Machine Safety
New & Updated Consensus Standards

By James R. Harris and Richard S. Current

According to Bureau of Labor Statistics (BLS, 2010b) data, machines were the primary or secondary source of 604 work-related fatalities in 2008. That same year, machinery was the source of 64,170 cases involving days away from work (BLS, 2010b). More than 25% of all machinery-related injuries that involved days away from work resulted in more than 31 days away from work (BLS, 2010a). OSHA (2010) has estimated the total cost of an amputation injury (indirect costs plus direct costs) to be $101,467. Clearly, machine-related injuries take a heavy toll on employers and employees.

The ANSI B11 Accredited Standards Committee for Machine Safety Standards oversees more than 30 standards and technical reports. The standards are organized in an A-B-C manner. Type-A standards are known as *basis standards* and identify basic concepts, principles for design and general aspects that are applicable to machinery in general. Type-B standards are known as *generic safety standards*; they deal with safety aspects or safeguards that are applicable to many machine types. Type-C standards are known as *machinery-specific safety standards* and contain guidelines that are germane to certain specific machine types.

IN BRIEF
- **SH&E professionals should be aware of recent changes to the ANSI B11.0 and B11.19 standards, and should be aware of select international standards and their differences from B11 standards.**
- **ANSI B11.0 was created to include elements of general machine safety and risk assessment information formerly found in a technical report. The standard includes guidelines for the risk assessment process as well as sample risk assessment matrices and references.**
- **ANSI B11.19 covers machine guarding performance requirements. Topics which have been added or updated to this standard include: protective safety stops; emergency stops; perimeter guarding; muting; bypass; hold-to-run control; guard interlocking switches; and presence-sensing device initiation.**

Specific equipment covered by C-level standards such as ANSI B11.1, Safety Requirements for Mechanical Power Presses, or ANSI B11.3, Machine Tools: Safety Requirements for Power Press Brakes, should be guarded according to those specific standards. If the machines are interfaced with another machine or process, then ANSI B11.20, Safety Requirements for Integrated Manufacturing Systems, would be appropriate, as would be using B11.0/B11.19. C-level standards can have machine-specific exceptions to the rules in B11.19, but generally they should follow the rules of B11.19.

This article concentrates on aspects of ANSI B11.0 and ANSI B11.19 that concern risk assessment and machine guarding. In addition, applicable sections of select international standards, as they relate to ANSI B11.0 and B11.19, also are briefly discussed.

Responsibilities in the B11 Series of Standards

The B11 series defines responsibilities broadly in terms of suppliers and users. Which category an entity fits into is determined by the actions it performs. In general, a supplier provides equipment or services; based on this definition, groups other than manufacturers could be called suppliers. Entities that build, modify and/or integrate would be considered suppliers while performing such work. A user utilizes a machine, machine production system or related equipment.

ANSI B11.0

General Overview

ANSI B11.0 was last updated and approved in December 2010. As an A-level (basis) standard, it provides basic guidelines applicable to many types of machines. The standard's scope limits application to "new, modified or rebuilt power driven machines, not portable by hand, used to shape and/or form metal or other materials by cutting, impact, pressure, electrical or other processing techniques, or a combination of these processes" (ANSI, 2010c). Additionally, requirements for risk assess-

James R. Harris, Ph.D., P.E., is a research safety engineer at NIOSH, in the Protective Technology Branch of the Division of Safety Research. Since 1993, he has conducted research to prevent acute traumatic workplace injury in the agriculture and manufacturing sectors. He holds a B.S. and M.S. in Mechanical Engineering, as well as a Ph.D. in Occupational Safety and Health, all from West Virginia University. Since 2006, Harris has been a member of the ANSI B11 Accredited Standards Committee on Safety Standards for Machines. He is an executive committee member of the American Society of Mechanical Engineers' Safety Engineering and Risk Analysis Division and is a professional member of ASSE's Northern West Virginia Chapter.

Richard S. Current, P.E., is a research safety engineer at NIOSH, working in the Protective Technology Branch of the Division of Safety Research. Before this, he worked for U.S. Department of Energy. At NIOSH, he has researched occupant crash protection of ambulance workers, fall protection and agricultural tractor rollovers, as well as machine safety in the manufacturing sector. He has been a member of the ANSI B11 Accredited Standards Committee since 2005. Current is a member of ASSE's Northern West Virginia Chapter and Society of Automotive Engineers.

ment, previously contained in ANSI B11.TR3, are now contained in B11.0.

Although many B11 standards address engineering controls in the injury prevention hierarchy, ANSI B11.0 also attempts to address some higher-level injury prevention techniques such as elimination and substitution. A term that is gaining recognition within the SH&E community is prevention through design (PTD) (ASSE, 2011). Terms such as *elimination by design*, *design out* and *substitution* have equivalent meanings and are discussed in B11.0.

