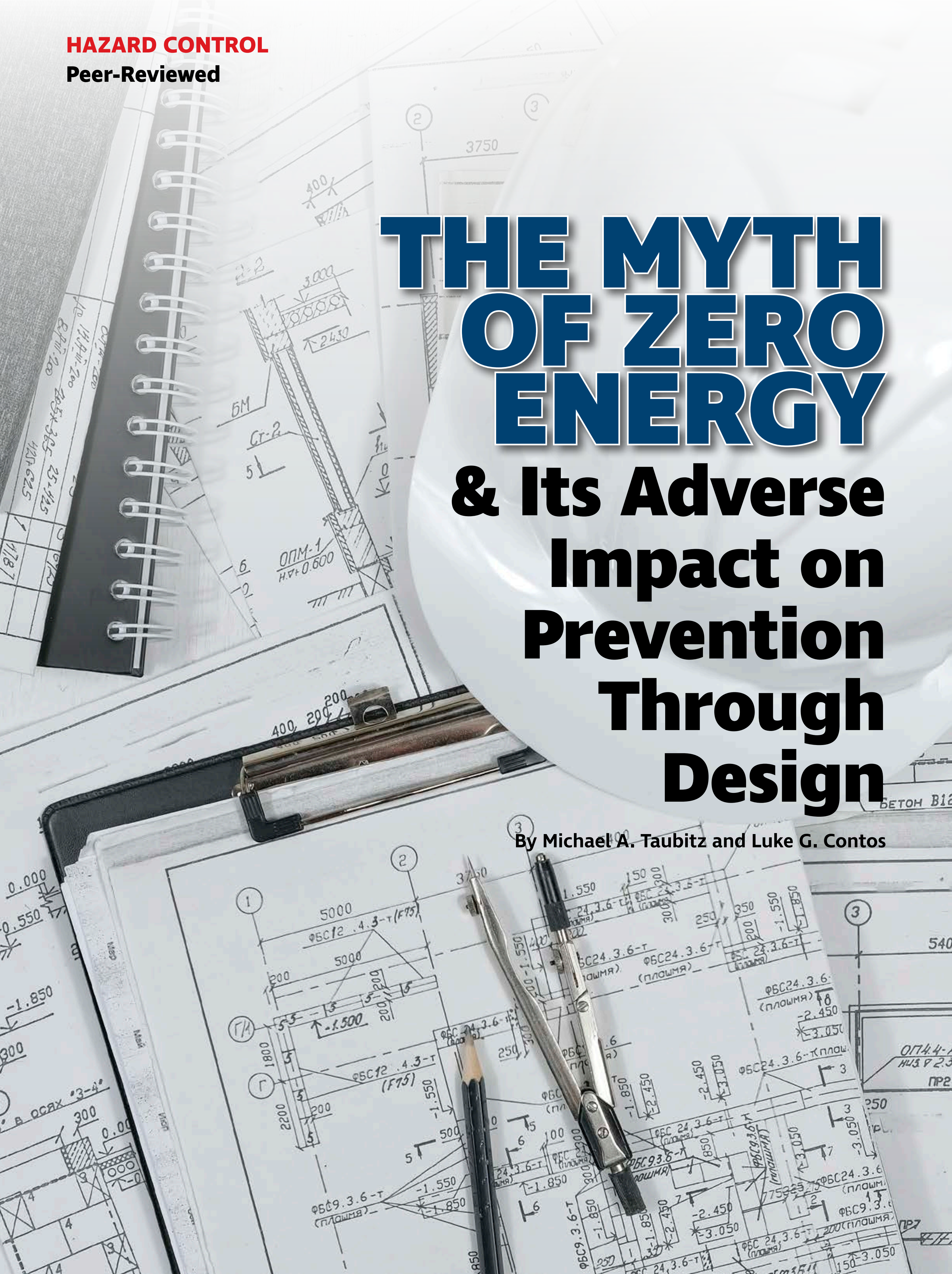


THE MYTH OF ZERO ENERGY & Its Adverse Impact on Prevention Through Design

By Michael A. Taubitz and Luke G. Contos

THIS ARTICLE IS FOCUSED ON prevention through design (PTD) and why use of the term "zero energy" lockout/tagout (LOTO) for all service and maintenance tasks creates a range of adverse impacts. Examples of such impacts are:

•impeding efficient and effective equipment designs when tasks (e.g., setup, maintenance, servicing, troubleshooting) are not considered in the concept and design phases of projects because zero energy is a perceived, yet infeasible, objective for all service and maintenance,

•shutting down production for longer than necessary, and

•believing that conditions leading to serious injuries and fatalities (SIFs) are reduced when, in fact, they are not.

The term "zero energy" is not the same as the control of hazardous energy, and is not found in any OSHA regulations or materials or in U.S. national consensus standards (e.g., ANSI). Of concern is how the concept of zero energy or a zero-energy state can negatively impact equipment design (hereafter, the term "equipment" is used to refer to machines, equipment, lines, cells, processes, etc.) because many production, service and maintenance tasks require some form of energy. The goal of PTD is to control hazardous energy to acceptable levels through a robust design process while still providing the energy necessary to perform work.

Through this article, the authors aim to prompt PTD practitioners to control hazardous energy more effectively during the design phase by better understanding OSHA regulations, ANSI standards, and rulings from the Occupational Safety and Health Review Commission (OSHRC), as well as better recognizing how to use risk assessment and determine feasible risk reduction for alternative methods to LOTO when energy is required for completing a task. This article also discusses means and methods for workers to safely perform service and maintenance tasks when energy is required.

The Zero-Energy Concept Negatively Impacts System Design

Following is a real-world example of a packaging machine in which a company's use of the zero-energy concept created adverse impact on production and safety.

Problem: Wrapper feeder for a packaging machine (Figure 1) often jammed during production.

Worker task: Adjust or clean the mechanism for feeding the wrappers in the packaging machine.

Worker exposure: To complete the task in the packaging machine, the worker may be exposed to hazardous energy.

Question: At which points would you control energy for a worker to complete a task safely: A, B, C, D or all (Figure 2)?

Company solution: Perceiving a greater level of safety to the worker, the company elected to require zero energy in all equipment prior to the start of any tasks. Analyzing the pros and cons of this decision (Table 1, p. 20) indicates that no additional safety was provided, and employees increasingly circumvented control of hazardous energy rules to maintain production. The attempt to better protect the worker by implementing a zero-energy policy across an entire line failed.

