



**OSHAcademy**<sup>TM</sup>  
Occupational Safety & Health Training

# Introduction to Machine Guarding

Unguarded machinery claims many limbs and lives from workers around the world each year. This course aids employers, employees, machine manufacturers, machine guard designers and fabricators, and all others with an interest in protecting workers against the hazards of moving machine parts in protecting workers from potential machine injuries. It identifies the major mechanical motions and the general principles of safeguarding them. There is also emphasis placed on the importance of machine maintenance and repair.

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# OSHAcademy Course 726 Study Guide

## Introduction to Machine Guarding

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Contact OSHAcademy to arrange for use as a training document.

This study guide is designed to be reviewed off-line as a tool for preparation to successfully complete OSHAcademy Course 726.

Read each module, answer the quiz questions, and submit the quiz questions online through the course webpage. You can print the post-quiz response screen which will contain the correct answers to the questions.

The final exam will consist of questions developed from the course content and module quizzes.

We hope you enjoy the course and if you have any questions, feel free to email or call:

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Revised: September 2, 2020

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## Introduction

### The Purpose for machine guarding

Unguarded machinery claims far too many limbs and lives from workers around the world. Such tragedies can be avoided by better training for machine operators, and most importantly, by making machines in the workplace safer.

This course examines dozens of possible ways to safeguard machinery.

This course has been prepared as an aid to employers, employees, machine manufacturers, machine guard designers and fabricators, and all others with an interest in protecting workers against the hazards of moving machine parts. It identifies the major mechanical motions and the general principles of safeguarding them.

Current applications of each technique are shown in accompanying illustrations of specific operations and machines. The methods described here may be transferred, with due care, to different machines with similar hazards. To determine whether or not safeguarding meets the requirements of the standard, any mechanical motion that threatens a worker's safety should not remain unguarded.

The approaches to machine safeguarding discussed in this course are not the only solutions which meet the requirements of the OSHA Machine Guarding standard. Why? Because practical solutions to safeguarding moving machine parts are as numerous as the people working on them. No course or publication could keep pace with all of these solutions or attempt to depict them all.

In machine safeguarding, as in other regulated areas of the American workplace, to a certain extent OSHA standards govern function and practice. This course, however, is not a substitute for the standards. It provides basic technical information and workable ideas which the employer may use as a guide to achieve compliance. It offers an overview of the machine safeguarding problem in the industrial setting, an assortment of solutions in popular use, and a challenge to all whose work involves machines.

## Module 1: The Basics of Machine Guarding

Crushed hands and arms, severed fingers, blindness -- the list of possible machinery-related injuries is as long as it is horrifying. There seem to be as many hazards created by moving machine parts as there are types of machines. Safeguards are essential for protecting workers from needless and preventable injuries.

A good rule to remember is: **Any machine part, function, or process which many cause injury must be safeguarded.** When the operation of a machine or accidental contact with it can injure the operator or others in the vicinity, the hazards must be either controlled or eliminated.

This course describes the various hazards of mechanical motion and presents some techniques for protecting workers from these hazards. General information covered in this chapter includes -- where mechanical hazards occur, the hazards created by different kinds of motions and the requirements for effective safeguards, as well as a brief discussion of non-mechanical hazards.

### Where Mechanical Hazards Occur

Dangerous moving parts in three basic areas require safeguarding:

**The point of operation:** that point where work is performed on the material, such as cutting, shaping, boring, or forming of stock.

**Power transmission apparatus:** all components of the mechanical system which transmit energy to the part of the machine performing the work. These components include flywheels, pulleys, belts, connecting rods, couplings, cams, spindles, chains, cranks, and gears.

**Other moving parts:** all parts of the machine which moves while the machine is working. These can include reciprocating, rotating, and transverse moving parts, as well as feed mechanisms and auxiliary parts of the machine.

### Quiz Instructions

After each section, there is a quiz question. Make sure to read the material in each section to discover the correct answer to these questions. Circle the correct answer. When you are finished go online to take the final exam. This exam is open book, so you can use this study guide.

**1. Any machine part, function, or process which may cause injury must be \_\_\_\_.**

- a. reported to OSHA
- b. safeguarded
- c. deenergized
- d. taken out of service

### **Hazardous Mechanical Motions and Actions**

A wide variety of mechanical motions and actions may present hazards to the worker. These can include the movement of rotating members, reciprocating arms, moving belts, meshing gears, cutting teeth, and any parts that impact or shear. These different types of hazardous mechanical motions and actions are basic in varying combinations to nearly all machines, and recognizing them is the first step toward protecting workers from the danger they present.

The basic types of hazardous mechanical motions and actions are:

#### **Motions**

- rotating (including in-running nip points)
- reciprocating
- transversing

#### **Actions**

- cutting
- punching
- shearing
- bending

**2. Which of the following is a hazardous mechanical motion?**

- a. Shearing
- b. Rotating
- c. Cutting
- d. Bending

## Rotation

"Rotation" is circular motion around an axis or center such as rotating collars, couplings, cams, clutches, flywheels, shaft ends, and spindles that may grip clothing or otherwise force a body part into a dangerous location. Even smooth surfaced rotating machine parts can be hazardous. Projections such as screws or burrs on the rotating part increase the hazard potential.

## In-running Nip Points

In-running nip point hazards are caused by the rotating parts on machinery. There are three main types of in-running nips.

1. **Parallel rotating parts:** Parts can rotate in opposite directions while their axes are parallel to each other. These parts may be in contact producing nip point. Stock fed between the rolls may also produces nip points. This danger is common on machines with intermeshing gears, rolling mills, and calendars.
2. **Tangentially moving parts:** Tangentially moving nip points are also created between rotating and tangentially moving parts. Some examples would be: the point of contact between a power transmission belt and its pulley, a chain and a sprocket, and a rack and pinion.
3. **Rotating and fixed parts:** Nip points can occur between rotating and fixed parts which create a shearing, crushing, or abrading action. Examples are: spoked handwheels or flywheels, screw conveyors, or the periphery of an abrasive wheel and an incorrectly adjusted work rest.

e.

## Reciprocating Motions

Reciprocating motions may be hazardous because, during the back-and-forth or up-and-down motion, a worker may be struck by or caught between a moving and a stationary part.

## Transverse Motions

Transverse motion (movement in a straight, continuous line) creates a hazard because a worker may be struck or caught in a **pinch or shear point** by the moving part.

## Rotating Shafts

**Warning:** Exposure to rotating shafts is the most dangerous machine safeguarding hazard. It is so dangerous we wanted to mention it again before moving on to other topics. There have been numerous accidents due to exposure to rotating shafts and, unfortunately, most of these accidents result in a fatality.

The danger of exposure to rotating shafts increases when projections such as set screws, bolts, nicks, abrasions, and projecting keys or set screws are exposed on rotating parts (see image to right). The image below on the right shows what can happen when a worker gets caught on a rotating shaft. In this case, massive internal injuries resulted in a tragic fatality. You should consider exposure to rotating parts as an "imminent danger" situation that must be corrected immediately.

#### 4. What is considered the most dangerous machine safeguarding hazard in the workplace?

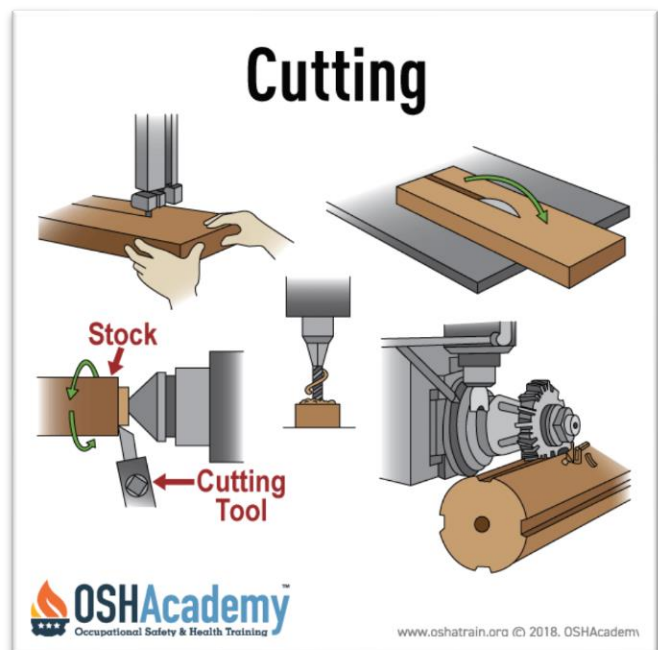
- Power presses for punching
- Reciprocating surfaces
- Pinch or shear points
- Rotating shafts

## Actions

### Cutting

Cutting action may involve rotating, reciprocating, or transverse motion. The danger of cutting action exists at the point of operation where finger, arm and body injuries can occur and where flying chips or scrap material can strike the head, particularly in the area of the eyes or face. Such hazards are present at the point of operation in cutting wood, metal, or other materials.

