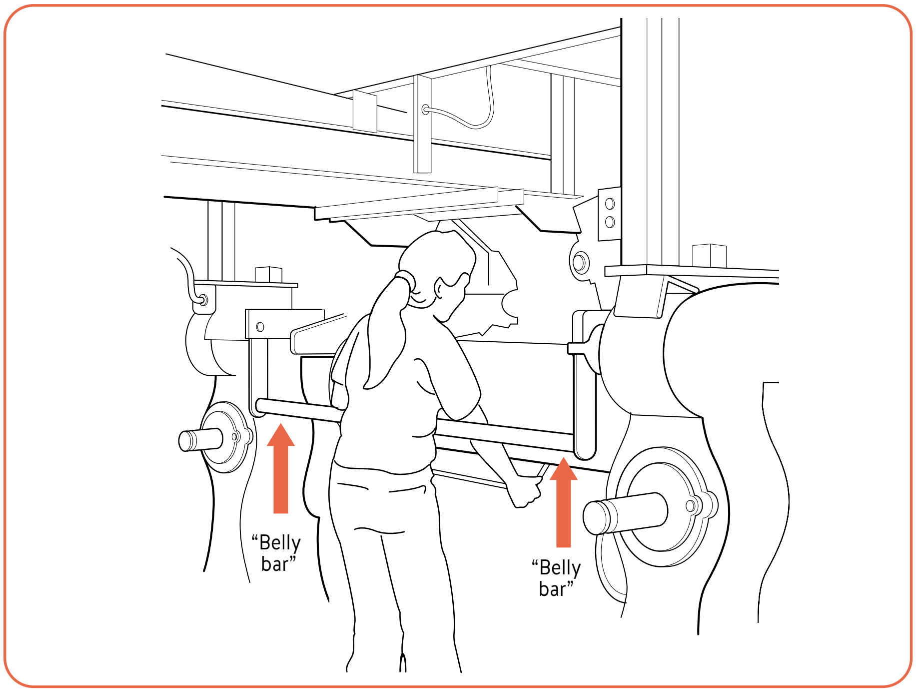


Figure 3.11. Emergency contact or tripping device in the form of an emergency "belly bar" on a calender. The operator cannot reach into the in-running feed rolls without automatically activating the machine's emergency stop bar.

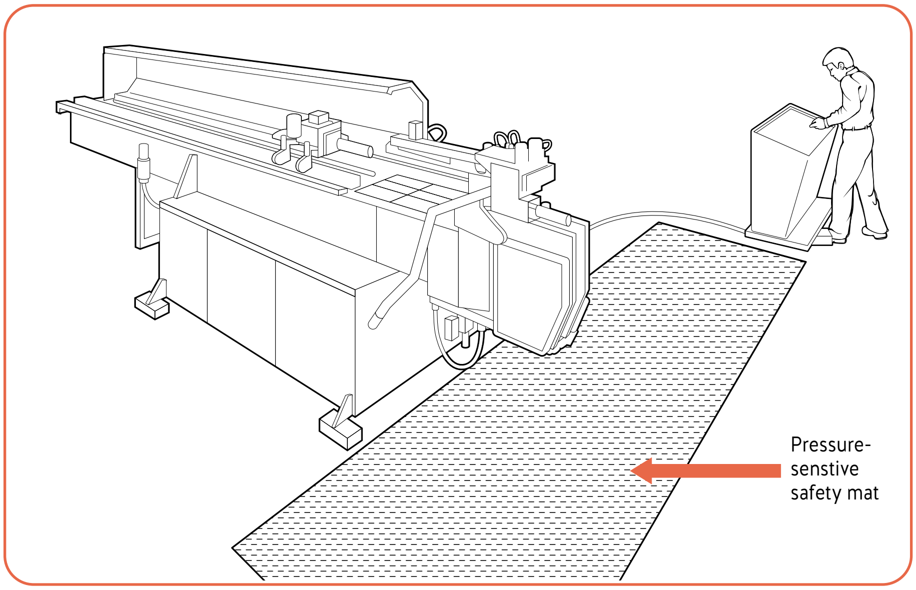


Figure 3.12. Pressure-sensitive safety mat safeguarding access to machine. The machine will come to an emergency stop if anyone, including the operator, steps on the mat.

Performance requirements for two-hand controls and trips

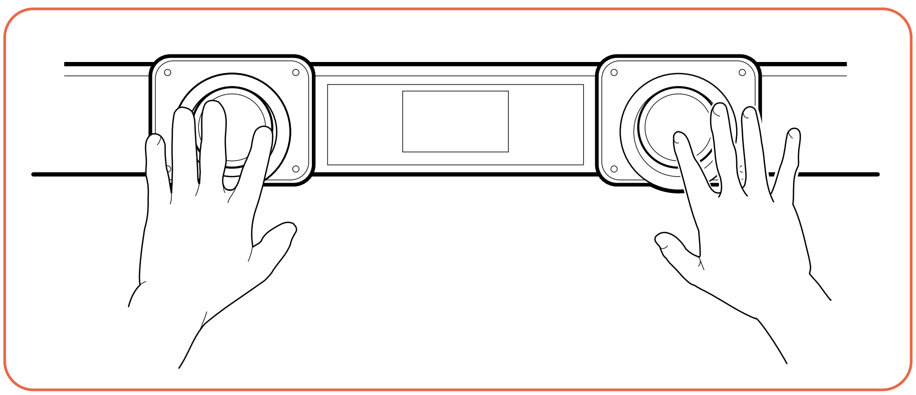
There are two types of two-hand operations: two-hand controls and two-hand trips.

Two-hand controls

The operator has to activate both controls (buttons, levers, or sensors) at the same time and keep them engaged throughout the entire hazardous portion of the machine cycle. If the operator releases the controls, the machine either stops or returns to top of stroke (the position that opens the dies). This type of machine operation is found on mechanically powered presses. Two-hand controls are commonly found with pneumatic clutches or brakes and with hydraulically powered machinery, such as brake presses.

Two-hand trips

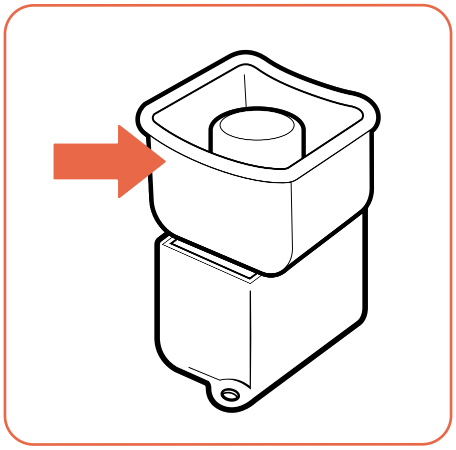
The operator has to activate both controls at the same time to initiate the machine cycle but releasing the controls will not interrupt the cycle. This type of machine operation is called full-revolution clutch or mechanical clutch. It is commonly found with hydraulically powered machinery, such as full-rotation mechanical presses.



Design and installation requirements

Two-hand controls and trips must be designed and installed to meet the following requirements:

- **Protected** against unintended or accidental operation. This is usually achieved by surrounding the activating button with a "ring" guard.



- **Separated** or otherwise designed so the operator has to use both hands to activate the controls. This helps prevent accidental activation if a hand or elbow strikes one of the controls.
- **Designed** so the operator has to release both controls before another cycle can be initiated. This is called an anti-repeat or anti-tie down feature. If the operator can run the machine with one of the controls tied down (for example, by using tape, a rubber band, or a wedge), then the two-hand controls are not properly designed or constructed.
- **Located** a safe distance from the nearest hazard so the operator cannot reach the hazard with a hand or other body part before all hazardous motion of the machine cycle has stopped. This safe distance is calculated using a universally adopted measurement called the hand-speed constant. This constant is the speed of an average person reaching into a machine's point of operation to retrieve an object or correct a fault. The hand-speed constant is 1600 mm (63 in.) per second.

The hand-speed constant doesn't take into account other body motions, which may have a different speed than hands.

In a simple example, the safe location of a two-hand control for a machine that comes to a complete stop one second after the controls are released would be 1600 mm (63 in.) from the nearest point of operation. For a machine that stops in one-half second, the safe distance would be 800 mm (31½ in.). For a machine that stops in one-quarter second, it would be 400 mm (15¾ in.). This example only provides approximate locations for the safeguard.

Two-hand controls alone may not provide sufficient safeguarding. In addition, guards may be required to protect workers other than the operator.

Precise locations must be determined based on the safe distance calculations in CSA Group standard *Z432 - Safeguarding of machinery.*

Determining the precise stopping time of a machine cycle requires specialized measuring equipment or devices. The response times of control system components (for example, air valves and friction brakes) and the actual braking effort are all elements that determine the actual stopping time. Refer to CSA Group standard *Z432.*

When a two-hand trip is used to safeguard a mechanical-clutch power press, the number of engagement points on the flywheel will have an effect on the stopping time calculation. Refer to CSA Group standard *Z142-10(R2014) - Code for power press operation: Health, safety, and safeguarding requirements.*

Performance requirements for presence-sensing devices

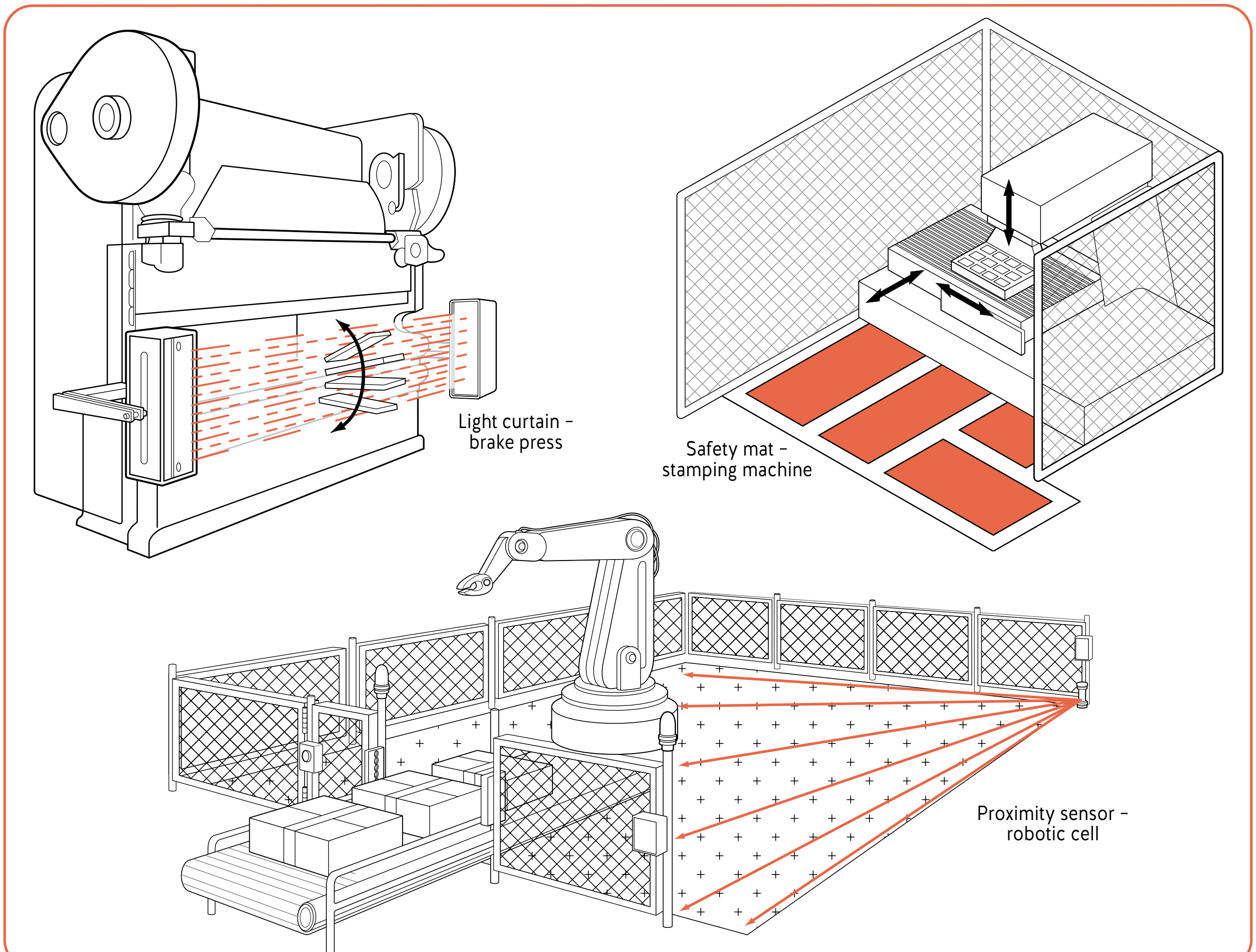


Figure 3.13. Presence-sensing devices.

