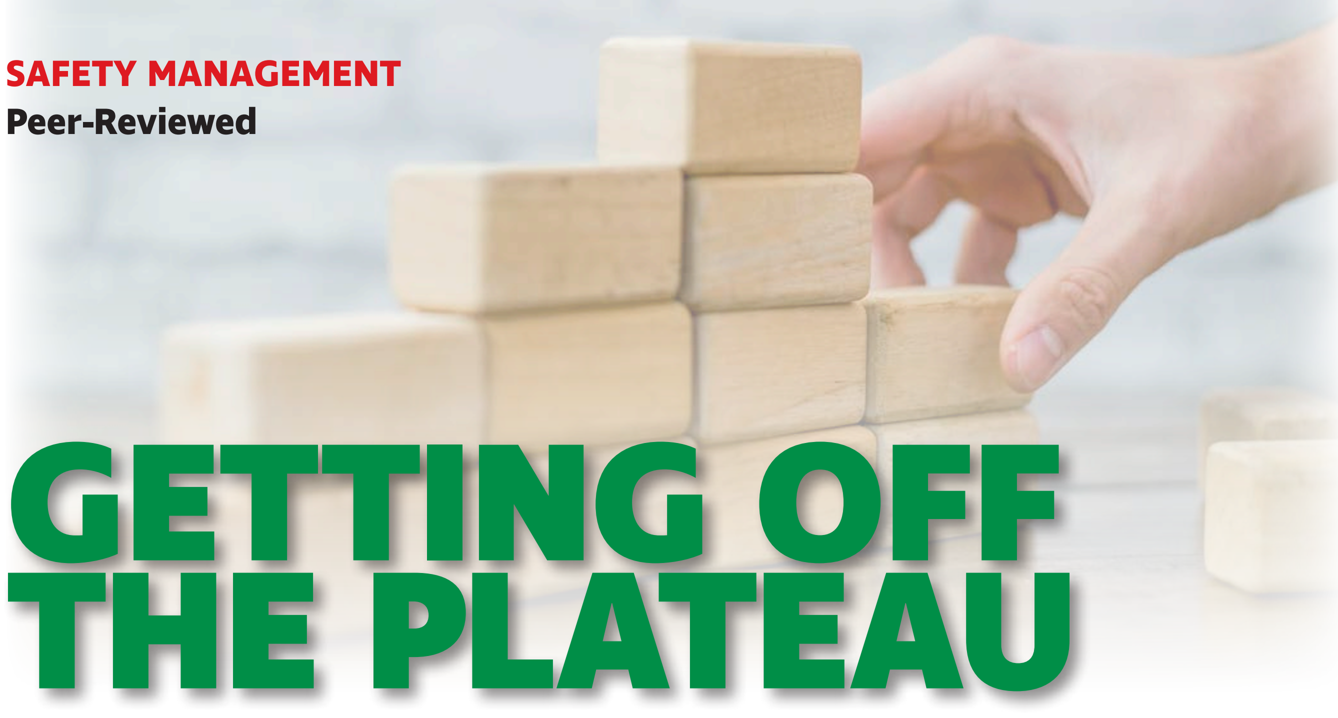
SAFETY MANAGEMENT

Peer-Reviewed



GETTING OFF THE PLATEAU

How to Improve Results

By Fred A. Manuele

THE REDUCTIONS IN THE NUMBER OF FATALITIES and the fatality rates from 1971 through 2016, as shown in the following statistical exhibits, are truly commendable. Those reductions occurred while employment increased 78%. But it is also plain to see that in the most recent 6 years, both the numbers of fatalities and the fatality rates are statistically in a very narrow range.

Relative & Supporting Statistics

Tables 1 through 5 display the significance of the incident reductions achieved over many years.

Although an increase in the number of fatalities and the fatality rate occurred in 2016, as shown in Table 1, safety practitioners should avoid suggesting that the trend itself is a major indicator. Fatality rates for the past 6 years have varied from 3.3 to 3.6, which is not statistically a large spread.

Also, safety practitioners should be particularly aware of the trend experienced by the organizations they advise and of the trend for their industry. Bureau of Labor Statistics (BLS) data for manufacturing are indicative; while the number of fatalities and the fatality rate were lower in 2016, the trend for the past 6 years is within a narrow range and may be considered as having plateaued.

As Table 3 shows, clearly a significant reduction occurred in the percent of lost workday cases for incidents resulting in less-severe injuries, from 1 day through 6 to 10 days. More serious injuries, from 21 to 30 through 31 or more days, are a larger share of the remaining total. Safety practitioners should be attentive to the signal in the 62% increase in cases resulting in 31 or more days of lost time.

Overall, the reductions achieved in employee injuries and illnesses in the recent past are also stellar. In the National Council on Compensation Insurance (NCCI) publication "2015 State of the Line," Kathy Antonello, chief actuary, notes, "Workers' compensation claim frequencies have dropped more than 50% over the last 20 years."

NCCI has issued several bulletins indicating that while claims frequencies have been reduced, the reductions are more prominent for injuries of lesser severity. Tables 4 and 5 (p. 52) support such statements.

Although the trending of incident rates for days-away-from-work, job transfer or restriction cases (the subject of Table 4) is not the best indicator of trending for serious injuries, incident data indicate that claims experience in recent years has also been in a very narrow range and, therefore, also may have plateaued.