B11.0-2010 contains nine clauses (or sections) and 11 annexes. The first four clauses have a similar format throughout the B11 series; in order, these clauses deal with the scope, normative references, definitions and responsibilities. In clauses 6 through 9, B11.0 addresses risk assessment, risk reduction, information for maintenance/use and training. Of the standard's 85 pages, the annexes account for more than 30 pages. These components are essential to practical application of the standard. They provide sample lists of machinery hazards, additional guidance on risk assessment and other informative references.

Key Points/New Features

Responsibilities

The functional distinction between suppliers and users is explained in general terms as follows. A supplier is typically responsible for machine design and construction, as well as for providing information on machine operation and maintenance. The user is responsible for the machine operation and maintenance.

A key concept in the delegation of these responsibilities is that suppliers and users should collaborate on safety and risk reduction as early in the process—and for as long as—is practicable. Readers should note that B- and C-level B11 standards also may apply to this process. If specific C-level standards exist, they generally take precedence over A- or B-level standards. If a machine is modified during its life cycle, the risk assessment/risk reduction process must be repeated; if practical, those involved should seek the original supplier's input.

Risk Assessment

The risk assessment team must be comprised of qualified personnel. The standard calls for individuals of "technical competence" and "relevant skill set." Operators, maintenance or engineering personnel may have the most to offer in this process. Figure 1 (p. 52) shows the process flow for conducting a risk assessment. (The numbers in parentheses indicate relevant clauses from the B11.0 standard.)

Key ideas in the risk assessment process involve the terms *residual risk* and *acceptable risk*. The standard defines residual risk as "the risk remaining after risk reduction measures (protective measures) are taken" while acceptable risk is defined as "a risk level achieved after risk reduction measures have been applied. It is a risk level that is accepted for a given task (hazardous situation) or hazard." ANSI B11.0 treats acceptable risk as synonymous with *tolerable risk*. The risk assessment process is continued until the residual risk is deemed acceptable.

As the risk assessment team identifies tasks and hazards, it is guided to include all reasonably foreseeable hazards regardless of the existence of risk reduction measures. For example, the team must consider whether guards supplied with a machine are sufficient for hazards or whether supplemental protection is necessary. The team also must consider reasonably foreseeable misuse of equipment and protective measures, as well as machine malfunction.

When identifying tasks for risk assessment, the team should consider scenarios in addition to machine operation. Situations noted in B11.0 include packing and transportation; unloading/unpacking; systems installation and assembly; start-up/commissioning; setup/changeover; operation (all modes); maintenance; shutdown; lockout/tagout; recovery from jams; troubleshooting; cleaning; and decommissioning, dismantling and disposal. The standard also suggests several hazard categories and advises that all reasonably foreseeable hazards be included. Categories mentioned include mechanical hazards; energy sources; unexpected starts; slips and falls; hot surfaces; combustible atmospheres or media; sharp edges; and operational hazards.

Assessing initial risk is step 3 in the risk assessment process (Figure 1, p. 52). Risk is defined as a function of severity of harm and probability of occurrence of that harm; in some instances, an additional factor of frequency of exposure will be applied (Brauer, 2006). This frequency takes into account the fact that an individual may not always be exposed to the risk under consideration. For example, the hazard may involve a maintenance procedure required only once per year. If frequency of exposure is considered, such a task would have a different risk than a maintenance procedure required each day, even if the probability of occurrence of harm is the same.

Following is a simple example of a two-factor qualitative risk scoring system from ANSI B11.0. Using this system, a severity of harm that is moderate, coupled with a very likely probability of occurrence of harm, would be considered high risk. In this sample system, risk has been divided into the categories of high, medium, low and negligible risk. For this example, assigning severity and probability categories can be aided by these sample definitions:

Severity

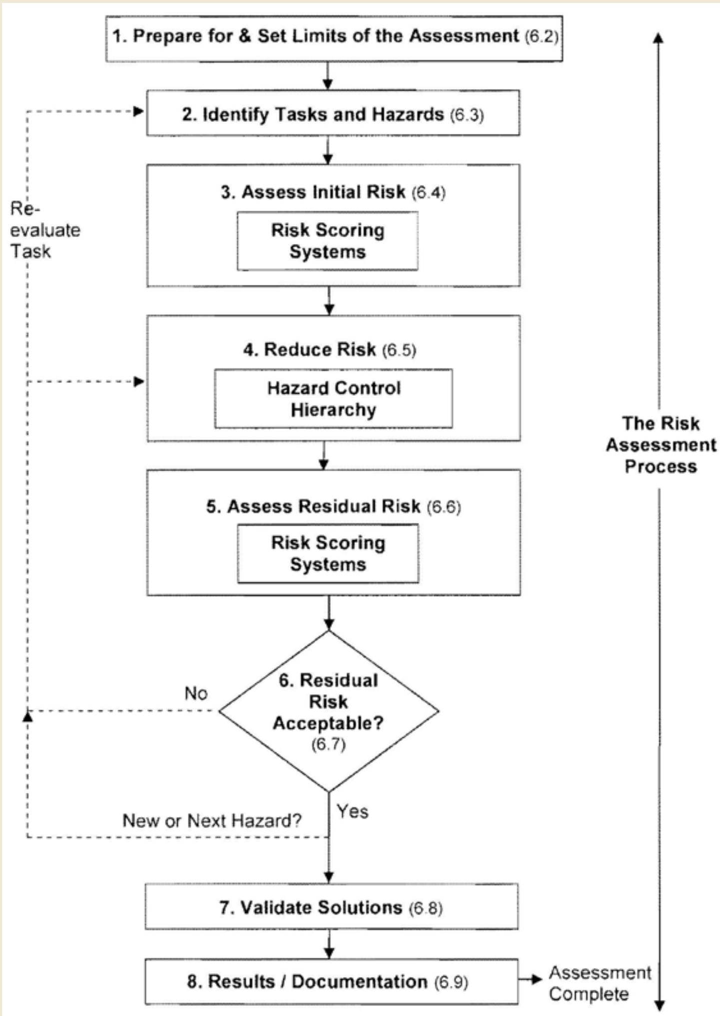
- Catastrophic: death or permanently disabling injury or illness (unable to return to work);
- Serious: severe debilitating injury or illness (can return to work at some point);
- Moderate: significant injury or illness requiring more than first aid (able to return to same job);
- Minor: no injury or slight injury requiring no more than first aid (little or no lost work time).

Probability

- Very likely: near certain to occur;
- Likely: may occur;

Figure 1

The Risk Assessment Process



Note. *From* Safety of Machinery—General Requirements and Risk Assessment (ANSI B11.0-2010)*, by ANSI, 2010, Leesburg, VA: Association for Manufacturing Technology. Reprinted with permission.*

This is a model process flow for conducting a risk assessment. The numbers in parentheses indicate relevant clauses from the B11.0 standard.

•Unlikely: not likely to occur;

•Remote: so unlikely as to be near zero.

If the residual risk calculated during risk assessment is greater than the acceptable risk, that risk must be reduced based on the hazard control hierarchy. B11.0 lists risk reduction measures from most preferred to least preferred: elimination or substitution (most preferred); guards and safeguarding devices; awareness devices; training and procedures; and PPE (least preferred). Once risk reduction measures are in place, the risk assessment is repeated until residual risk reaches acceptable risk.

After risk has been reduced to an acceptable level, risk reduction measures must be verified. Those involved must ensure that such testing does not expose an individual to potential harm if the measures fail. Use of programmable electronic safety control systems warrants special attention (see ANSI B11.TR6).

To complete the risk assessment process, B11.0 requires the following documentation:

•machinery assessed (e.g,. specifications, limits, intended use);

•relevant assumptions made (e.g., loads, strengths, safety [design] factors);

•information on which the assessment was based;

•names of risk assessment team members;

•date(s) of the risk assessment;

•tasks and hazards identified;

•initial risks associated with the machinery;

•risk reduction measures implemented to eliminate identified hazards or to reduce risk (e.g., based standards or other specifications);

•residual risks associated with the machinery;

•validation of risk reduction measures, including information on the responsible individual and the date of validation.

Annex H of the standard provides an example of documentation needed.

Changes From Previous Version

In 2009, the B11 ASC initiated the revision of ANSI B11-2008, which encompassed combining ANSI B11.TR3 into the standard. The result was B11.0-2010, which was approved by ANSI on Dec. 2, 2010.

Applicable International Standards

ISO 12100-2010, Safety of Machinery: General Principles for Design—Risk Assessment and Risk Reduction, replaced ISO 12100-1:2003, ISO 12100-2:2003 and ISO 14121-1:2007 (ISO, 2010a). Like ANSI B11.0, ISO 12100 is an A-level standard. It is organized into seven clauses and three annexes. The first three clauses address scope, normative references, and terms and definitions. Clause 4 addresses risk assessment and reduction strategy. Clauses 5 and 6 discuss risk assessment and risk reduction. Clause 7 describes documentation for the activities of clauses 5 and 6.

