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SAFETY BY DESIGN: HOW TO BUILD SAFETY INTO YOUR PROCESS

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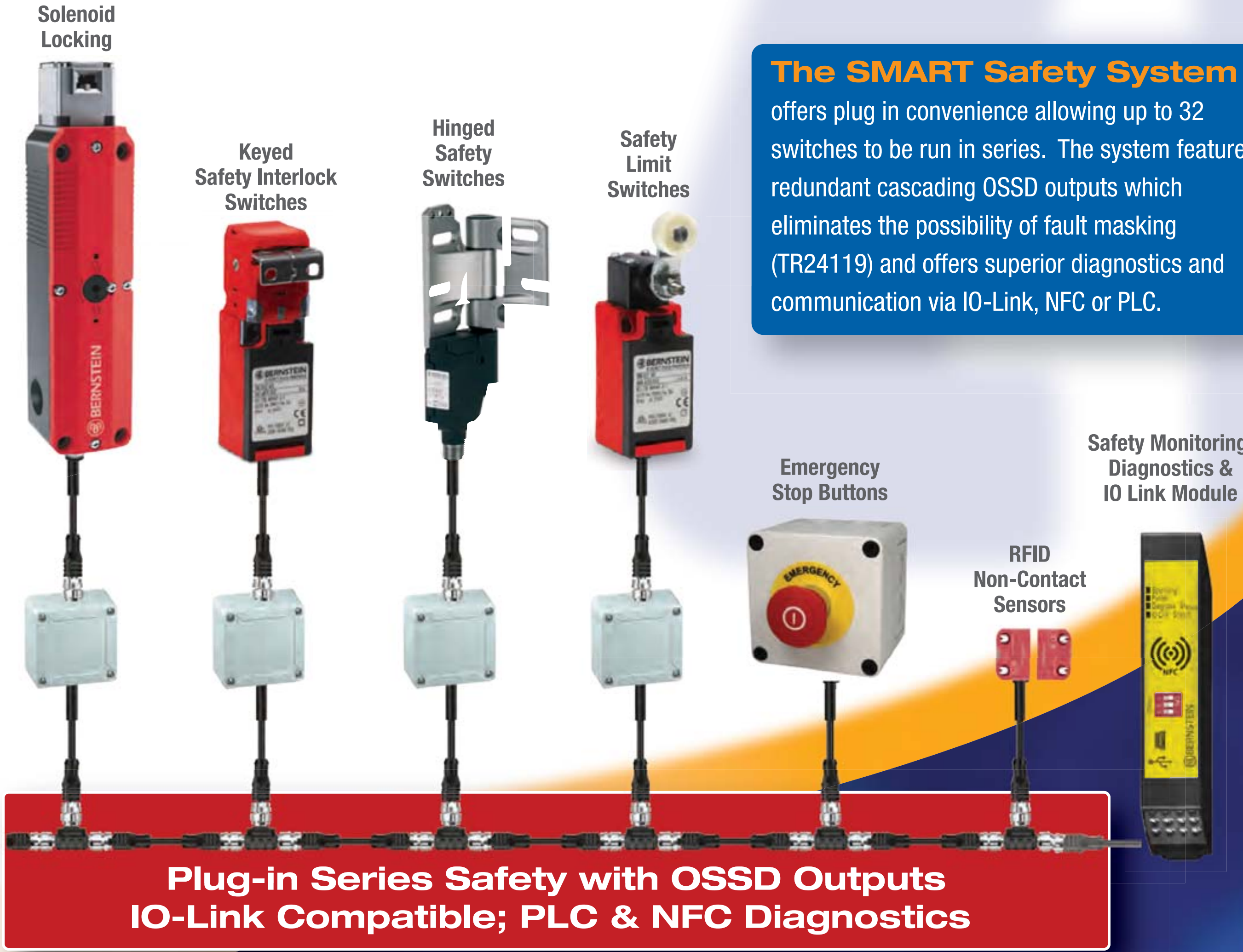
by BERNSTEIN



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SAFETY BY DESIGN: HOW TO BUILD SAFETY INTO YOUR PROCESS

CONTENTS

Bob Vavra, Senior Content Manager

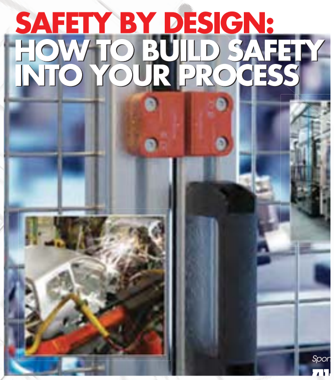
THE COST OF SAFETY in any plant can easily be calculated. The cost of an unsafe plant cannot be measured as easily.