How presence-sensing devices work

Unlike guards and two-hand controls, presence-sensing devices do not prevent access to a point of operation. However, they prevent hazardous machine motion if any part of a worker's body is in the hazardous area when a machine cycle is initiated. They are a good choice of safeguard when frequent access is required for loading parts and making adjustments during normal operation and physical guarding is too restrictive. These safety devices prevent hazardous machine motion by sensing the presence of a worker and sending a stop signal to the machine. Examples include light curtains, proximity sensors, and safety mats.

There are many technical factors, such as machine control reliability and safety distance, that affect the selection and positioning of presence-sensing devices. For more information, see the following standards referred to in the Regulation:

- CSA Group standard *Z432 - Safeguarding of machinery*
- CSA Group standard *Z142 - Code for power press operation: Health, safety, and safeguarding requirements*
- CSA Group standard *CAN/CSA-Z434 - Industrial robots and robot systems*
- ANSI standard *ANSI/RIA R15.06 - Industrial robots and robot systems - Safety requirements*

Limitations

Consider the following limitations when selecting these safeguards:

- Presence-sensing devices must be installed a minimum safe distance away from the hazardous point of operation, as specified in CSA Group standard *Z432.*
- Presence-sensing devices alone may not provide sufficient safeguarding. In addition, guarding may be required to protect workers other than the operator.
- Presence-sensing devices must never be used to safeguard a machine with a full-revolution clutch (e.g., power presses).
- Presence-sensing devices should not be installed until the requirements of the relevant standards have been reviewed.
- Presence-sensing devices should be used during normal production only. They are not an acceptable control when performing maintenance work, such as changing tooling.

Active opto-electronic protection devices (AOPDs)

Steam or dust can hinder the effectiveness of a light curtain.

These presence-sensing devices emit a "curtain" of infrared light beams in front of the hazardous area. When a person or object blocks any of the beams, the light-curtain control circuit sends a stop signal to the machine's control system. This type of safeguard

Pressure-sensitive safety mats may not be effective in certain work areas — for example, where there are lots of fasteners, scrap, and other metal objects that could puncture the mat and short it out, or in an area where forklifts run over the mat repeatedly until it no longer works. Safe-distance calculations should be performed for the correct placement of safety mats. See CSA Group standard *Z432*.

offers maximum protection with minimum impact on normal machine operation. It is particularly well suited to safeguarding part-revolution (friction-clutch) brake presses.

Note: Ensure that your system-required performance device is at the level identified in your risk assessment.

Pressure-sensitive safety mats

These presence-sensing devices are used to guard the floor area around a machine. A matrix of interconnected mats is laid around the hazard area, and a set amount of pressure (such as an operator's footstep) will cause the mat control unit to send a stop signal to the guarded machine. Pressure-sensitive safety mats are often used within an enclosed area containing several machines, such as flexible manufacturing or robotics cells. When an operator needs to access the area (for example, in the case of robot "teaching"), the mats prevent hazardous motion of the robot if the operator steps on the mat.

Performance requirements for safety interlocks

How safety interlocks work

If access to a point of operation (a feed point) is required during any mode of machine operation, an effective solution is to use a movable guard interlocked with the machine's control system, as specified by the performance requirement identified in the risk assessment. The control power for the machine is routed through the safety contact of the interlock. The interlock ensures the machine will not operate if the guard is in the open position.

Do not rely on interlocks in place of de-energization and lockout for maintenance activities.

If a machine has parts that keep on spinning after the machine has been de-energized and locked out, it is important to have safeguards in place to confirm that moving parts have stopped before workers carry out repairs or maintenance. To confirm that a part has stopped spinning, install sensors on moving parts that will indicate to the control system if a part is still moving.

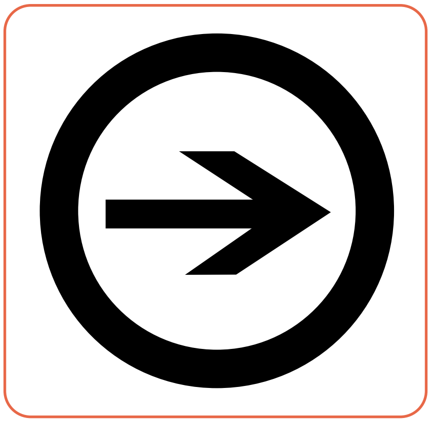
In the case of time-delay mechanisms, additional controls (e.g., awareness means or administrative controls) must be applied as specified by the hierarchy of controls.

Several technical factors affect the proper selection and positioning of safety interlocks. These are described in detail in CSA Group standard *Z432-16 - Safeguarding of machinery*, which should be reviewed when designing or selecting an interlock system.

Selecting safety-related parts of a control system

Consider the following when selecting safety-related parts of a control system:

- Safety devices used in safety-related parts of control systems must meet performance-level requirements established in the risk assessment. Where the risk assessment indicates a high risk level, there may be a need to monitor the integrity of the safety interlock circuit. In addition, the use of redundant interlocks may be required.
- Safety-rated interlock switches feature positive-break normally closed (NC) contacts. This ensures that the electrical contacts are forced open by a non-resilient mechanical action — that is, they do not rely on spring action to open the contacts. The international symbol for positive-break contacts is:



- Mechanical-safety interlock switches should be tamper-resistant and difficult to defeat or bypass using readily available means, such as a piece of wire or tape, or a simple hand tool. Safety interlock manufacturers address this by designing two-piece keyed interlocks or interlocks with coded magnet sensors or radiofrequency identification (RFID) technology.
- Safety interlocks should be installed using "positive-mode" mounting. When mounted in the positive mode, the mechanism that forces the NC contacts to open is directly driven by the safety guard. In this mounting mode, opening the safety guard physically forces the NC contacts to open.
- Safety interlocks may require certain parts of the machine to retain power when it is shut down. Lockout procedures or additional safeguarding devices must be implemented to address this concern.

- Safety interlocks must be suitable for the environment in which they are installed and must function reliably under expected operating conditions.
- Resetting whatever has activated a safety device (for example, closing a machine guard that has a safety interlock) should not, by itself, start a machine function.
- Safety interlocks must be installed according to good engineering practices.

Interlock example (movable gate)

An example of a safeguarding application using interlocking is a movable gate. It is commonly used to provide protection to an operator who is hand-feeding parts into a punch press, but it can be applied to various other machines. See figure 3.14.

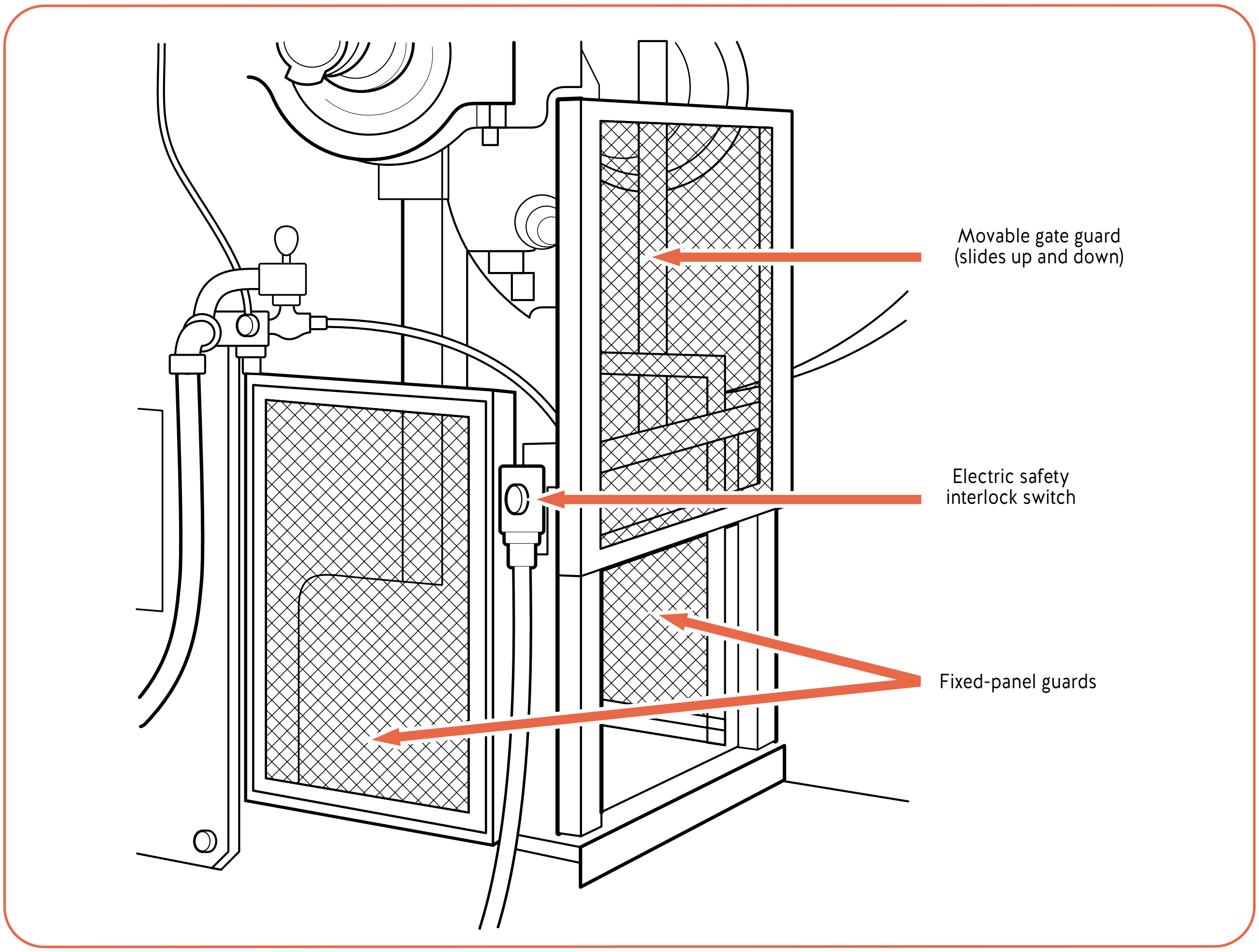


Figure 3.14. Movable interlocked gate mounted on a punch press.