KEY TAKEAWAYS

- **Data plainly indicate that the number of workplace fatalities and fatality rates have decreased significantly. But, statistics on fatalities for the past several years are in a narrow range. While serious injuries have also been reduced, they have become a larger percentage of workers' compensation claims. For both serious injuries and fatalities, stellar achievements seem to have plateaued.**
- **Results are such that safety practitioners should reassess the bases for the advice they provide decision makers and determine whether they should adjust that advice to further reduce the occurrence of serious injuries and fatalities. This article offers guidance to that purpose.**

Implications

What are the implications of these statistics? Accomplishments in reducing injury and fatality experience are commendable and should be recognized. But for management to continue that improvement, to get off the plateau, changes in the content and focus of their safety management systems are necessary. If management keeps doing what it has been doing, quite probably the plateaued experience will continue.

And how can safety practitioners help the organizations they advise to determine what changes in operational risk management systems should be undertaken? The following list includes suggested actions pertaining to this author's experience.

Actions to Be Considered by Safety Practitioners

Safety practitioners should:

1) Study the principles on which their practice is based to determine what is sound and not sound. Ask whether it is time to recognize evolving principles and practices.

2) Convince management that having good OSHA-type incident rates is not necessarily an indication that barriers and controls are adequate with respect to preventing serious injuries and fatalities.

FATCAMERA/E+/GETTY IMAGES

3) Convince management of the inappropriateness of Heinrich's principle that 88% of occupational incidents are caused by employee unsafe acts.

4) Persuade decision makers that, as the statistics noted indicate, focusing on reducing incident frequency may not result in an equivalent reduction in serious injuries.

5) Be aware of the changes in approach that have taken place in some circles with respect to addressing human errors/unsafe acts.

6) Appreciate the importance of barriers in safety management.

7) Encourage all engineers to recognize that they are also safety engineers and that they should be adept in making risk assessments both in original designs and in alterations.

8) Recognize the need to seek out hazards, risks and deficiencies in safety management systems.

9) Understand that the most important elements in an operational risk management system are the leadership, commitment and involvement, and the resulting culture that derives from the decisions made by the board of directors and senior management.

10) Promote identifying potential problems through performing risk assessments.

11) Recognize the benefits of applying prevention through design principles.

12) Appreciate the benefits of having an effective management of change (MOC) system in place.

13) Support the importance of a well-managed permit system.

14) Analyze the incident investigation system in place and propose improvements as necessary.

Particularly for the first five items, many safety practitioners must make significant changes in the bases for the advice they give. Safety initiatives, whatever their names, will not be sufficiently effective if they concentrate principally on what employees do or do not do, or on why their actions and inactions seemed reasonable at the time, rather than focusing on eliminating the shortcomings in the systems in which people work.

For emphasis, these subjects pertain to this author's experience, specifically with respect to having reviewed more than 1,900 incident investigation reports. This list is not meant to be all inclusive. Other safety professionals may cite other measures to be taken.

Evolving Knowledge & Principles

As the practice of safety has evolved over the past 60 years, some safety practitioners who sought beneficial effects from what they proposed have revised their views about what was or was not solid thinking as analyses were made. Safety practitioners should ask whether it is appropriate to recognize the evolving principles and practices. This author went through such an experience.

Into the 1960s, the author was a devoted advocate of Heinrich's (1959) principles. Heinrich wrote that 88% of occupational accidents were caused by employee unsafe acts and that focusing on reducing incident frequency would result in an equivalent reduction in serious injuries.

Studies commenced in the late 1960s showed that neither premise could be upheld (Manuele, 2011). When trying to assist management in preventing back injuries, it was common practice to run training programs for workers on how to lift safely. But, analyses showed that such training did not measurably reduce back injuries.

TABLE 1

NUMBER OF FATALITIES & RATES, U.S.

Year	No. of fatalities	Fatality rate	No. of workers (million)
1971	13,700	17.0	81
1991	9,800	8.0	96
2001	5,900	4.3	137
2011	4,693	3.5	134
2012	4,628	3.4	136
2013	4,585	3.3	139
2014	4,821	3.4	142
2015	4,836	3.4	142
2016	5,190	3.6	144

Note. Fatality rate is the number of fatalities per 100,000 equivalent full-time employees. Data from "Accidents Facts," by NSC, 1995, and "Census of Fatal Occupational Injuries: Current and Revised Data," by BLS, 2018.

TABLE 2

NUMBER OF FATALITIES & RATES, MANUFACTURING

Year	No. of fatalities	Fatality rate	No. of workers (million)
2016	318	2.0	15.9
2015	353	2.3	15.3
2014	341	2.2	15.5
2013	304	2.0	15.2
2012	314	2.1	15.0
2011	322	2.2	14.6

Note. Fatality rate is the number of fatalities per 100,000 equivalent full-time employees. Data from "Accidents Facts," by NSC, 1995, and "Census of Fatal Occupational Injuries: Current and Revised Data," by BLS, 2018.

TABLE 3

PERCENT OF DAYS-AWAY-FROM-WORK CASES, PRIVATE INDUSTRY TREND

	1 day	2 days	3 to 5 days	6 to 10 days	11 to 20 days	21 to 30 days	31 or more days
1995	16.9	13.4	20.9	13.4	11.3	6.2	17.9
2014	13.9	10.7	17.1	11.8	11.3	6.3	29.0
% change	-17.8	-20.1	-18.2	-1.2	0.0	+0.2	+62.0

Note. Data from "Lost-Worktime Injuries or Illnesses: Characteristics and Resulting Time Away From Work, 1995," Table 7, by BLS, 1996, Washington, DC: Author; and "Nonfatal Occupational Injuries and Illnesses Requiring Days Away From Work, 2014," Table 9, by BLS, 2015, Washington, DC: Author.