How the Control of Hazardous Energy Began

To better understand the current state of the control of hazardous energy, it is useful to review how we got here. In 1970, Congress passed the OSH Act, which set the stage for comprehensive safety regulation to protect American workers. These initial actions referenced some lockout-related provisions that focused on specific equipment and industries, but did not establish a broad, uniform regulation for LOTO during service and maintenance.

The 1970s saw a wave of lockout actions by various organizations along with the introduction of many new automation and control systems. In 1971, the National Safety Council (NSC) prepared its draft "Guidelines for a Lockout Program" and held a meeting for the formation of the committee to develop the ANSI Z244.1 standard, The Control of Hazardous Energy Lockout/Tagout and Alternative Methods. NSC's draft guidelines became the seed document for ANSI's initial work regarding this matter.

Around the same time, the American Foundrymen's Society developed ANSI Z241.1-1975, Safety Measures for the Control of Hazardous Energies: Lockout. This document introduced the concept of a zero mechanical state (ZMS), described as "that state of the machine in which the possibility of an unexpected energy movement has been reduced to a minimum." In the 1970s, it was common to find foundry equipment that was designed and built decades prior, and, as a result, most of the controls were mechanical and relatively simple.

FIGURE 1

PROCESS FLOW FOR PACKAGING LINE

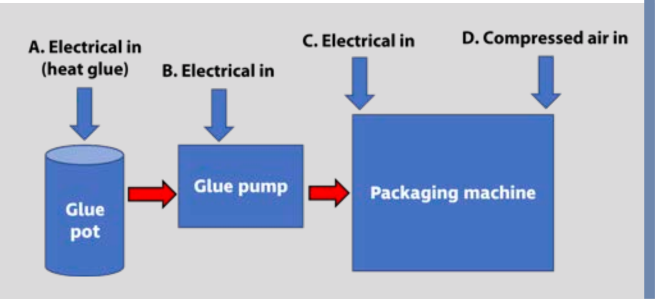
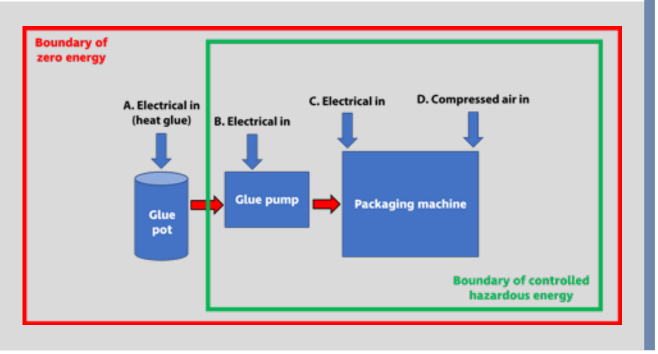


FIGURE 2

ENERGY CONTROL BOUNDARIES FOR PACKAGING LINE



KEY TAKEAWAYS

- **Identifying reasonably foreseeable maintenance and servicing tasks during the concept and design phases of equipment or projects and performing task-based risk assessment are key steps to feasible risk reduction and prevention through design.**
- **Where necessary, documenting the infeasibility of lockout/tagout is a first step to the designing and building of control-reliable circuitry that controls exposure to hazardous energy.**
- **Developing and validating an alternative method to a lockout/tagout procedure using approved ANSI standards to achieve acceptable risk can reduce risk and improve OSHA compliance.**

TABLE 1
COMPARISON OF ZERO ENERGY & CONTROLLING HAZARDOUS ENERGY

Objective	Attaining zero energy (red line)	Controlling hazardous energy (green line)
Energy control	Third party and safety team determined that energy into the packaging line was controlled at four points: A, B, C and D	Third party and safety team determined that energy into the packaging machine need only be controlled at three points: B, C and D
Facts	•Glue pot cooled for 2 hours to reach ambient temperature. •Due to solidification of glue, the feed line and pump required cleaning prior to start-up. •For each stoppage, 2 to 3 hours of production was lost.	Once the energy in the packaging machine was controlled, the worker could complete the task in 5 to 10 minutes.
Summary	•Hazardous energy in equipment upstream of the process was controlled during servicing of the packaging line. •Significantly increased downtime for no additional safety. •Operations and maintenance increasingly circumvented safety rules to maintain production.	•Hazardous energy potentially impacting the worker was controlled during servicing of the packaging machine. •Task completed safely and in a timely manner. •Safety, maintenance and operations teams worked in concert.

While ZMS may have been feasible in 1950s-era foundry equipment with simple controls, it failed to address significant challenges for many service and maintenance tasks in newer automated machining and assembly systems. ZMS did not consider the needs of skilled trades to set up, troubleshoot or adjust.

In March 1982, ANSI Z244.1-1982, Personnel Protection—Lockout/Tagout of Energy Sources—Minimum Safety Requirements, was approved and published. Of critical note: ANSI Z244.1 made no mention of ZMS or zero energy.

In 1983, NIOSH published "Guidelines for Controlling Hazardous Energy During Maintenance and Servicing," which recognized that all operations could not be reduced to a zero-energy state, noting that:

1. Energy is always present.
2. Energy is not always dangerous.
3. Danger occurs only when the amount of energy released exceeds human tolerances.

An important concept in the NIOSH guideline is that "Maintenance activities . . . are always performed with some form of energy on and some form of energy off." This fundamental principle was not included in the regulatory standard, 29 CFR 1910.147, The Control of Hazardous Energy.

Taubitz (2018) illustrates some of the real-world issues confronting General Motors (GM) when attempting to achieve a zero-energy LOTO state for service and maintenance tasks during the 1970s, before OSHA's regulation for the control of hazardous energy.

> Many fatalities occurred involving LOTO. The problem was that many tasks could not be done without power, and workers ignored their training to lock out machines. . . . The thought of zoning or leaving power on to certain parts of the equipment (e.g., to heaters so that the product would solidify) was not considered because the safety department specified zero energy. . . . Hard lessons were also learned when skilled workers pushed back that zero energy would crash overhead robots that were used to weld and assemble vehicles in assembly plant body shops. Energy was needed to hold these robots in the up position. When all energy was shut down, the overhead robots came down and created an unplanned maintenance situation, commonly referred to as "crashing the body shop." (p. 29)

Equipment and their safeguarding systems had to be designed to facilitate maintenance workers performing necessary tasks when operations broke down. There was also a growing awareness that reducing minor injuries would not necessarily reduce the risk of SIFs because the exposures related to SIFs were vastly different from those associated with recordable and minor injuries. For example, the hazards associated with a qualified electrician performing diagnostic work on a transfer line with 480 V equipment were dramatically different from those that contributed to soft-tissue and other common recordable injuries.