When the machine completes its cycle or returns to top of stroke (in the case of a power press), the gate automatically opens, allowing the operator to remove the formed part. The operator then places a feed stock (blank) into the machine and activates the controls to start another cycle. This can be done with either a foot control, a single-hand control, or even two-hand controls (which are preferred). The gate must close before the machine can cycle. A low-pressure air cylinder attached to the gate performs this closing function. If there are any obstructions under the gate, such as the operator's hands, it will not fully close. The interlock switch will prevent further machine operation until the obstruction has been removed and the controls are reset.

There are two types of movable gate guards. The A type is used to safeguard machines with full-revolution clutches. The following is a typical operation sequence for a complete cycle on a machine that uses an A gate:

1. Place part in machine and initiate the cycle. As long as there are no obstructions, the gate will close.
2. The machine makes one complete cycle.
3. The gate opens after the cycle has ended.

The B type protects the operator only on the downstroke of a press cycle (or closing stroke of a machine). This type should only be used to safeguard machines with part-revolution clutches. The following is a typical operation sequence on a machine that uses a B gate:

1. Place part in machine and initiate the cycle. As long as there are no obstructions, the gate will close.
2. Once the machine reaches the portion of the cycle where the point-of-operation hazard has been eliminated, and before the cycle has ended, the B gate opens, allowing the operator to remove the formed part.

Movable gate without locking

The interlock switches are designed so the machine will stop immediately if the operator opens the guard door at any time during machine operation.

Movable gate with guard locking

The interlock switches have a device that locks the guard door closed and will not release it until the machine comes to a safe stop. This device is similar to the feature on some spin-cycle clothes washing machines. The coasting-down time can be anywhere from several seconds to several minutes.

Miscellaneous emergency body-contact devices

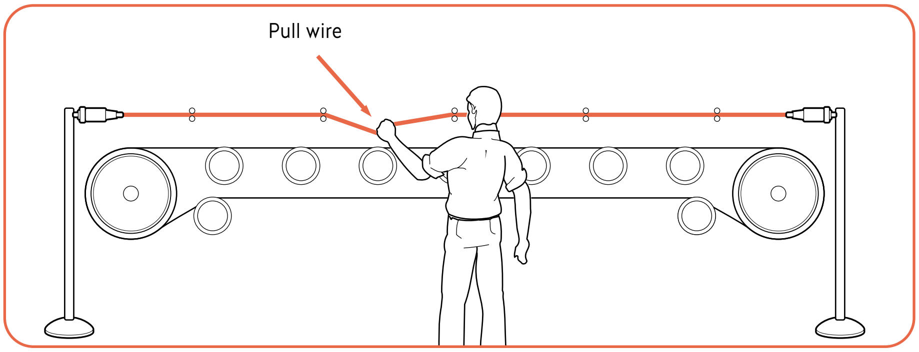


Figure 3.15. Emergency pull wire — conveyor system.

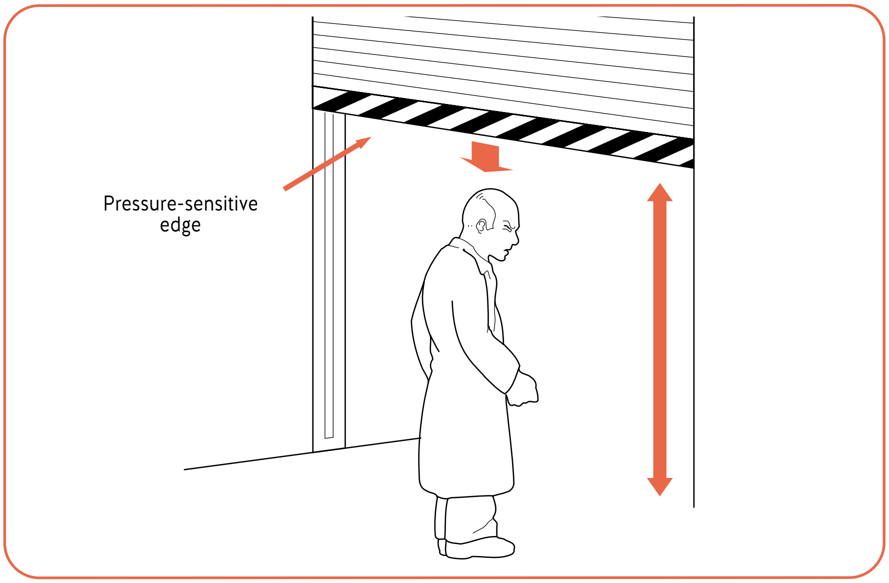


Figure 3.16. Safety contact bumper — overhead door machine.

How emergency body-contact devices work

These safeguarding devices function somewhat like presence-sensing devices. The difference is they may allow access to the hazardous area before they are activated and send a stop signal to the machine. This means there is some risk of injury. However, emergency body-contact devices may be the only reasonable choice of safeguarding when other, more effective means are not practicable.

Whenever possible, grab wires, pull wires, and contact bars such as “crash bars” or “belly bars” should be mounted so they will be activated involuntarily as the worker approaches the hazardous area. For example, a worker accidentally falling onto a conveyor belt would automatically activate the emergency trip wire.

A pre-shift inspection and test should be done wherever these devices are installed.

Grab-wire and pull-wire devices

These devices usually allow the worker a "first/last chance" to stop the machine in the event of accidental contact. They must be selected and mounted so a pull on the wire or cable from any direction will activate the emergency stop. The activating switch must also sense a broken or slack cable condition, which will automatically activate the emergency stop. Figures 3.17 and 3.18 show two examples of safe pull-wire installations.

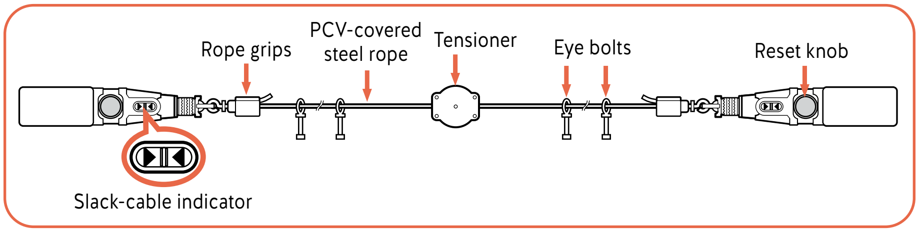


Figure 3.17. Pull-wire system using two emergency stop switches. The switch is activated by a pull from any direction.

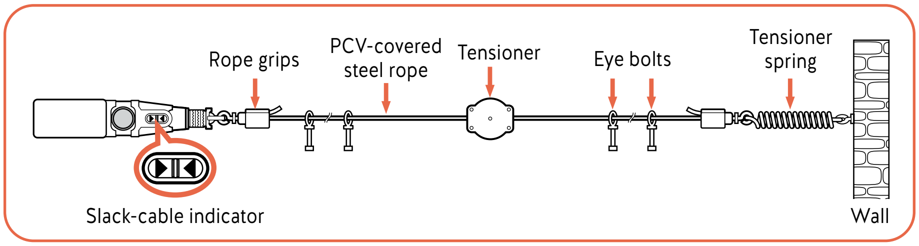


Figure 3.18. Pull-wire system using one emergency stop switch and a wall-mounted tension spring. The switch is activated by a pull from any direction.

Shields and awareness barriers

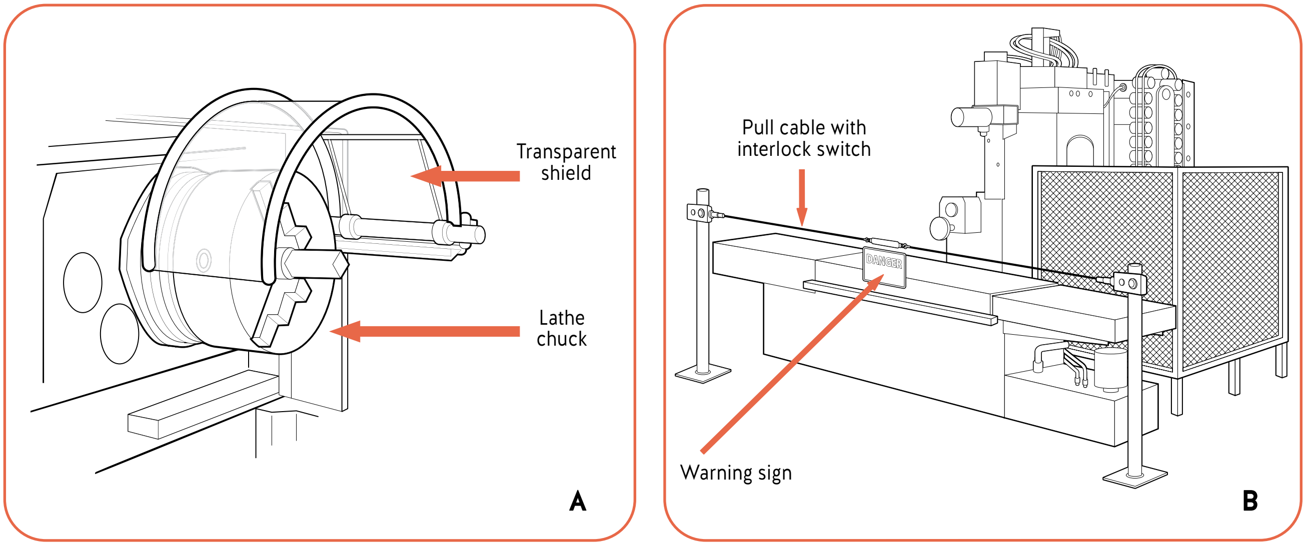


Figure 3.19. Shield and awareness barrier. (A) Shielded lathe chuck. (B) Sliding table with warning sign.

How shields and awareness barriers work

Shields are generally used to deflect chips, sparks, swarf, coolant, or lubricant away from the operator and other workers near a machine. Shields, usually transparent barriers, are typically installed on lathes, milling machines, boring machines, and drill presses. They can also be used on woodworking machines. Besides providing some protection as a barrier, most shields also provide good visibility into the point of operation.

Awareness barriers are meant to restrict worker entry to hazardous areas. Awareness barriers include electrically interlocked pull-cable assemblies installed in the rear area of machines, such as brake presses and shears. These areas are often out of the operator's view. If someone pulls or loosens the cable, the machine stops. A sign indicating the hazard should be placed on the pull cable.

Although shields and awareness barriers offer some degree of safeguarding, they aren't considered guards because they only restrict access to the hazardous area; they don't prevent access completely.

When installing these devices and before moving them from their normally applied positions, always turn off power to the machine and follow lockout procedures.