A safe working environment is a fundamental right of every worker, and most managers understand the costs of safety programs, equipment and training. But there are other factors involved. A worker who feels safe on the job and empowered to point out places where safety can be improved will be more productive and better engaged with their work. And the reverse is true—workers know when their workplace is unsafe, and won't risk their livelihood or their life.

Successful safety programs are both top-down and bottom-up processes. When workers see an investment in safety, they can do their job with confidence.

For safety professionals in industrial environments, the quest for a safer workplace is an ever-moving target. Safety systems must be in place to both protect against an unplanned event as well as to guard against human error.

As we look at safety systems in this ebook, we start with a look at an actual case study, and how to design out the hazards. Then we'll look at specific systems: hard guards, interlock guards, e-stops, stop switches and safety rope pull switches—to explore how each factor into a safer plant, and how together they form the backbone of a full safety system.



CHAPTER 1:

Employee pulled into running conveyor – Are You Designing Out The Hazards?

JOE TAVENNER CSP, CFPS

An employee was inspecting a conveyor belt that recently had been adjusted. As he perused the setup, a rotating part of the conveyor caught his clothing. He was pulled into the machine and sustained injuries that sent him to the nearest medical center.

A combination of the right engineering-design and administrative controls could have prevented this all-too-common injury. The sad truth is that such injuries are 100% avoidable through identification and correction of a few risks:

Machine guarding — Guards on rotating parts including shaft ends are critical for employee safety. OSHA requires guards for all projecting shaft ends more than one-half the diameter of the shaft. You can avoid accidents by cutting shaft ends smooth and down to the proper length or capping them.

Emergency stops — When a button-style emergency stop is present, designers must put it in reach of the employees. It is only effective when an employee is in its immediate proximity. In an emergency, an employee can't struggle to find it. In the incident described above, the conveyor was equipped with a button- style emergency stop that wasn't immediately accessible. A cord and button e-stop assembly can be much easier to locate and activate in emergencies and is a far better solution when a button-style device alone isn't enough.

A second consideration is ensuring protection on both the normal operating side and nonoperating side of the conveyor. In this incident, the conveyor inspection could have taken place on either side of the conveyor. So both sides required protection.

Proper dress code — Employee attire can be easily overlooked when it comes to safety. It was a primary contributing factor in this case when the running conveyor snagged the employee's clothing. To avoid potential tragedies, workplace rules should ban loose-fitting clothing and mandate that shirts be tucked in. As I walk through many facilities, I commonly see untucked shirts even when they are required. Make no mistake: Untucked shirts have caused serious injuries. In addition, long hair and jewelry, including rings and necklaces, can be dangerous. Personal adornments like these should be removed when working around machines and conveyors.

Employee safety training — Employees should understand the risks of conveyors, the rules of the facility, and the consequences if they are not followed. Managers who communicate these expectations and hold employees accountable help keep awareness high and support a safe work environment. Training may not have completely avoided the injury in this incident, but it would have helped.

Investigators who look into these types of injuries commonly identify a root cause by answering one question: Is the conveyor unsafe or is the employee unsafe? The answer is almost always both. With most incidents, injuries arise from multiple factors. The key lesson to be learned is that you can minimize the chance of an accident by reducing and eliminating these factors with judicious design and well-conceived work rules.

JOE TAVENNER, CSP, CFPS, is a long-time Certified Safety Professional who works in occupational safety and design for safety.

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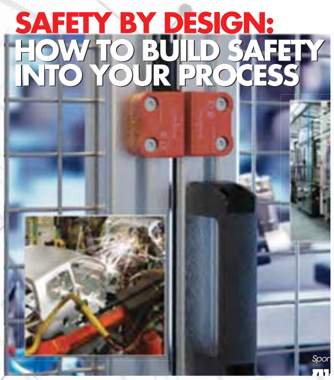


CHAPTER 2:

Safeguarding machines with hard guards

MORGAN EARLEY, Product manager, Altech Corp.

