Hazard Recognition

Bridging Knowledge & Competency for Process & Occupational Safety

By Michael Fleming and Brent Fischer

In highly hazardous chemical process facilities, it is critical to bridge workforce hazard recognition knowledge and competency for process safety and OSH. This is important for four reasons:

1) Understanding hazards and risk is essential for the success of process safety as well as OSH.

2) Hazards for both types of risk stem from the same physical origins: a harmful transfer or transformation of energy.

3) Workers are often responsible for making safety decisions that affect both types of risk, sometimes simultaneously.

4) A logical hazard recognition analysis process that bridges these dual risks with knowledge and competency is critical to the safety of workers in a facility as well as the safety of the surrounding community and the environment.

IN BRIEF

- **Hazard recognition is essential for the success of both process safety and OSH. Energy identification coupled with management of potentially harmful energy is the most effective and efficient means of recognizing hazards and preventing incidents.**
- **Workers in highly hazardous chemical processing facilities are faced with the dual risks of process and OSH concerns. The risks in process safety and OSH both stem from the potential for uncontrolled releases and/or unwanted contacts with energy.**
- **Developing workers' knowledge and competency with a simple, logical and universally applicable energy-based hazard recognition thought process is a safety imperative for both process safety and OSH.**

This article focuses on the needs of workers who must deal with both process and occupational hazards in highly hazardous chemical processing facilities. It uses both operators and maintenance workers to represent this industry's overall workers due to their hands-on physical work activities.

To help understand the differences and similarities of process safety and OSH, the following scenario is used for reference throughout the article.

Scenario

A gate valve must be changed on a process line that normally contains a highly flammable and toxic material flowing through the line. The valve is used to control the feed of this material into one of two reactor vessels. A similar valve is located on another line attached to a second reactor. Only one reactor train is in operation at a time. The process is continuous 24 hours a day.

The valve is located approximately 15 ft above the ground in a pipe rack. Many other process lines are positioned immediately underneath the valve. The top portion of the pipe rack frame is just above the valve, making the work area congested and awkward to access. The pipe rack does not have a fixed-access platform or stairs. The valve is normally operated using a chain-fall. The valve will be replaced with a remotely operated valve and, therefore, this project will require a management of change (MOC) procedure.

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Process Safety & OSH

A Worker's Viewpoint

The workforce in highly hazardous chemical process facilities faces the dual risk of catastrophic process incidents, and occupational injuries and illnesses on a daily basis. As workers perform their daily tasks, they rarely distinguish between these two types of risk. Based on the type of task involved, an occupational risk can transform into a process risk. Catastrophic process risk is an obvious occupational risk to the workers directly involved in a job or process that creates the event, and can be a significant danger to other site personnel, the natural environment, the surrounding community and the facility itself.

In effect, distinguishing between these two types of risk is similar to a painter blending the line between two areas of a painting. A blurred effect creates a continuum that connects two parts of a whole image, much like the continuum faced by these workers where the two types of risk can be separated to a degree, yet are inseparable.

The duality of risk these workers face creates a unique type of workforce and requires special attention to the development of their hazard recognition knowledge and competency. Dekker (2006) says, "Systems are not basically safe. People in them have to create safety by tying together the patchwork of technologies, adapting under pressure and acting under uncertainty" (p. 16). In other words, having a reliable thought process to evaluate the system and situation, determine options, select the best option and act (or not act in some cases) is what many people need in the process industry.

Process Safety & OSH Management Systems

A challenge for operators and maintenance personnel is that they must understand, practice and repeat many activities associated with both process and OSH management systems. Certain departments within an organization may focus on advancing one of these two incident prevention areas, but operators and maintenance workers must wear both hats simultaneously every day.

> **Scenario Application 1**
> The maintenance workers who must remove and replace the valve are faced with the risk of a small release of flammable and toxic material to the atmosphere. The leak might come from the residual material in the valve or in the line attached to the valve, which could expose workers on an occupational level. If the line they are working on is not isolated properly, especially on the inlet side of the valve, then the potential exists for a large or continuous release of flammable and toxic material that would constitute both an occupational and process risk.

Often workers must make risk reduction decisions quickly to prevent a process incident and/or an occupational injury or exposure to hazardous chemicals and other workplace hazards. Developing a simple, effective means for workers to efficiently identify and analyze hazards, communicate those hazards and help determine subsequent risk reduction actions with as much certainty as possible is a highly valuable investment.