TABLE 4
TRENDING OF LESS SERIOUS & MORE SERIOUS INJURIES, 2005-2009

After adjusting for inflation, the higher size ranges exhibit successively smaller declines.

Size of loss	Frequency change
Less than 2k	-25%
2k to 10k	-22%
10k to 50k	-20%
50k to 250k	-14%
250k and more	-9%

Note. Adapted from "Workers' Compensation Claim Frequency, 2011," Exhibit 20, by NCCI, 2011, Boca Raton, FL: Author.

TABLE 5
TRENDING OF INCIDENT RATES FOR NONFATAL DAFW, JOB TRANSFER OR RESTRICTION CASES, PRIVATE INDUSTRY

Year	Total incident rate, all categories combined
2013	1.7
2014	1.7
2015	1.6

Note. Data from "Employer-Reported Workplace Injuries and Illnesses," Table 7, by BLS, 2015, Washington, DC: Author.

Having visited several locations that had reported back injuries, it became obvious that the design of the workplace and the work methods were the problem. Often, a large percentage of the work population was required to handle excessive workloads as they did what they were expected to do.

Studies of the causes of back injuries led, progressively, into ergonomics, risk assessments, prevention through design, serious injury and fatality prevention, inadequacies in incident investigation and the benefit of having a sociotechnical workplace in which the technical aspects of the work and the social aspects are well balanced.

Over time, several writers influenced the author's evolving thought process. Chapanis (1980), prominent in ergonomics, coined the phrase *error-provocative*. His position was that if the workplace is designed to be error-provocative, it is nearly certain that errors will occur.

Ergonomics is design based, as is all of safety. Having become involved in ergonomics, it was easy to be a promoter of safety practitioners becoming participants in the design of the workplace and work methods.

Deming (1982), world renowned in quality management, proposed quality achievement principles that also applied to safety, such as to achieve superior (safety) quality, requires designing a system in which talented people can achieve superior (safety) quality. It became clear that the overall principles to be applied to achieve superior quality were the same as those needed to achieve superior safety.

Influential work of other authors includes Hammer's (1972) *Handbook of System and Product Safety*, several notable texts by Kletz (1991), such as *An Engineer's View of Human Error*, the Center for Chemical Process Safety (CCPS, 1994) publication, *Guidelines for Preventing Human Error in Process Safety*. Johnson's (1980) *MORT Safety Assurance Systems* is still referenced, as is U.S. Department of Energy's (DOE, 1992) MORT User's Manual.

As will be evident in the remainder of this article, the writings of many other more recent authors have also been influential as this author's concepts of operational risk management evolved.

Having Good OSHA-Type Rates: A Possible Deceiver

The OSH community is slowly recognizing that having good OSHA-type incident rates may not indicate that adequate controls and barriers are in place to prevent serious injuries and fatalities, and particularly to prevent major occurrences in the low probability/serious consequence category.

Nevertheless, many companies that have achieved stellar OSHA-type statistics occasionally experience serious injuries and fatalities. Relative to this subject, a case is made in CSB's (2016) final report on an explosion and fire that occurred on April 20, 2010, at the Macondo *Deepwater Horizon* rig in the Gulf of Mexico. That incident resulted in 11 fatalities, 17 injuries and extensive environmental damage. BP and Transocean were the two principal operators. Both companies celebrated their good OSHA-type incident rates while decisions made in operations resulted in an accumulation of hazardous conditions and practices, and the event occurred.

Management should be made aware that having good incident rates may be deceptive with respect to the adequacy of controls and barriers to avoid the occurrence of serious injuries and fatalities, and that focusing on incident frequency reduction may not result in an equivalent reduction in the incidents that result in serious injuries.

On Heinrich's Principles: Focusing on Unsafe Acts & Incident Frequency

Heinrich's 88-10-2 Ratios

H.W. Heinrich has had more influence on the practice of safety than any other author. His premises have been adopted as certainty by many safety practitioners. They permeate the safety literature. Four editions of his book *Industrial Accident Prevention* were printed, the last in 1959. Some of Heinrich's premises are questionable.

Heinrich's (1959) 88-10-2 ratios indicate that among the direct and proximate occupational incident causes, 88% are unsafe acts, 10% are unsafe mechanical or physical conditions, and 2% are unpreventable.

Current causation knowledge indicates that premise is invalid. Heinrich's 88-10-2 premise conflicts with the work of others, such as Deming (1982), whose research finds that root causes derive from shortcomings in management systems. Among all of Heinrich's premises, application of the 88-10-2 ratios has had the most significant impact on the practice of safety, and has also done the most harm, since the ratios promote focusing preventive initiatives on worker performance rather than on improving the operating system.

Those who continue to promote the idea that 88% of all occupational incidents are caused primarily by the unsafe acts of persons do the world a disservice. Safety practitioners must convince management of the inappropriateness of Heinrich's 88-10-2 principle.

Heinrich's Emphasis on Frequency

Heinrich's (1959) often-stated belief that the predominant causes of no-injury incidents are identical to the predominant causes of incidents resulting in major injuries is not supported by convincing statistical evidence. Application of the premise results in misdirection since those who apply it may presume, inappropriately, that if they concentrate on reducing the types of incidents that occur frequently, the potential for severe injury will also be addressed.