Hard guarding is a common approach to protecting both the visible and invisible hazardous areas of a machine. It can involve a variety of materials, including metal screening, or clear plastic to allow visibility. The only limiting factor is that the material must be strong enough to contain the impact from any debris or potential broken parts that could be ejected during the manufacturing process.

Hard guarding challenges

Fixed hard guarding is generally preferred due to its simplicity. However, since this prevents access to the machinery for maintenance, repairs, adjustments or product manipulation, other alternatives may need to be considered.

Incorporating a door or removable access panel can eliminate this problem, as long as the door or access panel remains closed when the dangerous condition is present. Incorporating interlock switches is a common approach, as they monitor the position of the guard. There are several different types of interlock switches available, including keyed safety switches, non-contact safety switches and hinged safety switches. Standard switches provide one or two closed contacts when the door or panel is in place, thereby blocking the hazardous condition. Usually these are connected in series, forming a one- or two-looped safety circuit that is monitored by a safety relay or safety programmable logic controller (PLC). Typically these monitoring devices shut off the power, stopping the dangerous moving parts and preventing the start of the machine when the guard is opened or removed.

Please provide a caption

Due to inertia, some machines may continue to run after power is disconnected. This can create a dangerous situation where it is possible to access moving, hazardous areas of the machine. Examples of these machines are saws, flywheel devices or K presses.

To eliminate this possibility, the guards must be placed at a sufficient distance for the process to stop completely before the operator is able to access it. This safety distance can be calculated based on the time it takes to open the guard, the response time of the safety relay and an average hand speed constant.

Locking vs. unlocked

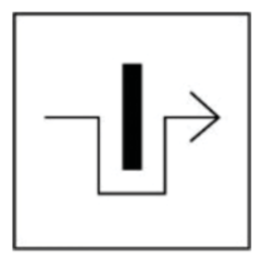
Another approach is to simply lock the guard or gate closed, allowing the machine enough time to safely wind down. This can be easily accomplished using solenoid-locking, keyed-interlock switches. These switches use a solenoid mechanism to lock a door-mounted activation key into the switch, preventing the guard, gate or door from being opened. Solenoid switches are available in two configurations: normally locked, in which the keys are locked into the switches automatically and the solenoid must be powered to remove them; or normally unlocked, with switches that require power to the solenoid to lock the keys into the switch.

A normally locked and normally unlocked solenoid switch. Source: Altech Corp.

Typically, the power to the locking solenoid is controlled using a zero-speed device to sense that all the dangerous motion has stopped, or a PLC or timer to ensure that enough time is provided for the machine to come to a complete stop.

Most normally locked solenoid locking switches include an emergency override that allows the locking actuator key to be removed manually in the event of a power failure. These are designed for emergency use only and usually require the use of a separate tool like a hex key to open. If quick access to the override is required, some switches offer an optional hand-operated manual override, which can only be reset with a special tool.

Many solenoid locking switches are available with multiple contacts that offer separate outputs to indicate when the key has been properly inserted into the switch and if the key has been locked. Older generations of switches sometimes required the key contacts and locking contacts to run in series to reach the highest safety levels. Newer switches feature a fail-safe locking design integrating both functions into one contact, indicating that the key is both in place and locked. There is a new symbol, according to ISO 14119, to designate these fail-safe contacts.


Symbol for a two-function fail safe locking solenoid. Source: Altech Corp.

Locking a door or gate closed to guard an area large enough to allow full-body access (e.g., a robotic manufacturing cell) could accidentally trap an operator inside the hazardous area. Since the locking control and switch override would be outside of the cell, the operator would have no means of accessing them and no means of escape. Some solenoid locking switches are available with optional emergency escape override accessible from the back of the switch. When mounted, the escape override extends through the guard, giving the operator access to unlock the switch from within the cell.

Non-locking and locking keyed interlock switches are not designed for use as physical stops for the doors or gates. This is especially true with large, heavy, door and gate designs. Many switches offer separate hardware that can be used in conjunction with the switches, to support the weight and forces required to secure the gate. These units, which are typically referred to as slide bolts or shock bolts, are equipped with a handle to allow the operator to open and close the gate by hand when unlocked.