Examples of mechanisms involving cutting hazards include band saws, circular saws,

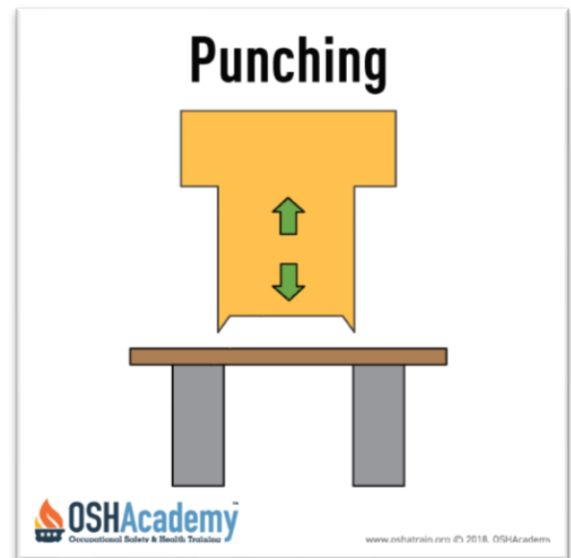


boring or drilling machines, turning machines (lathes), or milling machines. See Figure to the right.

### Punching

Punching action happens when power is applied to a slide (ram) for the purpose of blanking, drawing, or stamping metal or other materials. The danger of this type of action occurs at the point of operation where stock is inserted, held, and withdrawn by hand.

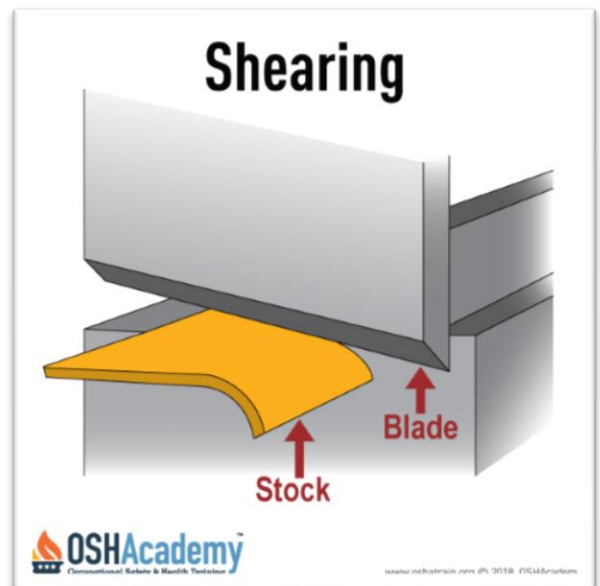
Typical machines used for punching operations are power presses and iron workers. See Figure to the right.



### Shearing

Shearing action involves applying power to a slide or knife in order to trim or shear metal or other materials. A hazard occurs at the point of operation where stock is actually inserted, held, and withdrawn.

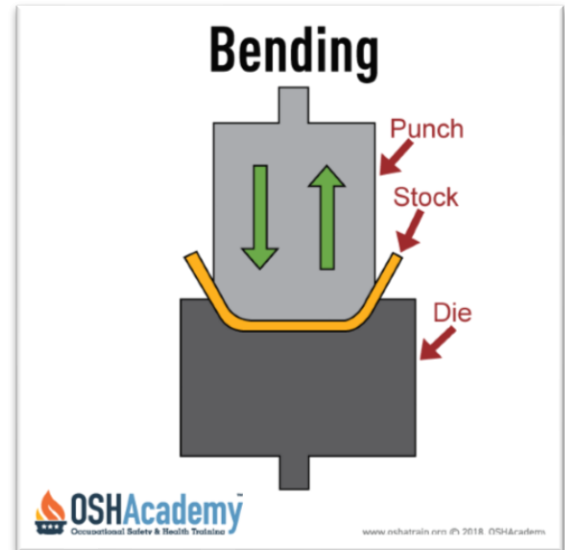
Examples of machines used for shearing operations are mechanically, hydraulically, or pneumatically powered shears. See Figure below.



## Bending

Bending action results when power is applied to a slide in order to draw or stamp metal or other materials. A hazard occurs at the point of operation where stock is inserted, held, and withdrawn.

Equipment that uses bending action includes power presses, press brakes, and tubing benders. See Figure to the right.



5. Which of the following actions involves applying power to a slide or knife in order to trim or shear metal or other materials?

- a. Cutting
- b. Shearing
- c. Punching
- d. Bending

## Requirements for Safeguards

What must a safeguard do to protect workers against mechanical hazards? Safeguards must meet these minimum general requirements:

**Prevent contact:** The safeguard must prevent hands, arms, and any other part of a worker's body from making contact with dangerous moving parts. A good safeguarding system eliminates the possibility of the operator or another worker placing parts of their bodies near hazardous moving parts.

**Secure:** Workers should not be able to easily remove or tamper with the safeguard, because a safeguard that can easily be made ineffective is no safeguard at all. Guards and safety devices should be made of durable material that will withstand the conditions of normal use. They must be firmly secured to the machine.

**Protect from falling objects:** The safeguard should ensure that no objects can fall into moving parts. A small tool which is dropped into a cycling machine could easily become a projectile that could strike and injure someone.

**Create no new hazards:** A safeguard defeats its own purpose if it creates a hazard of its own such as a shear point, a jagged edge, or an unfinished surface which can cause a laceration. The edges of guards, for instance, should be rolled or bolted in such a way that they eliminate sharp edges.

**Create no interference:** Any safeguard which impedes a worker from performing the job quickly and comfortably might soon be overridden or disregarded. Proper safeguarding can actually enhance efficiency since it can relieve the worker's apprehensions about injury.

**Allow safe lubrication:** If possible, one should be able to lubricate the machine without removing the safeguards. Locating oil reservoirs outside the guard, with a line leading to the lubrication point, will reduce the need for the operator or maintenance worker to enter the hazardous area.

**6. A safeguard designed to protect against mechanical hazards should \_\_\_\_\_.**

- a. prevent accidental contact at the point of operation
- b. protect the worker from falling temperatures
- c. create new hazards
- d. create interference at the point of operation

### Non-Mechanical Hazards

While this course focuses primarily on concepts and techniques for safeguarding employees from mechanical hazards (moving parts), machines present a variety of other non-mechanical hazards that should not be ignored. In this section, we'll briefly remind you of some hazards other than safeguarding moving parts that can impact your safety and affect the safe operation of machines.

#### *Electricity*

All power sources for machines are potential sources of danger. When using electrically powered or controlled machines, for instance, the equipment as well as the electrical system itself must be properly grounded. Replacing frayed, exposed, or old wiring will also help to protect the operator and others from electrical shocks or electrocution. High pressure systems, too, need careful inspection and maintenance to prevent possible failure from pulsation, vibration, or leaks. Such a failure could cause, among other things, explosions or flying objects.



## Noise

Machines often produce noise (unwanted sound) which can result in a number of hazards to workers. Noise can startle and disrupt concentration, and can interfere with communications, thus hindering the worker's safe job performance. Engineering controls such as sound-dampening materials, and personal protective equipment can help control the harmful effects of noise. Administrative controls that involve removing the worker from the noise source can also be an effective measure when feasible.

## Harmful Substances

Because some machines require the use of cutting fluids, coolants, and other potentially harmful substances, operators, maintenance workers, and others in the vicinity may need protection. These substances can cause ailments ranging from dermatitis to serious illnesses and disease. Specially constructed safeguards, ventilation, and protective equipment and clothing are possible temporary solutions to the problem of machinery-related chemical hazards until these hazards can be better controlled or eliminated from the workplace.

### **7. What are the basic two types of machines hazards that require safeguarding?**

- a. Mechanical and non-mechanical
- b. Noise and vibration
- c. Engineering and administrative
- d. Electrical and harmful substances

## Training

Even the most elaborate safeguarding system cannot offer effective protection unless the worker knows how to use it and why. Specific and detailed training is therefore a crucial part of any effort to provide safeguarding against machine-related hazards. Thorough operator training should involve instruction or hands-on training in the following:

1. a description and identification of the hazards associated with particular machines
2. the safeguards themselves, how they provide protection, and the hazards for which they are intended
3. how to use the safeguards and why
4. how and under what circumstances safeguards can be removed, and by whom (in most cases, repair or maintenance personnel only)

5. what to do (e.g., contact the supervisor) if a safeguard is damaged, missing, or unable to provide adequate protection

This kind of safety training is necessary for new operators and maintenance or setup personnel, when any new or altered safeguards are put in service, or when workers are assigned to a new machine or operation.

An effective training technique is to present a summary of an actual machine guarding accident, how it happened, and what would have prevented it.

Check out the sample story that gets the point across:

*A paper mill employee was killed after he became entangled in a rotating shaft at the company's paper mill. The worker, employed at the company for less than two weeks, was buffing the shaft when his clothing got caught on the rotating bold heads of the shaft.*

**8. Which of the following is considered the most effective safety training technique to emphasize the importance of safe work practices?**

- a. Group discussion
- b. Use a slide presentation
- c. Tell a story
- d. Show a video

### **Protective Clothing and Personal Protective Equipment**

Engineering controls, that eliminate the hazard at the source and do not rely on the worker's behavior for their effectiveness offer the best and most reliable means of safeguarding. Therefore, engineering controls must be the employer's first choice for eliminating machine hazards. But whenever engineering controls are not available or are not fully capable of protecting the employee (an extra measure of protection is necessary), operators must wear protective clothing or personal protective equipment.