Continued Progress for the Control of Hazardous Energy

On Sept. 1, 1989, OSHA promulgated 29 CFR Part 1910.147, Control of Hazardous Energy (Lockout/Tagout). It addressed procedures to disable machinery or equipment and prevent the release of potentially hazardous energy while maintenance and servicing activities were being performed. The standard applies to general industry under 29 CFR Part 1910.

The approval of ANSI/ASSE Z244.1-2003, Control of Hazardous Energy Lockout/Tagout and Alternative Methods, was another major step forward. The title of the standard was modified to recognize the broader universe of hazardous energy control where alternative methods to isolating and locking a primary energy source were sometimes needed.

In 2008, OSHA expanded its regulatory guidance with its compliance instruction CPL 02-00-147, "The Control of Hazardous Energy—Enforcement Policy and Inspection Procedures," which established the agency's enforcement policy and procedures for standards addressing control of hazardous energy.

None of the following regulatory, research or voluntary consensus standard documents contained any mention or variation of the term "zero energy":

- 1982 and 2003 ANSI/ASSE Z244.1 standards
- 1983 NIOSH "Guidelines for Controlling Hazardous Energy during Maintenance and Servicing"
- Preamble to 29 CFR 1910.147
- Final rule of 29 CFR 1910.147
- OSHA's 2008 compliance instruction CPL 02-00-147

Foundational Concepts for PTD

When machines are running in production, workers are protected by 29 CFR 1910.212, General Requirements for All Machines; Machine Guarding. When it is necessary to intentionally enter a zone of danger or hazard area in equipment for service or maintenance tasks, the worker must be protected by a procedure, whether it is:

•isolating and locking a primary energy source or an alternative method to LOTO when:

> An employee [performing service and maintenance] is required to place any part of his or her body into an area on a machine or piece of equipment where work is actually performed upon the material being processed (point of operation) or where an associated danger zone exists during a machine operating cycle. [1910.147(a)(2)(ii)(B)]

•Following a properly developed alternative measure for what is commonly referred to as the minor servicing exemption (MSE) where the task is routine, repetitive and integral to production, thus meeting the criteria of the exception:

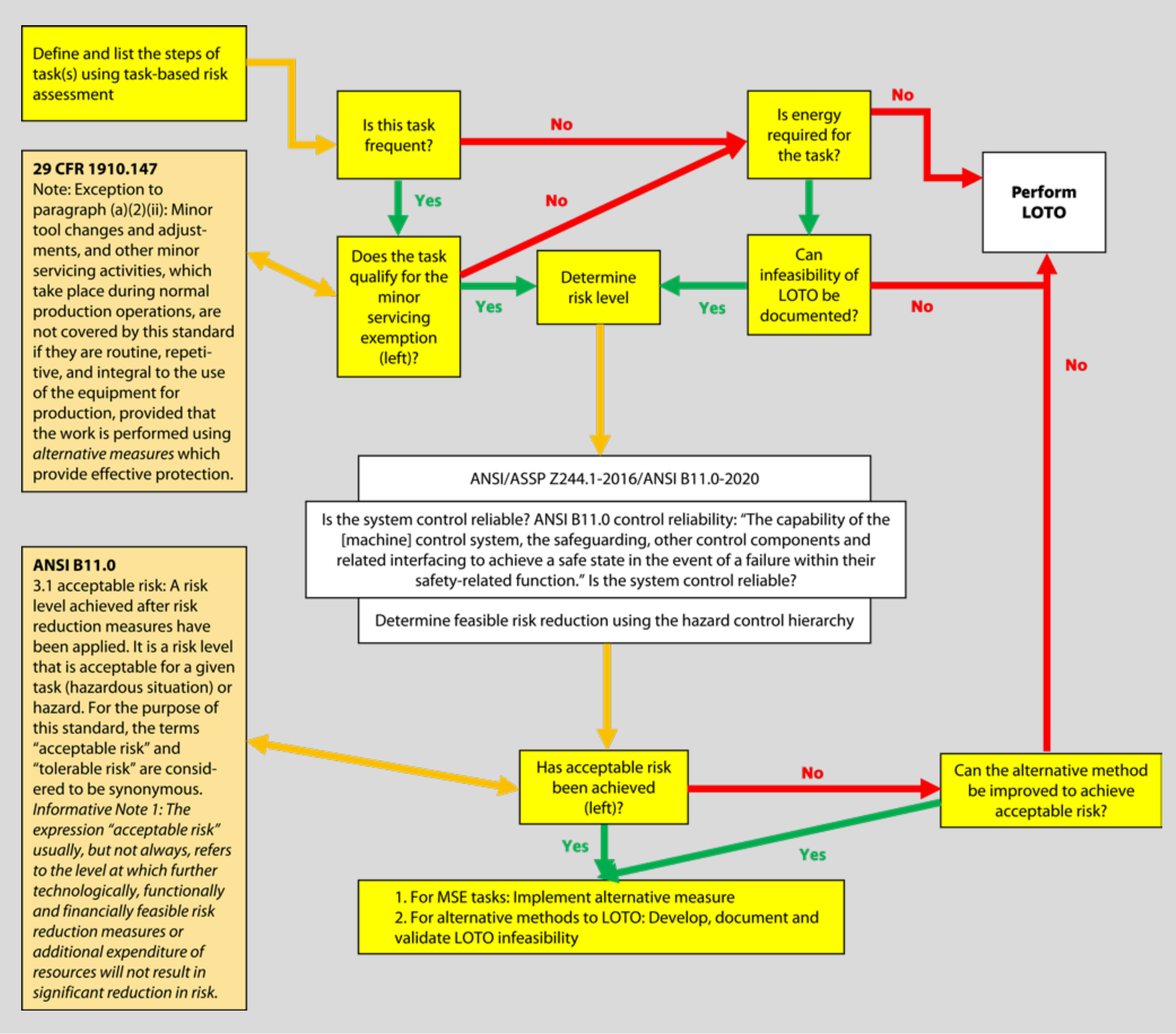
> Note: Exception to paragraph (a)(2)(ii): Minor tool changes and adjustments, and other minor servicing activities, which take place during normal production operations, are not covered by this standard if they are routine, repetitive and integral to the use of the equipment for production, provided that the work is performed using alternative measures which provide effective protection (see Subpart O of this Part).