One major difference between ISO 12100 and ANSI B11.0 is the explicit assignment of responsibilities within clause 4 of ANSI B11.0. Duties are typically delegated within the ANSI standard to the general categories of supplier and user. Within ISO 12100, another standard is referenced (ISO/TR 14121-2, an example document for 14121 that was not included in the new compilation document, ISO 12100); it provides specific methods for systematic hazard identification.

During risk estimation, ISO 12100 specifically cautions about the possibility of defeating or circumventing protective measures in four situations:

1) The protective measure slows down production or interferes with another activity or preference of the user.

2) The protective measure is difficult to use.

3) Persons other than the operator are involved.

4) The protective measure is not recognized by the user or not accepted as being suitable for its function.

During the iterative process of risk estimation, risk evaluation and risk reduction, those involved must take care to not introduce unaccounted-for risk through new protective measures. ISO 12100 does not use the term *acceptable risk*; instead, it mentions *adequate risk reduction*. In this standard, risk reduction is organized in the context of a three-step method: 1) inherently safe design methods; 2) safeguarding and/or complementary measures; and 3) information for use. Like ANSI B11.0, this standard's annexes provide more detailed guidance on hazard identification for the risk assessment.

ANSI B11.19

General Overview

ANSI B11.19-2010 is designed to be used with ANSI B11.0 as well as machine-specific C-level standards. This is the third revision of the standard, and it establishes "requirements for the design, construction, installation, operation and maintenance of the safeguarding, complementary equipment and measures, and safe work procedures" for risk mitigation associated with machines (ANSI, 2010a). As noted, clauses 1 through 4 are uniform across the B11 family of standards. In B11.19, clauses 5 and 6 address hazard control and general safeguarding requirements, respectively. Clauses 7 through 10 discuss these safeguarding topics: guards, safeguarding devices, awareness devices and safeguarding methods. The standard also has performance requirements for safe work procedures, complementary equipment and measures. The final two clauses contain information on inspection and maintenance of safeguarding and training on the use of safeguarding.

Key Points/New Features

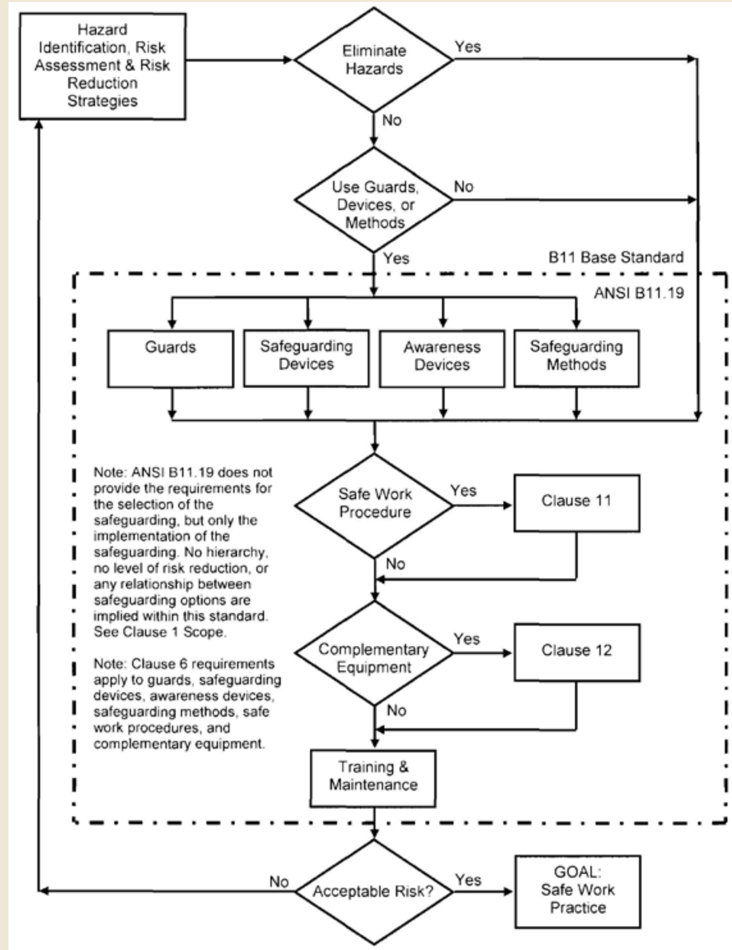
Topics added or changed in B11.19 include: protective safety stops, emergency stops, perimeter guarding, muting, bypass, hold-to-run control, guard interlocking switches and presence-sensing device initiation (PSDI). Requirements for transparent guarding (viewing windows) have been added as well. Also, the requirements of ASME B15.1, Mechanical Power Transmission Apparatus, have been absorbed into B11.0 and B11.19 with additions of safe-distance guarding and safe-location guarding. Where possible/practical, the standards were harmonized with ISO 13857 and other ISO standards. This revision contains approximately 60 new pages.