If it is to provide adequate protection, the protective clothing and equipment selected must always be:

1. appropriate for the particular hazards
2. maintained in good condition
3. properly stored when not in use, to prevent damage or loss

4. kept clean, fully functional, and sanitary

Protective clothing is, of course, available for different parts of the body. Hard hats can protect the head from the impact of bumps and falling objects; caps and hair nets can help keep the worker's hair from being caught in machinery. If machine coolants could splash or particles could fly into the operator's eyes or face, face shields, safety goggles, glasses, or similar kinds of protection may be necessary. Hearing protection may be needed when workers operate noisy machines. To guard the trunk of the body from cuts or impacts, there are certain protective coveralls, jackets, vests, aprons, and full-body suits. Workers can protect their hands and arms from the same kinds of injury with special sleeves and gloves. Safety shoes and boots, or other acceptable foot guards, can shield the feet against injury in case the worker needs to handle heavy objects which might drop on their feet.

It is important to note that protective clothing and equipment can create hazards. A protective glove which can become caught between rotating parts, or a respirator face piece which hinders the wearer's vision, for example, require alertness and continued attentiveness whenever they are used.

Other parts of the worker's clothing may present additional safety hazards. For example, loose-fitting shirts might possibly become entangled in rotating spindles or other kinds of moving machinery. Jewelry, such as bracelets and rings, can catch on machine parts or stock and lead to serious injury by pulling a hand into the danger area.

**9. Which of the following may create hazards when working around moving machine parts?**

- a. Protective eyewear
- b. Protective gloves
- c. Hard hats
- d. Caps and hair nets

## Module 2: Methods of Machine Safeguarding

### Introduction

There are many ways to safeguard machines. The type of operation, size or shape of stock, method of handling, physical layout of the work area, type of material, and production requirements or limitations will help to determine the appropriate safeguarding method for the individual machine.

As a general rule, power transmission apparatus is best protected by fixed guards that enclose the danger areas. For hazards at the point of operation, where moving parts actually perform work on stock, several kinds of safeguarding may be possible. One must always choose the most effective and practical means available.

### Five General Classifications of Safeguards

We can group safeguards under five general classifications.

1. Guards
2. Devices
3. Location/Distance
4. Potential Feeding and Ejection Methods
5. Miscellaneous Aids

**1. As a general rule, power transmission apparatus is best protected by which of the following?**

- a. Presence-sensing devices
- b. Warning signs placed between the worker and the work
- c. Fixed guards that enclose the danger area
- d. Mechanical arm restraints

## Guards

Guards are barriers which prevent access to danger areas. There are four general types of guards:

### Fixed Guards

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

Safeguarding Action	Advantages	Limitations
Provides a barrier	Can be constructed to suit many specific applications	May interfere with visibility
	In-plant construction is often possible	Can be limited to specific operations
	Can provide maximum protection	Machine adjustment and repair often require its removal, therefore necessitating other means of protection for maintenance personnel.
	Usually requires minimum maintenance	
	Can be suitable to high production, repetitive operations	

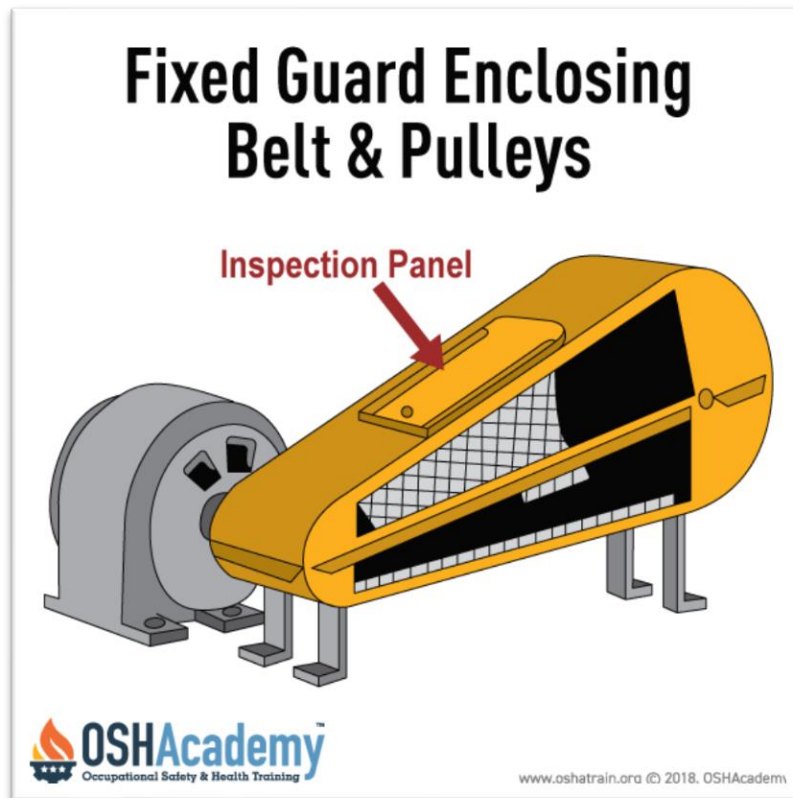


### Interlocked Guards

When this type of guard is opened or removed, the tripping mechanism and/or power automatically shut off or disengage, and the machine cannot cycle or be started until the guard is back in place.

An interlocked guard may use electrical, mechanical, hydraulic, or pneumatic power or any combination of these. Interlocks should not prevent "inching" by remote control if required. Replacing the guard should not automatically restart the machine. To be effective, all movable guards should be interlocked to prevent occupational hazards.

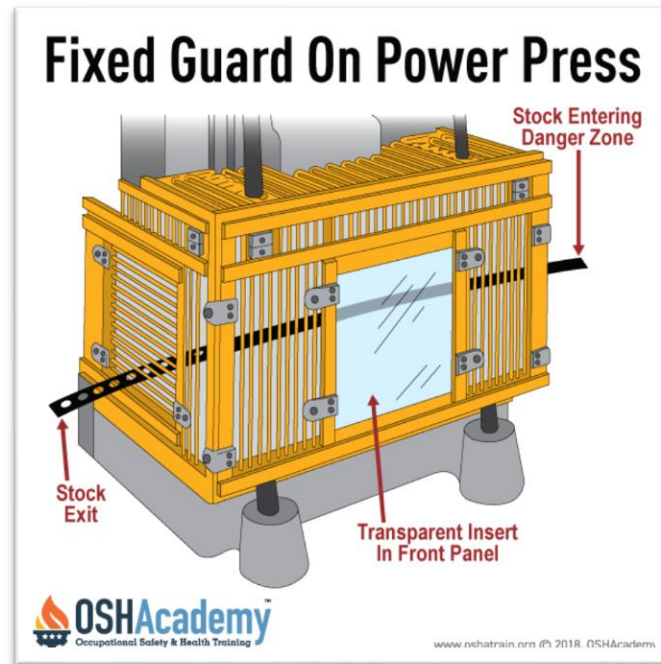
In the figure below, the beater mechanism of a picker machine (used in the textile industry) is covered by an interlocked barrier guard. This guard cannot be raised while the machine is running, nor can the machine be restarted with the guard in the raised position.



## Adjustable Guards

Adjustable guards are useful because they allow flexibility in accommodating various sizes of stock.

The figure below shows an adjustable enclosure guard on a band saw.



**2. Which of the following guards is not dependent upon moving parts to perform its intended function?**

- a. Adjustable guard
- b. Interlocked guard
- c. Fixed guard
- d. Self-adjusting guard

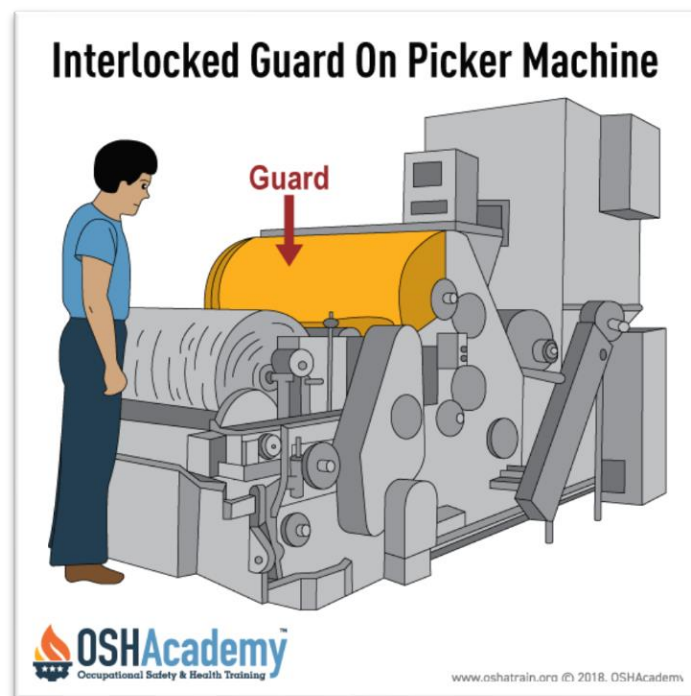


## Interlocked Guards

When this type of guard is opened or removed, the tripping mechanism and/or power automatically shuts off or disengages, and the machine cannot cycle or be started until the guard is back in place.

