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Binh Pham, M.Sc

Advanced Safety Management

Focusing on Z10 and Serious Injury Prevention

Fred A. Manuele

ADVANCED SAFETY MANAGEMENT FOCUSING ON Z10 AND SERIOUS INJURY PREVENTION

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FOREWORD

The team that eventually produced the ANSI Z10 standard met for the first time early in 2001. It may surprise readers to know that the meeting began with a contentious debate as to whether or not a standard on occupational health and safety management systems was appropriate or even necessary. The essential argument of those opposed to the development of such a standard was that if we got it "wrong," the consequences would be severe. After some spirited debate, a majority of the consensus body voted to move forward and set the stage for the five-year effort that resulted in Z10.

This tumultuous beginning is understandable, given the extraordinary breath of interests represented in the consensus body. Labor, industry, academia, professional associations, and government interests were each represented by leading voices with strong opinions on the approach the standard should take. However, by the time of our second meeting, barely a month after the tragedy of September 11, 2001, the necessity to put aside parochial biases was clear. The team coalesced and dedicated itself to a path of technical rigor.

In this light, the Z10 team produced a standard that was approved by the consensus body with no negative votes and sailed though the final ANSI approval process in an astonishingly short time. Such unanimous and quick approval is rare for any standard, let alone one as potentially controversial as ANSI Z10. This initial acceptance was followed by almost universal support by the technical community and substantial acceptance by the prospective user community.

While I believe that Z10 is the best tool available for those interested in developing occupational health and safety management systems, some will view it as

lacking. All of the basic elements are present. But, the required format for a management system standard does not allow entry of detailed direction on how users would apply its provisions.

In this book, Fred Manuele helps the reader understand the how and why of many of the principles introduced by Z10. This elucidation provides essential knowledge to help readers implement effective safety and health management systems in their organizations.

Alan Leibowitz

Chair, ANSI/AIHA Z10 Standard Writing Committee

PREFACE

The principal purpose of this book is to provide guidance to managements, safety professionals, educators, and students concerning two major, interrelated developments impacting on the occupational safety and health discipline. They are the:

- Issuance, for the first time in the United States, of a national consensus standard for occupational safety and health management systems
- Emerging awareness that traditional systems to manage safety do not adequately address serious injury prevention

On July 25, 2005, the American National Standards Institute approved a new standard, the Occupational Health and Safety Management Systems Standard, designated ANSI/AIHA Z10-2005. This standard is a state-of-the-art, best practices guide. Over time, Z10 will revolutionize the practice of safety.

Chapter 1, an overview of Z10, comments on all the provisions in the standard. Chapter 3 on Serious Injury Prevention gives substance to the position that adopting a different mind-set is necessary to reduce serious injury potential. Other chapters give implementation guidance with respect to the standard's principal provisions and to serious injury prevention.

Recognition of the significance of Z10 has been demonstrated. Its provisions are frequently cited as representing highly effective safety and health management practices. The sales record for Z10 is impressive. Safety professionals are quietly making gap analyses, comparing existing safety and health management systems to the provisions of Z10.

Even though the standard sets forth minimum requirements, very few organizations have safety and health management systems in place that meet all the

provisions of the standard. The provisions for which shortcomings will often exist, and for which emphasis is given in this book, pertain to:

- Risk assessment and prioritization
- Applying a prescribed hierarchy of controls to achieve acceptable risk levels
- Safety design reviews
- Including safety requirements in procurement and contracting papers
- Management of change systems

As ANSI standards are applied, they acquire a "quasi-official" status as the minimum requirements for the subjects to which they pertain. As Z10 attains that stature, it will become the benchmark, the minimum, against which the adequacy of safety and health management systems will be measured.

The chapter on Serious Injury Prevention clearly demonstrates that although occupational injury and illness incident frequency is down considerably, incidents resulting in serious injuries have not decreased proportionally. The case is made that typical safety and health management systems do not adequately address serious injury prevention. Thus, major conceptual changes are necessary in the practice of safety to reduce serious injury potential. That premise permeates every chapter in this book.

Safety and health professionals are advised to examine and reorient the principles on which their practices are based to achieve the significant changes necessary in the advice they give. Guidance to achieve those changes is provided.

Why use the word "Advanced" in the title of this book? If managements adopt the provisions in Z10 and give proper emphasis to the prevention of serious injuries, they will have occupational health and safety management systems as they should be, rather than as they are. A strong relationship exists between improving management systems to meet the provisions of Z10, a state-of-the-art standard, and minimizing serious injuries.

Acknowledgments

Many of the chapters in this book were reviewed in draft form by Wayne Christensen and Bruce Main. Their critiques have been influential. Valuable contributions by Paul Adams on the design review concept and by Dwayne Dunsmore and Edward A. Neal who have written about a practical application of the design review process are much appreciated. And, it is appropriate to recognize the fine work done by the committee that wrote the Z10 standard, about which much is written in this book.

FRED A. MANUELE

President, Hazards Limited

INTRODUCTION

An abstract is provided for each chapter to serve as a content reference. This book gives guidance on applying the provisions of ANSI/AIHA Z10-2005, the *Occupational Health and Safety Management Systems* Standard, and on serious injury prevention as *interrelated subjects*. The order in which chapters appear supports that rationale.

A professor who uses my books in his classes has suggested that each chapter be a stand-alone essay. Although that requires a little repetition, the reader benefits by not having to refer to other chapters while perusing the subject at hand. Partial success with respect to that suggestion has been achieved. Each of the chapter headings are listed in the following descriptions.

1. **An Overview of ANSI/AIHA Z10-2005: The American National Standard for Occupational Health and Safety Management Systems** Brief comments are made on all the sections in Z10. All safety and health professionals are encouraged to acquire a copy of the standard and to move toward applying it. Some of the subjects emphasized are: Management Leadership and Employee Participation—the most important section in the standard; the Significance of this state-of-the-art, consensus standard (it will become the benchmark against which the adequacy of safety management systems is measured); Societal implications; Specific provisions in the standard that are not included in typical safety management systems (the safety through design processes); and Management review provisions. The case is made that bringing safety and health management systems

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up to the Z10 level will reduce the probability of incidents occurring that result in serious injury and illness.

2. **The Plan-Do-Check-Act Concept (PDCA)** The writers of Z10 made it clear that the continual improvement of occupational health and safety management systems can be achieved by applying the "recognized quality concept of Plan-Do-Check-Act" (PDCA). However, no information is provided on the PDCA concept and methodology. This chapter: Discusses the origin and substance of the PDCA concept; Relates the PDCA concept to basic problem-solving techniques; and Gives guidance on initiating a PDCA process.

3. **Serious Injury Prevention** Awareness has emerged that traditional safety management systems do not adequately address serious injury prevention. Statistics are given showing that although the frequency of minor injuries is down substantially, serious injuries have not been reduced proportionately. Comments are made on the: Need for safety professionals to examine the effectiveness of the principles on which their practices are based; Types of activities in which many serious injuries occur; Need for a change in the culture that gives proper attention to serious injury prevention; and Prevention techniques to reduce serious injuries.

4. **Human Error Reduction** In the chapter on Serious Injury Prevention, it is established that reducing human errors as causal factors is necessary in an effort to minimize the occurrence of serious injuries. This chapter focuses on human errors that occur above the worker level that derive from deficiencies: In organizational safety cultures; Safety and health management systems; and Design and engineering decision making. Emphasis is also given to designing operating systems, in accord with Z10 provisions, so as to avoid creating preconditions for human errors, such as overly stressful or error-provocative work methods.

5. **Management Leadership and Employee Participation, Section 3.0** This is the most important section in Z10. Why so? Safety is culture-driven, and management creates the culture. As top management makes decisions directing the organization, the outcomes of those decisions establish its safety culture. This chapter comments on: the Requirements of managements to attain superior results; Policy statements; Defining roles, assigning responsibilities and authority, providing resources, and establishing accountability; Employee participation; Relating management leadership to preventing serious injuries; and Making a safety culture analysis.

6. **Achieving Acceptable Risk Levels: The Operational Goal** ANSI/AIHA Z10-2005 tersely states its purpose in Section 1.2 as follows: "The primary purpose of this standard is to provide a management tool to reduce the risk of occupational injuries, illnesses, and fatalities." This question logically follows. What risk reduction level is to be achieved? This chapter: Establishes that achieving a zero risk level is unattainable; Discusses the great variations in cultural and situational aspects of risk acceptance; and Combines the elements of risk (probability and severity) with ALARP (as low as reasonably practicable) to arrive at a definition of acceptable risk, the operational goal.

7. **Planning, Section 4.0** The success of an occupational health and safety management system is largely contingent on the thoroughness of the Planning processes. In Z10, the Planning process goal is to identify and prioritize the "issues" that are defined as "hazards, risks, management system deficiencies, and opportunities for improvement." Reviews are to be made to identify those issues: Priorities are to be set, objectives are to be established, and actions are to be outlined for continual improvement. This chapter discusses all the provisions in the Planning section. However, special emphasis is given to the Assessment and Prioritization requirements in Section 4.2, on which three related chapters follow.

8. A Primer on Hazard Analysis and Risk Assessment
9. Including Risk Assessment Provisions in Standards and Guidelines: A Trend
10. Three and Four Dimensional Numerical Risk Scoring Systems

8. **A Primer on Hazard Analysis and Risk Assessment, Section 4.2** The intent is to provide sufficient knowledge of hazard analysis and risk assessment methods to serve most of a safety and health professional's needs. This chapter: Explores what a hazard analysis is; Discusses how a hazard analysis is extended into a risk assessment; Outlines the steps to be followed in conducting a hazard analysis and a risk assessment; Includes descriptions of several commonly used risk assessment techniques; and Gives examples of risk assessment matrices.

9. **Including Risk Assessment Provisions in Standards and Guidelines: A Trend** Several safety standards and guidelines issued in recent years contain hazard analysis and risk assessment provisions. This is a significant trend. Comments are made on the content of several of those standards and guidelines. Taken as a whole, they are convincing indicators, along with the hazard analysis and risk assessment provisions in Z10, that safety and health professionals will be expected to know how to make risk assessments as a matter of career enhancement.

10. **Three- and Four-Dimensional Numerical Risk-Scoring Systems** For many years, the typical risk assessment practice was to establish qualitative risk levels by considering only two dimensions: Probability of event occurrence and the Severity of harm or damage that could result. Translating those assessments into numerical risk scores was not necessary. However, systems now in use may be three- or four-dimensional and require numerical risk scorings. This chapter reviews several numerical risk-scoring systems in use. A three-dimensional numerical risk-scoring system developed by this author to serve the needs of those who prefer to have numbers in their risk assessment systems is presented.

11. **Implementation and Operation, Section 5.0** All the previously described chapters related to the Z10 provisions pertain to the "Plan" step in the PDCA process. The Implementation and Operation section moves into the "Do" step. The standard states that elements in this section "provide the backbone of an occupational health and safety management system and the means to pursue the objectives from the planning process." This is a very brief chapter. Comments are made only on certain of its provisions: Contractors; Emergency preparedness; Education,

training, awareness; Competence; Communications; and Document and Record Controls. Since several of the provisions in Section 5.0 are truly "the backbone of an occupational health and safety management system," separate chapters are devoted to them. They are chapters 12, 13, 15 and 16.

12. Hierarchy of Controls: The Safety Decision Hierarchy
13. Safety Design Reviews
14. Lean Concepts: Opportunities for Safety Professionals
15. Management of Change
16. The Procurement Process

The applied lean concepts as discussed in this book relate to the safety design review provisions in Z10, and a chapter on lean concepts follows the design chapter.

12. **Hierarchy of Controls: The Safety Decision Hierarchy, Section 5.1.1** This Z10 section states that "The organization shall implement and maintain a process for achieving feasible risk reduction based on the following order of controls." Achieving an understanding of this order of controls is a step forward in the practice of safety. This chapter: Reviews the evolution of hierarchies of control; Discusses the Z10 hierarchy and provides guidelines on its application; Comments on the logic of applying the hierarchy of controls; Places the hierarchy within good problem-solving techniques, as in The Safety Decision Hierarchy; and Provides General Design Requirements that relate to Z10's hierarchy of controls.

13. **Safety Design Reviews, Section 5.1.2** Design Review and Management of Change requirements are addressed jointly in Section 5.1.2. Although the subjects are interrelated, each has its own importance and uniqueness. Guidance on the management of change concept is provided in the next chapter. This chapter discusses the design review processes in Z10 and includes: A review of safety through design concepts; Comments on how some safety professionals are engaged in the design process; A review of the design-in safety practices in auto manufacturing; A composite of safety through design procedures in place; and A general design safety checklist. An Addendum provides a nearly ideal Environmental, Health, and Safety Equipment Design Philosophy, an Intel Corporation issuance.

14. **Lean Concepts: Opportunities for Safety Professionals** Applied lean concepts are to eliminate waste, improve efficiency, and lower production costs. Elements of waste that should be addressed in the lean process are the direct and ancillary costs of accidents. This chapter Discusses the origin of lean concepts and how broadly they are being applied; Gives examples of lean applications in which hazards and risks were not addressed; Comments on the opportunity for effective involvement in lean initiatives by safety professionals; and Outlines a unique merging of lean and safety through design concepts. An Addendum offers A Simplified Initial Value Stream Map To Identify Waste (Muda) and Opportunities for Continuous Improvement (Kaizen).

15. **Management of Change, Section 5.1.2** The objective of a management of change system is to prevent introducing new risks into the work environment. The management of change process is addressed separately in this book to promote

a broad understanding and application of the change analysis concept that is at its base. This chapter: Defines the purpose and methodology of a management of change system and relates it to the change analysis concept; Establishes its significance in preventing serious injuries and illnesses and major property damage incidents; and Outlines management of change procedures. An addendum is titled Management of Change Policy and Procedures.

16. **The Procurement Process, Section 5.1.3** Although the requirements in Z10 for Procurement processes are plainly stated, they are brief in relation to the enormity of what will be required to implement them. As is the case for the provisions in Z10 on safety design reviews, the Procurement processes are to avoid bringing risks into the workplace. This chapter: Comments on prevalent purchasing practices; Establishes the importance of including safety specifications in purchasing orders and contracts; and Provides resources and guidance on design specifications that become purchasing specifications to be met by vendors who supply machinery, equipment, and materials. Examples of design specifications that become safety specifications in purchasing documents are not easily acquired. Nevertheless, this chapter contains two Addenda: the first, The DaimlerChrysler Ergonomic Design Criteria For Engineers, Designers, Builders, Vendors, Suppliers, and Contractors; and the second, a composite of General Design and Purchasing Guidelines in use.

17. **Evaluation and Corrective Action, Section 6.0** In the Plan-Do-Check-Act process, it is important to determine whether the results intended are achieved from the management systems put in place. That is the purpose of Section 6.0. This chapter comments on: Monitoring, measurement, and assessment requirements; Provisions for taking corrective actions; and Communications on the lessons learned being fed back into the Planning and Management Review initiatives. Separate chapters on two provisions considered vital in the Evaluation and Corrective Action section follow. They are chapters:

18. Incident Investigation
19. Audit Requirements

18. **Incident Investigation, Section 6.2** The requirements for incident investigation in Z10 are concisely set forth in one paragraph, with no subsections. Organizations are to establish and implement processes to investigate and analyze hazardous incidents in a timely manner so as to identify occupational health and safety management issues, and other possible incident causal factors. This chapter: Encourages that incident investigation be given a higher place within the elements of a safety management system; Comments on the cultural difficulties facing those who try to have incident investigations improved if an organization has condoned low-quality performance; Suggests making needs, opportunities, and courses of action studies; Reviews the content of a good incident investigation form and provides materials to assist in crafting an investigation procedure; Promotes the adoption of root causal factor identification, analysis and resolution systems; and Provides several resources on incident investigation.

