Machine Guarding Program

Berkeley Environment, Health & Safety

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Quick Start

Regulatory Requirement

The California Occupational Safety and Health Administration (Cal/OSHA) code requires that any machine part, function, or process that may cause injury 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. All physical machine guards must be appropriate for the hazard involved, secured in place, constructed of substantial material, and have surfaces free of hazardous projections.

Injury Reduction

This program describes various types of physical guards, interlocks, and safeguarding methods for facilities, research equipment, and machinery.. This program can assist you in identifying the hazardous parts of a machine, determining the need for safeguards, and obtaining or fabricating the necessary guards.

Policy Requirement

Application of, and adherence to, this program will ensure compliance with California Code of Regulations, Title 8, Subchapter 7. General Industry Safety Orders.

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Purpose

This program provides information and outlines safety requirements, as mandated by Cal/OSHA, for identifying and guarding hazardous locations on machines and equipment used by University of California, Berkeley (UC Berkeley) employees, students, and contractors in carrying out their work duties. It assigns responsibilities for ensuring machinery and equipment safety through hazard identification and evaluation, safeguarding, training, maintenance, and operation of all kinds of machinery and equipment. This program works in conjunction with other Environment, Health & Safety (EH&S), Safety Programs, such as the Energy Isolation Lockout/Tagout (LOTO) Program, Laser Safety, Electrical Safety, etc.

For the purpose of this program, the terms “machine” and “equipment” will be used interchangeably.

Applicability and Scope

This program applies to anyone who operates UC Berkeley-owned machines or equipment, and/or research equipment developed and used on University property, regardless of their affiliation to the University.

This program extends to all machinery used in education, research, operations, and maintenance activities, whether the equipment was purchased turnkey, designed, or built by UC Berkeley affiliates.

This program does not cover the use of powered and non-powered portable hand tools, such as hammers, screwdrivers, wrenches, staple guns, electric sanders, electric drills, etc.

Roles and Responsibilities

Authorized Equipment Operators

Any person who must operate a machine as part of their work must:

- Complete required training and be authorized by their supervisor prior to operating machines
- Wear all appropriate Personal Protective Equipment (PPE)
- Observe and follow all safety guidelines, signage, and operating instructions ·
- Understand and practice approved machine safeguarding methods ·
- Ensure the proper machine guards are in place before using the machine by inspecting machines before each use
- Not use a machine when manufacturer-supplied guards are not installed on it
- Report machine safeguarding malfunctions or problems to a supervisor immediately
- Lock and/or Tag out broken or damaged equipment so that others cannot accidentally use it, and make the broken or damaged condition known to a supervisor

- Report unauthorized or unsafe use of machines and equipment to a supervisor
- Do not operate machines without safeguards in place
- Do not operate machines that are broken or damaged or otherwise unguarded
- Do not defeat or remove guards or safety devices

Equipment Owners: Managers, Supervisors, Principal Investigators, and Responsible Persons

Equipment owners are managers, supervisors, principal investigators (PIs), and responsible persons who purchase or operate machines and or supervise others should:

- Ensure all newly acquired machines, as well as older machines without guards, are properly guarded prior to being put into service
- Restrict access to machines and equipment to prevent unauthorized use or unnecessary exposure
- Ensure machines are properly safeguarded and that guards remain in place and functional by conducting periodic machine-specific safeguarding evaluations
- Immediately correct machine safeguard deficiencies or remove damaged or unprotected equipment from service. Refer to the UC Berkeley Energy Isolation Lockout/Tagout (LOTO) Program as necessary. Ensure users are trained, qualified, and competent in the proper and safe operation before authorizing access to machines and equipment
- Communicate safe operating practices and rules to authorized users and affected personnel
- Exercise appropriate disciplinary action when users fail to follow safety requirements
- Provide PPE to all users. See PPE webpage and learn more about our Hazard Assessment Tool.

Maintenance and Service Personnel

Maintenance and service personnel work to preserve a campus built environment that is conducive to teaching, learning, and research; and should:

- Lockout and tagout machines and equipment prior to removing or bypassing guards (implement UC Berkeley Lockout Tagout /Energy Isolation Program, as necessary)
- Report any damaged or ineffective guards or safeguarding devices to their supervisor and the equipment owner
- Replace all safeguards and interlocks after maintenance and servicing are complete
- Develop safe work protocols around unguarded equipment and seek support
- Follow LOTO program procedures, as necessary for Jogging and testing equipment without guards installed).

EH&S

EH&S workers provide guidance and services to the campus community that promote health, safety, and environmental stewardship. EH&S:

- Provides machine-guarding consultation services to UC Berkeley departments
- Provides training on the implementation and adoption of this program to all affected personnel
- Develops specific machine guarding procedures, processes, and training
- Assists in the selection of appropriate guards, safeguarding methods, and PPE
- Conducts periodic inspections to ensure machine guarding safety guidelines are being followed
- Reviews this program periodically or whenever there is a change to the governing regulations.

Definitions

Fail-safe – A term used to define how a machine is to stop or otherwise immediately cease operation when any interlock or machine guard is removed, or any fault condition is detected by the equipment's operation logic, or one or more utilities are interrupted during equipment operation. The fail-safe design of equipment ensures that if any abnormal condition happens, the equipment will immediately default to a state of suspended operation, will stop at rest, and/or shut down in a safe condition without any hazard to the operator or nearby personnel or property loss potential.

Interlock – A series of sensors, software, relays, and other machine control-logic and components that collectively monitor the status of a machine's hazardous locations and operations and prevent unsafe starting, or may stop or safely shut down, a machine when any interlock component or control-logic is violated or not in a proper or safe condition.

Machine Guard – A physical barrier placed between the machine user and hazardous parts of a machine. Also sometimes called a safeguard. Such a guard is for debris and fluid disbursement, and a means to prevent any part of their body from accessing the point of operation.

Personal Protective Equipment (PPE) – Specialized clothing or equipment worn by employees for protection against health and safety hazards associated with their workplace or specific work tasks.

Point of Operation - The part of a machine that performs an operation on the stock or material and/or the point or location where stock or material is fed to the machine. The point of operation is the location where material is positioned, inserted, or manipulated, or where work such as shearing, punching, shaping, cutting, boring, forming, or assembling is being performed on the stock material.

NOTE: A machine may have more than one point of operation. Milling machines, power presses, Computer Numerical Control (CNC) turning machines, jointers, power saws, hand tools, guillotine cutters, and shears are all examples of machines that require point of operation guards.

Power Transmission Device - The power transmission apparatus is all components of the mechanical system that transmits 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.

Pneumatic presses - A pneumatic press derives its primary mechanical action (such as shearing, punching, bending, forming, drawing, extruding, assembly, or other action) from a pressure source by means of compressed air (OSHA).

Protocol – Similar to a procedure, when designing interlock systems, machine-logic is designed into the wiring, software, and sensor selection that areall part of the safety protocol of safe operation and continuous operating status monitoring for that machine.

Risk Assessment – The process of identifying hazards and estimating the level of risk involved with various hazard-control methods.

Safeguard – A collective set of physical barriers, fail-safe control logic, interlocks, and other equipment components that function to ensure a machine will not expose an operator or other personnel nearby to any hazardous function or condition.

General Safeguarding Procedures

Machine Guarding Requirements for All Machines

One or more methods of physical machine-guarding must be provided to protect the operator and other personnel in the machine area from hazards such as the point of operation, the power transmission device, and other hazardous motions and actions.

Any machine part, function, or process that may cause injury must be guarded. All machine-guards must be constructed of appropriate materials, secured in place, have surfaces free of projectiles, serving as controls for potential hazards.

See Appendix 1 for general considerations regarding Hazard Control Hierarchy.

Physical machine guards must protect personnel from mechanical, electrical, pneumatic, thermal, and other hazards. To do so, these machine guards must:

- **Prevent contact** – The machine guard must prevent hands, arms, or any other part of an operator or other person's body from making contact with dangerous moving parts while the machine is in operation. As a general rule, install machine guards on all openings of ¼ inch or greater and all equipment that is less than seven feet above the floor or working level.
- **Be secured to the machine** – Guards must be affixed to the machine when possible and secured elsewhere if for any reason attachment to the machine is not possible. Operators should not be able to remove or tamper easily with the guard.
- **Protect from falling objects** – Objects should not be able to fall into any moving parts of the machine. Small objects or tools dropped into cycling machines can easily become projectiles.

- **Create no new hazards** – Machine guards must have surfaces free of hazardous projections, unfinished surfaces, or sharp edges. If necessary, other means or methods that will provide *equivalent protection* must be used if a guard is not feasible.
- **Allow for safe lubrication of the machine** – Guards must be hinged or have sliding or removable sections to allow for the admission of oil and lubricants. Where machines or parts must be lubricated while in motion, the lubricant fittings must be located at least 12 inches from all unguarded moving parts. Machine parts or transmission equipment in inaccessible locations must be equipped with extension lubricant fittings. Locating oil reservoirs outside the guards with a line leading to the lubrication point will reduce the need for the operator or maintenance worker to enter the hazardous area.

