Chapter Fourteen Mechanical Hazards and Machine Safeguarding

Learning Objectives

List the more common mechanical injuries

Define the term safeguarding

Summarize OSHA's requirements for machine safeguarding

Explain the concept of risk assessment in machine operation

Describe the design requirements for safeguards

Explain the concept of point-of-operation guards

Explain the concept of point-of-operation devices

Summarize the key elements of a machine guarding self-assessment

Describe the various kinds of feeding and ejection systems

Describe the types of safeguards used with robots

Explain how lockout/tagout systems are used to control hazardous energy in machines

Explain how permanent electrical safety devices are used in lockout/tagout programs

List the general precautions to be observed in machine safeguarding

Explain the basic content for a machine safeguarding program

Summarize how to take corrective action when a mechanical hazard is observed

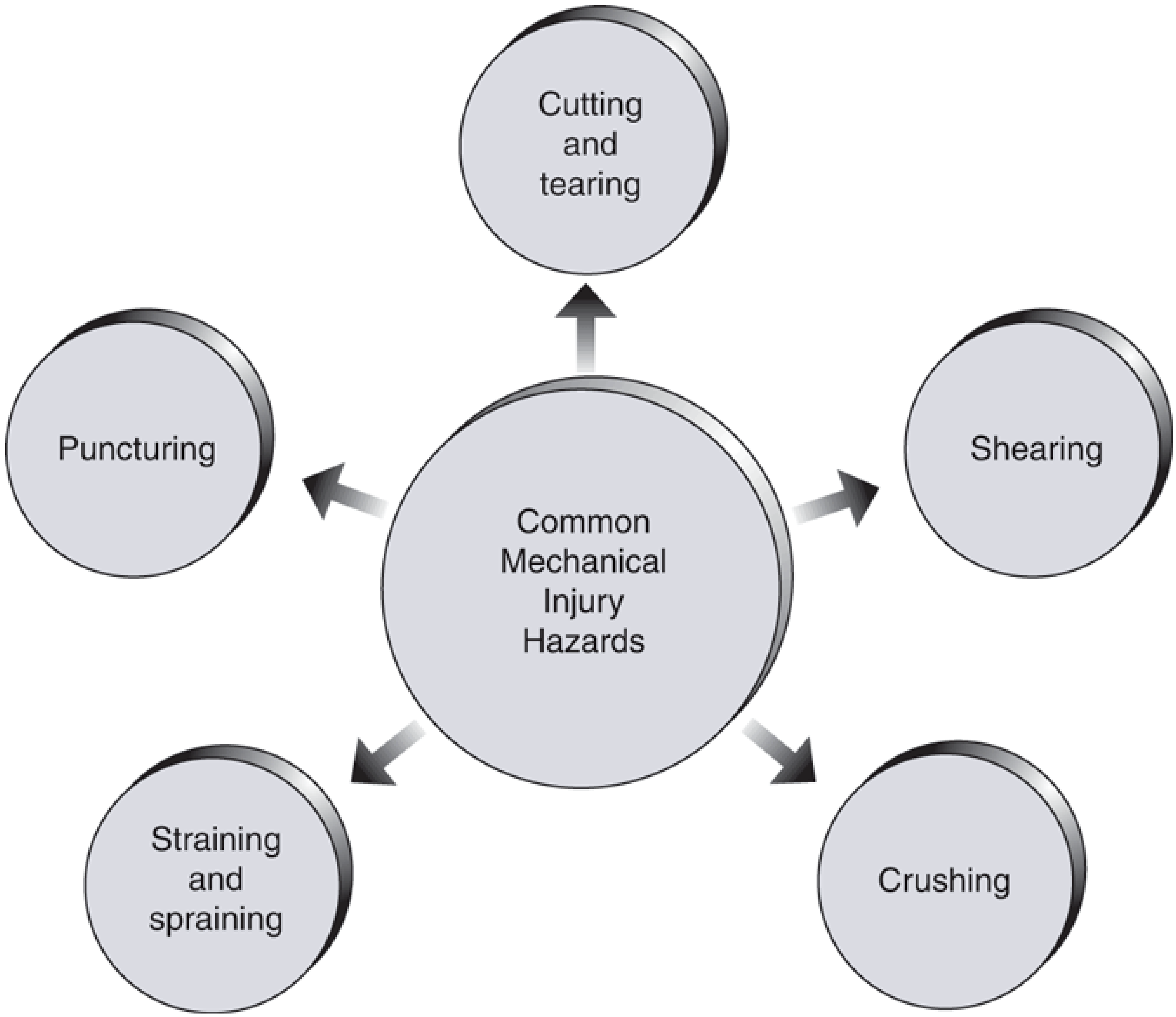
Failure to provide proper machine guards and enforce their use can be costly for companies. A manufacturing firm in Syracuse, New York, learned this fact the hard way when it was cited by the Occupational Safety and Health Administration (OSHA) for failure to provide appropriate machine guards and require their proper use by employees. Because the company had been issued a similar citation earlier, it was fined $119,000. Mechanical hazards that are not properly guarded are implicated in thousands of workplace injuries every year.

As another example, a windshield manufacturing firm was fined more than $105,000 by OSHA when it allowed employees to be exposed to electrical hazards and knowingly failed to meet lockout/tagout standards. The small gains in productivity that might be obtained by willfully bypassing mechanical safeguards on machines can cost companies huge fines and even expensive medical bills.

Mechanical hazards are those associated with power-driven machines, whether automated or manually operated. Concerns about mechanical hazards date back to the Industrial Revolution and the earliest days of mechanization. Machines driven by steam, hydraulic, or electric power introduced new hazards into the workplace. In spite of advances in safeguarding technologies and techniques, mechanical hazards are still a major concern today. In addition, automated machines have introduced new concerns.

Common Mechanical Injuries

In an industrial setting, people interact with machines that are designed to drill, cut, shear, punch, chip, staple, stitch, abrade, shape, stamp, and slit materials such as metals, composites, plastics, and elastomers. If appropriate safeguards are not in place or if workers fail to follow safety precautions, these machines can apply the same procedures to humans. When this happens, the types of mechanical injuries that result are typically the result of cutting, tearing, shearing, crushing, breaking, straining, or puncturing (see Figure 14–1). Information about each of these hazards is provided in the following paragraphs.