An interlocked guard may use electrical, mechanical, hydraulic, or pneumatic power or any combination of these. Interlocks should not prevent "inching" by remote control if required.

Replacing the guard should not automatically restart the machine. To be effective, all movable guards should be interlocked to prevent occupational hazards.



Safeguarding Action	Advantages	Limitations
Shuts off or disengages power, stops the moving parts and prevents starting of the machine when the guard is open; should require the machine to be stopped before the worker can reach into the danger area	Can provide maximum protection	Requires careful adjustment and maintenance
	Allows access to the machine for removing jams without time consuming removal of the fixed guards	May be easy to disengage

**3. Which type of guard automatically shuts off or disengages when it is opened or removed?**

- a. Adjustable guard
- b. Interlocked guard
- c. Fixed guard
- d. Self-adjusting guard

**Adjustable Guards**

Adjustable guards are useful because they allow flexibility in accommodating various sizes of stock. They provide a barrier that may be adjusted to facilitate a variety of production operations.

<b>Safeguarding Action</b>	<b>Advantages</b>	<b>Limitations</b>
Provides a barrier that may be adjusted to facility a variety of production operations	Can be constructed to suit many specific applications	Hands may enter danger area-protection may not be complete at all times
	Can be adjusted to admit varying sizes of stock	May require frequent maintenance and/or adjustment
		The guard may be ineffective by the operator
		May interfere with visibility



**4. Which type of guard allows flexibility in accommodating various sizes of stock?**

- a. Adjustable guard
- b. Interlocked guard
- c. Fixed guard
- d. Self-adjusting guard

**Self-Adjusting Guards**

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

Safeguarding Action	Advantages	Limitations
Provides a barrier that moves according to the size of the stock entering the danger area	Off-the-shelf guards are often commercially available	Does not always provide maximum protection

	Can be adjusted to admit varying sizes of stock	May interfere with visibility
		May require frequent maintenance and adjustment



5. As the operator moves the stock into the danger area, this guard is pushed away, providing an opening which is only large enough to admit the stock.

- a. Adjustable guard
- b. Interlocked guard
- c. Fixed guard
- d. Self-adjusting guard

## Module 3: Methods of Machine Safeguarding - Devices

### Introduction

A safety device may perform one of several functions. It may stop the machine if a hand or any part of the body is inadvertently placed in the danger area; restrain or withdraw the operator's hands from the danger area during operation; require the operator to use both hands on machine controls, thus keeping both hands and body out of danger; or provide a barrier which is synchronized with the operating cycle of the machine in order to prevent entry to the danger area during the hazardous part of the cycle.

### Photoelectric

The photoelectric (optical) presence-sensing device uses a system of light sources and controls which can interrupt the machine's operating cycle; if the light field is broken, the machine stops and will not cycle.

It must be used only on machines which can be stopped before the worker can reach the danger area. The design and placement of the guard depends upon the time it takes to stop the mechanism and the speed at which the employee's hand can reach across the distance from the guard to the danger zone.

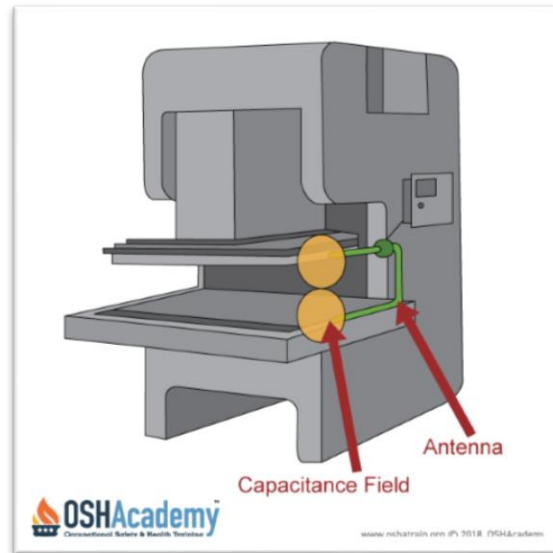
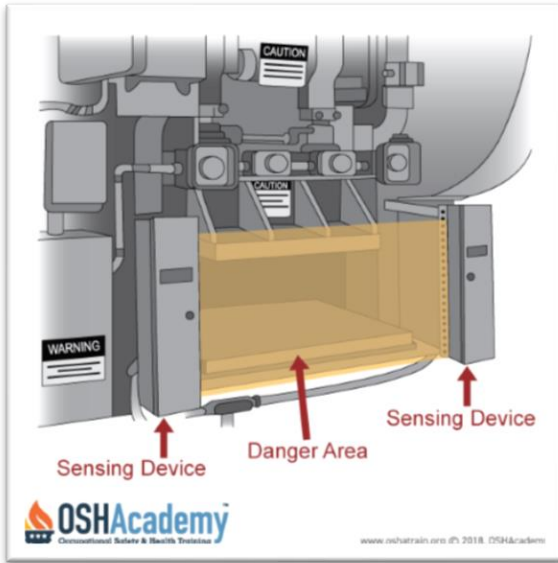
Safeguarding Action	Advantages	Limitations
Machine will not start cycling when the light field is interrupted	Can allow freer movement for operator	Does not protect against mechanical failure
When the light field is broken by any part of the operator's body during the cycling process, immediate machine braking is activated	Simplicity of use	Limited to machines that can be stopped
	Used by multiple operators	
	Provide passerby protection	

	No adjustment required	
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**Radiofrequency**

A radiofrequency presence-sensing device mounted on a part-revolution power press. The electromechanical sensing device has a probe or contact bar which descends to a predetermined distance when the operator initiates the machine cycle. If there is an obstruction preventing it from descending its full predetermined distance, the control circuit does not actuate the machine cycle.

Safeguarding Action	Advantages	Limitations
Machine will not start cycling when the capacitance field is interrupted	Can allow freer movement for operator	Does not protect against mechanical failure
When the capacitance field is broken by any part of the operator’s body during the cycling process, immediate machine braking is activated		Antennae sensitivity must be properly adjusted; this adjustment must be maintained properly
		Limited to machines that can be stopped



**1. What happens when the light field is broken while using a photoelectric presence-sensing device?**

- a. An alarm sounds
- b. The machine works since no one is present
- c. The machine stops and will not cycle
- d. Strobe lights begin flashing

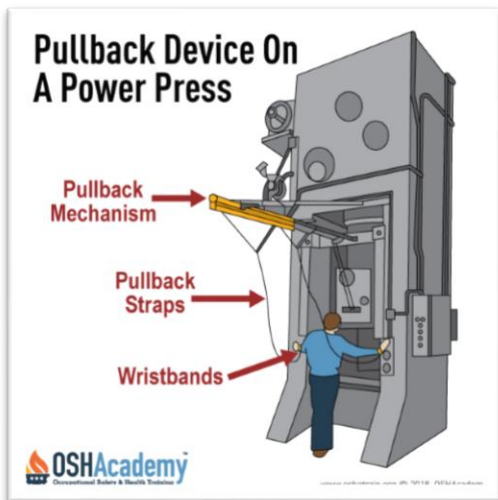
### Pullback Devices

Pullback devices utilize a series of cables attached to the operator's hands, wrists, and/or arms. This type of device is primarily used on machines with stroking action. When the slide/ram is up between cycles, the operator is allowed access to the point of operation. When the slide/ram begins to cycle by starting its descent, a mechanical linkage automatically assures withdrawal of the hands from the point of operation.

Figures 1 and 2 below show a pullback device on two different power presses. When the slide/ram is in the "up" position, the operator can feed material by hand into the point of operation. When the press cycle is actuated, the operator's hands and arms are automatically withdrawn.



Safeguarding Action	Advantages	Limitations
As the machine begins to cycle, the operator's hands are pulled out of the danger area	Eliminates the need for auxiliary barriers or other interferences at the danger area	Limits movement of the operator
		May obstruct work space around the operator
		Adjustments must be made for specific operations and for each individual
		Requires frequent inspections and regular maintenance
		Requires close supervision of the operator's use of the equipment



**2. Which type of safeguard device uses a series of cables attached to the operator's hands, wrists, and/or arms?**

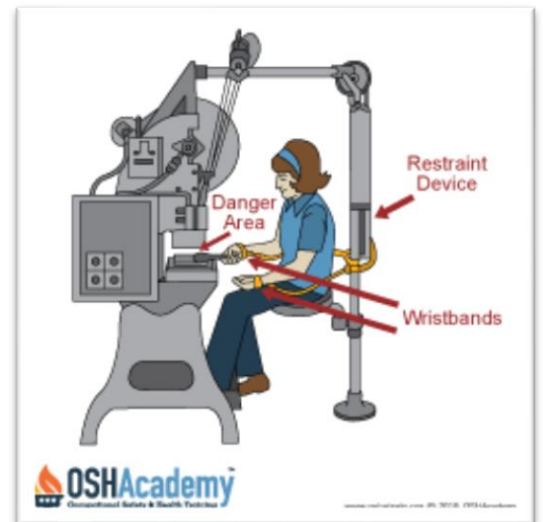
- a. Presence-sensing device
- b. Pullback device
- c. Restraint device
- d. Safety trip device

**Restraint Devices**

The restraint (holdout) device in figure to the right uses cables or straps that are attached to the operator's hands at a fixed point.

