Program Development

Machine Safeguarding

Building a successful program

By Steven M. McConnell

SAFEGUARDING MACHINE HAZARDS is a common goal for many SH&E professionals. Operating unguarded equipment introduces risks including the potential for serious injury, equipment damage, increased workers' compensation costs and vulnerability to OSHA citations. Although machine safeguarding has improved since the era prior to the organized safety movement, companies continue to receive OSHA citations and workers continue to be injured, even killed, by machine tools and equipment.

In the early 1900s, transmission machinery (e.g., gears, belts, pulleys, shafting) was often operated while completely unguarded. At that time, the countersunk setscrew used on shafting had not been invented and projecting setscrews were involved in many horrific accidents (Blake 175). Machines were built with little regard for worker safety, meaning that many workers were killed or seriously injured before definitive action was taken to improve safety in the workplace.

The first patent for a machine safeguard was issued in 1868 for a mechanical interlock (Brauer 147). Other patents followed, and as methods for safeguarding machinery and tools were developed, standards were written and programs were established to monitor factories for compliance. Many of those standards continue to govern how workers are protected today. Many machine tools built in the 1940s, 1950s and 1960s are still in use. In terms of safeguarding, these machines may be considered poorly designed, improperly safeguarded or simply unguarded. In addition to the potential threat of OSHA citations, these conditions expose operators to serious hazards.

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OSHA Enforcement

Enforcement actions, in the form of compliance inspections, are conducted by OSHA (state or federal depending on the location). Federal OHSA requirements for machine guarding are found in 29 CFR 1910, Subpart O: Machinery and Machine Guarding (with specific requirements contained in 1910.211 through 1910.219). Despite improvements in safeguarding, OSHA continues to identify violations at an alarming frequency. Federal data covering October 2001 through September 2002 indicate that machine guarding standards accounted for five of the 13 most frequently cited OSHA standards. Table 1 lists the 20 most frequently cited OSHA standards for the period referenced; those related to machine guarding are highlighted.

One factor in this trend may be the array of hazards that employers must identify. This responsibility is explained in 1910.212(a)(1), which states that one or more methods of machine guarding shall be provided to protect operators and other employees in the machine area from hazards such as those created by the point of operation, ingoing nip points, rotating parts, flying chips and sparks. However, the standard only explains what must be done (provision of one or more methods of machine guarding), not how to do it.

Any of the following potential situations in a work area may be cited as a violation of OSHA standards for machine guarding:

- contact with a moving part during normal operation of the machine;
- clothing caught in any moving part of the machine;
- random ejection of material during normal operation;
- controls not easily reached for emergency shutoff;
- operator able to bypass guards;
- insufficient space for operation and maintenance;
- insufficient illumination in the area;
- inadequate ventilation for machines that generate dusts, fumes, vapors, mists or gases;
- poor housekeeping in machine shop area (Kavianian and Wentz 10).

In many cases, citations are issued because the appropriate safeguard has not been provided or is not in use at the time of inspection. In other cases, interpretations of what the standard requires may vary among OSHA inspectors—in the author's experience, a situation that occurs more frequently for organizations that operate in multiple states. Safeguarding efforts considered adequate in one locale may be considered inadequate in another due to the inspector's interpretation of the standard or application of a state-run OSHA requirement. Therefore, the SH&E professional must be familiar with enforcement practices in various regions in order to help the organization avoid unnecessary citations and associated penalties. The fundamental principle—safeguarding workers—must be the overriding objective at all times and the goal should be to provide a consistent level of protection at each location.

The SH&E Professional's Role

One of the SH&E professional's roles is to monitor operations and advise line management as to what actions are needed with respect to safety. Safety is owned by line management—the responsibility to enforce the program belongs to line management, not the SH&E professional. In many settings, the SH&E professional is tasked with assessing operations and identifying potential hazards and controls associated with machine use. S/he will be expected to write the machine safeguarding program and to help ensure its effective implementation, including employee training.

Once these responsibilities are fulfilled, the SH&E professional should help line management administer the program. First, assess what line management knows about safeguarding machines, then devlop a succinct training course to raise the knowledge base to a satisfactory level. It is helpful to schedule one-on-ones (or small group meetings) with line managers to walk their areas of responsibility and identify operations that present safeguarding hazards. This is also an excellent opportunity to educate managers about hazards and controls in their assigned areas and to help them understand what is expected of them (and workers) so they can appropriately enforce requirements.

Management Buy In

As noted, the need for an effective machine safeguarding program is clear based on the number of OSHA citations issued every year. To gain management's support for the program, the SH&E professional should conduct a thorough analysis of the problem. Both passive and active surveillance techniques can be used to obtain the data needed to develop the proposal.

Passive Techniques

•Review OSHA injury logs to identify incidents related to machine safeguarding.

•Review pertinent injury reports to determine the causal factors related to machine-safeguarding-related incidents.