Cutting and tearing
Puncturing
Shearing
Common Mechanical Injury Hazards
Straining and spraining
Crushing

Cutting and Tearing

A cut occurs when a body part comes in contact with a sharp edge. The human body's outer layer consists of the following, starting from the outside: epidermis, the tough outer covering of the skin; dermis, the greatest part of the skin's thickness; capillaries, the tiny blood vessels that branch off the small arteries and veins in the dermis; veins, the blood vessels that collect blood from the capillaries and return it to the heart; and arteries, the larger vessels that carry blood from the heart to the capillaries in the skin. The seriousness of cutting or tearing the skin depends on how much damage is done to the skin, veins, arteries, muscles, and even bones.

Shearing

To understand what shearing is, think of a paper cutter. It shears the paper. Power-driven shears for severing paper, metal, plastic, elastomers, and composite materials are widely used in manufacturing. In times past, such machines often amputated fingers and hands. These tragedies typically occurred when operators reached under the shearing blade to make an adjustment or placed materials there and activated the blade before fully removing their hand. Safeguards against shearing accidents are explained later in this chapter.

Crushing

Injuries from crushing can be particularly debilitating, painful, and difficult to heal. They occur when a part of the body is caught between two hard surfaces that progressively move together, thereby crushing anything between them. Crushing hazards can be divided into two categories: squeeze-point types and run-in points.

Squeeze-point hazards exist where two hard surfaces, at least one of which must be in motion, push close enough together to crush any object that may be between them. The process can be slow, as in a manually operated vise, or fast, as with a metal-stamping machine.

Run-in point hazards exist where two objects, at least one of which is rotating, come progressively closer together. Any gap between them need not become completely closed. It need only be smaller than the object or body part lodged in it. Meshing gears and belt pulleys are examples of run-in point hazards (see Figures 14–2, 14–3, and 14–4).

Figure 14–2 This nip point can pull hands, feet, or articles of clothing.

Figure 14–3 Fingers might get caught between the bench top and the revolving wheel.

Figure 14–4 Nip points can catch fingers, hands, hair, clothing, etc., with dangerous results.

Body parts can also be crushed in other ways—for example, a heavy object falling on a foot or a hammer hitting a finger. However, these are impact hazards, which are covered in Chapter 15.

Breaking

Machines used to deform engineering materials in a variety of ways can also cause broken bones. A break in a bone is known as a fracture. Fractures are classified as simple, compound, complete, and incomplete.

A simple fracture is a break in a bone that does not pierce the skin. A compound fracture is a break that has broken through the surrounding tissue and skin. A complete fracture divides the affected bone into two or more separate pieces. An incomplete fracture leaves the affected bone in one piece but cracked.

Fractures are also classified as transverse, oblique, and comminuted. A transverse fracture is a break straight across the bone. An oblique fracture is diagonal. A comminuted fracture exists when the bone is broken into a number of small pieces at the point of fracture.

Straining and Spraining

There are numerous situations in an industrial setting when straining of muscles or spraining of ligaments is possible. A strain results when muscles are overstretched or torn. A sprain is the result of torn ligaments in a joint. Strains and sprains can cause swelling and intense pain.

Puncturing

Punching machines that have sharp tools can puncture a body part if safety precautions are not observed or if appropriate safeguards are not in place. Puncturing results when an object penetrates straight into the body and pulls straight out, creating a wound in the shape of the penetrating object. The greatest hazard with puncture wounds is the potential for damage to internal organs.

Safeguarding Defined

All the hazards explained in the previous section can be reduced by the application of appropriate safeguards. CFR 1910 Subpart O contains the OSHA standards for machinery and machine guarding (1910.211–1910.222). Safeguarding can be defined as follows:

Machine safeguarding is to minimize the risk of accidents of machine-operator contact. The contact can be:

An individual making the contact with the machine—usually the moving part—because of inattention caused by fatigue, distraction, curiosity, or deliberate chance taking

From the machine via flying metal chips, chemical and hot metal splashes, and circular saw kickbacks, to name a few

Caused by the direct result of a machine malfunction, including mechanical and electrical failure1

Safeguards can be broadly categorized as point-of-operation guards, point-of-operation devices, and feeding/ejection methods. The various types of safeguards in these categories are explained later in this chapter.

OSHA’s Requirements for Machine Guarding

The OSHA standard containing the general requirements for machine guarding is 29 CFR 1910.212. A more specific standard (29 CFR 1926.300) exists for the construction industry. This section focuses on 29 CFR 1910.212—OSHA’s requirements for all industries. Those requirements are summarized as follows:

Types of guarding. One or more methods of machine guarding must be provided to protect people from point-of-operation hazards such as nip points, rotating parts, flying chips, and sparks. “Point of operation” refers to the area on the machine where work is performed on the material being processed. Examples of point-of-operation machine guards are barriers, two-hand switches and tripping devices, and electronic sensors.

General requirements for machine guards. Where possible, guards should be affixed to the machine in question. When this is not possible, guards should be secured in the most feasible location and method away from the machine. Guards must be affixed in such a way that they do not create a hazard themselves.

Guarding the point of operation. Any point of operation that might expose a person to injury must be guarded. Guarding devices must comply with all applicable standards. In the absence of applicable standards, the guard must be designed, constructed, and installed in such a way as to prevent the machine operator from having any part of his body (including clothing, hair, etc.) in the danger zone during the operating cycle of the machine.

Machines requiring point of operation guards. The following are examples of machines that require point of operation guards: guillotine cutters, shears, alligator shears, power presses, milling machines, power saws, jointers, portable power tools, forming rolls, and calendars.

Exposure of blades. Fans must be guarded in any case in which the periphery of the fan blades is less than seven feet above the floor or working level. Guards for fans shall have no openings that exceed one-half inch.

Anchoring fixed machinery. Machines that are designed to be fixed in one location must be securely anchored to prevent movement.2

Minimum General Requirements for Safeguards

OSHA Standard 29 CFR 1910.212 requires that machine safeguards for all industries meet the following minimum requirements:3

Prevent contact. Must prevent any part of the worker's body from making contact with dangerous moving parts.

Be secure. Must be secure enough to prevent workers from easily removing them, durable enough to withstand normal use, and firmly secured to the machine where possible (or secured elsewhere if it is not possible to secure them to the machine).