19. **Audit Requirements, Section 6.3** Provisions in Z10 require that safety audits be made "to determine whether the organization has appropriately applied and effectively implemented the occupational health and safety management system elements, including identifying hazards and controlling risks." This chapter: Establishes that the purpose of an audit is to improve the safety culture; Discusses the implications of observed hazardous situations; Explores management expectations; Comments on auditor qualifications; Discusses the need to have safety and health management system audit guides tailored to the location being audited; and Provides resources to develop suitable audit guides. One such resource is the audit guide, the VPP Site Worksheet for Star Approval, that is used by the Occupational Safety and Health Administration (OSHA) when screening applicants for Voluntary Protection Program (VPP) recognition. It appears as an addendum.

20. **Management Review, Section 7.0** The importance of the Management Review requirements in Z10 is inverse to the length of this chapter. Having a periodic Management Review process in place to determine the effectiveness of the problem-solving and operations improvement actions taken is a "must" step in the PDCA process. It was said in Chapter 1 that Management Leadership and Employee Participation is the most important section in Z10. It was also stated that the Management Review section was a close second in importance. That is because the thoroughness of feedback provided to fulfill the review process impacts on the quality of management leadership and decision making.

This chapter comments on the Management Review elements pertaining to: Hazard identification; Risk assessment and prioritization; Progress made in risk reduction; The effectiveness of procedures to eliminate or control identified hazards and risks; Actions taken on the recommendations made in safety and health audits; and The extent to which set objectives have been met.

21. **Z10, Other Safety Standards and Guidelines, and VPP Certification** This chapter commences with a comparison of the provisions in Z10 with other safety and health standards and guidelines. The conclusion is that Z10 is superior and that it is a state-of-the-art standard. The desire some companies have for their safety and health management systems to be "certified as being superior" is recognized. A comparison is made of the provisions in Z10 with those in the VPP program administered by OSHA. Organizations are encouraged to consider being certified as meeting the VPP qualifications. Achieving that status will result in having safety and health management systems close to Z10 provisions. The requirements to obtain the VPP Star Designation are provided in an Addendum.

CHAPTER 1

AN OVERVIEW OF ANSI/AIHA Z10-2005: THE AMERICAN NATIONAL STANDARD FOR OCCUPATIONAL HEALTH AND SAFETY MANAGEMENT SYSTEMS

INTRODUCTION

On July 25, 2005, the American National Standards Institute approved the Occupational Health and Safety Management Systems Standard, designated as ANSI/AIHA Z10-2005. Thus, for the first time in the United States, a national consensus standard was issued for safety and health management systems applicable to organizations of all sizes and types.

The standard represented a major development. It provides senior managements with a well-conceived state-of-the-art concept and action outline to improve their safety and health management systems. The drafters of Z10 adopted many of the best worldwide practices. As employers make improvements to meet the standard's requirements, it can be expected that the frequency and severity of occupational injuries and illnesses will be reduced. The beneficial societal implications of Z10 are substantial.

This new standard will have a significant and favorable impact on the content of the practice of safety and on the knowledge and skill requirements for safety and health professionals. Over time, Z10 will revolutionize the practice of safety. All persons responsible for occupational safety and health within an organization or who give counsel on occupational safety and health management systems to entities other than their own should have a copy of this standard and be thoroughly familiar with its content.

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Since Z10 is state-of-the-art, it is not surprising that many organizations do not have management systems in place that meet all its provisions. To identify the shortcomings and develop an improvement plan, a gap analysis should be made in which the safety and health management systems in place or those recommended by consultants are compared with Z10 requirements.

To assist in developing an understanding of the content and impact of this standard, this overview chapter, in addition to giving brief comments on each section of the standard, comments on:

- Its history and development as the standard writing committee reached consensus
- A prominent and major theme within Z10
- How that major theme relates to serious injury prevention
- Z10 being a management system standard, not a specification standard
- International harmonization and compatibility
- Long-term influences and societal implications
- The continual improvement process: the Plan-Do-Check-Act (PDCA) concept

HISTORY, DEVELOPMENT, AND CONSENSUS

The American Industrial Hygiene Association obtained approval as the ANSI Accredited Standards Committee for the development of Z10 in March 1999. The first full meeting of the committee took place in February 2001. Over a 6-year period, as many as 80 safety and health professionals were involved as committee members, alternates, resources, and interested commenters. They represented industry, labor, government, business associations, professional organizations, and academia, and other individuals having a general interest in health and safety management systems. Thus, broad participation in the development of and acceptance of the standard was achieved.

One of the reasons for the Z10 committee's success was its strict adherence to the due diligence requirements in developing an ANSI standard. There was a balance in the stakeholders providing input, and the open discussions resulted in their vetting each issue raised to a conclusion. In the early stages of the committee's work, safety and health, quality, and environmental standards and guidelines from throughout the world were collected, examined, and considered. In crafting Z10, the intent was not only to achieve significant safety and health benefits through its application, but also to impact favorably on productivity, financial performance, quality, and other business goals.

Employers who have a sincere interest in reducing employee injuries and illnesses will welcome discussions on how their safety and health management systems can be improved. A good number of companies have issued safety policy statements in which they affirm that they will comply with or exceed all relative laws and standards. Those employers, particularly, will want to implement provisions in the standard that are not a part of their safety and health management systems.

A MAJOR THEME

Throughout all the sections of Z10, starting with Management Leadership and Employee Participation through the Management Review provisions, the following theme is prominent.

Processes for continual improvement are to be in place and implemented to assure that:

- Hazards are identified and evaluated.
- Risks are assessed and prioritized.
- Management system deficiencies and opportunities for improvement are identified.
- Risk elimination, reduction, or control measures are taken to assure that acceptable risk levels are attained.

In the standard, these definitions are given:

- *Hazard:* A condition, set of circumstances, or inherent property that can cause injury, illness, or death
- *Exposure:* Contact with or proximity to a hazard, taking into account duration and intensity
- *Risk:* An estimate of the combination of the likelihood of an occurrence of a hazardous event or exposure(s), and the severity of injury or illness that may be caused by the event or exposures

In Z10's Appendix E, which gives guidance on risk assessment and prioritization, the definitions above are duplicated, and this definition is added:

- *Risk Assessment:* The identification and analysis, either qualitative or quantitative, of the likelihood of the occurrence of a hazardous event or exposure, and the severity of injury or illness that may be caused by it

Understanding the standard's major theme and these definitions is necessary to successfully apply its provisions.

RELATING THIS MAJOR THEME TO SERIOUS INJURY PREVENTION

A plea is made here in Chapter 3, "Serious Injury Prevention," for organizations to extend their safety cultures so that a focus on the prevention of serious injuries is embedded into every aspect of their safety and health management systems. In the economic world that now exists, staffs at all levels are expected to do more with less. Seldom will all the resources, money, and personnel be available to address all risks. To do the greatest good with the limited resources available, risks presenting the potential for the most serious harm must be given higher priority for management consideration and action.

Z10 IS A MANAGEMENT SYSTEM STANDARD

The Z10 committee set out to write a management system standard for continual improvement, not a safety management primer or a specification standard. What is the difference between a management system standard and a specification standard? In a management system standard, general process and system guidelines are given for a provision without specifying the details on how the provision is to be carried out. In a specification standard, such details are given. Section 5.2-B of Z10 is used to illustrate the difference:

> Section 5.2: Education, Training, Awareness, and Competence. The organization shall establish processes to:
>
> B. Ensure through appropriate education, training, or other methods that employees and contractors are aware of applicable OHSMS requirements and are competent to carry out their responsibilities as defined in the OHSMS.

If Z10 was written as a specification standard, requirements comparable to the following might be extensions of Section 5.2-B.

a. A minimum of 12 hours of training shall be given initially to engineers and safety professionals in safety through design, to be followed annually with a minimum of 6 hours of refresher materials.
b. All employees shall be given a minimum of 3 hours of training annually in hazard identification.
c. All employees shall be given a minimum of 2 hours of training annually in the use of personal protective equipment.
d. All training activities conducted as a part of this provision shall be documented and the records shall be retained for a minimum of 5 years.

Sections 5.2-A, C, D, and E of Z10 speak of management processes, not specifications, for defining and assessing training and competency needs, ensuring access to participation in education and training, providing training in a language trainees understand, and ensuring that trainers are competent. Comments are made in the advisory part of the standard on specific subjects for which personnel should be trained, such as safety design, incident investigation, hazard identification, good safety practices, and the use of personal protective equipment. Those advisory comments are not a part of the standard.

COMPATIBILITY, HARMONIZATION, AND POSSIBLE INTERNATIONAL IMPLICATIONS

One of the goals of the drafters of Z10 was to assure that it could be easily integrated into the management systems an organization has in place. The standard's

structure is compatible and harmonized with the ISO 9000 family of standards on quality management and the ISO 14000 family of standards on environmental management. Also, Z10 is written as a generic standard and patterned after the style of those standards. In this context, generic means that the standards can be applied to *all*:

- Organizations of any size or type
- Sectors of activity, whether a business enterprise, a non-profit service provider, or a government entity

Of particular note is the recognition that Z10's Introduction gives to the International Labour Organization's Guidelines on Occupational Health and Safety Management Systems, designated ILO-OSH 2001, as a resource. It is a good, additional reference for safety and health management systems. For access to the Guidelines, go to http://www.ilo.org/public/english/support/publ/xtextoh.htm. Intentionally, Z10 adopts from and is in harmony with ILO-OSH 2001. Similarities between the Guidelines and Z10 are notable. However, Z10 goes beyond the Guidelines in some respects, and it may very well be considered a model at the International Organization for Standardization (ISO).

ISO is the world's largest nongovernmental developer of standards, working with a network of national standards institutes representing 148 countries. The United States is represented at ISO by the American National Standards Institute. On two occasions—in 1996 and again in 2000—votes were taken at ISO on developing a standard for an occupational safety and health management system. In the latter year, the vote against a standard carried by a narrow margin. A consensus among the members of ISO for such a standard had not yet emerged.

Since Z10 is compatible and in harmony with the ISO 9000 and ISO 14,000 series of standards, and since Z10 represents current best practices, and since consideration will more than likely be given again to the development of an international safety and health management system standard at ISO, one can easily speculate on Z10 becoming the model for that standard. Continue the speculation and international requirements for accredited safety and health management systems related to Z10 may be envisioned.

LONG-TERM INFLUENCE: SOCIETAL IMPLICATIONS

As the provisions of this ANSI standard are brought to the attention of employers and they strive to have safety management systems in place that are compatible with those provisions, its impact on what employers and society believe to be an effective safety and health management system will be extensive.

Over time, Z10 will become the benchmark against which the adequacy of occupational safety and health management systems will be measured. Societal expectations of employers with respect to their safety and health management systems will be defined by the standard's provisions.

Employment Implications

As the requirements of Z10 become more prominently known, it can be expected that employers of safety and health professionals will seek candidates who have the knowledge and skills necessary to give counsel on meeting those requirements. In that respect, certain provisions of the standard are of particular note—provisions to which safety professionals should give particular attention. Those provisions appear in the Planning section (4.0) and the Implementation and Operations section (5.0). They state that employers "shall" establish and implement processes to:

- Identify and control hazards in the design process and when changes are made in operations—which requires that safety design reviews be made for new and altered facilities and equipment.
- Have an effective management of change system in place—through which hazards and risks are identified and evaluated in the change process.
- Assess the level of risk for identified hazards—for which knowledge of risk assessment methods will be necessary.
- Utilize a prescribed hierarchy of controls to achieve acceptable risk levels—for which the first steps are to design out or otherwise eliminate or reduce the hazard.
- Avoid bringing hazards into the workplace—by incorporating safety and health design and material specifications in procurement contracts for facilities, equipment, and materials.

Educational Implications

Furthermore, the content of college-level safety degree programs will be impacted as employers of safety professionals seek candidates who are equipped to give counsel on the standard's requirements. Since one of the criteria for success of a technical degree program is the employment possibilities for its graduates, prudent professors responsible for those programs will assure that core courses properly equip students to meet employer needs.

Certification Implications

Z10 will also have an impact on the content of the examinations for the Certified Safety Professional (CSP) designation. Those examinations are reviewed about every 5 years to assure that they are current with respect to what safety professionals actually do. As the substance of the practice of safety changes, what the safety professionals who participate in the examination review process say about the content of their work at that time will have an influence on the content of the CSP examinations.

OSHA Implications

A good reference on the possible implications of Z10 with respect to OSHA and to legal liability potential is the March 2006 published paper titled *Legal*

Perspectives—ANSI Z10-2005 Standard: Occupational Health and Safety Management Systems. It was written by Adele Abrams, an attorney and an American Society of Safety Engineers advocate in Washington, D.C. A modified version of the paper appears as an Addendum to this chapter. It is "must" reading. Briefly, Abrams writes that:

- Although it is unlikely that OSHA will resume regulatory activity to adopt a federal safety and health management systems standard at this time, if such activity was commenced in the future, OSHA would be obligated to consider adopting Z10 as that standard. Federal legislation and administrative rules direct agencies to use voluntary consensus standards in lieu of developing government-unique standards, except when such use would be inconsistent with the law or otherwise impractical.
- Z10 could also have enforcement ramifications under OSHA's General Duty Clause (Section 5a), which requires that employers maintain a place of employment that is free from recognized hazards that are causing or are likely to cause death or serious injuries.
- Meeting the requirements of Z10 could be agreed upon during discussions between OSHA and employers as they developed consent orders to resolve citations made during inspections.

Two OSHA regional directors have said that reference to Z10 by OSHA would likely come about, to begin with, in discussions to resolve citations resulting from inspections.

Legal Liability Implications

For safety consultants who give advice on safety and health management systems to employers other than their own employer, the issuance of this standard presents legal liability potentials about which they should be knowledgable. These excerpts from Abrams's paper are pertinent:

> Safety and health professionals have an obligation to keep abreast of the latest knowledge and to include "best practices" in their safety programs and consultation activities, to the maximum extent feasible. Knowledge and comprehension of the ANSI Z10 standard may be imputed to safety professionals, in terms of determining what a "reasonable person" with similar training would be likely to know. Willful ignorance of the best practices set forth in Z10 and/or failure to incorporate such preventative measures in the workplace or programs under the safety and health professional's direction or oversight could lead to personal tort liability or professional liability.

Consider this scenario. An employer receives a citation from OSHA. In the negotiations that follow, the employer agrees with OSHA that the safety management system must be improved. You, a safety consultant, receive a phone call from the obviously stressed employer asking that you provide counsel on the improvements to be made so that the safety and health management system meets good standards.