The Energy Behind Hazards

Energy Release Theory

Haddon (1970) helped establish the principle that energy transfer is a fundamental event occurring in all incidents. His article serves as the fundamental principle for understanding the energy behind hazards.

> More recently, William Haddon proposed the idea that many accidents and injuries involve the transfer of energy. Objects, events or environments interacting with people illustrate this idea: fires, hurricanes, projectiles, motor vehicles, various forms of radiation and other items produce injuries and illnesses of various sorts. The energy theory suggests that quantities of energy, means of energy transfer, and rates of transfer are related to the kind and severity of injuries. Sometimes the theory is called the *energy release theory*, because the rate of release is an important component. This theory is attractive for many safety engineering problems and suggests the ideas for controlling many unsafe conditions. (Brauer, 2006, p. 27)

The energy release theory can be expanded to include the concepts that energy can be transferred and transformed. Harm caused by energy stems from the transfer of energy from one object or human being to another or the transformation of the energy from one form to another. For example, heat can be transferred from a steam line to a worker's arm or chemical energy can be transformed into motion, heat and pressure during a vapor cloud explosion.

> **Scenario Application 2**
> While the workers begin changing the valve, a small release of the toxic material (energy release) could be transferred to their respiratory system by inhalation, creating a harmful health outcome. The same energy released on a larger scale can be transferred by air currents causing the flammable material to reach an ignition source some distance away, resulting in a vapor cloud explosion that in turn creates a thermal and kinetic blast force causing large-scale harm. The procedural protocols required to isolate, de-energize and void the line and valve to prevent a small-scale occupational release of flammable material will help significantly in the prevention of the large-scale process incident. In other words, two levels of risk are associated with the job. The workers will most likely follow a job safety analysis for their task along with other in-facility procedural or permit requirements for process opening.

Most process facilities use an array of job planning tools to prevent occupational and process incidents. These tools include job safety (hazard) analysis, prejob risk assessments, dynamic risk assessments and permit-to-work systems.

Job safety analysis usually focuses on the sequential order of particular tasks be performed, identification of hazards from each job step and a selection of methods to reduce risk while performing the work. While most often used to analyze OSH risks, this tool also has implications for process safety.

Permit-to-work systems comprise multiple situational risk topics, for example: hot work, confined space entry, process opening and blinding, working at heights and ground disturbance. Each topic is partially related to the prevention of incompatible forms of energy coming together in a manner and time that could result in an occupational or process incident. Evidence of identifying or quantifying energy are usually present in check boxes or fields for entry of measured energy levels such as the lower explosive limit of flammable materials for hot work, or temperature and humidity for confined space work. Permits often focus on the general conditions of the work site where specialized work will be performed, and may rely on other tools such as job safety analysis to identify and evaluate task- or job-specific hazards.

Ensuring that the energy and inherent associated risks involved in a process system are fully evaluated, and that the information is captured in safe work procedures (practices), MOC documentation and risk assessment protocols are essential to achieve sustainable incident prevention and support the development of worker hazard recognition competency.

MORT

In the 1960s and early 1970s, U.S. Department of Energy developed and produced the management oversight and risk tree (MORT). The MORT diagram and instruction manual provide a comprehensive incident causation model. MORT was originally published in 1973, revised in 2002 and again in 2009 by the Noordwijk Risk Initiative (NRI) Foundation (Kingston, Koornneef, van den Ruit, et al., 2009).

Figure 1 shows an excerpted view of a critical "and" gate, labeled SA1, in the MORT diagram. Gate SA1 was introduced to the MORT diagram based on Haddon's theory of energy release. Note that the term *accident* is used in the MORT diagram and that this term is synonymous with the term *incident*, which is used throughout this article. The term *people* can include workers and the general public. The term *vulnerable objects* can include the environment and physical assets.

Gate SA1 represents the point at which an incident will occur only if certain elements are present; the incident would not happen if any one of these elements were absent. Haddon's concept of energy exchange is a triad consisting of three elements: 1) presence of a potentially harmful energy flow; 2) exposure of vulnerable people or objects; and 3) the absence of adequate protective controls or barriers. A fourth element includes the activities or events (e.g., job, task, upset condition, process dynamics) that create the physical opportunity for the three energy exchange elements to combine to produce an incident.