•Tally the number of injuries, lost/restricted workdays and WC costs and assign a realistic monetary value or loss to the organization.

Table 1

20 Most Frequently Cited OSHA Standards

Standard	# Cited	Description
1910.1200	3,344	Hazard Communication
1910.147	3,166	Control of Hazardous Energy (LOTO)
1910.134	2,549	Respiratory Protection
1910.212	**2,403**	**Machines, General Requirements**
1910.305	1,998	Electrical Wiring Methods
1910.219	**1,716**	**Mechanical Power Transmission Apparatus**
1910.303	1,390	Electrical Systems Design
1910.178	1,377	Powered Industrial Trucks
1910.217	**1,195**	**Mechanical Power Presses**
1910.95	1,130	Occupational Noise Exposure
1910.213	**1,075**	**Woodworking Machinery Requirements**
1910.132	1,061	Personal Protective Equipment
1910.215	**1,003**	**Abrasive Wheel Machinery**
1910.23	939	Guarding Floor and Wall Openings
1910.146	847	Permit-Required Confined Spaces
1910.157	818	Portable Fire Extinguishers
1910.266	742	Pulpwood Logging
1910.22	711	Walking-Working Surfaces
1910.107	698	Spray Finishing with Flammable/Combustible Materials
1904.106	691	Flammable and Combustible Liquids

Source: OSHA.

•Review internal/external inspection records to determine the number and type of machine safeguarding deficiencies.

Active Techniques

•Assess line management knowledge of safeguarding principles and requirements.

•Observe worker compliance with safeguarding requirements.

•Document safeguarding hazards using a digital camera and incorporate these photos into the presentation to management as appropriate.

•Verify that deficiencies noted in OSHA citations have been corrected and document whether conditions continue to meet expectations.

•Develop a detailed action plan to address identified hazards.

The next step is to present the proposal to management. To prepare, practice the presentation, anticipate likely questions and be prepared to explain the anticipated benefits of the program. Also, carefully consider which managers should attend and choose a time when those people can attend.

The Written Program

The written machine safeguarding program should be either a stand-alone document or a section within the overall safety manual. In either case, senior management must endorse it. The written program should clearly define safeguarding requirements and the roles and responsibilities of employ-

Table 2

Potential Machine-Related Hazards

Location	Machines/Equipment	Hazard
Machine shops	Metalworking tools including shears, brake presses, drill presses, lathes, mills, grinders, etc.	Machine motions and actions, shafts, belts, pulleys, flying objects
Wood shops	Woodworking equipment including table saws, band saws, mill tools, lathes, lathe circular saws, blades, vertical skill saws, planers, jointers, drill presses, etc.	Machine motions and actions, shafts, pulleys, belts, flying objects, sharp blades, etc.
Mechanical rooms	Boilers, pumps, compressors	Belts, pulleys, power transmission equipment
Roofs	HVAC, plenums, fans	Shafts, pulleys, belts
Shipping/receiving	Conveyor equipment	Belts, rollers, chain drives, gears, pulleys, belt transfer points, return idlers
Waste treatment areas	Pumps, mixers, separators	Shafts, pulleys, belts
Production packaging	Palletizers, conveyor systems	Reciprocating, hydraulic "sweeping" arms, chain drives, belts, belt transfer points, return idlers
Production floor	Power presses, punch presses	Machine motions and actions, shafts, belts, pulleys, flying objects, stroking action, material feeding and ejection
Production floor	Conveyors, packages, robotics	Shafts, belts, rollers, chain drives, pinch points, nip points
Refrigeration room	Pumps	Shafts, pulleys, belts

ees, supervisors and management. The program's objective is straightforward: To ensure adequate safeguarding of machines and tools (and enforcement of their use) in order to maximize productivity and eliminate injuries.

Success is more likely if a group of shop supervisors and workers is involved in the process of developing the program. This is also true when reviewing an existing program. Although the SH&E professional may lead the group due to his/her knowledge of applicable standards, the objective is to achieve buy-in from this group before a new or modified program is implemented.

Key elements of the written program include:

• **purpose statement** customized to the organization/location;

• **policy statement** that addresses the use of safeguards within the organization;

• **roles/responsibilities** to clearly articulate what is expected of workers, first-line supervisors, management and the SH&E professional (this element should also be emphasized during training);

• **scope of coverage** to indicate that requirements apply to all company-owned machine tools and equipment and all tools and equipment brought on site by contractors;

• **requirements** broken down by topical area such as general, woodworking tools, metalworking tools, conveyors, belts, pulleys and shafts.

• **types of safeguards** that describe how and where various types of safeguards are used—and prohibit makeshift safeguards;

• **program assessments** which detail who conducts assessments and on what frequency (e.g., initial assignment of safety responsibilities, when new machine tools and/or equipment are purchased);

• **required training.**

Other important program elements include:

• **Location-specific operator qualification program.** A sitewide operator qualification program should be established and the rule enforced that only trained, qualified personnel are allowed to operate machine tools and equipment.

