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Practical Approach to Risk Assessment and Risk Reduction

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Introduction

Risk assessment and risk reduction may seem like foreign terms to many in the field of industrial safety. While many environmental, health, and safety (EHS) professionals are charged with the responsibility of providing a safe work environment for the employees of their organization, machine safeguarding becomes just one of the many topics of human safety which must be addressed.

The Occupational Safety and Health Administration (OSHA) created the first guidelines for employers in 1971 with the passing of the Occupational Safety and Health Act. These guidelines, which were revolutionary for their time, have since fallen by the way side with the introduction of new manufacturing technologies, best practices, and a changing work force since their initial publication. These standards, particularly those in §1910 Subpart O (Machinery and Machine Guarding), have now become the bare minimum requirements enforceable by law.

Consensus standards, including those presented by the American National Standards Institute (ANSI), draw on the expertise and experience of individuals with a direct interest in the topic covered by each publication. Although these standards are intended for voluntary use, they may be applied as mandatory requirements in commerce and industry. Furthermore, these standards are reaffirmed, rewritten, or withdrawn on a continual basis in order to keep up with the changes that occur in industry. These standards, therefore, reflect the time-tested and most commonly used state of the art at the time of their approval.

As these consensus standards are continually updated and as more standards are written to address emerging technologies, the job of the EHS professional becomes more challenging. In order for the safety professional to effectively cover all topics of employee safety, the individual must become acquainted with the relevant laws, applicable standards, and current best practice approaches. For someone responsible for plant-wide safety to become an expert in every field is very difficult, even impractical, to say the least. As a result, these professionals must learn to identify their needs and call on the expertise of individuals and organizations which specialize in those areas.

Once the safety authority learns to identify the needs of their organization, they must then learn how to identify qualified service providers to effectively reach the objective of a safe work environment. When it comes to machine safeguarding, the EHS professional needs to identify contractors who are experienced and well versed in the current requirements which apply to their applications. This includes a thorough understanding of the risk assessment and risk reduction process, as well as a practical approach to the implementation and the additional services necessary to support such a project.

When a safety professional is searching for a service provider capable of performing complete machine safeguarding projects, the professional must first understand the basics of risk assessment and risk reduction in order to obtain and evaluate relevant information received from such vendors. In addition, potential service providers should be able to provide an OSHA 300 Form log upon request to demonstrate their own safety record and understanding of safe work procedures. Companies unable to provide this information may have a poor internal safety program or may not follow the pertinent OSHA record keeping requirements.

As with many self improvement processes, machine safeguarding can be broken down into a twelve step process. When discussing risk assessment and risk reduction with a potential service provider, the EHS professional should try to determine if the following twelve essential steps are followed. The potential contractor should be able to exhibit a detailed understanding of each step and confidently supply the required information as requested. Many providers exist and will try to get your business; however, only a few can perform all of the fundamental steps listed here, and even fewer come with the experience and capabilities to do the job correctly.

Step 1 – Identify Machine / Process

More often than not, identifying applications which require some level of safeguarding is the easiest step for the individual responsible for safety, as these applications usually present themselves through accidents and near misses. A review of a facility's accident history will easily assist in the identification of hazardous scenarios. Additionally, common sense can also play a large role. Generically speaking, a hand fed mechanical power press usually presents a greater risk than a drill press. This is not to say that the drill press does not present risks which could be detrimental to the health and well being of individuals; rather, on a global view the power press is much more likely to have a high risk associated with it, requiring immediate attention in terms of safeguarding. Traditionally, employers have taken the approach of addressing the high risk machines first and foremost, and then following down the line towards the lower risk applications until all of the machines are at a tolerable risk level. To accommodate this, some facilities conduct risk assessments on every machine present before implementing the risk reduction portion of the plan in order to prioritize the plan of attack. Obviously, this may not be appropriate when a few machines exist where accidents or near misses continually occur.

Step 2 – Collect Proper Information

Once the machine or process has been identified for a risk assessment, the next step is to collect all of the pertinent information relating to the application. This information includes the limits of the machine, its lifecycle requirements, any information concerning energy sources, and all available design drawings, sketches, system descriptions, or other means of establishing the nature of the machine. In addition, previous accident and incident history (on the subject machine or similar type machines), information regarding damage to health, as well as details regarding existing or proposed system and building layouts are also important to the risk evaluation process. Finally, a list of the exposed people, both the affected personnel (including their level of training, experience, or ability), as well as others who could be exposed to the hazards of the machine where it can be reasonably foreseen, is useful in identifying the majority of the scenarios which could lead to an accident.