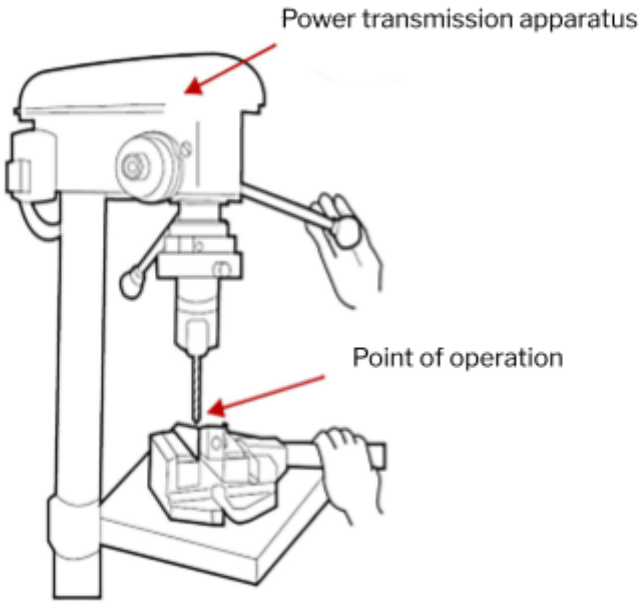
UC Berkeley operators must not access areas of the machine that are classified as prime movers, power transmission equipment, or associated parts. Such operations must be contracted to companies that take responsibility for the repairs. There are exceptions such as changing belts in a drill press; in these cases, LOTO procedures must be used, the person using themmust have been trained on the procedure, and the written procedure must be in place for that process.

Hazardous Parts, Motions, Actions, and Other Machine Hazards

Machine safeguarding needs widely differ due to varying physical characteristics, work environments, and operator involvement. Regardless of whether a process is manual or automated, any hazardous movement or other equipment process that poses a risk to personnel must be guarded as follows:

Point of Operation

Milling machines, power presses, Computer Numerical Control (CNC) turning machines, jointers, power saws, hand tools, guillotine cutters, and shears are all examples of machines that require point of operation guards. As defined above, points of operation are the parts of a machine that performs an operation on the stock or material and/or the point or location where stock or material is fed to the machine.



Power Transmission Apparatus

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

Auxillary Parts

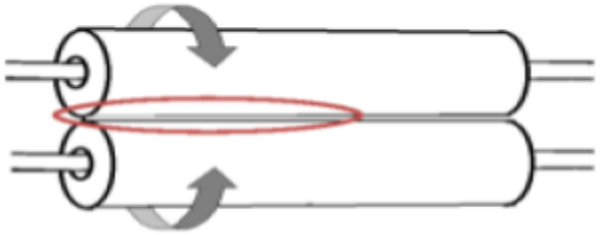
Auxiliary parts of a machine and any part that moves while the machine is working must be guarded to prevent accidental contact.

Hazardous Motions

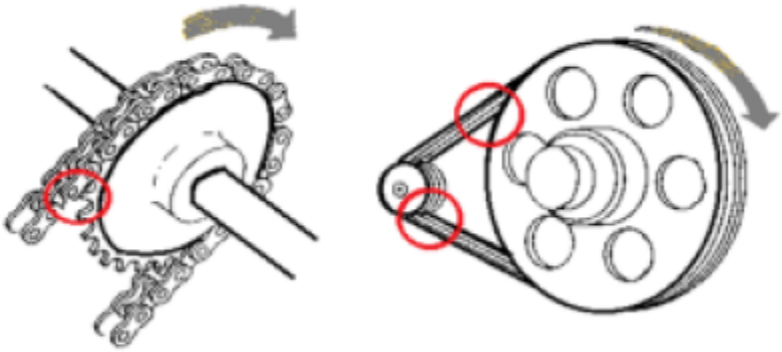
Different types of mechanical motions are found on nearly every machine in various combinations. Recognizing these hazards is the first step toward protecting workers.

Rotation

Rotating motion is very dangerous. Even smooth, slowly rotating shafts can grip hair and clothing, pulling a worker into a hazardous position. Common rotating mechanisms are: collars, couplings, cams, clutches, flywheels, shaft ends, spindles, meshing gears, and horizontal or vertical shafting. Projections (such as set screws and bolts) or nicks and abrasions exposed on rotating parts increase the hazard.



Nip points



Nip points

In-running nip points

In-running nip point hazards are caused by the rotating parts on machinery. Parts can rotate in opposite directions while their axes are parallel to each other.

These parts may be in contact or in close proximity. For example, stock fed between two rolls produces a nip point.

Nip points are also created between rotating and tangentially moving parts. Some examples include the point of contact between two gears, a power transmission belt and its pulley, a chain and a sprocket, and a rack and pinion gear set.

Nip points can occur between rotating and nearby fixed parts which create a shearing, crushing, or abrading action, such as a flywheel and nearby structural support, a screw conveyor, and the conveyor housing, or an abrasive grinding wheel and an incorrectly adjusted work rest and tongue.

Reciprocation

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.

Traversing

Traverse motion, which is defined as 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 in relation to a nearby fixed object.

Hazardous Actions

Different types of mechanical actions are found, in varying combinations, on nearly every machine. Recognizing these hazards is the first step toward protecting workers.

Cutting

Cutting action may involve rotating, reciprocating, or traversing 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, and other materials. Examples of mechanisms involving cutting hazards include band saws, circular saws, boring and drilling machines, turning machines, lathes, or milling machines.

Punching

Punching action results when power is applied to a slide (ram) for 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 hydraulic ironworkers.

Bending

Bending action results when power is applied to a slide 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.

Shearing

Shearing action involves applying power to a slide or knife to trim or shear metal or other materials. A hazard occurs at the point of operation where stock is physically inserted, held, and withdrawn. Examples of machines used for shearing operations are mechanically, hydraulically, or pneumatically powered shears. Other Machine Hazards and Utilities

There can be many other parts or machine components that present a hazard to the operator and surrounding personnel. Any part that could suddenly or unexpectedly move and injure a worker, or energy source that powers that part, should be safeguarded.

Compressed gasses and hydraulic fluids

Normally associated with machines that run on hydraulic or pneumatic power, compressed gasses and fluids are under extreme pressure. Incidents may occur with parts that are not hard piped or shrouded in heavy-duty tubing (conduit or Seal-Tite).

Utilities

Steam or water piping and hoses are a common hazard and should always be securely fastened to prevent hose ends from whipping around. Electrical supplies and equipment must be designed/installed per design code requirements with guards that are strong enough to prevent any kind of access to the electrical conductor even when accidentally impacted by heavy equipment or falling objects.

Counterweights, loaded springs, and shock absorbers

Weights that act to balance or offset another are commonly found on elevator car frames, cranes, and valves. Springs may be under tension or compression with large amounts of stored energy. Shock absorbers may have stored energy or pressure inside the absorber when the machine is *at rest*. All these components should be guarded to prevent access to the hazard. The area directly below the counterweights must be effectively barricaded against access.

Temperature extremes

Extreme temperatures can present a hazard by creating dangerously hot or cold surfaces. Surfaces in excess of 140 degrees F (60 degrees C) must be covered with a thermal insulating material or otherwise guarded against contact to meet code requirements.

Electrical, Hydraulic, and Pneumatic Hazards:

Hazard	Action
Electrical hazards	Must be isolated inside solid-walled or flexible metal conduits to prevent contact with electrical conductors.
Hydraulic hazards (including pump and motor noise)	Must be isolated inside solid-walled isolation guards or containers, reinforced high-pressure piping, moving actuators guarded, etc.
Pneumatic Hazards	Must be isolated inside solid-walled or flexible conduit to prevent impact or/ damage to compressed air piping, muffled exhaust noise, etc.

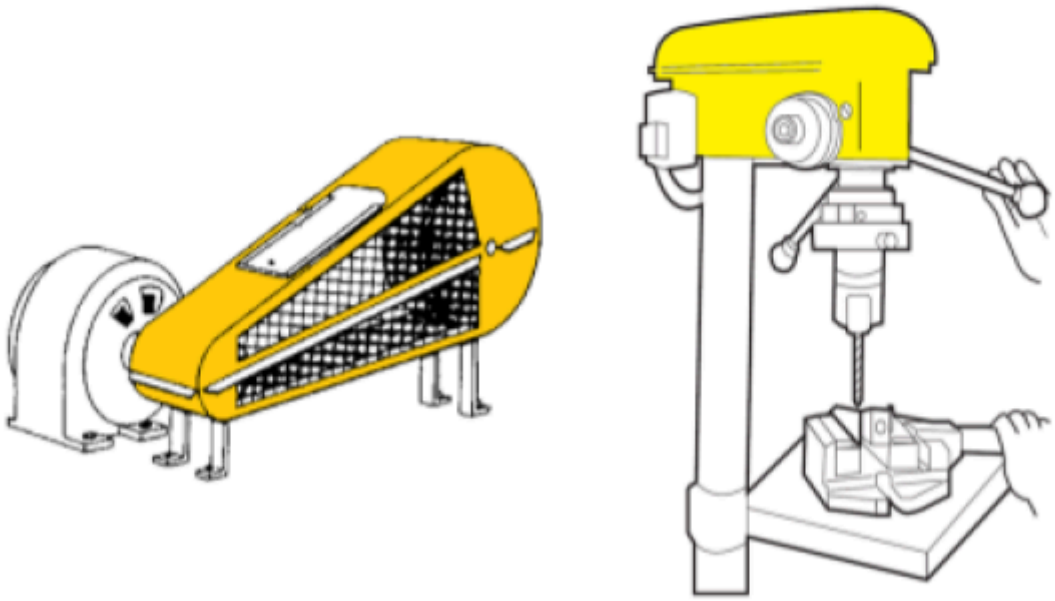
Types of Machine Guards and Controls

Common types of machine guards include: Fixed, Interlocked, Adjustable, and Self-Adjusting. See Appendix 3 for general examples of machine guards in addition to the specific examples below.