Protect from falling objects. Must ensure that falling objects cannot fall into moving parts.

Create no interference. Must not impede the worker’s ability to perform required tasks quickly and comfortably.

Allow safe lubrication. Must be able to be lubricated without removal from the machine if possible.

Risk Assessment in Machine Operation

Risk assessment in this context is the process of quantifying the level of risk associated with the operation of a given machine. It should be a structured and systematic process that answers the following four specific questions:

How severe are potential injuries?

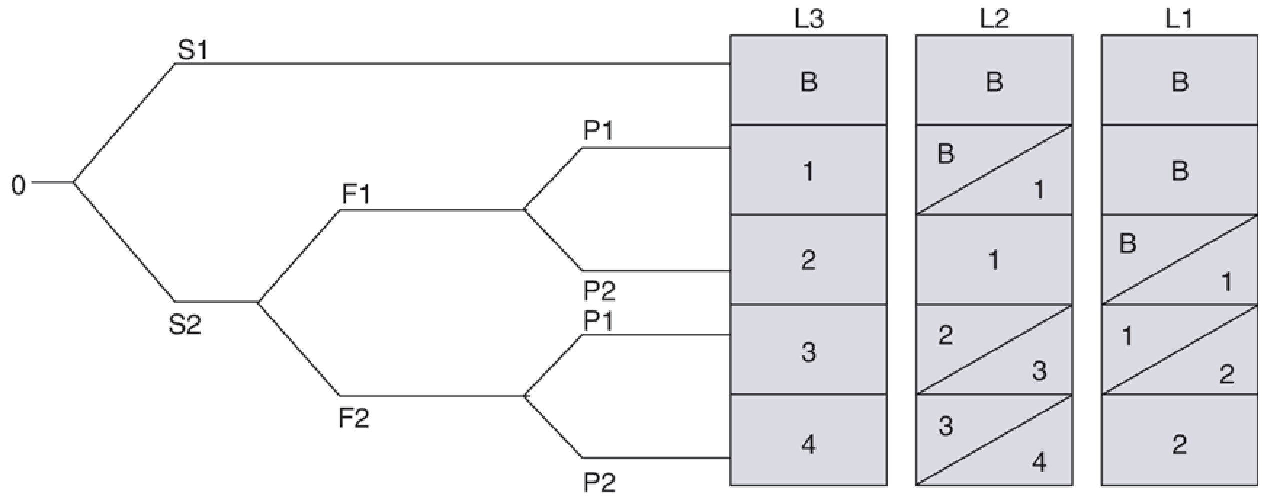
How frequently are employees exposed to the potential hazards?

What is the possibility of avoiding the hazard if it does occur?

What is the likelihood of an injury should a safety control system fail?

A widely used risk-assessment technique is the decision tree, coupled with codes representing these four questions and defined levels of risk. Figure 14–5 is an example of a risk-assessment decision tree. In this example, the codes and their associated levels of risk are as follows:

Figure 14–5 Risk-assessment decision tree.



S = Severity

Question 1: Severity of potential injuries

S1 Slight injury (bruise, abrasion)

S2 Severe injury (amputation or death)

F = Frequency

Question 2: Frequency of exposure to potential hazards

F1 Infrequent exposure

F2 From frequent to continuous exposure

P = Possibility

Question 3: Possibility of avoiding the hazard if it does occur

P1 Possible

P2 Less possible to not impossible

L = Likelihood

Question 4: Likelihood that the hazard will occur

L1 Highly unlikely

L2 Unlikely

L3 Highly likely

RL = Risk Levels

Associated risk factors ranging from lowest (B) to highest (4)

By applying the decision tree in Figure 14–5 or a similar device, the risk associated with the operation of a given machine can be quantified. This allows safety personnel to assign logical priorities for machine safeguarding and hazard prevention.

Risk Assessment Model

The decision tree in Figure 14–5 is one tool for assessing the level of risk associated with machine operation. For safety professionals who prefer a different kind of tools the following model is also an effective tool:

Make a list of the various machines/processes in the facility. Then prioritize the list on the basis of hazard level. Machines/processes with the highest hazard levels should be dealt with first when taking steps to mitigate the hazards.

Collect pertinent information for the machine/process in question. What is the energy source for the machine/process? What specific tasks does the machine/process perform? Who operates the machine/process? How much training and experience are required of those who operate the machine/process? Do all personnel who operate the machine/process have the required levels of training and experience? Are other personnel besides the operators exposed to the risk associated with the machine/process? Is there a history of accidents/injuries associated with the machine/process?

Remove all safeguards. In the next step the machine/process will be observed with a mind to identifying potentially hazardous conditions. This should be done without safeguards in place so that a hazard is not overlooked simply because it is mitigated by a safeguard.

Observe the machine/process in operation without safeguards and make a list of potential hazards. Observe each step that is necessary to operate the machine/process and make note of any potential hazards. These operational steps should include at least the following: set-up, start-up, normal operation, tool installation, tool changes, housekeeping and clean-up, and regular maintenance tasks. Look for potential hazards such as contact with live parts, cutting, crushing, puncturing, slip and fall, trip and fall, contact with ejected parts, contact with ejected fluids, and electrical hazards.

Choose a method for labeling risk levels. There are several widely recognized methods that can be used for labeling risk levels on machines/processes. One of the more widely used methods is contained in ANSI B11.TR3. Section 7.2 of ANSI B11.TR3 addresses the potential severity of harm and labels these levels as catastrophic, serious, moderate, or minor. Section 7.3 of ANSI B11.TR3 addresses the probability of the occurrence of harm and labels the probability as very likely, likely, unlikely, or remote.

Choose safeguards on the basis of the level of risk associated with the machine/ process. Safeguards should be chosen on the basis of risk level as assigned in the previous step. For example, a machine or process that has the potential to produce a catastrophic injury should be fitted with safeguards that provide the highest level of risk reduction. Safeguards providing the highest level of risk reduction are barrier guards or devices that prevent intentional exposure of a body part to the hazard. Safeguards that provide a high to intermediate level of risk reduction are barrier guards or devices that prevent unintended exposure of a body part to the hazard. Safeguards that provide a low to intermediate level of risk reduction are barrier guards or devices that prevent inadvertent exposure of a body part to the hazard. Safeguards that provide a low level of risk reduction are physical barriers that provide only tactile or visual awareness of the hazard.