Solenoid with reverse override. Source: Altech Corp.

Many solenoid locking switches are now vertically designed to make them much easier to mount on extruded aluminum rail systems, which are popular for hard guarding applications. Some also feature a combination of plastic and metal in their construction components to make them both durable and cost effective.

Slide bolt solenoid. Source: Altech Corp.

Conclusion

Since 1984, Altech Corporation has grown to become a leading supplier of automation and industrial control and safety components. Headquartered in Flemington, NJ, Altech has an experienced staff of engineering, manufacturing and sales personnel to provide the highest quality products with superior service. With the Bernstein line of safety products, Altech offers electrical and electronic switching, sensing and enclosure systems. The Bernstein range offers over 25,000 high quality, durable and innovative switches, sensors and enclosure products. Our well trained technical experts welcome the opportunity to answer your technical questions and provide solutions to your automation and control needs. Visit www.altechcorp.com to learn more or reach out to us directly: morgan@altechcorp.com.

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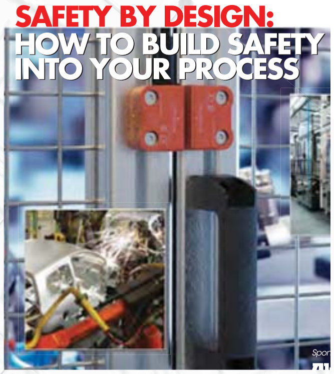


CHAPTER 3:

Engineering Basics: Why Interlock Guards Trump Lockout/Tagout

JEFF WARREN, CEO and Chief Engineer, The Warren Group

Here's a look at some of the reasons why interlocked safety guards prevent more accidents than lockout/tagout procedures and rules

Many of the annual 3.3 million workplace injuries result from broken OSHA rules. And of the top 10 OSHA rules most frequently broken, two directly concern machine design: lockout/tagout procedures (LO/TO) and machine guarding. Engineers designing machinery must often choose whether to protect workers by designing-in interlocked guards or adding them later, or by relying on operators and maintenance technicians adhering to LO/TO. The safest route is to use interlocked guards.

Let's see why.

Interlocked Guards & LO/TO

Engineers designing machines that will be used or serviced by human operators have a duty to perform a risk analysis and use the most effective means possible and feasible to prevent injuries is the risk is unacceptable.

One effective safeguard, interlocked guards, stops machines from operating when a barrier is opened or removed. They are more effective in preventing injuries than LO/TO procedures that workers might not follow and companies might not enforce. If safeguards are not feasible, warnings must be issued about the machine's hazards and risks. Finally, proper training and procedures such as the company's LO/TO policy should be established, promulgated, and followed.

Properly implemented, LO/TO provides a high degree of protection. Its weakness lies in the foreseeable, predictable failures of workers to always follow the policy.

It is common for employers to fault workers for accidental injuries or deaths because "they were trained and should have known better." Employers often terminate workers for

Engineers designing machinery should always eliminate hazards if they can, according to the System Safety Design in Order of Precedence for Mitigating Hazards, often called the Safety Hierarchy. If they can't, then they should design safeguards into the machine that prevent workers from coming into contact with hazards.

failing to properly LO/TO a machine before it is serviced, a violation of OSHA standards that can result in an OSHA citation. Most workers know that violating LO/TO policies is an "at-risk" behavior that can cause serious injury or death, and even if there are no accidents, violations could still get them fired. Therefore, it seems illogical that any employee would violate LO/TO standards. Yet it happens.

A lock out tag caries a warning not to remove the tag and start the machine, along with information on who locked out the machine and why.

Designer's Dilemma

It's easy for engineers to ensure a paragraph is put in the operator's manual saying that employees should LO/TO a machine before removing a guard to service or maintain it. This makes it easy for engineers to fault employers who receive OSHA LO/TO citations and injured employees who commit violations.