Fixed Guards

As its name implies a fixed guard is a permanent part of the machine. It is not dependent upon moving parts to function. This guard is usually preferable to all other types. Fixed guards can be constructed to suit many specific applications and provide maximum protection to operators while requiring minimum maintenance. One limitation of a fixed guard is that it may interfere with visibility.

Also, adjustments and repairs to the machine often require its removal, thereby necessitating other means of protection for maintenance personnel.



Fixed portion of guard highlighted.

Interlocked Guards

When an interlocked guard is opened or removed, the tripping mechanism 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 operate on electrical, mechanical, hydraulic, pneumatic power, or any combination of these. To be most effective, all removable guards should be interlocked to prevent occupational hazards.

Interlocks should be designed to discourage the capability to easily bypass the interlock with readily available items such as tape, pieces of metal, screws, tools, etc. Some interlock devices use special keys, trapped keys, or actuators that make the interlock more difficult to bypass. There are also interlocking devices that physically obstruct or shield the interlock with the guard open, and others that use electrical, mechanical, magnetic, or optical coding.

NOTE: Replacing the guard should not automatically restart the machine. When an interlock is triggered and a machine shuts down, the machine must not be able to be restarted simply by repairing or restoring the interlock or guard.

Latch Guard Power Controls

Interlocks must be wired through a utility-power latch c circuit that “drops out” when any of the interlocks are triggered. The latch control circuit shuts off the main control power or in some other way stops the equipment in a fail-safe condition. When all interlocks are restored so that the machine can safely restart, the latch control circuit now can allow the machine to be restarted. But, the equipment operator must go through the normal procedures for the equipment to safely restart.

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; however, because they are adjustable, they are subject to human error and being “out of adjustment” at any given time.

Self-adjusting Guards

The openings of the guard barrier are determined by the movement of the stock or by automatic adjustment based on machine motion and position. As the operator engages the machine’s point of operation with the stock, the guard is automatically pushed away providing an opening that is only large enough to admit the stock into the point of operation.

A self-adjusting guard

Chop Saw with Self-adjusting Guard

After the stock is removed, the guard returns to the safe position. This guard protects the operator by placing a barrier between the danger area and the operator. Self-adjusting guards offer different degrees of protection. Off-the-shelf guards are often commercially available, but they don’t always provide maximum protection. A common example of this kind of guard is a hand-held circular saw blade guard that adjusts, exposing the blade as the cut is made by the operator.

Machine Guard Construction

Guards must be constructed of substantial material so they can withstand the vibration, shock, and wear to which they will be subjected during normal operation. Guards are usually constructed of metal, impact-resistant plastic, woven wire mesh, or wood (good for corrosive environments). One type of material is not necessarily superior to the other, as long as it meets the performance objective of the guard.

To be effective, they must safeguard the operator and nearby personnel while allowing the work to continue with minimal disruption to the machine's process. Guards should be hinged or have sliding or removable sections to allow for the admission of oil and lubricants, change belts, and to make adjustments. Guards should be affixed to the machine where possible and secured elsewhere if for any reason attachment to the machine is not possible.

A machine guard should not have any shear points, sharp edges, or unfinished surfaces which could cause lacerations. If a machine guard creates a new hazard, it defeats its purpose.

Manufactured versus Aftermarket / Retrofit Guards

Manufacturers of many single-purpose machines provide point-of-operation and power transmission safeguards as standard equipment. Unfortunately, not all machines in use have built-in safeguards provided by the manufacturer, and many older machines were built without being fully guarded. In these cases, it is necessary to purchase aftermarket guards or fabricate them.

The tables that follow discuss the advantages and disadvantages of both manufacturer-built and user-built guards.

Guards Designed and Built by The Manufacturer	
Advantages	Disadvantages
• 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. • Maintains manufacturer warranty. The manufacturer assumes some liability in the event a guard fails or does not function as planned or designed.	• They can be cost-prohibitive. • They are subject to availability • The manufacturer may no longer be in business or offer guards for older • equipment models.

Guards Fabricated by The Machine Owner / User	
Advantages	Disadvantages
• Often, with older machinery, they are the only practical solution. • They permit options when skilled personnel construct them. • They can be designed and built to fit unique and changing situations or needs. • They can be installed on individual dies and feeding mechanisms.	• They may not conform well to the configuration and function of the machine. • They may be poorly designed or built. • They may not comply with regulatory requirements. • Installing an after-market guard may void the machine's warranty.

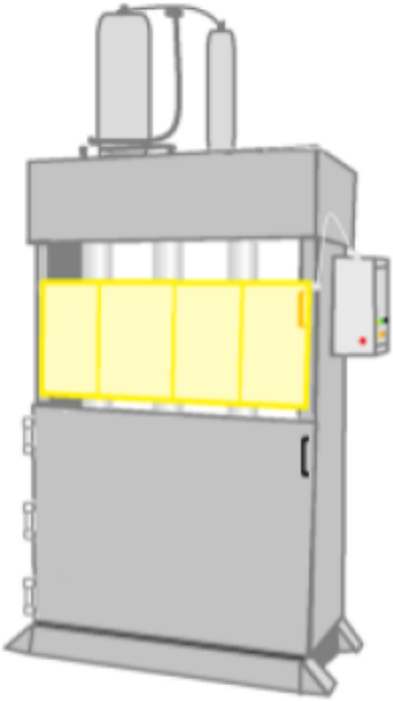
Safeguarding Devices

A safeguarding device or control works by keeping the operator's hands and body outside of the danger zone or by stopping the machine if the operator's hands or body enters the danger zone.

Barriers and Gates

A barrier is a device or object that provides a physical boundary to the hazard. Barrier devices are designed and constructed to enclose the hazard zone prior to the start of the hazardous portion of the machine cycle. They are held closed until completion of the cycle or until the machine has ceased motion.

Gates are movable barriers that protect the operator at the point of operation before the machine cycle can be started. Gates are usually interlocked and, in many instances, designed to be operated with each machine cycle. If the gate does not fully close, the machine will not function.



Interlocked gate on bailer

Presence-Sensing Devices

An optical presence-sensing device uses a system of light beams or curtains that can interrupt the machine's operating cycle. If the sensing field is broken, the machine stops and will not cycle. This device must be used only on machines that can be stopped before the worker can reach into the danger area.

Optical light beam on a press.

An electromechanical presence-sensing device has a probe or contact bar that 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 machine will not cycle.

Pressure-sensitive Devices

When depressed, a pressure-sensitive device will deactivate the machine. Examples of pressure-sensitive devices are body bars, bump or contact strips, or mats.

Pullbacks and Restraints

A pullback device is designed to protect the machine operator by keeping the operator's hands out of the danger zone during the hazardous portion of the machine cycle. It utilizes a series of cables attached to the operator’s hands, wrists, or arms which physically withdraws them before a cycle.

The restraint device protects the operator by physically holding the operator's hands away from the hazard zone at all times. This is usually accomplished by the use of wrist straps.

Physical Restraint Device

Both pullback and restraint devices are adjustable and therefore subject to human error.

Two-hand Control and Trip Devices

A two-hand control requires constant, concurrent pressure to activate the machine. 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.

A two-hand trip requires concurrent application of both of the operator's control buttons to activate the machine cycle, after which the hands are free. This device is used with machines equipped with full-revolution clutches.

The trips must be placed far enough from the point of operation to make it impossible for the operators

to move their hands from the trip buttons or handles into the point of operation before the first half of the cycle is completed to prevent them from being accidentally placed in the danger area prior to the slide/ram or blade reaching the full *down* position.

Machine Safeguarding and Risk Reduction Methods

The following safeguards and methods may be used in conjunction with primary machine guarding devices and controls to reduce the risk or create awareness of a hazard. Although these aids do not give complete protection from machine hazards, they may provide the operator with an extra margin of safety. Most designs and techniques for safeguarding machines focus on mechanical motion; however, machines create many non-mechanical hazards that should be protected against as well.

Access to Machinery

Machines must be designed and constructed in a way that allows all necessary tasks to be carried out but provides an acceptable level of protection for surrounding personnel. When feasible, access to hazardous machinery should be restricted to authorized personnel only. This can be accomplished by locating the machines and equipment in a separate room accessible only by key or keycard. Another option would be establishing a one-way traffic flow where users pass a check-in desk. Access may also include restrictions to certain hours and dates, although this is impossible to accomplish with a mechanical lock and key.