Design Requirements for Safeguards

The various machine motions present in modern industry involve mechanisms that rotate, reciprocate, or do both. This equipment includes tools, bits, chucks, blades, spokes, screws, gears, shafts, belts, and a variety of different types of stock. Safeguards can be devised to protect workers from harmful contact with such mechanisms while at the same time allowing work to progress at a productive rate. The following requirements should be met when designing safeguards:

Prevent contact. Safeguards should prevent human contact with any potentially harmful machine part. The prevention extends to machine operators and any other person who might come in contact with the hazard.

Be secure and durable. Safeguards should be attached so that they are secure. This means that workers cannot render them ineffective by tampering with or disabling them. This is critical because removing safeguards in an attempt to speed production is a common practice. Safeguards must also be durable enough to withstand the rigors of the workplace. Worn-out safeguards won’t protect workers properly.

Protect against falling objects. Objects falling onto moving machine mechanisms increase the risk of accidents, property damage, and injury. Objects that fall on a moving part can be quickly hurled out, creating a dangerous projectile. Therefore, safeguards must do more than just prevent human contact. They must also shield the moving parts of machines from falling objects.

Create no new hazard. Safeguards should overcome the hazards in question without creating new ones. For example, a safeguard with a sharp edge, unfinished surface, or protruding bolts introduces new hazards while protecting against the old.

Create no interference. Safeguards can interfere with the progress of work if they are not properly designed. Such safeguards are likely to be disregarded or disabled by workers feeling the pressure of production deadlines.

Allow safe maintenance. Safeguards should be designed to allow the more frequently performed maintenance tasks (e.g., lubrication) to be accomplished without the removal of guards. For example, locating the oil reservoir outside the guard with a line running to the lubrication point will allow for daily maintenance without removing the guard.4

Design and construction of safeguards are highly specialized activities requiring a strong working knowledge of machines, production techniques, and safety. However, it is critical that all the factors explained in this section be considered and accommodated during the design process.

Point-of-Operation Guards

Guards are most effective when used at the point of operation, which is where hazards to humans exist. Point-of-operation hazards are those caused by the shearing, cutting, or bending motions of a machine. Pinch-point hazards result from guiding material into a machine or transferring motion (e.g., from gears, pressure rollers, or chains and sprockets). Single-purpose safeguards, because they guard against only one hazard, typically are permanently fixed and nonadjustable. Multiple-purpose safeguards, which guard against more than one hazard, typically are adjustable.5

Point-of-operation guards are of three types, each with its own advantages and limitations: fixed, interlocked, and adjustable (Figure 14–6).

Figure 14–6 Point-of-operation guards may be used on machines such as this CNC machining center.

Fixed guards provide a permanent barrier between workers and the point of operation. They offer the following advantages: They are suitable for many specific applications, can be constructed in-plant, require little maintenance, and are suitable for high-production, repetitive operations. Limitations include the following: They sometimes limit visibility, are often limited to specific operations, and sometimes inhibit normal cleaning and maintenance.

Interlocked guards shut down the machine when the guard is not securely in place or is disengaged. The main advantage of this type of guard is that it allows safe access to the machine for removing jams or conducting routine maintenance without the need for taking off the guard. There are also limitations. Interlocked guards require careful adjustment and maintenance and, in some cases, can be easily disengaged.

Adjustable guards provide a barrier against a variety of different hazards associated with different production operations. They have the advantage of flexibility. However, they do not provide as dependable a barrier as other guards do, and they require frequent maintenance and careful adjustment. Some guards in this category are self-adjusting.

Figures 14–7 through 14–10 show various guards used in modern manufacturing settings.

Figure 14–7 When the doors are opened, the milling tool stops automatically.


VF3
20HP
VECTOR
DRIVE
WARNING

Figure 14–8 In order for this shearing machine to cut, both the foot pedal and the hand button must be engaged.

Figure 14–9 This door protects the operator in the event of an exploding or shattering grinding wheel.

