Whittingham, R. B. The Blame Machine: Why Human Error Causes Accidents. Burlington, MA: Elsevier Butterworth-Heinemann, 2004.

Workers Compensation Claim Frequency Down again: NCCI, 2005

Walten Mary. Deming Management at Work. New York: Rutnam Publishing Group, 1990.

"Task Analysis Methods: Critical Incident Technique." Infopolis at www._ul_ie/ infopolis/ methods/incident_html

2003 Liberty Mutual Workplace Safety Index. Liberty Mutual Insurance Company. Hopkinton, MA

Walton, Mary. *The Deming Management Method*. New York: Putnam Publishing Company, 1986

Whittingham, R. B. *The Blame Machine: Why Human Error Causes Accidents*. Burlington, MA: Elsevier Butterworth-Heinemann, 2004.

"Workers Compensation Claim Frequency Down Again." National Council on Compensation Insurance News Bulletin, June 2005

FOR THE CRITICAL INCIDENT TECHNIQUE

Accident Prevention Manual: Administration & Programs, Twelfth Edition. Itasca, IL: National Safety council, 2001

Johnson, William G. MORT Safety Assurance Systems. New York: Marcel Dekker, 1980

Manuele, Fred A. On the Practice of Safety, 3rd ed. Hoboken, NJ: John Wiley & Sons, 2003.

Tarrants, William, ED. *The Measurement of Safety Performance*. New York: Garland Press Publishing, 1980

"Task Analysis Methods: Critical Incident Technique." www._ul_ie/ infopolis/methods/ incident_html

Welker, Paul A. et al. "The Critical Incident Technique" A Manual for Its Planning and Implementation." www.tiu.edu/psychology/Twelker/critical_incidenttechnique.htm

CHAPTER 4

HUMAN ERROR REDUCTION

INTRODUCTION

Several references were made in Chapter 3, "Serious Injury Prevention," to human errors as the causal factors for accidents. And it was said that many serious injuries result from recurring but potentially avoidable human errors, and that organizational, cultural, technical, and management systems deficiencies often lead to those errors. Emphasizing human error reduction above the worker level, although proposed many years ago as a preventive measure, is not prominent in the work of safety professionals.

Fortunately, a renewed interest in being able to explain why human errors occur in the occupational setting is emerging. For example, the American Society of Safety Engineers held a 'Human Error in Occupational Safety Symposium' in March 2003. Dan Petersen was a speaker at that symposium and made an interesting observation about the direction the practice of safety should now take:

> For the last 90 years, safety has gone through many frontiers, many fads, and occasionally a true paradigm shift. Interest in Behavioral Safety has paled and some are discovering the importance of management and culture. But even in an environment with good management and a good culture, people are still being injured due to human error, their own or someone else's. We need to be able to explain why human

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error happens and what it is. That knowledge will open up the next frontier in safety management.

Petersen presents an interesting proposal—that acquiring knowledge of how and where human errors occur and offering advice on human error reduction will open up the next frontier in safety management. That ties in well with the theme of this chapter. It also relates closely to my research which shows that *human errors at some level* are causal factors for many incidents resulting in serious injuries, particularly low-probability/serious-consequence events that have multiple, complex, and cascading causal factors.

Safety professionals will do a better job in giving counsel on serious injury prevention if they are aware of human error causal factors. Focusing on improving management systems to meet Z10 provisions and minimizing serious injuries, this chapter:

- Encourages safety professionals to become more involved in human error reduction, particularly above the worker level.
- Explores human errors as causal factors for low-probability/serious-consequence incidents.
- Brings attention to human errors that derive from deficiencies in
  - Organizational safety cultures
  - Safety management systems
  - Design and engineering decision making
  - Error-provocative operations.
- Provides a selected literature and resource review.
- Comments on the relationship between behavioral safety, human error reduction, and serious injury prevention.