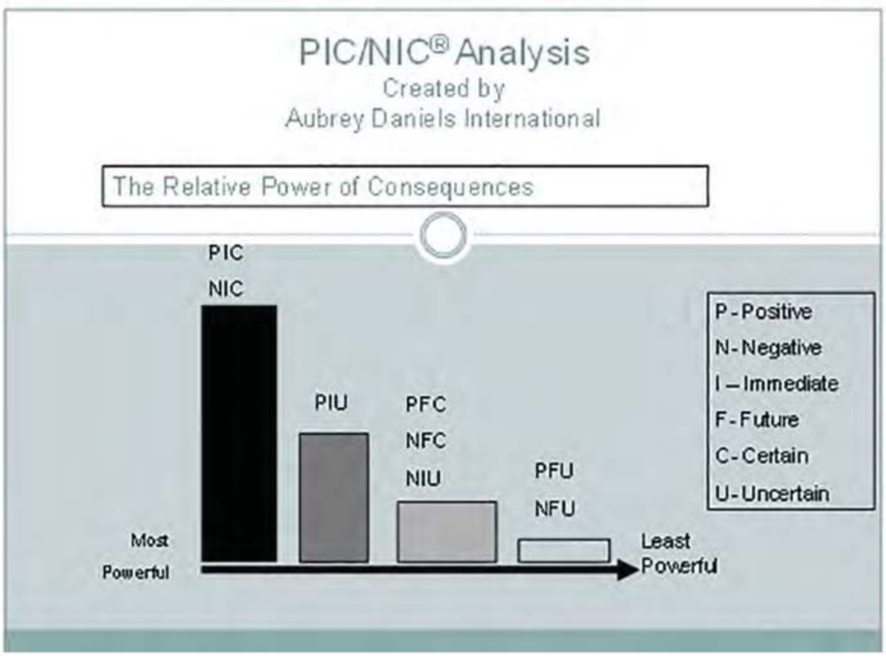
However, the ultimate goal for machine designers should be to come up with machines that have proper safeguards, if reasonably possible, that anticipate and tolerate user errors, mistakes, and violations. It is irresponsible for engineers and machine manufacturers to shift responsibility to employer or employees by requiring LO/TO when a hazard should really be eliminated or safeguarded through design. Therefore, engineers should always determine if an interlocked guard should be installed on machines requiring routine, repetitive service or maintenance during normal production. Only as a last resort should engineers or machine manufacturers rely solely on LO/TO.

Failure to provide interlocked guards on machines that should have them is a design defect that may lead to product liability claims against the machine manufacturer. But other than avoiding large verdicts, why provide interlocked guards? The answer is that interlocked guards provide an effective, alternative form of protection that tolerates worker errors and prevents workers from being injured. And worker errors, mistakes, and rule violations are inevitable.

Why LO/TO Fails

Workers do not wake in the morning and decide to go to work, make mistakes, and get hurt. In behavioral science, there is significant research on human error and why people make mistakes. Designers should understand this science. For example, in the recent book, *Safe by Accident: How to Take the Luck Out of Safety* (2010), the authors describe the ABC model of behavior. It says that behavior (B) is influenced by the antecedent (A) or what comes before, and the consequences (C), or what follows.

Every behavior has consequences that have one of two effects: they either increase or decrease the likelihood of repeating that behavior. The pattern of consequences determines the performer's behavior.



Positive, immediate, and certain consequences are more powerful and influential than positive, immediate, but uncertain consequences. And immediate consequences outweigh future consequences.

Authors Agnew and Daniels note that "if the pattern of consequences favors at-risk behavior, then at-risk behavior will occur. If the pattern favors safe behavior, then safe behavior will occur." If a worker believes that cleaning a machine without shutting it down properly contributed to (or favored) increased productivity, then they would continue that behavior--especially if there were no perceived negative consequences to themselves.

The power or strength of each consequence is also determined by the timing and probability of a consequence. Daniels and Agnew state, "Consequences that are immediate are much more powerful than those that are in the future." Furthermore, consequences that are certain are much more powerful than uncertain ones. The strength or power of any consequence can be analyzed by determining whether it is positive or negative, immediate or future, certain or uncertain (as shown in the PIC/NIC Analysis diagram).

As Daniels and Agnew document, "It is all too clear that employees can and will engage in unsafe behavior to get stuff out the door."

Machine design can tolerate and resist at-risk behavior by including safety mechanisms such as interlocked guards. Therefore, designing machines that can be used safely and tolerate foreseeable human behavior is paramount.