Heinrich's (1959) premise derives from his Foundation of a Major Injury, the 300-29-1 ratios (Heinrich's triangle). His premise is:

> Analysis proves that for every mishap resulting in an injury there are many other accidents in industry which cause no injuries whatever. From data now available concerning the frequency of potential-injury accidents, it is estimated that in a unit group of 330 accidents, 300 result in no injuries, 29 in minor injuries and 1 in a major or lost-time case. (p. 26)

Conclusions pertaining to the 300-29-1 ratios were revised from one edition to the next, without explanation, thus presenting questions about which, if any, version is valid. It is impossible to conceive of incident data being gathered through the usual reporting methods in which 10 out of 11 reports would pertain to incidents that resulted in no injury.

Investigation of numerous incidents resulting in fatality or serious injury by modern-day safety professionals leads to the conclusion that their causal factors are different and that they may not be linked to the causal factors for incidents that occur frequently and result in minor injury.

Safety practitioners must persuade decision makers that, as the statistics noted indicate, focusing on reducing incident frequency may not result in an equivalent reduction in serious injuries.

Consideration of Unsafe Acts: Human Errors, a Different Approach

Reason (1990) says that latent failures may not be immediately apparent but can serve both to promote unsafe acts and to weaken defense (barrier) systems. Reason was somewhat sympathetic to the person who allegedly committed an unsafe act that was considered the causal factor to an incident. Importantly, he wrote that "preconditions or psychological precursors are *latent* states [emphasis added]. They create the potential for a wide variety of unsafe acts" (p. 205).

Dekker (2006) supports Reason's view about employee unsafe acts being influenced by the latent conditions and practices that have developed in an organization over time.

When the causal factor for an incident is identified as an employee unsafe act, actions typically taken are retraining, reposting the written standard operating procedure, or holding a group meeting wherein the unsafe act is reviewed and the correct way to do the job is discussed.

Dekker, and others, soundly propose that a different approach be taken when errors (unsafe acts) occur. A few excerpts from Dekker (2006) follow:

> If you want to understand human error, you have to assume that people were doing reasonable things given the complexities, dilemmas, trade-offs and uncertainty that surrounds them. Just finding and highlighting mistakes people make explains nothing. Saying what people did not do, or what they should have done does not explain why they did what they did. (p. 13)
>
> Human error is not a cause of failure. Human error is the effect, or symptom, of deeper trouble. Human error is not random. It is systematically connected to features of people's tools, tasks and operating systems. *Human error is not the conclusion of an investigation. It is the starting point* [emphasis added]. (p. 15)
>
> Sources of error are structural, not personal. If you want to understand human error, you have to dig into the system in which people work. You have to stop looking for people's shortcomings. (p. 17)

Important in the professional practice of safety, Dekker's comment bears repeating: "If you want to understand human error, you have to dig into the system in which people work" (p. 17). If you dig into the system in which people work, it is logical as the digging takes place to explore the decision making that resulted in barriers being nonexistent, inadequate or disengaged.

Reason (2006) implied similarly that employees are exposed to that which management creates through its decision making and, thus, the focus in the practice of safety should be improving the work system to have sufficient and effective barriers.

> Rather than being the main instigators of an incident, operators tend to be the inheritors of system defects created by poor design, incorrect installation, faulty maintenance and bad management decisions. Their part is usually that of adding the final garnish to a lethal brew whose ingredients have already been long in the cooking. (p. 173)

Reason may have exaggerated slightly. But, what does all this mean? In the practice of safety, the emphasis is slowly moving away from trying to change the behavior of workers, which, for some time, was the emphasis of many safety practitioners, toward reducing operational risks through digging "into the system in which people work" and promoting prevention in the design processes, and the existence of adequate physical and administrative barriers.

Reason (1997) is strong on reducing the risks in the workplace rather than to trying to change how people think. He says:

> Workplaces and organizations are easier to manage than the minds of individual workers. You cannot change the human condition, but you can change the conditions under which people work. In short, the solutions to most human performance problems are technical rather than psychological. (p. 223)

CCPS's (1994) *Guidelines for Preventing Human Error in Process Safety* is an excellent reference on human error prevention. Although it was written for the process industry, the following excerpts are generic. They advise on where human errors occur, who commits them and at what levels, the influence of organizational culture and where attention is needed to reduce the occurrence of human errors.

Safety practitioners should seriously consider the following statements and relate them to the premises on which their work is based:

> •It is readily acknowledged that human errors at the operational level are a primary contributor to the failure of systems. It is often not recognized, however,

> that these errors frequently arise from failures at the management, design or technical expert levels of the company. (p. xiii)
>
> •A systems perspective is taken that views error as a natural consequence of a mismatch between human capabilities and demands, and an inappropriate organizational culture. From this perspective, the factors that directly influence error are ultimately controllable by management. (p. 3)
>
> •Almost all major accident investigations in recent years have shown that human error was a significant causal factor at the level of design, operations, maintenance or the management process. (p. 5)
>
> •One central principle presented in this book is the need to consider the organizational factors that create the preconditions for errors, as well as the immediate causes. (p. 5)

Note particularly that "failures [were] at the management, design or technical expert levels of the company" and that "human error was a significant causal factor at the level of design, operations, maintenance or the management process." Those failures and human errors affect the design of the workplace and the work methods: the operating system.