This chapter is not a text on human error reduction. Selected publications are noted that provide the knowledge which safety professionals should have on the subject. They need not be concerned over a lack of resources. Enter the term "human error reduction" into a search engine and over 2,500,000 results will appear. Some of those results relate to workshops and symposia on human error reduction.

As references are cited in this chapter, take note of those that have been published in recent years. Interest in human error reduction is warming up. The new literature relates to human errors as causal factors for injuries to employees; injuries to users of personal products; and damage to property and the environment. The amount of new literature indicates that human error reduction has acquired a new life.

DEFINING HUMAN ERROR AND HUMAN ERROR REDUCTION

It seems that every author on human error has his or her own definition, and they vary somewhat. Some are obscure and esoteric. Nevertheless, the many definitions

have some similarities. Two selected definitions of human error follow. James Reason's principal research area has been in human error and the way people and organizational processes contribute to the breakdown of complex, well-defended technologies. In *Human Error*, Reason offers this definition:

> (Human) Error will be taken as a generic term to encompass all those occasions in which a planned sequence of mental or physical activities fails to achieve its intended outcome, and when these failures cannot be attributed to the intervention of some chance agency.

Reason's book was written for cognitive psychologists, human factors professionals, safety managers, and reliability engineers. His definition covers all the bases, but is not quite as specific as is needed in the occupational setting.

Trevor Kletz, in *An Engineer's View Of Human Error*, gives a definition that relates more precisely to the places in which people work:

> I have tried to show that so-called human errors are events of different types (slips and lapses, mistakes, violations, errors of judgment, mismatches and ignorance of responsibilities), made by different people (managers, designers, operators, construction workers, maintenance workers and so on) and that different actions are required to prevent them happening again: in some cases better training or instructions, in other cases better enforcement of the rules, in most cases a change in the work situation.

Kletz's definition of human error fits well with this author's studies of accident reports. For simplicity and to have a terse definition of human error that relates directly to the occupational setting in which exposures to injuries and illnesses occur, I present this definition:

> *Human error:* a decision, an oversight, or a personnel action or inaction out of which the potential arises for the occurrence of a harmful incident or exposure.

Then, human error reduction is to minimize the probability that decisions or oversights, made individually or accumulatively, and personnel actions or inactions, will bring about the occurrence of harmful incidents and exposures.

A BIT OF HISTORY

Dan Petersen's paper "Human Error" appeared in the December 2003 issue of *Professional Safety*. Petersen offers an interesting observation on how long ago knowledge of human factors as incident causal factors has been available. He also suggests that safety professionals have been delinquent in not absorbing and utilizing that knowledge to their professional advantage:

> As an industrial engineering graduate, the author studied work simplification, plant layout and motion study, not for the purpose of reducing error, but rather to increase

productivity. Years later, I became acquainted with human factors concepts in graduate work in psychology. It seemed that this was a natural for the safety profession. That was in 1971, and for some reason, the profession found OSHA and its standards to be considerably more interesting. From a human factors standpoint, it seems that safety has lost 30 years of possible progress in reducing human error.

What Petersen says is true. Safety-related literature on human errors occurring at several organizational levels that become the source of causal factors for injuries dates back at least to the 1970s. Nevertheless, a large share of safety professionals ignored it. For a long while many safety professionals were consumed by OSHA, which took effect in 1971. In later years a form of behavioral safety that focused on improving worker behavior attracted a great deal of their attention and time.

A SELECTED REVIEW OF THE LITERATURE

Willie Hammer's *Handbook of System and Product Safety*, published in 1971, contributed significantly to this author's developing an interest in the levels at which human errors occur. Hammer wrote this:

> Almost every mishap can be traced ultimately to personnel error, although it may not have been error on the part of the person immediately involved in the mishap. It may have been committed by a designer, a worker manufacturing the equipment, a maintenance worker, or almost anyone other than the person present when the accident occurred.
>
> It often happens that the person involved is overwhelmed by failures due to causes beyond his or her control, failures that could have been forestalled by incorporation of suitable measures in the design stage. In many instances, due consideration was not given to human capabilities and limitations and to the factors that can and may affect a human being.