Responsibility

Under B11.19, the safeguarding supplier (which may be the user if the user acts as a supplier) must meet the design, construction, integration and installation requirements in addition to providing installation, operation and maintenance instructions, and maintenance requirements. The user (usually the employer) is responsible for ensuring that the safeguarding has been provided, integrated, installed, maintained and used properly. If the equipment is ordered without safeguarding, the user is responsible for determining appropriate safeguarding or providing it. If the user designs, constructs, installs or modifies the safeguarding, the user becomes the supplier. The user is responsible for ensuring that the safeguarding remains effective and proper if process or tooling changes are made. The user also must properly train all associated personnel within the scope of their work activity. Finally, personnel must follow training and operating procedures set forth by the user.

Figure 2

Safeguarding Flowchart



Note. *From* Performance Criteria for Safeguarding (ANSI B11.19-2010), *by ANSI, 2010, Leesburg, VA: Association for Manufacturing Technology. Reprinted with permission.*

As Figure 2 shows, B11.19 recommends a process flow of hazard identification, risk assessment and risk reduction strategies (covered in B11.0). If hazards cannot be eliminated, then guards, safeguarding devices, awareness devices or safeguarding methods should be used. If these four options will not work, safe work procedures, complementary equipment, or training and maintenance should be used (in that order). With safeguarding in place, residual risk must be assessed to ensure that it is below acceptable risk. In this assessment, the team must make sure that no new risks are introduced. Let's now focus on each safeguarding approach.

General Safeguarding Requirements

Basic to safeguarding is the concept that if an unsafe act or presence is detected the machine must be stopped prior to contact. Protective safety stops are physical or virtual within a controller, and are initiated by the actuation of a safeguarding device. These are used to stop a machine in a safe and determined manner when, for example, an operator crosses through a light curtain and into a hazard zone. Because there are requirements specific

Risk Assessment Scoring Systems

ANSI B11.0 and B11.19 do not prescribe a specific scoring system to use in the risk assessment process. The standard does, however, lead the reader through a minimum recommended scope of hazard assessment, and recommendations about the process without prescribing specific scoring. This can be helpful but also can create difficulties. Legacy assessment systems exist: in other standards, both North American and ISO; in corporate procedures; and in assessments done by outside consultants who have their own systems. For the experienced, or those who have to work with legacy systems, it is helpful in that it allows freedom to integrate with other risk assessment processes. For the less experienced, at first it seems the rigid step-by-step system, for which users were hoping, is missing. However, B11.0 recommends a few sources for those without a prescribed legacy or corporate system.

B11.0 recommends the use of scoring systems from RIA 15.06, MIL-STD 882D or from ISO standards. It is believed that the process of assessment is more important than the scoring method in properly applying guarding. One concern, however, is that the selected system or combination thereof should not allow an infrequent event with high probability of injury when it is performed to be poorly guarded due to a low overall risk rating. For example, a maintenance task performed once per year or less in which for the few minutes a technician is performing the task a high likelihood exists of severe injury or death should never be rated at a low risk.

One example is MIL-STD 882D which is a freely downloadable government document (**www.assistdocs.com** or **www.system-safety.org**). MIL-STD 882D uses a two-factor approach with risk comparable to the result of probability and severity (see below). The standard has four levels of risk—high, serious, medium and low. Four levels of granularity should be enough to lead the user to differing safety solutions without over-stratification that would be confusing as to how to mitigate the concerns.

	Severity			
Probability	*Catastrophic*	*Critical*	*Marginal*	*Negligible*
Frequent	High	High	Serious	Medium
Probable	High	High	Serious	Medium
Occasional	High	Serious	Medium	Low
Remote	Serious	Medium	Medium	Low
Improbable	Medium	Medium	Medium	Low

The other example is RIA 15.06 (Robotic Industries Association), a good method for many situations and especially applicable in situations where integration with robotic systems is applicable. This system has three factors: severity of injury, exposure and avoidance. A key difference here is that the previous concept of probability is replaced with exposure and avoidance. Some systems might use likelihood (the inverse of avoidance), which might seem more mathematical and more difficult than asking if something can be avoided. Avoidance might also be more natural to the specific situation of robotic motion.

The figures below illustrates how to apply RIA 15.06. For example, the hazard being rated would be determined to have a severity of injury of S2 serious injury in the first column. In the second column (exposure) with choices of frequent and infrequent, it is determined to be E1 infrequent. Then between A1 and A2 in the third column (avoidance) a decision of A1 likely is made resulting in a risk reduction category in the last column of R2B. Looking at the third column of risk reduction and safeguarding matrix, engineering controls are recommended under RIA 15.06. For a machine under B11, this might be interlocked guards or other controls of generally high protective nature. The specific circumstances of the hazard will still determine the best hazard mitigation strategy.