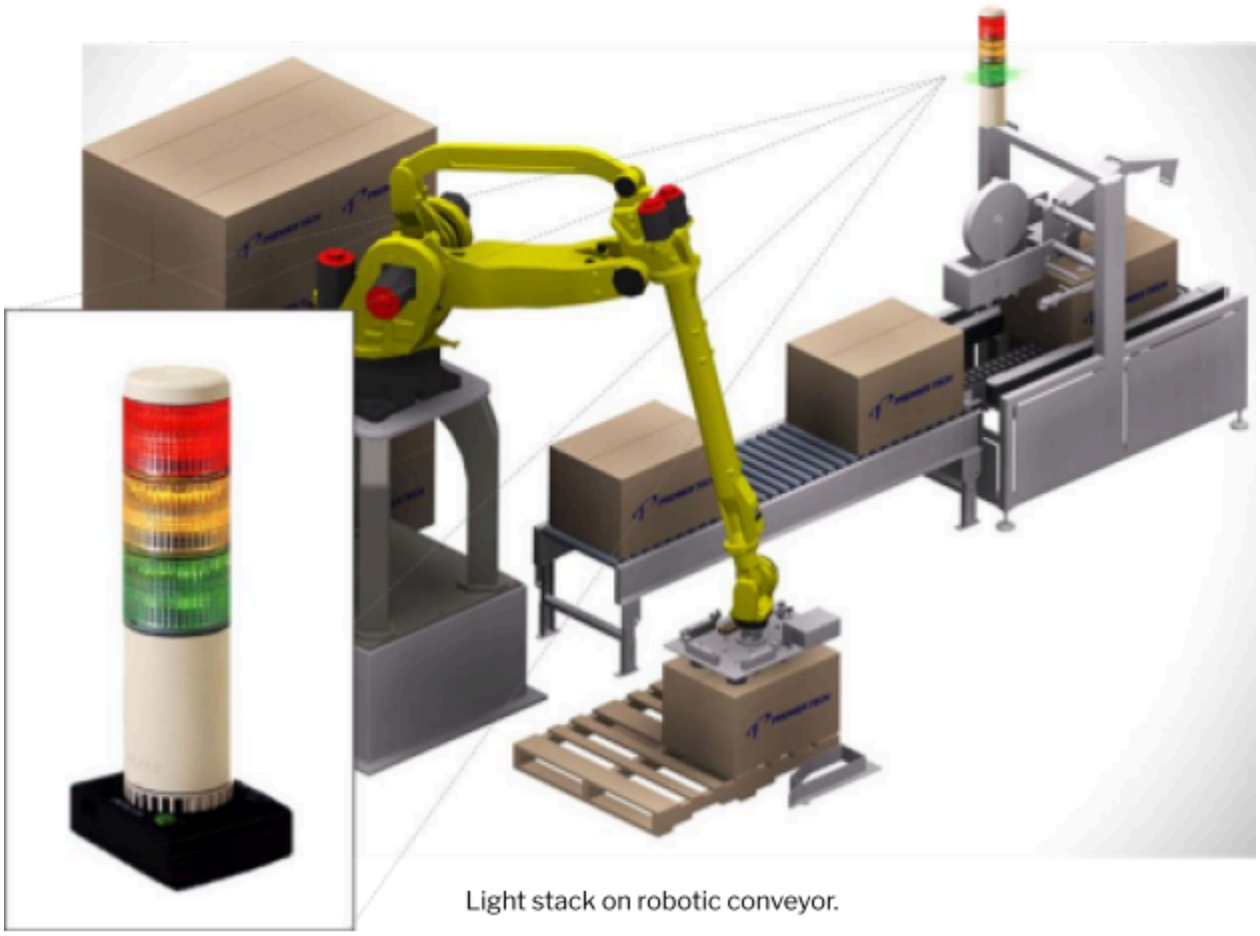
Anchoring Fixed Machinery

A machine designed for a fixed location must be securely anchored to a building's structure to prevent walking or moving.

Awareness Barriers and Signals

Awareness barriers do not provide physical protection but serve as reminders to persons that they are approaching the danger area. An awareness barrier may move or be adjusted to allow entry of workpieces and personnel but prevents anyone from reaching the hazard without awareness. In addition, it provides visual boundaries and indicates the hazard zone.

Awareness signals provide a recognizable audible or visual signal of an approaching or present hazard. Indicator lamps, usually white, red, and green, may be provided to indicate that the device is functioning. Indicator lights should be labeled or have distinct patterning or flashing.



Light stack on robotic conveyor.

Audible awareness signals, like annunciators or bells, should have a distinctive sound and intensity such that they will be distinguished from the highest ambient noise level in the hazard zone.

Controls

Control systems must be designed to enable the operator to interact safely with the machine. Ideally, a machine will have separate control zones for start-up functions, emergency stopping, stopping as a result of a safeguard device, and isolation or energy dissipation.

Each control must require deliberate action to initiate the operation. In addition, controls must be:

- Permanently and clearly labeled and identified
- Located, positioned, or safeguarded to prevent unintentional activation
- Designed to accommodate the foreseeable use of personal protective equipment (such as gloves and footwear)
- Located out of reach of the hazard zones (except for emergency stop controls)
- Mounted in a location that affords the operator safe operation and optimum visibility of the machinery
- Ergonomically designed
- Functionally grouped (i.e., the start button is located near the stop button); and indicated in a consistent manner.

Where the start/stop function is performed using a hold-to-run, orjog, control, a separate stop control device must be provided.

Various styles of machine start/stop controls.

Emergency Stop Devices

All machines must be equipped with adequate means whereby the operator of the machine or other person can disconnect the power promptly in case of an emergency. If the machine's power switch is not located near the operator/point of operations, an emergency stop device must be provided that will immediately cut power to the equipment and cause motion or other operations to cease.

Exceptions:

- In the case of robotic control where power disconnection could cause the robot to physically collapse under the force of gravity, potentially causing injury. In such situations, the emergency stop may cause the robot to "freeze" motion but not remove power from its servo-motor controls.
- Additionally, some machines such as lathes and mills do not come to a complete stop after killing the power and a brake lever must be engaged to stop all motion.

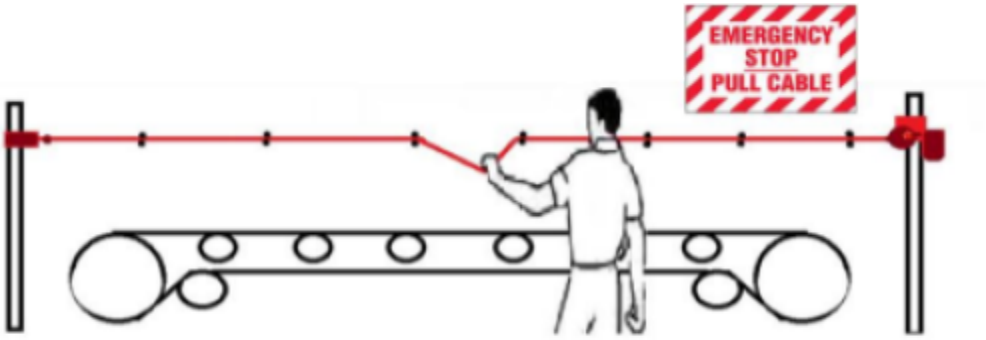
Emergency stop devices must be continuously operable, clearly identified, clearly visible, and readily accessible.

The device must be actuated by a single human action and initiate an immediate stop command. The emergency stop command must override all other functions and operations in all modes for hazardous motion. These devices must be manually reset to restart the machine.

Examples of emergency stop devices are:

Pushbutton - Pushbutton-type emergency stop devices must be installed so that it is unobstructed and can be actuated by the palm of the hand. The actuator of a pushbutton-operated device must be of the palm or mushroom-head type.

Tripwire, cable, or bar -A safety tripwire, cable, or bar is a device located near the danger area of a machine. When pulled or pressed by the operator, the device deactivates the machine. The operator must be able to reach the device during emergencies, so proper position is critical.



Safety pull cable near conveyor

Foot-operated devices - Foot-operated devices may be used when the foot pedal must be continuously activated by the operator when they are at a safe location during machine operation. If the operator removes their foot from the pedal, it will act like an *emergency stop* device and immediately stop machine operation. The base of the foot-operated device must be anti-slip and capable of being permanently mounted. Its location must not create a trip hazard and, once determined, bolted at the safe location for safe operation.

All emergency stop devices **must be colored red**. The background immediately around devices and disconnect switch actuators used as emergency stop devices must be colored yellow. The red/yellow combination is reserved exclusively for the emergency stop and emergency switching off applications. Learn more about safety signs, labels, and color coding.

Energy Isolation – Lockout Tagout (LOTO)

When operators are required to place any part of their body into a hazardous zone, procedures for shutdown, energy isolation, and lock-out/block-out/tag-out must be established and followed.

Minor Servicing Exception - Alternative energy control methods are allowed for minor tool changes and adjustments, and other minor servicing activities, that take place during the machine's normal production operations if both of the following conditions exist:

- The minor activities are routine, repetitive, and integral to the use of the equipment or machinery for production.
- The alternative measures provide effective protection for the employee against moving machinery and equipment. If either of these conditions is not met, then the employer must implement a full lockout/ tagout/blockout program.

The process for safely controlling or dissipating hazardous stored energy must be identified for all machines as part of their design or installation for easy Lockout /Tagout/ Energy Isolation. When servicing or adjustment operations must be performed with the power on and safeguards removed (i.e., fine adjustments, testing, and identifying the source of a problem), separate procedures must be developed to protect personnel during these situations. Refer to the UC Berkeley Energy Isolation Lockout/Tagout (LOTO) Program for details on how to conduct LOTO and design or develop equipment for ease of LOTO application.

Energy Source and Utility Interruption

Machinery must be designed to prevent hazardous conditions resulting from interruption or excessive fluctuation of any energy source or utility used by the machine to maintain safe operation. In the event of loss of energy/utility, all devices whose permanent operation is required for safety (e.g., locking, clamping devices, cooling or heating devices, braking) must operate to maintain safety even with the utilities removed.

Fail-Safe Design Fail-safe design is the design of interlocks and machine-control-logic wiring and programming to ensure the safety of the operator, personnel nearby, and machine processes. A fail-safe system should be designed to default to its safest state of being in the event of any kind of "out-of-normal" failure condition, such as utility, wiring, or component failures. The design assumption is that failure will eventually occur but when it does, it will fail in a manner as to mitigate injuries and losses. Consult with EH&S (510-642-3073) to help develop fail-safe designs for your research and other equipment.