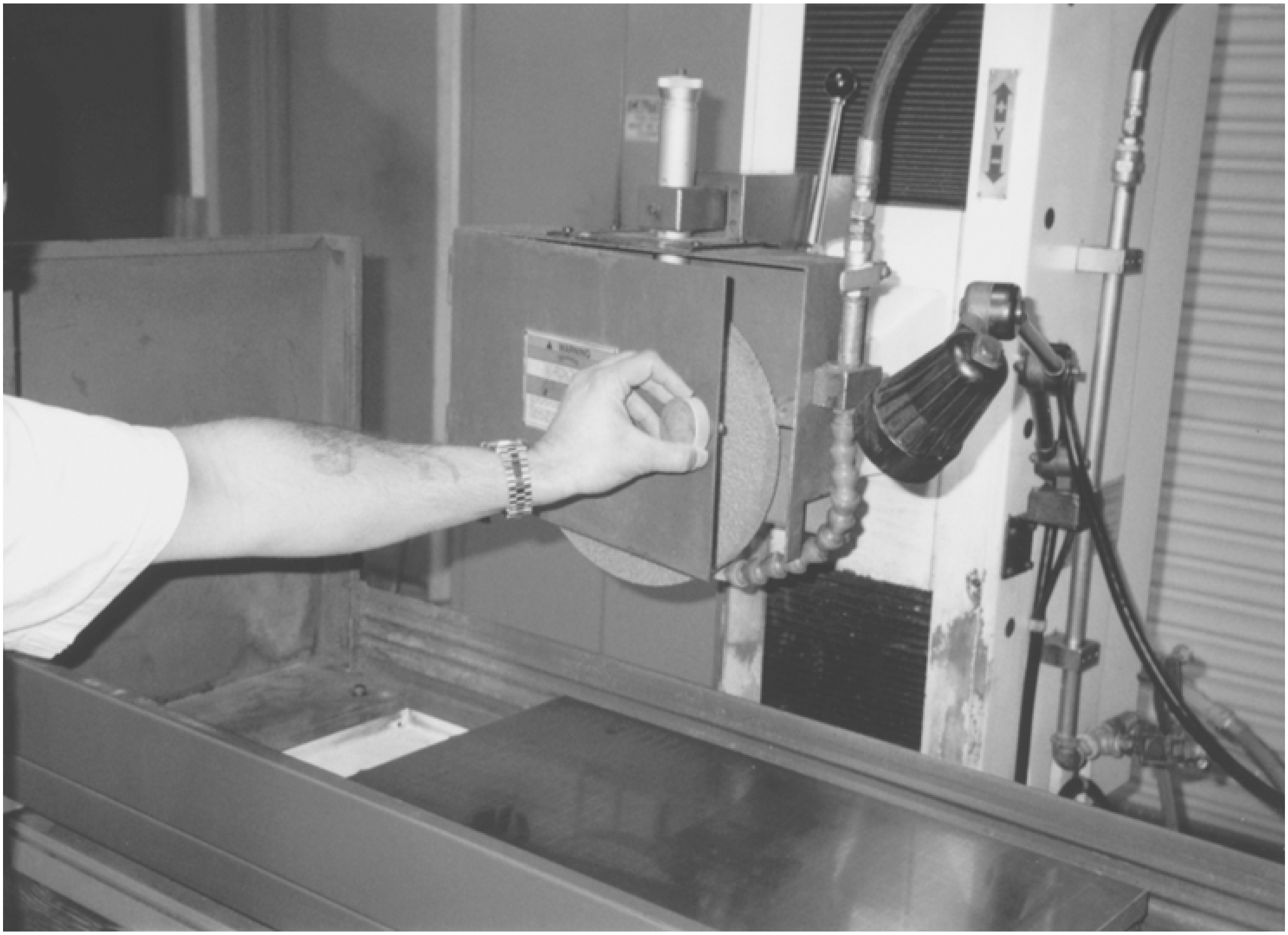


Figure 14–10 The safety door on this drilling machine must be closed or the drill will not operate.

Point-of-Operation Devices

A number of different point-of-operation devices can be used to protect workers. The most widely used are explained in the following paragraphs:

Photoelectric devices are optical devices that shut down the machine whenever the light field is broken. These devices allow operators relatively free movement. They do have limitations including the following: They do not protect against mechanical failure, they require frequent calibration, they can be used only with machines that can be stopped, and they do not protect workers from parts that might fly out of the point-of-operation area.

Radio-frequency devices are capacitance devices that brake the machine if the capacitance field is interrupted by a worker’s body or another object. These devices have the same limitations as photoelectric devices.

Electromechanical devices are contact bars that allow only a specified amount of movement between the worker and the hazard. If the worker moves the contact bar beyond the specified point, the machine will not cycle. These devices have the limitation of requiring frequent maintenance and careful adjustment.

Pullback devices pull the operator’s hands out of the danger zone when the machine starts to cycle. These devices eliminate the need for auxiliary barriers. However, they also have limitations. They limit operator movement, must be adjusted for each individual operator, and require close supervision to ensure proper use.

Restraint devices hold the operator back from the danger zone. They work well, with little risk of mechanical failure. However, they do limit the operator’s movement, must be adjusted for each individual operator, and require close supervision to ensure proper use.

Safety trip devices include trip wires, trip rods, and body bars. All these devices stop the machine when tripped. They have the advantage of simplicity. However, they are limited in that all controls must be activated manually. They protect only the operator and may require the machine to be fitted with special fixtures for holding work.

Two-hand controls require the operator to use both hands concurrently to activate the machine (e.g., a paper cutter or metal-shearing machine). This ensures that hands cannot stray into the danger zone. Although these controls do an excellent job of protecting the operator, they do not protect onlookers or passers-by. In addition, some two-hand controls can be tampered with and made operable using only one hand.

Gates provide a barrier between the danger zone and workers. Although they are effective at protecting operators from machine hazards, they can obscure the work, making it difficult for the operator to see.6

Wireless control devices. Wireless communication is now so widely used that it is only natural that there would be safety applications for this technology. Wireless machine control devices are being used increasingly for risk reduction in machine operation. The most widely used wireless technologies for machine safety applications are Bluetooth and WLAN or Wi-Fi. Bluetooth technology uses radio waves in the 2.4 GHz frequency to transmit signals. It is more popular than Wi-Fi in some cases because it can transmit through walls and solid objects using less power than Wi-Fi. WLAN (Wireless Local Area Network) or Wi-Fi devices operate in one of two modes: peer-to-peer or infrastructure. In peer-to-peer mode (sometimes called ad hoc mode), wireless devices communicate directly with each other without the need for central access points. In infrastructure mode, a wireless network is connected to a wired Ethernet network and central access points are needed. Regardless of the type of wireless technology used, risk reduction is accomplished by a signal that is sent from the sensor device that, in turn, brakes or otherwise incapacitates the machine to prevent intentional or inadvertent contact between the hazard and a body part.

How to Choose a Machine Guard or Device

Choosing the right machine guard or device is a critical step in the risk reduction process. Earlier in this chapter, a model was presented for assessing the level of hazards relating to specific machines/processes. Such an assessment should be completed and the result known before attempting to choose the right machine guard or device. The type of machine guard chosen for a given situation depends on the level of risk reduction desired. When choosing a machine guard or device, apply the following criteria and read the specification of guards and devices to determine if they can meet the criteria:

For the highest level of risk reduction, choose a guard or device that (1) is secured with a lock or fasteners the operator cannot remove; (2) prevents intentional contact with the hazard; and (3) has built-in redundancy with continuous self-checking.

For a high level of risk reduction, choose a guard or device that (1) is not removable or adjustable by unauthorized personnel; (2) does not require adjustments by the operator; (3) prevents unintentional contact with the hazard; and (4) has redundancy with self-checking built in.

For an intermediate level of risk reduction, choose a guard or device that (1) is movable; (2) can be adjusted by the operator; (3) prevents inadvertent contact with the hazard; and (4) has redundancy that must be checked manually.

For a low level of risk reduction, choose a guard or device that (1) provides only minimal protection (tactile or visual awareness) against inadvertent contact with the hazard and (2) is moveable by the operator.

Machine Guarding Self-Assessment

One of the most effective ways to ensure that machines are properly guarded is to conduct periodic self-assessments7. These self-assessments can be conducted by safety personnel, supervisors, or employees. Developing self-assessment criteria and encouraging supervisors and employees to use them daily is an excellent strategy for safety and health professionals. The following questions can be used for conducting machine guarding self-assessments:

Are all machines that might expose people to rotating parts, nip points, flying chips, sparks, flying particles, or other similar hazards properly guarded?