Emergency stops (E-stops)

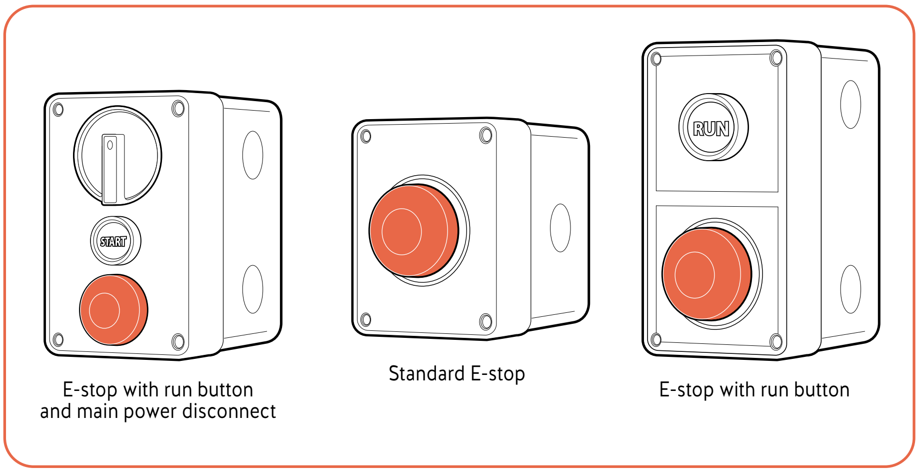


Figure 3.20. E-stops.

How E-stops work

An *emergency stop* (E-stop) is a red, mushroom-shaped stop button that an operator can manually press in the event of an emergency condition, upset condition, or accident. E-stops must not be used for lockout because they require intentional activation and rarely prevent accidents. An E-stop is considered an after-the-fact device rather than a safeguarding device. However, operators can use E-stops to stop a machine immediately after an accident has occurred or to prevent an unsafe machine operation from continuing.

E-stop requirements

Various published safeguarding standards contain specific requirements for E-stops, including how many are required and where they should be located. In addition to those specifications, the following requirements apply to all E-stop devices:

- The E-stop must be located within immediate and unimpeded reach of the operator or others who are directly affected by the machine operation.
- It must have a red, mushroom-shaped button with a yellow background.
- It must be designed to allow immediate activation with any part of the body (i.e., no ring guards or recessed positions).
- The E-stop requires a manual push to activate, and it remains in the depressed position when activated (i.e., not a "hold-to-run" switch).
- It must be hard-wired into the control circuit with an electro-mechanical power contactor that removes power to the machine.
- It must have a manual pull or twist to reset the E-stop device so the machine can be returned to operation. It must also have a second, independent control that has to be activated before the machine will start. The machine must not restart merely by pulling out and resetting the E-stop.

Employers must also consider the machine's pneumatic and hydraulic systems. These systems may retain stored energy even after the E-stop has been activated. This retained energy may be a hazard, or it may be required to maintain the status of the safeguards installed on the machine. Before restarting a machine after an E-stop, first verify that the hazardous situation has been mitigated.

Safeguarding by location

The Regulation permits installations in place before January 1, 1999, to have unguarded parts more than 2.1 m (7 ft.) but less than 2.5 m (8 ft.) above the floor, walkway, or platform, unless the work process presents an undue risk to workers or until such time as the installation is substantially overhauled or renovated.

When a hazard is out of reach, it may be considered safeguarded by location. However, if a work activity puts workers in reach of the hazard (e.g., a worker uses a ladder to reach the hazardous area), it is no longer safeguarded by location.

In the case of power-transmission parts, the safe clearance when reaching up to an unguarded hazard with the body upright and standing at full height is 2.5 m (8 ft.) (see figure 3.21). Any hazardous moving parts beyond this distance may be considered to be guarded by location. If access to an unguarded hazard is gained by the use of ladders or scaffolds, for example, guarding or lockout procedures must be used.

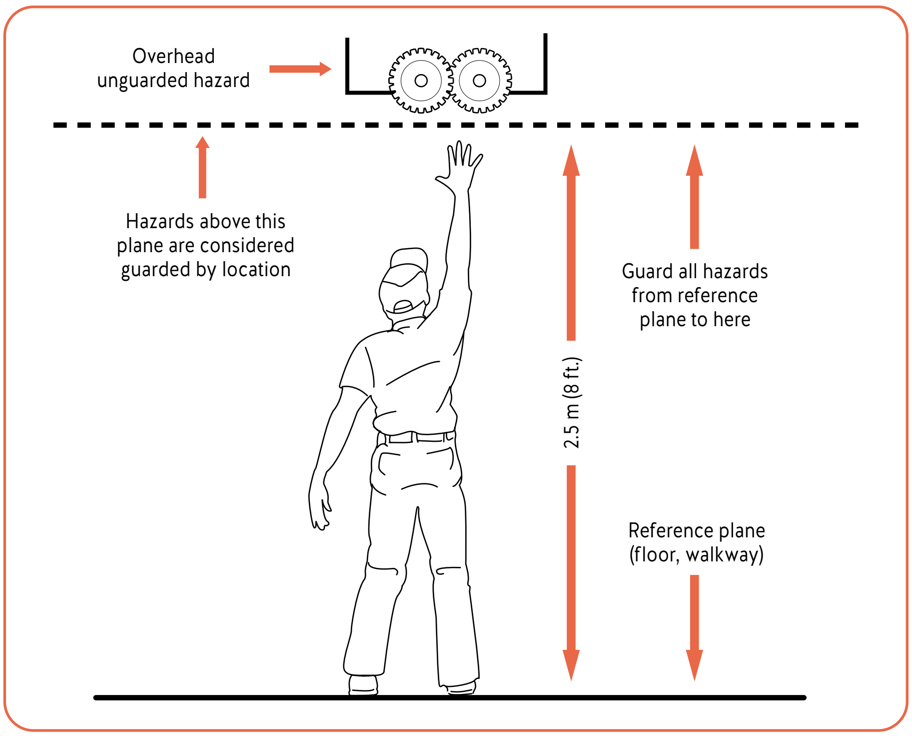


Figure 3.21. Safe distance for reaching up to an unguarded hazard.

Safeguarding equipment that is accessed infrequently

When it comes to safeguarding equipment located out of the way of normal work areas, there are sometimes comments such as “nobody ever goes there,” or “we access that equipment only when it is locked out.” However, if a worker can access unguarded moving parts that are not safeguarded by location, an accident can occur. Although the level of risk may be quite low, over time the chances of an accident occurring will increase.

The bottom line is that all hazardous locations must be safeguarded. However, it’s also important to assess risk levels to determine which locations are more hazardous and which are less hazardous. The idea is to prioritize risk levels so you can start by safeguarding the higher-risk locations and then move on to safeguarding lower-risk locations. Determine risk levels for each hazardous location by conducting risk assessments and machine surveys.

Selecting the right safeguards

Reassess controls after implementation

An initial risk assessment helps determine the risks associated with a piece of machinery or equipment so you can select and implement effective controls. It's also a good idea to reassess controls after they have been implemented to make sure they are working as expected.

If all machines were alike, it would be simple to design a universal guard and install it during the fabrication of the machine. However, machines are not all alike. To further complicate the issue, purchasers of the same model of machine may use it in different ways and for different purposes. The uses may even change during the lifetime of the machine. In some cases, machines are used for purposes the manufacturer did not envision.

It is important to ensure you have the right machine for the work being performed. Don't modify or adapt machinery without consulting the manufacturer or another qualified person, such as a professional engineer. Manufacturers don't always install or provide point-of-operation safeguarding because they may not know how you intend to use the machine.

Generally speaking, you will need to perform a risk assessment before you can select appropriate safeguards for a piece of machinery. As part of the selection process, you may find it useful to refer to the decision chart in figure 3.22 and the guide in table 3.4.

The most effective safeguard is a device or system that provides the maximum protection with the minimum impact on normal machine operation.

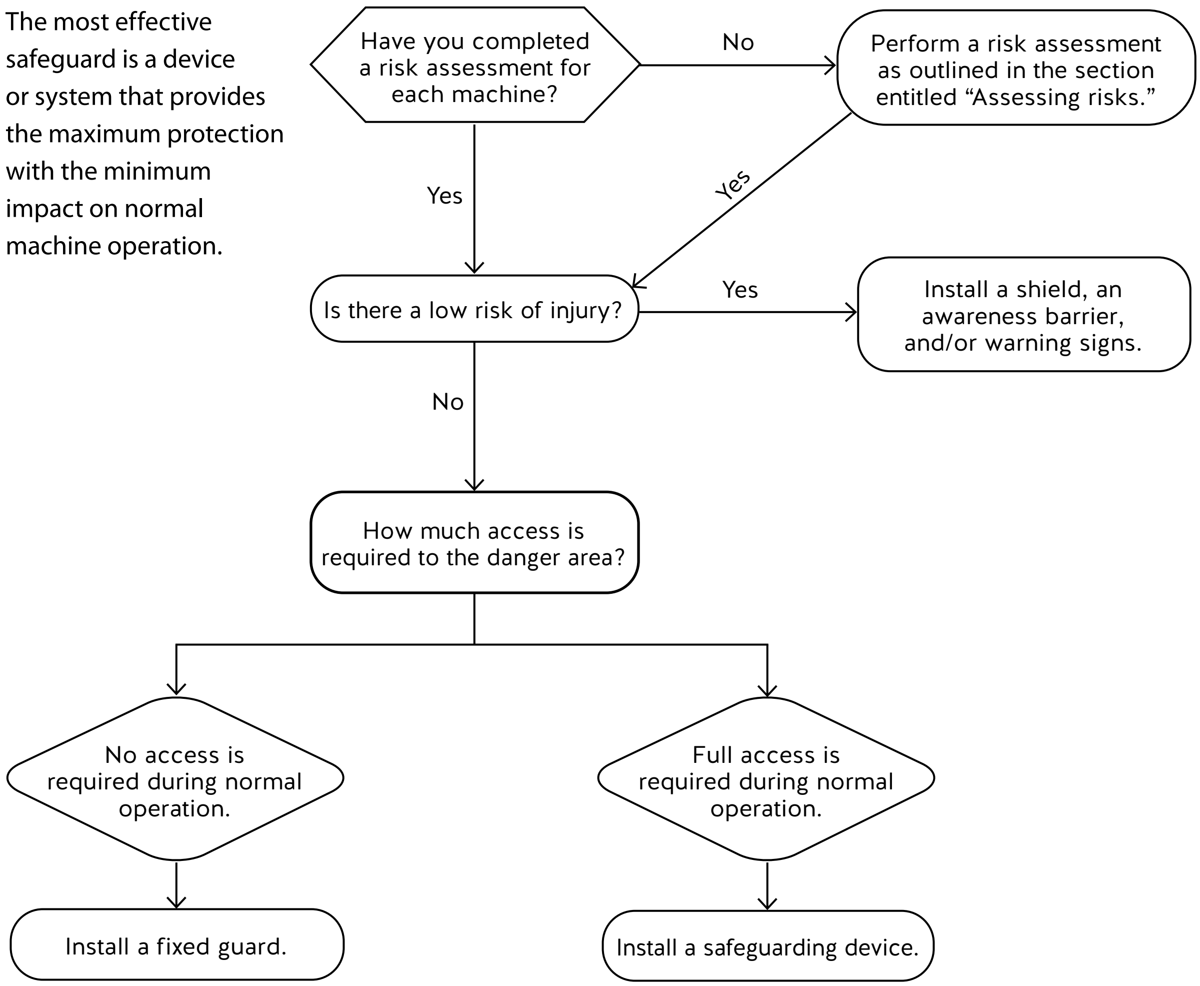


Figure 3.22. Selecting the right safeguard.