Feeding and Ejection Methods

Many feeding and ejection methods do not require operators to place their 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 operator involvement after the machine starts to function. Using feeding and ejection methods does not eliminate the need for safeguarding. Guards and other devices

must be used wherever they are necessary to provide protection from hazards. Feeding and ejection methods can be automatic or semiautomatic.

Hand-Feeding and Retrieval Tools

Hand-feeding and retrieval tools can place or remove stock. Hand-feeding tools are intended for placing and removing materials into the danger area of a machine. Hand-feeding tools are not a point of operation guards or protection device and shall not be used in lieu of appropriate safeguards, but as a supplement. A typical use would be for reaching in the danger area of a press or press brake. Another example would be a push stick or block used when feeding stock into a saw blade. When it becomes necessary for hands to be in close proximity to the blade, the push stick or block may provide a few inches of safety and prevent a severe injury.

Various hand feeding and retrieval tools.

Location / Distance

To consider a part of a machine to be safeguarded by location, the dangerous moving part of a machine must be located in areas that are not accessible to operators or personnel and do not present a hazard during the normal operation of the machine.

This may be accomplished by using enclosure walls or fences. Another possible solution is to have dangerous parts located high enough to be out of the normal reach of any worker. Locating a machine in a separate and restricted access area may qualify as guarding by location.

Shields

Shields can protect workers from flying particles, chips, sparks, and oils, but do not provide protection from machine hazards. Shields must not interfere with the worker's ability to operate the machine or reduce the operator's field of vision.

Image of a shield

Safety Signs

Signs, Labels, and Color Coding

Color-coding certain parts of a machine will make the employee aware of potentially hazardous conditions. Color is also is used to highlight danger areas.

Color used to highlight danger areas

Red DANGER tags should be used in major hazard situations where an immediate hazard presents a threat of death or serious injury to employees.

All emergency stop devices **must be colored red**.

Yellow should be used to identify physical hazards such as striking against, stumbling, falling, and being caught in between. For example, yellow CAUTION tags shall be used in minor hazard situations where a non-immediate or potential hazard or unsafe practice presents a lesser threat of employee injury.

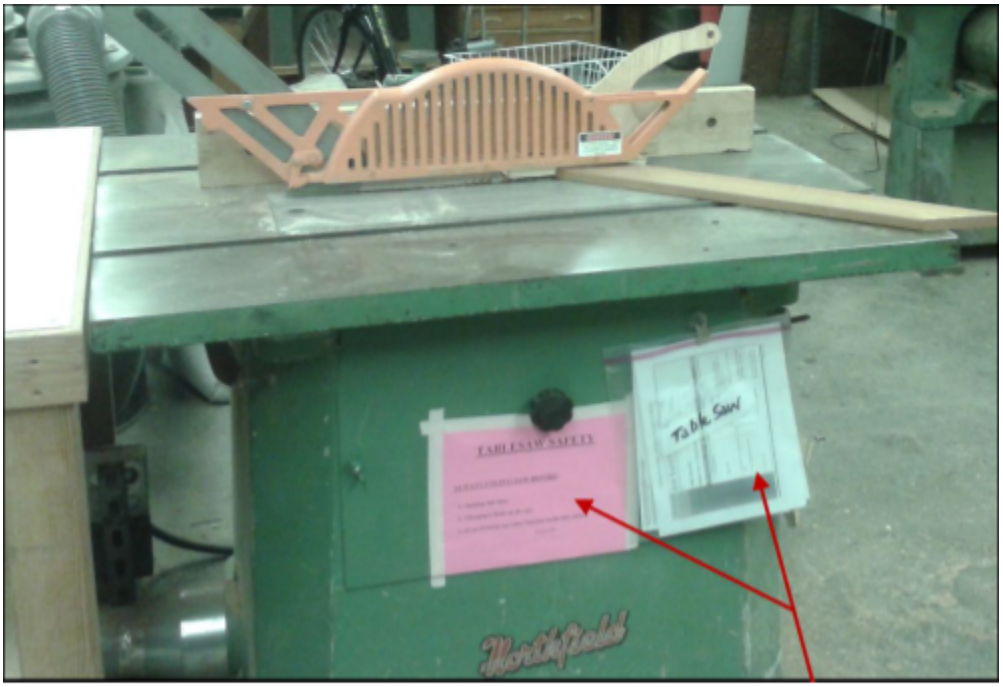
Orange should be used to identify hazardous parts of the machines, such as exposed edges, pulleys, gears, rollers, cutting devices, power jaws, etc. Orange WARNING tags should be used to represent a hazard level between "Caution" and "Danger," should have a signal word of "Warning" followed by the appropriate message.

Blue NOTICE signs are reserved for non-hazard related messages. No safety alert symbol is used. They are appropriate for signs delineating risk of property damage, security, sanitation and/or housekeeping rules.

For an overview on color usage and meaning for safety purposes, see OSHA's & American National Standards Institute's (ANSI) Safety Sign Classification Table. For more information on safety signs and safety graphics, see OSHA & ANSI Safety Graphics Best Practices.

Warnings, stickers, labels, and safety reminders should be affixed to highlight the dangerous areas.

Equipment-specific operating procedures should be established and posted on/near each machine. If possible, have the equipment's operating manual available to workers.



Operating procedures, copy of owner's manual, and JSAs posted on a table saw.

Administrative Procedures

Through the implementation of this program, UC Berkeley departments are responsible for assigning and training personnel to ensure that machines and equipment are properly guarded and designed to *fail safe* ensuring maximum safety for machine operators and nearby personnel. In addition, equipment found to be deficient must be removed from service until machine guards and/or safeguards can be implemented to ensure safety while operating or maintaining the equipment. To do this, assigned personnel must be trained as outlined in this program, and conduct safeguarding assessments.

In addition, contact EH&S (510-642-3073) to discuss when retrofitting of aftermarket guards and/or safeguarding methods may be needed to bring existing equipment into compliance.

Safeguarding Assessment

When conducting a machine guarding assessment, it is imperative to analyze all potential hazards associated with normal operating procedures: start-up, shutdown, setup, inspection, servicing, maintenance, and lockout/tagout. It is also important to consider unusual operations, equipment malfunction, broken tooling, and foreseeable misuse of the equipment.

To determine the need for machine guards or other safeguarding methods, use the Machine Guarding Assessment Checklist and the information in this program. EH&S can also provide further assistance.

Similar machines may be used as a starting point when tasks and hazards are comparable. Using this information does not eliminate the need to follow a risk assessment process for the specific conditions of use. For example, when a shear used for cutting plastic is compared with a shear used for cutting metal, the risks associated with the different materials should be assessed.

The extent of safeguarding needs can vary based on numerous factors, such as degree of exposure, potential for harm, and experience of the operator. A basic risk assessment can assist with determining this extent.

Review the following guidelines to conduct the basic risk assessment:

- **Who is exposed?** Machines used by students should be given the most safeguards, while professional equipment used by seasoned machinists may be outfitted with the minimal amount required for compliance. For example, a lathe used primarily by students should be guarded with a lead screw cover; this is not normally seen or accepted in a professional shop. If the equipment is used by both students and professionals, guard for the riskiest population.
- **How many people use the equipment?** Multiple users increase the chances that equipment could be set up incorrectly or poorly maintained. The more people who use the equipment, the more the equipment is exposed to a variety of worker behaviors.
- **What is the experience level and knowledge of the average user?** Operators who have little or no prior experience are at a higher risk of injury and would benefit from additional safeguards.
- **What is the frequency and duration of equipment use?** The more a piece of equipment is used, the probability that an accident will occur increases. On the opposite end of the spectrum, operators who rarely use a piece of equipment may be at an increased risk of injury because they may forget the specifics of operation or nuances of the safe operation of the machine.
- **What is the probability that an accident will occur?** Additional safeguarding methods should be applied when the probability of an accident, incident, or mishap is imminent or extremely likely.
- **What would be the severity of an accident?** The areas and opportunities to cause serious injuries or illnesses should be given the most consideration.

EH&S recognizes that compliance with safeguarding may impede work performance or process. In these cases, please consult with EH&S about guarding options and safe equivalents that protect workers from injury.

Machine Operator Procedures & Training Requirements

Users of Machines with Safe-Guards

Users of machines that are provided with guards or interlocks by their manufacturer must:

- Obtain training on any equipment that they are not familiar with by asking a knowledgeable person on the equipment's safe use and operation procedures.
- Complete required training and obtain authorization prior to operating machines and equipment

- Recognize through training the locations where guards and interlocks should be installed on any machine. Ensure machine guards are properly installed before using the machine. Do not use a machine when manufacturer-supplied guards are not installed on it.
- Inspect machines and equipment before each use to verify they are in good operating condition with all the required guards in place.
- Bring to management's attention when an unguarded machine location should be guarded
- Understand and practice approved machine safeguarding methods
- Observe all safety protocols and any standard operating procedures
- Wear all appropriate personal protective equipment (PPE)
- Report machine safeguarding/interlock malfunctions or problems to a supervisor / PI immediately
- Report unauthorized or unsafe use of machines and equipment to a supervisor / PI
- Never defeat or remove guards or interlocks or other safety devices
- Never operate machines without ensuring safeguards or interlocks are in place and confirmed to be functioning properly.
- Never bypass a machine guard or interlock without following strict safety procedures to ensure equal measure of safety in the workplace.