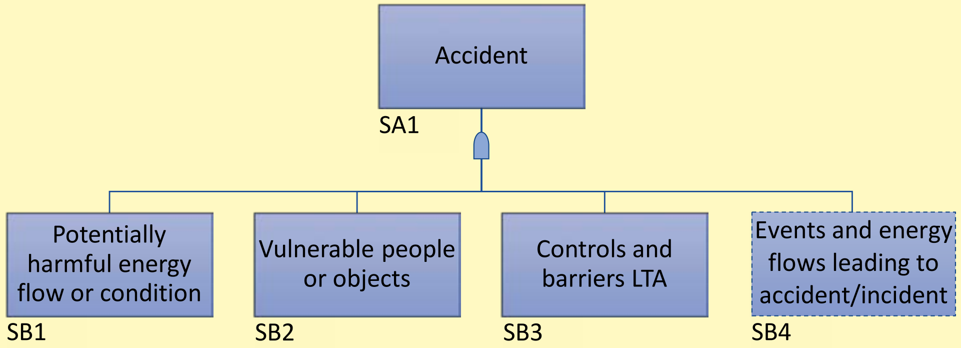
Gate SA1 provides insight into the physical event that takes place in an incident and is the key component of energy-based hazard recognition. While many other factors can influence the possibility of an incident occurring, without the transfer or transformation of energy no physical incident can take place.

Barrier Analysis

One important guide to understand energy-based hazard recognition is barrier analysis. Trost and Nertney (1995) describe the essence of this important guide to the construction of an energy-based hazard recognition and analysis thought process with special attention to the identification of energy sources and the subsequent analysis of hazards and risk.

> Energy is the physical capacity to do work and is, therefore, essential to performance. . . . Of concern here are the phenomena that involve the transfer of energy in such ways and amounts, and at such rapid rates that people could be injured or objects could be damaged. Energy, with its capacity to do damage, is essential to injury of personnel, damage to objects, or process degradation. The management of the harmful effects of energy transfer is a basic preventative approach and involves, among other things, identifying the energy source. The point to be made is that an incident or an accident is an abnormal or unexpected release of energy, and injury or damage could occur. . . . Whenever there is a possibility that persons may come in contact with energy flows that interfere with normal energy exchange, it is necessary to isolate the points of hazard by safely enclosing them or providing other

FIGURE 1
MORT Diagram Gate SA1



Note. *LTA = less than adequate*

FIGURE 2
Energy Icons

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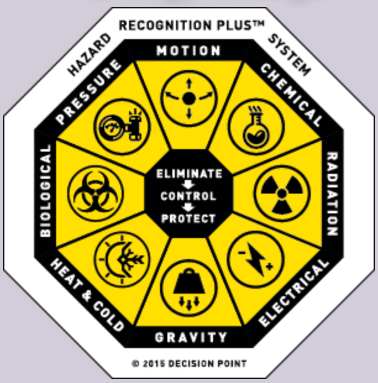
FIGURE 3
HRP Energy Octagon



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barriers to preclude workers from the proximity of the hazard. (Trost & Nertney, 1995, p. 5)

Scenario Application 3

The job steps, including the lockout/tagout/verify procedure to ensure that the valve is isolated and that depressurization of the line and valve is complete, all relate to Gate SA1 (events and energy flows leading to accident/incident) of the MORT. The flammable material under pressure (i.e., chemical and pressure energy) relates to SB1 (potentially harmful energy flow or condition). The workers, plant personnel, surrounding community and the facility itself relate to SB2 (vulnerable people or objects). The permits, lockout/tagout/verify procedures, job safety analysis and other activities undertaken to prevent an uncontrolled release of the flammable material relate to SB3 (controls and barriers LTA).

A Simplified Viewpoint for Workers

Energy-Based Hazard Definition

A common definition of *hazard* is:

> An inherent characteristic of a chemical, a physical condition or an activity that has the potential for causing harm to people, property or the environment. (CCPS, 2012, p. 118)

Considering Haddon's energy release theory, MORT and barrier analysis, a more accurate energy-based definition for *hazard* is:

> The potential for an uncontrolled release of or an unwanted contact with an energy source that can result in harm to people, the environment, assets or company's reputation. (Fleming, 1999)

This definition is derived from the energy release theory and harmful transfer of energy, and is simplified to a worker-oriented viewpoint. Uncontrolled releases of energy and unwanted contacts with energy are directly related to energy release, transfer or transformation, and are more readily understood by a wide variety of people.