• **Workspace layout.** Assess the design of the shop floor with these principles in mind:

• Tool room is centrally located.

• Straight line, turning, milling and grinding operations are grouped.

• Ample space is provided around tools and equipment for handling large pieces.

• Access to small spaces between machines is prevented at all times.

• Lift-assist devices are provided and appropriately located for intended use.

Safeguarding Principles & Their Application

To develop an effective program, the SH&E professional must understand the principles of safeguarding equipment. As noted, many of these principles have gone largely unchanged since the early 1900s, and many ANSI and OSHA standards have been written with these principles in mind. Although their application and worker compliance may present challenges, the principles themselves are sound and are key to improving operator safety.

The principles for safeguarding have been described as follows:

1) All power working machines that have gears, sprockets, chains, belts, bands, pulleys, clutches, wheels, shafting, spindles, couplings, counterweights, revolving or reciprocating parts and all other dangerous points, parts or projections are guarded in an approved manner.

Figure 1

Machine Safeguarding Assessment

Assessor: ____________________
Date: ____________________
Area/Location: ____________________
Action Required yes____ no__

Item	Yes	No	Action Required	Person	Date Due
Written program is current and addresses machinery/equipment in area.					
Layout of shop/area machinery and equipment is adequate for personnel safety.					
New machinery/equipment has been added to inventory and a risk assessment is complete.					
Machinery/equipment has been properly anchored in position.					
Machine-specific checklists are used for monthly inspections by supervisors.					
Machinery/equipment appears in safe operating condition.					
Labels/placards (in good condition) are provided.					
Operators have completed required qualification requirements.					
Operators have completed LOTO training as required.					
Written procedures exist for each piece of equipment subject to LOTO.					
Machine/equipment guards are properly installed and used where required.					
Machine safeguards are provided and used where required.					
Guards/safeguards are in satisfactory condition and are functional.					
Interlocks are used where appropriate and are functional.					
Machinery/equipment are protected from falling objects.					
Emergency stops are located appropriately and are protected from accidental activation.					
Operators/maintenance personnel are issued (and use) appropriate PPE.					
Accidents involving machines or equipment are investigated and appropriate controls are implemented.					

Identify responsible person

Detail actions required to mitigate safety concern

Monitor corrective action and due dates

2) All roller-fed machines on which operators' hands come within the danger zone are to be guarded at the point of operation in an approved manner.

3) All machines that have a sheering, pressing, squeezing or cutting action on which operators' hands come within the danger zone are to be guarded at the point of operation in an approved manner (Hansen 113).

The Role of ANSI Standards

ANSI is a private, nonprofit entity that coordinates the U.S. voluntary standardization and conformity assessment system. It is recognized as an organization that impacts the adoption, amendment or repeal of OSHA standards. The majority of ANSI standards addressing machinery/equipment safeguarding are found in the B series standards. Examples include:

- B7.5, Abrasives;
- B11, Machine Tools;
- B15.1, Power Transmission Apparatus;
- B65, Printing Equipment;
- B71.1, Garden Equipment;
- B154.1, Rivet Setting Equipment;
- B155.1, Packaging Machinery;
- B173, Hand Tools;
- B165, Power Tools;
- B186.1, Portable Air Tools;
- B209, Hand Tools;
- B208.1, Pipe Threading Machines;
- O1, Woodworking Machinery;
- R15.06, Robots;
- Z245.5, Baling Equipment.

Many ANSI standards have been adopted by reference in OSHA standards. Others serve as excellent reference and represent the consensus of experts with respect to ensuring worker safety. Therefore, much like being familiar with applicable OSHA standards, the SH&E professional should be aware of applicable ANSI standards.

Identifying Hazards

Machine and/or equipment hazards exist in nearly every type of organization. To identify safeguarding concerns, a detailed assessment of facilities and operations should be conducted. This evaluation should include basements, mechanical rooms, rooftops and other out-of-the-way places. Table 2 illustrates typical machines/equipment and hazards found in various areas of an industrial facility. This table is not intended as an all-inclusive list of potential hazards, but as an example; those involved should create a site-specific hazard list.

The assessment must be thorough and the evaluator should follow the "operational process path," then walk the extraneous areas. Using a systematic approach helps to ensure that no areas are overlooked. Employee opinions about and concerns regarding safeguarding should be solicited as well. The assessment should focus on the machine/equipment motions and actions (see pg. 22) because these will pose potential hazards to all operators. Housekeeping should also be evaulated, as poor housekeeping practices increase the likelihood of injuries; for example, an employee who trips and falls on debris could become entangled in an operating machine.

After examining the facility, the assessor should indicate:

- whether an appropriate safeguard has been provided;
- type and condition of safeguard provided;

•whether the safeguard was in place and operable at the time of observation.