Severity of injury	Exposure	Avoidance	Risk reduction category
S2 Serious injury (more than first aid)	E2 Frequent exposure	A2 Not likely	R1
		A1 Likely	R2A
	E1 Infrequent exposure	A2 Not likely	R2B
		A1 Likely	R2B
S1 Slight injury (first aid)	E2 Frequent exposure	A2 Not likely	R2C
		A1 Likely	R3A
	E1 Infrequent exposure	A2 Not likely	R3B
		A1 Likely	R4

Risk reduction index	Safeguard selection
R1	Hazard elimination
R2A	Engineering controls
R2B	
R2C	
R3A	Non-interlocked barriers, clearance, procedures and equipment
R3B	
R4	Awareness means

to their interface with the machine and operation, these stops are included in this version of B11.19.

Safeguarding can protect an area, point of operation or perimeter. Perimeter guarding is any guarding that encloses an area and only detects on the perimeter. Once a person has passed through the perimeter, the guarding does not know where the individual is, and multiple safety hazards may exist in the area. B11.19 contains guidance on the specific safety implications of perimeter guarding.

An important concept in evaluating the hazard mitigation strategy is the performance or reliability of the safety-related function. A component or system failure will prohibit the safety-related function when a stop command is issued. To prevent this scenario, the safety-related function must do the following until the failure is corrected or the control system is manually reset: prevent initiation of hazardous machine motion; initiate an immediate stop command and prevent reinitiation of hazardous machine motion; or prevent reinitiation of hazardous machine motion at the next normal stop command. The standard also requires that when the user recognizes the failure of the safety-related function, repetitive manual reset must not be used to circumvent the state.

While safeguarding must operate reliably, at times it must be manually or automatically suspended to enhance usability or allow for a specific operation; risk present in this altered mode must also be assessed. Bypass means to temporarily render any part of the safety function unusable or ineffective. Muting is a temporary automatic suspension of a safety function. For example, muting would allow a workpiece or worker to pass through the safeguarding at specified times. The standard provides requirements to help ensure safety during use and guidance for restart. While muting and bypass are certainly not new ideas, their inclusion in B11.19 will help SH&E professionals to appropriately consider risk of these modes.

Safety Distance Calculations

Often, safeguarding is presence sensing or location based in nature. Many safeguards are subject to a safety distance calculation, which determines the minimum distance that a safeguard must be installed from the hazard so that it is difficult for the operator to reach the point of operation or hazard zone. These calculations are used for safeguards such as palm buttons, single-start controls, light curtains and pressure mats.

The calculation is based on these factors: individual approach speed; safeguarding device response time; interface response time; hazardous motion braking time of the machine; and the device's depth of penetration factor. B11.19 recommends 63 in./s (as used in OSHA) or greater, in addition to having information on depth of penetration, which is the extra distance a body part will penetrate into a safeguarding device before activating it.

Guards

Guards, sometimes referred to as barrier guards, are defined in B11.19 as "barrier that prevents exposure to a hazard." They are classified as fixed, adjustable or interlocked, and are generally considered a highly reliable choice for risk reduction, which is why they are located high in the structure of Figure 2 (p. 53).

With respect to performance and application of transparent guarding or viewing windows, all guards (whether transparent or opaque) have certain performance criteria. For example, the guard construction material must be of sufficient strength to protect individuals from the hazards. Because guard material, plastic or metal, may deteriorate over time (especially with environmental considerations such as cutting fluid), suppliers shall provide a replacement schedule for guards or other guidance to determine when replacement is needed.

Additionally, the assessment team must consider the risk of individuals reaching over, around or through the guard to access the hazard. Guard openings and gaps should follow Figure D.9 in B11.19. In 2003, B11.19 was revised with modified gap opening requirements; these data are more conservative than OSHA requirements except for between the distance of 6.5 to 7.5 in., where the ANSI standard's allowable gap is greater than the OSHA value.

Guards that can be removed (such as access doors and panels) may be required to be interlocked to shut down circuits or secured with difficult-to-remove fasteners. Requirements for guard interlocking switches are new to B11.19, and the standard provides guidance for their design and operational use.

Safeguarding Devices

According to B11.19, a safeguarding device "detects or prevents inadvertent access to a hazard." The ISO 12100 "protective device" category is broader than the B11.19 "safeguarding device" category. The ISO category would include items considered "complementary equipment" in B11.19.