You call on the employer, agree on a course of action and a price, and the arrangements are confirmed through a letter contract. You decide that the framework you will use to help the employer is a typical safety management system, which does not contain the prevention through design provisions in Z10 pertaining to safety design reviews, management of change, risk assessments and prioritization, a hierarchy of controls, and including safety and health specifications in purchasing agreements. Your counsel is well received and acted upon. Your contract is fulfilled and you have been paid.

Later, an incident occurs in the employer's operations and an employee is seriously injured. Since workers compensation laws govern, the employee cannot sue the employer. The employee's lawyer casts a large net to identify defendants. She discovers that you provided counsel on improvements to be made in the employer's safety management system.

You are on the witness stand. The employee's lawyer is ready. She studied the safety management system document on which you based the advice you gave your client. And she has knowledge of ANSI Z10. You are led through the substance of the advice you gave to your client. Then, she establishes that you, a safety professional, have knowledge of ANSI standards. She gets you to agree that ANSI standards establish the minimum requirements for the subjects to which they apply and that, over time, they acquire a quasi-official status.

She takes the position that Z10 represents the state-of-the-art. She works you through the elements in Z10 that were not addressed in the counsel you gave to your client and relates your omissions to the causal factors for the injuries that occurred to her client. She establishes that you, as a safety professional, have an obligation to be familiar with and apply the state-of-the-art in the counsel you give. She emphasizes that your counsel was not based on the state-of-the-art. Since you were negligent, you are liable.

Consultants who give advice on a fee basis to organizations to improve their safety and health management systems have reviewed the foregoing scenario and say it is plausible.

Z10'S TABLE OF CONTENTS

To provide a basis for review and comparison with the safety and health management systems with which safety professionals are familiar, Z10's table of contents is listed here:

The 11 annexes give valuable explanatory comments, examples of forms and procedures, and reference sources for many of the major sections. Information in the annexes is advisory and not part of the standard.

THE CONTINUAL IMPROVEMENT PROCESS: THE PDCA CONCEPT

The standard is built on the well-known Plan–Do–Check–Act (PDCA) process for continual improvement. Understanding the PDCA concept is necessary to effectively implement the standard. A brief review of the concept is given in Chapter 2, "The Plan-Do-Check-Act Concept (PDCA)." In Z10's Introduction, there is a chart based on the PDCA concept. A slightly reduced form of the chart is presented at the beginning of each of the standard's major sections. That version is shown in Chapter 2.

Similar continual improvement charts, based on the PDCA concept, are shown in the ANSI/ISO/ASQ Q9000-2000 series, the Quality Management Systems Standards. The ISO 14000 series on environmental management was revised in 2004 to make it compatible with the ISO 9000 series. It is also based on the PDCA concept. And the U.S. Environmental Protection Agency (EPA) suggests building an environmental management system on a PDCA model.

Throughout the standard, the words "process", "processes", "implemented", and "continual improvement" are often repeated. That is also the case in the previously cited standards on quality and environmental management. Z10 is based on a continual improvement approach. The standard outlines the *processes* to be put in place, *not the specifics*, to have an effective safety and health management system.

Brief comments will be made here to provide an overview of the major sections of the standard. With respect to these remarks, keep in mind the intent of the terms "shall" and "should." As is common in ANSI standards, requirements are identified by the word "shall." An organization that chooses to conform to the standard is expected to fulfill the "shall" requirements. The word "should" is used to describe recommended practices or give an explanation of the requirements. Recommended practices and advisory comments are not requirements of the standard.

SECTION 1.0: SCOPE, PURPOSE, AND APPLICATION

The Scope section (1.1) states that the standard defines the *minimum requirements* [emphasis added] for occupational health and safety management systems (OHSMS). The emphasis in the advisory data is on a generic and systems approach for continual improvement in safety and health management, and the avoidance of specifications. Further, the writers of the standard recognized the uniqueness of the culture and organizational structures of individual organizations and the need for each entity to "define its own specific measures of performance."

In the United States, meeting minimum requirements may not be enough. Ralph L. Barnett is chairman of Triodyne Inc. and a professor of mechanical and aerospace

engineering at the Illinois Institute of Technology. In a Triodyne safety bulletin titled "Minimum Safety Standard—An Oxymoron," he indicates that while complying with a standard is necessary, doing so may not be sufficient:

> Technologists, by and large, treat a standard as a "bible" which provides guidance for the discharge of their professional duties. Throughout the world, compliance or noncompliance with a safety standard is the criterion for determining whether or not safety has been achieved. Only in the United States of America is compliance with an appropriate standard treated as a necessary but not sufficient condition for precluding liability. . . . [Thus, the term] minimum standard is an oxymoron.

ANSI standards acquire a quasi-official status and are viewed as the minimum, but not necessarily sufficient, requirements. Repeating for emphasis–Safety consultants who give counsel on safety and health management systems to employers other than their own should recognize the status that ANSI standards acquire from a legal liability viewpoint.

The Purpose section (1.2) states that the primary purpose of Z10 is to provide a management tool to reduce the risk of occupational injuries, illnesses, and fatalities. Although Z10's purpose is simply stated, it defines precisely what the application of the standard is to accomplish to reduce occupational risk.

The Application section (1.3) states that this standard is applicable to organizations of all sizes and types. As is the case in the ISO 9000 and ISO 14000 series of standards, there are no limitations or exclusions in Z10 by industry or business type or number of employees. Z10 applies to all employers. In the Introduction and in comments in the advisory column opposite Section 1.3, it is made clear that the structure of the standard is to allow integration with quality and environmental management systems. Doing so is a good and noble idea.

SECTION 2.0: DEFINITIONS

As is typical in ANSI standards, definitions of some of the terms used in the standard are given. Although there are no surprises in the definitions, safety professionals should become familiar with them.

SECTION 3.0: MANAGEMENT LEADERSHIP AND EMPLOYEE PARTICIPATION

It should be understood that Section 3.0 is the standard's most important section. Safety professionals will surely agree that "Top management leadership and effective employee participation are crucial for the success of an Occupational Health and Safety Management System (OHSMS)." Top management leadership is vital because it sets the organization's safety culture and because continual improvement processes cannot be successful without sincere top management direction. Key statements in the "shall" column of the standard follow:

- Top management shall direct the organization to establish, implement, and maintain an OHSMS.
- The organization's top management shall establish a documented occupational health and safety policy.
- Top management shall provide leadership and assume overall responsibility.
- The organization shall establish and implement processes to ensure effective participation in the OHSMS by its employees at all levels.

As management provides direction and leadership, assumes responsibility for the OHSMS, and ensures effective employee participation, the purpose of the standard must be kept in mind—to reduce the risk of occupational injuries, illnesses, and fatalities. That will be done best if personnel in the organization understand that in the application of every safety and health management process, the outcome is to achieve acceptable risk levels, and that a special focus must be given to identifying the causal factors for incidents that result in serious injuries. Chapter 6, "Achieving Acceptable Risk Levels: The Operational Goal," offers guidance on achieving acceptable risk levels.

Supporting data appear Annexes A–C on Policy Statements, Roles and Responsibilities, and Employee Participation. Another good reference on management leadership and employee involvement is the chapter "Superior Safety Performance: A Reflection of an Organization's Culture" in *On The Practice Of Safety*.

SECTION 4.0: PLANNING

In the PDCA process, planning is the first step. This section requires that processes be established to identify hazards, risks, and shortcomings in safety management systems and to establish and implement plans for continual improvement. Measurable objectives are to be established to achieve the greatest probable risk reduction.

An initial review of the OHSMS in place is to be made for that purpose (Section 4.1.1). Issues identified during the review are to be assessed and prioritized, and documented risk reduction objectives established for the issues selected. An ongoing review process is to be maintained for the same purposes (Section 4.1.2).

In the continual improvement process, as elements in the standard are applied, information defining opportunities for further improvements in the safety and health management system, and thereby risk reduction, is to be fed back into the planning process.

Section 4.2: Assessment and Prioritization

Subsection 4.2 in the Planning Section sets forth additional problem identification mechanisms in its requirements for Assessment and Prioritization. In summary, employers are to have processes in place to identify and analyze hazards, assess the risks deriving from those hazards, and establish priorities for amelioration that, when acted on, will attain acceptable risk levels. Appendix K: Bibliography and

References provides a list of publications that describe risk assessment methods. There are many such methods. For example, in the *System Safety Analysis Handbook*, comments are made on 101 methods.

The breadth of the field of knowledge in risk assessment can be daunting but it does not have to be. One of the purposes of Chapter 8, "A Primer on Hazard Analysis and Risk Assessment," is to counter the dread that safety practitioners may experience in thinking about achieving an understanding of risk assessment techniques, and to give an assurance that acquiring that understanding will not be overly difficult.

Annex E provides information on the Assessment and Prioritization requirements in Section 4.2. A part of Annex E is a brief outline titled "Hazard Analysis and Risk Assessment Guide." It sets forth an easily understood and applied thought and action process on how to make a hazard analysis and a risk assessment. The process does not have to be complex.

Annex E also gives an example of a risk assessment matrix and promotes the use of such a matrix in communicating on risk reduction. Several examples of risk assessment matrices appear in Chapter 8, and in Chapter 10, "Three- and Four-Dimensional Numerical Risk-Scoring Systems." Risk assessment matrices set forth incident probability categories, ranges of severity of harm or damage, and resulting risk levels. A risk assessment matrix can serve as a valuable instrument in working with decision makers in arriving at risk levels and prioritizing ameliorating actions.

Section 4.3: Objectives and Section 4.4: Implementation Plans and Allocation of Resources

These sections logically follow the previous assessment and prioritization requirements. They require that documented processes "shall" be established to set objectives (Section 4.3) and to implement those objectives, an element of which is allocating the necessary resources (Section 4.4). As feedback is received on the application of provisions in the standard, objectives are to be modified in accord with the continual improvement process.

SECTION 5.0: IMPLEMENTATION AND OPERATION

"This section defines the operational elements that are required for implementation of an effective OHSMS. These elements provide the backbone of the occupational health and safety management system." All of Section 4.0 pertained to problem identification and analysis, establishing implementation plans, and providing the resources necessary for continual improvement. Section 5.1 states that organizations "shall establish and implement the operational elements set forth in this section" to achieve the improvements outlined as objectives were established. Comments follow on each of the operational elements.

Section: 5.1.1: Hierarchy of Controls Although it was said earlier that Z10 is a management system standard and not a specification standard, the provisions pertaining to a hierarchy of controls are the exception. A specifically defined

hierarchy of controls to reduce risks is outlined. The organization "shall" apply the methods of risk reduction in the order prescribed.

Annex G provides a pictorial and verbal display of the Hierarchy of Controls listed in Section 5.1.1 with application examples for each element. In Chapter 12, "Hierarchy of Controls: The Safety Decision Hierarchy," the state-of-the-art is moved forward through extensions that this author believes are now necessary in the first step within the hierarchy: Elimination. Also, the hierarchy is enveloped within a sound problem-solving technique. The chapter includes a section titled "The Logic of Taking Action in an Order of Effectiveness."

Section 5.1.2: Design Review and Management of Change Since I consider processes for making safety design reviews and for management of change to be vital but separate elements in a safety and health management system, I comment on each subject individually.

Design Reviews For quite some time, I—along with others—have professed that the most effective and economical way to minimize risks is to have the hazards from which they derive addressed in the design process. That is what Z10 requires. This is an exceptionally important element in this standard. Its impact can be immense.

To become qualified to give counsel on the design review provisions in Z10, a large percentage of safety professionals will have to acquire new knowledge and skill. Chapter 13, "Safety Design Reviews," is an introductory read on this subject. *Safety Through Design* is also a good reference.

If a design safety review management system is not in place in an organization, safety professionals should anticipate a long-term effort to achieve the culture change necessary to meet the requirements of Z10. This often means establishing a management system that mobilizes engineering, purchasing, quality control and other departments that may not be accustomed to working collaboratively.

To develop an understanding of the depth of what is to be undertaken, the chapter "Achieving the Necessary Culture Change" in *Safety Through Design* will help.

Management of Change Employers are to have processes in place to identify and take appropriate steps to prevent or otherwise control hazards and reduce the potential risks associated with them when changes are made to existing operations, products, services, or suppliers. Getting effective management of change procedures in place and maintaining them is not easy. As generalists in the practice of safety assist in drafting and implementing management of change procedures, they can learn from the safety personnel in organizations that have met the management of change requirements of the *OSHA Rule for Process Safety Management of Highly Hazardous Chemicals*, 29 CFR 1910.119.

Several safety professionals encouraged me to include a chapter on management of change in this book because they recognized the importance of having such a system in place. The experience of those safety professionals is in parallel with my research that shows, for all occupations, many incidents resulting in serious

injury occur when changes take place—when out-of-the-ordinary situations arise, particularly when unusual and nonroutine work is being done and when there are sources of high energy present. I am convinced that the application of Z10 management of change processes will serve to reduce the frequency of incidents that result in serious injuries.

Safety practitioners should study well the management of change requirements of Z10 to determine how they might assist in achieving the culture change necessary for their implementation. Applying change management methods will be necessary to overcome the normal resistance to change that will be experienced. Chapter 15, "Management of Change," provides guidance on initiating a management of change process.

Section 5.1.3: Procurement Although the requirements for procurement are plainly stated and easily understood, they are brief in relation to the enormity of what will be required to implement them. An interpretation of the requirements could be–safety and health professionals, you are assigned the responsibility to convince managements and purchasing agents that, in the long term, it can be very expensive to buy cheap. In summary, the procurement provisions require that safety specifications be included in purchasing and contract papers so that hazards and risks are not brought into the workplace.

Only a small percentage of employers have included specifications in their purchasing agreements and contracts that require suppliers to identify the hazards and assess the potential risks in the equipment and materials being purchased. As a safety director in a major company said recently, the only safety specification in their contracts is that OSHA standards and other legislative requirements be met. Chapter 16, "The Procurement Process," provides guidance on how to avoid bringing hazards into the workplace. Having procurement processes that include safety specifications could have startling good results in reducing the frequency of hazardous incidents and exposures.

Section 5.1.4: Contractors The intent of this section is to control the risks to an organization's employees from the work of contractors on the premises, and to protect the contractor's employees from risks deriving from the organization's operations. Many entities have such procedures in place. One of the "shall" provisions indicates that the process is to include "contractor health and safety performance criteria." That implies, among other things, vetting the contractor with respect to its previous safety performance before awarding a contract.

Section 5.1.5: Emergency Preparedness To meet the requirements of this provision, an organization is to have management systems in place to "prepare for, and/or respond to emergencies." Those systems are to minimize the risks that occur during emergencies. Also, periodic drills are to be conducted to test the emergency plans, and they are to be updated periodically.

Section 5.2: Education, Training, Awareness, and Competence

Obviously, this is an important section. Fortunately, the literature pertaining to it is abundant. Although processes are expected to be in place to ensure appropriate

education and training and that the training is given in a language the trainees understand, there is a unique emphasis in this provision.

It has five alpha-designated provisions. In three of them, the words "competence" or "competent" appear. The needed competence of employees and contractors is to be identified. Employees and contractors are to be competent to fulfill their responsibilities. Trainers are to be competent to train.

Section 5.3: Communication

Communication processes are to be established that inform about the implementation plan for occupational health and safety management systems, encourage prompt reporting of hazards, risks, and injuries, and identify and remove barriers to good communication.