Step 3 – Gather Proper Individuals

Currently, over half of the states in the U.S. require companies to have safety committees. Obviously, this resource should be used to its fullest extent when it is available. When a formal safety committee is not present, however, it is best to gather input from all individuals who have a vested interest in the safeguarding process. In order to obtain the input of everyone involved, it is best to compile a team of individuals who would normally form a safety committee. Completing this step of the process alone can help companies move in the right direction toward forming a safety committee. The EHS professional will most likely always be involved, and sometimes this person also acts as the team leader.

Obtaining feedback from the operators and maintenance personnel is essential for two reasons. First, these individuals work on and around the machine on a daily basis, which means they are most likely to be the individuals able to identify hazards otherwise hidden to people less involved in the day to day operation of the machine. Secondly, it is important to gain buy in from these individuals. If a safeguarding system is installed and the people who have to work with it are not pleased and their concerns are not heard at the planning stage, it is possible that the safeguarding system will not meet their needs or may prevent them from conducting specific required tasks. Therefore, their input at the earliest stages is important to reduce the likelihood of implementing a safety measure which must be bypassed to continue production. It could be argued that impractical safeguards are more dangerous than no safeguards at all. This is based on the fact that people who rely on safeguards suddenly have a false sense of security once the safeguard is bypassed or removed (which is often done without proper approval or notification).

Additional individuals to involve in the process are engineers and electricians. These people will be able to provide detailed information about the machine, including what measures are currently in place and what options are available. When ever possible, it is also beneficial to have production managers involved. Their buy in and involvement help ensure that a practical safety solution is implemented which does not drastically reduce the output of the machine or the operators. Lastly, outside specialists can help give insight into capabilities, benefits, and disadvantages regarding specific machines, devices, or safety measures.

It is important to adequately address the concerns of all affected individuals in order to avoid incentives to defeat or circumvent a protective measure. These incentives may include the idea that the protective measure prevents the task from being performed, it slows down production or interferes with any other activities or preferences of the user, it is difficult to use, personnel other than the operator are exposed to the hazard, or it is not recognized by personnel or is not accepted as suitable for its function.

Step 4 – Observe Machine in Use

Although many machines are similar in design, end users adapt machinery to produce specific parts based on customer and market demands. Therefore, although many machines may be produced similarly in design, they can be easily altered to make a drastic difference in the level of risk. For instance, let's consider a robot application. Although the robot manufacturer may produce thousands of identical robots, each robot can be incorporated into a variety of systems, each with its own hazards. One robot may be used for material handling, one for a welding application, and another in a paint booth. Each of these 'identical' robots now have different hazards, and potentially different risk levels, based on the end effector used, the environment they are located in, and how they are integrated into a system with other types of machinery. Even changing a die or the workpiece may affect the exposed hazards of a machine. Because of this, it is important to view each machine as it is used for each application. It is also important to see how different personnel work on or near the machine, as different techniques may lead to a best practice approach which could be adopted elsewhere within a company to increase safety.

Step 5 – Identify Hazardous Areas

This technique, also know as a task/hazard approach, creates a detailed list of all potentially hazardous scenarios. First, the team should try to identify each and every task imaginable during the entire lifecycle of the machine. Obviously, this list will include tasks required for loading and unloading, all modes of operation, planned and unplanned maintenance, tool change, troubleshooting, and housekeeping. In addition, the team must consider tasks required for transporting, start up, installation, decommissioning, and even disposal of the machine. Once every foreseeable task is listed, the team must then try to identify every potential hazard associated with each task. Types of hazards include in-running nip points, pinch points, crushing, electric shock, release of stored energy, ergonomic strain, and slips, trips, and falls, just to name a few.

Step 6 – Identify the Risk Level

After all of the foreseeable task/hazard pairs have been identified, the next step is to assign a risk level to each pair. There are many consensus methods available that prescribe systems to assist in labeling risk levels. Examples of these are consensus standards, such as ANSI B11.TR3, ANSI/RIA R15.06, ANSI/PMMI B155.1, SEMI S10-1103, MIL-STD-882D, CSA Z432, CSA Z434, and ISO 14121 (EN 1050), as well as third-party software applications. Which ever method is chosen, it is important that the assessment team is comfortable with the process and how to properly use it.