Terminology is critical for OSHA compliance. "Alternative measure" is a term from the MSE and should be used only for legitimate minor servicing tasks. "Alternative method" is a term found in both ANSI/ASSP Z244.1-2016 (R2020), The Control of Hazardous Energy Lockout, Tagout and Alternative Methods, and ANSI B11.0-2020, Safety of Machinery.

Because of the common confusion of the terms, it is important to understand that both terms are means and methods, or procedures used to accomplish two different tasks. The issue is one of regulatory compliance. An alternative

FIGURE 3

HAZARDOUS ENERGY CONTROL: THE RELATIONSHIP OF OSHA & ANSI



measure in 29 CFR 1910.147 is only for those tasks considered to be routine, repetitive and integral to an operation. If the task is considered service and maintenance requiring LOTO for compliance, but LOTO is infeasible because power is needed, then an alternative method to LOTO must be developed following ANSI/ASSP Z244.1-2016 or ANSI B11.0-2015 or 2020. These two standards contain identical definitions of alternative method: "A means of controlling hazardous energy (other than energy isolation) to reduce risk to an acceptable level."

Neither ANSI standard mentions the term "zero energy" or ZMS. Figure 3 (p. 21) provides a logic diagram to help readers determine whether a task qualifies for the MSE in 29 CFR 1910.147.

In the words of George Box (1976), "all models are wrong, but some are useful." Figure 3 (p. 21) is not intended to capture every step necessary to implement alternative measures or alternative methods but is an attempt to help readers better understand OSHA regulation and applicable ANSI standards via a simple visual model. Following the appropriate ANSI standards is the technical path for practitioners of PTD to achieve acceptable risk for alternative measures or alternative methods. This model may seem complicated, but the authors have found that putting the concept on one slide useful to facilitate client understanding of a complicated compliance path.

The most difficult issue is how to deal with a task that does not qualify for the MSE, but traditional isolation and locking the primary energy source will not allow the task to be performed. The first question to ask is whether the energy is beneficial (i.e., power to keep equipment elevated) or nonhazardous (i.e., energy is present but does not pose a hazard, or risk is acceptable for the task being performed). If neither condition exists, it could be that energy is necessary to perform the task, which could present a hazard and risk of injury. Such tasks often pose potential high risk, with exposures that can lead to SIFs but may be overlooked by the traditional tools of job safety analyses, safety audits, behavior-based safety and other traditional safety methods used to assess risk of standardized, production-type tasks. In cases of potential SIF exposure, it becomes important to analyze and document that locking the primary energy source is not feasible.

Feasibility

OSHA's 2020 Field Operations Manual describes why feasibility is essential for an employer offering an affirmative defense against a citation involving 29 CFR 1910.147. Guidance for a compliance officer found at III.B.2.a. is, "Section 5(a)(1) therefore does not mandate a particular abatement measure but only requires an employer to render the workplace free of recognized hazards by any feasible and effective means the employer wishes to use."

Most safety professionals are well versed in the OSH Act, OSHA regulations and OSHA as a regulatory body. However, what safety professionals may not recognize is the importance of OSHRC rulings. OSHRC is a federal agency independent of OSHA, created by Congress to allow for the adjudication of OSHA law and regulation. The commission:

> Functions as a two-tiered administrative court, with established procedures for (1) conducting hearings, receiving evidence, and rendering decisions by its Administrative Law Judges (ALJs) and (2) discretionary review of ALJ decisions by a panel of Commissioners. (OSHRC, n.d.)

Secretary v. Loren Cook (2006) provides relevant guidance on the issue of feasibility:

> On Nov. 4, 2004, the Secretary issued Cook a one-item citation alleging a repeat violation of § 1910.212(a)(1), for failing to provide machine guarding on certain semiautomatic spinning machines. . . . In order to prove the affirmative defense of infeasibility, the employer must show:
>
> (1) the means of compliance prescribed by the applicable standard would have been infeasible, in that (a) its implementation would have been technologically or economically infeasible or (b) necessary work operations would have been technologically infeasible after its implementation, and (2) there would have been no feasible alternate means of protection. . . . Other than engaging in speculation, the Secretary failed to offer sufficient evidence to rebut Cook's showing of technology infeasibility. . . . Cook has established it would be economically infeasible for it to retrofit the spinning machines with door guards. . . . Cook has established its affirmative defense of infeasibility, both technological and economic.

Practitioners of PTD will find valuable feasibility guidance in Informative Note 1 to the definition of acceptable risk in ANSI B11.0-2020: "the level at which further technologically, functionally and financially feasible risk reduction measures or additional expenditure(s) of resources will not result in significant reduction in risk." However, this definition does not go far enough if you are to defend analysis with management or OSHA. In ANSI B11.0-2020, the informative note to Table 3, Hazard Control Hierarchy, offers criteria against which a practitioner can assess a proposed risk-reduction method, be it guarding or LOTO. (Note: the criteria are compatible with Z244.1 but the 2020 edition of B11.0 changed the term "practicable" to "feasible" for better alignment with OSHA and OSHRC and is preferred by the authors for that reason.) These criteria include:

- regulatory obligations and introduction of new hazards
- effectiveness and machine performance
- usability and productivity
- durability, maintainability and ability to clean
- ergonomic impact
- economic and technological feasibility

The authors have found that creating a simple two-column matrix analyzing feasibility using these criteria for a specific task is both simple and effective. It is the responsibility of safety professionals to facilitate and document assertions of infeasibility, whether addressing OSHA compliance or demonstrating the value of PTD throughout the company.

Today's safety professional has sufficient information to tackle what is one of the most misunderstood issues facing industry. Most employers think of setting up a machine for a new production run as meeting the MSE definition, therefore, being an alternative measure because the task generally requires control circuit power to move (e.g., inch, jog, adjust) the machine when preparing for a new production run. The dilemma is that a 1993 OSHRC case found otherwise.

Pivotal OSHRC Ruling: Westvaco, 1993

In 1993, Westvaco challenged OSHA's alleged violation of 29 CFR 1910.147 before the OSHRC, which ruled, in part:

Westvaco claims that it was not required to provide an energy control program to protect the helper because it is covered by the exception to the requirements of the lockout/tagout standard at the end of 29 CFR 1910.147(a)(2)(ii).

The judge noted that "setting up" is listed as an activity under the definition of "servicing and/or maintenance" in section 1910.147(b), and that servicing and maintenance activities are expressly covered by the lockout standard, under 29 CFR 1910.147(a)(2)(i). . . . He stated that, based on the plain meaning of the exception and these definitions, "work performed on the machine while the machine is not being operated to actually produce its product is either servicing or maintenance."