Within B11.19, safeguarding devices are divided into the following groups:

- movable barrier devices;
- pull back (pull out) and restraint devices;
- presence-sensing safeguarding devices (electro-optical, RF, area scanning);
- two-hand operating lever, trip and control devices;
- safety mat devices;
- safety edge devices;
- probe detection devices;
- single-control safeguarding devices;
- close proximity point of operation active optoelectronic protective devices (apply to press brakes).

Movable barrier devices can be classified as type A or type B. The primary difference concerns when the barrier is open. Type A devices are designed to prevent access to the hazard zone prior to the hazardous portion of the machine cycle, and they remain closed until motion is stopped and the machine is at the initial starting position. Type B devices prevent access to the hazard zone only during hazardous portion of machine motion.

Pull-back and restraint devices are designed to keep the operator's hands away from the hazard zone during the hazardous portion of the machine cycle. Special consideration is required for more than one operator to ensure adequate protection.

Presence-sensing devices create a field to detect an operator's presence. Use of these devices requires attention to minimum object sensitivity of the device as well as safety distance from the hazard zone. B11.19 provides guidance on the effective sensing field size (height, width, depth) so an individual can be detected entering the hazard zone.

Two-hand safeguarding devices are configured so that each hand is required to actuate a device in a nearly simultaneous manner (within 500 milliseconds) for continued operation of the machine during hazardous motion. If either hand is released during the hazardous portion of the machine cycle, an immediate stop command must be initiated. Location of these devices involves calculation of an appropriate safety distance (detailed in Annex D of B11.19) so that the operator cannot reach the hazard zone before hazardous motion ceases. Individual hand controls are required for each operator if there is more than one operator, and they are to be safeguarded by using two-hand trip or control devices.

Safety mats detect the presence of individuals on the sensing surface and initiate an immediate stop command to prevent hazardous operation of the machine. Individuals must not be able to access the hazard zone by reaching over, under or around the mat's sensing surface. The mat must not be used as an enabling device for initiation or continuation of hazardous motion.

A safety edge device detects an individual's presence through force or pressure applied along its sensing surface. The device must have a sufficient sensing surface so that an individual's exposure to the hazard is detected.

A probe detection device is designed to prevent initiation or stop the machine cycle if an individual's hand or finger is in the hazard zone.

A single-control safeguarding device requires only single actuation to initiate machine motion. Such a device must be located at a safe distance to ensure that the operator cannot reach the hazard zone during hazardous machine motion. Controls that can easily be moved closer than the safe distance to the hazard do not meet the requirements of a single-control safeguarding device.

Awareness Devices

Awareness barriers, signals and signs can all be considered awareness devices. Awareness barriers must be designed so that individuals cannot reach into the hazard zone without conscious effort and/or contact with the barriers. Awareness signals must generate a noticeable (distinctive by sound or intensity) audible or visual signal to warn of an approaching or present hazard. Awareness (safety) signs must meet consensus standard requirements of ANSI Z535.1, Z535.3, Z535.4 and Z535.5.

Safeguarding Methods

Safeguarding methods fit one of four categories: safe-distance safeguarding; safe-holding safeguarding; safe-opening safeguarding; and safe-location safeguarding. The use of these methods requires specific training and supervision.

Safe-distance safeguarding must include a safety program that details work procedures, training and retraining, and supervision. Material position gages of sufficient height and size/shape must be used to prevent slipping of the material beyond the gages. The gages also should prevent the operator from unintentionally getting closer to the hazard than the safe distance; the safe distance is determined based on the job and visually identified at the machine.

Safe-holding safeguarding requires that a worker's hands be away from the hazardous zone during the hazardous portion of the machine cycle; both hands must be used to hold or support the workpiece or one hand must hold or support the workpiece while the other hand operates the machine.

Safe-opening safeguarding utilizes the workpiece itself as part of the safeguard to ensure that openings are small enough to prevent the operator from accessing the hazard zone. The machine must be prevented from hazardous motion when the workpiece is not in place and the hazard zone can be accessed.

Safe-location safeguarding includes ANSI B15.1 safety distance and ANSI B15.1 safe location requirements. Access to the hazard zone from a walking or working surface must be prevented through vertical distance of sufficient height, horizontal distance, or a combination of vertical and horizontal distance. Safe-location safeguarding also can limit access to a hazard by placing the hazard in an enclosure (e.g., room, vault); behind permanent, substantial partitions/fencing/railing or screens that meet other B11.19 requirements; or on an elevated platform where incidental contact is not possible.

Safe Work Procedures

According to ANSI B11.19, safe work procedures may be needed (perhaps in addition to other protective measures) where:

- tasks are complex;
- tasks have high risk;
- training, skill or work experience is limited;
- other safeguarding is removed or bypassed;
- required to augment other safeguarding.