Are all mechanical power transmission belts and the nip points they create properly guarded?

Are all exposed power shafts located less than seven feet above the working level properly guarded?

Are all hand tools and other hand-operated equipment inspected regularly for hazardous conditions?

Is compressed air used to clean tools, machines, equipment, and parts reduced to less than 30 pounds per square inch (psi)?

Are power saws and similar types of equipment properly guarded?

Are the tool rests for grinding wheels set to within one-eighth or less of the grinding wheel?

Are hand tools regularly inspected on a systematic basis for burred ends, cracked handles, and other potentially hazardous conditions?

Are all compressed gas cylinders inspected regularly and systematically for obvious signs of defects, deep rusting, or leakage?

Do all employees who handle and store gas cylinders and valves know how to do so without causing damage?

Are all air receivers periodically and systematically inspected, including safety valves?

Are all safety valves tested regularly, systematically, and frequently?

Feeding and Ejection Systems

Feeding and ejection systems can be effective safeguards if properly designed and used. The various types of feeding and ejection systems available for use with modern industrial machines are summarized as follows:

Automatic feed systems feed stock to the machine from rolls. Automatic feeds eliminate the need for operators to enter the danger zone. Such systems are limited in the types and variations of stock that they can feed. They also typically require an auxiliary barrier guard and frequent maintenance.

Semiautomatic feed systems use a variety of approaches for feeding stock to the machine. Prominent among these are chutes, moveable dies, dial feeds, plungers, and sliding bolsters. They have the same advantages and limitations as automatic feed systems.

Automatic ejection systems eject the work pneumatically or mechanically. The advantage of either approach is that operators don't have to reach into the danger zone to retrieve workpieces. However, these systems are restricted to use with relatively small stock. Potential hazards include blown chips or debris and noise. Pneumatic ejectors can be quite loud.8

Semiautomatic ejection systems eject the work using mechanisms that are activated by the operator. Consequently, the operator does not have to reach into the danger zone to retrieve workpieces. These systems do require auxiliary barriers and can be used with a limited variety of stock.

Robot Safeguards

Robots have become commonplace in modern industry. The safety and health concerns relating to robots are covered in Chapter 23. Only the guarding aspects of robot safety are covered in this section. The main hazards associated with robots are (1) entrapment of a worker between a robot and a solid surface; (2) impact with a moving robot arm; and (3) impact with objects ejected or dropped by the robot.

The best guard against these hazards is to erect a physical barrier around the entire perimeter of a robot's work envelope (the three-dimensional area established by the robot's full range of motion). This physical barrier should be able to withstand the force of the heaviest object that a robot could eject.

Various types of shutdown guards can also be used. A guard containing a sensing device that automatically shuts down the robot if any person or object enters its work envelope can be effective. Another approach is to put sensitized doors or gates in the perimeter barrier that automatically shut down the robot as soon as they are opened.

These types of safeguards are especially important because robots can be deceptive. A robot that is not moving at the moment may simply be at a stage between cycles. Without warning, it might make sudden and rapid movements that could endanger any person inside the work envelope.

Control of Hazardous Energy (Lockout/Tagout Systems)

OSHA's standard for the control of hazardous energy, often referred to as the "lockout/tagout" standard, is 29 CFR 1910.147. The purpose of this standard is to protect people in the workplace from hazardous energy while they are performing service or maintenance on machines, tools, and equipment. A key element of the standard is to prevent the accidental or inadvertent activation of a machine while it is being serviced or repaired. The lockout/tagout standard identifies the proper procedures for shutting down machines and equipment and locking or tagging it out so that accidental or inadvertent activation does not occur. The standard also calls for employee training and periodic inspections. The overall requirement of 29 CFR 1910.147 is that before service or maintenance are performed, the machines or equipment in question must be disconnected from their energy source, and the energy source must be either locked out or tagged out to prevent accidental or inadvertent activation.9 In addition, 29CFR 1910.333 establishes requirements to protect employees working on electrical circuits and equipment.

Lockout/Tagout Language

The following terms and phrases are frequently used in the language of lockout/tagout. Safety and health professionals should be knowledgeable of these terms:

Affected employee. Employees who perform their jobs in areas in which the procedure in question is implemented and in which service or maintenance operations are performed. Affected employees do not implement energy control procedures unless they are authorized.

Authorized employee. Employees who perform service or maintenance on a machine and use lockout/tagout procedures for their own protection.

Energized. Machines, equipment, and tools are energized if they are connected to an energy source or when they still contain stored or residual energy even after being disconnected.

Capable of being locked out. A device is considered to be capable of being locked out if it meets one of the following requirements: (1) it has a hasp to which a lock can be attached; (2) it has another appropriate integral part through which a lock can be attached; (3) it has a built-in locking mechanism; or (4) it can be locked without permanently dismantling, rebuilding, or replacing the energy-isolating device.

Energy-isolating device. Any mechanical device that physically prevents the release or transmission of energy (e.g., circuit breakers, disconnect switches, or blocks).

Energy source. Any source of power that can activate a machine or piece of equipment (e.g., electrical, mechanical, hydraulic, pneumatic, chemical, or thermal).

Energy control procedure. A written document containing all the information an authorized person needs to know in order to properly control hazardous energy when shutting down a machine or equipment for maintenance or service.

Energy control program. A systematic program for preventing the accidental or inadvertent energizing of machines or equipment during maintenance or servicing. This is sometimes called the organization’s lockout/tagout program.

Lockout. Placing a lockout device such as a padlock on an energy-isolating device to prevent the accidental or inadvertent energizing of a machine during maintenance or servicing.

Lockout device. Any device (see Figure 14–11) that uses a positive means to keep an energy-isolation device in the safe position to prevent the accidental or inadvertent energizing of a machine or piece of equipment.

Figure 14–11 Lockout system.

Figure 14–11 Full Alternative Text

Tagout. Placing a tag (see Figure 14–12) on an energy-isolation device to warn people so that they do not accidentally or inadvertently energize a machine or piece of equipment.

Figure 14–12 Tagout system.

Figure 14–12 Full Alternative Text

Tagout device. Any prominent warning device such as a tag that can be affixed to an energy-isolation device to prevent the accidental or inadvertent energizing of a machine or piece of equipment.