Hammer's message was important for me. He made plain that it would be advantageous in the practice of safety to look for root causal factors that occur above the level of the worker who may have been involved in a mishap.

Another researcher and often published author whose work has influenced this author's view of incident causation is Dr. Alphonse Chapanis. He was exceptionally well known in ergonomics and human factors engineering circles. His work is often quoted, particularly on the benefits of considering the capabilities and limitations of workers as systems are designed. Chapanis was strong on designing to avoid error-provocative work methods.

Early in my career, I became aware that musculoskeletal injuries, particularly back injuries, were prominent in the incident experience for every client I was advising. At that time, the principle method to reduce back injuries was to conduct training programs for workers, teaching them proper lifting techniques. Very soon, I became aware that those methods did not achieve the results expected, for a very good reason.

My research into incident causation showed that the problem was not the worker. Study after study showed that the problem was the design of the work methods. They were overly stressful and error-provocative for a very large share of the working population. It became apparent that focusing on worker behavior was minimally productive if the real problem was the design of the work methods. The solution was to convince managements that, to reduce musculoskeletal injuries, methods to minimize overly stressful and error-provocative characteristics of work methods should be applied.

That incident causation research led me into what was then mostly called human factors engineering and now is more often referred to as ergonomics. From Chapanis's writings and my research, I make this observation with respect to management decision making for every type of occupational injury: If the design of the workplace or the work methods is error-provocative, you can be sure that human errors will occur.

Chapanis was the author of a chapter titled "The Error-Provocative Situation" in *The Measurement of Safety Performance*, a 1980 publication. The following are very brief excerpts from that chapter. Note that they relate to decision-making possibilities above the worker level:

- The improvement in system performance that can be realized from the redesign of equipment is usually greater than the gains that can be realized from the selection and training of personnel.
- Design characteristics that increase the probability of error include a job, situation, or system which:
  a. Violates operator expectations
  b. Requires performance beyond what an operator can deliver
  c. Induces fatigue
  d. Provides inadequate facilities or information for the operator
  e. Is unnecessarily difficult or unpleasant
  f. Is unnecessarily dangerous.

Improvement in system performance and the design of the work or operating system is principally a management responsibility, although it is wise to seek worker input in the improvement process. An appropriate goal for safety professionals is to educate decision makers so that avoiding the creation of work situations that are error-provocative or overly stressful is ingrained in their thinking.

James Reason's *Human Error*, which was previously mentioned, is also a highly recommended resource. First published in 1990, it has since had 12 reprintings. Reason discusses: The Nature of error; Studies of human error; Performance levels and error types; Cognitive underspecification and error forms; A design for a fallible machine; The detection of errors; Latent errors and system disasters; and Assessing and reducing the human error risk.

In the chapter on Assessing and reducing human error risk, Reason acknowledges that the bulk of his book favors theory rather than practice and that this final chapter seeks to "redress the balance by focusing on remedial possibilities." He

also asserts that this chapter was written with safety professionals and psychologists in mind.

Reason also brings to mind the antiquity of the literature on human error reduction. In his final chapter, he reviews THERP, (the technique for human error rate prediction). This methodology was developed by Alan Swain in 1963.

Particular attention is given here to the *Guidelines for Preventing Human Error in Process Safety*, a 1994 publication. Although "process safety" appears in the book's title, the first two chapters provide an easily read primer on human error reduction. The content of those chapters was largely influenced by personnel with safety management experience at a plant or corporate level.

Extensive highlights from the book follow, with the permission of the publisher, AICHE. Safety professionals should view them as generic and broadly applicable. They advise on where human errors occur, who commits them and at what level, and where attention is needed to minimize their occurrence. These highlights apply to organizations of all types and sizes. Note that the word "chemical" appears but once in the following excerpts.