Errors, Mistakes, and Violations

In general, two main types of errors cause workplace accidents: slips and lapses. Slips are actions that do not go as planned, such as a slip of the hand, slip of the tongue, or slip of the pen. They are often preceded by a distraction or preoccupation.

Distractions are common in workplace environments. Lapses, on the other hand, are largely failures of memory. Lapses do not necessarily show up in actual behavior and may only be obvious to those who experience them. Errors of any kind are a guaranteed part of human behavior and an unfortunate certainty in the workplace.

Mistakes differ from errors. Errors are unplanned. Mistakes can happen when actions are performed according to plan, but the plan is inadequate to yield the desired outcome. Mistakes can also be failures in judgment. In terms of human behavior, mistakes are more subtle, more complex, and less understood than slips or lapses. As a result, they constitute a far greater danger.

Violations are somewhat different. They are not a direct component of individual human behavior, but are made in the context of some society norm in which behavior is governed by operating procedures, rules, and codes of practice. Violations are deviations from those practices deemed necessary by designers, managers, or regulatory agencies to maintain safe operations of a potentially hazardous system. They can be inadvertent or intentional, and unfortunately can become routine.

People often make routine violations because of a natural tendency to take the path of least resistance. Violations frequently occur when employees work in relatively indifferent environments and rarely get punished for noncompliance or, conversely, are rarely rewarded for compliance. In his book, *Human Error* (1990), James Reason states, “Everyday observation shows that if the quickest and most convenient path between two task-related points involves transgressing an apparently trivial and rarely sanctioned safety procedure, it will be violated routinely by operators.”

Sadly, it only takes one mistake, error, or violation to be fatal. Reason adds, “Such a principle suggests that routine violations could be minimized by designing systems with human beings in mind at the outset.”

While designers, manufacturers, employers, and policy creators encourage workers to be careful, minimize errors, and follow proper procedures for safety, expecting workers to be “perfect” is unrealistic. It won’t happen. Therefore, machine designers should expect the worst and design machines to accommodate errors, mistakes, and violations where reasonable, or technologically and economically feasible. Machines should tolerate errors, mistakes, and violations, if the risk is acceptable and it is reasonable to do so.

The science of human behavior demonstrates that errors, mistakes, and violations are inevitable. Safety through design tolerates these errors. Safety through design also tolerates human at-risk behavior, and interlocked guards are a shining example. A machine with an uncontrolled hazard that can result in death or serious injury is, in most circumstances, unreasonably dangerous and defective if the risk is unacceptable and it is technologically and economically feasible to install a safeguard such as an interlocked guard. Furthermore, failing to provide interlocked guards may result in a products liability case against the machine manufacturer.

Lockout/Tagout Basics

OSHA created the lockout/tagout (LO/TO) standard to reduce the number of workplace injuries and fatalities. As defined by OSHA 1910.147(a) (1) (i), LO/TO refers to “specific practices and procedures to safeguard employees from the unexpected energization or startup of machinery and equipment, or the release of hazardous energy during service or maintenance activities.”

In practice, it requires an operator or maintenance worker to turn off the machine, activate all energy-isolating devices, dissipate or release all energy stored in the machine, and place a tag on the machine identifying why the machine is locked out and who did it, along with a lock that prevents the machine from being turned on. The worker secures the lock and keeps the key until he completes the work.

The LO/TO standard also covers servicing and maintenance activities. OSHA standard 1910.147(b) defines servicing and/or maintenance as workplace activities in which employees may be exposed to unexpected energization or startup of equipment or release of hazardous energy (OSHA, 1989). However, OSHA recognizes several circumstances in which some minor servicing and maintenance activities would and could be performed during normal production without LO/TO. In particular is the minor servicing exception in OSHA 1910.147(a)(2)(ii), which acknowledges that “if the servicing operation is routine, repetitive, and must be performed as an integral part of the production process, lockout or tagout may not be necessary because these procedures would prevent the machine from economically being used in production.” It is important to note that LO/TO standards only apply if employees are exposed to hazardous energy during service and maintenance. Minor servicing activities, such as cleaning, lubricating, or adjusting, are not covered by the standard if they are routine, repetitive, and integral to production--as long as alternative measures provide protection.