Users of Machines with Unguarded Hazards

Users of a machinery and equipment that is old, proprietary, or designed "in-house" and was not designed, built, or installed with appropriate guards must:

- Obtain training on any equipment that they are not familiar with by asking a knowledgeable person on the equipment's safe use andoperation
- Recognize through training the locations where guards and interlocks should be installed on any machine
- Bring to management's attention when an unguarded machine location should be guarded
- Develop a plan to work away from the unguarded location or otherwise limit access to the unguarded location while using the machine
- **Consult EH&S:**
    - To develop safe-work protocols to include safety-interlocks on research and other equipment that would enhance compliance and safe use andoperation of the equipment for personnel
    - To develop a plan to retrofit "after-market" guards and/or interlocks on equipment.
    - To discuss work-demands, budget, and time constraints.
    - To request additional training opportunities.

Personnel Operating Machines

Personnel who operate machines with hazards must be trained on these hazards and their safeguards. They must be trained upon initial assignment, when any new safeguards are put in place, or when new hazards are recognized or created by new machine operations or processes. Training must include the following:

- Their Roles and Responsibilities as outlined in that section of this program. Identification and description of the hazards associated with the machine;
- The safeguards, how they provide protection, and the hazards being controlled for which the safeguards are intended;
- Precautions to take when a machine is unguarded during maintenance and repair; and
- What to do and who to contact if a guard is damaged, missing, or defective.

Retraining should be provided whenever:

- There is a change in job assignments
- A change in machines, equipment, or processes that presents a new hazard
- An inspection reveals, or whenever the Equipment Owner has reason to believe, that there are deviations from or inadequacies in the operator's knowledge of related procedures
- An injury or near-miss occurs related to a machine safeguarding hazard or deficiency which provides a learning opportunity for affected personnel.

Equipment Owners: Managers, Supervisors, Principal Investigators, and Responsible Persons

Equipment owners must be trained on:

- Their Roles and Responsibilities as outlined in that section of this program
- The contents of how to identify safeguards, how they provide protection, and the hazards being controlled for which the safeguards are intended;
- The resources available to them from EH&S for support in implementing this program.

Maintenance and Service Personnel

Maintenance and service personnel must be trained on:

- Their *Roles and Responsibilities* as outlined in that section of this program
- The contents of how to identify safeguards, how they provide protection, and the hazards being controlled for which the safeguards are intended;
- The resources available to them from EH&S for support in implementing this program.
- Lockout and tagout machines and equipment prior to removing or bypassing guards (implement UC Berkeley LOTO Program, as necessary).

Record-Keeping Requirements

Each department is responsible for maintaining its own records of machine safeguarding inspections and surveys. In addition, departments must maintain training records of personnel who have been trained on this program and/or on specific equipment as may be necessary to demonstrate training compliance to a regulatory agency. Documents such as JSAs, Standard Operating Procedures (SOP), operation manuals, signage, etc. may all function to demonstrate record keeping, safe operation, warning, and training activities.

If modifications are made to any machine, keep all documentation (drawings, specs, receipts, etc.) for as long as the equipment is in service or owned by the University.

Retain all training records for ten years after employees have retired or left University employment. For students, retain records for ten years after the student's projected graduation date.

References

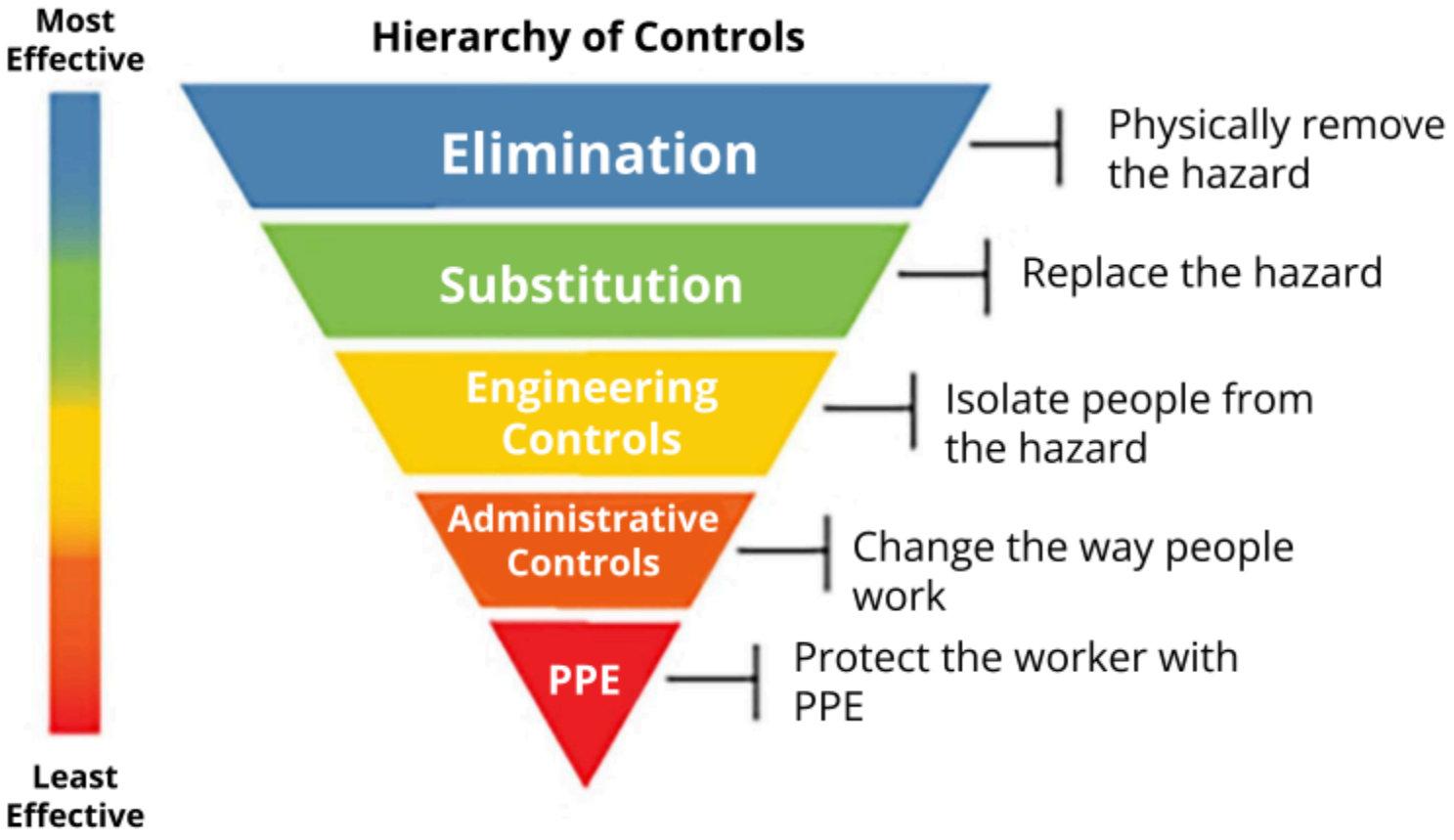
- 29 Code of Federal Regulations 1910, Subpart O. Machinery and Machine Guarding
- California Code of Regulations, Title 8, Subchapter 7. General Industry Safety Orders Group 8. Points of Operation and Other Hazardous Parts of Machinery
- Occupational Safety and Health Administration (OSHA) Machine Guarding eTool
- OSHA & ANSI Safety Graphics Best Practices
- Hierarchy of Hazard Controls

Appendix/Attachments

1. Hazard Control Hierarchy
2. Machine Guarding Assessment Checklist
3. Machine-Specific Examples
4. OSHA & ANSI Safety Sign Classification

Appendix 1 - Hazard Control Hierarchy

If the level of machine-risk is not acceptable, risk reduction measures must be implemented to reduce that risk. Use the hazard control hierarchy to select the most appropriate risk reduction measures for your equipment.



Source: NIOSH

Hazard Control Hierarchy Examples & Risk Factors

Control Method *(Most to Least Effective)*	Example(s)	Influence on Risk Factors
Elimination	Eliminate pinch points (increase clearance) Have intrinsically safe (energy containment) Use automated material handling (robots, conveyors, etc.) Redesign the process to eliminate or reduce human interaction	Impact on overall risk (elimination) by affecting severity and probability of harm
Substitution	Substitute less hazardous chemicals	May affect severity of harm, frequency of exposure to the hazard under consideration, and/or the possibility of avoiding or limiting harm depending on which method of substitution is applied.
Engineering Controls (Guards & Safeguarding Devices)	Barriers, Interlocks Presence sensing devices (light curtains, safety mats, area scanners, etc.) Two hand control and two-hand trip devices	Greatest impact on the probability of harm (Occurrence of hazardous events under certain circumstance) Minimal if any impact on the severity of harm
Administrative Controls	**Awareness Devices**: Lights, beacons, and strobes , Computer warnings Signs and labels Beepers, horns, and sirens **Trainings and Procedures**: Safe work procedures, Safety Trainings Safety equipment inspections, Lockout / Tagout	Potential impact on the probability of harm (avoidance) No impact on severity of harm
PPE	Safety glasses and face shields Earplugs, Gloves, Protective footwear Respirators	Potential impact on the probability of harm (avoidance and/or exposure) No impact on severity of harm
NOTE: Risks can be reduced by removing the hazard altogether, decreasing the potential severity of harm presented by the hazard, improving the possibility of avoiding the harm, and/or reducing the need for access to the hazard zone. Measures which can be incorporated at the design stage of the machine or the design of the work / research process are preferable and usually more cost effective over time to those which are implemented at a later stage, or rely on specific behaviors or procedures to be effective.		