Deficient conditions—such as missing or inoperable safeguards—should be promptly communicated to the area manager(s) for correction. Those involved in the assessment must understand company and OSHA requirements for safeguards. Here, the SH&E professional can provide appropriate training to those participating in the assessment.

Identified hazards should be engineered out where feasible, then an appropriate control(s) implemented; these may include engineering controls (guards, barriers, devices), administrative controls and PPE. With respect to safeguarding machines and equipment, deciding whether a guard is necessary may be more difficult than determining which type of safeguard to provide (DeReamer 109). Some questions to be considered in making this determination include:

•Can a person come into direct contact with a moving machine part during normal production/maintenance operations?

•Are rotating or moving screws, keys, bolt heads, burrs or other projections so exposed as to snag a worker's clothing or to inflict injury?

•If tools, jigs or other work fixtures are required, are they stored conveniently but where they will not interfere with the work?

•Is the work area well-illuminated, with additional point-of-operation lighting where necessary?

•Is ventilation adequate, particularly for tasks that create dusts, mists, vapors, fumes or gases?

•Is the operator using applicable PPE?

•Is housekeeping satisfactory, with no debris, tripping hazards or spills on the floor?

Machine Motions & Actions

Although the fundamental principle of safeguarding machines—to protect operators and coworkers from hazards associated with the operation of those machines—is fairly straightforward, it can be a daunting task. Most hazards emanate from the mechanical motions and actions of the equipment during operation.

Hazardous Mechanical Motions

The basic types of hazardous mechanical motions are: Rotating (including in-running nip points); reciprocating; and transverse (OSHA 2). Rotation is exemplified by turning shafts, cams, flywheels, etc., and creates the hazard of gripping gloves or clothing and pulling the worker into the machinery or placing him/her in a dangerous position during the operation of the machine.

Reciprocating motion describes the up-and-down or back-and-forth movement of a machine. The motion creates the hazard of a worker being caught between a moving and stationary part or being struck by the part in motion.

Transverse motion refers to movement in a straight, continuous line. This type of motion exposes the worker to being struck by the moving part or caught in a pinch point or shear point.

Hazardous Mechanical Actions

The basic types of hazardous mechanical actions are: Cutting, punching, shearing and bending. The actions of machines are somewhat more straightforward and easy to recognize. Hazards associated with machine actions occur at the point of operation where parts of the body (such as fingers, arms or head) can be injured. Flying particles and chips are another potential hazard.

To be effective, safeguards must:

•prevent the worker from making contact with dangerous moving parts;

•be made of substantial, durable material and be secured (to the equipment when possible);

•provide protection from objects falling into the moving machine;

•not to create a new hazard/operator interference;

•be designed to allow for lubrication without removal of the safeguard.

The SH&E professional should be involved in the design of safeguards to help ensure that they meet these requirements. Usually, this entails communicating with the safeguard's manufacturer to ensure that the device will provide adequate protection.

Safeguarding Terminology

To develop an effective program, the SH&E professional must also be familiar with some key terms.

•*Device:* Mechanism or control designed for safeguarding at the point of operation, such as presence-sensing, pullback, two-hand-trip devices.

•*Enclosure:* Barrier or cover that protects workers from other danger zones (other than the point of operation) within the operation.

•*Guard:* Barriers designed to safeguard the point of operation.

•*Nip points or bites:* Hazardous area created by two or more mechanical parts that are rotating in opposite directions within the same plane and in close interaction.

•*Pinch point:* Any place where a body part can be caught between two or more moving parts.

•*Point of operation:* Area on a machine where material is positioned for processing—where work is actually performed on the material.

•*Power transmission:* All mechanical parts such as gears, cams, shafts, pulleys, belts, clutches, brakes and rods that transmit energy and motion from the source of power to the equipment or machine.

•*Safeguarding:* Any means of preventing workers from coming in contact with the moving parts of machinery or equipment, potentially causing physical harm (NSC 382).

OSHA standards (and compliance inspections) are primarily directed at hazards associated with these terms. This makes good sense since noncompliance with requirements related to these hazards places workers at risk of serious injury. Therefore, SH&E professionals should focus on these issues as well.

Types of Safeguards

Effective means of safeguarding machines and equipment include guards (e.g., fixed/enclosure,

Figure 2

Maintenance & Repair Assessment

Assessor: ____________________
Date: ____________________
Area/Location: ____________________
Action Required yes___ no__

Are individuals meeting expectations?

Item	Yes	No	Action Required	Person	Date Due
Maintenance workers have received up-to-date instruction on the machines they service.					
Maintenance workers have been trained to lockout/tagout requirements.					
Maintenance workers lockout/blockout machinery and equipment before beginning work or repairs.					
Multiple lockout devices are used whenever LOTO is required and more than one maintenance worker is assigned to the job.					
Guards/safeguards are repositioned properly when maintenance or service work is completed.					
Maintenance workers use appropriate and safe tools and equipment.					
Required guards are used on maintenance tools and equipment.					
Maintenance work is not performed on operating equipment accept when necessary for alignment or performance testing purposes.					
Where possible, provisions have been made to lube machinery and equipment without removing guards.					
Displaced guards and miscellaneous parts associated with maintenance and service work are located in such a manner as to preclude slip/fall hazards.					
Maintenance personnel inform operations personnel of their intent to perform work, and the location of the job, prior to beginning work.					
Job-made guards/safeguards are not installed on machinery or equipment without permission from the safety department.					