Setting up does not occur during normal production operations. Therefore, setting up cannot, by definition, fall within section 1910.147(a)(2)(ii).

It is the responsibility of safety professionals to facilitate and document assertions of infeasibility, whether addressing OSHA compliance or demonstrating the value of PTD throughout the company.

The Westvaco case was pivotal in its interpretation of what constituted normal production operations versus service and maintenance. Since it is typically infeasible (usually impossible) to set up machines and equipment without using machine functions powered by control circuitry, employers have attempted to use alternative measures defined in the MSE to 29 CFR 1910.147 as the basis for their actions. The OSHRC has ruled against that argument. Setup procedures using control functions such as jog or inch for new product runs may be safe, but without analysis and documentation of the infeasibility of LOTO, employers are not in OSHA compliance.

Alternative Methods in Concept & Design

Once infeasibility is documented, it is possible to develop an alternative method to LOTO. The goal of developing an alternative method is to achieve acceptable risk. ANSI/ASSP Z244.1-2016 (R2020) and ANSI B11.0-2020 have similar definitions that are paraphrased as a risk level achieved after risk-reduction measures have been applied. It is a level that is accepted for a given task (hazardous situation) or hazard.

It does little good for safety professionals or engineers to develop an alternative method that achieves acceptable risk for controlling hazardous energy if the system and procedures are not compliant with 29 CFR 1910.147. Typically, someone in management will properly ask if something is OSHA compliant. Practitioners of PTD and those involved in the design, engineering, procurement and operation of the equipment must be able to show that the organization has:

1. a properly developed alternative method that prevents unexpected energization or start-up and achieves acceptable risk, and
2. a documented feasibility analysis.

To meet the criteria of the Westvaco OSHRC ruling during the design phase, engineers and safety professionals should identify reasonably foreseeable tasks such as machine setup. Where LOTO is infeasible for a task, either redesign the process or equipment or document the infeasibility of LOTO. For tasks that require an alternative method, developing the means and methods with feasible risk reduction can be applied in a more cost-effective manner during the design phase as compared to installing safety devices and rewiring for control reliability after equipment arrival and installation. Understanding four other key OSHRC cases can help the reader gain a broader view of how OSHRC rulings can be used to improve design, engineering and procurement of equipment.

Four More Key OSHRC Rulings

GM Delco Chassis, 1995

In 1995, General Motors challenged OSHA's interpretation and requirement before the OSHRC. Following are salient parts of the decision.

GM believes it was not necessary to lock out the machine because the number of steps required to cause the machine to cycle would allow any employee working on the machine sufficient time to remove himself or herself from the zone of danger before exposure occurred. The Secretary has failed to establish that 1910.147(c)(4)(i) was breached by respondent and item 1 of Citation No. 2 will be vacated. (*Secretary of Labor v. General Motors Corp.*, 1995)

This ruling had important ramifications for all cases where the term "unexpected" was an issue regarding the application of LOTO.

It is undisputed that the machines had extensive precautions to protect servicing and maintenance employees. An electronically interlocked gate surrounded the machine area in each case. Once an employee opened that gate or pushed an emergency stop button, a time-consuming series of eight to twelve steps were required before any hazardous movement could occur. The evidence indicated that the restart procedures would provide plenty of warning to the employees, in the form of alarms and visible motions, so that they could avoid any hazardous movement of the machinery.

Finally, we find no merit in the Secretary's claim that Judge Salyer's reading of the standard: (1) violates the requirement that the authorized employee have exclusive control over his/her safety, and (2) rewrites the definition of "energy isolating device." That claim presumes that there is a hazard of unexpected energization, etc., on every industrial piece of equipment during service and maintenance. The terms of the standard clearly place the burden on the Secretary to show that there is a hazard as to the cited machines and equipment. (*Secretary of Labor v. General Motors Corp.*, 1995)

As a result of the GM case and a subsequent OSHA (1999) letter to the United Auto Workers, the use of task-based risk assessment (TABRA) was recognized as an acceptable analysis process. In ANSI standards, it is used for defining a methodology to identify and document all steps and hazards in a task, listing the controls and other risk-reduction means and methods necessary to bring risk to acceptable levels, and documenting the infeasibility of LOTO.

TABRA was the foundation for ANSI B11.TR3-2000, Risk Assessment and Risk Reduction: A Guide to Estimate, Evaluate and Reduce Risks Associated With Machine Tools. In turn, ANSI B11.TR3 became the foundation for other important industry

Implementation of PTD facilitates systems that control hazardous energy and provides opportunities to improve worker safety.

FIGURE 4
ROBOT, SAFEGUARDED PERIMETER

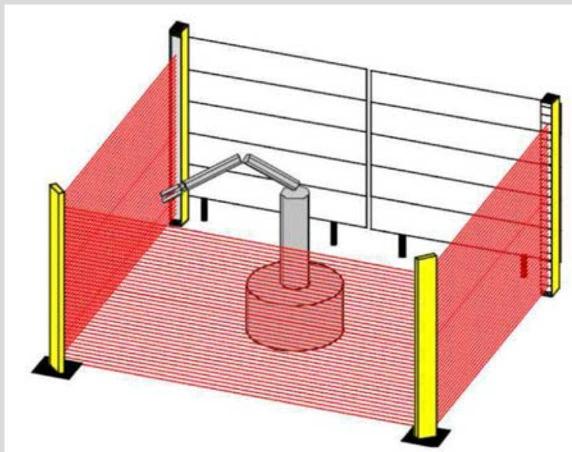
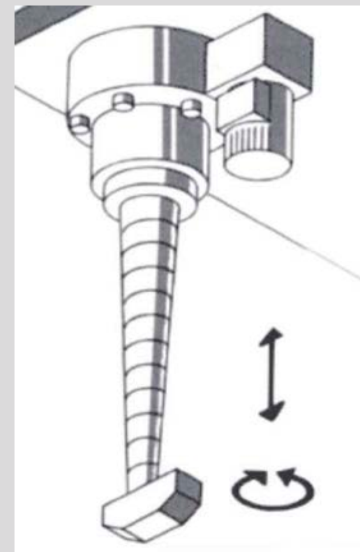


FIGURE 5
SLIDE LOCK EXAMPLE



standards. ANSI/PMMI B155.1-2016, Safety Requirements for Packaging and Processing Machinery, ANSI B11.0-2020, Safety of Machinery, and ANSI Z244.1-2016 (R2020), The Control of Hazardous Energy Lockout/Tagout and Alternative Methods, all made use of this important concept.