Energy in the Workplace

Work is generally understood to be physical or mental effort expended toward accomplishing a goal. In physics, *work* is specifically defined as the transfer of energy from one system to another. Work can also be defined as the controlled release or use of energy to accomplish a task. Operators and maintenance personnel encounter many forms of energy throughout a typical day.

In a complex process, such as a refinery or chemical manufacturing facility, a significant amount of energy is transferred between systems, units and process areas. As with the physical jobs or tasks that workers perform, it is important for them to understand how the energy in a process is used to safely create a desirable outcome.

Identifying Energy

Giving workers a simple and systematic approach to energy identification provides a vital basis for consistent and universal examination of the energy in their respective processes and daily tasks. Using energy identification as a starting point, workers are better equipped to prevent incidents by recognizing hazards as potential events that can occur from the uncontrolled releases of energy or unwanted contacts with energy, then managing the potentially harmful energy.

All people have the potential to make errors, whether from missed subtleties in their view of a job or process operation, lack of knowledge or outright errors. Therefore, a checklist can be a valuable tool. A checklist approach is a simple and powerful method for promptly considering key issues, especially in complex situations (Gawande, 2009).

Although checklists provide standardization for evaluation and inspection activities, OSH professionals must beware of their potential pitfalls. For example, workers might create a habit of simply ticking the necessary boxes before performing a task, rather than actually evaluating the items on the checklist. This may occur with permits as well, especially in operations with a high volume of permitted activities. The mere existence of an issued permit may cause some workers to erroneously assume that all job hazards have been addressed.

Simplifying the world of energy to have an effective platform for hazard recognition, evaluation and determination of energy management techniques to reduce risk is key. The many forms of energy encountered can be simplified so that workers have a set of energy reminders that prompt them to check for and think about the involvement of en-

TABLE 1

Hazards That Can Result From Energy

Eight simple energy categories	Hazard examples in process safety	Hazard examples in OSH
Motion	•Excessively high flow rate of product moving through a pipe •Vibrating equipment that loosens anchors	•Tools slipping or breaking when in use •Swinging suspended load
Chemical	•Leak of flammable liquid and vapors •Pipe corrosion leading to loss of containment	•Low oxygen levels in a confined space •High concentration of H_2S in a work area
Radiation	•Malfunctioning radioactive measuring device for tank level	•Welding light exposure to eyes
Electrical	•Static electricity that ignites flammable chemicals •Loss of electrical power to a facility or part of a process	•Electrical shock when contacting a battery •Contact to exposed wiring on an extension cord
Gravity	•Bromine leak that results in the gas settling on the pad of a loading rack •Heavy lift over live process lines	•Dropped objects from scaffolding •Low-hanging pipe over a walkway
Heat/cold	•Cold fatigue causing metal failure in process valves •Low boiling point chemical storage in a hot environment	•Contact with a hot pipe •Hyperthermia
Biological	•Legionella in cooling towers •Rodents chewing on electrical wires	•Viruses and illness among worker crews •Contact with spiders, bees or wasps
Pressure	•Low-/high-pressure interface during blowdown and cleaning procedures •Venting vessels and tanks to atmosphere due to plugged flare system	•Excessive noise levels •Open-ended valve getting caught on clothing and inadvertently opening

ergy in the processes they work with and the tasks they perform. Figure 2 (p. 55) provides a glimpse of a few icons used to call attention to the presence of certain forms of energy and associated hazards.

Brauer (2006) and CCPS (2010) each list more than 20 different views of energy-based hazards that must be addressed in process safety and OSH. The lists are often repeated in various formats with different headings in safety publications and regulations such as OSHA's (2011) Control of Hazardous Energy standard.

Collectively these sources provide valuable information for engineers and safety professionals. However, the number and complexity of the references can be overwhelming for workers tasked with evaluating the hazards of a particular process plant job. A simplified approach can help workers remember what to evaluate and serves as a prompting guide to ensure that key energy is not missed when evaluating a job or process interface.

An example of a simplified energy reminder is the HRP Energy Octagon (Figure 3, p. 55), which provides workers with eight simple energy categories to consider in hazard evaluation. These eight energy categories represent the types of energy that most workers will encounter. They are universal across all types of industrial operations with variations of energy sources in each category for a given type of job or process within a particular industry.

Using such a tool can simplify the hazard analysis process for workers and improve their competency by providing a reliable prompting tool to think about hazardous energy and combinations of hazardous energy involved in a job or process interface.