What will mitigate the deficiency?

Do corrective actions occur on time?

interlocked, adjustable, self-adjusting); devices (e.g., presence-sensing, pull back, restraint (holdout), safety trip controls, two-hand controls, two-hand trip, gate/cage; and location/distance (e.g, position of operator's control station, distance between machine feeding process and operator's hands). Other means include robotics and automatic feeds.

Guards

Guards are usually made of metal, plastic or wood. Metal is often preferred because of its strength and durability. Plastic is typically used in situations that require a higher level of visibility or when it is desirable for the operator to position the guard in relation to the work being performed. Wood guards are flammable and generally lack the durability and strength of guards made of metal or plastic. Use of wood guards is limited by 29 CFR 1910.219(o)(2) as follows:

> Wood guards may be used in the woodworking and chemical industries, in industries where the presence of fumes or where manufacturing conditions would cause the rapid deterioration of metal guards; also in construction work and in locations outdoors where extreme cold or extreme heat make metal guards and railings undesirable. In all other industries, wood guards shall not be used.

Fixed guards or enclosures are the preferred type of protection because they prevent operator access to dangerous parts of the machine at all times. This type of safeguard can be applied to many types of equipment including presses, chain and belt drives, rotating shafts, reciprocating parts and gears. The fixed guard can be adjustable to allow for the use of various tools or materials.

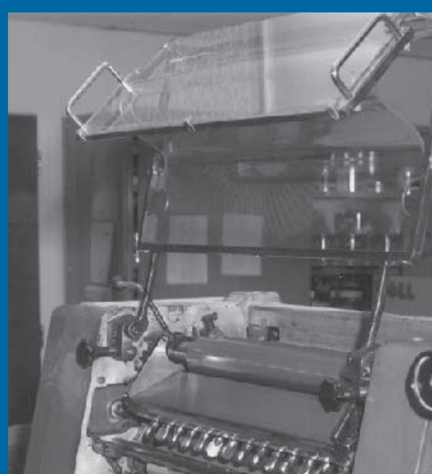
Interlocking guards prevent the control that places the machine into operation from working until the guard is in proper position. An interlocking safeguard may be electrical, mechanical, pneumatic or some combination. This guard is "open" when dangerous parts of the machine are exposed and is "closed" when the machine is in operation.

Manufactured Guards vs. Fabricated Guards

Some organizations are able to construct safeguards in-house. Whether this approach is cost-effective can be difficult to determine. If a specific piece of machinery has a history of being involved in accidents, the SH&E professional can complete a simple cost-benefit analysis by comparing the cost of purchasing suitable safeguarding with the total cost of the injuries. However, it is not as easy to conduct a cost-benefit analysis between a purchased safeguard and a fabricated one. Even though the cost of a vendor-supplied device can be determined, and the cost of in-house fabrication (time, materials, installation) estimated, such an analysis may not tell the whole story. For example, the analysis must also consider the potential for increased liability to the organization if fabricated guards are used.

In-house or makeshift safeguards carry several inherent problems:

- may not meet OSHA/ANSI requirements;
- may not fully protect workers;
- may be made from flimsy material leading to their subsequent damage;
- may not properly fit the machine;
- may impede production;
- may be removed easily by the worker.



Clockwise from top: Devices such as pressure-sensitive mats (top) and interlocking guards (above, right; below, right) stop or prevent operation of machines to protect operators. In many cases, however, guards can be bypassed or removed (above), exposing the operator to the risk of serious injury.

PHOTOS (TOP AND RIGHT) COURTESY SCIENTIFIC TECHNOLOGIES INC.

Most manufacturers build safeguards that meet or exceed ANSI requirements and, thus, provide the needed protection to workers. Furthermore, it is often less expensive to purchase required safeguards at the time the equipment is purchased. Therefore, firms must avoid the temptation to purchase the equipment without safeguards on the promise of manufacturing them in-house or purchasing them later (when funding is available).

Devices

Safeguarding devices perform one of several functions to protect the operator. They may stop the machine when the operator's hand or other body part enters the danger area; restrain or withdraw the operator's hands from the danger area during machine operation; require the operator to use both hands to operate a machine; or provide a barrier synchronized with the machine's operating cycle to prevent the operator from coming in contact with dangerous parts during machine operation.

Presence-sensing devices may be photoelectric, radio frequency (capacitance) or electromechanical in design and effectively stop a machine when their light field, capacitance or probe-sensing mechanisms are tripped or broken.