- 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.
- The application of the science of human factors to eliminating error in all aspects of process design, management, operation, and maintenance is the focus of this work.
- Human error has been a major cause of almost all of the catastrophes that have occurred in the chemical process industries.
- A systems perspectives is taken, which 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.
- Almost all the 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.
- One of the central principles presented in this book is the need to consider the organizational factors that create the preconditions for errors, as well as the immediate causes.
- The plant and corporate management levels determine conditions at the operational level that either support effective performance or give rise to errors.
- The safety beliefs and priorities of the organization will influence the extent to which resources are made available for safety as opposed to production objectives.
- Attitudes toward blame will determine whether or not an organization develops a blame culture, which attributes error to causes such as lack of motivation or deliberate unsafe behavior.
- Factors such as the degree of participation that is encouraged in an organization, and the quality of the communication between different levels of management and the workforce, will have a major impact on the safety culture.

- The existence of clear policies that will ensure good quality procedures and training will also impact strongly on error likelihood.
- Organizational and plant design policies are influenced by senior management.
- The plant and corporate management policies will be implemented by line management. This level of management has a major impact on the conditions that influence error. Even if appropriate policies are adopted by senior management, these policies may be ineffective if they do not gain the support of line management.
- Plants are particularly vulnerable to human error during shutdowns for repair and maintenance. This is partly due to the higher level of direct human involvement with the plant, when errors are likely if procedures and supervision are poor.
- Factors that directly affect error causation are located at the next level. These factors, which include the characteristics of the job performed by the worker (complexity, mental versus physical demands, etc.) and individual factors such as personality and team performance factors, are collectively performance-influencing factors, or PIFs.

In the *Guidelines*, all of the foregoing statements are addressed with a good number of case studies. The book is an easy and informative read. This question is asked in the *Guidelines*, and the answer given is applicable in all but a few organizations: Why is human error neglected in the chemical process industry?

> A major reason for the neglect of human error in the chemical process industry is simply lack of knowledge of its significance for safety, reliability, and quality. It is also not generally appreciated that methodologies are available for addressing error in a systematic, scientific manner. This book is aimed at rectifying this lack of awareness.

Although it has been known for quite some time that the foundations for human errors may be in "failures at the management, design, or technical expert levels of the company," offering counsel to reduce human errors at those levels is not usually a significant element within safety management systems. As the interest in serious injury prevention becomes more prominent, safety professionals will be challenged to become knowledgable about reducing human errors above the worker level.

Another of James Reason's books—*Managing the Risks of Organizational Accidents*—is a "must" read for safety professionals who want an education in human error reduction. It was published in 1997 and has been reprinted five times. Reason writes about how the effects of decisions *accumulate over time* and become the causal factors for incidents resulting in serious injuries or damage when all the circumstances necessary for the occurrence of a major event come together. This book was referenced in Chapter 3, "Serious Injury Prevention," because it stresses the need to focus on decision making above the worker level to prevent major accidents. Reason writes this:

> Latent conditions, such as poor design, gaps in supervision, undetected manufacturing defects or maintenance failures, unworkable procedures, clumsy automation, shortfalls in training, less than adequate tools and equipment, may be present for many years

before they combine with local circumstances and active failures to penetrate the system's layers of defenses.

They arise from strategic and other top-level decisions made by governments, regulators, manufacturers, designers and organizational managers. The impact of these decisions spreads throughout the organization, shaping a distinctive corporate culture and creating error-producing factors within the individual workplaces.

In addition, Reason states, that the traditional occupational safety approach alone, directed largely at the unsafe acts of persons, has limited value with respect to the "insidious accumulation of latent conditions" that he notes are typically present when organizational accidents occur.

Over and over, writers and researchers have reiterated that errors are made at an organizational, managerial and design levels, that they form a distinctive corporate culture and create error-producing factors within the occupational setting. Minimizing the probability of such human errors occurring is the new frontier for safety professionals.