The cables or straps must be adjusted to let the operator's hands travel within a predetermined safe area.

There is no extending or retracting action involved. Consequently, hand-feeding tools are often necessary if the operation involves placing material into the danger area.



Safeguarding Action	Advantages	Limitations
Prevents the operator from reaching into the danger area	Little risk of mechanical failure	Limits movement of operator
		May obstruct work space
		Adjustments may be made for specific operations and each individual

		Requires close supervision of the operator's use of the equipment
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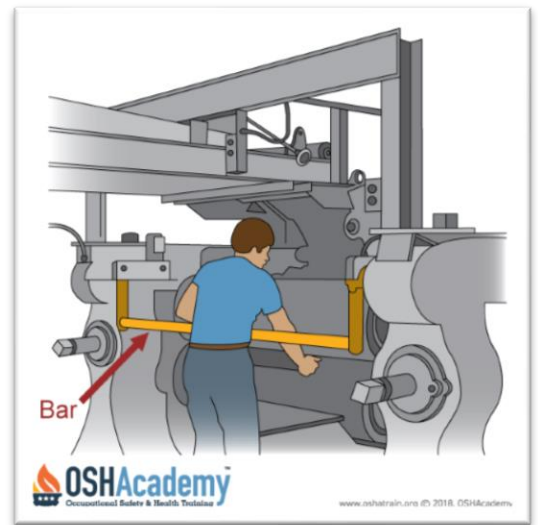
**3. Which one of the following safeguard devices uses cables or straps that are attached to the operator's hands at a fixed point?**

- a. Presence-sensing device
- b. Pullback device
- c. Restraint device
- d. Safety trip device

**Safety Trip Controls**

Safety trip controls provide a quick means for deactivating the machine in an emergency situation.

A pressure-sensitive body bar, when depressed, will deactivate the machine. If the operator or anyone trips, loses balance, or is drawn toward the machine, applying pressure to the bar will stop the operation. The positioning of the bar, therefore, is critical. It must stop the machine before a part of the employee's body reaches the danger area. The figure here shows a pressure-sensitive body bar located on the front of a rubber mill.



Safeguarding Action	Advantages	Limitations
Stops machine when tripped	Simplicity of use	All controls must be manually activated

		May be difficult to activate controls because of their location
		Only protects the operator
		May require special fixtures to hold work
		May require a machine brake

**4. Which one of the following safeguard devices provides a quick means for deactivating the machine in an emergency situation?**

- a. Presence-sensing device
- b. Pullback device
- c. Restraint device
- d. Safety trip device

**Two-Hand Control Devices**

The two-hand control requires constant, concurrent pressure by the operator to activate the machine. (figure 1) This kind of control requires a part-revolution clutch, brake, and a brake monitor if used on a power press as shown in the figure 2. With this type of device, the operator's hands are required to be at a safe location (on control buttons) and at a safe distance from the danger area while the machine completes its closing cycle.

Figure 1

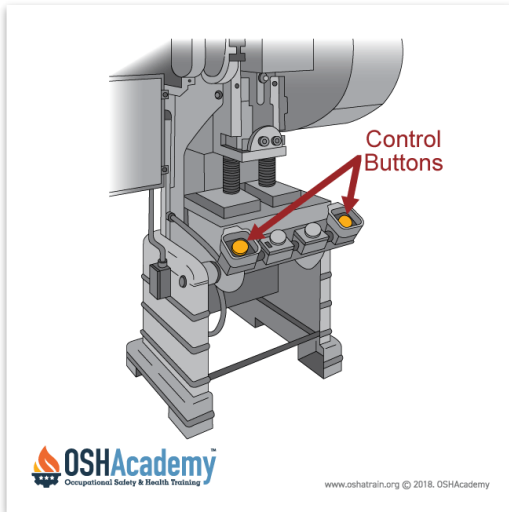
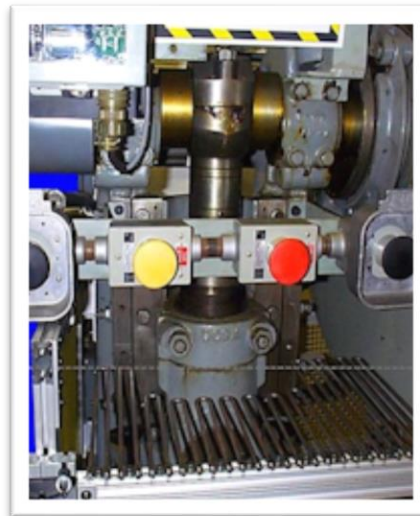


Figure 2



Safeguarding Action	Advantages	Limitations
Concurrent use of both hands is required, preventing the operator from entering the danger area	Operator's hands are at pre-determined location	Requires a partial cycle machine with a brake
	Operator's hands are free to pick up a new part after first half of the cycle is completed	Some two-hand controls can be rendered unsafe by holding with arm or blocking, thereby permitting one-hand operation
		Only protects the operator

**5. Which safeguard device requires constant, concurrent pressure by the operator to activate the machine?**

- a. Presence-sensing device
- b. Pullback device
- c. Two-hand control device
- d. Two-hand trip device

**Two-Hand Trip Devices**

The two-hand trip in the figure below requires concurrent application of both the operator's control buttons to activate the machine cycle, after which the hands are free. This device requires the joint operation of two trigger buttons located away from the "danger zone" of the press. To be effective, both two-hand controls and trips must be located so that the operator cannot use two hands or one hand and another part of his/her body to trip the machine.

Activation of the machine stroke requires only a "trip" of the controls whereas a two-hand control requires continued pressure. The two-hand trip requires the operator's hands to be away from the point of operation to activate the machine stroke.

Safeguarding Action	Advantages	Limitations
Concurrent use of two hands on separate controls prevents hands from being in the danger area when machine cycle starts	Operator's hands are away from danger area	Operator may try to reach into danger area after tripping machine
	Can be adapted to multiple operations	Some trips can be rendered unsafe by holding with arm or blocking, thereby permitting one-hand operation
	Does not require adjustment for each operation	Only protects the operator

		May require special fixtures
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**6. Which safeguard device requires concurrent application of both the operator's control buttons to activate the machine cycle, after which the hands are free?**

- a. Presence-sensing device
- b. Pullback device
- c. Two-hand control device
- d. Two-hand trip device

**Gates**

The gate is a moveable barrier that protects the operator at the point of operation before the machine cycle can be started. Type "A" and "B" Gates (See below) are commonly used with presses and, in many instances, designed to be operated with each machine cycle.

To be effective, the gate must be interlocked so that the machine will not begin a cycle unless the gate is in place. It must be in the closed position before the machine can function. If the gate is not permitted to descend to the fully closed position, the press will not function. Operators must be prevented from placing their hands or any other body parts in the point of operation during the die-closing portion of the press stroke.

Another potential application of this type of guard is where the gate is a component of a perimeter safeguarding system. Here the gate may provide protection not only to the operator but to pedestrian traffic as well.

Safeguarding Action	Advantages	Limitations
Concurrent use of two hands on separate controls prevents hands from being in the danger area when machine cycle starts	Operator's hands are away from danger area	Operator may try to reach into danger area after tripping machine

	Can be adapted to multiple operations	Some trips can be rendered unsafe by holding with arm or blocking, thereby permitting one-hand operation
	No obstruction to hand feeding	Only protects the operator
		May require special fixtures

### Type A Gate

**"A" Gate Sequence of Operation.** Type "A" Gates protect the operator during the entire machine stroke. This means the gate will not open until after the crankshaft rotation is complete (360°) and the machine is stopped at top dead center. Although Type "A" Gates can be used on either part or full revolution clutch presses, best safety practice is the "A" gate should be used only on full revolution clutch presses.

The "A" gate is designed to enclose the point of operation before the press stroke can be started, and it must remain enclosed until all slide motion has stopped. The following is a typical sequence of operation of a complete cycle on a press which uses an "A" gate.

1. Initiate the cycle. As long as there are no obstructions, the gate closes by gravity.
2. The machine makes one complete cycle and returns to "top of stroke" and stops.
3. The gate opens, after the cycle has stopped.

### Type B Gate

**"B" Gate Sequence of Operation.** Type "B" Gates protect the operator during the downstroke only. The gate starts to open before the crankshaft rotation is complete (generally after 180° crankshaft rotation). The gates must open on the upstroke of the machine cycle before the crankshaft rotation is complete.