Alro Steel, 2015

It took 20 more years, but the 2015 Alro Steel decision reinforced the earlier GM decision:

> The Secretary asserts that the cited LOTO standard apply to the blade changing activities performed by Alro's band saw operators. There is no dispute that Alro's blade changing activities constituted service and maintenance. . . . [One of Alro's experts] testified that, in fact, there were six elements on [one of the saws] to keep the blade from moving: the saw blade power-on switch, the emergency e-stop switch, the spring loaded start switch, the PLC (program logic controller) switch, and two interlocks. He stated "[t]o me it's a wild exaggeration to think that all six could fail. (*Secretary of Labor v. Alro Steel Corp.*, 2015)

The commission found that a preponderance of the evidence demonstrated that neither of Alro's saws was subject to inadvertent start-up and unexpected energization. The Alro Steel case reinforced that a machine using a properly designed control circuit to control rather than isolate or interrupt primary energy is not necessarily a violation of 29 CFR 1910.147. A violation only occurs if the machine was subject to inadvertent start-up or unexpected energization.

A theoretical failure mode was not sufficient to show that an employee could be exposed to a hazard. This case advanced opportunities for PTD to control hazardous energy more effectively during the design phase by 1. fostering the integration of robust controls designed to control hazardous energy, and 2. documenting the risk assessment process.

Matsu, 2016

Another OSHRC decision in 2016 further cemented the findings from the Alro Steel case:

> The Respondent, Matsu Ohio Inc. (Matsu), is an automotive supplier that manufactures stamped metal parts at its plant in Edgerton, OH. Matsu operates 10 partial revolution mechanical power presses at the plant.
>
> The Secretary's theory with respect to all except one of the alleged LOTO violations rests on the premise that "control circuit type devices" do not constitute "energy isolating devices" as defined in the LOTO standard, and thus are ineffective in isolating hazardous energy under the LOTO standard. The Secretary's premise is correct, but it pertains to whether an employer has complied with the terms of the LOTO standard (the second element of the Secretary's burden of proof), and completely bypasses the first element of the Secretary's burden of proof, which is to show that the LOTO standard applies to the cited service and maintenance activities.
>
> The Commission has decided that control circuit type devices in machines may operate in such a manner that eliminates the potential of hazardous energy for certain servicing or maintenance activities, so that the LOTO standard does not apply to those activities.

Wal-Mart/Swiss Log, 2018

The 2018 Wal-Mart case was unique. The OSHRC noted, "But the LOTO standard is not applicable to situations where the energization or start-up of equipment is expected, yet an employee is injured anyway." There was no violation of the cited standard because the matter did not involve an "unexpected energization or start-up."

Opportunities for PTD

Implementation of PTD in concept and design facilitates systems that control hazardous energy and provides opportunities to improve worker safety, whether utilizing LOTO, alternative methods to LOTO or minor servicing activities.

OSHRC decisions help answer whether the proposed risk reduction is OSHA compliant. The control of hazardous energy regulations do not apply when a company can demonstrate that the unexpected energization or start-up will not occur or a properly designed alternative method effectively controls hazardous energy and provides effective protection to workers such that there is no exposure to a hazard.

It should now be evident that PTD practitioners have an opportunity to design proper alternative methods. Several examples for the control of hazardous energy that can be addressed in the concept and design phases are described here.

Changing Weld Tips

In this example, weld tips on a robot in a fenced cell had to be changed every 400 to 500 welds. The task of changing weld tips qualified for the MSE because it took place during normal production and was routine, repetitive and integral to the use of the equipment for production.

Figure 4 shows a typical single robot with light screens and hard guarding establishing a safeguarded perimeter. By creating a cross-functional PTD collaborative process, the following was achieved:

- the robot end of the arm weld unit was brought to an opening in the cell fencing,
- hazardous energy was controlled by control reliable circuitry, and
- the task was completed without exposure to unexpected start-up or energization.

The resulting PTD collaboration protected the employee, saved time by not requiring entry into the welding cell and minimized downtime.

Slide Locks

Slide locks are used for making the slide safe when working in the die space of mechanical and hydraulic presses. Figure 5 shows one type of a slide lock. An electric motor and a gearbox are used to move a threaded nut up and down. The tie rod, which is in the parked position (fully extended), first performs a 90° rotation, then moves directly to the slide and prevents it from being lowered accidentally (see OSHA, 2007, for more detail on this concept).

This concept, first discussed by Taubitz (2018), is repeated here to emphasize that such devices must be part of the concept and bid process for new equipment so that the technical aspects can be addressed during design. Failure to do so will typically result in resorting to the decades-old use of die blocks, because trying to retrofit a slide lock after the fact will be excessive in cost and lead time.

Human Machine Interfaces Design

The authors have found many production operations where all power is disabled when isolating and locking out a 480 V disconnect. In far too many cases, LOTO (in a misguided attempt to try to achieve zero energy) stopped even trickle power or low-voltage power to maintain software in the human machine interfaces (HMI) or control panel. After authorized personnel completed tasks performed under LOTO, skilled trades frequently found that the machine would not start. Software would often have to be reinstalled or, at a minimum, rebooted to get the machine back in production. This system design creates an incentive to not utilize LOTO because of the well-known challenges getting back into production.

TABRA would typically identify that power to the HMI or built-in battery backup did not pose a hazard to workers doing service or maintenance on the equipment. Obviously, if tasks were performed on the HMI itself, that energy would have to be assessed to determine whether it posed a hazard. By using PTD to segregate low- and high-voltage circuitry, the design could allow for low-voltage control systems to remain energized while high voltage that poses hazards to the worker were de-energized. It also allowed for a production line to be wired in sections or segments as opposed to de-energizing the entire line or system. Such issues should be addressed during the concept and design phase.

Alternative Methods for Setup

Knowing that an alternative method in lieu of LOTO is necessary for setting up a machine, it makes sense to have the alternative method be part of the design and installation of new equipment. That opportunity should be addressed at the time of requesting bids for machinery or equipment. On large, expensive custom machines, in the authors' experience, safety devices and control circuits cost little to nothing if addressed before the design is finalized and the contract is awarded.

If the company or machine supplier believes all tasks, regardless of exposures and controls, require zero energy, retrofit or OSHA compliance issues may result. Identifying the common (reasonably foreseeable) tasks to be performed on a machine as part of PTD will eliminate costly retrofits required to achieve alternative methods to LOTO.

