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Design and Selection Criteria for Safeguards
Design and Selection Criteria for Safeguards

What is a safeguard?

A safeguard is a solution or a combination of solutions that eliminate or reduce the risk of exposure to hazardous moving parts or other harmful conditions. Safeguards range from fixed barrier guards (most effective) and safeguarding devices to safe work procedures and personal protective equipment (least effective) (see the hierarchy of safeguarding solutions on page 18). A comprehensive risk assessment will determine which safeguards are most effective.

Classification of safeguards

There are six general ways to safeguard machinery and equipment:

- Barrier guards
- Safeguarding devices
- Location
- Awareness means
- Training and procedures
- Personal protective equipment

Barrier guards

Properly designed and installed barrier guards provide the most effective protection to workers. Fixed barrier guards are the first choice of engineering control to keep workers from contacting hazardous moving parts or to contain harmful fluids and projectiles, particularly when access is not normally required during operation. Fixed barrier guards must be secured with at least one fastener requiring a tool for removal.

When a barrier guard must be moved aside to enable a worker to access a point of operation or feed point during normal production work, the guard must be interlocked to disable the control system until the guard is put back in place and the control system is reset. Some barrier guards are adjustable to allow materials of varying thickness to be fed into a machine. Some guards are attached to the tooling or dies that fit into a machine. These are a special type of barrier guard called die enclosure guards.

A common requirement of all barrier guards is that they physically prevent a worker from reaching around, over, under, and through the guard to the danger area. Unless interlocked with the control system, a barrier guard must be secured with at least one fastener requiring a tool for removal.
Safeguarding devices

Access to feed points and ejection of formed parts is often required during normal machine operation. This may make the use of a fixed barrier guard, or even an interlocked guard, impracticable. Fortunately there are a number of safeguarding devices that can provide a high level of protection to workers.

These devices generally operate in one or a combination of ways:

- Requiring the operator to remove his or her hands or entire body from the danger area before the machine can be cycled. **Two-hand controls** and **interlocked gate guards** function this way.

- Stopping the machine if the operator or another worker enters the danger area while the machine is cycling. **Presence-sensing devices** such as **light curtains** and **photoelectric devices** and **pressure-sensitive mats** function this way. These devices depend for their effectiveness on a very reliable braking system and associated control system.

- Physically restraining the operator from reaching into the danger area of the machine at any time. This can be done through the use of a **restraint device** such as a safety belt and lanyard.

- Involuntary tripping or activation of an **emergency stop device** if all or part of a worker’s body approaches or enters the danger area. Examples include a “crash bar” or “belly bar” in front of a trim saw in-feed lug chain; the emergency contact bar in front of the in-running feed rolls of a flatwork ironer; and the emergency trip wire installed along a conveyor system.

- Limiting machine movement or travel to a safe range or speed. Examples include operating the machine in a “jog,” “inch,” or “setup” mode, activated by special control buttons (printing presses); limiting die movement to 6 mm (inch) or less before a piece can be inserted into the dies; 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. Examples include a foot control fastened to the floor a safe distance from the machine (called “captive” or “hostage” control); the activating control for an X-ray machine located in an isolated room.

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

To view relevant WorkSafeBC Hazard Alerts, go to WorkSafeBC.com, click “Find a hazard alert poster” under Safety at Work, then click “Guarding” under Topic.
“Hold-to-run controls,” which require the operator to keep the control activated in order for the machine to continue to operate (also known as “deadman” or “operator-maintained” controls).

“Captive key systems,” which use a series of keys and locks to start or shut down a hazardous operation in a prescribed and safe sequence.

**Safeguarded by location**

Machinery may be safeguarded by location if the distance to dangerous moving parts is greater than 2.4 metres (8 feet) from any floor, walkway, access platform, or service ladder. Any work on the machine must be performed using lockout.

**Warning devices**

Some machine hazards cannot be practicably safeguarded using the methods described above. In these cases, less effective means may have to be used to minimize or reduce the danger to workers. These may include such devices as splash shields; flashing lights, strobes, and beacons; audible warning devices such as beepers, horns, and sirens; warning signs, decals, and barrier chains and ropes to restrict access. You will need to consider the work environment and layout to determine whether these measures will be effective.