Pullback devices make use of a series of cables that are attached to the operator's hands, wrists and/or arms. Such devices are primarily used on machines with stroking actions, such as power presses and press brakes, and allow the operator to access the point of operation between cycles. These devices automatically pull the operator's hands out of the danger area during the cycling of the machine.

Restraint devices also use cables or straps attached to the operator's hands or wrists. The cables or straps must be adjusted for individual operators to ensure that they cannot access the machine's danger zone. Hand-feeding tools are usually necessary because there is no extending or retracting action associated with this type of safeguard.

Safety trip controls allow a machine to be stopped quickly in an emergency. Examples of these controls include a pressure-sensitive body bar and tripwire cables. Pressure-sensitive body bars are often located in front of a machine and will deactivate the machine when the operator makes contact with the bar. Tripwires are usually found around the perimeter of the danger area and must be located within the operator's reach.

Two-hand control systems require the operator to apply consistent, concurrent pressure to operate the machine. This process keeps the operator's hands away from the danger area during operation.

Similarly, two-hand trip devices require concurrent pressure on each control button to activate the machine cycle. Once the cycle has been activated, the operator's hands are free. This type of safeguard must be located far enough away from the point of operation that the operator cannot access this area prior to the first half of the machine cycle being completed.

A gate or cage is a movable barrier designed to protect the worker at the point of operation before the machine cycle can be activated. The device must be interlocked to prevent activation of the machine unless the device is in the proper position.

Location/Distance

In some cases, workers may be safeguarded by location/distance from the hazard. In such cases, the machine may be located in such a manner that the worker is not exposed to dangerous parts during normal machine operation. For example, a machine may be placed against a wall so that the operator is isolated from its power transmission components. The dangerous components of a machine/equipment may be located a sufficient height (varies between seven and eight feet by standard) above the walking/working surface so that it is inaccessible to the worker. Another example is to enclose the power transmission components behind a permanent fence. In other cases, the operator's control station may be located a safe distance away from the machine. In addition, workers may be adequately safeguarded by distance in cases where material stock several feet long is being worked on on one end while the operator holds the other end.

OSHA 29 CFR 1910.217, Mechanical Power Presses, provides several formulas that are used to determine the minimum distance (from the hazard) for adequate safeguarding. For example, 29 CFR 1910 .217(c)(3)(g)(iii)(e) provides the following formula for use in determining the required safe distance from the sensing field of a presence-sensing device to the point of operation on a mechanical power press:

D_s = 63 in./s x T_s

where:

D_s = minimum safety distance (inches); 63 in./s = hand speed constant;

T_s = stopping time of the press measured at approximately 90-degree position of crankshaft rotation (seconds).

It should be noted that OSHA requires all areas of entry to the point of operation not protected by the presence-sensing device to be protected by the use of guards.

Types of Machine Guards

By Scientific Technologies Inc.

Preventing Access

Three common options are available to prevent access to the machine during dangerous motion.

Fixed Enclosing Guards

Where a hazard exists on a machine that never requires access, fixed enclosing guards should be utilized for permanent protection.

Movable Guards with Interlocking Switches

Where access to the hazardous area is required for maintenance, the machine should be outfitted with a moveable guard that is interlocked with the hazard's power source. Properly installed, this ensures that when the guard door is open power to the hazard will be off.

Two-Hand Controls

Two-hand control systems are devices where two start buttons must be depressed at the same time for machine actuation. This ensures that both hands of the operator are occupied in a safe position (i.e., at the controls) and therefore cannot be in the hazardous area. This type of measure only protects the operator and does not give protection to other personnel.

Preventing Dangerous Motion

Where frequent access is necessary, presence-sensing safety devices can be used to prevent dangerous motion. These devices allow unrestricted access by sensing the presence of the operator and sending a stop signal to the machine.

Infrared Safety Light Curtains

These devices consist of an array of harmless infrared-light-emitting diodes. They create a "curtain" of light beams in front of the hazardous area. When any of the beams is blocked, the light curtain control circuit sends a stop signal to the guarded machine. They are available with a wide variety of features and configurations. Their flexibility makes them suitable to safeguard most applications ranging from perimeter guarding of industrial robots, to point of access guarding of half-revolution presses.

Area Scanning Devices

Area scanning devices will detect an intrusion into a defined hazardous area. They are particularly unique in their ability to be reprogrammed should the configuration of the guarded area change. These devices frequently include a programmable "warning zone" to warn an intruder from entering into the work cell, without stopping the robot or other machinery.

Pressure-Sensitive Safety Mats

Pressure-sensitive mats are often used within an enclosed area containing several machines. A matrix of interconnected mats is laid around the hazardous area. The proper amount of pressure (e.g., an operator's footstep) will cause the mat control unit to send a stop signal to the guarded machine.

Pressure-Sensitive Edges

These devices can be fixed to the edge of a moving part where there is a crushing or shearing hazard. They can also be used on machines where there is a risk of operator entanglement. Contact with the safety edge will trip the switch and send a stop signal to the machine.