Thus, it is reasonable to suggest that the focus in the practice of safety should be on improving the operating system by stressing prevention through design and the need for adequate and effective barriers so that acceptable risk levels can be achieved and maintained.

Also, with respect to human error (the unsafe act) attention must be given specifically to "the organizational factors that create the preconditions for errors." Then, in the design process, attempts would be made to anticipate and avoid "preconditions for error." That calls for including the necessary barriers.

Barriers Defined

What is a barrier? Hollnagel's (2004) writings on barriers are extensive and informative. They prompted this author to refresh his knowledge and history with respect to barriers. Hollnagel says:

> An accident can be described as one or more barriers that have failed, even though the failure of a barrier only rarely is a cause in itself. A barrier is, generally speaking, an obstacle, an obstruction or a hindrance that may either:
>
> 1) prevent an event from taking place, or
>
> 2) thwart or lessen the impact of the consequences if it happens nonetheless.
>
> In the former case the purpose of the barrier is to make it impossible for a specific action or event to occur. In the latter case the barrier serves, for instance, to slow down uncontrolled releases of matter and energy, to limit the reach of the consequences or to weaken them in other ways. (p. 68)

Hollnagel's comments on barriers can be highly influential for safety practitioners who seek more precise knowledge about how accidents happen. To paraphrase Hollnagel, an accident happens because of the failures of one or more barriers. Think about that premise.

When Hollnagel says that "failure of a barrier only rarely is a cause in itself," the implication is that the failure probably results from deficiencies in the relative management systems.

Stephans (2004) gives a rather broad definition of barriers. And his definition is considered appropriate:

> Barrier: Anything used to control, prevent or impede energy flows. Types of barriers include physical, equipment design, warning devices, procedures and work processes, knowledge and skills, and supervision. Barriers may be control or safety barriers or act as both. (p. 357)

Noordwijk Risk Initiative Foundation's (NRI, 2009) MORT User's Manual jointly considers definitions of barriers and controls:

> [In this Manual], the barriers and controls branch considers whether adequate barriers and controls were in place to prevent vulnerable persons and objects from being exposed to harmful energy flows and/or environmental conditions. (p. 5)

Analyzing for the adequacy or inadequacy of barriers and controls is particularly significant in applying the MORT system. NRI's coverage of the subject is extensive, as is DOE's (1992). The MORT system may have been the first to emphasize the necessity of having adequate barriers (for more on MORT, see Hollnagel, 2004, p. 79).

Barriers are not exclusively physical. They may include, as Stephans (2004) says, aspects such as having a qualified staff, training, supervision, appropriate procedures, maintenance, communications and more.

Hollnagel (1999) also published a briefer reference, "Accidents and Barriers" that safety practitioners may find interesting. CGE Risk Management Solutions (2017) has an interesting dissertation on barrier types, barrier functions and barrier systems, which takes a slightly different approach. Haddon's (1970) unwanted energy release theory is cited as one of the first categorizations of barrier function.

Safety practitioners and decision makers should appreciate the importance of barriers in safety management.

All Engineers Are Also Safety Engineers

Why encourage all engineers to recognize that they are also safety engineers and that they become adept in making risk assessments? For two reasons:

1) Over many years, as engineers and designers continued to improve facilities and work systems, their reductions of hazards and risks had a major impact on the decreases in fatalities and fatality rates, and in serious injuries, although they may not be aware of it;

2) They should understand that the decisions they make in the design and redesign processes have a major influence on the safety of an operation.

How significant can the decisions made by engineers and designers be? Stephenson (1991) writes and Stephans (2004) repeats: "The safety of an operation is determined long before the people, procedures, and plant and hardware come together at the work site to perform a given task."

Thousands of safety-related decisions are made by engineers in their day-to-day design and redesign work. Usually, those decisions meet (or exceed) applicable safety-related codes and standards with respect to, for example: the contour of exterior grounds; sidewalks and parking lots; building foundations; facility layout and configuration; floor materials; roof supports; process selection and design; determination of the work methods; aisle spacing; traffic flow; hardware; equipment; tooling; materials to be used; energy choices and controls; lighting, heating and ventilation; fire protection; and environmental concerns.

Decisions made by designers establish what they implicitly believe to be acceptable risk levels. Why encourage all engineers to recognize that they are also safety engineers? Doing so would result in their recognizing the impact that their decisions have on whether risks are acceptable. If designers recognize that their decisions have a major influence on the existence or absence of operational hazards, there will be fewer hazards for which expensive retrofitting is necessary.

Ideally engineers would say, as they sign off on plans for new or altered facilities and systems, that they have given the proper attention to avoiding serious injuries and fatalities, and the occurrence of low probability/serious consequence events.

Fundamentals: Hazards, Risks & Management System Deficiencies

While the ANSI/ASSP Z10-2012 (R2017), Occupational Health and Safety Management Systems standard is recommended in its entirety, it is cited here because it contains a particularly basic and sound premise. In the standard, safety and health issues are defined as "hazards, risks and management system deficiencies" (p. 9). That is a seminal definition. It is basic in the practice of safety.

If there are no hazards, no potential for harm, incidents cannot occur. And if there are no hazards, there will be no risks. In the practice of safety, all risks derive from hazards; there are no exceptions. It is a given that the practice of safety is hazard and risk based. Hazards and risks may exist because of deficiencies in management decision making that relates to the barriers and controls needed in a particular operation. Characteristics of that decision making may reflect an organization's culture.