The exception lets machine designers offer protective measures that will keep their workers safe. An interlocked guard with control logic that gives a single operator exclusive control over the machine is an example of an effective, alternative protection that precludes LO/TO.

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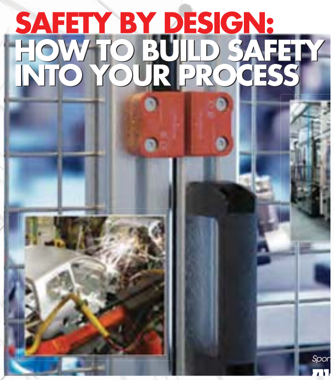

CHAPTER 4:

FAQ: Understanding and Using E-Stops

FREQUENTLY ASKED QUESTIONS

Q1: What is an e-stop and how is it used?

A: E-Stops, or emergency stop switches, are used to ensure machine as well as personnel safety. They are used to provide a consistent and predictable failsafe response on a wide range of electrical machinery and must stop the machine without creating additional hazrds. The devices can be highly specialized for emergency shutdown of equipment and meet workplace and machine safety standards established by international and U.S. regulatory commissions.

Q2: Is there a difference between e-stops and regular stop switches?

A: E-Stops provide what can be considered foolproof equipment shutdown, and always requires a human action for resetting. Often, the switch requires an additional step—a twist, pull, or key—in order to release the electrical contacts prior to the machine being in a position to be restarted. As a general standard, E-Stops must be a red operator with a yellow background. Companies often offer additional product options for particular applications. For example, some companies offer the same operators in various specialty colors. These non-red operators do not qualify as “Emergency Stops,” but can be applied in a similar way to stop applications. Black operators are used as a Machine Stop, similar in function as E-Stops, but are simply a different color. Typical application for these devices is when the machine’s “OFF” button is required to be manually reset before restarting the machine. Blue operators are an accepted designated color for stopping water or sprinkler systems, and yellow operators are an accepted designated color for shutting off gas lines. Different color operators were designed for customers with specific needs.

Q3: What standards must E-Stops adhere to in order to be considered properly certified?

A: Always check with your supplier to assure their devices are tested and approved by appropriate institutions relevant to your application. Some important standards include: IEC60947-5-1 and EN60947-5-5; VDE0660; UL508; CSA: C22.2 No. 14-95; and NEMA Type 4X, 12. These are some of the most used in the U.S. while other compliance and rating bodies also exist for other countries as well.

Q4: What types of applications are required to have e-stops installed?

A: All industry segments mandate E-Stops for safe operation, including, but not limited to industries involving vehicles and transportation, medical treatment and diagnostics, industrial machinery, oil and gas, food and beverage, water and waste water, and instrumentation. Therefore, designers will want to have a knowledge of E-Stop fundamentals, and switch characteristics and capabilities, as well as the international and U.S. standards and compliance requirements that need to be met for their application.

Q5: How can I begin to select the right e-stop for my application?

A: The first steps is to determine where the E-Stop fits within your machine control system and what category of emergency shutdown is needed according to the standard you are adhering to. The intended application often determines the electrical and mechanical specifications, as well as the size and placement. So, a thorough understanding of the machinery and associated control systems is key to making the right E-Stop choice. Requirements vary

by industry segment, therefore standards for E-Stops used in the transportation industry may differ significantly from those used on process machinery or medical equipment, and will be governed by different regulatory bodies specific to those segments. Note that Altech Corporation, just like most manufacturers provide online access to information that allows designers to select the panel opening size, type of actuator, type and number of contact blocks, and all the electrical ratings you'll need to adhere to.

Q6: Are there specific changes in any of the standards that I should be aware of?

A: There are continual adjustments being made to the standards as issues arise. One of particular interest recently if concerned about generators—a key component in many industries. The NEC 2017 standard has recently changed for article 445 on disconnecting means and shutdown of prime mover, and should be read through before finishing your design. This new change in the NEC standard requires the generator installer to include a lockable disconnecting means that would disable all prime mover start control circuits—which would then require a mechanical reset. This additional shutdown E-Stop switch is to be located outside the equipment room or enclosure and should not be installed with an E-Stop lock out or a lockable shroud.

A: What is the difference between E-Stop lock out shrouds and E-Stop guards?