Although there are many methods available to identify levels of risk, most of them consider the main functions of a hazard; severity of the potential injury, frequency of exposure to the potential hazard, possibility of avoiding the hazard as it occurs, and likelihood of occurrence in event of a failure. It is important that the individuals involved in the risk estimation be familiar with and agree upon the definitions of the criteria for these factors. Often, the resulting risk levels are classified into three or four categories, ranging anywhere from high to negligible.

It is important that the initial risk estimation be conducted assuming no safeguards are installed. By doing so, the risk evaluation will produce a risk level which will more accurately identify the proper safeguarding methods to help reduce the risk of existing hazards.

Step 7 – Evaluate the Risk Level

Evaluating the risk level which resulted from the previous step helps determine if further safeguarding methods should be applied to the machine or process to make it safe. To determine if a hazard requires further safeguarding, the risk level should be at a tolerable level, meaning that it should be within a reasonable and acceptable level of risk that a person would normally expect to take. It is widely recognized that zero risk does not exist and cannot be attained. However, a good faith approach to risk assessment and risk reduction should achieve a tolerable risk level.

If the level of risk after the first risk estimation is at a tolerable level, the safety team should continue on to Step 12 below. If, however, the risk level is not tolerable, the team must continue with the following steps to reduce the level of risk as much as possible until tolerable risk is achieved.

Step 8 – Create an Appropriate Risk Reduction System

If each risk is not initially tolerable, protective measures need to be applied which will effectively reduce the risk of a hazard to an acceptable level. The selection and implementation of one or more of these measures is to be done in accordance with the hierarchy shown in Table 1 until the associated risk is tolerable. This order of precedent is based on effectiveness and reliability. It is apparent from this hierarchy that the methods which rely more heavily on human behavior are at the bottom of the scale, as these methods are less reliable and more difficult to ensure.

	Protective Measure	Examples
Most Effective	Elimination or Substitution	• Eliminate human interaction in the process • Eliminate pinch points (increase clearance) • Automated material handling (robots, conveyors, etc.)
	Engineering Controls (Safeguarding Technology / Protective Devices)	• Barriers • Interlocks • Presence sensing devices (light curtains, safety mats, area scanners, etc.) • Two hand control and two hand trip devices
	Awareness Means	• Lights, beacons, and strobes • Computer warnings • Signs and labels • Beepers, horns, and sirens
	Training and Procedures (Administrative Controls)	• Safe work procedures • Safety equipment inspections • Training • Lockout / Tagout / Tryout
Least Effective	Personal Protective Equipment (PPE)	• Safety glasses and face shields • Ear plugs • Gloves • Protective footwear • Respirators

Table 1. Hierarchy of protective measures.

When selecting appropriate protective measures from the hierarchy, it is necessary to evaluate the application of the solution against factors such as risk-reduction benefit, usability, productivity, technological feasibility, economic and ergonomic impact, durability, and maintainability.

Step 8A – Hazard Elimination or Substitution

Although elimination or substitution of a hazard is by far the most effective method of reducing risk, often it is only possible during the design stages of a machine or process line. Because of this, it is best to introduce the OEM to the risk assessment and risk reduction process at the earliest stages of inception. Many times, however, it is the end user who is applying a risk reduction strategy to a machine that is already on the plant floor and eliminating or substituting a hazard is not a feasible option. In this case, the next best measure is to apply engineering controls.

Step 8B – Engineering Controls

When implementing engineering controls to mitigate risks, it is important to select effective solutions which are adequate for the hazard. In addition to the selection of appropriate technology and devices, the proper control system (electric, hydraulic, and pneumatic circuits) must also be selected. Many of the risk estimation tools listed above also include recommendations for appropriate circuit reliability levels. The requirements vary slightly between standards, but common terms of circuit reliability include ‘simple’, ‘single channel’, ‘single channel with monitoring’, and ‘control reliable’.

It is important to remember that whenever a discrepancy arises regarding which level of protective measure or circuit reliability to select, it is always safest to choose the higher of the two. A conservative method such as this is a good faith approach which will help ensure a safer work environment for your employees.

Another concept to keep in mind when selecting engineering controls is safe mounting distance. Safety devices which do not physically prevent individuals from reaching into a hazard area must be either stop or prevent the start of hazardous motion (or situation) when an individual is exposed to the hazard. For the devices to accomplish this requirement, they must be located at a distance from the hazard such that hazardous motion (or situation) is prevented, completed or stopped before the individual can be harmed. OSHA provides minimum requirements for safe mounting distance of protective devices in OSHA §1910.217, however more stringent and conservative requirements are provided in national consensus standards, such as ANSI B11.19 and ANSI/RIA R15.06.