**Training, supervision, and procedures**

Also known as administrative controls, training, supervision, and procedures are near the low end of the hierarchy of protection because their effectiveness depends on human factors such as adequate training and supervision. Lockout is an example of such a procedure.

**Personal protective equipment**

Personal protective equipment may have to be used even when other machine hazards are effectively safeguarded. In some cases, such as operating a powered forging hammer, the only protection available to the operator, besides training and safe work procedures, may be eye and face protection, hearing protection, and hand protection.
Barrier guards

Typical barrier guards

Figures 3.1 to 3.3 show examples of typical barrier guards.

Figure 3.1. Fixed power transmission guard.

Figure 3.2. Adjustable guards. (A) Adjustable band saw guard. (B) Adjustable power press feed guard.
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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. A left-handed person often has difficulty operating a handheld circular saw.

**Design and performance requirements for barrier guards**

Barrier guards are the preferred means of safeguarding when access is **not** required during normal operation.

Fixed barrier guards **must**:

- Prevent access to the danger area from all directions (AUTO: around, under, through, over)
- Not create additional pinch points or other hazards
- Safely contain broken parts (such as belts and chains).
- Be secured by at least one fastener requiring a tool for removal, unless properly interlocked with the machine control system
- Allow for safe lubrication and minor adjustments

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**AUTO –**

Fixed barrier guards must be designed to prevent access to the danger areas by reaching:
- **Around**
- **Under**
- **Through**
- **Over**
Fixed barrier guards should:
- Offer good visibility to feed points
- Stand up to normal wear and tear
- Meet normal production and quality needs
- Be 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 any person from reaching through the openings and contacting the danger point. 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 danger point is illustrated in Figure 3.4.

<table>
<thead>
<tr>
<th>Fingertip</th>
<th>Finger</th>
<th>Hand to Ball of Thumb</th>
<th>Arm to Armpit</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Diagram" /></td>
<td><img src="image2.png" alt="Diagram" /></td>
<td><img src="image3.png" alt="Diagram" /></td>
<td><img src="image4.png" alt="Diagram" /></td>
</tr>
</tbody>
</table>

**Table:**

<table>
<thead>
<tr>
<th>Opening Size (mm)</th>
<th>Minimum Distance (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4-8</td>
<td>15</td>
</tr>
<tr>
<td>8-12</td>
<td>80</td>
</tr>
<tr>
<td>12-20</td>
<td>120</td>
</tr>
<tr>
<td>20-30</td>
<td>200</td>
</tr>
<tr>
<td>30-150</td>
<td>850</td>
</tr>
</tbody>
</table>

If $a$ is between $4$ and $8$ mm ($\frac{3}{8}$ and $\frac{3}{8}$ in), then $b$ must be at least $15$ mm ($\frac{5}{8}$ in).

If $a$ is between $8$ and $12$ mm ($\frac{5}{8}$ and $1\frac{1}{2}$ in), then $b$ must be at least $80$ mm ($3\frac{1}{8}$ in).

If $a$ is between $12$ and $20$ mm ($1\frac{1}{2}$ and $\frac{3}{4}$ in), then $b$ must be at least $120$ mm ($4\frac{3}{8}$ in).

If $a$ is between $20$ and $30$ mm ($3\frac{1}{8}$ and $1\frac{1}{8}$ in), then $b$ must be at least $200$ mm ($7\frac{3}{8}$ in).

If $a$ is between $30$ and $150$ mm ($1\frac{1}{16}$ and $6$ in), then $b$ must be at least $850$ mm ($33\frac{3}{8}$ in).

$a =$ vertical dimension of the guard opening

$b =$ distance from the nearest danger point inside the guard

**Figure 3.4.** Relationship between size of opening in a grid guard and distance to the danger point.
**Point-of-operation (feed) 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 danger point. Table 3.1 and Figure 3.5 give 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.