Regardless of their titles, the entirety of purpose of those responsible for safety is to manage their endeavors with respect to hazards so that the risks deriving from those hazards are acceptable. To achieve acceptable risk levels, the necessary barriers and controls must be in place, effective and properly used.

Management & Cultural Causal Factors

An organization's safety culture is a subset of its overall culture. Management owns the culture that is represented by the reality of its goals, performance measures. An organization's culture is demonstrated by its sense of responsibility to its employees, to its customers and to its community. Over the long term, the injury and illness, property and environmental damage experience attained are a direct reflection of an organization's culture.

The most important elements in an organization's operational risk management system are the decisions made by the board of directors and senior management. Those decisions derive from their leadership, commitment and involvement, positive or negative. An organization's culture reflects those decisions. Causal factors and incidents may derive from deficiencies at those levels.

If management decides to give additional efforts to serious injury and fatality prevention, it should recognize that achieving the desired results will require adopting a different mind-set and achieving a culture change.

Risk Assessments

Review of several texts on problem-solving techniques indicate that their authors agree on at least one vitally important premise: the first step in problem solving is to define the problem.

To prevent incidents, management must identify the potentials of hazards and their related risks. To know of those potentials, hazards identification and analyses and risk assessments must be conducted. Thus, making risk assessments should be considered a potential problem identification venture. Management would apply a hierarchy of controls to determine what actions should be taken to achieve acceptable risk levels.

CSB (2016) says:

> Companies need an effective, and realistic, risk reduction goal because they cannot eliminate every risk completely—absolute safety is not possible. The question then becomes, when are efforts to reduce the level of residual risk sufficient? This challenge led to reducing risk to a level as low as is reasonably practicable, or ALARP, an important concept to explore in risk reduction practices. (Vol. 3, p. 170)

This is a strong statement, especially from a government agency. What does all this mean? Safety practitioners should understand that organizations must have an effective and realistic risk assessment and reduction system.

Risk assessments made in the design process provide opportunities to avoid bringing hazards into the workplace. Risk assessments made in existing facilities can identify the potentials of discovered hazards and their accompanying risks so that preventive action can be taken, including the provision of effective barriers and controls.

To the credit of its authors, ANSI/ASSP Z10 includes a provision requiring that risk assessments be made. ISO 45001, the international standard for occupational safety and health, also includes a provision requiring that risk assessments be made.

The EU gives importance to risk assessment:

> Risk assessment is the cornerstone of the European approach to prevent occupational accidents and ill health. It is the start of the health and safety management approach. If it is not done well or not at all the appropriate preventative measures are unlikely to be identified or put in place. (OSHWiki, 2018)

If an organization chooses to improve on serious injury and fatality prevention, an early step would be to define its potentials for serious injuries and fatalities to occur. Risk assessments can serve that purpose.

Some safety practitioners have used the term *precursors* to identify those potentials. A composite definition is a harbinger that foreshadows what is to come. Seeking precursors is a valid and worthwhile venture. But searching for and making modifications for precursors is not sufficient. If precursors exist, the reasons for their existence, deficiencies in management systems, must also be determined and acted upon.

If the precursors exist because of design shortcomings, information about corrective actions should also be communicated to design people so that they can eliminate similar precursors in future designs. Whatever the reasons for the existence of precursors, appropriate barriers and controls should be provided for as long as the precursors exist.

Provisions requiring that risk assessments be made should be a cornerstone of an operational risk management system.

Prevention Through Design

During this author's review of incident investigation reports, it was apparent that system design deficiencies as possible causal factors were largely ignored although incident descriptions indicated that design shortcomings could exist either in the work systems or the work methods.

Slowly, recognition has increased in recent years that additional attention is needed to avoid shortcomings in the design processes. Examples of that growing recognition follow.

- In 2011, ANSI approved the ANSI/ASSP Z590.3-2011 standard, Guidelines for Addressing Occupational Hazards and Risks in Design and Redesign Processes. This standard was reaffirmed in 2016.

•By intent, the terminology in Z590.3 was kept particularly broad so that the guidelines could be applicable to all hazards-based fields, such as product safety, environmental controls and property damage that could result in business interruption.

•Awareness developed at ASSP that safety practitioners should be capable of making risk assessments and to participate in the design and redesign processes. Thus, in February 2013, the Society's board of directors approved and funded the creation of the Risk Assessment Institute.

•In October 2017, ASSP announced the availability of an online course on prevention through design.

•A colleague of the author's noted that at a conference on robots, all but one speaker discussed risk assessments and their need to achieve acceptable risk levels in robotic safety.

Safety practitioners must further recognize that incidents happen because of design deficiencies. The existence of such deficiencies calls for appropriate barriers and controls.

Management of Change

Reviews of incident investigation reports, mostly for serious injuries, support the need for and benefit of having MOC systems in place. They revealed that a significantly large share of incidents resulting in serious injury occur:

•when unusual and nonroutine work is being performed;

•in nonproduction activities;

•in at-plant modification or construction operations (e.g., replacing an 800-lb motor to be installed on a platform 15 ft above the floor);

•during shutdowns for repair and maintenance, and startups;

•where sources of high energy are present (e.g., electrical, steam, pneumatic, chemical);

•where upsets occur: situations going from normal to abnormal.

Having an effective MOC system in place would have served to reduce the probability of serious injuries and fatalities occurring in these operational categories.