I suggest Donald A. Norman's *The Psychology of Everyday Things*, published in 1988, as an additional and important resource. Norman's background is in both engineering and the social sciences. This book was also referenced in Chapter 3, "Serious Injury Prevention," because it concentrates on "breakdowns and errors" that are the causal factors for major accidents:

> Explaining away errors is a common problem in commercial accidents. Most major accidents follow a series of breakdowns and errors, problem after problem, each making the next more likely. Seldom does a major accident occur without numerous failures: equipment malfunctions, unusual events, a series of apparently unrelated breakdowns and errors that culminate in major disaster; yet no single step has appeared to be serious. In many cases, the people noted the problem but explained it away, finding a logical explanation for the otherwise deviant observation.

What Norman says about "numerous failures" being typical when major accidents occur is identical with my experience. I urge that the following comments by Reason and Norman be seriously considered as attempts are made to reduce serious injury potential:

> *Reason*: The impact of [top-level] decisions spreads throughout the organization, shaping a distinctive corporate culture and creating error-producing factors within individual workplaces.
>
> *Norman*: In many cases, the people noted the problem but explained it away, finding a logical explanation for the otherwise deviant observation.

Because of my sea-going experience, I was pleased to see that the U.S. Coast Guard s up to par in recognizing the sources of human errors. At http://www.uscg.mil/hq/g-m/risk/e-guidelines/RBDM/html/Vol4/Volume4/Gen-Rec/HumanErr.htm "Human Error and Marine Safety" can be found. It was written by Dr. Anita M. Rothblum, U.S. Coast Guard Research & Development Center. The following excerpt is from hat paper:

> While human errors are all too often blamed on "inattention" or "mistakes" on the part of the operator, more often than not they are symptomatic of deeper and more complicated system problems. Human errors are generally caused by technologies, environments, and organizations which are incompatible in some way with optimal human performance. These incompatible factors "set up" the human operator to make mistakes. So what is to be done to solve this problem? Traditionally, management has tried either to cajole or threaten its personnel into not making errors, as though proper motivation could somehow overcome inborn human limitations. In other words, the human has been expected to adapt to the system. *This does not work*. Instead, what needs to be done is to *adapt the system to the human*.

The operator is not the problem. It is the error-provocative system that sets up the operator to make errors. Others have also said that expecting humans to adapt to the system does not work. The proper approach is to adapt the system to the human.

R. B. Whittingham's *The Blame Machine: Why Human Error Causes Accidents*, a 2004 publication, is also referenced and recommended in Chapter 3, "Serious Injury Prevention." Its emphasis is on human errors and defective management systems as causal factors for major accidents. From the Preface:

> *The Blame Machine* describes how disasters and serious accidents result from recurring, but potentially avoidable, human errors. It shows how such errors are preventable because they result from defective systems within a company.

W. Johnson is the author of *Human Error, Safety and Systems Development*, a 2004 publication. It is another recently issued text indicating that a transition is taking place and that additional emphasis is being given to human error reduction.

> Recent developments in a range of industries have increased concern over the design, development, management and control of safety-critical systems. Attention has now been focused upon the role of human error both in the development and in the operation of complex systems.

Cognition and Safety: An Integrated Approach to Systems Design and Assessment was written by Oliver Strater and published in 2005. Strater's purpose is to promote making risk assessments in the design process. This is a worthy goal. It fits well with the design review provisions in Z10. Studies have shown that engineering students do not acquire knowledge about hazards, risks, and risk assessments. That results sometimes, as Strater says, in designers creating constraints at the sharp-end, which eventually lead to human errors. "Sharp-end" is a British term, meaning the point where the work or task is done. Strater says this in his Preface:

> Safety suffers from the variety of methods and models used to assess human performance. For example, operation is interested about human error while design is aligning the system to workload or situational awareness. This gap decouples safety assessment from design. As a result, design creates constraints at the sharp-end, which eventually leads to human errors.

WORKSHOPS ON HUMAN ERROR REDUCTION

A few workshops on human error reduction that were located on the Internet are listed here. Although this author does not personally know of them, safety professionals interested in furthering their education may want to inquire into their suitability. For course descriptions, enter the company names into any search engine; this will give you access to related promotional pieces. Readers with Internet skills better than mine may be able to locate yet other courses.