<table>
<thead>
<tr>
<th>Barrier opening size (smallest dimension)</th>
<th>Minimum distance from hazard</th>
</tr>
</thead>
<tbody>
<tr>
<td>mm</td>
<td>Slotted opening</td>
</tr>
<tr>
<td>6.1 – 11.0</td>
<td>¼ – ⅝</td>
</tr>
<tr>
<td>11.1 – 16.0</td>
<td>⅞ – ⅞</td>
</tr>
<tr>
<td>16.1 – 32.0</td>
<td>⅞ – 1⅛</td>
</tr>
<tr>
<td>32.1 – 49.0</td>
<td>1¼ – 2</td>
</tr>
<tr>
<td>49.1 – 132.0</td>
<td>2 – 5</td>
</tr>
</tbody>
</table>

Figure 3.5. Visual representation of Table 3.1.
Perimeter fences and rail enclosures: reach distances to moving parts

For **low- and medium-risk** situations, a perimeter fence or rail enclosure can be used to effectively protect a worker from contacting hazardous machine parts. Where possible, a perimeter fence or rail enclosure should be at least 1.8 metres (6 feet) high. If this is not practicable, the reach distance from the guardrail or perimeter fence to the danger point must be in accordance with Figure 3.6 and Table 3.2. For example, if the height of the danger zone (A) is 1,400 mm (55 inches) and its horizontal distance (C) from the proposed protective barrier is 1,000 mm (40 inches), the height of the protective barrier (B) must be at least 1,120 mm (44 inches).

**Figure 3.6. Factors to consider in designing a protective barrier: A = height of the danger zone,**

\[ B = \text{height of the protective barrier}, \quad C = \text{horizontal distance to the danger zone}. \]

**Table 3.2. Recommended height of protective barriers based on distance to hazard.**
### Design and Selection Criteria for Safeguards

#### Height of fixed barrier or protective structure (B), mm (in)

<table>
<thead>
<tr>
<th>Height of danger zone (A), mm (in)</th>
<th>1000 (40)</th>
<th>1120 (44)</th>
<th>1400 (55)</th>
<th>1600 (63)</th>
<th>1800 (71)</th>
<th>2000 (78)</th>
<th>2200 (86)</th>
<th>2400 (94)</th>
<th>2500 (98)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2500 (98)</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>2400 (94)</td>
<td>100 (4)</td>
<td>100 (4)</td>
<td>100 (4)</td>
<td>100 (4)</td>
<td>100 (4)</td>
<td>100 (4)</td>
<td>100 (4)</td>
<td>100 (4)</td>
<td>–</td>
</tr>
<tr>
<td>2200 (86)</td>
<td>600 (24)</td>
<td>600 (24)</td>
<td>500 (20)</td>
<td>500 (20)</td>
<td>400 (16)</td>
<td>350 (14)</td>
<td>250 (10)</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>2000 (78)</td>
<td>1100 (43)</td>
<td>900 (36)</td>
<td>700 (28)</td>
<td>600 (24)</td>
<td>500 (20)</td>
<td>350 (14)</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>1800 (71)</td>
<td>1100 (43)</td>
<td>1000 (40)</td>
<td>900 (36)</td>
<td>900 (36)</td>
<td>600 (24)</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>1600 (63)</td>
<td>1300 (51)</td>
<td>1000 (40)</td>
<td>900 (36)</td>
<td>900 (36)</td>
<td>500 (20)</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>1400 (55)</td>
<td>1300 (51)</td>
<td>1000 (40)</td>
<td>900 (36)</td>
<td>500 (20)</td>
<td>100 (4)</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>1200 (48)</td>
<td>1400 (55)</td>
<td>1000 (40)</td>
<td>900 (36)</td>
<td>500 (20)</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>1000 (40)</td>
<td>1400 (55)</td>
<td>1000 (40)</td>
<td>900 (36)</td>
<td>300 (20)</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>800 (32)</td>
<td>1300 (51)</td>
<td>900 (36)</td>
<td>600 (24)</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>600 (24)</td>
<td>1200 (48)</td>
<td>500 (20)</td>
<td>–</td>
<td>–</td>
<td>–</td>
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<td>–</td>
</tr>
<tr>
<td>400 (16)</td>
<td>1200 (48)</td>
<td>300 (12)</td>
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<tr>
<td>200 (8)</td>
<td>1100 (43)</td>
<td>200 (8)</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>0 (0)</td>
<td>1100 (43)</td>
<td>200 (8)</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
</tbody>
</table>