Another example can be found in Stanley and Taubitz (2021). Use of controls and presence-sensing devices invites opportunities where the design of the safety related parts of the control system provides proper protection for a worker performing a specific task, as explained in the following excerpt:

> From the perspective of workers and nontechnical personnel, the adjective "passive" seems accurate because a worker can safely enter the safeguarded space, perform a task and exit with automatic restart (see Figure [6] inset). From the perspective of the controls engineer who designed the safety related parts of the control system noted in Figure [6], the system

FIGURE 6
CONTROL RELIABLE SENSORS

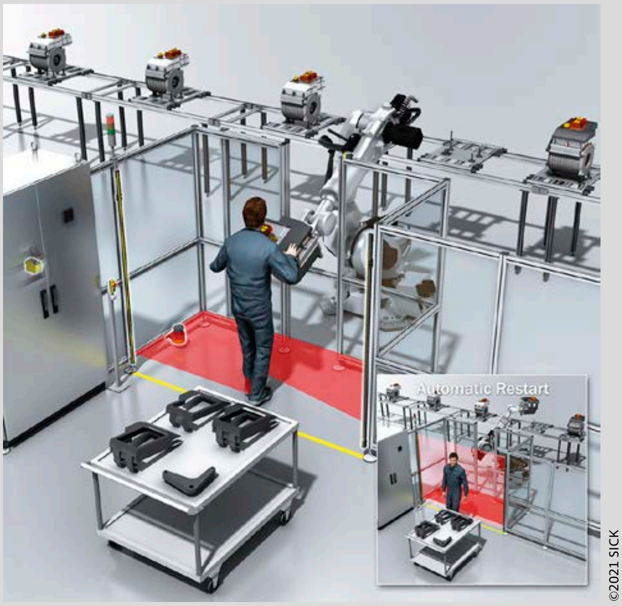


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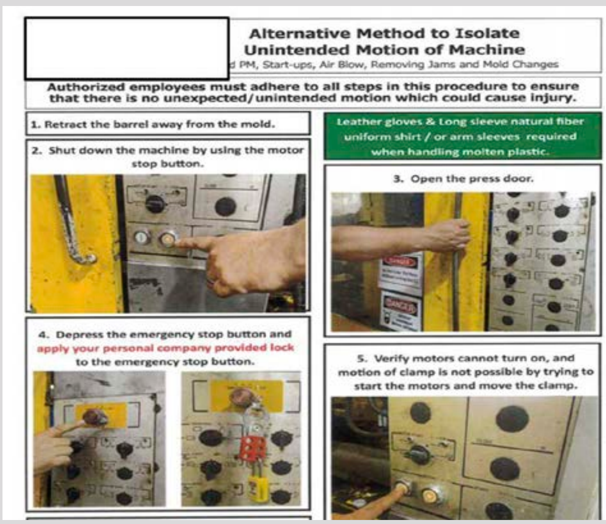
FIGURE 7
ALTERNATIVE METHOD PLACARD



> is far from passive. It has many active engineered controls, including a light curtain (which detects access at the yellow line), an area scanner (red sensing field created by the device at far left of access area) and a control-reliable interface in the control cabinet (incorporated into the panel at the left).
>
> This simplistic view of a highly complex safety system should be the goal of safety professionals and OSHA for the future of PTD in real-world applications. (Stanley & Taubitz, 2021, p. 28)

Such innovation can only happen if it is part of concept and design. The technology and risk assessment methodologies are available to achieve acceptable risk. In so doing, designs can make a given task easier and can improve productivity. To meet the challenge of determining whether designs or systems are legal, it is critical to follow the methods of the ANSI/ASSP Z244.1-2016 (R2020) and ANSI B11 standards to demonstrate that the designs are safe and in compliance with OSHA because they align with OSHRC rulings.

There is no shortcut to designing a safe and compliant hazardous energy control system. Those who believe that hitting an emergency stop and perhaps one other control such as manual mode provide adequate worker safety are mistaken. That quick solution is neither safe, nor will it pass the test of compliance. The completion of a risk assessment, documentation of infeasibility, design of the safety-related parts of a control system and procedures for specific tasks are necessary for the system to be considered compliant.

Using Risk Assessment to Document Alternative Methods

Properly developed alternative methods to LOTO are great opportunities to reduce risk and improve compliance. TABRA is the first step in developing an alternative method. After identifying steps of the task, associated risks and selecting appropriate risk-reduction methods from the hazard control hierarchy, PTD practitioners can achieve acceptable risk.

The control reliability of the safety-related parts of the machine control system must be evaluated to conform to the requirements for control reliability found in ANSI B11.0-2020 and ANSI B11.19-2019, Performance Requirements for Risk-Reduction Measures: Safeguarding and other Means of Reducing Risk. Control reliability is defined as "the capability of the [machine] control system, the engineering controls—devices, other control components and related interfacing to achieve a safe state in the event of a failure within the safety related parts of the control system."

In Figure 7, an engineering analysis was required to determine whether new or already installed components would meet the definition of control reliability. With documentation of the infeasibility of LOTO, attainment of control reliability and acceptable risk, the steps of TABRA provided a ready reference to develop a procedure that was both safe and compliant for changing mold tooling. When posted at point of use, these alternative methods closely resembled a typical LOTO placard.

Advancing PTD

The preceding discussion should give readers a better understanding of the reasons for not using the term "zero energy." Guidance from ANSI standards provide the means and methods to reduce risk and maintain compliance with OSHA, consistent with past OSHRC rulings.

Perhaps the most crucial point is that the practice of PTD requires manufacturing engineers, purchasing staff and safety professionals to deal with the concepts of risk and risk mitigation in the concept and design phases of any project. This is particularly true for the control of hazardous energy.

ANSI/ASSP Z590.3 focuses on eliminating and controlling hazards in the design (or redesign) process and can be applied to any occupational setting. It provides a management framework to facilitate decisions about workplace risks and hazards that can be used in the design and redesign efforts of tools, equipment, machinery, work areas, processes and substances. As noted by Fred Manuele (as cited in *OH&S*, 2011), chair of the Z590.3 committee in 2011, "This standard supports and gives guidance for the well-established premise that occupational hazards and risks are most effectively and economically avoided, eliminated or controlled in the design and redesign process."