The "B" gate only protects the operator on the down-stroke of the press slide. The following is a typical sequence of operation of a complete cycle on a press which uses a "B" gate.



1. Initiate the cycle. As long as there are no obstructions, the gate closes by gravity.
2. Once the machine reaches the portion of the stroke where the pinch point has been eliminated and before the stroke has stopped, the "B" gate and the slide go up at the same time.

**7. Which of the following is a moveable barrier that protects the operator at the point of operation before the machine cycle can be started?**

- a. Guard
- b. Gate
- c. Restraint
- d. Lock

## Module 4: More Safeguarding Methods

### Safeguarding by Location and Distance

In order for a machine to be considered “safeguarded by location,” the dangerous moving part of the machine must be positioned so those “guarded” areas are not accessible or do not present a hazard to a worker during the normal operation of the machine.

This may be accomplished by locating a machine so that the hazardous parts of the machine are located away from operator work stations or other areas where employees walk or work. This can be accomplished by positioning a machine with its power transmission apparatus against a wall and leaving all routine operations conducted on the other side of the machine. Additionally, enclosure walls or fences can restrict access to machines. Another possible solution is to have dangerous parts located high enough to be out of the normal reach of any worker.

The feeding process can be safeguarded by location if a safe distance can be maintained to protect the worker's hands. The dimensions of the stock being worked on may provide adequate safety.

For instance, if the stock is several feet long and only one end of the stock is being worked on, the operator may be able to hold the opposite end while the work is being performed. An example would be a single-end punching machine. However, depending upon the machine, protection might still be required for other personnel.

The positioning of the operator's control station provides another potential approach to safeguarding by location. Operator controls may be located at a safe distance from the machine if there is no reason for the operator to tend it.

**1. To consider a machine safeguarded by location, the hazardous parts of the machine must be so positioned so that they \_\_\_\_\_.**

- a. are not visible
- b. are not within arm's length
- c. do not present a hazard during normal operation
- d. will not move if the guard is removed

## Feeding and Ejection Methods

Many feeding and ejection methods do not require the operator to place his or her hands in the danger area. In some cases, no operator involvement is necessary after the machine is set up. In other situations, operators can manually feed the stock with the assistance of a feeding mechanism. Properly designed ejection methods do not require any operator involvement after the machine starts to function.

Some feeding and ejection methods may even create hazards themselves. For instance, a robot may eliminate the need for an operator to be near the machine but may create a new hazard itself by the movement of its arm.

Using these feeding and ejection methods does not eliminate the need for guards and devices. Guards and devices must be used wherever they are necessary and possible in order to provide protection from exposure to hazards.

## Automatic Feed Systems

Automatic feeds such as the figure to the right reduce the exposure of the operator during the work process, and sometimes do not require any effort by the operator after the machine is set up and running.

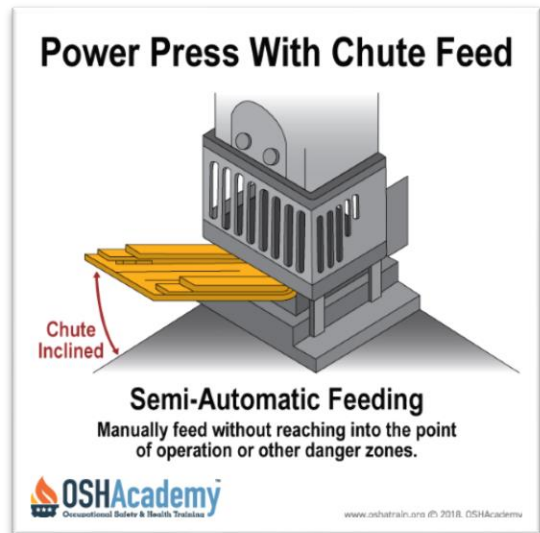
**2. Properly designed \_\_\_\_\_ do not require any operator involvement after the machine starts to function.**

- a. ejection methods
- b. injection methods
- c. semi-automatic feeding methods
- d. robotic feeding systems

### Semi-Automatic Feeding Systems

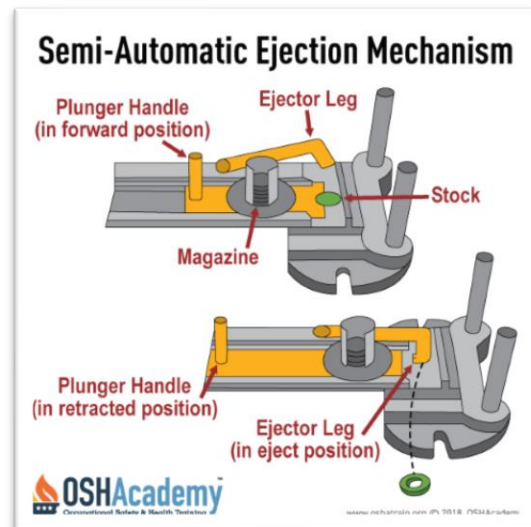
With semiautomatic feeding, as in the case of a power press, the operator uses a mechanism to place the piece being processed under the ram at each stroke. The operator does not need to reach into the danger area, and the danger area is completely enclosed.

The figure to the right shows a chute feed. It may be either a horizontal or an inclined chute into which each piece is placed by hand. Using a chute feed on an inclined press not only helps center the piece as it slides into the die but may also simplify the problem of ejection.



### Semi-Automatic Ejection Systems

The figure to the right shows a semiautomatic ejection mechanism used on a power press. When the plunger is withdrawn from the die area, the ejector leg, which is mechanically coupled to the plunger, kicks the completed work out.



**3. With \_\_\_\_\_ feeding when operating a power press, the operator uses a mechanism to place the piece being processed under the ram at each stroke.**

- a. continual
- b. robotic
- c. automatic
- d. semi-automatic

### Robot Systems

Essentially, robots perform work that would otherwise have to be done by an operator. They are best used in high-production processes requiring repeated routines where they prevent

other hazards to employees. However, they may create hazards themselves, and if they do, appropriate guards must be used.

Robots are machines that load and unload stock, assemble parts, transfer objects, or perform other tasks.

Robots are used for replacing humans who were performing unsafe, hazardous, highly repetitive, and unpleasant tasks. They are utilized to accomplish many different types of application functions such as material handling, assembly, arc welding, resistance welding, machine tool load/unload functions, painting/spraying, etc.

All industrial robots are either servo or non-servo controlled.

**Servo robots** are controlled through the use of sensors which are employed to continually monitor the robot's axes for positional and velocity feedback information. This feedback information is compared on an on-going basis to pre-taught information which has been programmed and stored in the robot's memory.

**Non-servo robots** do not have the feedback capability of monitoring the robot's axes and velocity and comparing with a pre-taught program. Their axes are controlled through a system of mechanical stops and limit switches to control the robot's movement.

**4. Which type of robot system uses a pre-taught learning program to monitor its movement and velocity?**

- a. Non-Servo
- b. Servo
- c. Automatic
- d. Programmed

### Types of Robot Hazards

The use of robotics in the workplace also can pose potential mechanical and human hazards.

Mechanical hazards might include workers colliding with equipment, being crushed, or trapped by equipment, or being injured by falling equipment components. For example, a worker could collide with the robot's arm or peripheral equipment as a result of unpredicted movements, component malfunctions, or unpredicted program changes.

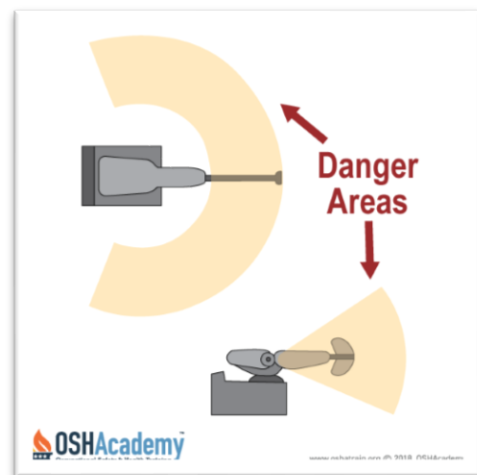
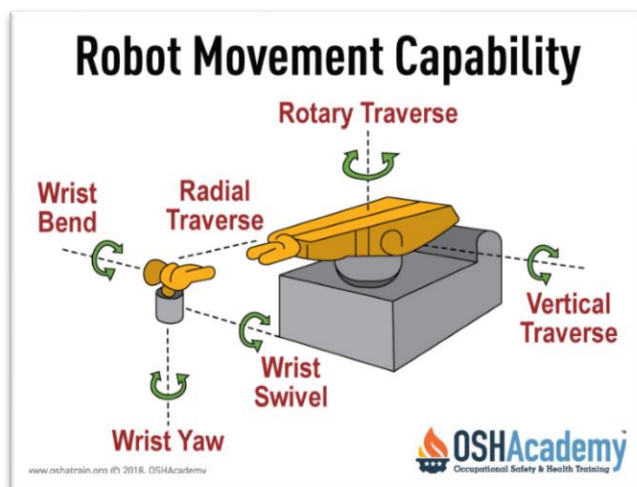
A worker could be injured by being trapped between the robot's arm and other peripheral equipment or being crushed by peripheral equipment as a result of being impacted by the robot into this equipment.