**Note:** Barriers are not foolproof and they cannot stop a person intent on gaining access. Therefore, as a person’s intent to reach a hazardous part increases (for example, climbing on chairs, ladders, or the barrier itself), the protection provided by a barrier will decrease. You may have to consider providing a fully guarded enclosure.

**Safeguarding devices**
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 time period of each other. (B) Two-hand control levers – paper guillotine shear. The shear will not cycle unless both levers are activated, which requires the use of both hands within a certain time period of each other.

Figure 3.8. Light curtain or similar photoelectric sensing device. (A) Light curtain – brake press. The press is operated in the normal manner 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 person enters the doorway 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 danger area. (B) Brake press operator using fixed restraint devices. The operator’s hands cannot reach the danger area; hand tools would be 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.
Design and performance requirements for two-hand controls and trips

There are two types of two-hand operations:

- **Two-hand controls**, where both controls (buttons, levers, sensors) must be activated at the same time and kept engaged throughout the entire hazardous portion of the machine cycle. If the controls are released, the machine either stops or returns to top of stroke (the position that opens the dies). This type of machine operation is called **part revolution clutch** or **friction clutch**. It is commonly found with pneumatic clutches/brakes and with hydraulically powered machinery such as brake presses.

- **Two-hand trips**, where both controls must be activated at the same time to initiate the machine cycle but releasing the controls will not interrupt the machine cycle. This type of machine operation is called **full revolution clutch** or **mechanical clutch**.

Two-hand controls and trips must be designed and installed so that each control is:

- **Protected** against unintended or accidental operation. This is usually achieved by surrounding the activating button with a “ring” guard.
• **Separated** or otherwise designed to require concurrent use of both hands to activate the controls (should prevent improper operation by hand and elbow).

• **Designed** so that both hands must be released 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 (using tape, rubber band, wedge, etc.), then the two-hand controls are not properly designed or constructed.

• **Located** at a safe distance from the nearest hazard so that 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, and is 1,600 mm (63 inches) per second.

In a simple example, the safe location of a two-hand control for a machine that comes to a complete stop in 1 second after the controls are released would be 1,600 mm (63 inches) from the nearest point of operation. For a machine that stops in one-half second, the safe distance would be 826 mm (32½ inches); for a machine that stops in one-quarter second, it would be 413 mm (16½ inches), etc.

Determining the precise stopping time of a machine cycle requires specialized measuring equipment. The response time of the control system components (air valves, friction brakes, etc.), as well as the actual braking effort, are all elements that determine the actual stopping time. Refer to CSA Standard Z432, Safeguarding of Machinery.

When 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 Standard Z142, Code for Punch Press and Brake Press Operation: Health, Safety and Guarding Requirements.

**WARNING!** Two-hand controls alone may not provide sufficient safeguarding. Additional barrier guards may be required to protect workers other than the operator.
Design and performance requirements for presence-sensing devices

How they work

Unlike barrier guards and two-hand controls, presence-sensing devices do not prevent access to a hazardous point of operation. However, they prevent dangerous machine motion if any part of a worker’s body is in the danger 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 dangerous motion while permitting unrestricted access by sensing the presence of the operator and sending a stop signal. 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 proper selection and positioning of light curtains, proximity sensors, and safety mats. Refer to the following standards referred to in the Occupational Health and Safety Regulation:

- CSA Standard Z432, Safeguarding of Machinery
- CSA Standard Z434, Industrial Robots and Robot Systems – General Safety Requirements

There are four important limitations when selecting these safeguards:

- Presence-sensing devices alone may not provide sufficient safeguarding. Additional barrier 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.
- No attempt should be made to install a presence-sensing device until the requirements of the relevant standards have been reviewed.
- Presence-sensing devices are to be used during normal production only. They are not a substitute for lockout!