Complementary Equipment & Measures

ANSI B11.19 defines *complementary equipment* as "devices or methods used to ensure or augment the proper operation of safeguarding." These devices include safety blocks, chain locks, locking pins, limiting/blocking pins; slide locks; workholding equipment; stopping performance monitor; process malfunction, detection and monitoring equipment; hand tools; safety interface relay modules; shields; emergency stop devices; enabling devices; hold-to-run controls; and zero-speed monitoring devices.

Safety blocks, chain locks, locking pins, limiting/blocking pins and slide locks are a class of devices designed to hold the static load of a machine and prevent hazardous motion. They must hold the full load at actuation or be interlocked. Machine-specific standards such as B11.1 (mechanical power presses) and B11.2 (hydraulic power presses) may contain guidance other than that found in B11.19.

Workholding equipment such as clamps, jigs, fixtures and back gages should not create new hazards such as restricted visibility or the need to enter the hazard zone. They may reduce the possibility of part ejection.

A stopping performance monitor assesses the performance of the stopping function. It will prevent process initiation if the stopping time is found to be less than the required time to maintain the safety distance as determined by a risk assessment.

Process malfunction, detection and monitoring equipment is used to detect hazardous situations such as part ejection, misfeed, transfer, overload or similar problems. Such systems are not directly a guard, but they monitor hazards and usually shut down the machine accordingly. Hand tools are not guarding, but they should be of sufficient size and shape as to keep hands out of the hazard zone. Materials should not shatter, and the tool itself should not create a hazard.

Safety interface relay modules are a part of the safety system and should meet the requirements of clause 6.1 (Performance of the Safety-Related Function), as well as the proper safety level as required by the risk assessment.

Shields appear in different work processes. When shields are used as safeguarding, they must meet the requirements of clause 7 (Guards). Shields may need to block particle ejections or part ejections, or stop hands from entering the area like a guard does.

Emergency stop devices are not safeguarding devices because they require action by someone usually after a hazardous event has occurred. They do not prevent access or exposure. However, emergency stop devices can limit exposure. Possible design references are ISO 60204-1, ISO 13850 and IEC 60947-5-5. Examples include push buttons; and rope-pull, cable-pull, foot-operated, rod-operated and push-bar-operated devices. They must remove all power to the entire machine and must be sustained until a full reset. The device should not interfere with the safe operation of other safeguarding.

Enabling devices and hold-to-run controls ensure that an operator is paying attention or that multiple operators have given consent to machine operation and are located away from the hazard zone. Enabling devices are configured in a three-position format (off-run-off), with run in the center. Hold-to-run controls require the operator(s) to physically hold the button(s) in place to operate the machine. They operate much like a voting button for multiple operators to ensure that all are ready and in the proper location. Zero-speed monitoring devices detect that motion has completely stopped in a dynamic process. These might be used to interlock a door or a guard. Again, these devices must meet the appropriate safety performance level as determined by a risk assessment.

Training, Inspection & Maintenance

Users must document safeguarding and provide maintenance instructions, recommendations and procedures to maintenance personnel. This material can be found in manufacturer recommendations, in the standard and in the requirements identified in the risk assessment. The safeguarding must perform as intended.

Procedures are written and do not become actions unless the personnel executing them are trained to do so. Also, personnel must be trained how to use the safeguarding and to recognize hazards. Training can increase safety by informing workers of hazardous processes and the consequences of improper actions. Training is required for safety and maintenance operations as well.

Changes From the Previous Version

PSDI has been added to B11.19 and is also covered in B11.0. Both standards provide recommendations for utilizing PSDI on many devices. PSDI is a mechanism of using a presence-sensing device (e.g., light curtain) as a safeguard and as a process initiation device. Because the device allows someone to penetrate the hazard zone with the machine in a ready state and actuate after s/he withdraws, a poorly designed system could easily injure a worker. In addition, ANSI B15.1, Safety Standard for Mechanical Power Transmission Apparatus, was a base standard used in the power transmission applications in many industries. This standard has been discontinued, and the information has been incorporated into B11.0 and B11.19.

Applicable International Standards

Many supporting and international standards address safeguarding. Although only a few machine-specific international standards exist, ISO is developing more. Implementation of international standards in the U.S. can be problematic because of possible references to European Union regulations or testing certifications not available in the U.S. However, B11.19 effectively refers readers to complementary ISO standards. Annex I includes a table of 76 safeguarding devices and their applicable ANSI and international references. B11.19 also makes reference to ISO standards in the explanatory information throughout as informative references, but not as normative (mandatory) reference.

Conclusion

As the BLS data cited earlier indicate, machine-related injuries take a heavy toll on employers and employees. By understanding machine safeguarding as outlined in federal, consensus and international standards, SH&E professionals can help better protect workers from these risks. **PS**

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