A 2011 BST study produced results in support of having MOC systems in place (T. Krause, personal communication, 2011). Shortcomings in prejob planning, another name for MOC, were found in 29% of incidents that had serious injury or fatality potential. Focusing on reducing that noteworthy 29% would be an appropriate goal.

MOC is a commonly used technique, the purpose of which for the practice of safety is to ensure that:

•hazards are identified and analyzed, and risks are assessed;

•appropriate avoidance, elimination or control decisions are made so that barriers and controls are appropriate, and acceptable risk levels are achieved and maintained throughout the change process;

•new hazards are not knowingly brought into the workplace by the change;

•changes do not impact negatively on previously resolved hazards;

•changes do not make the potential for harm of an existing hazard more severe.

Incidents occur when changes are not analyzed in advance, and the barriers and control measures are deficient with respect to avoiding hazardous situations and achieving and maintaining acceptable risk levels.

Permit Systems

Why include commitments on permit systems in this article? Violations of such systems, particularly for serious injuries and fatalities and for extensive property damage, have appeared regularly in incident investigation reports.

For example, in former employment that included fire protection consulting, the staff jokingly observed that if they could be assured that no fires and injuries would occur because of violation of the permit system for welding, they could write all of the property insurance in the world at a 25% discount and still be profitable.

It is much easier to write commendable permit control systems than it is to have them followed; when not adhering to a permit system appears in incident investigation reports, the recommendations proposed too often focus on what an employee did or did not do.

If employees are not following an established procedure, it may indicate a management system deficiency and a culture problem. When the permit system is not followed, inquiry should be made to determine whether:

•supervision was lacking at that time;

•supervisors regularly condone ignoring the permit system;

•an employee decided to ignore the system.

Note that all of these items pertain to culture problems in which management, perhaps at several levels, does not require close adherence to the written permit system.

To achieve an effective permit system, management must make it clear by what it does that such is its intent.

Incident Investigation & Analysis

Research has shown that the quality of incident investigations in many companies has been less than stellar (Manuele, 2014). One purpose for that article was to convince safety practitioners that their learned advice on incident investigations is seriously needed at all levels of management. This is an important subject for which inadequacy is often condoned by management.

Incident investigations should be a good source from which determinations can be made about the adequacy of barriers and controls, and possible deficiencies in management systems. Opportunities to reduce risks and avoid injury or damage to people, property and the environment are lost when incident investigations do not identify the reality of causal factors.

Incident investigations could also be a good reference from which to establish leading indicators.

Preventive Maintenance: System Integrity

Maintenance at a high level impacts on the mechanical integrity of operations. Maintenance done well or not well results in barriers being adequate or not adequate. Quality of maintenance sends messages to the entire staff informing them of the reality of an organization's intent with respect to controlling hazards and maintaining acceptable risk levels.

In the best operations, cleanliness and superior maintenance are truly virtues. Barriers and controls are adequate and well maintained.

How Incidents Happen

If asked, "How do incidents happen?" safety practitioners would have a variety of responses. This author's postulation follows:

An incident occurs when a confluence of causal factors arises from deficiencies in management systems that result in inadequately controlled and unacceptable hazards and risks. As hazards reach their potential for harm or damage, the activation may have a harmful effect on people, property or the environment. Thus:

•Barriers or controls are nonexistent, insufficient or made inoperative.

•All of the elements necessary for an incident to occur converge;

•Causal factors are usually, but not always, a combination of active failures (unsafe acts) and latent factors (hazardous situations).

•An incident process begins with an initiating event and the hazard's potential is released.

•Unwanted energy flows or exposures to harmful substances exist.

•Multiple interacting events may occur sequentially or in parallel.

•Harm or damage results or could have resulted in slightly different circumstances.

At this point it is appropriate to ask what the terms *hazard, risk* and *acceptable risk* mean. The following definitions are from ANSI/ASSE Z590.3-2011 (R2016):

Hazard: The potential for harm to people, property and the environment. [Note: Hazards include all aspects of technology and activity that produce risk. Hazards include the characteristics of things (e.g., equipment, technology, processes, dusts, fibers, gases, materials, chemicals) and the actions or inactions of people.] (p. 12)

Risk: An estimate of the probability of a hazard-related incident exposure occurring and the severity of harm or damage that could result. (p. 13)

Acceptable risk: That risk for which the probability of an incident or exposure occurring and the severity of harm or damage that may result are as low as reasonably practicable (ALARP) in the setting being considered. (p. 12)

ALARP: That level of risk which can be further lowered only by an increase in resource expenditure that is disproportionate in relation to the resulting decrease in risk. (p. 12)

Conclusion

Reductions made in the occurrence of incidents and injuries of all types in recent years have been notable and significant. Safety practitioners who have given advice to management that resulted in those reductions should feel good about themselves.

But, the record is clear. Reductions in injuries having lesser severity are greater than those resulting in more lost workdays, and the rate for the more serious injuries may have plateaued. While the reductions in the number of fatalities and the fatality rates have been commendably good, the data plainly show that numbers and rates have not improved in recent years. They are close to stationary.