Harmful Outcomes

People, objects and events interact with a transfer or transformation of energy to produce harm; this forms the basis for answering the question, "What can go wrong?" posed by the risk-based process safety formula for understanding risk (CCPS, 2007). The same question can be asked in OSH situations. The magnitude of potential harm is the general characteristic that differentiates process hazards from occupational hazards. In many situations a combination of energy sources from one or more energy categories working in sequence or in tandem can produce a harmful outcome.

According to the law of conservation of energy, energy cannot be created or destroyed but it can be transferred or transformed. Workers might find it easier to understand that the energy will go somewhere (transfer) or change form (transform). Understanding more about the different types of energy and how to identify, evaluate and manage energy for safe job outcomes is part of the science of preventing both process safety and OSH-related incidents.

Every incident involves the uncontrolled release of energy or unwanted contact with energy. In all incidents, a flow of energy occurs (either by transfer or transformation) from one place or state to a

TABLE 2

Factors Affecting the Magnitude for Potential Harm

Harm factors	Examples of energy transfer or transformation considerations in process safety	Examples of energy transfer or transformation considerations in OSH
Energy characteristics	•temperature of pressurized gas •reactivity	•decibel level of sound •chemical toxicity
Stored energy	•suspended loads over process lines •compressed gas in a vessel	•contraction of muscles •heat retained in motors after being turned off
Dynamic energy	•chemicals transfer between vessels •temperature rise in reactors	•electrical current in extension cords •rotating equipment
Release direction	•wind direction when gasses are released into the atmosphere	•objects dropped off a scaffold
Multiple energy sources	•incompatible chemical mixture	•human entering a confined space
Lack or loss of energy	•lack of lubrication in a fan's bearing casing causing a fan to heat up and start a fire	•lack of oxygen in a confined space
Route of entry	•incompatible chemicals or air leaking into a process stream	•injection of oil into an arm
Point of contact	•loss of primary containment •corrosive chemical leaking into piping	•chemical irritant on the skin •heavy projectile hitting a person's head
Asset exposures	•airborne chemicals degrading plastic components •sulfide stress cracking in steel due to absorption of H_2S	•repetitive banging that can cause deformation of a catwalk •dragging, rolling, walking resulting in worn, smooth, slippery surfaces
Environmental contamination	•process leak causing toxic materials to be dispersed in the atmosphere •hazardous materials leak that contaminates soil and groundwater	•debris, trash, or garbage produced and left by temporary or permanent operations •excessive noise produced by industrial operations
Duration	•rapid or instantaneous burst of a pressure vessel •slow leak of gas from a container until container is empty	•intermittent exposure to a chemical over a year •continuous contact with the vibration of a machine
Target resilience	•metal thickness and corrosion resistance of process equipment •fire protection coating of structures	•individual body mass and physical conditioning •immune system
Detection of energy using human senses	•smelling or seeing a chemical release from a process line	•seeing a radiation sign and using a protective shield when X-ray equipment is in operation
Nonhuman detection systems	•gas detection for flammable/explosive mixtures	•amperage and voltage meters to measure electricity

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target resulting in harm or, in the case of a near-hit, potential harm to the target. Many factors affect the flow of energy and the resulting harm or potential harm. Predicting the exact combination of energy, harm factors and timing of physical events is the challenge in preventing incidents and managing risk. Workers must be able to predict the outcome of a series of events that can produce loss or harm to targets including people, environment and assets, all of which can ultimately affect a company's reputation.

Table 1 provides examples of the parallels of the eight simple energy categories and examples of hazards represented by each category.

The quantity of energy, and means and rates of energy transfer relate to incident severity (magnitude of potential harm) that forms part of the basis for answering the question, "How bad could it be?" posed by the risk-based process safety formula for understanding risk (CCPS, 2007). In addition, OSH professionals must consider the target resilience upon which the energy acts to determine the level of harmful results. Table 2 lists a range of factors affecting the magnitude for potential harm in both process safety and OSH. The characteristics listed are examples only.

Managing Energy

Managing energy for a safe job outcome requires a deliberate selection of risk elimination or reduction methods before proceeding with the job. In this context, risk is a combination of the probability and severity of a potentially harmful outcome.