**Photoelectric light curtains**

These devices emit a “curtain” of harmless infrared light beams in front of the hazardous area. When any of the beams is blocked, the light curtain control circuit sends a stop signal to the machine’s control system. This type of safeguard offers the maximum protection with the minimum impact on normal machine operation. It is particularly well suited to safeguarding brake press operations. Note: steam or dust can inadvertently affect a light curtain.

**Pressure-sensitive safety mats**

These devices are used to guard the floor area around a machine. A matrix of interconnected mats is laid around the hazard area, and the proper 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 mats are often used within an enclosed area containing several machines, such as flexible manufacturing or robotics cells. When access into the cell is required (for example, in the case of robot “teaching”), the mats prevent dangerous motion if the operator strays from the safe area.
Design and performance requirements for safety interlocks

How they work

If access to a point of operation (a feed point) is required during normal operation, a movable openable barrier guard interlocked with the machine’s power source can be a reliable and cost-effective solution. The control power for the machine is routed through the safety contact of the interlock. The interlock ensures that the machine will not operate if the guard is in the open position. The power source for the machine is usually electrical, but it could also be pneumatic or hydraulic.

If the interlocked guard can be opened during operation, the machine will stop. This is called simple interlocking. Some interlock switches also have a locking device that locks the guard door closed and will not release it until the machine comes to a safe stop. The feature is found in some households’ spin cycle washing machine. It is referred to as power interlocking. It is used with machinery such as tumblers and centrifuges, where the coasting-down time may take several seconds to several minutes.

Several technical factors affect the proper selection and positioning of safety interlocks. These are described in detail in CSA Standard Z432, Safeguarding of Machinery, which should be reviewed when designing or selecting an interlock system.
Here are some key points to consider when selecting a safety interlock system:

- Is the interlock switch recommended by the manufacturer for use in a safety-related application? Most interlock switches are intended for use in production processes. They may not have the integrity and reliability required for worker safety.

- Where the risk assessment indicates a high level of risk, 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 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.

- Interlock switches should be tamper-resistant and difficult to defeat or bypass using readily available means, such as a piece of wire, tape, simple hand tool, and so on. Safety interlock manufacturers address this by designing two-piece keyed interlocks or interlocks using coded magnet sensors.

- Interlocks should be installed using “positive-mode” mounting. When mounted in the positive mode, the non-resilient mechanical mechanism that forces the normally closed (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.

- Power interlocks may require that certain parts of the machine retain a supply of power when the machine is shut down. The implementation of lockout procedures should address this concern. Lockout must be performed if this safeguard becomes ineffective.

**Movable gate**

A unique safeguarding application using interlocking is the movable gate device. It is commonly used to provide protection to an operator when hand-feeding parts into a punch press, but it can be applied to various other machines. See Figure 3.13.
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 (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), the gate will not fully close. The interlock switch will prevent further machine operation until the obstruction has been removed and the controls reset.

There are two types of movable gate guards. The **A type** is used to safeguard machines with **full revolution clutches** (see page 33). The following is a typical sequence of operation of 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 press cycle (or closing stroke of a machine). This type can be used to safeguard only machines with **part revolution clutches** (see page 33). The following is a typical sequence of operation 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.

### Miscellaneous emergency body contact devices

<table>
<thead>
<tr>
<th>Emergency trip wire – Conveyor system</th>
<th>Safety contact bumper – Overhead door machine</th>
</tr>
</thead>
</table>

#### How they work

These safeguarding devices function somewhat like presence-sensing devices. The difference is that they may permit access to the actual danger area before they are activated and send a stop signal to the machine, thus entailing a limited risk of injury. They may, however, 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,” “belly bars,” and similar devices should be mounted so that they will be activated involuntarily as the worker approaches the danger 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 that a pull on the wire/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 3.14 and 3.15 show two examples of safe pull wire installations.