Step 8C – Awareness Means

After selecting the most appropriate engineering controls for the hazard, the next step is to apply any awareness means which could help reduce the level of risk further. Often, this includes appropriate signage as well as visual and audible awareness devices. It is best to maintain existing practices within a facility when applying visual and audible awareness devices so as not to create conflicting signals; in other words, maintain current color codes and audible signaling practices whenever possible, as long as they are compliant with current standards and regulations. Consideration should be given to literacy levels, color blindness, and primary languages of employees when considering visual awareness measures. Additionally, appropriate volume levels of audible signals should be evaluated in order to be heard over normal operating noise while not creating a potential source of hearing loss. Additionally, awareness means should be located where they will best serve their intended purpose. For instance, a sign instructing employees not to operate a machine without a guard in place is better placed behind where the guard belongs – if the sign is on the guard and the guard is removed, the sign may not be visible.

Step 8D – Administrative Controls

The next step toward reducing risk is to implement administrative control, including training and safe work procedures. When deciding if safe work procedures would be beneficial, ideas to consider include when tasks are complex or have an inherently high risk; when training, skill or work experience is limited; when tasks require other safeguards to be removed are bypassed; or when required to augment other safeguarding measures.

When creating training programs, the user should consider all instructions, specifications and recommendations from all applicable suppliers. Training programs should be created for operators, helpers, maintenance personnel, supervisors and other individuals who may be exposed to hazards of a machine or process. The objectives of the training process should include the purpose of the safeguarding measures and their function; procedures, especially those dealing with health and safety; hazards presented by, capabilities of, and tasks associated with the machine or process; and safety concepts.

Once the required training has been developed, the user should ensure that all affected personnel are trained, verify each persons understanding, and provide for their continued competency. At this point, each individual person is responsible for following the training and safety procedures provided by the user.

It is always best to document all training procedures as well as when training has been completed by each individual. After initial training has been completed, retraining should be provided to assure safe operation as well as any machine or process changes. Retraining may occur after personnel or system changes or after an accident.

Another concept to be addressed at this stage includes lockout / tagout / tryout. This method of controlling hazardous energy is essential in order to protect personnel where injury can occur as a result of the unexpected release of hazardous energy. This can include any unintended motion, energization, start-up or release of stored energy, deliberate or otherwise, from the perspective of the individuals at risk. Proper guidelines, including OSHA §1910.147 and ANSI/ASSE Z244.1, should be followed when creating such programs.

Step 8E – Personal Protective Equipment

When engineered safeguards, awareness means, administrative controls, or a combination thereof, do not provide an acceptable level of protection, authorized individuals should be provided with appropriate personal protective equipment (PPE) to protect from injury. Personal protective equipment includes safety glasses, hearing protection, gloves, hard hats, respirators, and adequate foot protection.

Once adequate safeguarding system(s) have been selected to reduce the level of risk, it is important to present the proposed system to all affected personnel or their representatives. By doing so, many problems which may occur during the installation or start-up phases can be reduced or even eliminated. These problems may include operator interferences, production slow downs, or maintenance difficulties. Identifying and addressing these issues at the design stage of the safety system will help reduce the final costs of the process.

Step 9 – Accurately Estimate System Costs

Whether the implementation of the selected safeguarding system will be performed by in-house resources or an outside supplier, it is important to accurately identify all costs associated with the final system. Common mistakes committed by facilities installing their own systems include the omission of costs associated with labor and seemingly trivial material costs, including conduit and wiring, which can add up to a noticeable change in final expenditures. When using outside resources, it is important to evaluate the costs associated travel and expenses, including travel costs and per diem charges, when applicable.

Step 10 – Provide All Required Services and Materials

No matter how the installation will be completed, it is important that proper materials are selected and installed using tried and true methods. These methods should be in accordance with appropriate national, regional, and local regulations; applicable consensus standards; user specifications; and device and machine manufacturers' recommendations. In order to comply with these guiding principles, it is important to first identify which guidelines are relevant and are important to the application. Once these have been recognized, the second step is to find installers with an intimate familiarity and understanding of these standards. There are no set rules for qualifying installers of safeguarding systems, but some ideas to consider include years of field experience, knowledge of product capabilities and limitations, and understanding of (and preferably involvement in the development of) safety standards. It is important to become familiar with and form a working relationship with the team responsible for the installation of the safety system because these individuals are those responsible for the final effectiveness and reliability of the system.