This provides opportunities for safety practitioners to do the analyses recommended and develop the advice to be given to management so that continued reductions can be made. **PSJ**

References

ANSI/ASSP. (2016). Prevention through design: Guidelines for addressing occupational hazards and risks in design and redesign processes [Z590.3-2011 (R2016)]. Retrieved from https://store.assp.org/PersonifyEbusiness/Store/Product-Details/productId/29237329

ANSI/ASSP. (2017). Occupational health and safety management systems [Z10-2012 (R2017)]. Retrieved from https://store.assp.org/PersonifyEbusiness/Store/Product-Details/productId/29237335

Antonello, K. (2015). 2105 state of the line: Analysis of workers' compensation results. Boca Raton, FL: National Council on Compensation Insurance.

Bureau of Labor Statistics (BLS). (1996). Table 7. Lost-worktime injuries and illnesses: Characteristics and resulting time away from work, 1995. Washington, DC: Author.

BLS. (2015). Table 7. Employer-reported workplace injuries and illnesses. Washington, DC: Author.

BLS. (2015). Table 9. Nonfatal injuries and illnesses requiring days away from work, 2014. Washington, DC: Author.

BLS. (2018). Census of fatal occupational injuries: Current and revised data. Retrieved from www.bls.gov/iif/oshcfoi1.htm

Center for Chemical Process Safety (CCPS) of the American Institute of Chemical Engineers. (1994). *Guidelines for preventing human error in process safety.* New York, NY: Author.

CGE Risk Management Solutions. (2017). Barrier types. Retrieved from www.cgerisk.com/knowledgebase/Barrier_types

Chapanis, A. (1980). The error-provocative situation. In W.E. Tarrants (Ed.), *The Measurement of Safety Performance.* New York, NY: Garland Publishing.

CSB. (2016, April 20). Investigation report (Volumes 1-4): Drilling rig explosion and fire at the Macondo well (Report No. 2010-10-I-OS). Retrieved from www.csb.gov/macondo-blowout-and-explosion

Dekker, S. (2006). *The field guide to understanding human error.* Burlington, VT: Ashgate Publishing Co.

Deming, W.E. (1982). *Out of the crisis.* Cambridge, MA: MIT Center for Advanced Engineering Study.

Haddon, W., Jr. (1970, Dec.). On the escape of tigers: An ecologic note. *American Journal of Public Health and the Nation's Health, 60*(12), 2229-2234.

Hammer, W. (1972). *Handbook of system and product safety.* Englewood, NJ: Prentice Hall.

Heinrich, H.W. (1959). *Industrial accident prevention: A scientific approach (4th ed.).* New York, NY: McGraw-Hill.

Hollnagel, E. (1999). Accidents and barriers. Retrieved from www.researchgate.net/publication/228595147_Accidents_and_barriers

Hollnagel, E. (2004). *Barriers and accident prevention.* Burlington, VT: Ashgate Publishing.

Johnson, W.G. (1980). *MORT Safety Assurance Systems.* New York, NY: Marcel Dekker.

Kletz, T. (1991). *An engineer's view of human error (2nd ed.).* Rugby, U.K.: Institution of Chemical Engineers.

Manuele, F.A. (2008, Dec.). Serious injuries and fatalities: A call for a new focus on their prevention. *Professional Safety, 53*(12), 32-39.

Manuele, F.A. (2011, Oct.). Reviewing Heinrich: Dislodging two myths from the practice of safety. *Professional Safety, 56*(10), 52-61.

Manuele, F.A. (2013). *On the practice of safety (4th ed.).* New York, NY: John Wiley & Sons.

Manuele, F.A. (2014, Oct.). Incident investigation: Our methods are flawed. *Professional Safety, 59*(10), 34-43.

Manuele, F.A. (2016, May). Root-causal factors: Uncovering the hows and whys of incidents. *Professional Safety, 61*(5), 48-55.

National Council on Compensation Insurance (NCCI). (2011). Exhibit 20. Workers' compensation claim frequency, 2011. Boca Raton, FL: Author.

Noordwijk Risk Initiative Foundation (NRI). (2009). NRI MORT user's manual: For use with the management oversight and risk tree analytical logic diagram (NR-1). Delft, The Netherlands: Author.

NSC. (1995). *Accident facts.* Itasca, IL: Author.

OSHWiki. (2018). Prevention and control strategies. Retrieved from https://oshwiki.eu/wiki/Prevention_and_control_strategies

Reason, J. (1990). *Human error.* New York, NY: Cambridge University Press.

Reason, J. (1997). *Managing the risks of organizational accidents.* Burlington, VT: Ashgate Publishing Co.

Stephans, R.A. (2004). *System safety in the 21st century.* Hoboken, NJ: John Wiley & Sons.

Stephenson, J. (1991). *System safety 2000.* Hoboken, NJ: John Wiley & Sons.

U.S. Department of Energy (DOE). (1992). MORT user's manual: For use with the management oversight and risk tree analytical logic diagram. Washington, DC: Author.

Fred A. Manuele, P.E., CSP, is president of Hazards Limited, which he formed after retiring from Marsh & McLennan, where he was a managing director and manager of M&M Protection Consultants. His experience in the practice of safety spans several decades. Manuele's books *On the Practice of Safety* and *Advanced Safety Management: Focusing on Z10 and Serious Injury Prevention* have been adopted by several professors for undergraduate and graduate safety degree programs. Manuele is an ASSP Fellow and received NSC's Distinguished Service to Safety Award. He is a former board member of ASSP, NSC and BCSP, which he also served as president. Manuele received a BCSP Lifetime Achievement Award in 2013, University of Central Missouri's Distinguished Service Award in 2015, and ASSP's President's Award in 2016 for his dedication in advancing the practice of safety.