Table 3.4. Guide to selecting the right safeguard*

Type of safeguard	Typical applications	Action of safeguard	Advantages	Limitations
Physical guards				
Fixed power transmission guard	• V-belt drives • Chain sprocket drives • Motor couplings and power take-offs (PTOs) • Flywheels	• Completely prevents hands or body parts from entering the hazardous area	• Provides complete protection if kept in place • Easy to install	• May interfere with lubrication unless modified
Fixed point-of-operation guard	• Bread slicers • Meat grinders • Sheet metal shears • In-running nip points of rubber, paper, and textile rolls • Power presses	• A complete enclosure that admits feed stock or removal of finished product but will not allow hands into hazardous area	• Provides complete protection if kept in place • May leave both hands free • Suitable for any type of machine clutch (part or full revolution)	• Generally limited to flat feed stock • May require special tools to remove jammed stock • May interfere with visibility
Guard (hinged or sliding) with interlocking	• Most power presses • Balers or compactors • Foundry presses • Robotic systems	• Opening the guard will stop the machine • Machine will not start with guard open	• Leaves both hands free for feeding • Opening and closing of guard can be automatic	• Location of controls must comply with safety distance requirements • Depends on control reliability for safe functioning
Guard (hinged or sliding) with powered interlocking (guard locking)	• Foundry tumblers • Laundry extractors, dryers, and tumblers • Centrifuges • Paint mixers • Some dough and pastry mixers	• Machine will not start with guard open • Guard cannot be opened until machine movement is at complete rest	• Provides complete and positive enclosure until machine is at rest • Doesn't hold up production	• Requires careful adjustment and maintenance • May not function if there is an electrical or mechanical failure

* Ensure that your system-required performance device is at the level identified in your risk assessment.

Type of safeguard	Typical applications	Action of safeguard	Advantages	Limitations
Automatic or semiautomatic feed with point of operation enclosed	• Power press blanking operations • Coining and stamping machines • Drop chute chippers • Pastry machines	• Stock fed by mechanisms, such as chutes, hoppers, conveyors, rolls, or movable dies • Enclosure will not admit any body part	• Increases production • Workers cannot place hands in hazardous area	• High installation cost for short runs • May require skilled maintenance
Limited feed opening or slide travel	• Foot-powered shears • Some punch and brake presses	• Feed opening or machine travel is limited to 6 mm (¼ in.) or less • Fingers cannot enter hazardous area	• Provides positive protection • No maintenance or adjustment needed	• Small opening limits size of stock • Requires effective supervision and training
Safeguarding devices				
Two-hand controls	• Hand-fed power press operations • Hydraulic presses • Rebar formers • Tube benders • Paper guillotine shears	• Simultaneous activation of both controls initiates a machine cycle • Releasing either control during cycle causes machine to stop	• Forces both hands out of hazardous area • No interference with hand feeding • No adjustments required • Easy to install • Allows feeding and removal of complex parts not possible with a guard	• Location of controls must comply with safety distance requirements • Depends on control reliability for safe functioning • Hands not free to support feed stock • Hazards to workers other than operator must be safeguarded

Type of safeguard	Typical applications	Action of safeguard	Advantages	Limitations
Presence-sensing device: • **Light curtains** • **Radio frequency antennae** • **Pressure-sensitive mats**	• Brake presses • Part-revolution (air-clutch) presses only • Robotic systems	• When sensing field is interrupted, a stop signal is sent to quickly stop the machine	• Doesn't interfere with normal feeding or production • No obstruction on the machine or around the operator	• Expensive to install • Location of device must comply with safety distance requirements • Depends on control system reliability for safe functioning • Hazards to workers other than operator must be safeguarded • May require frequent adjustment and calibration
Limited machine movement devices ("jog," "inch," and "setup" modes)	• Printing presses • Power presses (during setup and maintenance)	• Provides operator or maintenance with a means to "inch" or "jog" machine movement during setup	• Gives operator and maintenance safe control over hazardous machine movement	• Can be hazardous if used during production mode on power presses (CSA Group standard *Z142-10 (R2014) - Code for power press operation: Health, safety, and safeguarding requirements* notes these must not be used for production purposes)

Type of safeguard	Typical applications	Action of safeguard	Advantages	Limitations
Self-adjusting feed guard	• Band saws • Table saws • Mitre saws • Circular hand saws • Jointers • Wood shapers • Large-capacity steel plate shears	• Barrier or enclosure will admit operator's hands but warn before hazardous area is reached	• Makes hard-to-guard machines safer • Generally doesn't interfere with production • Easy to install • Admits varying sizes of stock	• Protection not complete at all times — hands may enter hazardous area • Guard may be easily defeated • Choice of last resort
Emergency body-contact devices: • **Crash bar** • **Panic bar** • **Trip wire** • **Belly bar**	• Trim saws • Flat roll ironers • Calenders • Rubber mills • Platen presses • Conveyors • Wood chippers	• Without intentional movement, worker contacts the emergency stop device, which sends a stop signal to the machine	• Makes hard-to-guard machines safer • Doesn't interfere with production	• Requires proper installation and maintenance • Depends on control-system reliability for safe functioning • May require installation of a machine braking system
Passive worker restraint devices ("hold-backs")	• Horizontal-fed sawmill chippers • Soil auger feed points • Power press operations	• Worker is tethered by a safety belt and lanyard or by hand wristlets and fixed cables, and cannot access the hazardous area	• Easy to install • Inexpensive • Permits maximum hand feeding	• Can be difficult to supervise • Worker resistance (changing old habits) • Must be adjusted to individual operator

Type of safeguard	Typical applications	Action of safeguard	Advantages	Limitations
Active worker restraints ("pull-backs")	• Mechanical clutch power presses • Brake presses • Embossing presses	• A cable-operated attachment connected to the operator's hands pulls them back if they remain in the hazardous area	• Acts even if there is an accidental mechanical repeat • Easy to install • Adaptable to frequent die changes	• Requires effective supervision • Worker resistance (changing old habits) • Must be adjusted to individual operator and operation
Shields	• Lathe chucks • Milling machines • Drill presses • Machine tools	• Partial barriers contain liquids and flying chips or turnings	• Easy to install • Doesn't impede operation	• Provides limited protection against harmful contact with moving parts

Buying and setting up machinery

CSA Group standard *Z432-04 - Safeguarding of machinery, Clause 4.1.1 - New machinery* applies to newly manufactured and newly installed machinery, as well as rebuilt or redeployed machinery.

Communication between manufacturers and buyers is important when machinery is being purchased. Manufacturers and buyers both have responsibilities during the purchasing process.

If you are buying a machine, you have a responsibility to tell the manufacturer about your safety requirements and specifications. For example, tell the manufacturer how you will be using the machine, the conditions of operation, and the maintenance program you will be following.

For their part, manufacturers are responsible for assessing your specifications and ensuring machines will suit your needs, and that safeguarding is appropriate and effective. Before selling machines, manufacturers are responsible for performing risk assessments to identify potential hazards.

Suggestions for buying and setting up machinery

When buying and setting up machinery, whether it is new or used, you need to make sure it is safe before workers start using it. Always conduct a risk assessment for the machine before startup. In addition, consider the following:

- Ensure that a manufacturer's manual is available, as well as any necessary written instructions on how to operate the machine safely.
- Ensure there are no missing parts.
- Ensure that maintenance records are provided.
- Ensure that any modifications were performed as specified in the manufacturer's instructions or as specified by a professional engineer.
- Ensure that the controls on the machine are marked clearly.
- Ensure that there are E-stops for the machine capable of a start function at each workstation.
- Inspect the area around the machine. Ensure that there is sufficient space around the machine and there are no hazardous products nearby.
- When installing machinery, ensure that the machine and the work process don't create a hazard to others who work around or pass by the machine.

Suggestions for inspecting newly purchased machinery

When inspecting a newly purchased machine, consider the following:

- Are the manufacturer's instructions clear and comprehensive?
- Is the machinery complete?
- Are there any hazardous parts, such as exposed gears?
- Does the machine have guards? Are they in place?
- Will the machine still operate if the guards are removed?
- Are the controls easily understandable?
- Will the machine produce respiratory hazards?
- Will the machine produce excessive noise or vibration?
- Are there any exposed parts that will be extremely hot or cold?
- Are there any live electrical parts that are exposed or easy to access?
- Does the machine have any special features?

Appendices

Appendix 1: Safeguarding checklist

This checklist will help you inspect machines and equipment in your workplace. Please note that this checklist is only meant as a starting point. It doesn't include every item you may need to complete your safeguarding inspection. Add to this checklist as necessary to customize it for your specific workplace.

Requirements for safeguarding	Yes	No
• Could changes be made to the machine or process to eliminate the hazard entirely?	☐	☐
• Do the existing safeguards meet minimum regulatory requirements?	☐	☐
• Can the existing safeguards be made more effective?	☐	☐
• Does the safeguard prevent hands, arms, and other body parts from contacting hazardous moving parts?	☐	☐
• Does the machine stop when an interlocked guard is opened or removed?	☐	☐
• Is there a procedure for shutting down the machine before removing safeguards?	☐	☐
• Does the safeguard ensure that no objects will fall into the moving parts or contain any materials that may be ejected?	☐	☐
• Does the guard permit safe, comfortable, efficient, and relatively easy operation of the machine?	☐	☐
• Can the machine be lubricated without removing the guard?	☐	☐
• Is the guard firmly secured, requiring a tool to remove?	☐	☐
Mechanical hazards	**Yes**	**No**
Point of operation		
• Is a point-of-operation safeguard provided for the machine?	☐	☐
• Does the safeguard keep the operator from contacting the point of operation?	☐	☐
• Is there evidence that the safeguards have been tampered with or removed?	☐	☐
Power-transmission components		
• Are there any unguarded gears, sprockets, pulleys, or flywheels?	☐	☐
• Are there any exposed belts or chain drives?	☐	☐

• Are there any exposed set screws, keyways, collars, or rotating shafts?	☐	☐
• Are starting and stopping controls within easy reach of the operator?	☐	☐
• If there is more than one operator, does each operator have access to the machine controls?	☐	☐
Other moving parts		
• Are safeguards provided for all hazardous moving parts of the machine, including auxiliary parts?	☐	☐
Non-mechanical hazards	**Yes**	**No**
• Are workers safeguarded against noise levels?	☐	☐
• Have special guards, enclosures, or PPE been provided, where necessary, to protect workers from exposure to harmful substances used in machine operation?	☐	☐
Electrical hazards	**Yes**	**No**
• Is the machine installed as required by code?	☐	☐
• Is the machine properly grounded and bonded as required by code?	☐	☐
• Are the power supply and equipment correctly fused and protected?	☐	☐
Education and training	**Yes**	**No**
• Do all workers have the necessary education and training to use the safeguards?	☐	☐
• Does education include examples of how workers have been injured from lack of safeguarding?	☐	☐
• Have all workers been trained in where the safeguards are located, how they provide protection, and what hazards they protect against?	☐	☐
• Have all workers been trained in how and under what circumstances safeguards can be removed?	☐	☐
• Have all workers been instructed in the procedure to follow if they notice safeguards are damaged, missing, or inadequate?	☐	☐
• Do workers have the necessary qualifications to design, build, and install safeguarding?	☐	☐
• Does education include assessment of personal characteristics (e.g., long hair) that could pose a hazard with inadequately guarded machinery (e.g., long hair and rotating shafts)?	☐	☐

Personal protective equipment and clothing (PPE)	Yes	No
• Is PPE required for tasks identified in the operation and maintenance of the machine?	☐	☐
• Is PPE appropriate for the job, in good condition, kept clean and sanitary, and stored carefully when not in use?	☐	☐
• Is the operator dressed safely for the job (i.e., no loose-fitting clothing or jewellery)?	☐	☐
Machinery maintenance and repair	**Yes**	**No**
• Have qualified workers received up-to-date instructions on the machines they service?	☐	☐
• Have qualified workers been provided with the information, instruction, education, and training on de-energization and lockout for all energy sources before repairing or maintaining equipment?	☐	☐
• Are written lockout procedures in place as required by the Regulation before workers carry out a task?	☐	☐
• When several workers are working on the same machine, do they use readily available group lockout procedures developed by a qualified person and multiple lockout devices, as required by the procedure?	☐	☐
• Do workers use tools that are safe and appropriate for the task at hand?	☐	☐
Safety-control system (if applicable)	**Yes**	**No**
• Has the safety-control system been reviewed by a qualified person and determined to be compliant?	☐	☐
• Does the existing control system use safety-rated components that are compliant, such as safety-monitoring relays, force-guided relays, or a safety-rated PLC?	☐	☐
• Has the safety-control system been reviewed for compliance with the required level of reliability?	☐	☐
• Do operators have access to machine starting and stopping controls?	☐	☐

Appendix 2: Standards in the OHS Regulation

The Regulation requires employers to follow the requirements of the standards listed in the following table.