Section 5.4: Document and Record Control

Documentation requirements of certain processes are specified in several places in Z10. As a performance standard would do, the document and record control processes are to fit the requirements of the safety and health management systems put in place. Document retention is required to demonstrate conformance with the requirements of Z10; documents are to be accessible; and forms and records are to be updated as necessary.

SECTION 6.0: EVALUATION AND CORRECTIVE ACTION

This section outlines the processes to evaluate the performance of safety and health management systems and to take corrective action when shortcomings are found. Communications on lessons learned are to be fed back into the planning process. The expectation is that new objectives and action plans will be written in relation to what has been experienced.

Section 6.1: Monitoring, Measurement and Assessment

Management systems for monitoring and performance measurement are to apply to such as workplace inspections, exposure assessments, incident tracking, employee input, and other needs as required by the employer's occupational health and safety management system. Findings deriving from those processes are to be communicated to interested parties.

Section 6.2: Incident Investigation

Because of studies I made, I now give greater emphasis to the importance of incident investigation because of its value in identifying cultural, operational, and technical causal factors for incidents that result in serious injuries and illnesses. However, the requirement for incident investigation in Z10 is contained in one

brief paragraph, with no subsections. Processes are to be established to investigate and analyze accidents in a timely manner so that deficiencies in safety and health management systems can be identified and their causal factors determined.

Advisory comments on incident investigation are more extensive. A significant advisory comment states that there is a value in feeding lessons learned from investigations into the planning and corrective action processes. That fits well with the emphasis being given here to serious injury and illness prevention. Chapter 18 addresses "Incident Investigation."

Section 6.3: Audits

Many organizations may make substantial revisions in their audit systems as they achieve conformance with Z10. Requirements are for safety and health management systems audits, not specification audits. Periodic audits are to measure the organization's effectiveness in implementing the elements of the occupational health and safety management systems. Thus, the audits are to determine whether the management systems in place do or do not effectively identify hazards and control risks.

Although many safety professionals are familiar with safety audit processes, I suggest that they review what the standard requires and determine whether it will be to their benefit to revise their systems. Annex I is helpful in this respect. It contains a brief example of an audit outline that matches all the PDCA sections of Z10. An expanded treatise on safety audits is presented here in Chapter 19, "Audit Requirements."

Section 6.4: Corrective and Preventive Actions

To fulfill the requirements of this section, employers are to have processes in place to address the deficiencies in their OHSMS, identify newly created hazards, and take action quickly on hazards that may be the causal factors for serious injuries and illnesses.

Section 6.5: Feedback to the Planning Process

The purpose here is to assure that hazards, risks, and safety and health management deficiencies observed in the monitoring and measurement, audit, incident investigation, and corrective and preventive action activities are properly communicated and considered in the continual planning and management review processes.

SECTION 7.0: MANAGEMENT REVIEW

The Management Review section and extensive advisory comments pertaining to it are "must" reading. It was said earlier in this chapter that Management Leadership and Employee Participation is the most important section in Z10. This section on Management Review is a close second. Making periodic reviews of the effectiveness of management systems is an important part of the PDCA process.

Section 7.1: Management Review Process

The opening sentence in this section reads as follows: "The organization shall establish and implement a process for top management to review the OHSMS at least annually, and to recommend improvements to ensure its continued suitability, adequacy, and effectiveness."

These are a few of the subjects to be reviewed: progress in the reduction of risk; effectiveness of processes to identify, assess, and prioritize risk and system deficiencies; how well the underlying causes of risks and system deficiencies are addressed; whether objectives have been met; and the performance of the OHSMS relative to expectations.

Section 7.2: Management Review Outcomes and Follow-Up

In accord with good management procedures, senior management is expected to give direction to implementing the changes needed in safety and health management processes to continually reduce risks. The standard requires that "Results and action items from the management reviews shall be documented and communicated to affected individuals, and tracked to completion." This provision gives the needed importance to the management review process.

CONCLUSION

Z10 represents an important step in the evolution of the practice of safety. It is a continual improvement management systems standard for which processes are to be in place to address hazards, risks, and deficiencies in safety management systems. Thus, Z10 is an occupational risk management standard.

Realistically, it can be expected that Z10 will become the benchmark against which safety and health management systems will be measured. As the effectiveness of safety and health management systems improves, it is logical to expect that the frequency and severity of occupational injuries and illnesses will be reduced.

It would be folly for safety and health professionals to ignore the long-range impact that Z10 will have on societal expectations concerning the quality of the safety and health management systems employers have in place, and on the expectations employers will have concerning the knowledge and capabilities of their safety and health staffs.

Prudent safety and health professionals will study the requirements of the standard to determine whether additional skills and capabilities are needed and move forward to acquire those skills when necessary. Having done so, they will be equipped to give guidance to managements on putting in place the safety management system elements that may not exist in the organizations to which they give counsel.

REFERENCES

Abrams, Adele. *Legal Perspectives—ANSI Z10-2005 Standard: Occupational Health and Safety Management Systems.* Des Plaines, IL: American Society of Safety Engineers, March 2006.

ANSI/AIHA Z10-2005. *Occupational Health and Safety Management Systems Standard.* Fairfax, VA: American Industrial Hygiene Association, 2005. Also available at, http://www.aiha.org/marketplace.htm.

ANSI/ISO/ASQ Q9000-2000 Series. *Quality Management Systems Standards.* Milwaukee, WI: American Society for Quality, 2000.

Barnett, Ralph L. "Minimum Safety Standard—An Oxymoron." *Safety Bulletin* 5, no. 3. June 1997

Casada, M. L., A. C. Remson, D. A. Walker, and J. S. Arendt. *A Manager's Guide to Implementing and Improving Management of Change Systems*. Washington, DC: Chemical Manufacturers Association, 1993.

Christensen, Wayne C., and Fred A. Manuele, eds. *Safety Through Design*. Itasca, IL: National Safety Council, 1999.

ILO-OSH 2001. *Guidelines on Occupational Health and Safety Management Systems*. Geneva, Switzerland: International Labour Organization, 2001. http://www.ilo.org/public/english/support/publ/xtextoh.htm.

ISO 14000 Series on Environmental Management. http://www.iso.org/iso/en/prods-services/otherpubs/iso14000/index.html.

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

Manuele, Fred A. "Risk Assessment and Hierarchies of Control." *Professional Safety*, May 2005.

OSHA Rule for Process Safety Management of Highly Hazardous Chemicals. 29 CFR 1910.119. Washington, DC: U.S. Department of Labor, 1992.

Stephans, R. A., and W. W. Talso. *System Safety Analysis Handbook*, 2nd ed. Albuquerque, NM: System Safety Society, 1997.

U.S. EPA. *Environmental Management Systems (EMS): Plan, Do, Check, Act Model*. http://www.epa.gov/ems/info/plan.htm.

ADDENDUM

LEGAL PERSPECTIVES — ANSI Z10-2005 STANDARD: OCCUPATIONAL HEALTH AND SAFETY MANAGEMENT SYSTEMS

This addendum is reprinted with the permission of Adele Abrams and the American Society of Safety Engineers, the entity that commissioned her paper. Abrams is an attorney, safety professional, and trained mediator who represents employers and contractors nationwide in OSHA and MSHA litigation, and in worker's compensation and other employment matters. She also provides safety, health, and environmental training and consultation services to both small and large businesses. She is president of Adele L. Abrams P.C. in Beltsville, Md., and can be contacted at safetylawyer@aol.com *or 301-595-3520*.

The July 2005 release of the ANSI Z10-2005 standard, Occupational Health and Safety Management Systems, has significant implications for safety and health practitioners and employers—with equal measures of danger and opportunity. In general, the utilization of national consensus standards will be of increased importance to this country as the economy of the United States moves towards more of a global perspective. National consensus safety and health standards, such as ANSI Z10, reflect the opinions of safety and health professionals and end-users working at all levels of the public and private sectors in technology development, manufacturing, training and academia.

Adoption of the basic precepts in such standards has many benefits and may protect users of the standard, while furthering the interests of affected businesses. However, the far-reaching implications of such standards in OSHA enforcement actions and in tort litigation also must be recognized. It is also essential to focus on the fact that such standards are voluntary, until such time as they are incorporated by reference into a binding regulation. Even reference to the ANSI Z10 standard

Advanced Safety Management Focusing on Z10 and Serious Injury Prevention, by Fred A. Manuele

in policy documents created by federal or state governments does not convert the nature of the standard from voluntary to mandatory.

The goal of the ANSI Z10 standard is to use recognized management system principles, compatible with quality and environmental management system standards such as the ISO 9000 and ISO 14000 series as well as with principles adopted by the International Labour Organization, to encourage integration of safety into other business management systems. However, at the present time, there is no apparent Z10 certification scheme similar to the international recognition program developed pursuant to the ISO standards.

The basic elements of the standard address management leadership and employee participation, planning, implementation, evaluation and corrective action and management review. Thus, in many important aspects, the Z10 standard encompasses the basic tenets that the Occupational Safety and Health Administration (OSHA) first propounded in its draft Safety and Health Management Standard, which was later withdrawn from its regulatory agenda.[1] However, the ZI10 standard goes beyond the OSHA draft standard's requirements because it also contains provisions that address risk controls, audits, incident/accident investigations, responsibilities and authorities.

It is unlikely that OSHA will resume regulatory activity concerning its withdrawn Safety and Health Management Standard under the current administration. However, if it should proceed in the future, it would be statutorily required to consider adoption of ANSI Z10 to address this issue based upon the requisites of the National Technology Transfer and Advancement Act (N1TAA), 15 USC §272, and the Office of Management and Budget's (OMB) Circular A-119, Federal Participation in the Development and Use of Voluntary Consensus Standards and in Conformity Assessment Activities.

The OMB Circular [consistent with Section 12(d) of the NTIAA] directs agencies to use voluntary consensus standards in lieu of developing government-unique standards, except when such use would be inconsistent with the law or otherwise impractical. However, under the current OSH Act, only national consensus standards that have been adopted as or incorporated by reference into an OSHA standard pursuant to Section 6 of the OSH Act provide a means of compliance with Section 5(a)(2) of the Occupational Safety and Health Act, 29 U.S.C. §651 et seq. ("the OSH Act").[2] Therefore, at some future time, OSHA could adopt Z10 as a mandatory safety and health standard through notice-and-comment rulemaking.

But aside from formal rulemaking, ANSI Z10 serves as a valuable reference. It could also have possible enforcement ramifications under the General Duty Clause (GDC) by federal OSHA. It may be employed to satisfy regulatory requirements of certain state-plan OSHA programs. A number of states have enacted laws mandating such programs for some or all employers,[3] so adoption of ANSI Zl0 may satisfy the compliance obligations for employers in those jurisdictions. Insurance companies encourage their client companies to implement safety and health management programs, and therefore use of Z10 may generate monetary savings on insurance (both liability and workers' compensation).[4]

Subpart C of OSHA's construction standards, 29 CFR Part 1926, contains specifications for safety and health training and management programs. See 29 CFR

1926.20 and 1926.21. Aside from these mandatory standards, the OSH Act's General Duty Clause, Section 5(a)(1), outlines every employer's legal obligation to keep its workplace free from recognized hazards that are likely to cause death or serious physical harm to its employees for which a feasible means of abatement exists.

Citations for violation of the GDC are issued when the four components of this provision are present and when no specific OSHA standard has been promulgated to address the recognized hazard. These four elements are: 1) the employer failed to keep its workplace free of a "hazard," 2) the hazard was "recognized" either by the cited employer individually or by the employer's industry generally, 3) the recognized hazard was causing or was likely to cause death or serious physical harm and 4) there was a feasible means available that would eliminate or materially reduce the hazard.

By definition, the GDC requirements of Section 5(a)(1) encompass recognized threats that result in occupational illness or injury. Thus, recognized experts' findings that a series of actions or conditions are required to prevent harm to workers are likely to satisfy the requirement for GDC applicability under the applicable legal tests. Voluntary guidelines, including standards promulgated by ANSI, have been used to support GDC citations and to enunciate an industry "standard of care" although the consensus standards themselves are not specifically enforceable by the agency. However, although decisions have varied over the years, in at least one case, the Occupational Safety and Health Review Commission ("OSHRC") has stated that OSHA consensus standards taken from private standard-setting organizations "were not intended to be used as mandatory, inflexible legal requirements."

The Mine Safety and Health Administration (MSHA) has no comparable general duty clause. To date, neither OSHA nor MSHA have referenced the ANSI Z10 standard in any of their standards, but this remains a future possibility that would enhance the stature of the standard in agency enforcement actions. At the present time, ANSI Z10 is strictly voluntary and does not create any specific duties under the OSH Act. Therefore, an employer's failure to implement the programmatic provisions of this consensus standard—absent from other findings—does not constitute a violation of Section 5(a)(1).

In summary, national consensus standards lack the force and effect of codified rules, which can only be promulgated after notice-and-comment rulemaking under the Administrative Procedures Act., 5 V.S.C. § 551 et seq. And, as noted by the U.S. Court of Appeals in *B & B Insulation, Inc. v. OSHRC, et al*., 583 F.2d 1364, 1367–1368 (5th Cir. 1978), the law requires only those protective measures which the knowledge and experience of the employer's industry would clearly deem appropriate under the circumstances.

Another important potential function of ANSI Zl0 concerns OSHA's Voluntary Protection Program (VPP). For over two decades, OSHA has approved worksites with exemplary safety and health management programs as participants in its VPP. Thus, for companies that aspire to attain VPP status, adoption of ANSI Z10 may help to jump start the application process and may foster participation by smaller companies that might otherwise be without adequate guidance on how to design

and implement such management systems. Data suggest that companies in the VPP have reported injury and illness rates that are sometimes 20% or less than the average for other establishments in their industry.

In tort litigation actions arising from workplace accidents, the presence or absence of a recognized and substantive safety and health management program can be critical in controlling financial liability.[7] Thus, the extent to which OSHA and MSHA reference Zl0 in future publications or rulemaking activities will increase its judicial recognition and create a guideline against which employer programs will be benchmarked.[8]

Safety and health professionals also have an obligation to keep abreast of the latest knowledge and to include "best practices" in their safety programs and consultation activities, to the maximum extent feasible. The fundamental difference between an ordinary suit for negligence and a suit for malpractice lies in the definition of the prevailing standard of care.[9] Knowledge and comprehension of the ANSI Zl0 standard may be imputed to safety professionals, in terms of determining what a "reasonable person" with similar training would be likely to know.

Willful ignorance of the best practices set forth in Z10 and/or failure to incorporate such preventative measures in the workplace or programs under the safety and health professional's direction or oversight could lead to personal tort liability or professional liability. To the extent that the safety and health professional is a management representative of the employer, the negligence could be imputed under the theory of respondeat superior. Thus, careful scrutiny and consideration of ANSI Z10's applicability to programs and practices is certainly warranted by all safety and health professionals.

Finally, ANSI Z10 has possible value in constructing settlement agreements or consent orders with federal OSHA, state-plan OSHA agencies and MSHA. Often employers who have systemic safety problems will be encouraged or required, as a condition of abatement or settlement, to design and implement programs that will address management failures in a cohesive manner. The scope and function of Z10 would likely satisfy the enforcement goals of prevention of future safety issues while encouraging penalty reductions to offset the costs of program implementation. There is the strong potential of the standard being included in settlement proceedings for occupational safety and health citations.