![Figure 3.14. Pull wire system using two emergency stop switches. The switch is activated by a pull from any direction.](image)

**Shields and awareness barriers**

**How they work**

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

**Awareness barriers** include installations such as electrically interlocked pull cable assemblies installed in the rear area of machines such as brake presses and shears to restrict worker entry. These areas are often out of the operator’s view. The machine is stopped if someone pulls or loosens the cable. It is recommended that a sign denoting the danger be placed on the pull cable.

Although shields and awareness barriers offer some degree of safeguarding, *they cannot be considered guards because they only restrict but do not prevent access to the danger area.*

When installing these devices and before moving them from their normally applied position, always turn off power to the machine; follow lockout procedures if there is a risk of accidental startup.

**Safeguarding by location**

With the body upright and standing at full height, the safe clearance when reaching upward to an unguarded hazard is a minimum of 2.5 metres (8 feet) (see Figure 3.16). Any hazardous moving parts beyond this distance are considered to be guarded by location. If access to hazardous locations is gained by use of ladders, scaffolds, and so on, temporary guarding or lockout procedures must be used.

![Figure 3.16. Safe distance for reaching up to an unguarded hazard.](image-url)
Safeguarding equipment with infrequent access

When the question is raised of safeguarding equipment that is located out of the way of normal work areas, comments such as “nobody ever goes there” or “we access that equipment only when it is locked out” are sometimes heard.

The fact that a worker can access unguarded moving parts that are not already safeguarded by location means that accidental contact can occur. And an accident will occur over time, although the level of risk on any given day may be quite low. It is not a question of whether these locations will be safeguarded but rather of establishing priorities and determining which machinery in the plant will be safeguarded first based on a risk assessment and machine survey.

E-stops

How they work

“E-stop” is the industry term for Emergency Stop. It is a red mushroom-shaped stop button that is manually depressed in the event of an emergency condition, upset condition, or accident.

An emergency stop is not considered a primary safeguarding device. Because it requires intentional activation, it seldom prevents accidents. An emergency-stop device is an after-the-fact device. It may, however, prevent an unsafe machine operation from continuing and, when activated, will stop a machine after an accident has occurred.

The various published safeguarding standards contain specific
requirements for E-stops, including how many are required and where they should be located. The following requirements apply to all E-stop installations:

- Located within immediate and unimpeded reach of the operator or other persons directly affected by the machine operation.
- Mushroom-shaped and red in colour.
- Designed to allow immediate activation with any part of the body (no ring guards or recessed position).
- Requires a manual push to activate and a manual pull to reset; remains in the depressed position when activated (not a “hold-to-run” type switch).
- A check for safe machine operation is required before an E-stop is reset.
- Must be hard-wired into the control circuit to allow the magnetic coil to drop out (cannot be routed through a Programmable Logic Controller [PLC] except for monitoring purposes).
- The machine must not restart merely by pulling out and resetting the E-stop. A second, independent control must also be activated before the machine will restart.

**Guide to selecting the right safeguard**

If all machines were alike, it would be simple to design a universal guard and install it during the fabrication of the machine. Machines are not all alike, however. To further complicate the problem, purchasers of the same model of machine may use it in different ways and for different purposes, and these may change during the lifetime of the machine. In some cases, machines are used for purposes that the manufacturer did not envision. It is important that you ensure that you have the right machine and tool for the work being performed. Don’t modify or adapt machinery without consultation with the manufacturer or other qualified person (for example, a Professional Engineer). This is why effective point-of-operation safeguarding cannot always be installed by the manufacturer.

In many cases, a safeguard can be selected only after the user has performed a risk assessment. The decision chart in Figure 3.17 and the guide in Table 3.3 may assist in the selection process.

**Figure 3.17. Selecting the right safeguard.**

**Table 3.3. Guide to selecting the right safeguard.**
The most effective safeguard is a device or system that provides the maximum protection with the minimum impact on normal machine operation.