Type of equipment	Standards referred to in the Regulation
Abrasive equipment	• ANSI standard *B7.1 - The use, care, and protection of abrasive wheels*
Automotive lifts and supports	• ANSI standard *ANSI/ALI B153.1 - American national standard for automotive lifts - Safety requirements for the construction, care, and use* • ANSI standard *ASME PALD - Safety standard for portable automotive lifting devices*
Chain saws	• CSA Group standard *Z62.1-15 - Chain saws*
Control systems — general requirements	• ISO standard *13849 - Safety of machinery - Safety-related parts of control systems*
Conveyors (all types)	• ANSI standard *ASME B20.1 - Safety standards for conveyors and related equipment*
General machinery safeguarding	• CSA Group standard *Z432 - Safeguarding of machinery*
Industrial robots	• CSA Group standard *CAN/CSA-Z434 - Industrial robots and robot systems* • ANSI standard *ANSI/RIA R15.06 - Industrial robots and robot systems - safety requirements*
Iron workers	• ANSI standard *B11.5 - American national standard for machine tools - Ironworkers - Safety requirements for construction, care and use*
Marking physical hazards	• CGSB standard *CAN/CGSB-24.3-92 - Identification of piping systems* • CSA Group standard *CAN/CSA-Z321-96 - Signs and symbols for the workplace* • ANSI standard *Z535.1 (R2011) - Safety colors* • ANSI standard *Z535.2-2011 - Environmental and facility safety signs* • ISO standard *3864-1:2011 - Graphical symbols - Safety colours and safety signs (Part 1: Design principles for safety signs and safety markings)* • ISO standard *3864-2:2016 - Graphical symbols - Safety colours and safety signs (Part 2: Design principles for product safety labels)*
Power-actuated tools	• ANSI standard *A10.3 - American national standard for construction and demolition operations - Safety requirements for power-actuated fastening systems*

Type of equipment	Standards referred to in the Regulation
Power presses and brake presses	• CSA Group standard *Z142 - Code for power press operation: Health, safety, and safeguarding requirements*
Sheet metal and plate shears	• ANSI standard *B11.4 - American national standard for machine tools - Safety requirements for shears*
Welding	• CSA Group standard *CAN/CSA-W117.2-2012 - Safety in welding, cutting, and allied processes*

Industry associations and other organizations have developed many other machine-safety standards. Although such standards are not referred to in the Regulation, they provide specific guidance for safeguarding nearly any type of manufacturing equipment or industrial process. You can find machine safety standards at worksafebc.com.

Other resources

For more information, visit worksafebc.com and search for "guarding."

Appendix 3: Safeguarding risk assessment tables

The general risk assessment process is conducted to determine the appropriate level of control for the hazard. The higher the risk, the higher the level of control required. In the hierarchy of controls, engineering controls are the third-highest level of control, after elimination and substitution. An engineering control may include a safeguarding device.

Safeguarding devices are designed and configured to be used in appropriately designed and integrated systems to meet certain levels of risk. Once it has been determined that an engineering control such as a safeguarding device, or "safety-related part of a control system" (SRP/CS), is the appropriate safeguarding option, the next step is to evaluate the SRP/CS and the architecture (design) of the control system (CS) that supports this device, to ensure that it will provide the appropriate protection for the level of risk. This is an important step because the safeguarding device is only as effective as its design and integration into the machine, equipment, or process. When control of the risk is so dependent upon the SRP/CS, the design of the SRP/CS must provide sufficient reliability to resist faults that could cause the system to fail.

An SRP/CS is part of a control system that responds to safety-related input signals and generates safety-related output signals.

> **Note 1:** The combined safety-related parts of a control system start at the point where the safety-related input signals are initiated (including, for example, the actuating cam and the roller of the position switch) and end at the output of the power-control elements (including, for example, the main contacts of a contactor).
>
> **Note 2:** If monitoring systems are used for diagnostics, they are also considered as SRP/CS.*

In discussions of safeguarding, many definitions are used to explain similar concepts. You may encounter these different definitions from various standards as part of the process of a safeguarding risk assessment. The tables in this appendix illustrate how the different definitions relate to each other as part of the risk assessment process and required control measures.

* *ISO 13849-1, Clause 3.1.1, Safety-related part of a control system.*

Safeguarding standards

In the following pages, references are made to standards produced by different organizations. The purpose, concept, and information provided by these standards are very similar. The tables on the following pages show similar provisions in the pertinent standards.

CSA Group standard *Z432, Safeguarding of machinery*

The Canadian Standards Association (CSA) is a non-profit organization made up of representatives from industry, government, and consumer groups. *CSA Z432-16* assigns responsibilities for machinery safety to manufacturers, integrators and installers, and users. It applies to the protection of persons from hazards arising from the use of mobile or stationary machinery. It specifies the criteria to be met and describes the selection and application of guards and safety devices. This standard is intended for those who design, modify, install, use, operate, or maintain machinery, machinery guarding, or safety devices.

ISO standard *13849-1, Safety of machinery – Safety-related parts of control systems – Part 1: General principles for design*

The International Standards Organization (ISO) is an independent, non-governmental organization made up of members from the national standards bodies of 163 countries. *ISO 13849-1* provides safety requirements and guidance on the principles for the design and integration of safety-related parts of control systems. It specifies the performance level required for carrying out safety functions, and provides for risk estimation/risk reduction and identification of hazards, including the severity of possible harm. It applies to SRP/CS for high-demand and continuous mode, regardless of the type of technology and energy used (for example, electrical, hydraulic, pneumatic, or mechanical), for all kinds of machinery.

ANSI standard *B11.TR3, Risk assessment and risk reduction – A guideline to estimate, evaluate and reduce risks associated with machine tools*

The American National Standards Institute (ANSI) is a non-profit, voluntary organization that develops its guidelines and procedures based on a national consensus process. The purpose of the *ANSI B11* series of machine tool safety standards is to devise and propose ways to minimize risk associated with existing and potential hazards.

Permission to use extracts from ISO standard *13849-1:2015* and ISO standard *12100:2010* was provided by the Standards Council of Canada (SCC). No further reproduction is permitted without prior written approval from SCC.

Comité Européen de Normalisation (CEN), or European Committee for Standardization

CEN is a public standards organization whose mission is to foster the economy of the European Union in global trading, the welfare of European citizens, and the environment by providing an efficient infrastructure to interested parties for the development, maintenance, and distribution of coherent sets of standards and specifications.

Hierarchy of controls merged with CSA Group standard *Z432* and ISO standard *13849* — Simple

Table 1 compares the requirements of CSA Group standard *Z432 - Safeguarding of machinery* and ISO standard *13849 - Safety of machinery - Safety-related parts of control systems,* and shows the relationship of these standards to the hierarchy of safeguarding controls presented in CSA Group standard *Z432.*

The standards use different definitions to address similar issues. *CSA Z432* is the standard that must be followed in the assessment of risk and in determining the appropriate level of safeguarding for a machine or piece of equipment. *ISO 13849-1:2006* is referenced in *CSA Z432.*

Table 1 harmonizes the different approaches used by *CSA Z432* and *ISO 13849* to determine the required safeguarding control. It compares the high-level risk assessment process of *CSA Z432* to *ISO 13849* and shows the relationship of these standards to the hierarchy of controls found in *CSA Z432.* By following from “Start” in the first column and progressing through the risk assessment process, you will arrive at the appropriate type of safeguarding control for different combinations of severity of injury, duration and frequency of exposure to a hazard, possibility of avoiding a hazard, and performance level (PL) required for the safeguarding control.

Table 1. Hierarchy of controls based on criteria found in CSA Group standard *Z432* and ISO standard *13849-1*

<table>
<tr><td rowspan="10">Start</td><td>Severity of injury[1]</td><td colspan="2">Exposure (CSA) Frequency[1] (ISO)</td><td colspan="2">Avoidance (CSA) Possibility[1] (ISO)</td><td>Engineering PLr[2] ISO 13849-1</td><td>Hierarchy of safeguarding controls (refer to table 5.1)[3] CSA Z432-16</td></tr>
<tr><td></td><td>CSA Z432-04</td><td>ISO 13849-1</td><td>CSA Z432-04</td><td>ISO 13849-1</td><td colspan="2"></td></tr>
<tr><td rowspan="4">S2</td><td rowspan="2">E2</td><td rowspan="2">F2</td><td>A2</td><td>P2</td><td>PL e</td><td rowspan="8">Generally greater risk and therefore higher required PL will necessitate a safeguarding solution higher in the hierarchy of controls.
• Hazard elimination
• Substituting other material, process, or equipment
• Engineering controls
• Systems that increase awareness of potential hazards
• Administrative controls
• Personal protective equipment (PPE)</td></tr>
<tr><td>A1</td><td>P1</td><td rowspan="2">PL d</td></tr>
<tr><td rowspan="2">E1</td><td rowspan="2">F1</td><td>A2</td><td>P2</td></tr>
<tr><td>A1</td><td>P1</td><td rowspan="2">PL c</td></tr>
<tr><td rowspan="4">S1</td><td rowspan="2">E2</td><td rowspan="2">F2</td><td>A2</td><td>P2</td></tr>
<tr><td>A1</td><td>P1</td><td rowspan="2">PL b</td></tr>
<tr><td rowspan="2">E1</td><td rowspan="2">F1</td><td>A2</td><td>P2</td></tr>
<tr><td>A1</td><td>P1</td><td>PL a</td></tr>
</table>

PL is applicable only to ISO standard *13849-1*, and the hierarchy of safeguarding controls is applicable to CSA Group standard *Z432-16*. Implemented safeguarding solutions should be validated as per the requirements set forth in ISO standard *13849-2-2012*. Note that PLr can only be loosely linked to the hierarchy of safeguarding controls since PL defines the required performance of the SRP/CS, which is an engineering control. PLr can be more directly correlated with options within the category of engineering controls.

There is no intent to imply that this is other than a general comparison and not a detailed analysis between performance level and the hierarchy of controls (CSA).