Safety professionals should be encouraged to take the following actions:

- Obtain a copy of this standard, review the standard and the background materials about it, and discuss it with senior management and legal counsel so that all parties are aware of what is expected. A legal opinion written by corporate counsel would also be a prudent action to take.
- Write and publish a policy addressing Zl0 in regard to how it fits in with the organization's current program and the U.S. Occupational Safety and Health Act.
- Write, implement, and document communication structures detailing how information is passed up the communication chain to senior management.

- Conduct through assessments to identify significant safety exposures and the means used to communicate them to those in a position of authority.
- The Z10 Standard places significant emphasis on accountability by senior management. There is some correlation with the requirements of Sarbanes Oxley Act of 2002 Public Law 107-204. It is important to ensure that safety audits are independent and that the results are reported and acted upon. Those safety practitioners who author/sign those audit reports and who fail to follow up on the recommended actions may be subject to sanctions such as listed under the new law. The point has been made that they now have a duty that goes beyond just informing management.
- Follow the ASSE Code of Conduct.

In summary, ANSI ZI10 provides safety and health professionals with a significant new tool to help enhance existing program design or to help smaller employers create a program that can protect workers while at the same time satisfying regulatory entities and insurers, effectuating cost savings and minimizing legal liability.

1 The complete original text of the non-mandatory guidelines is found in the *Federal Register* 54(18):3094–3916, January 26, 1989. When OSHA announced a proposed rule in its 1990s regulatory agenda, the agency articulated its intent to have a mandatory standard that would include at least the following elements: management leadership of the program; active employee participation in the program; analysis of the worksite to identify serious safety and health hazards of all types; training; and program evaluation. All of these components are present in the ANSI ZI0 standard.

2 Specific national consensus standards [e.g., American National Standards (ANSI) standards], which the Secretary of Labor adopted on May 29, 1971, were either used as a source standard and published in Part 1910 as an OSHA standard or explicitly incorporated by reference in an OSHA standard.

3 See, e.g., Cal-OSHA's standard at http://www.dir.ca.~ov/title8/8406.html.

4 One recent example was the recommendation in the 9/11 Commission Report that stated it "encourage[d] the insurance and credit-rating industries to look closely at a company's compliance with the ANSI standard [on emergency preparedness] in assessing its insurability and creditworthiness. CRS Report to Congress RL32520, Feb. 4, 2005, at p. CRS 4 (citing the 9/11 Commission Report at 397–398).

5 Dun-Parf Engd. Form Co., 12 BNA OSHC 1949, 1954, 1986–87, CCH OSHD ¶27,650, p. 36,021 (No. 79-253, 1986).

6 But see *National Realty & Construction Co., Inc. v. OSHRC*, 489 F.2d 1257, 1266 (D.C. Cir. 1973) (the court stated: "[t]he question is whether a precaution is recognized by safety experts as feasible, not whether the precaution's use has become customary").

7 Consensus standards may be used by plaintiff's attorneys to demonstrate the appropriate "standard of care" which, when violated, support awards for personal injuries. See, e.g.,

Hansen v. Abrasive Engineering & Manufacturing, Inc., 831 P.2d 693 (Ct. App. Ore. 1992) (jury considered ANSI standard violation in determining liability because it was relevant to standard of care manufacturer should be expected to meet, even though it was voluntary consensus standard). See also *Bowles v. Litton Industries, Inc*., 518 So. 1070 (La. Ct. App. 1987).

8 A national consensus standard that is "known generally" in a particular industry can reasonably be construed as providing the requisite actual or constructive knowledge to support a cause of action in litigation brought by OSHA or private sector third parties. See *United States v. B&L Supply Co*., 486 F.Supp. 26 (N.D. Tex. 1980) (recognized hazard is one known after taking into account standard of knowledge in the industry, and employer cannot defend citation by claiming ignorance of the practice/condition or its potential for harm); *Titanium Metals Corp. v. Usery*, 579 F.2d 536 (9th Cir. 1978) (OSHA General Duty Clause citation was affirmed because the National Fire Code provided substantial evidence that the industry recognized the particular hazard presented); *Getty Oil Co. v. OSHRC*, 530 F.2d 1143 (5th Cir. 1976) and Boeing Co., Wichita Div., 1977–78 CCH OSHD ¶ 22266 (1977) (violations affirmed where employer deviated from "standard industry practice" or "industry pressure vessel code" concerning testing of pressure vessels); *American Smelting & Refining Co. v. OSRHC*, 501 F.2d 504 (8th Cir. 1974) (affirming General Duty Clause citation where employer exposed workers to lead concentrations "greater than an acceptable nationwide standard"); *Bethlehem Steel Corp. v. OSHRC & Marshall*, 607 F.2d 871 (3d Cir. 1979) (company safety officer admitted that advisory ANSI standard represented industry consensus); Betten Processing Corp., 75 OSAHRC 43/E2,2 BNA OSHC 1724, 1974–75 CCH OSHD P19,481 (No. 2648, 1978) (judge erred in failing to consider ANSI standard as evidence of recognized hazard). This, to the extent industry consensus standards reflect an industry's recognition of a hazard, they are relevant, probative evidence of a recognized hazard in the view of American federal courts.

9 W. P. Keeton, D. B. Dobbs, R. E. Keeton, & D.G. Owen, *Prosser & Keeton on Torts*, West Publishing, Fifth Edition (Hornbook Series, pp. 185–193). If an individual is sued for ordinary negligence, the court will compare his/her behavior to what any reasonable person would have done under the circumstances. However, if a safety and health professional is sued for malpractice, the court will compare his/her behavior to what a reasonable member of the profession would have done. Professional standards are much higher and much better documented and often ANSI standards such as Z10 serve to satisfy the evidentiary burden and to determine the appropriate standard of care.

CHAPTER 2

THE PLAN-DO-CHECK-ACT CONCEPT (PDCA)

INTRODUCTION

The writers of ANSI/AIHA Z10-2005, the Occupational Health and Safety Management Systems (OHSMS) Standard, emphasized that the "OHSMS continual improvement cycle [is] based on the recognized quality concept of Plan-Do-Check-Act (PDCA)." A depiction of the PDCA concept appears at the beginning of each of the Scope, Purpose, Application, and Definitions sections. Figure 1 duplicates that depiction.

However, little information is provided on the PDCA concept and applying it in problem-solving initiatives undertaken for continual improvement. Thus, this chapter will:

- Discuss the origin and substance of the PDCA concept.
- Comment on the process, systems, and continual improvement aspects of PDCA.
- Discuss variations in PDCA applications.
- Relate the PDCA concept to basic problem-solving techniques.
- Give guidance on initiating a PDCA process.

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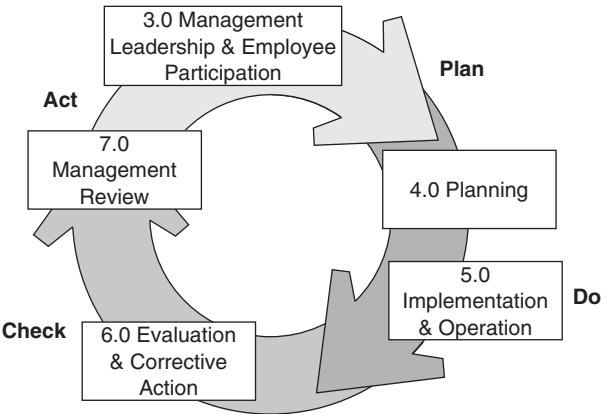

FIGURE 1 Plan-Do-Check-Act (PDCA). Used with permission of the American Industrial Hygiene Association, 2007.

ORIGIN AND SUBSTANCE OF THE PDCA CONCEPT

In *Out of the Crisis,* W. Edwards Deming provided a diagram designated as "The Shewhart Cycle." This is what Deming said about it:

> The perception of the cycle shown came from Walter A. Shewhart. I called it in Japan in 1950 and onward the Shewhart cycle. It went into immediate use in Japan under the name of the Deming Cycle, so it has been called ever since.

Deming became world-renowned for his successful approaches to quality management. Deming's depiction of The Shewhart Cycle predates all other diagrams this author has been able to locate that are comparable to what is now known as the PDCA concept.

Walter A. Shewhart was a Bell Laboratories scientist and friend and mentor of Deming. Shewhart is credited with having developed a Statistical Process Control Method in the late 1920s. Thus, the origin of the PDCA concept lies in statistical process control, a methodology developed to address the need for improvement in product quality. The emphasis of the PDCA concept with respect to product quality applications is process control and continual improvement. That is also the case in Z10. The words "process" and "processes" and the phrase "continual improvement" appear in Z10 over 60 times.

Deming's original depiction of The Shewhart Cycle is a six-step, numerically identified process in which the words "plan," "do," "check," and "act" do not appear boldly as in later PDCA depictions. These are the six steps. Keep in mind that this is a quality improvement process:

1. What would be the most important accomplishments of this team? What changes might be desirable? What data are available? Are new observations needed? If yes, plan a change or test. Decide how to use the observations.

2. Carry out the change or test decided upon, preferably on a small scale.
3. Observe the effects of the change or test.
4. Study the results. What did we learn? What can we predict?
5. Repeat Step 1, with knowledge accumulated.
6. Repeat Step 2, and onward.

The foregoing represents good thinking to achieve continual improved. As Deming has indicated, The Shewhart Cycle became known as the Deming Cycle, and it metamorphosed into the PDCA form.

Out of the Crisis was published in 1982. Deming's *The New Economics for Industry, Government, Education, Second Edition*, was published in 1994. Figure 2 appears in Deming's later book.

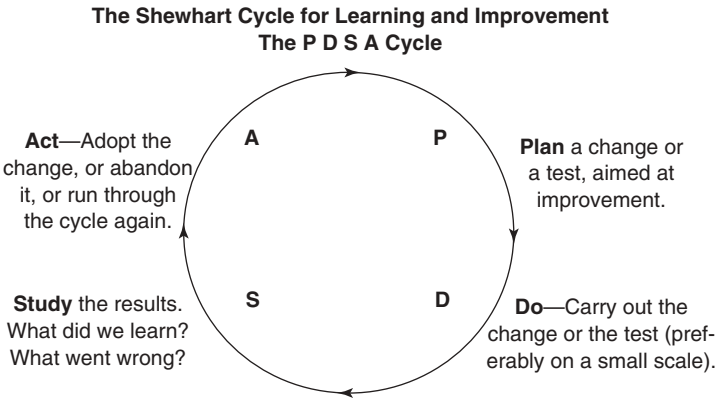

FIGURE 2 A flow diagram for learning and for improvement of a product or process. Reprinted with permission from MIT Press. Deming, W. Edwards, *The New Economics for Industry, Government, Education, second edition.*

Note that Deming's PDCA cycle became a Plan-Do-Study-Act (PDSA) cycle. Nevertheless, the main theme has been retained. One author has suggested that Deming was concerned that "Check" might be interpreted as meaning "to hold back," and that is the reason he replaced "Check" with "Study" in his latest version of the cycle. That replacement term has not been adopted broadly. Most of the literature on the continual improvement process refers to the PDCA model. In his latest book, Deming continued to recognize Shewhart as the source of the "Cycle for Learning and Improvement."

DEFINING PDCA

A variety of descriptive terms appear in the literature on PDCA and safety professionals should adopt the language that best suits their purposes. In the following examples, emphasis is added with underscores:

In the Introduction to Z10, the writers of the standard say that the occupational health and safety management systems continual improvement cycle [is] based on the recognized quality concept of "Plan-Do-Check-Act."

In *Out of the Crisis*, Deming wrote that "the Shewhart cycle will be helpful as a procedure to follow for improvement of any change."

In *The New Economics*, Deming said that "the PDSA cycle is a flow diagram for learning, and for improvement of a product or a process."

On the Internet, a paper issued by the North Carolina Department of Environmental and Natural Resources is captioned: "Plan-Do-Check-Act—A Problem Solving Process."

The U.S. Environmental Protection Agency has issued guidelines on implementing Environmental Management Systems in which this caption appears: "Plan, Do Check, Act Model."

In ANSI/ISO/ASQ Q9001-2000, the American National Standard on *Quality Management Systems—Requirements*, reference is made to "The model of a process-based quality management system, and the methodology known as 'Plan-Do-Check-Act.' " The standard gives a brief but adequate definition of the PDCA processes, as follows:

Plan:	Establish the objectives and processes necessary to deliver results in accordance with customer requirements and the organization's policies.
Do:	Implement the processes.
Check:	Monitor and measure processes and product against policies, objectives, and requirements for the product and report the results.
Act:	Take actions to continually improve process performance.

So, PDCA is a concept, cycle, procedure, flow diagram, process, model, and methodology—all for continual improvement. To relate directly to Z10 and the work of safety professionals who give counsel on its implementation, and striving for simplicity, I offer the following definition: The PDCA concept is a sound problem-solving and continual improvement model.

ON PROCESSES, SYSTEMS, AND CONTINUOUS IMPROVEMENT

Throughout Z10, there is frequent repetition of the premise that "the organization shall establish and implement *processes* [emphasis added] to ensure" that the elements of the OHSMS are established and implemented. In accord with the PDCA concept, Z10 is a process standard.

What is a process? In the context within which the term is used in Z10, a process is a management system designed to achieve a specific element in the standard.

The emphasis given to processes is appropriate and important. Having effective processes—that is, management systems—is necessary in the fulfillment of the PDCA concept. Furthermore, stressing the need for effective processes appropriately puts the focus in determining causal factors for injuries and illnesses on the adequacy or inadequacy of the processes, that is, the management systems.

Focusing on deficiencies in management systems is particularly advantageous in an attempt to identify the leading indicators and select the actions to be taken to reduce the probability of incidents or exposures occurring that may result in serious injuries or illnesses.

Deming emphasized making system improvements to achieve significant advances in product quality, rather than directing efforts on what employees do. In her book *Deming Management At Work*, Mary Walton recorded how Deming expressed the need to focus on improving the system:

> In the American style of management, when something goes wrong the response is to look around to blame or punish or to search for something to "fix" rather than to look at the system as a whole for improvement. The 85-15 Rule holds that 85 percent of what goes wrong is with the system, and only 15 percent with the individual person or thing.

The goal in applying the PDCA model is to improve processes. Taken as a whole, the processes make up the management system. In applying Z10, processes are to be established and implemented to create an OHSMS. Although Z10 does state that "employees shall assume responsibility for aspects of health and safety over which they have control," the focus of the standard is improving processes controlled by management.

Each process is interdependent on the other for the overall management system to achieve its goals. In the application of the PDCA concept, the impact that making a change in one process may have in another process must be considered. Deming addresses the interdependence of processes in *The New Economics,* as follows:

> A system is a network of interdependent components that work together to accomplish the aim of the system. A system must have that aim. Without an aim, there is no system. The greater the interdependence between components, the greater will be the need for communication and cooperation between them.

Here are some examples. Changes or alterations in the operating system may require new job hazard analyses and revisions in the standard operating procedures, the content of training programs, maintenance procedures, and inspection details; changes in design specifications have an impact on the safety-related specifications to be included in purchasing documents.