Provisions of the Standard

OSHA’s standard for control of hazardous energy contains provisions in the following areas: energy control program, energy control procedure, energy-isolating devices, lockout/tagout devices, periodic inspections, application of controls and lockout/tagout devices, removal of locks and tags, testing or positioning of machines, outside personnel, group lockout or tagout, and shift or personnel changes. Those provisions are as follows:

Energy control program. Organizations must establish energy control programs that have fully documented energy control procedures, provide employee training, and ensure periodic inspections.

Energy control procedure. Organizations must develop, document, and use energy control procedures that contain at least the following elements: (a) a statement on how the procedure will be used; (b) procedural steps used to shut down, isolate, block, and secure machines or equipment; (c) steps designating the safe placement, removal, and transfer of lockout/tagout devices and who has responsibility for them; and (d) specific requirements for testing machines or equipment to verify the effectiveness of energy control measures.

Energy-isolating devices. Organizations must have appropriate energy-isolating devices for preventing the accidental or inadvertent release of energy on all machines and equipment. The preferred type of device is one that can be locked out. However, when this type of device is not feasible, tagout procedures may be used. When a tagout system is used, employees must receive training on the following limitations of tags: (a) tags are just warning devices and do not provide the safety margin of locks; (b) tags may be removed only by the person who affixes them and should never be bypassed, ignored, or otherwise overcome; (c) tags must be legible and understandable by all employees (this can mean providing labels in more than one language); (d) tags and their means of attachment must be made of material that is durable enough to withstand the environment to which they will be subjected; (e) tags can evoke a false sense of security; and (f) tags must be attached securely enough that they will not come off during servicing or maintenance operations.

Requirements for lockout/tagout devices. Lockout and tagout devices must meet the following requirements: (a) durable enough to withstand the environment to which they will be exposed; (b) standardized in terms of color or size and print and format; (c) substantial enough to minimize the likelihood of accidental or unauthorized removal; and (d) identifiable in terms of the employee who affixed them and the warning message (e.g., Do Not Start, Do Not Close, Do Not Energize, Do Not Open).

Employee training. Organizations must provide both initial training and retraining as necessary and certify that the necessary training has been given to all employees covered in the standard (e.g., authorized, affected, and other). Training for authorized employees must cover the following topics at a minimum: (a) details about the types and magnitude of hazardous energy sources present in the workplace and (b) methods, means, and procedures for isolating and controlling these sources. Training for affected employees (usually machine operators or users) and other employees must cover the following topics at a minimum: (a) how to recognize when the energy control procedure is implemented and (b) the importance of never attempting to start up a locked-out or tagged-out machine. All training must ensure that employees understand the purpose, function, and restrictions of the energy control program and that authorized employees have the knowledge and skills necessary to properly apply, use, and remove energy controls.

Periodic inspections. Inspections must be performed at least annually to ensure that the energy control program is up to date and being properly implemented. In addition, the organization must certify that the periodic inspections have actually taken place.

Application of controls and lockout/tagout devices. Controls and lockout/tagout devices must be applied properly. The appropriate procedure consists of the following steps that must be implemented in sequence: (a) prepare for shutdown; (b) shut down the machine or equipment in question; (c) affix the lockout or tagout device; (d) render safe any residual or stored energy that might remain in the machine; and (e) verify that the energy source has been effectively isolated and that the machine or equipment has been effectively de-energized.

Removal of locks or tags. Before locks or tags are removed, the following procedures must be completed: (a) inspect the work area to ensure that nonessential items have been removed and that the machine is capable of operating properly; (b) check the area around the machine to ensure that all employees are safely back or removed from the area; (c) notify affected employees immediately after removing the energy control devices and before energizing the machine; and (d) ensure that energy control devices are removed by the individual who affixed them (if this is not possible, make sure that the person who does remove them follows the proper procedures).

Additional safety requirements. OSHA allows for special circumstances as set forth in this subsection. When a machine must be energized in order to test or position it, energy control devices may be removed only as follows: (a) clear the machine of tools and materials; (b) remove employees from the area; (c) remove the devices as set forth in the standard; (d) energize the machine and conduct the test or proceed with the positioning procedure; and (e) de-energize the machine, isolate the energy source, and reapply the energy control devices. Organizations must ensure that outside personnel such as contractors are fully informed about energy control procedures. In group lockout or tagout situations, each individual employee performing maintenance or service tasks must be protected by his or her own personal energy control device. Organizations must have specific procedures for ensuring continuity in spite of personnel and shift changes.

Permanent Electrical Safety Devices in Lockout/Tagout Programs

An emerging technology in electrical safety is the permanent electrical safety device (PESD). PESDs have excellent potential to help workers safely isolate electrical energy, especially when used as part of an organization's Lockout/Tagout Procedures. "With PESDs incorporated into safety procedures, installed correctly into electrical enclosures, and validated before and after each use, workers can transition the once-risky endeavor of verifying voltage into a less precarious undertaking that never exposes them to voltage . . . every electrical incident has one required ingredient: voltage. Electrical safety is radically improved by eliminating exposure to voltage while still validating zero energy from outside the panel."10

Traditionally electrical energy that might be present is detected using a voltage detector. To ensure safety, NFPA 70E 120.1(5) requires that voltage detectors be checked before and after every use to ensure that they are operating properly. This requirement means that voltage detectors must be checked against an independent source before being used to detect the present of electrical energy in a machine a worker needs to use. Then after checking the machine for electrical energy, the voltage detector must be validated again to an independent source.

This same principle applies to PESDs, but because they are permanently mounted PESDs cannot be moved between two power sources as voltage meters can. With PESDs, the validation technique is different. The PESD validation technique is based on the detection of a small amount of current flowing between two sources. A voltage detector is used to relate this small current flow to actual voltage. The worker is then given an appropriate visual or audible signal to indicate whether it is safe to proceed.

PESDs are designed for one purpose and one purpose only: to ensure electrical safety. Consequently, when used properly they can be even more reliable than the traditional method of using voltage meters. Further, PESDs can be used by the workers themselves without the need for having an electrician make the determination of the presence or absence of electrical energy. PESDs improve electrical safety by eliminating exposure to voltage while still ensuring zero voltage from outside the panel. It has been estimated that using PESDs can allow as much as 75 percent of locked out and tagged out equipment to be put back into service.