1 The table found in note 1 to table 2 is also relevant to this table. It shows the definitions of the different categories of severity of injury, exposure/frequency, and avoidance/possibility used in CSA Group standard *Z432-04* and ISO standard *13849-1*.

2 Performance level (PL) is determined by the structure (category) and enhancements (mean time to dangerous failure [MTTFd], diagnostic coverage [DC], and common cause failure [CCF]). For more details, see table 3 and figure 1 (machinery categories), and note 4 to table 2. PL is mentioned only in ISO standard *13849-1*.

3 Although it parallels the risk reduction process described in ISO standard *12100:2010* (which specifies basic terminology, principles, and a methodology for achieving safety in the design of machinery), the hierarchy of safeguarding controls is mentioned only in CSA Group standard *Z432-16*. For more details on how they relate to other standards, see table 3 and figure 1. Implemented safeguarding solutions should be validated as per the requirements set forth in another standard: ISO standard *13849-2*.

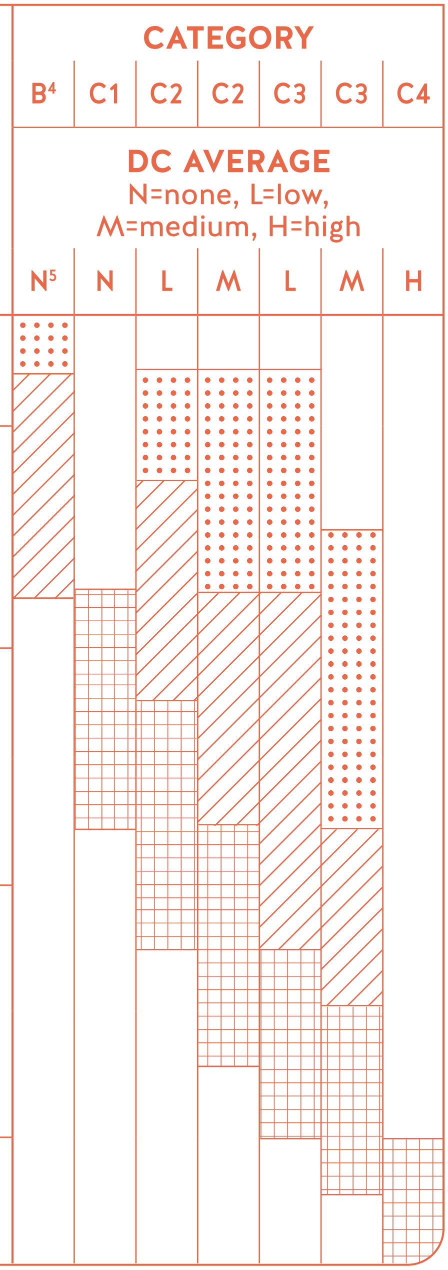
Safeguarding performance level comparisons

Table 2 adds detailed information regarding the safeguarding performance levels shown in the "PLr" (determination of required performance level) column in table 1. As you work through the columns from left to right (using the information from the risk assessment — severity of injury, exposure/frequency, and avoidance/possibility), you can use the risk index to determine the performance required of the safeguard, the control system, and the supporting architecture (design). The performance and reliability of the system as a whole must match the assessed risk.

Note that in tables 1 and 2, severity of injury, exposure/frequency, and avoidance are shown in reverse order. This is because the other columns in table 1 are shown from most effective to least effective, whereas the other columns in table 2 are reversed (least effective to most effective).

Table 2. The risk assessment process and its relationship to required circuit performance of safety-related parts of the control system

	Severity of injury[1]	Exposure (CSA)[1]	*Frequency (ISO)*[1]	Avoidance (CSA)[1]	*Possibility (ISO)*[1]	Circuit performance[2]	PLr[3]
Start	S1	E1	*F1*	A1	*P1*	Simple	PL a
				A2	*P2*		PL b
		E2	*F2*	A1	*P1*	Single channel	
				A2	*P2*		PL c
	S2	E1	*F1*	A1	*P1*	Single channel with monitoring	
				A2	*P2*	Control reliable	PL d
		E2	*F2*	A1	*P1*		
				A2	*P2*		PL e



Mean time to dangerous failure (MTTFd): Low Medium High

Note: Regular text = CSA Group standard *Z432-04 - Safeguaring of machinery*; italicized text = ISO standard *13849-1 - Safety of machinery - Safety-related parts of control systems*. There is no intent to imply that this is other than a general comparison and not a detailed analysis between performance level and the hierarchy of controls (CSA). For an overview of the risk assessment process, please see page 20.

1 The following table shows the definitions of the different categories of severity of injury, exposure/frequency, and avoidance/possibility used in CSA Group standard *Z432-04 - Safeguarding of machinery* and ISO standard *13849-1 - Safety of machinery - Safety-related parts of control systems.*

Definitions from ISO standard *13849-1*			**Definitions from CSA Group standard *Z432-04***		
Severity of injury	S1	Slight (normally reversible injury)	Severity of injury	S1	Slight injury; normally reversible; only first aid
	S2	Serious (normally irreversible injury or death)		S2	Serious injury; more than first aid
Frequency and/or exposure to hazard	F1	Seldom-to-less-often and/or exposure time is short	Exposure	E1	Infrequent exposure
	F2	Frequent-to-continuous and/or exposure time is long		E2	Frequent exposure
Possibility of avoiding hazard or limiting harm	P1	Possible under specific conditions	Avoidance	A1	Likely
	P2	Scarcely possible		A2	Not likely

2 Safety control system performance criteria, as specified in *CSA Z432-04*.

3 Performance level (PLr), defined in *ISO 13849-1,* is a discrete level used to specify the ability of safety-related parts of control systems to perform a safety function under foreseeable conditions. Performance level is determined by the structure (category) and enhancements (MTTFd), diagnostic coverage (DC), and common cause failure (CCF) of a safeguard or protective device and is generally considered as:

PL = category + MTTFd + DC + CCF

where:

MTTFd = expectation of the mean time to dangerous failure (see table below)

DC = diagnostic coverage, a measure of the effectiveness of diagnostics (see table below)

CCF = reliability of the entire safety-related control system in terms of foreseeable common cause failures

Mean time to dangerous failure (MTTFd)

Fill		Range of each channel
	Low	3 years ≤ MTTFd < 10 years
	Medium	10 years ≤ MTTFd < 30 years
	High	30 years ≤ MTTFd ≤ 100 years

Diagnostic coverage

Denotation	Range
None	DC < 60%
Low	60% ≤ DC < 90%
Medium	90% ≤ DC < 99%
High	99% ≤ DC

4 CEN/ISO machinery categories. For more details see table 3.

5 Diagnostic coverage. For more details, see table in note 3 above.

Supporting information for tables 1 and 2

Table 3. Safeguarding selection matrix (adapted from CSA Group standard *Z432-04 - Safeguarding of machinery*)

	Severity of injury	Exposure	Avoidance	Safeguard performance	Circuit performance[1]	European category
Start	Serious	Frequent	Not likely	Hazard elimination or hazard substitution	Control reliable	3 and 4
			Likely	Engineering controls preventing access to the hazard or stopping the hazard (e.g., fixed guards, interlocked guards, light curtains, safety mats, or other pressure-sensing devices)	Control reliable	3 and 4
		Infrequent	Not likely		Control reliable	3 and 4
			Likely		Single channel with monitoring	2
	Slight	Frequent	Not likely		Single channel	1
			Likely	Non-interlocked barriers, clearance, procedures, and equipment	Single channel	1
		Infrequent	Not likely		Simple	B
			Likely	Awareness means	Simple	B

Note: There is no intent to imply that circuit performance classifications are equivalent to ISO standard *13849-1*.

1 For more details, see table 5.

Table 4. Example descriptions of risk factor categories (CSA Group standard *Z432-04 - Safeguarding of machinery*)

Factor	Category		Criteria
Severity	S2	Serious injury	Fatality, irreversible injury, loss of consciousness, loss of sight, limb amputation, severe laceration, or broken bone.
	S1	Slight injury	Normally reversible, or requires only first-aid treatment.
Exposure	E2	Frequent exposure	Typically, exposure to the hazard more than once per hour.
	E1	Infrequent exposure	Typically, exposure to the hazard less than once per day or shift.
Avoidance	A2	Not likely	Cannot move out of the way; or inadequate reaction time; or machine speed greater than 250 mm/s.
	A1	Likely	Can move out of the way; or sufficient warning/reaction time; or machine speed less than 250 mm/s.

Table 5 summarizes the circuit performance requirements under CSA Group standard *Z432-04* for different control systems that may be used in safety devices. For a summary of the relationship between circuit performance and type of control required based on severity, exposure, and avoidance (likelihood), see table 3.

Table 5. Safety control system performance criteria (adapted from CSA Group standard *Z432-04 - Safeguarding of machinery*)

Safety control system	Performance criteria
Simple	Simple safety control systems shall be designed and constructed using accepted single channel circuitry and may be programmable. **Note:** This type of system should be used for signalling and annunciation purposes only.
Single channel	Single channel safety control systems shall: (a) be hardware based or comply with Clause 8.3; (b) include components, which should be safety rated; and (c) be used in compliance with manufacturer's recommendations and proven circuit designs (e.g., a single channel electro-mechanical positive break device that signals a stop in a de-energized state). **Note:** In this type of system, a single component failure can lead to the loss of the safety function.
Single channel with monitoring	Single channel safety control systems with monitoring shall: (a) include the requirements for single channel; (b) be safety rated; and (c) be checked (preferably automatically) at suitable intervals. The check of the safety function(s) shall be performed: (a) at machine startup; and (b) periodically during operation (preferably at each change in state). The check shall either allow operation if no faults have been detected or generate a stop if a fault is detected. A warning shall be provided if a hazard remains after cessation of motion. The check itself shall not cause a hazardous situation. Following detection of a fault, a safe state shall be maintained until the fault is cleared. **Note:** In this type of system, a single component failure may also lead to the loss of the safety function.
Control reliable	Control reliable safety control systems shall be dual channel with monitoring. Such systems shall be designed, constructed, and applied such that any single component failure (including monitoring) shall not prevent the stopping action of the equipment. These safety control systems shall be hardware based or comply with Clause 8.3 and include automatic monitoring at the system level conforming to the following: (a) The monitoring shall generate a stop if a fault is detected. A warning shall be provided if a hazard remains after cessation of motion. (b) Following detection of a fault, a safe state shall be maintained until the fault is cleared. (c) Common mode failures shall be taken into account when the probability of such a failure occurring is significant. (d) The single fault should be detected at time of failure. If not practicable, the failure shall be detected at the next demand upon the safety function. (e) These safety control systems shall be independent of the normal program control (function) and shall be designed to be not easily defeated nor easily bypassed without detection.

Designated architecture for categories B and 1–4

ISO standard *13849-1* states in section 6.2.2:

> The structure of a SRP/CS is a key characteristic having great influence on the performance level (PL). Even if the variety of possible structures is high, the basic concepts are often similar. Thus, most structures which are present in the machinery field can be mapped to one of the categories. For each category, a typical representation as a safety-related block diagram can be made. These typical realizations are called designated architectures and are listed in the context of each of the following categories.

The following diagrams from CSA Group standard *Z432-16 - Safeguarding of machinery* show the design of the architecture for the machine categories and information shown in tables 2, 3, and 5. These diagrams are for use by the designer/integrator of the machine or safeguarding device.