Appendix 2 - Machine Guarding Assessment Checklist

Using the Checklist: Items marked **No** in the columns below should be corrected.

Requirements for all Hazardous Locations	Yes	No
Is there a point-of-operation guard?		
Are all belts or chain drives fully enclosed by guards?		
Are all gears, sprockets, pulleys, or fly-wheels fully enclosed by guards?		
Are all rotating set screws, key ways, or collars fully enclosed by guards?		
Are all rotating parts, reciprocating or traversing motions fully enclosed by guards?		
Are all in-running nip point hazards fully guarded for the entire length of the nip?		
Are all parts that can entangle, draw-in, or trap an operator's clothing or hair fully guarded?		
Are any hazards created by high pressure gas or fluid properly guarded or isolated from the work area?		
Do all openings providing access to danger-areas of ¼ inch or greater size properly guarded?		
Are there warning labels, color-coding or markings to show hazardous areas?		
Hazard and Machine Controls	**Yes**	**No**
Are the on/off or start/stop switches separate, not a "toggle-style" switch, are push-button and/or mushroom head style?		
Are they color coded green for start, red for stop?		
Are starting and stopping controls within easy reach of the operator?		
If there is more than one operator, are separate controls provided?		
Are emergency stop buttons, wires, or bars provided?		
Are the emergency stops clearly identified?		

[*Continued on next page*]

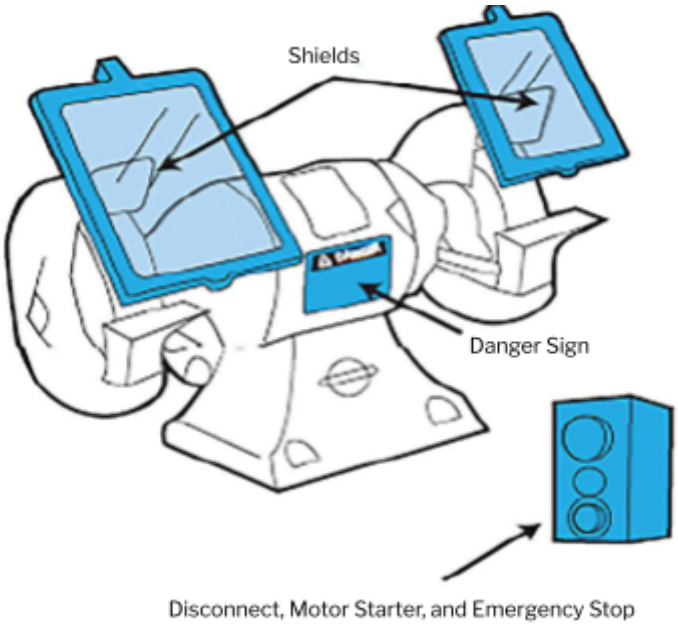
Electrical Hazards	Yes	No
Are all electric plugs three-prong with a ground, and plugged into a grounded outlet?		
Are electric wires fully protected by double-wire insulation near the plug's cord grip?		
Are all conduit fittings tight and appear to be in good repair and undamaged?		
Is the path to ground from the equipment continuous and permanent?		
Are wires and cables adequately supported and properly terminated to prevent shock and fire hazards?		
Is the power supply correctly fused and protected?		
Are the lockout/tagout points labeled and identified?		

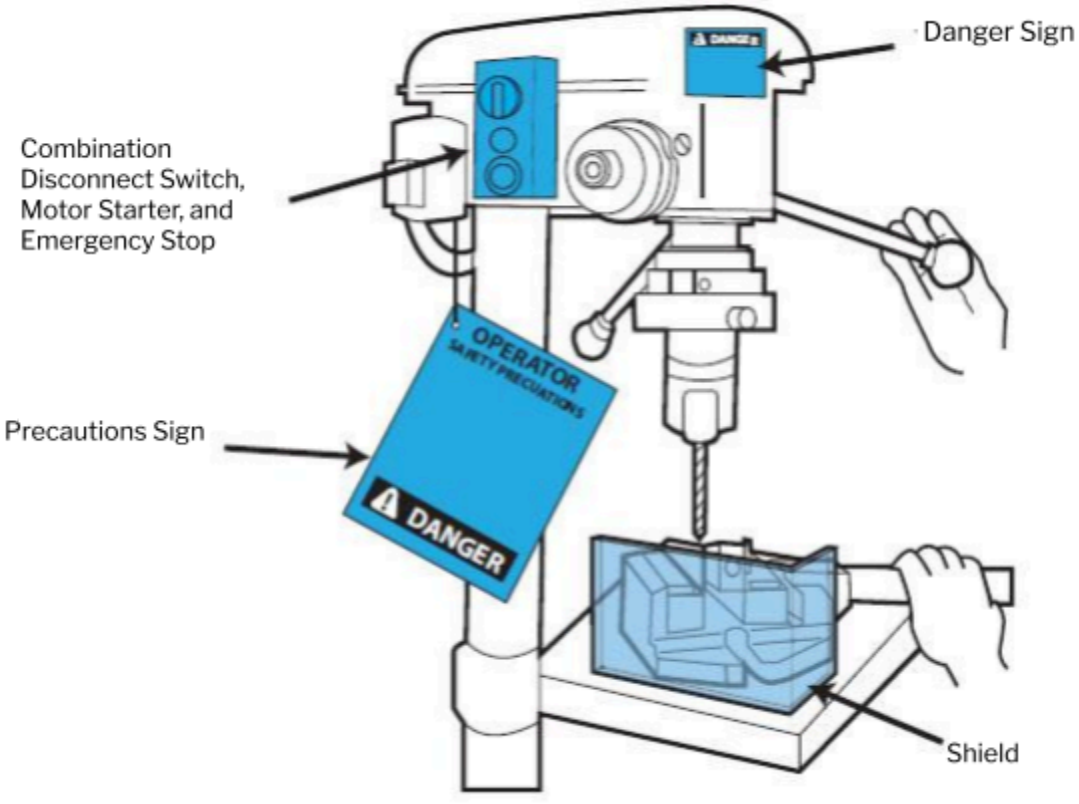
[*Continued on next page*]

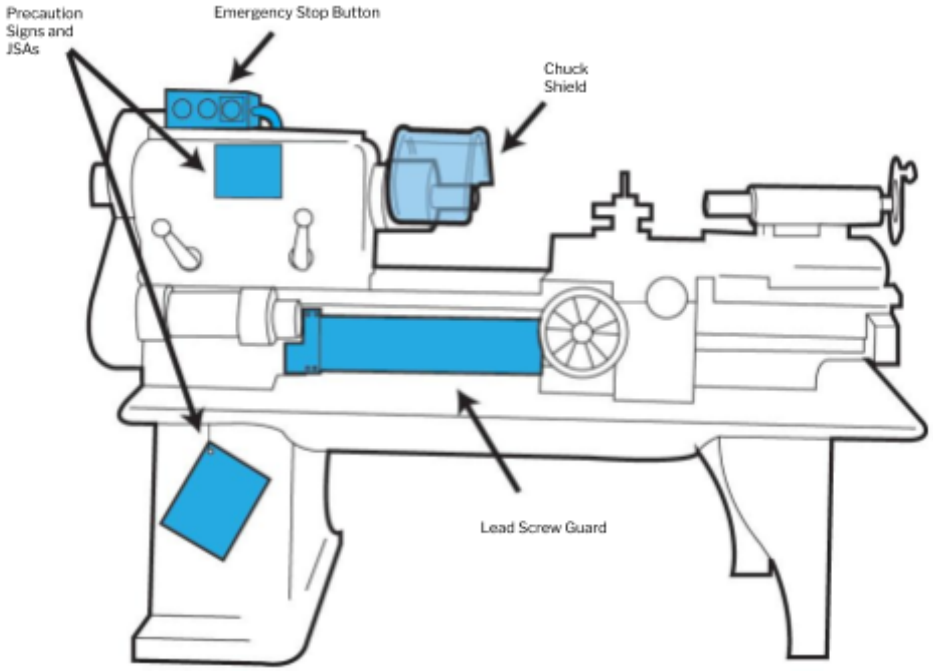
Requirements for All Existing Safeguards	Yes	No
Do the safeguards prevent workers' hands, arms, and other body parts from making contact with dangerous moving parts?		
Are the safeguards firmly secured to the machine?		
Are safeguards tamper-resistant and difficult to remove or bypass?		
Do the safeguards permit safe, comfortable, and relatively easy operation of the machine?		
Are the guards free of hazardous projections, unfinished surfaces, weld splatter, sheared-exposed edges, or other kind of sharp edge?		
Do the safeguards ensure that no objects will fall into the moving parts?		
Can the machine be lubricated without removing the safeguard?		
Is there a procedure for shutting down the machinery and locking / tagging it out before safeguards are removed?		
Are existing safeguards adequate to keep safe all personnel from hazards associated with normal machine operation and possible malfunction?		
Is there a more practical or effective safeguard?		
Will this machine "fail safe" if one or more utilities are impeded or removed?		
Will this machine "fail safe" if sensors, interlocks, or operational components fail?		
Will this machine "fail safe" if machine control logic malfunctions?		
Will this machine "fail safe" if an interlock or emergency stop is activated?		