<table>
<thead>
<tr>
<th>Question</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Have you completed a risk assessment for each machine?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Is there a low risk of injury?</td>
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<tr>
<td>How much access is required to the danger area?</td>
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</tr>
<tr>
<td>No access is required during normal operation</td>
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<tr>
<td>Install a fixed barrier guard</td>
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<tr>
<td>Full access is required during normal operation</td>
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<tr>
<td>Install a safeguarding device</td>
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</tr>
</tbody>
</table>

Perform a risk assessment as outlined in the section entitled “Assessing Risk”
<table>
<thead>
<tr>
<th>Type of Safeguard</th>
<th>Typical Applications</th>
<th>Action of Safeguard</th>
<th>Advantages</th>
<th>Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Physical guards</strong></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Fixed power transmission barrier guard</td>
<td>V-belt drives</td>
<td>Completely prevents hands or body parts from entering the danger area</td>
<td>Provides complete protection if kept in place</td>
<td>May interfere with lubrication unless modified</td>
</tr>
<tr>
<td></td>
<td>Chain sprocket drives</td>
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<td></td>
<td>Motor couplings and power take-offs (PTOs)</td>
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<td></td>
<td>Flywheels</td>
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</tr>
<tr>
<td>Fixed point-of-operation barrier guard</td>
<td>Bread slicers</td>
<td>A complete enclosure that admits feed stock or removal of finished product but will not allow hands into danger zone</td>
<td>Provides complete protection if kept in place</td>
<td>Generally limited to flat feed stock</td>
</tr>
<tr>
<td></td>
<td>Meat grinders</td>
<td></td>
<td></td>
<td>May require special tools to remove jammed stock</td>
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<td></td>
<td>Sheet metal shears</td>
<td></td>
<td></td>
<td>May interfere with visibility</td>
</tr>
<tr>
<td></td>
<td>In-running nip points of rubber, paper, and textile rolls</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Power presses</td>
<td></td>
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</tr>
<tr>
<td>Barrier guard (hinged or sliding) with simple interlocking</td>
<td>Most power presses, Balers/compactors, Foundry presses, Robotic systems</td>
<td>Opening the guard will stop the machine, Machine will not start with guard open</td>
<td>Leaves both hands free for feeding, Opening and closing of guard can be automatic</td>
<td>Location of controls must comply with safety distance requirements, Depends on control reliability for safe functioning</td>
</tr>
<tr>
<td>Barrier guard (hinged or sliding) with powered interlocking (guard locking)</td>
<td>Foundry tumblers, Laundry extractors, dryers, and tumblers, Centrifuges, Paint mixers, Some dough and pastry mixers</td>
<td>Machine will not start with guard open, Guard cannot be opened until machine movement is at complete rest</td>
<td>Provides complete and positive enclosure until machine is at rest, Does not inhibit production</td>
<td>Requires careful adjustment and maintenance, May not function in the event of electrical or mechanical failure</td>
</tr>
<tr>
<td>Automatic or semi-automatic feed with point of operation enclosed</td>
<td>Power press blanking operations, Coining and stamping machines, Drop chute chippers, Pastry machines</td>
<td>Stock fed by chutes, hoppers, conveyors, rolls, movable dies, etc., Enclosure will not admit any part of the body</td>
<td>Increase in production, Worker cannot place hand in danger zone</td>
<td>High installation cost for short runs, May require skilled maintenance</td>
</tr>
<tr>
<td>Limited feed opening or slide travel</td>
<td>Foot-powered shears, Some punch and brake presses</td>
<td>Feed opening or machine travel is limited to 6 mm (¼ inch) or less, Fingers cannot enter danger area</td>
<td>Provides positive protection, No maintenance or adjustment needed</td>
<td>Small opening limits size of stock, Requires effective supervision/training</td>
</tr>
<tr>
<td>Type of Safeguard</td>
<td>Typical Applications</td>
<td>Action of Safeguard</td>
<td>Advantages</td>
<td>Limitations</td>
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</tr>
<tr>
<td>Two-hand controls</td>
<td>Hand-fed power press operations</td>