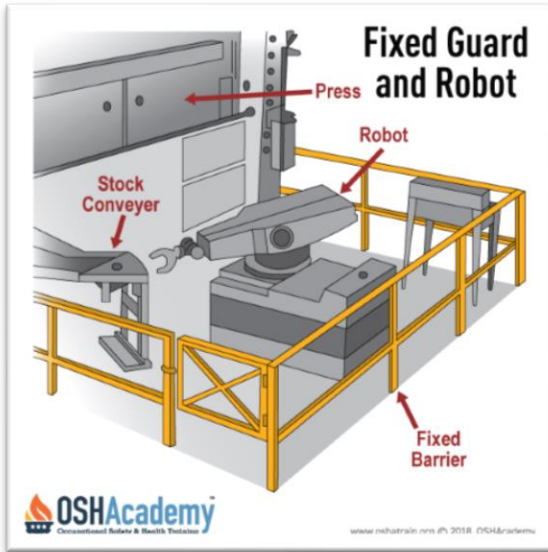
Mechanical hazards also can result from the mechanical failure of components associated with the robot or its power source, drive components, tooling or end-effector, and/or peripheral equipment. The failure of gripper mechanisms with resultant release of parts, or the failure of end-effector power tools such as grinding wheels, buffing wheels, de-burring tools, power screwdrivers, and nut runners to name a few.

Human errors can result in hazards both to personnel and equipment. Errors in programming, interfacing peripheral equipment, connecting input/output sensors, can all result in unpredicted movement or action by the robot which can result in personnel injury or equipment breakage.

Human errors in judgment result frequently from incorrectly activating the teach pendant or control panel. The greatest human judgment error results from becoming so familiar with the robot's redundant motions that personnel are too trusting in assuming the nature of these motions and place themselves in hazardous positions while programming or performing maintenance within the robot's work envelope.

The figures below show a type of robot in operation, the danger areas it can create, and an example of the kind of task (feeding a press) it can perform.





**5. What is the greatest human judgment error when working around robots?**

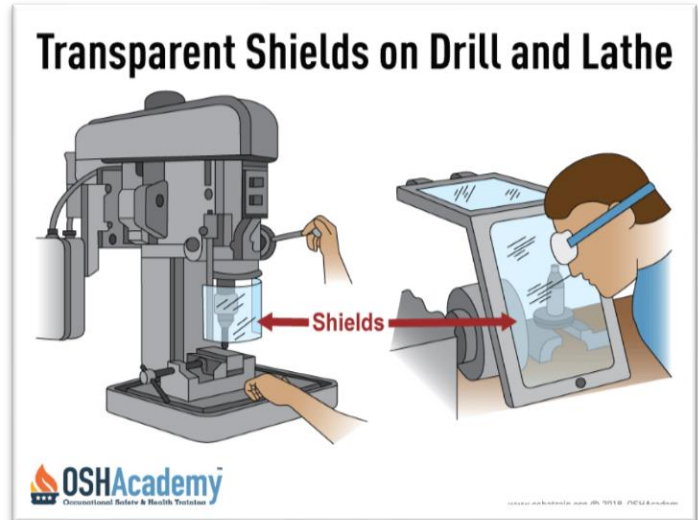
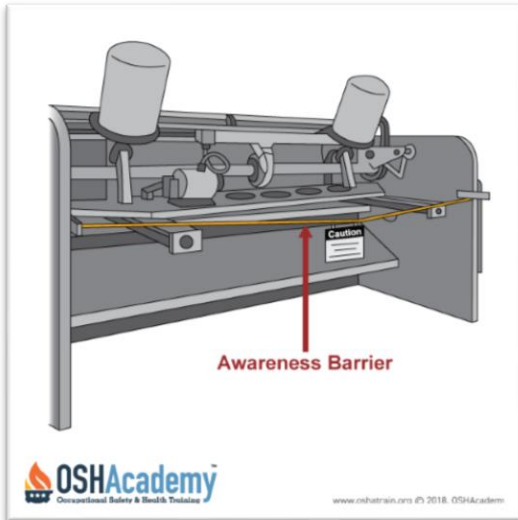
- a. Employees connecting input/output sensors
- b. Employees are too trusting of redundant robot motions
- c. Employees assume robots are not activated upon entering danger zones
- d. Employees being crushed by peripheral equipment

**Miscellaneous Aids**

While these aids do not give complete protection from machine hazards, they may provide the operator with an extra margin of safety. Sound judgment is needed in their application and usage. Below are several examples of possible applications. An **awareness barrier** does not provide physical protection but serves only to remind a person that he or she is approaching the danger area. Generally, awareness barriers are not considered adequate when continual exposure to the hazard exists.

The figure below shows a rope used as an awareness barrier on the rear of a power squaring shear. Although the barrier does not physically prevent a person from entering the danger area, it calls attention to it. For an employee to enter the danger area an overt act must take place, that is, the employee must either reach or step over, under or through the barrier.

**Shields**, another aid, may be used to provide protection from flying particles, splashing cutting oils, or coolants. The figure below on the right shows more potential applications.

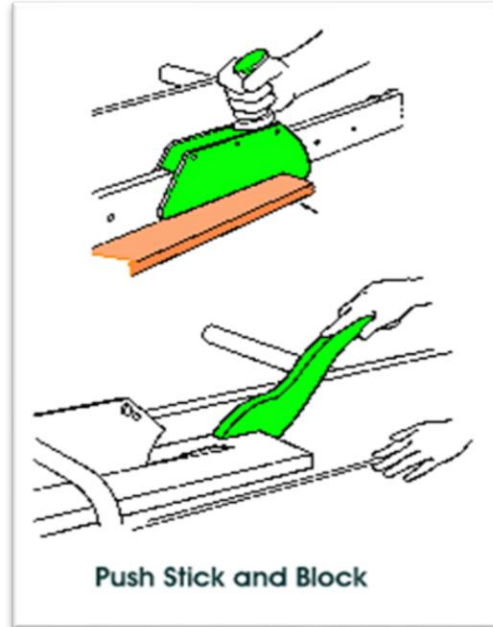


6. Which of the following is not considered adequate protection when continual exposure to a hazard exists?

- a. Hand tools
- b. Awareness barrier
- c. Shields
- d. Push sticks

**Special hand tools** may be used to place or remove stock, particularly from or into the point of operation of a machine. A typical use would be for reaching into the danger area of a press or press brake. The figure to the right shows an assortment of tools for this purpose. Holding tools should not be used instead of other machine safeguards; they are merely a supplement to the protection that other guards provide.





**7. Which of the following is a miscellaneous aid that should be used when feeding stock into a saw blade?**

- a. A push stick or block
- b. A holding tool
- c. Vacu-tongs
- d. A pair of feeding tongs

## Module 5: Machine Guard Construction

### Builder-Designed Guards

Today many builders of single-purpose machines provide point-of-operation and power transmission safeguards as standard equipment. However, not all machines in use have built-in safeguards provided by the manufacturer.

#### Advantages of Builder-Designed Guards

Guards designed and installed by the builder offer two main advantages:

- They usually conform to the design and function of the machine.
- They can be designed to strengthen the machine in some way or to serve some additional functional purposes.

#### 1. What is a major advantage of builder-made machine guards?

- a. They are often the only practical solution
- b. They can be built to fit unique situations
- c. They help promote safety consciousness
- d. They conform to the design and function of the machine

### User-Built Guards

#### Advantages of User-Built Guards

User-built guards are sometimes necessary for a variety of reasons. They provide the following advantages:

- Often, with older machinery, they are the only practical safeguarding solution.
- They may be the only choice for mechanical power transmission apparatus in older plants, where machinery is not powered by individual motor drives.
- They permit options for point-of-operation safeguards when skilled personnel design and make them.
- They can be designed and built to fit unique and even changing situations.
- They can be installed on individual dies and feeding mechanisms.

- Design and installation of machine safeguards by plant personnel can help to promote safety consciousness in the workplace.

### Disadvantages of User-Built Guards

User-built guards also have disadvantages:

- User-built guards may not conform well to the configuration and function of the machine.
- There is a risk that user-built guards may be poorly designed or built.

#### **2. Which of the following is a disadvantage of user-built machine guards?**

- a. They must be built by skilled personnel
- b. They may be poorly designed or built
- c. They are often placed within older equipment
- d. They cannot fit unique machine requirements

### Point-of-Operation Guards

Point-of-operation guards are designed to prevent workers from accidentally or intentionally inserting a finger, hand, foot, or any other body part into the operating machine.

Point-of-operation safeguarding is complicated by the number and complexity of machines and also by the different uses for individual machines. For these reasons, not all machine builders provide point-of-operation guards on their products.

In many cases a point-of-operation guard can only be made and installed by the user after a thorough hazard analysis of the work requirements. Poorly designed, built or installed guards may create a hazard rather than eliminate one.