Emergency Stops

Emergency stop devices are intended for use wherever there is potential for operator danger on a machine.

Emergency Stop Buttons

These are mushroom-head-type push buttons that the operator strikes in the event of an emergency. These buttons must be strategically placed around the machine to ensure that one is always within reach in the event of an emergency.

Emergency Rope Pull Switches

With machinery such as conveyors, it is often more convenient and effective to route a grab-wire (rope) device along the hazardous area. These devices use a steel wire rope connected to a latching pull switches so that pulling on the rope will operate the switch and cut off power to the machine.

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Other Protective Means

Robots have become more common in recent years. In effect, robots safeguard workers by performing many repetitive, highly hazardous and unpleasant jobs. However, use of robotics in the workplace also presents hazards to the human worker, including those categorized as "struck by" and "caught between." These hazards must be assessed and properly safeguarded as well.

Semi-automatic and automatic feeds can reduce exposure to hazards during machine operation by eliminating the need to reach into the danger area when feeding stock material into the machine. Examples can be found on various types of power presses and other production machinery.

Additional information on safeguards is available in *Safety and Health for Engineers* (Brauer) and "Concepts and Techniques of Machine Safeguarding" (OSHA Bulletin 3067). Organizations that specialize in the fabrication/provision of safeguards and consultants with expertise in machine/equipment safeguarding are another potential resource.

Safeguarding the Point of Operation

The point of operation refers to the area on a machine where work is actually performed. This area often creates a serious injury hazard when the machine is functioning. More than 50 years ago, Heinrich cited seven principles related to point-of-operation guarding. These principles still apply:

- Design tools so that guards are not required.
- Provide enclosures, covers and barricades.
- Provide mechanical feeding devices.
- Provide devices that prevent or interrupt the movement of tools when the operator's hands are in the danger zone.

Selecting the Right Safety Light Curtain

By Scientific Technologies Inc.

Type 2 and Type 4 safety light curtains provide different levels of safety performance and capabilities.

•Type 2 devices are not considered control reliable to OSHA or ANSI standards, while Type 4 devices are.

•Type 2 devices have a larger effective optical angle resulting in the possibility of an optical "short circuit." As a result, an object in the sensing field may not be detected, as the light bends or reflects around the object.

•At the expense of control reliable circuitry, lower precision and fewer features, Type 2 devices can cost up to 30 percent less than an equivalent Type 4 device.

The decision to use a Type 2 versus a Type 4 light curtain should only be made after a complete risk assessment has been performed. If some doubt still exists after the assessment, it is best to be conservative. Type 2 devices should never be used where ANSI B11.19, OSHA 1910.212 or 1910.217 apply. Additionally, they must not be used where regulations require the use of control reliable circuitry, and should never be used to safeguard a mechanical power press. (For more information on risk assessments refer to ANSI B11.TR3, ANSI/RIA R15.06-1999, and/or EN1050.)

Type 2 light curtains should be used only where a risk analysis determines low risk *and* low severity. Type 2 light curtains are an effective guarding solution in several safety and non-safety applications, such as semiconductor equipment, storage and conveying equipment, small textile equipment, packaging equipment (with the exception of palletizers), process protection, parts counting, tooling guarding and inspection equipment.

Where a risk assessment identifies the severity of a potential injury, regardless of its probability, as greater than that requiring simple first aid as defined by OSHA 1904.12, a Type 4 device should be used.

Type 2 and Type 4 devices both play a role in keeping workers safe and productive. It is important to remember, however, that a safety light curtain may not be right for every machine safeguarding application. Other safety equipment, such as safety mats, safety interlock switches, hard guards or a combination of equipment may offer the optimum solution.

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•Provide remote-control operating mechanisms.

•Provide mechanical devices that remove hands from the danger zone.

•Combine devices (Heinrich 227).

Heinrich suggested that prospective SH&E professionals would profit by carefully studying and memorizing these principles. Although he firmly believed that human failure was the major cause of industrial accidents, he recognized that proper safeguards would make the work area more safe.

Employee Compliance

Whether safeguards will be used properly by workers is an ongoing concern. Line management must take the lead in enforcing program requirements. Line management observes work activities on a daily basis, therefore, monitoring use of safeguards is relatively easy because machine tools are generally used in fixed locations. The simple observation process, whether formal or informal, can be an effective tool for maintaining the integrity of the program. In all cases, both line management and the SH&E professional must be vigilant in monitoring compliance and correcting situations as noticed. Failure to correct at-risk work practices will be viewed as passive permission to continue at-risk work practices.

The potential for the employee to remove, disable or override a machine safeguard is another concern. An employee may engage in such behavior for a variety of different reasons. For example, s/he may believe the safeguard slows production or makes the equipment/machinery more difficult to use. S/he may believe that production goals or pressure from line management make it necessary to override the safeguards. Perhaps, the employee may believe that such behavior is appreciated, even encouraged by supervision.