Figure 1. Designated architecture for categories B and 1–4

Figure 8.1 Designated architecture for category B
(See Clause 8.2.2.1)

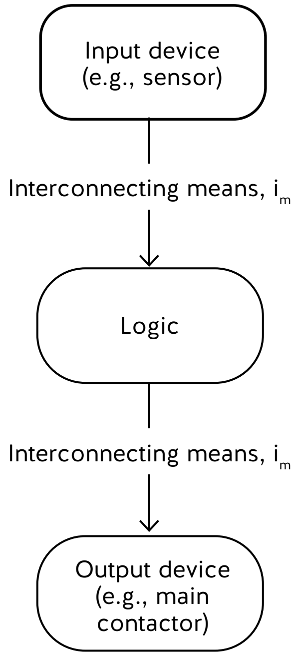


Figure 8.2 Designated architecture for category 1
(See Clause 8.2.2.1)

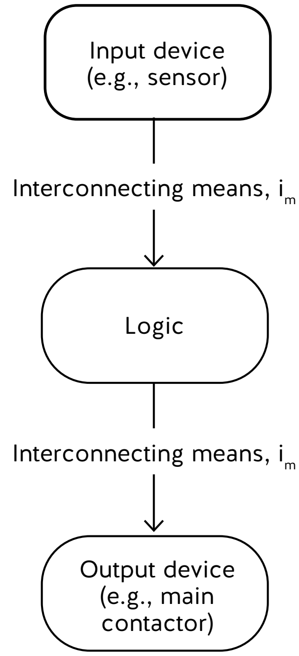


Figure 8.3 Designated architecture for category 2
(See Clause 8.2.2.1)

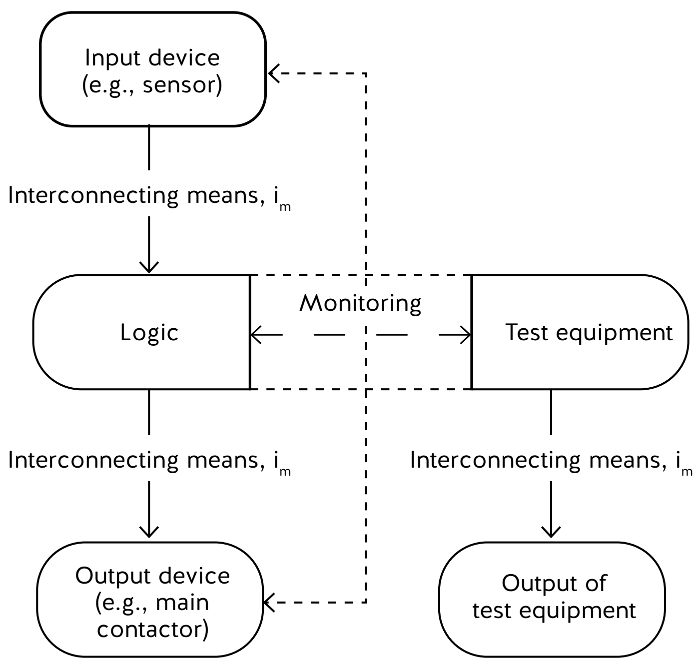


Figure 8.4 Designated architecture for category 3
(See Clause 8.2.2.1)

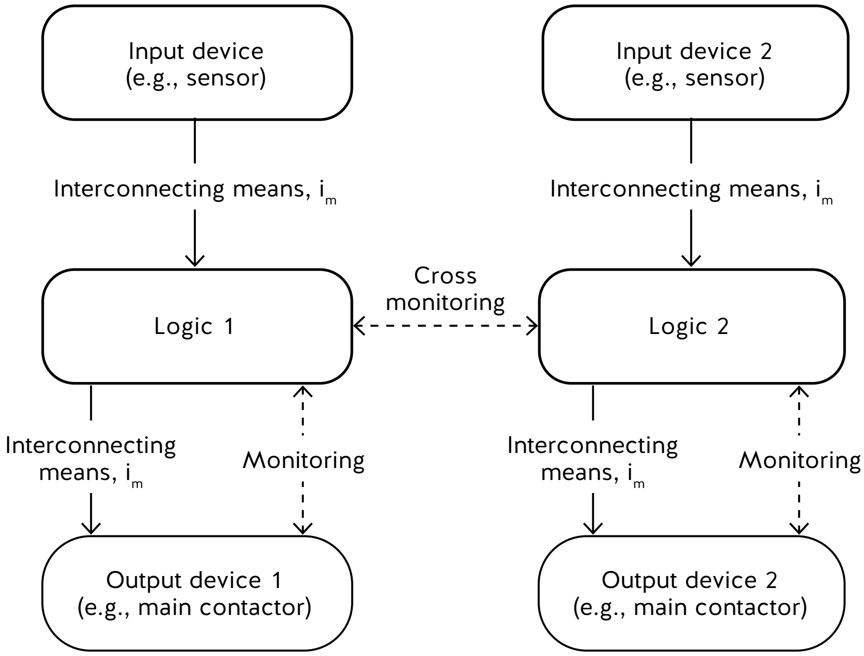
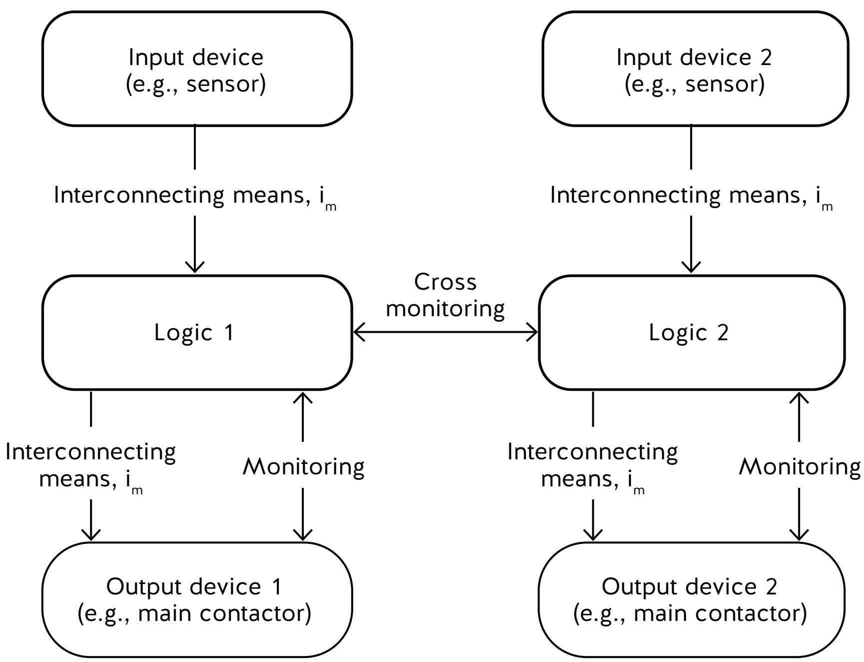
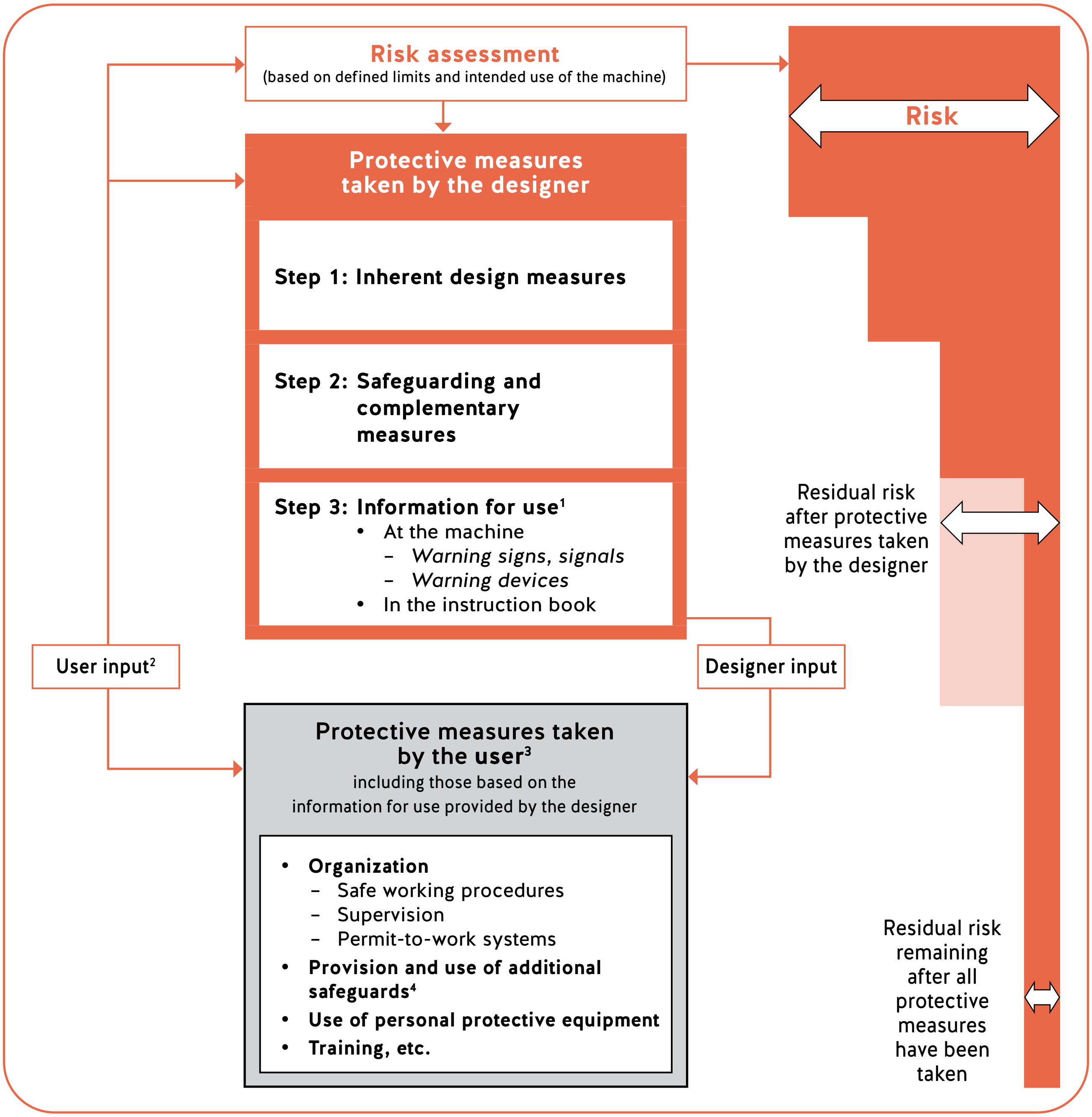


Figure 8.5 Designated architecture for category 4
(See Clause 8.2.2.1)



Note: Solid lines for monitoring represent diagnostic coverage that is higher than in the designated architecture for category 3.

Figure 2. Risk assessment process



1 Providing proper information for use is part of the designer's contribution to risk reduction, but the protective measures concerned are only effective when implemented by the user.

2 User input is that information received by the designer from either the user community regarding the intended use of the machine in general or that which is received from a specific user.

3 There is no hierarchy between the various protective measures taken by the user. These protective measures are outside the scope of this standard.

4 Those protective measures required due to specific process(es) not envisaged in the intended use of the machine or to specific conditions for installation that cannot be controlled by the designer.

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