A PESD becomes a real safety device only after it is included as part of a written Lock Out Tag Out (LOTO) procedure. Without this, it is nothing more than another electrical component. The LOTO procedure must explain to the worker each step that involves the PESD. At a minimum, workers will need to verify proper operation of the PESD before and after performing a LOTO procedure. Mechanical maintenance workers receive a huge benefit when these devices are used in mechanical LOTO procedures. Workers performing mechanical LOTO procedures (work involving no contact with conductors or circuit parts) still must isolate electrical energy. PESDs provide a means of checking voltage inside an electrical panel without exposure to that same voltage. Without these devices, a mechanic performing mechanical LOTO would be required to work in tandem with an electrician using a voltmeter to physically verify zero voltage inside an electrical panel before work begins. With PESDs, the mechanic can single-handedly check for zero electrical energy without any exposure to voltage, thereby making the LOTO procedure safer and more productive.11

Evaluating Lockout/Tagout Programs

Lockout/tagout violations are frequently cited by OSHA during on-site inspections. The following questions can be used to evaluate an organization's lockout/tagout program:

Are all machinery or equipment capable of movement required to be de-energized or disengaged and blocked or locked out during cleaning, servicing, adjusting, or setting up operations?

Where the power disconnect equipment does not disconnect the electrical control circuit, are the appropriate electrical enclosures identified?

If the power disconnect for equipment does not disconnect the electrical control circuit, is a means provided to ensure that the control circuit can be disconnected and locked out?

Is it required to lock out main power disconnects instead of locking out control circuits?

Are all equipment control valve handles equipped with a means for locking out?

Does the lockout procedure require that stored energy—whether it is mechanical, hydraulic, or air—be released or blocked before the equipment is locked out for repairs?

Are appropriate employees provided with individually keyed personal safety locks?

Are these employees required to keep personal control of their keys while they have safety locks in use?

Is only the employee exposed to the hazard required to install or remove the safety lock?

Are employees required to check the safety lockout by attempting a startup after making sure no one is exposed?

After the safety is checked, does the employee again place the switch in the “off” position?

Are employees instructed always to push the control circuit stop button before reenergizing the main power switch?

Are all employees who are working on locked-out equipment identified by their locks or accompanying tags?

Are enough accident prevention signs, tags, and safety padlocks provided for any reasonably foreseeable repair emergency?

When machine operations, configuration, or size require the operator to leave his or her control station to install tools or perform other operations, is he or she required to lock or tag out separately any parts of the machine that could move if accidentally activated?

If the equipment or lines cannot be shut down, locked out, and tagged, is a safe job procedure established and rigidly followed?

Have employees been trained not to start machinery or equipment if it is locked out or tagged out?

Are all workers notified when the machinery or equipment they usually use is shut down and locked out for maintenance or servicing purposes?

After maintenance is completed, is the machinery checked to ensure that nonessential items have been removed and the machine is operationally intact?

Before the machinery is activated, are employees removed from possible danger?

When the machinery is fully operational, are employees notified?12

Discussion Case

What Is Your Opinion?

John Martin, director of manufacturing, is not happy with his colleague Pete Chang, who is director of safety and health at Robbins Engineering Corporation. Chang has ordered two machines in the Manufacturing Department tagged out until point-of-operation guards are replaced. The machining supervisor, in an attempt to increase output, had his machinists remove the guards. As a result, there have been several minor injuries and a couple of more serious near misses. The issue is short-term productivity versus the safety and health of employees. What is your opinion on this issue?

General Precautions

The types of safeguards explained in this chapter are critical. In addition to these specific safeguards, there are also a number of general precautions that apply across the board in settings where machines are used. Some of the more important general precautions are as follows:

All operators should be trained in the safe operation and maintenance of their machines.

All machine operators should be trained in the emergency procedures to take when accidents occur.

All employees should know how to activate emergency shutdown controls. This means knowing where the controls are and how to activate them.

Inspection, maintenance, adjustment, repair, and calibration of safeguards should be carried out regularly.

Supervisors should ensure that safeguards are properly in place when machines are in use. Employees who disable or remove safeguards should be disciplined appropriately.

Operator teams (two or more operators) of the same system should be trained in coordination techniques and proper use of devices that prevent premature activation by a team member.

Operators should be trained and supervised to ensure that they dress properly for the job. Long hair, loose clothing, neckties, rings, watches, necklaces, chains, and earrings can become caught in equipment and, in turn, pull the employee into the hazard zone.

Shortcuts that violate safety principles and practices should be avoided. The pressures of deadlines should never be the cause of unsafe work practices.

Other employees who work around machines but do not operate them should be made aware of the emergency procedures to take when an accident occurs.

Basic Program Content

Machine safeguarding should be organized, systematic, and comprehensive. A company’s safeguarding program should have at least the following elements:

Safeguarding policy that is part of a broader company-wide safety and health policy

Machine hazard analysis

Lockout/tagout (materials and procedures)

Employee training

Comprehensive documentation

Periodic safeguarding audits (at least annually)

Taking Corrective Action

What should be done when a mechanical hazard is observed? The only acceptable answer to this question is, take immediate corrective action. The specific action indicated will depend on what the problem is. Figure 14–13 shows selected examples of problems and corresponding corrective actions.

Figure 14–13 Selected examples of problems and corresponding actions.

Problem	Action
Machine is operating without the safety guard.	Stop machine immediately and activate the safety guard.
Maintenance worker is cleaning a machine that is operating.	Stop machine immediately and lock or tag it out.
Visitor to the shop is wearing a necktie as he observes a lathe in operation.	Immediately pull the visitor back and have him remove the tie.
An operator is observed disabling a guard.	Stop the operator, secure the guard, and take disciplinary action.
A robot is operating without a protective barrier.	Stop the robot and erect a barrier immediately.
A machine guard has a sharp, ragged edge.	Stop the machine and eliminate the sharp edge and ragged burrs by rounding it off.

These are only a few of the many different types of problems that require corresponding corrective action. Regardless of the type of problem, the key to responding is immediacy. As shown in the examples given earlier in this chapter, waiting to take corrective action can be fatal. It is important to note that it is often prudent to exceed some OSHA guarding requirements (i.e., the seven-foot rule).