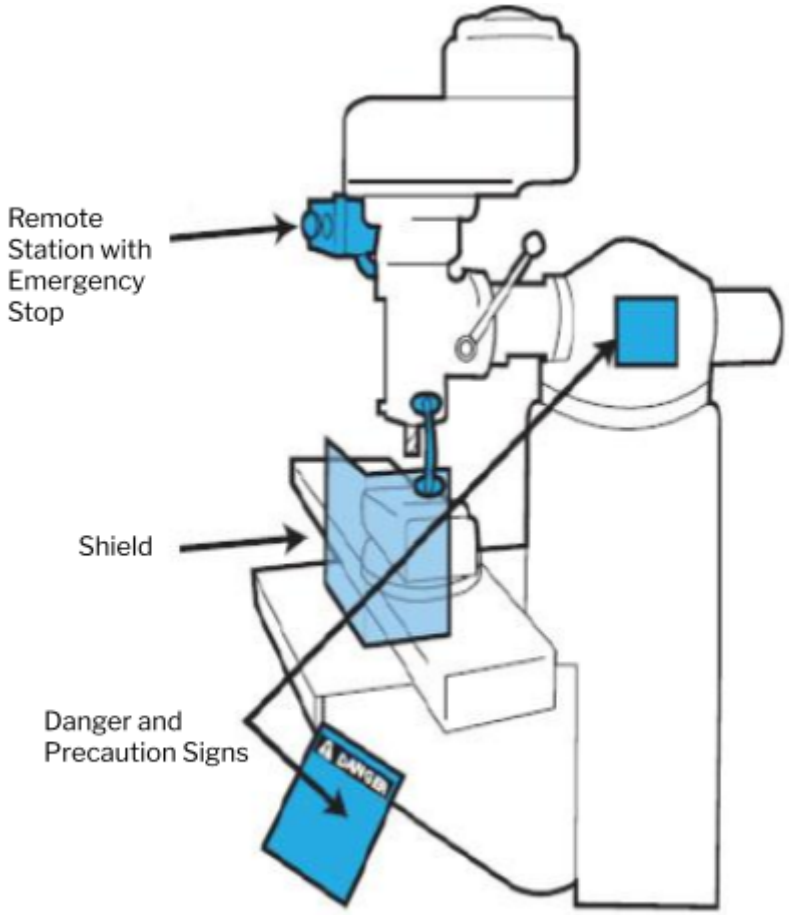
NOTE: This checklist is not all-inclusive or exhaustive. It does NOT address physiological hazards (e.g., noise, illumination, vibration), ventilation (dust, emissions), chemical hazards, environmental concerns or ionizing / non-ionizing radiation

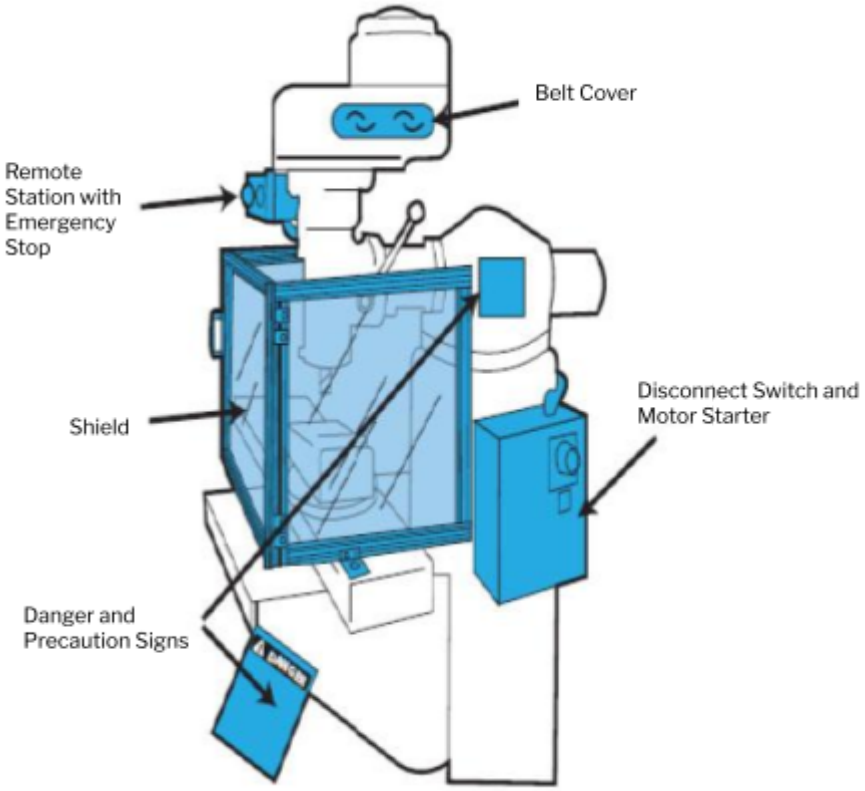
Appendix 3 - Machine Specific Examples of Guards

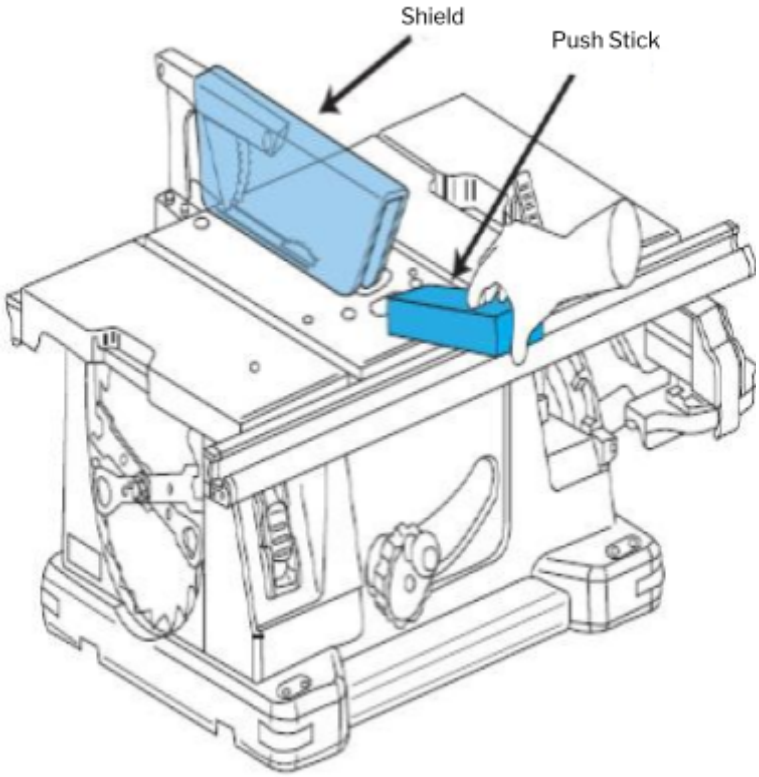





Precaution Signs and JSAs
Emergency Stop Button
Chuck Shield
Lead Screw Guard


Remote Station with Emergency Stop
Shield
Danger and Precaution Signs
DANGER


Belt Cover
Remote Station with Emergency Stop
Shield
Disconnect Switch and Motor Starter
Danger and Precaution Signs


Shield
Push Stick

Appendix 4 : OSHA & ANSI Safety Sign Classification

OSHA & ANSI SIGN CLASSIFICATION TABLE

OSHA uses the terms "sign," "signs," "tag," and "tags" interchangeably.

Sign	OSHA	ANSI
DANGER	Danger tags shall be used in major hazard situations where an immediate hazard presents a threat of death or serious injury to employees. OSHA §1910.145(f)(5)	Indicates a hazardous situation that, if not avoided, will result in death or serious injury. The signal word is to be limited to the most extreme situations. ANSI Z535.2-2017 (4.11.1)
WARNING	Warning tags may be used to represent a hazard level between "Caution" and "Danger," instead of the required "Caution" tag, provided they have a signal word of "Warning" and an appropriate major message. OSHA §1910.145(f)(7)	Indicates a hazardous situation that, if not avoided, could result in death or serious injury. ANSI Z535.2-2017 (4.11.2)
CAUTION	Caution tags shall be used in minor hazard situations where a non-immediate or potential hazard or unsafe practice presents a lesser threat of employee injury. OSHA §1910.145(f)(6)	Indicates a hazardous situation that, if not avoided, could result in minor or moderate injury. ANSI Z535.2-2017 (4.11.3)
NOTICE	Other tags may be used in addition to those required by §1910.145(f), or in situations where §1910.145(f) does not require tags, provided that they do not detract from the impact or visibility of the signal word or major message of any required tag. OSHA §1910.145(f)(9)	Reserve for non-hazard related signs. No safety alert symbol is used. Ideal for signs displaying property damage, security, sanitation and housekeeping rules. ANSI Z535.2-2017 (4.11.4)
SAFETY	Safety instruction signs shall be used where there is a need for general instructions and suggestions relative to safety measures. OSHA §1910.145(c)(3)	Signs used to indicate general instructions for safe work practices or indicate the location of safety equipment. Examples include signs for equipment and lockout procedures. ANSI Z535.2-2017 (4.11.5)
BIOHAZARD	Biological hazard tags shall be used to identify the actual or potential presence of a biological hazard and to identify equipment, containers, rooms, experimental animals, or combinations thereof, that contain or are contaminated with hazardous biological agents. OSHA §1910.145(f)(8)(i)	

For more information, see OSHA & ANSI Safety Graphics Best Practices.

Revision History

REVISION DATE	SECTIONS REVISED	SUMMARY OF CHANGES	CHANGE WRITTEN BY / AUTHORIZED BY
June 5, 2024	Entire Document	Sheduled Revision	Health & Safety Specialist, Assistant Manager, Health & Safety
April 15, 2013	N/A	Original Issue date	Associate Director of Health and Safety