<td>Simultaneous activation of both controls initiates a machine cycle</td>
<td>Forces both hands out of danger zone</td>
<td>Location of controls must comply with safety distance requirements</td>
</tr>
<tr>
<td></td>
<td>Hydraulic presses</td>
<td>Releasing either control during cycle causes machine to stop</td>
<td>No interference with hand feeding</td>
<td>Depends on control reliability for safe functioning</td>
</tr>
<tr>
<td></td>
<td>Re-bar formers</td>
<td></td>
<td>No adjustments required</td>
<td>Hands not free to support feed stock</td>
</tr>
<tr>
<td></td>
<td>Tube benders</td>
<td></td>
<td>Easy to install</td>
<td>Hazards to workers other than the operator must be safeguarded</td>
</tr>
<tr>
<td></td>
<td>Paper guillotine shears</td>
<td></td>
<td>Allows feeding and removal of complex parts not possible with a barrier guard</td>
<td>May require frequent adjustment/calibration</td>
</tr>
<tr>
<td>Presence-sensing device:</td>
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<tr>
<td>• Light curtains</td>
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<tr>
<td>• Radio frequency antennae</td>
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<tr>
<td>• Pressure-sensitive mats</td>
<td></td>
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<tr>
<td></td>
<td>Brake presses</td>
<td>When sensing field is interrupted, a stop signal is sent to quickly stop the machine</td>
<td>Does not interfere with normal feeding or production</td>
<td>Expensive to install</td>
</tr>
<tr>
<td></td>
<td>Part revolution (air clutch) presses only</td>
<td></td>
<td>No obstruction on the machine or around the operator</td>
<td>Location of device must comply with safety distance requirements</td>
</tr>
<tr>
<td></td>
<td>Robotic systems</td>
<td></td>
<td></td>
<td>Depends on control system reliability for safe functioning</td>
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<td></td>
<td>Hazards to workers other than the operator must be safeguarded</td>
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<td></td>
<td></td>
<td></td>
<td>May require frequent adjustment/calibration</td>
</tr>
<tr>
<td>Limited machine movement devices</td>
<td>Printing presses</td>
<td>Provides operator or maintenance with a means to “inch” or “jog” machine movement</td>
<td>Gives operator and maintenance safe control over hazardous machine movement</td>
<td>Can be dangerous if used during production mode on power presses (the CSA Standard notes that these must not be used for production purposes)</td>
</tr>
<tr>
<td>(“jog,” “inch,” and “setup” modes)</td>
<td>Power presses (during setup and maintenance)</td>
<td>during setup</td>
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<tr>
<td>Self-adjusting feed guard</td>
<td>Band saws</td>
<td>Barrier or enclosure will admit operator’s hands but warn him before danger zone is reached</td>
<td>Makes hard-to-guard machines safer</td>
<td>Protection not complete at all times – hands may enter danger zone.</td>
</tr>
<tr>
<td></td>
<td>Table saws</td>
<td></td>
<td>Generally does not interfere with production</td>
<td>Guard may be easily defeated</td>
</tr>
<tr>
<td></td>
<td>Mitre saws</td>
<td></td>
<td>Easy to install</td>
<td>Choice of last resort</td>
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<td></td>
<td>Circular hand saws</td>
<td></td>
<td>Admits varying sizes of stock</td>
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<td></td>
<td>Jointers</td>
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<td></td>
<td>Wood shapers</td>
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<tr>
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<td>Large-capacity steel plate shears</td>
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<tr>
<td>Type of Safeguard</td>
<td>Typical Applications</td>
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</table>
| Emergency body contact devices: | • 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  
• Does not 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 means of a safety belt and lanyard, or by hand wristlets and fixed cables, and cannot access the danger 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 |
| 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 danger zone | • Acts even in the event of 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 |
| Awareness barriers: | • Lathe chucks  
• Milling machines  
• Drill presses  
• Machine tools | • Partial barriers that contain liquids and flying chips or turnings | • Easy to install  
• Does not impede operation | • Provides limited protection against harmful contact with moving parts |

Safeguarding Machinery and Equipment: General Requirements