The aim of the OHSMS, in accord with the PDCA concept, is clearly established: "To provide a management tool to reduce the risk of occupational injuries, illnesses, and fatalities." Each continual improvement process is an integral part of the system

to achieve the desired risk reduction. To reduce the risk of injuries and illnesses, the goal in applying every element in the PDCA concept in the continual improvement process must be to achieve acceptable risk levels.

MEASUREMENT SYSTEMS

A continual improvement process requires that measurement systems be in place to observe progress toward achieving stated goals. Section 6.0, Evaluation and Corrective Action, in Z10 defines requirements for processes to evaluate the performance of the OHSMS through monitoring, measurement, assessment, incident investigations, and audits. Their purpose is to determine whether the processes are functioning as designed. The process measurements chosen must be compatible with an organization's size, operations, and other measurement systems.

Valid statistical measures, such as control charts, are convincing. In some situations, such as initiating the cultural change necessary to call attention to serious injury prevention, the frequency of occurrence data on such incidents that would be placed on a control chart will not be available since the subject is low-probability/severe-consequence events that do not occur often. Cost data for such events can be influential. For an additional reference, see "Measurement of Safety Performance" in *On The Practice Of Safety*.

VARIATIONS ON A THEME

Entering Plan-Do-Check-Act into a search engine on the Internet will bring up thousands of variations of the PDCA concept. There are so many adaptations of the PDCA concept because, through its use, it has proven to be a sound problem-solving and continual improvement model. However, there is a major difference in the literature on the PDCA concept and the literature on age-old, problem-solving techniques. The literature on PDCA seems to concentrate a great deal more on processes and the theme of continual improvement.

Comments are made here on two PDCA innovations in which many safety practitioners have an interest. They are Six Sigma and the U.S. EPA's Environmental Management Systems (EMS).

Six Sigma is principally a management strategy to achieve a product or service defect level at 3.4 defects per million opportunities, or lower. Writers on Six Sigma refer to the system as a parallel to Deming's PDSA cycle (*Six Sigma and Beyond: Deming and Six Sigma).*

As Deming does in his 14 Points of Management in *Out of the Crisis*, Six Sigma emphasizes the importance of designing processes and systems to enable the staff to achieve six sigma performance levels. Quoting from Deming in *Out of the Crisis:* "A theme that appears over and over in this book is that quality must be built

in at the design stage. It may be too late once plans are on the way." The same principle applies in Six Sigma and OHSMS. In Six Sigma programs, the adaptation of Deming's PDSA is called "Define, Measure, Analyze, Improve, and Control" (DMAIC).

Achieving a Six Sigma quality level is a major accomplishment. How does it relate to occupational injury and illness performance? OSHA's recordable incident rate is based on 200,000 hours worked. Project the 200,000 base to a million by multiplying by 5. If an organization had an OSHA recordable incident rate of 0.68, it would be operating at the Six Sigma level. For most organizations, that would be notable.

A search for easily available literature on the PDCA concept that would be helpful to safety professionals, and particularly smaller and medium sized organizations, was not overly fruitful. However, publications of the U.S. EPA on developing Environmental Management Systems (EMS) provide good conceptual information for managers and safety professionals who are about to adopt the PDCA concept.

In each of four bulletins, EPA makes it clear in bold letters that the EMS is based on the PDCA model. All of these bulletins are downloadable. The first bulletin on the Plan step can be accessed at http://www.epa.gov/ems/info/plan.htm. The other bulletins can be accessed at the EPA site by clicking on Do, Check, and Act. The bulletins for the Plan and Do steps are substantial and conceptually helpful; the other two are only a page each.

In the Plan and Do bulletins, reference is made to a publication titled *Environmental Management Systems: An Implementation Guide for Small and Medium Sized Organizations*. It can be accessed by clicking on the title. Although the title implies that the publication is for small and medium businesses, the document runs over 200 pages long. This *Guide* repeats again and again that the EMS model is built on total quality management concepts, as in the PDCA model.

The Guide is copyrighted by NSF International Strategic Registrations Ltd. NSF says that fair use of the materials is not limited, but that "Fair use shall not include the preparation of derivatives." The Guide is downloadable. The NSF organization describes itself as a world leader in management systems registrations. (Go to http://www.nsf-isr.org for more information).

RELATING PDCA CONCEPTS TO BASIC PROBLEM-SOLVING TECHNIQUES

Safety professionals who have an understanding of basic problem-solving techniques and how they are applied to hazard identification and analysis, making risk assessments, and risk elimination or control will have a relatively easy time adapting to the PDCA concept. The following list under the heading "Problem-Solving Methodology" is a composite of the methods shown in several texts on problem solving. Consider the following alignments:

Problem-Solving Methodology	Plan-Do-Check-Act
Identify the problem	*Plan*: Identify the problem
Analyze the problem	*Plan*: Analyze the problem
Explore alternative solutions	*Plan*: Develop solutions
Select a plan and take action	*Do*: Implement solutions
Examine the effects of the actions taken: If the results are not acceptable, start over	*Check*: Evaluate the results *Act*: Adopt the change, abandon it, or start over

In applying either the problem-solving methodology or the PDCA concept to prevent injuries and illnesses, the process is as follows.

1. Hazards are identified and analyzed.
2. The risks deriving from the hazards are assessed.
3. Alternative solutions for risk elimination or reduction are determined in accord with a prescribed hierarchy of controls.
4. Remedial risk elimination or reduction actions are selected and actions taken to implement them.
5. Review processes are to determine whether the desired risk reduction was achieved, and the residual risk is acceptable or unacceptable.
6. If the residual risk is unacceptable, start over.

To repeat, the only important difference in the literature on the PDCA concept in relation to the writings on age-old, problem-solving techniques is that more emphasis is given in the PDCA literature to continual improvement of processes.

That Z10 is a process and continual improvement standard cannot be said enough. Improvements in the processes, as the PDCA concept is applied, are to address the OHSMS issues. Those issues are defined in the standard as "Hazards, risks, management systems deficiencies, and opportunities for improvement."

Giving due recognition to the emphasis in the standard on PDCA processes and continual improvement, this author nevertheless believes that safety professionals who are schooled in basic problem-solving techniques can take comfort in knowing that they need make only minor adjustments in their thinking to adapt to the PDCA concept.

INTRODUCING THE PDCA CONCEPT

Assume that a safety professional wants to take leadership of applying the PDCA concept to an organization's safety and health management systems. To begin with, an assessment should be made of the opportunity for success. After reviewing the situation at hand, the safety professional would bring to bear the technical, small-group leadership, planning, and communication skills necessary to motivate

management's buy-in to the PDCA concept. The goal is to create strategies for success. There cannot possibly be a one-size-fits-all approach. Consider these extremes:

1. The organization has been certified with respect to the ISO 9000 (quality) and ISO 14,000 (environmental) standards. The management staff is familiar with the PDCA concept and welcomes with enthusiasm that the proposals being made to achieve continual improvement in the safety management systems are in accord with their PDCA applications. Even then, a few successful hands-on demonstrations that lead to process improvements related to hazards, risks, and deficiencies in the safety management system will be beneficial.
2. A safety professional is employed in a 500 employee organization in which the management knows little about the PDCA concept and is resistant to change. That does not preclude the safety professional from framing risk elimination and reduction proposals in a way to favorably affect the processes set forth in Z10 and to seek continual improvement in those processes. In that respect, the principles on which PDCA is based—good problem-solving techniques—would be applied. Achieving successes in that manner may be convincing and gain the respect of management for the PDCA concept.

To move forward in applying the process and continual improvement concept, change management techniques must be brought to bear. The participation of technically qualified people in all departments will be necessary, and the knowledge and capabilities of the people doing the work should be sought. Help with respect to change management can be found in Chapter 15, "Management of Change."

The starting point in undertaking a continual improvement initiative can be as narrow as addressing a particular hazard or as broad as installing a process that does not exist (e.g., risk assessment.) Two real-world indicators of micro and macro applications of the PDCA concept follow:

- Workers complain that although the Standard Operating Procedure (SOP) requires that they lockout/tagout electric power when a set-up job is being done in the production line, the location of the lockout station is too far away. It is at the opposite end of the building—a walk of about 400 feet. They say that the inconvenience promotes taking excessive risks and ignoring the SOP and that they have done so under pressure to get the production line working again. The safety professional is brought into the discussions. He looked into the lockout/tagout design process, the outcome of which is the error-provocative work situation described by the workers. He promoted a meeting of the design, operating, and maintenance personnel at his location.

- The hazards were identified and the risks were judged to be excessive.
- It was agreed that when error-provocative work situations and methods exist, errors will most likely occur, and that in this instance, the injury potential could be a fatality.
- A plan of action was agreed upon to study and correct all situations where the lockout/tagout station is not readily available.
- Responsibilities were assigned, with target dates for completion.
- The plan was put into effect.
- It was determined that the action plan achieved its purpose. The risks were reduced to acceptable levels.

In another multilocation operation, a fatality resulting from electrocution occurred in a situation comparable to that just described. The CEO took charge. She recognized that shortcomings in the design of lockout/tagout systems result in unacceptable risks and that those risks may be pervasive.

The safety professional was asked to work with operating executives and put together a Plan. It was recognized that the electrical hazards had to be identified and corrected. Under the direction of the division vice presidents, each location manager was required to Do, that is, to create study groups consisting of all levels of employment to identify potential electrocution situations, outline the actions to be taken to correct them, assign responsibilities and resources, and monitor the actions taken.

Location managers had to report that a Check had been made to assure that the hazard identification and risk assessment actions had been thorough and the necessary risk reduction measures has been taken. Furthermore, location managers were expected to Act by demonstrations of leadership to reinforce the culture change that had been achieved.

It became understood that during safety audits, all levels of employees would be interviewed concerning the effect of the actions taken. Throughout this activity, which took several months, the safety professional was available to personnel at the many locations for consulting. He was quite busy.

CONCLUSION

The drafters of Z10 did well in basing the Occupational Health and Safety Management Systems Standard on the PDCA concept. Doing so makes the standard compatible with other internationally accepted standards and facilitates melding the provisions in Z10 with other business practices.

The PDCA concept is a sound problem-solving and continual improvement model with which safety practitioners should be familiar. Fortunately, those safety professionals who have knowledge of basic problem-solving methods are well equipped to adopt the PDCA concept.

REFERENCES

ANSI/ISO/ASQ Q9001-2000. American National Standard: Quality Management systems—Requirements. Milwaukee, WI: American Society For Quality, 2000.

Deming, W. Edwards. *Out of the Crisis*. Cambridge, MA: Massachusetts Institute of Technology for Advanced Engineering Study, 1982.

Deming, W. Edwards. *The New Economics for Industry, Government, Education*, *Second Edition*. © 2000W. Edwards Deming Institute. Published Cambridge, MA: The MIT Press, 1994.

Environmental Management Systems: An Implementation Guide for Small and Medium Sized Organizations. http://www.epa.gov/ems/info/plan.htm, Copyright is held by NSF International Strategic Registrations, Ltd., Ann Arbor, MI.

Manuele, Fred A. *On the Practice of Safety*, *Third Edition*. Hoboken, NJ: John Wiley & Sons, 2003.

Six Sigma and Beyond: Deming and Six Sigma. http://www.pqsystems.com/eline/2000/04/qualitytip.htm.

Walton, Mary. *Deming Management at Work*. New York, Putnam Publishing Group, 1990.

CHAPTER 3

SERIOUS INJURY PREVENTION

INTRODUCTION

This chapter will help operations managers and safety professionals understand the adverse trending with respect to serious injuries and their costs, the challenges they face in implementing the conceptual and culture changes necessary to reduce serious injuries, and the actions that can be taken to prevent serious injuries. Thus, this chapter presents:

- Statistics displaying the noteworthy progression over the past several years with respect to serious injuries and workers compensation costs
- Data on the types of activities out of which many serious injuries occur and the results of studies on the characteristics of serious injuries
- Discussions of significant conceptual barriers to serious injury prevention that must be overcome
- The significance of an organization's safety culture in serious injury prevention and causal factor determination
- A procedure safety professionals can use to analyze serious incident experience and determine what proposals should be made for improvements in safety management systems
- Actions that can be taken to reduce serious injury potential

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For simplification, the term "serious injury" as used in this chapter encompasses serious occupational trauma, serious occupational illnesses, and all occupational fatalities.

SERIOUS INJURY PREVENTION MUST BE EMBEDDED IN AN ORGANIZATION'S SAFETY CULTURE

All who undertake an inquiry to determine what additional actions may be taken to reduce serious injury potential will learn from R. B. Whittingham's *The Blame Machine: Why Human Error Causes Accidents*. Whittingham describes how disasters and serious accidents result from recurring but potentially avoidable human errors. He shows how such errors are preventable because they result from defective systems within a company.

From his analyses of several events, he identifies the common causes of human error and the typical system deficiencies that led to those errors. Those deficiencies were principally organizational, cultural, technical, and management systems failures. (I draw similar conclusions from studies of causal factors for incidents resulting in serious injuries.)

Whittingham asserts that in some organizations, a "blame culture" exists whereby the focus in the investigation of incidents resulting in severe consequences is on individual human error, and the corrective action taken occurs at that level, rather than within the system that may have enabled the human error. He stresses that placing responsibility for the incident on what an individual did or did not do results in overly simplistic causal factor determination.

In his Introduction, Whittingham makes a disturbing statement that derives from his investigative experience—one that safety professionals should think about as they give counsel to their clients. He states that in many organizations, and sometimes whole industries, there is an unwillingness to look closely into error-provocative system faults.

In those organizations where there is a reluctance to explore systemic causal factors, the incident investigation stops after addressing the individual human error—the so-called unsafe act. Thus, a more thorough investigation that looks into the reality of the systemic root causal factors is avoided. Whittingham's observation poses a serious question: In some organizations are technical, organizational, management systems, and cultural root causal factors for incidents that result in serious injuries glossed over when incident investigations are made?

To answer that question for myself, I thought about the studies I made of over 1200 incident investigation reports completed by supervisors or investigation teams. I have not had an experience with an organization in which avoiding the reality of root causal factors was an active process. By that I mean—I have not encountered a situation in which instructions were given to avoid the identification of systems causal factors.

However, it is a certainty that avoiding the reality of systems causal factors occurs passively in many places. For some of my studies, safety directors in several large companies were asked to send me completed incident investigation reports

so that I could assess their quality and determine how deeply the investigations delved into causal factors.

On a scale of 1 to 10, with 10 being the highest score, some of these companies—large companies—scored as low as 2. Causal factor determination was abysmal, corrective actions were superficial, and opportunities to select leading indicators that define how safety management systems could be improved were overlooked.

In *Managing Maintenance Error: A Practical Guide*, James Reason and Alan Hobbs comment appropriately on the need to inquire into the systemic causal factors that "shape" human error:

> Errors are consequences not just causes. They are shaped by local circumstances: by the task, the tools and equipment and the workplace in general. If we are to understand the significance of these factors, we have to stand back from what went on in the error maker's head and consider the nature of the system as a whole.

To emphasize: If the intent is to reduce serious injury potential, the causal factors that derive from a system as a whole must be identified and acted on. It must be understood that to reduce the probability of serious injuries occurring, management must embed that purpose within its culture so that avoiding the causal factors for serious injuries is considered in the application of every element in its safety management system. The intent would be to achieve an understanding that personnel have a particular responsibility to:

- Give specific emphasis to anticipating and taking corrective action on hazards that may have serious injury potential.
- Assure in-depth reviews of the reality of the root causal factors for incidents that result in serious injury.
- Identify leading indicators that relate to serious injury potential.
- Address organizational, operational, technical, and cultural causal factors.