Step 11 – Conduct Follow-Up Risk Assessment

After installation of the selected safeguarding solution, it is imperative to conduct a follow-up risk assessment to verify that the risk level has been reduced to a tolerable level. If, after conducting the secondary risk assessment, the level of risk is not effectively reduced, the process should be repeated until a tolerable risk level is achieved.
If, however, the resulting risk level is determined to be negligible, the process is near completion.

Step 12 – Process Close-Out and Sign-Off

Before releasing the machine to full production capacity, the final step is to complete the required documentation. First, the residual risk should be identified and documented. Next, the safeguarding system should be verified for effectiveness and compliance. When validating the installed system, it is important to ensure that individuals are not placed at risk. This is accomplished by following the device and machine manufacturers' recommended set-up and try-out procedures. Additionally, all safe work procedures and training material should be updated to reflect the changes of the system and then presented to all affected personnel. After completion of any required training, good practice is to complete a machine or process sign-off verifying that the system is in proper working condition and that required tasks may be completed safely. The end product of this process will be a safe system for personnel and a documented report identifying that this has been achieved. It should be noted that any group unwilling or reluctant to provide the necessary documentation as proof of compliance and tolerable resulting risk should be re-evaluated before commencing with the process.

Other Steps

Outside of the risk assessment and risk reduction method outlined here, other common steps to help ensure a safe work environment include regular training sessions to build and maintain employee skill sets, creating collaborative efforts to review existing and create new machine safeguarding specifications to ensure compliance, assist in device selection, and provide impartial approval of compliance with applicable standards. If selecting outside service providers to assist with a machine safeguarding directive, the offering (or lack of offering) of these additional services may help identify qualified or preferred suppliers.

In conclusion, it is important to complete a risk reduction process for obvious reasons, first and foremost of which is to ensure the health and safety of personnel. By creating a safer work environment, quality improvement is increased, making companies more competitive in the market place, as well as indirectly improving the bottom line. In addition, increased safety can improve company morale and create a culture that is focused on the well being of others.

Bibliography

AMT (The Association for Manufacturing Technology). Performance Criteria for Safeguarding. ANSI B11.19: 2003. McLean, VA: AMT, 2003.

AMT (The Association for Manufacturing Technology). Risk Assessment and Risk Reduction – A Guide to Estimate, Evaluate and Reduce Risks Associated with Machine Tools. ANSI B11.TR3: 2000. McLean, VA: AMT, 2000.

ASSE (American Society of Safety Engineers). American National Standard for Control of Hazardous Energy – Lockout/Tagout and Alternative Methods. ANSI/ASSE Z244.1: 2003. ASSE, 2004.

CSA (Canadian Standards Association). Safeguarding of Machinery – Occupational Health and Safety. CSA Z432: 2004. Mississauga, Ontario: CSA, 2004.

CSA (Canadian Standards Association). Industrial Robots and Robot Systems – General Safety Requirements. CSA Z434: 2003. Mississauga, Ontario: CSA, 2003.

DOD (Department of Defense). Standard Practice for System Safety. MIL-STD-882D: 2000. Dayton, OH: DOD, 2000.

ISO (International Standards Organization). Safety of machinery – Principles of risk assessment. ISO 14121: 1999. Geneva: ISO, 1999.

OSHA (Occupational Safety and Health Administration). The control of hazardous energy (lockout/tagout). 29 CFR 1910.147: 1996. Washington, D.C.: U.S. Department of Labor, 1996.

OSHA (Occupational Safety and Health Administration). Mechanical power presses. 29 CFR 1910.217: 1996. Washington, D.C.: U.S. Department of Labor, 1996.

PMMI (Packaging Machinery Manufacturers Institute). Safety Requirements for Packaging Machinery and Packaging-Related Converting Machinery. ANSI/PMMI B155.1: 2006. Arlington, VA: PMMI, 2006.

RIA (Robotic Industries Association). Safety Requirements for Industrial Robots and Robot Systems. ANSI/RIA R15.06: 1999. Ann Arbor, MI: RIA, 1999.

SEMI (Semiconductor Equipment and Materials International). Safety Guideline for Risk Assessment and Risk Evaluation Process. SEMI S10-1103: 2007. San Jose, CA: SEMI, 2007.