Modern incident prevention approaches use a hierarchy of controls to eliminate or reduce risk associated with workplace hazards. *Hierarchy of controls* can be defined as follows:

> A systematic way of thinking and acting, considering steps in a ranked and sequential order, to choose the most effective means of eliminating or reducing hazards and the risks that derive from them. (Manuele, 2008)

It is important for engineers and safety professionals to fully assess the traditional hierarchy of controls when designing equipment applications, processes, facilities and when considering MOC.

TABLE 3

Correlation Between Traditional Hierarchy of Controls & Simplified Energy Management Techniques

Traditional hierarchy of controls		Simplified energy management techniques
Elimination •Inherently safer design **Substitution** •Substitute with a less hazardous material, process, operation or piece of equipment	Increasing effectiveness	**Eliminate** •Complete removal of an energy source or energy sources from a system, piece of equipment or task •Substitution of a hazardous chemical with a nonhazardous chemical
Engineering •Design engineering controls to minimize risk **Warnings** •Use automatic and manual warning systems, signs and labels **Administrative controls** •Provide training, policies, clear work methods, exposure limits and monitoring		**Control** •Energy is still present in the system, equipment or task •Energy is controlled in some manner such as: •adjustments in magnitude (temperature, pressure or volume); •directions of travel or flow; •amount of time that a person is exposed; •access to the energy; •substitution with less hazardous form of an energy source; •other physical and administrative controls.
PPE •Make the proper type of equipment available for the task; ensure that it is easy to use	Decreasing effectiveness	**Protect** •Energy is still present in the system, equipment or task •A protective barrier is provided to block or prevent transfer of the energy from one object to another or to people •The protective barrier could be: •guard; •wall; •distance or orientation to the line-of-fire; •PPE.

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A simplified version of the hierarchy of controls focused on energy management allows for selection of risk reduction options that are more readily available to workers in daily operations, and maintenance activities that are relevant to the hazards involved in the work to be performed. This simplified hierarchy of controls includes three options: 1) eliminate the energy; 2) control the energy; and 3) protect against contact or transfer of the energy. Table 3 shows the correlation between the traditional hierarchy of control models and a simplified energy-based hierarchy of controls.

Scenario Application 4

This scenario has two general risk reduction issues. First, the very nature of the project is to replace a manually operated valve with an automated valve. This should require an MOC procedure. The traditional hierarchy of controls applies to this type of risk evaluation and may even have been initiated by the facility operators. The actual job to change the valve involves managing the energy associated with the task at hand. In this situation, elimination of the flammable material in the line and valve as a preliminary step to opening the process is part of the simplified hierarchy of controls: actions available to the workers. The unit operators likely would use the local permit-to-work system to guide the initial isolation of the valve and line and eliminate the flammable material before the maintenance personnel begin work. Maintenance personnel would need to verify the isolation, then they would be using a combination of energy controls and protective barriers relevant to the task hazards to conduct the actual valve replacement.

Warning Signs: Stop-the-Job Triggers

A key component in hazard recognition is the ability to recognize warning signs and the commitment to act on that recognition to prevent incidents. Much has been written about warning signs in the process industry, including several books by Andrew Hopkins (as cited in CCPS, 2012), who emphasizes the need to address these warning signs:

> Prior to any major accident there are always warning signs which, had they been responded to, would have averted the incident. But they weren't. They were ignored. Very often there is a whole culture of denial operating to suppress these warning signs. (Hopkins, as cited in CCPS, 2012)

Hopkins is referring to many types of warning signs that point to impending process incidents. These warning signs, or stop-the-job triggers, are applicable to process safety and OSH. The relevance of warning signs and stop-the-job triggers is emphasized in the following statement:

> As the events began to unfold that led to the catastrophic incident, the workers failed to recognize one or more of the following three things:
> •the warning signs that a catastrophic event was imminent;
> •the speed at which the event occurred;
> •the potential consequences of the event. (CCPS, 2012)

Table 4 lists some general categories of warning signs (stop-the-job triggers) that must be addressed in highly hazardous chemical process facilities from both process and OSH perspectives. Teaching workers to be aware of both and to act on