To be effective they must safeguard the employee while allowing the work to continue with minimum disruption to the production process.

**3. Which type of machine safeguards are designed to prevent workers from inserting a body part into the operating machine?**

- a. Presence-sensing
- b. Automatic feed
- c. Point of operation
- d. Power distribution

### **Mechanical Power Transmission Apparatus Guarding**

A significant difference between power transmission guards and point-of-operation guards is that the former type needs no opening for feeding stock. The only openings necessary for power transmission guards are those for lubrication, adjustment, repair, and inspection. These openings should be provided with interlocked covers that cannot be removed except by using tools for service or adjustment.

To be effective, power transmission guards should cover all moving parts in such a manner that no part of the operator's body can come in contact with them.

**4. To be effective, power transmission guards should cover all moving parts in such a manner that \_\_\_\_\_ cannot come in contact with them.**

- a. any part of the operator's body
- b. fingers and hands
- c. the head or hair
- d. feet or legs

### **Guard Material**

Under many circumstances, metal is the best material for guards. Guard framework is usually made from structural shapes, pipe, bar, or rod stock. Filler material generally is expanded or perforated or solid sheet metal or wire mesh. It may be feasible to use plastic or safety glass where visibility is required.

Guards made of wood generally are not recommended because of their flammability and lack of durability and strength. However, in areas where corrosive materials are present, wooden guards may be the better choice.

**5. It is recommended that machine safeguards should generally be made from any of the following EXCEPT \_\_\_\_\_.**

- a. wood
- b. pipes
- c. metal bars
- d. rod stock

## Module 6: Machinery Maintenance and Repair

### Machinery Maintenance and Repair

Good maintenance and repair procedures contribute significantly to the safety of the maintenance crew as well as that of machine operators. The variety and complexity of machines to be serviced, the hazards associated with their power sources, the special dangers that may be present during machine breakdown, and the severe time constraints often placed on maintenance personnel all make safe maintenance and repair work difficult.

### Hazard Identification and Reporting

Training and aptitude of people assigned to these jobs should make them alert for the intermittent electrical failure, the worn part, the inappropriate noise, the cracks or other signs that warn of impending breakage or that a safeguard has been damaged, altered, or removed.

By observing machine operators at their tasks and listening to their comments, maintenance personnel may learn where potential trouble spots are and give them early attention before they develop into sources of accidents and injury.

Sometimes all that is needed to keep things running smoothly and safely is machine lubrication or adjustment. Any damage observed or suspected should be reported to the supervisor; if the condition impairs safe operation, the machine should be out of service for repair. Safeguards that are missing, altered, or damaged also should be reported so appropriate action can be taken to insure against worker injury.

#### 1. What should workers do first if they discover or suspect any damage to machinery?

- a. Bypass reporting and immediately fix the problem
- b. Report it immediately to the supervisor
- c. Immediately place the machinery out of service
- d. If it's not in your department, just ignore it

### Machine Guard Design Considerations

If possible, machine design should permit routine lubrication and adjustment without removal of safeguards. But when safeguards must be removed, and the machine serviced, the lockout procedure of 29 CFR 1910.147 must be adhered to. The maintenance and repair crew must never fail to replace the guards before the job is considered finished and the machine released from lockout.

Is it necessary to oil machine parts while a machine is running? If so, special safeguarding equipment may be needed solely to protect the oiler from exposure to hazardous moving parts. Maintenance personnel must know which machines can be serviced while running and which cannot. "If in doubt, lock it out." Obviously, the danger of accident or injury is reduced by shutting off and locking out all sources of energy.

**2. What is required if safeguards must be removed when a machine is serviced?**

- a. Lockout/Tagout (LOTO) procedures
- b. Maintenance inspection of all parts
- c. Through lubrication and cleaning
- d. Job Hazard Analysis (JHA)

**Sources of Hazardous Energy during Maintenance and Repair**

In situations where the maintenance or repair worker would necessarily be exposed to electrical elements or hazardous moving machine parts in the performance of the job, there is no question that all power sources must be shut off and locked out before work begins. Warning signs or tags are inadequate insurance against the untimely energizing of mechanical equipment.

Thus, one of the first procedures for the maintenance person is to disconnect and lock out the machine from all of its power sources, whether the source is electrical, mechanical, pneumatic, hydraulic, or a combination of these. Energy accumulation devices must be "bled down."

**Electrical Energy Hazards**

Unexpected energizing of any electrical equipment that can be started by automatic or manual remote control may cause electric shock or other serious injuries to the machine operator, the maintenance worker, or others operating adjacent machines controlled by the same circuit.

For this reason, when maintenance personnel must repair electrically powered equipment, they should open the circuit at the switch box and padlock the switch (lock it out) in the "off" position.

This switch should be tagged with a description of the work being done, the name of the maintenance person, and the department involved. When more than one worker is to be engaged in the servicing/maintenance function a lockout hasp may be used to which each may affix a personal lock.

**3. What must occur if a maintenance worker could be exposed to electricity or hazardous moving machine parts?**

- e. All power sources must be shut off and locked out before work begins
- f. An information tag must be placed at the point of operation
- g. Each worker must inform others of the hazards
- h. Moving parts must be noted and tagged

**Mechanical Energy Hazards**

The figure to the right shows safety blocks being used as an additional safeguard on a mechanical power press, even though the machine has been locked out. The safety blocks prevent the ram from coming down under its own weight.

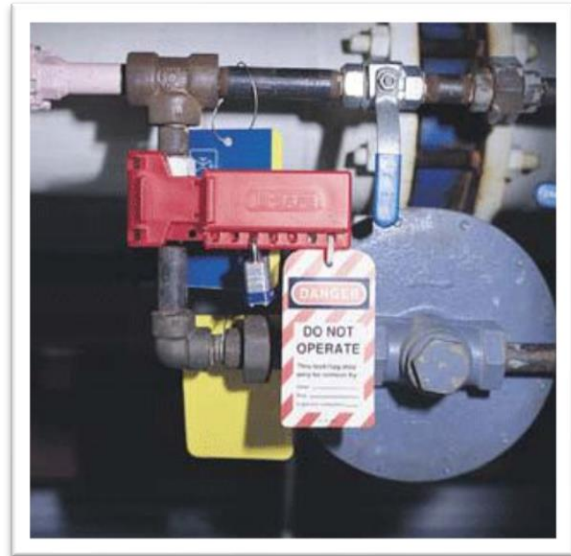




## Pneumatic and Hydraulic Energy Hazards

The figure to the right shows a lockout valve. The lever-operated valve used during repair or shutdown to keep a machine or its components from operating can be locked open or shut. Before the valve can be opened, everyone working on the machine must use his or her own key to release the lockout.

A sliding-sleeve valve exhausts line pressure at the same time it cuts off the air supply. Valves used to lock out pneumatic or hydraulic-powered machines should be designed to accept locks or lockout adapters and should be capable of "bleeding off" pressure residues that could cause any part of the machine to move.



**4. Which of the following is used as an additional safeguard to protect against a mechanical energy (gravity) hazard even though the machine has been locked out?**

- i. A chain
- j. A block
- k. A lock
- l. A tag

## Performing Lockout/Tagout (LOTO) Procedures

In order to prevent the hazards we have discussed, each machine or piece of equipment should be safeguarded during the conduct of servicing or maintenance by:

1. notifying all affected employees (usually machine or equipment operators or users) that the machine or equipment must be shut down to perform some maintenance or servicing
2. stopping the machine
3. isolating the machine or piece of equipment from its energy source

4. locking out or tagging out the energy source
5. relieving any stored or residual energy
6. verifying the machine or equipment is isolated from the energy source

Although this is the general rule, exceptions can be made when the servicing or maintenance is not hazardous for an employee, is minor in nature, and is done as an integral part of production and the employer utilizes alternative safeguards which provide effective protection as is required by OSHA standards.

- 5. When machinery is about to be worked on, maintenance workers should notify \_\_\_\_.**
- a. all supervisory and management staff
  - b. only those employees exposed to hazards
  - c. affected employees operating or using the machinery
  - d. all employees working within the department

### Release from Lockout/Tagout Procedures

When the servicing or maintenance is completed, there are specific steps which must be taken to return the machine or piece of equipment to service. These steps include:

1. inspection of the machine or equipment to ensure that all non-essential items (e.g., tools, spare parts) have been removed, and are guards and other safety devices are in place and functional;
2. checking the area to ensure that energization and start-up of the machine or equipment will not endanger employees;
3. removal of the lockout devices;
4. reenergization of the machine or equipment; and
5. notification of affected employees that the machine or equipment may be returned to service.

The steps to lockout described above are only a part of the total energy control program which must exist in the workplace. In addition, the employer should:

- develop procedures for all machines and equipment
- train employees in their duties and responsibilities under the energy control program, and
- periodically inspect performance to maintain the effectiveness of the program.

**6. The first step for release from lockout/tagout is to \_\_\_\_.**

- a. remove the lockout devices
- b. make sure all guards and devices are in place and functional
- c. make sure reenergization does not endanger employees
- d. notify affected employees about equipment return to service