It is also possible that safeguards may be removed or left disabled by maintenance crews. Once a crew releases the equipment back to operation, the operator may run the equipment in the unsafe condition, resulting in an increased risk of injury. Operating equipment/machinery when safeguards are removed, disabled or overridden presents the same risks as operating equipment/machinery that has never been equipped with appropriate safeguards.

Preventing such behavior or work practices is a challenge—but as noted, it is a responsibility that falls to line management, not the SH&E professional. To help line management meet this duty, the SH&E professional might recommend the following:

•Establish a program of accountability associated with the proper use of safeguards.

•Use fixed guards where possible.

•Install interlocks between safeguards and equipment/machinery where practical.

•Install audible sensors that "sound off" when equipment/machinery is operated without safeguards in place.

•Hold the shift supervisor or maintenance supervisor (or both) accountable for inspecting each completed maintenance job order prior to releasing equipment/machinery back to operation.

Assessing an Existing Program

Because situations change over time, and new equipment and machine tools may be added, it is a good practice to periodically assess a facility's safeguarding program. Biennial assessments are probably adequate, with partial assessments completed at more frequent intervals based on changes in the operation. The SH&E professional should work with line management to establish the optimum frequency for these evaluations. Training provided to line managers should include instructions on monitoring their areas for installation of new machine tools and equipment—and additional controls that may be needed.

Program assessments should be documented. Figure 1 provides a sample safeguarding checklist and Figure 2 illustrates a sample assessment form specific to assessing machinery maintenance and repair activities. Both forms can be customized to meet site-specific operations. Deficiencies identified should be documented and corrective action(s) assigned to the responsible individual. Follow-up activites should be performed to verify timely correction of these conditions. Formal assessments may be supplemented by periodic meetings with line managers to refresh them on safeguarding requirements. This is another opportunity to learn about any new machine tools or equipment that have been or will be purchased.

A quick review (annually) of the OSHA injury log will help the SH&E professional determine whether the machine safeguarding program is effective. Injuries indicate a problem—perhaps a safeguard was missing, was not operating as designed or was removed by the operator or maintenance crew. In such cases, line management either failed to detect the hazardous condition or failed to act on what was reported or observed. Assessing appropriate injury reports also helps the SH&E professional identify program weaknesses that need renewed attention.

Investigating Incidents

As noted, machine/equipment operators are exposed to various hazards each time they energize the equipment. Incident investigation is an important component of understanding the injury problem, identifying causes and making meaningful changes to promote incident prevention. Simply citing human failure as the root cause of incidents is shortsighted. Thorough investigations seek to identify the true root causes—which is often related to management systems. As Petersen notes, "an accident is an indication of something wrong with the management system" (15). While a worker may have suffered an injury while operating a machine tool after the guard had been removed, that injury likely did not occur the first time the guard was removed. It is also unlikely that the supervisor had never seen an individual operating the equipment in this manner. Something in the organization's culture allowed (or perhaps encouraged) the operation of that machine tool in the stated condition.

Petersen's point is simple: Although the worker was at fault for having operated the tool in this condition (perhaps even removed the guard), it is the management system that allows the condition to exist. Therefore, the SH&E professional must identify and address weaknesses within the management system. An investigation report that cites the unsafe act as operating the machine tool without the proper guard in place and the unsafe condition as the missing guard merely identifies symptoms, not why these conditions were allowed to exist. Safety will only improve when true root causes are identified and addressed.

Conclusion

Hazards associated with machine tools and equipment exist in nearly every industry. The SH&E professional tasked with developing a safeguarding program should consider the following key steps:

•Systematically assess all machine-involved operations using both passive and active techniques to identify the hazards and controls associated with machine use.

•Develop a convincing presentation to propose a safeguarding program to company management.

•Create the written program using input from line management and workers.

•Articulate the key roles and responsibilities for workers, first line supervisors, management and the SH&E professional.

•Implement an operator qualification program to control who operates machines and equipment.

•Develop and implement a machine tool and equipment safeguarding training module.

•Help line management to periodically assess the safeguarding program.

An effective safeguarding program will prevent injuries, improve production and employee morale, and favorably impact the bottom line. Therefore, this is an area worthy of the SH&E professional's attention—and a subject worthy of continuous vigilance from all stakeholders. ■

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www.gov.mb.ca/labour/safety/publication/guidelines/machine/guard.html. Canadian site provides general information about machine guarding.

www.labsafety.com/refinfo/ezfacts/ezf169.htm. Offers a summary of OSHA machine guarding requirements.

www.osha.gov. OSHA's site offers access to machine-guarding-related federal OSHA standards, letters of interpretation and other useful information (www.osha-slc.gov/SLTC/machineguarding/index.html) as well as the agency's machine guarding checklist (www.osha-slc.gov/Publications/Mach_SafeGuard/checklist.html).

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