A: E-Stop shrouds are usually lockable and used where safety is a requirement for the particular application's specific design and installation parameters. E-Stop guards, on the other hand, are not lockable and can be used in any application where protection of the operator is required but the operator has a full access to the E-Stop operator. This guard is meant to prevent the machine operator from accidentally bumping into the E-Stop while working, but does not provide a lock out function.

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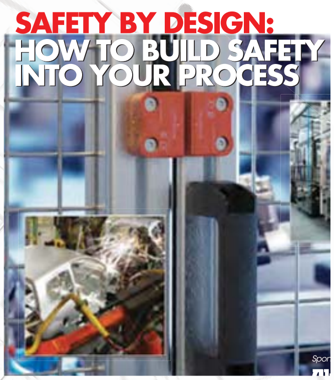
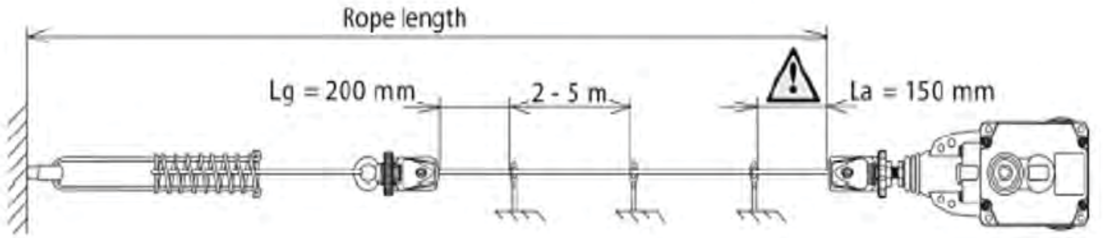


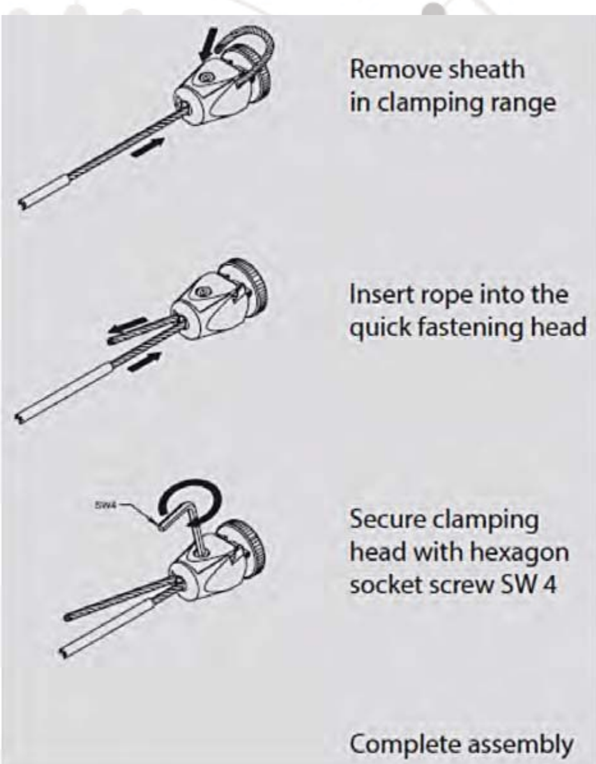


CHAPTER 5:

SRM Metal Body Rope Pull Switches

ALTECH CORP., Flemington, NJ is introducing a new series of Safety Rope Pull Switches, which are designed to provide access to e-stop capabilities over the entire length of the rope.

They are typically use to directly control the power to the devices that provide motion to the conveyer or machine and can be set up to control a local areas or zones.



The SRM has a metal body and is designed for use in more rugged applications like conveyor or machine systems. They are latching style switches which must be mechanically reset by the device on the switch. In addition to the reset button some models are also equipped with a built in push/pull e-stop button.

The proper tension on the rope must be maintained in order to set and reset the contacts. Both versions have a built in tension monitors which can be viewed through an integrated inspection window.

The SRM also has a second viewing window that indicates the internal contact positions. Some versions of the SRM are available with a tension warning device that will send an output signal if the cable begins to slacken (before the switch changes state).

Many SRM switches are available with a Quickfix rope mounting system, which saves a great deal of time attaching and adjusting the rope tension.

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