- *Safety Performance Solutions* This company led by Scott Geller, offers a course titled: "Designing and Modifying Jobs to Reduce Human Error." Geller has been prominent in behavioral safety. Offering workshops on modifying job designs to reduce human error represents a major shift in emphasis.
- *ABS Consulting* Offers a course titled "Human Error Prevention and Mitigation."
- *HTS—High Technology Seminars* Offers a course titled "Human Error Prevention."
- *AXIOM Technology Corporation* Offers a course titled "Human Error Reduction & Workplace Accident Prevention."
- *Process Improvement Institute* Offers a course titled: "Preventing Human Errors."

BEHAVIORAL SAFETY, HUMAN ERROR REDUCTION, AND SERIOUS INJURY PREVENTION

The following excerpts from Reason's *Managing the Risks of Organizational Accidents* bear directly on the history of behavioral safety, human error reduction, and the prevention of serious injuries.

> [A] problem that needs to be confronted is the belief held by many technical managers that the main threat to the integrity of their assets is posed by the behavioural and motivational shortcomings of those at the "sharp end." For them, the oft-repeated statistic that human errors are implicated in some 80–95 per cent of all events generally means that individual human inadequacies and errant actions are the principal causes of all accidents. What they hope for in seeking the help of a human factors specialist is someone or something to "fix" the psychological origins of these deviant and unwanted behaviours.
>
> But this—as I hope is now clear—runs counter to the main message of this book. Workplaces and organizations are easier to manage than the minds of individual workers.

However, a good many behavioral safety consultants built their businesses on the premise that 80% or more of occupational accidents are caused principally by the unsafe acts of workers. Let me take you back to the symposium held on behavioral

safety by the American Society of Safety Engineers (ASSE) in February 1998. That was a major event, considered by some to be the high-water mark for behavioral safety. Most of the big players in behavioral safety delivered presentations.

Some, not all, of the speakers at that symposium led their audiences to believe that worker-focused behavior-based safety was the greatest elixir ever created and that you need only apply their behavioral approaches to workers and all of your problems would be solved. In their presentations, little or nothing was said of the cultural, organizational, design, engineering, and operational sources out of which many error-provocative situations arise. I can still hear the voices of some of the speakers asserting that since H. W. Heinrich had said 88% of accidents are caused by the unsafe acts of workers, the most effective approach to preventing accidents was to apply their behavioral safety methods to workers. Heinrich was wrong. Voices promoting worker-focused behavior-based safety as a cure-all, by itself, have largely been stilled.

Worker-focused behavior-based safety does not examine the sources of human error in an organization above the worker level and has limited impact on serious injury prevention.

Things have changed. Several of the prominent speakers in the behavioral safety field now speak of safety systems, workplace design, qualities for effective safety leadership, the need to achieve a culture change, performance improvement, and an organizational culture of citizenship. In that respect, I will comment on the work of one of the most prominent leaders in behavioral safety to provide an indication of how thinking has changed about incident causation and preventive measures. Comparable changes are documented in the writings of other behavior-based safety practitioners.

Dr. Thomas A. Krause is the chairman of the board at Behavioral Science Technology, a major player in behavior-based safety. In June 2000, at the American Society of Safety Engineers Professional Development Conference, Krause gave a speech titled "Moving to the 2nd Generation in Behavior-Based Safety." In May 2001 an article having the same title appeared in the ASSE magazine *Professional Safety*. Krause speaks of a model that "combines ABA (applied behavioral analysis) with techniques of quality management and organizational development to create a comprehensive safety improvement methodology." He writes:

> Use of observation data is a significant element of an integrated BBS program. By using behavioral data to develop action plans for improvement, the focus shifts from the worker to systems, design, maintenance, and other, more subtle mechanisms such as purchasing and decision making.