TABLE 4

Examples of Process & Occupational Warning Signs

Warning sign/ stop-the-job trigger	Process safety examples	OSH examples
Normalization of deviance	•Alarms that evolve into nuisance alarms •Repeated procedure deviations	•Toxic material flange leak •Shortcuts to access an elevated valve
Culture of denial	•Multiple years without major process incident	•Low personal injury rates over an extended period
Leadership and culture	•Pressure or perceived pressure to work quickly to maintain production •Leaders do not demonstrate positive culture by acting on warning signs to shut down activities	•Pressure/perceived pressure to work quickly to maintain production •"That is what the procedure says, but we do not follow that here"
Training and competency	•Operators passing competency test without full understanding of the process	•Compressed workplace safety training without competency demonstration
Process safety information	•Records lagging facility changes such as MOC	•Operators lacking chemical hazard knowledge
Procedures	•Procedures not matched to reality •Incomplete shift handover	•Generic maintenance procedures •Operators unfamiliar with procedures
Asset integrity	•Run to failure philosophy •Bypassed alarms	•High frequency of leaks •Safety systems circumvented
Risk analysis and MOC	•Inadequate process hazard analysis system •Lack of hazard analysis follow-up •Management of change items left incomplete	•Inadequate job hazard analysis system •Prejob hazard analysis treated as "permission to go to work paper" and lacks real worker engagement
Audits	•Goal of audit is high performance (causing skewed or misleading findings)	•Audit findings not communicated to affected workers
Learning from experience	•Frequent spills/releases without correction •Failure to self-report process near-hits or challenges	•Spills and releases are viewed as common occurrence •Incident findings unclear or not communicated to affected workers
Physical warning signs	•Odors detected •Abnormal vibration of equipment •Loose bolts and equipment anchors	•Odors detected •Pressure relief valves frequently relieving •Plugged vent lines

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them when they are realized is one key to improve incident prevention in process facilities. The key to success is worker situational awareness to be able to detect stop-the-job triggers, and have the competency to decide clearly and act swiftly to prevent incidents.

A key to success in incident prevention is knowing when things are not going right. While this is challenging, it can be achieved if workers are prepared with stop-the-job triggers based on knowing what energy is involved, what to expect from the energy and how to determine whether the energy involved is about to transfer or transform in an uncontrolled or unwanted manner. This is the essence of developing energy-based hazard recognition competency and equipping people with the knowledge to perform work safely.

Energy Detection

Workers must rely on their knowledge and experience to search for clues about workplace hazards either through situational awareness or through formal hazard assessments. Human brains receive sensory information and identify the presence of energy sources based on knowledge and experience. So, workers must also use their five physiological senses (i.e., sight, hearing, touch, smell, taste) to detect energy source clues in their surroundings. Using human senses is key to evaluating a job, task, job site and environment before performing work. These senses are equally important to help workers detect the presence of energy sources, changes in energy sources and introduction of unexpected energy sources that could cause harm while work is being performed. Remember that workers can be at risk for harmful exposure to energy sources whether they are using their senses actively or passively.

As CCPS (2010) says, "Sensory detection is not a substitute for established hazard detection and control measures" (p. 46). In highly hazardous chemical process facilities, many forms of energy detection equipment and systems are used to provide early warning to prevent exposure to people or indicate the possibility of a catastrophic event. In some cases, humans may not be able to detect a certain form of energy, so the mechanical detection systems become an important safeguard. Motion detectors, chemical sensors, vibration sensors and temperature gauges are examples of systems a facility can implement to recognize energy sources and warn workers of the presence or change in state of energy before workers are exposed or a process risk escalates.

A Worker-Oriented Hazard Recognition Thought Process

Five Important Questions

Understanding hazards from an energy-based point of view creates an opportunity to develop hazard recognition knowledge and competency of workers in unique dual-risk workplaces. The framework is a simple, logical and universally applicable hazard recognition thought process. *Simple* means it is easy to remember and use. *Logical* means it follows a reliable structure to identify and evaluate hazards. *Universal* means it can be applied to any job, any process, any industry, in any environment, and can be used for both process and occupational hazards.

Such a process can be represented by five questions (Fleming, 1999) that can help workers recognize, evaluate and manage hazards for a safe job outcome:

1) What is the job?
2) What energy is involved?
3) Where is the energy going?
4) How will we manage the energy for a safe job?
5) What are the specific stop-the-job triggers?

The answers to these questions are the key to accurately identifying hazards and determining the harm posed by the hazards, and they provide a basis for formulating risk reduction options. Whether ascending a ladder, repairing a pump, or manipulating the flow, temperature and pressure of highly volatile chemicals within a process, the hazard recognition thought process is the same.

Scenario Application 5

In the scenario, the five questions have relevance. If the work were conducted on a hot, humid day with bright sunlight, the environment would present energy factors to consider. Bird droppings on the valve present a biologic energy issue. Use of a pneumatic wrench would introduce further considerations.