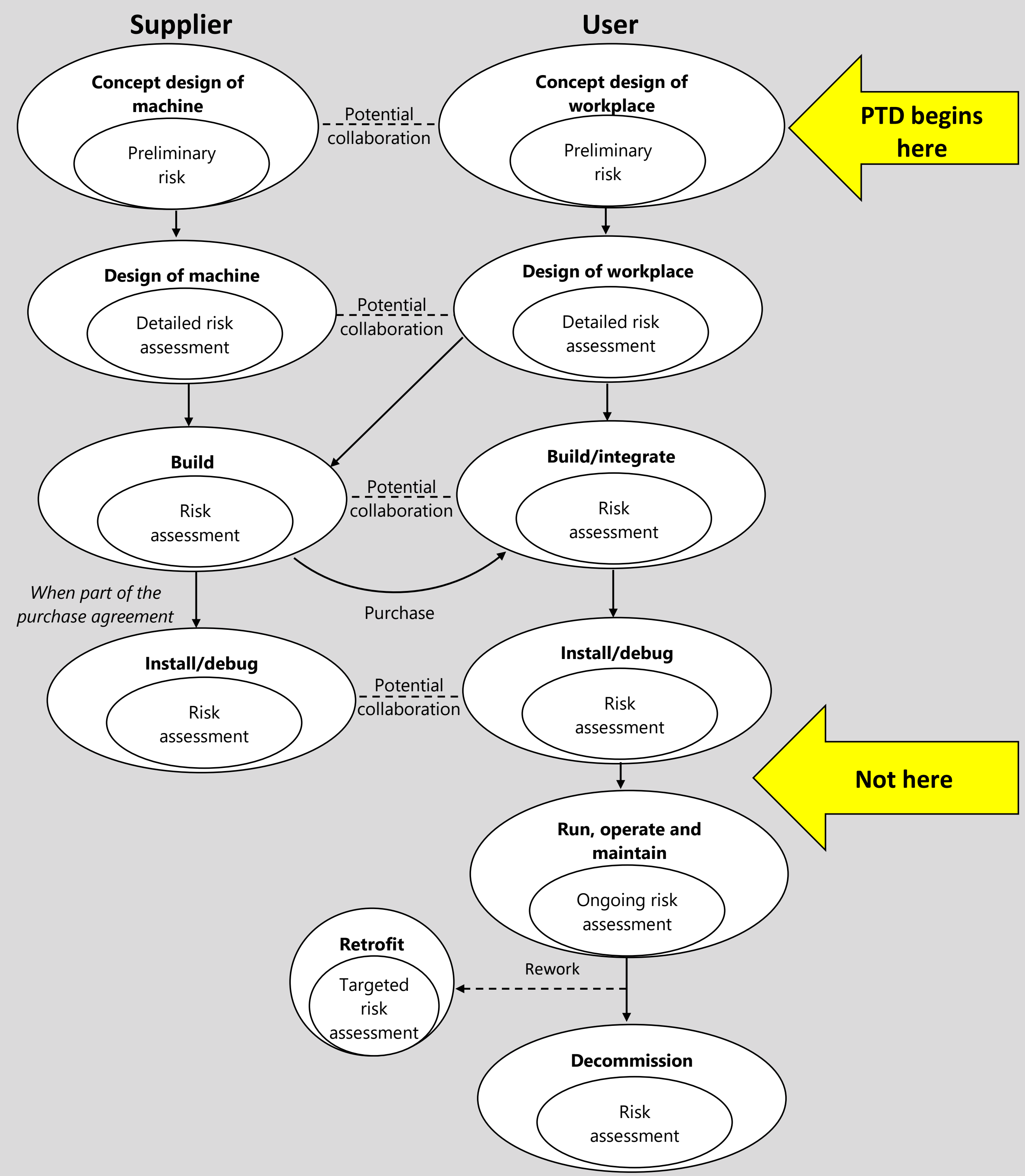
Both ANSI/ASSP Z244.1-2016 (R2020) and ANSI B11.0-2020 provide necessary technical guidance that complements ANSI/ASSP Z590.3. As stated in the foreword to ANSI B11.0-2020:

> The objectives of risk assessment, risk reduction and elimination of hazards as early as possible are integral and not new to this standard. The phrase "prevention through design" is used within the standard, as are other equivalent terms such as "elimination by design," "design out" and "substitution" to thoroughly address risk assessment and apply it to the life cycle and operations of the machine.

Figure 8 provides a visual map for engaging in PTD. When PTD practitioners attempt to retrofit risk-reduction measures for the control of hazardous energy later than the concept and design stage, it should be expected that one will encounter significant extra cost and lead time necessary to make desired changes. Those constraints may well render an engineered risk reduction that was feasible in concept and early design to now be infeasible. PTD takes concerted effort between engineering, supply chain, operations and safety teams working together before new machines and equipment are purchased. This collaboration, along with a firm understanding of OSHA regulation and ANSI standards, will ensure that safety risks and feasible risk mitigation are

FIGURE 8

EXAMPLE OF MACHINERY LIFE CYCLE RESPONSIBILITIES



considered in the earliest stages. PTD takes time, planning and effort, but the dividends are a safer and more efficient operation.

Conclusion

To build safety more efficiently and effectively into machines, lines, processes and other areas, companies should take action during concept and design to:

•Inventory reasonably foreseeable maintenance and servicing tasks and assess those that meet the MSE, require LOTO or require an alternative method to LOTO.

•Design and construct control reliable circuitry that meets ANSI B11.19, Performance Requirements for Risk-Reduction Measures: Safeguarding and Other Means of Reducing Risk, and ANSI B11.26, Functional Safety for Equipment, standards to control hazardous energy before a person is exposed.

•Consider audible or visual systems and delays where necessary so that employees are warned before a machine starts or restarts.

When a situation arises in which LOTO is not feasible (e.g., setup):

• TABRA must be performed to 1. identify steps of the task and exposure to hazards in each step, 2. document the infeasibility of LOTO, and 3. reduce risk to an acceptable level. If the risk level is not acceptable, improve the alternative methods to achieve an acceptable risk level or resort to LOTO.

•Develop and validate the alternative method to LOTO procedure.

To reiterate for emphasis: Neither ANSI, NIOSH nor OSHA reference the terms "zero energy" or "zero mechanical state" in any document.

PTD practitioners can control hazardous energy more effectively during the design phase by better understanding OSHA regulations, ANSI standards, and OSHRC rulings, as well as better recognizing how to use risk assessment and determine feasible risk reduction for alternative methods to LOTO when energy is required for completing a task. PSJ

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