As safety professionals study serious injury causal factors and identify the improvements needed in safety management systems, they may find that a culture change is necessary. They would be taking a significant leadership role to achieve that change.

STATISTICAL INDICATORS

Statistics given here on serious injury trending over the last several years derive from macro studies, or may relate to specific industries. But, it must be understood, as my studies have shown, that serious injury experience varies greatly by industry. Data on serious injuries and workers compensation claims costs have been extracted from two primary sources: the Bureau of Labor Statistics (BLS) in the U.S. Department of Labor and the National Council on Compensation Insurance (NCCI).

Bureau of Labor Statistics

For many years, the BLS has issued reports titled "Lost-Worktime Injuries and Illnesses: Characteristics and Resulting Time Away From Work." The data in Tables 1 and 2 here were taken from Table 10 in the BLS 1995 and 2005 reports. Table 10 records the "Percent distribution of nonfatal occupational injuries and illnesses involving days away from work." It shows the percents of selected days-away-from-work categories as each category relates to the total number of days-away-from-work cases reported in a given year.

TABLE 1 Percent of Days-away-from-work Cases Involving Various Numbers of Days

	1	2	3–5	6–10	11–20	21–30	31 or more
1995	16.9	13.4	20.9	13.4	11.3	6.2	17.9
2005	14.3	11.6	19.0	12.7	11.5	6.5	24.2
% Change from 1995	−15.4	−13.4	−09.1	−5.2	+1.8	+4.8	+35.2

From 1995–2005:

- The decreases—the trending—in the percentages for the first four days-away-from-work categories are noteworthy.
- For the 11–20 days-away-from-work category, the increase of 1.8% only begins to have statistical significance.
- The 4.8% increase for the 21–30 days-away-from-work category is significant.
- Also significant is the increase of 35.2% for the 31 or more days-away-from-work category.

I asked Alan Hoskin, manager of the statistics department at the National Safety Council, whether the trending for lost workday cases with 31 or more days-away-from-work is statistically significant. He said it is. But, the lost workday case reporting rules on how days away from work are counted were revised by OSHA for 2002. Obviously, the trend data shown above need a closer look. Using the base data from the BLS reports for 1995–2001 and assuming the rules had not changed, Hoskin statistically projected numbers for 2002 and 2003.

TABLE 2 Thirty-one or More Days away from Work

Year	Percent		
2001	22.0	+22.9% over	1995
2002	25.1	Projected	23.4%
2003	26.2	Projected	25.0%

Table 2 shows the percent of days-away-from-work cases involving 31 or more days away from work for 2001, 2002 and 2003 as in the BLS reports and as projected by Hosking assuming no change had been made in the reporting ruled. For 2002 the projection for lost workday cases with 31 or more days away from work is 23.4%. In the BLS report for 2002 the recording is 25.1%. For 2003 the projection is 25.0%. The corresponding number in the BLS report on 2003 data is 26.2%.

The differences are small—1.2% and 1.7%—and not overly significant. They could result from the change in reporting rules on how days away from work are counted.

It cannot be concluded from the BLS data that the number of incidents resulting in severity has increased. The data do indicate that incidents resulting in severity are a larger segment of all days-away-from-work cases reported.

National Council on Compensation Insurance

BLS data on lost worktime injuries and illnesses track well with the NCCI reports. If you enter "Remarkable Story of Declining Frequency—Down 30% in the Past Decade" into any search engine, you will get many results linking to a 12-minute video prepared by the NCCI. That video shows the frequency of workers compensation claim is down considerably, not only in the United States but also in several industrialized countries.

However, as is indicated in a 2005 NCCI paper titled "Workers Compensation Claim Frequency Down Again,"

- There has been a larger decline in the frequency of smaller lost-time claims than in the frequency of larger lost-time claims.
- There have been significant increases in average indemnity and medical costs.

Take a look at the trend numbers in Table 3, taken from a 2005 NCCI paper titled "State of the Line." They show reductions in selected categories of claim values for the years 1999 and 2003, expressed in 2003 hard dollars.

Although the frequency of workers compensation cases is down, the greatest reductions are in lower-cost claims. The reduction for cases valued at over $50,000 is about one-fifth of that for cases valued at less than $2,000. Thus, costly

TABLE 3 Trending: By Claim Values: NCCI-2005

Value of Claim	Declines in Frequency
Less than $2,000	34%
$2,000 to $10,000	21%
$10,000 to $50,000	11%
More than $50,000	7%

claims—those with a larger number of days away from work—loom larger within the spectrum of all claims reported.

Now observe what has happened to costs. These data derive from the 2006 version of the "State of the Line" report issued by the NCCI. The data pertain to lost time claims. From January 1995–2005, the average:

- Indemnity claim costs increased 88%.
- Medical claim costs increased 137%.

To determine how such cost increases related to inflation in the economy as a whole, a visit was made through the Internet to http://www.InflationData.com. Using the Inflation Data Calculator provided there, with 1995 having a base of 1, a computation indicated that the accumulated inflation from January 1995–December 2005 was 35%. In those years, the increases in average workers compensation indemnity and medical claim costs stood at a factor of approximately 3.5 times inflation. That is significant, deserves attention, and defines opportunities for safety professionals to demonstrate additional value. In addition, data on the cost of serious injuries in relation to lesser injuries have been available for quite some time. Note the following indicators.

Liberty Mutual Insurance Company

In the 2003 Liberty Mutual Workplace Safety Index, the following statement appears:

> A small percentage of workers compensation claims continue to be responsible for the bulk of direct costs—in 2000, disabling workplace injuries were 18 percent of workers compensation claims but 93 percent of direct costs.

Employers Insurance of Wausau

A paper issued by Employers Insurance of Wausau some 25–30 years ago titled "Pareto's Law and the Vital Few" includes data similar to that in the Liberty Mutual paper:

> A study showed that 86% of total injuries produced only 6% of total costs, while 14% of total injuries produced 94% of total costs. Here we can distinguish between the "Trivial Many" and the "Vital Few." It becomes readily apparent that the logical approach to effective loss control is to concentrate major efforts on the "Vital Few."

That a small percentage of workers compensation claims represent a very large proportion of total costs fits well with Pareto's law, which is commonly referred to as the 20/80 rule, or the law of the trivial many and the critical few. In a large statistical sampling, 20% of the units will represent 80% of the financial impact, as well as the opportunity for improvement. Spending a disproportionate amount of time on the 80%, the literature on Pareto's law tells us, may achieve very little return in relation to the expenditures made. Giving additional emphasis to the critical few is the theme of this chapter.

Summarizing with Respect to Trending

To summarize at this point: Overall, the frequency of worker injuries is down; serious injuries are more prominent within the entirety of the lost worktime cases reported; and average workers compensation claims costs have risen at a remarkable rate. In light of these developments, it is suggested that safety professionals make studies to determine how these data might apply in the operations to which they give counsel. As a beginning, they should carefully review the content of the BLS's annual publication "Lost-Worktime Injuries and Illness: Characteristics and Resulting Days Away From Work." It contains 15 tables giving a great variety of data on the characteristics of lost worktime injuries and illnesses, such as for occupations of the injured persons, nature of injury and illness, experience by industry, events or exposures from which the injuries and illnesses derive.

CHARACTERISTICS OF INCIDENTS RESULTING IN SEVERITY

A statistical history supports proposing that safety professionals pay particular attention to the characteristics of incidents resulting in serious injuries, particularly with respect to the nature of work being done and the job titles of injured personnel.

My Analyses

Analyses I made of over 1,200 incident investigation reports revealed the Following:

- A large proportion of incidents resulting in severe injury occur in unusual and nonroutine work, in nonproduction activities, and where sources of high energy are present. Also, they occur in what I refer to as at-plant construction operations. (At-plant construction encompasses work such as this: A motor is to be replaced. It weighs 800 pounds, It sits on a platform 15 feet above the floor. The work is to be done by in-house personnel.)
- Causal factors for low probability/high consequence events are seldom represented in the analytical data on accidents that occur frequently. (Some ergonomics-related incidents are the exception.)
- Many incidents resulting in serious injury are unique and singular events, having multiple and complex causal factors that may have organizational, technical, operational systems, or cultural origins.

Giving Dan Petersen Due Recognition

One other safety professional has made observations that fit closely with my analyses, and his work deserves recognition. Dan Petersen supports the view that serious injury potential needs special attention. The following excerpts are from Petersen's *Safety Management, Second* Edition. Note the similarity to my findings.

> If we study any mass data, we can readily see that the types of accidents that result in temporary total disabilities are different from the types of accidents resulting in permanent partial disabilities or in permanent total disabilities or fatalities.
>
> The causes are different. There are different sets of circumstances surrounding severity. Thus if we want to control serious injuries, we should try to predict where they will happen.

Repeating for emphasis: The causes and circumstances surrounding severity are different; we should try to predict where serious injuries may occur.

United Auto Workers Data

At an auto industry workshop held in April 2004, Dr. Franklin Mirer, then director of the United Auto Workers (UAW) Health and Safety Department, stated that over a period of 20 years, skilled trades personnel—representing 20% approximately of the UAW membership of about 700,000—had experienced 41% of the fatalities.

Skilled trades people are maintenance personnel, millwrights, tinsmiths, machinists, electricians, and steamfitters. Skilled trades people are not production workers. Mostly, they do nonroutine work, are exposed to sources of high energy, and are engaged sometimes in at-plant construction. Hours worked during the period that Mirer references stand in the billions. His fatality numbers are statistically significant.

General Motors

In the January 2005 issue of *Professional Safety*, "Building a Better Safety Vehicle: Leadership-Driven Culture Change at General Motors" written by Steven Simon and Pat Frazee appears. This is a statement on the General Motors (GM) experience:

> Statistics showed that 80% of all serious accidents at GM occurred among the skilled trades, not on the assembly line. [Discussions with one of the authors revealed that, for this article, serious means life-threatening.]

Additional Studies I Made

In February 2004, a study was made to determine what percent of lost workday cases with days away from work occurred to personnel engaged in the company's principle business operation, that is, making a product or providing a service, and what percent occurred to ancillary or support personnel. The sample was small and the variations by company were considerable.

Contributors of data also provided OSHA incidence and lost workday case rates. Some of the companies with high OSHA rates had higher percentages of lost workday cases with days away from work occurring to workers engaged in the

principle business than for ancillary workers. The opposite was true for companies where the OSHA rates were low for their industry classes. Think about the possible significance of the following.

The three largest companies that provided data had a total of 230,000 employees. Each company had an OSHA recordable rate less than 0.5 and a lost workday case rate less than 0.2. A composite of the data for those companies indicated that 74% of lost workday cases with days away from work occurred to ancillary and support personnel. A safety director in one of the companies observed that it appeared as if his company had taken good care of safety in the production line but had not given equivalent consideration to the people who kept the production line going.

However, two safety directors asked to contribute data for the study said that the study was unnecessary because if incident frequency was reduced, severity potential would also be comparably reduced. More about that later.

In 2006, I made two similar studies, both for companies whose OSHA incident rates were well below average for their industries. Incident investigation reports on serious injuries only were sent to me for review. In one instance, 63% of serious injuries occurred to nonproduction personnel; in the other study, 67%. Although the percentages fall within a narrow range, other research shows that such ratios are not found when the work requires intensive manual labor and when the work is highly repetitive and physically stressful.

BARRIERS TO THE PREVENTION OF SERIOUS INJURIES

One could ask the following: Since the characteristics of serious injuries, the types of activities or exposures out of which many serious injuries occur, and the statistical trending concerning them have been known for some time, why have they not received more attention from the safety community? There are two age-old beliefs, often promoted by safety professionals, that are barriers to making the necessary inquiry into the reality of design and engineering, operational systems, and cultural causal factors for incidents resulting in serious injury. Those beliefs, which derive from statements made in H. W. Heinrich's *Industrial Accident Prevention*, are:

- Reducing incident frequency will equivalently reduce the occurrence of low-probability/serious-consequence events.
- Unsafe acts of workers are the principal causal factors for occupational incidents.

Heinrich's 300-29-1 Ratios

Heinrich was the originator of the type of pyramid, or triangle, that depicted his 300-29-1 ratios. Other triangles with different ratios have appeared. None will withstand statistical analysis. Heinrich's wording in support of the 300-29-1 ratios has changed from edition to edition of his book. Here is the version that appears in the fourth edition:

> Analysis proves that, in the average case, for every mishap resulting in an injury there are many other similar accidents that cause no injuries whatsoever. From a review of the data available concerning the frequency of potential-injury accidents, it is estimated that in a unit group of 330 accidents of the same kind *and involving the same person*, 300 result in no injuries, 29 in minor injuries, and 1 in a major lost-time injury.

In the above extract, the italics are Heinrich's. The phrase "and involving the same person" was not a part of the supporting statements for the ratios in the second edition of *Industrial Accident Prevention*. No explanation is given for adding the phrase in the third and fourth editions.

The ratios apply to accidents both of the same kind and involving the same person. Think about it. The premise lacks plausibility on its face. Consider this example. A worker reports to a construction job, takes the hoist to the tenth floor, and within minutes backs into an unguarded floor opening and falls to his death. For how many types of accidents occurring to the same person will the odds be 10 out of 11 that no injury occurs? (Heinrich makes it clear in his fourth edition of *Industrial Accident Prevention* that the ratios pertain to accidents, and not unsafe acts.)

After the discussion of his ratios, Heinrich makes the following statement, the broad influence of which lies at the base of a barrier to addressing the particulars of incidents resulting in severity:

> The foregoing statements and figures justify the conclusion that in the largest injury group—the minor injuries—lie the more valuable clues to accident causes.

Heinrich often stated his belief that the predominant causes of no-injury accidents are identical to the predominant causes of accidents resulting in major injuries. That led many safety professionals (I was one of them) to believe that if preventive efforts are focused on the types of accidents that occur frequently, the potential for serious injury would also be addressed. Even though the record shows otherwise, that belief is still widely held. However, consider what others say, and the following published records.

DNV Consulting and the "Major Accident Reality"

In 2004 DNV Consulting distributed a paper titled "Leading Indicators For Major Accident Hazards—An Invitation to Industry Partners." The purpose of its Invitation was to get financial support from the process industries for research on the causal factors for severe-consequence incidents. (Note that DNV did not receive the financing it needed.) Here are excerpts from the invitation that refer to observations made over a 20-year period by DNV personnel:

> Much has been said over the years about the classical loss control pyramid, which indicates the ratio between no loss incidents, minor incidents and major incidents, and it has often been argued that if you look after the small potential incidents, the major loss incidents will improve also.

> The major accident reality however is somewhat different. What we find is that if you manage the small incidents effectively, the small incident rate improves, but the major accident rate stays the same, or even slightly increases.

DNV said in its paper that the next step in managing risks is to develop leading indicators for incidents resulting in severity. That is an exceptionally worthy thought. I give this challenge to individual safety professionals—to propose procedures for identifying the leading indicators for low-probability/serious-injury potentials in the entities to which they give counsel.