Note: The following question responses are examples only. If this job were to be fully evaluated, additional considerations would be required for each question.

Question 1: What is the job?

The job, initiated by an MOC requirement, is to replace a valve on an elevated line in a congested work area. It will require a permit for operations personnel to isolate the valve and for maintenance personnel to access the area to perform the work. A detailed job safety analysis, with job steps, and permits will be required.

Question 2: What energy is involved?

•Motion: material flow in the line and through the valve, movement of personnel to access the valve, hoisting of the valve to remove from the area;

•Chemical: the flammable material (would require SDS information);

•Radiation: bright sunlight (could present glare issues);

•Electrical: none for the valve replacement until the electrical controls are installed and activated;

•Gravity: working at heights;

•Heat/cold: hot/humid day;

•Biological: bird droppings;

•Pressure: pressure in the line and valve, pressure in the pneumatic tool, pressure points for workers' feet and hands, and noise from surrounding process equipment.

Question 3: Where is the energy going?

If the valve and line are not isolated, depressurized and purged, then the chemical can be released under pressure and affect the workers and possibly the facility. Working at heights presents possible falls, dropped objects (tools) and the risk of dropping the valve onto a live process line. The pneumatic wrench poses possibilities of a hose leak or rupture resulting in a whipping motion of the hose that could hit workers. The heat of the day presents heat stress issues for workers, and bird droppings present a potential biological hazard.

Question 4: How will we manage the energy for a safe job?

•Eliminate: Eliminate the chemical and pressure in the line via energy isolation, often called lockout/tagout/verify. This may require the operators to isolate and divert the line contents to a flare or other portion of the process. Steps to ensure that all isolation valves are closed, depressurization and line draining are complete, and, in some locations, installation of blinds to block the inlet and outlet lines may be required. A risk assessment may require the process lines below the valve to be shut down and isolated.

•Control: Control of the gravity using a scaffold, fall protection and parts containment would be required. A lift plan may be required along with safety measures for a crane if used. A whipcheck or hose restraint for the pneumatic hose to control motion in the event of a hose break would be required, along with inspection of the pneumatic hose and nozzle prior to start. Cleaning work surfaces would be required to remove bird droppings.

•Protect: Protective barriers include a drop-zone below the work point for gravity issues, respirators matched to the chemical, gloves and protective outerwear for workers. Additional protective barriers in the form of shields or platforms may be required to prevent the valve or other objects from landing on the process lines below.

Question 5: What are the specific stop-the-job triggers?

If energy isolation of the valve cannot be verified the job must be stopped until all verifications are positive. Anyone entering the drop zone, scaffolding irregularities, crane misalignment with vertical lift point, respirators and gloves are not available, and pneumatic hose line or nozzle in poor condition are examples of stop-the-job triggers.

Conclusion & Challenge

Building Worker Hazard Recognition Knowledge & Competency

Three levels of training help build worker hazard recognition knowledge and competency:

1) hazard recognition fundamentals;
2) job-specific training;
3) practice hazard recognition.

Hazard Recognition Fundamentals

Hazard recognition fundamentals should include:

•energy-based hazard definition;
•logic to understand how physical incidents occur;
•energy forms in the process and work environment;
•incompatible energy forms in the process and work environment;
•previously identified process and occupational energy-based hazards;
•methods to detect the presence and changes in state of energy;
•factors that influence the magnitude of potential harm;
•energy management techniques to prevent incidents;
•stop-the-job triggers (and associated process safety warning signs).

Job-Specific Training

All workers should be provided training relevant to the known or previously identified hazards within their work area or within the scope of work they may perform. Evaluating previously identified hazards to determine the types of energy involved, how the potential for an uncontrolled release of or unwanted contact with energy can cause harm, and clarifying the best energy management techniques to achieve a safe job outcome can provide excellent incident prevention learning opportunities. Integrating energy-based hazard knowledge of process and OSH risks into facility documentation including risk assessments, process hazard analyses, MOC, job safety analysis and other related process safety management tools will support worker competency during the training process.

Practice Hazard Recognition

People who practice an activity usually become more proficient at that activity. Practicing energy-based hazard recognition in support of existing process safety and OSH management system activities is an excellent way to begin developing hazard recognition competency. Feedback for workers and evaluation of the hazard recognition process is vital to ensure that workers learn the process properly to gain competency. **PS**

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