A later article by Krause titled "Improving the Working Interface" appeared in the September 2001 issue of *Occupational Hazards*. Under the heading "Understanding the Working Interface," Krause said:

> Broadly speaking, in the workplace there are three factors influencing exposure to injury: management systems (methods and procedures), conditions (facilities and

equipment) and the critical things that people do. To achieve lasting improvement in safety performance, all three of these factors need ongoing calibration with each other.

The fact that barriers to safe behavior are primarily related to hardware and management systems rather than to individual choice changes the focus of safety improvement efforts from the worker to the systems than enable safe behavior.

We call the interaction of these three factors—conditions, management systems, and what people do—the **working interface**. The working interface is essentially *how the work is done*, the place where conditions, procedures and behavior interact with each other.

To accept that the focus of improvement should not be on the worker, but on the systems that enable safe behavior, is a conceptual sea change for behavioral safety practitioners. Krause's article titled "Influencing the Behavior of Senior Leadership" was published in the June 2004 issue of *Professional Safety*. Consider these comments:

The primary goal of safety initiatives, whether at the site or corporate level, is to reduce the amount of exposure that occurs in the workplace—referred to as the "working interface." While not all exposure is equal in terms of the severity potential, all incidents result from exposure to hazards. Reducing that exposure is the primary mechanism of safety improvement.

Think about the significance of the foregoing, coming from someone who has been a prominent leader in behavior-based safety: The focus of safety improvement efforts [should shift] from the worker to the systems that enable safe behavior; although not all exposure is equal in terms of the severity potential, all incidents result from exposure to hazards; reducing that exposure is the primary mechanism of safety improvement.

Krause is also the author of *Leading with Safety*, published in 2005, in which he writes of leadership, organizational sustaining systems, safety-enabling systems, organizational culture, and the working interface. The latter is described as the "interaction of equipment, facilities, procedures, and the worker." Krause also says that "a combination of these factors creates or eliminates exposures to hazards." Remember, Krause has been a major player in worker-focused behavior-based safety. And he now writes this:

Many in the safety community believe a high percentage of incidents, perhaps 80–90%, result from behavioral causes, while the remainder relate to equipment and facilities. We made this statement in our first book in 1990. However, we now recognize that this dichotomy of causes, while ingrained in our culture generally and in large parts of the safety community, is not useful, and in fact can be harmful.

So, I say to the many safety professionals who still base their practice on the premise that a very large percentage of occupational injuries and injuries result from the unsafe acts of workers and who still promote worker-focused behavior-based safety as the primary consideration in the safety efforts they sponsor—you may want to

reexamine your premises in light of the foregoing. Additionally, I suggest they consider the:

- Focus of Z10, which is on reducing hazards, the risks that derive from hazards, safety management systems and process deficiencies, and on identifying opportunities for improvement.
- Case made for special attention being given to serious injury prevention in the chapter with that title.
- Achievements that can derive from learning about and giving counsel on human error reduction, particularly above the worker level.

CONCLUSION

General observations can be drawn from the several sources cited here and this author's experience:

- Human errors, of commission or omission, are factors in the occurrence of nearly all hazards-related incidents.
- Typical safety management systems do not address human error reduction, particularly on an anticipatory basis.
- You cannot change the human condition but you can change the conditions under which people work.
- The solutions to most human performance problems are technical rather than psychological.
- Potentials for human error derive largely from top-level decisions, and the impact of those decisions spreads throughout the organization, shaping a distinctive corporate culture and creating error-provocative situations.
- To avoid hazard-related incidents resulting in serious injuries, human error potentials must be addressed at the cultural, organizational, management systems, design, and engineering levels, and with respect to the work methods prescribed.

All this spells opportunity for safety professionals to acquire new knowledge with respect to human error reduction and to enhance their professional status. Human error reduction may very well become the frontier for the practice of safety.

REFERENCES

Chapanis, Alphonse. "The Error-Provocative Situation". In *The Measurement of Safety Performance*, edited by William E. Tarrants. New York: Garland Publishing, 1980.

Guidelines for Preventing Human Error in Process Safety. New York: Center for Chemical Process Safety of the American Institute of Chemical Engineers, 1994.