National Safety Council

This extract appears in the National Safety Council's *Injury Facts*, 2003 Edition:

> From 1973 to 2001, the occupational injury and illness rate for private industry dropped 50%—from 11.3 to 5.7. In the same period, the incidence rate for Total Lost Workday Cases decreased 18%—from 3.4 to 2.8.

Obviously, the reduction in the lost workday incidence rate did not equal the reduction in incident frequency. These data on injury trending are important and thought-provoking. They contravene the commonly held belief that efforts concentrated on reducing injury frequency will equivalently impact on injury severity. To go along with that belief, one must assume that the causal factors for incidents occurring frequently (minor scratches, abrasions, and paper cuts) are the same as those for incidents resulting in serious injury. My studies, and studies made by others, show that the causal factors for many incidents resulting in severity are different, multiple, and complex.

To test the validity of published accident ratios and triangles, I did the research resulting in the publication of a paper titled "Injury Ratios." The most important conclusion drawn from that research is that variations on the inherent risk levels in industries and businesses—as indicated by the substantial differences in OSHA incidence recordable rates and the percent of incidents that result in lost workday cases—are so great that it is impossible to develop meaningful injury ratios which are universally applicable.

Heinrich's 88-10-2 Ratios

Heinrich professed that among the direct and proximate causes for industrial accidents, 88% are unsafe acts of persons, 10% are unsafe mechanical or physical hazards, and 2% of accidents are unpreventable. For Heinrich, "man failure" is the problem and the focus of prevention should be on what the worker does. He stressed applying remedies to the first proximate and most easily prevented causal factor and on psychology, as in the following:

> Selection of remedies based on practical cause-analysis that stops at the selection of the first proximate and most easily prevented cause (such procedure is advocated

> in this book) and considers psychology when results are not produced by simpler analysis.

This concept permeates Heinrich's work. It does not encompass what has been learned subsequently about the complexity of accident causation or that other causal factors may be more significant than the first proximate cause. Heinrich was open about his analytical methods. As indicated above, his focus was on "the first proximate and most easily prevented cause."

In the 1950s, studies made of accident experience in which all identified causal factors were entered into the analytical system produced greatly different results. (See the eighth edition of the National Safety Council's *Accident Prevention Manual for Industrial Operations: Administration and Programs*.) However, Heinrich continued to advocate his method and wrote this about it:

> In this research, major responsibility for each accident was assigned either to an unsafe act of a person or to an unsafe condition, but in no case were both personal and mechanical causes charged.

Unfortunately, such an analytical method—focusing on "the first proximate and most easily prevented cause" and assigning but one causal factor for an accident—would produce questionable results. Many safety professionals have promoted safety management systems that focus extensively on what the worker does, meaning on the prevention of worker unsafe acts. (I did that early in my career.) And some management personnel have been taught by safety professionals that the focus of their safety management systems should be principally on worker behavior.

W. Edwards Deming was world-renowned in the area of quality management. His premise on the appropriate focus to improve product or service quality also applies to safety. This is the rule, cited in Mary Walton's *Deming Management At Work:*

> The Rule holds that 85 percent of the problems in any operation are within the system and are the responsibility of management, while only 15 percent lie with the worker.

Since the majority of the causal factors for incidents that result in serious consequences are systemic, the safety efforts should be directed to improving the system. Focusing prevention efforts principally on the worker will not address systemic problems. In a safety management system that concentrates on worker behavior, management allocates resources predominantly to the worker behavior aspects of safety. Thus, inadequate attention is given to systemic causal factors deriving from design and engineering shortcomings, the hazards in the operational procedures, and the system of expected behavior that has developed.

Great progress in the prevention of incidents resulting in serious injury will not be made for as long as the two premises cited here remain as barriers to determining the reality of their causal factors.

WHY CHANGE IS NECESSARY

In a speech at the 2003 Behavioral Safety Now Conference, James Johnson, a managing director at Liberty Mutual Insurance Company, stated the following:

> I'm sure that have many of us have said at one time or another that frequency reduction will result in severity reduction. This popularly held belief is not necessarily true. If we do nothing different than we are doing today, these types of trends will continue.

There is symmetry between what Johnson said and one of the often quoted philosophical statements made by Dr. Lawrence Berra (also known as Yogi Berra):

> If you keep doing what you did, you will keep getting what you got.

Dr. Berra's philosophical statement brings to mind one of the many definitions of insanity:

> Doing the same thing over and over and expecting different results.

Listen to Jim Johnson and Yogi Berra and this author. Frequency reduction does not necessarily produce equivalent severity reduction. If we do nothing different than we are doing today, we will not significantly reduce serious injuries.

NEEDS ASSESSMENT: AN EVALUATION OF THE SAFETY CULTURE IN PLACE

Safety professionals should consider making a needs assessment, from the top down, to determine how much creative destruction and reconstruction through re-education are needed to achieve a mind-set that gives a proper place to reducing the potential for serious injury. Safety management systems that concentrate largely on the personal aspects of safety do not include activities to anticipate and identify the causal factors for low-probability/severe-consequence accidents. Nor do they include specially crafted efforts for their prevention.

Another author has written similarly. James Reason, in *Managing the Risks of Organizational Accidents*, observes that occupational safety approaches directed largely on the unsafe acts of persons have limited value with respect to the prevention of accidents having severe consequences.

In a news release concerning a grant made by Alcoa to the Foundation for Indiana University of Pennsylvania (IUP) to "support a national forum on fatality prevention in the workplace," Dr. Lon Ferguson, chair of the IUP Safety Sciences Department, is quoted as saying, "The reliance on traditional approaches to fatality prevention has not always proven effective." I extend Ferguson's statement to include serious injury prevention.

SIGNIFICANCE OF ORGANIZATIONAL CULTURE

Reference is made several times in this book to an organization's safety culture and how it impacts on the injury experience attained, favorable or unfavorable. Since causal factors for incidents resulting in serious injury are largely systemic and their accumulation is a reflection of the organization's safety culture, that subject must be explored. Comments made on organizational culture in the "August 2003 Report of the Columbia Accident Investigation Board" on the Columbia space ship disaster are pertinent here. They follow.

> The physical cause of the loss of Columbia and its crew was a breach in the Thermal Protection System on the leading edge of the left wing. In our view, the NASA organizational culture had as much to do with this accident as the foam.
>
> Organizational culture refers to the basic values, norms, beliefs, and practices that characterize the functioning of an institution. At the most basic level, organizational culture defines the assumptions that employees make as they carry out their work. It is a powerful force that can persist through reorganizations and the change of key personnel. It can be a positive or a negative force.

In every organization, its "values, norms, beliefs, and practices" are translated into a system of expected behavior, and that expected behavior impacts positively or negatively on decisions taken with respect to management systems, design and engineering, operating methods, work methods, and prescribed task performance.

Consider a real-world indication of how an organization's culture is translated into a system of expected behavior. Previous to making a presentation on avoiding serious injuries and fatalities, I asked that serious injury reports be sent to me, from which I selected six for discussion. Mostly, the causal factors in those reports focused on the unsafe acts of employees, and training, further education, and reinforcing employee safe practice rules was the corrective action.

After a half-hour of lecturing during which I cited the inadequacies in the investigation reports and stressed how an organization's culture could be a source of causal factors and could foster or impede root causal factor determination, I assigned the investigation reports to discussion groups with the provision that each would choose a leader who would give a report on how the investigations could have been conducted more thoroughly. Each group was provided with a causal factor guide.

After the session, a woman approached me and said, "Mr. Manuele, I think at my location, I have the kind of a culture problem you discussed because I believe that our risks are overlooked and a lot of risk taking is accepted. I say that because all of the incident investigation reports that hit my desk put the responsibility for what happened on the worker. The reports always say things like they reinstructed the worker or discussions about safety were held with the workers or the safe practice rules are being reinforced. They don't ever really analyze the situation."

I asked her what her job was. She responded that she was the plant manager. Cautiously, I said "You are the problem because you accept those shabby reports. They describe an aspect of the pattern of expected behavior, the safety culture,

which has evolved in your shop. It has become accepted that determining and eliminating or controlling the systemic causal factors is not necessary. And you can be the solution."

She was sharp and quickly said: "You mean I have to convince my staff that I'm not going to accept their B.S. any more." I said: "Yes." And I really enjoyed her response: "Mr. Manuele, I know how to do that."

Consider the following two examples that demonstrate how the culture accommodated a system of expected behavior which minimized concern over hazardous situations and supported excessive risk taking.

- Two workers refuse to do a job, saying that the work is too hazardous. Another worker is assigned by a supervisor to do the work, and he becomes a fatality. Speculate on the possible cultural and operational causal factors for that situation.
- There is deterioration in a tray of electrical cables and occasionally the workers experience a minor jolt. Work orders are reshuffled every Monday to establish priorities for the overly stressed maintenance personnel. Each week, the work order to make the needed repairs to the insulation in the cable tray is given a low priority. Over time, little notice is given to the jolts and the hazard's potential is played down. Getting an occasional jolt becomes an accepted norm. The deterioration continues. In time, a worker makes contact that results in his electrocution. What does this sort of incident say about cultural and operational problems? Does it not establish that, within the organization, excessive risk taking had become acceptable—that the system of expected behavior permitted giving safety orders a lower priority?

For many incidents resulting in serious consequences, there had been, over time, a continuum of less than adequate safety decision making that resulted in a system of expected behavior which condoned considerable risk taking. James Reason describes how systemic causal factors accumulate in *Managing the Risks of Organizational Accidents*. I highly recommend his book. Reason's principal research area has been human error and the way organizational processes and people contribute to system breakdown. He writes:

> 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.

As an additional resource, I suggest Donald A. Norman's *The Psychology of Everyday Things*. Norman has a background in both engineering and the social sciences. He writes:

> 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. For emphasis: I urge that the following comments by Reason and Norman be specifically and 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.

PROPOSING A STUDY OF SERIOUS INJURIES

Earlier in this chapter, it was stated that statistics given on serious injury trending derived from macro studies or may relate to specific industries. To produce information that relates directly to the entities to which safety professionals give counsel, I propose that they make studies of the serious injuries which have occurred in those entities. They will not be time-consuming since the data to be collected and analyzed should already exist or can be obtained easily.

A study outline follows that can be modified to fit particular needs. Safety professionals who make the study proposed here are encouraged to add other criteria suitable to the entity's organizational structure, culture, and incident experience.

1. Define the parameters for the incidents to be studied. A definition of a serious injury, suitable to the situation being evaluated, must be established. For instance, a safety professional may define a serious injury as one that results in lost workday cases involving 11 or more, 21 or more, or 31 or more days away from work. If using money values is appropriate in a given situation, cases valued at $25,000 or more, or $50,000 or more, may be selected for analysis.
2. Gather incident investigation and injury data related to the serious injury definition chosen, for at least a 3-year period.

3. For each incident:
   - Record the nature of the work being done.
   - Note the job titles of the injured personnel.
   - Determine whether the injured persons were engaged in the entity's principle business—making a product or providing a service—or whether they were ancillary personnel.
   - Identify the reality of the causal factors (design and engineering, operational system, cultural, organizational, etc.).
4. Analyze and summarize the data to determine what modifications in safety management systems should be proposed.

If the money value of injuries is to be used in selecting a severity category, Table 4 may help in choosing a cut-off level. It derives from an analysis of 280,000 workers compensation claims in the year 2003.

TABLE 4 280,000 Workers Compensation Claims in 2003

- 3% of claims valued at $25,000 to $50,000 represent 20% of total claims costs.
- 3% of claims valued over $50,000 represent 52% of total claims costs.
- 6% of claims valued at $25,000 or more produced 72% of total claims costs.

INCIDENT INVESTIGATION

Although it is suggested that, in the study proposed, the reality of the design and engineering, operational systems, and cultural causal factors be identified and analyzed, safety professionals should not be surprised if the incident investigation reports are inadequate for in-depth causal factor determination. Mention was made previously of my studies of over 1200 incident investigation reports and that I found, in many instances, that causal factor determination was dismal.

Comments made about incident investigation in the previously mentioned "August 2003 Report of the Columbia Accident Investigation Board" are identical to the conclusions I drew as a result of that research. As the following excerpts from that report are read, I suggest that safety professionals think about how they relate to the quality of the incident investigation systems in the entities with which they are involved.

> Many accident investigations do not go far enough. They identify the technical cause of the accident, and then connect it to a variant of "operator error." But this is seldom the entire issue. When the determinations of the causal chain are limited to the technical flaw and individual failure, typically the actions taken to prevent a similar event in the future are also limited: fix the technical problem and replace or

> retrain the individual responsible. Putting these corrections in place leads to another mistake—the belief that the problem is solved.
>
> Too often, accident investigations blame a failure only on the last step in a complex process, when a more comprehensive understanding of that process could reveal that earlier steps might be equally or even more culpable. In this Board's opinion, unless the technical, organizational, and cultural recommendations made in this report are implemented, little will have been accomplished to lessen the chance that another accident will follow.

As a result of the analyses I made of incidents resulting in serious injuries, I now suggest that incident investigation:

- Be considered as a prime source for selecting leading indicators for safety management system improvement. Because—If incident investigation is done well, the reality of the technical, organizational, methods of operation, and cultural causal factors in the work system will be revealed.
- Deserves a much higher place within all the elements of a safety management system. Because—The quality of incident investigation emerges as one of the primary markers in evaluating an organization's safety culture.

TO REDUCE SERIOUS INJURY POTENTIAL

Innovations in safety and health management systems to reduce serious injury potential may arise from a needs assessment, from a gap analysis that compares existing safety management systems to the requirements in Z10, and from studies safety professionals make of incident experience. Because of their pertinence to this chapter, comments are made here on three specific, low-expenditure measures that also should be considered.

Institute a Pre-Job Planning and Safety Analysis System

Since research shows that many accidents resulting in serious injuries occur when unusual and nonroutine work is being done, when high energy is encountered, and during at-plant construction operations, I strongly recommend that safety professionals consider drafting and proposing the implementation of a pre-job planning and safety analysis system. Its purpose is to provide a means to study how the work is to be done and the hazards and risks that may be encountered before the work actually commences. In those situations where such an idea has been implemented, it does not take long for supervisors and their workers to recognize that the work gets done more easily, more quickly, and with less risk.

Installing such a pre-job planning and safety analysis system is one method of fulfilling the Management of Change requirements in Z10, which are addressed in Chapter 15. A Pre-job Planning and Safety Analysis System is presented in

that chapter, along with discussion on how it was successfully implemented. An outline of such a system is given in the chapter's Addendum B. In addition, Chapter 15 includes a more detailed outline of a Management of Change System in its Addendum A.

Encourage the Institution of a Variation of the Critical Incident Technique

The purpose of the critical incident technique is to identify and take action on the hazards that have serious injury potential, utilizing the knowledge of safety professionals and the work staff. A system requiring interviews, form completion, or computer entry is put in place whereby employees are asked for their input on serious injury potential, including "near miss" hazardous situations. For the process to succeed, it must be recognized that the workers providing input are a valuable resource in identifying hazards and risks because of their extensive knowledge of how the work gets done.

A critical incident communication system fits very well with the Management Leadership and Employee Participation Section (3.0) of Z10. Highly valuable information can be obtained from the application of this relatively inexpensive data-gathering method.

At http://www._ul_ie/∼infopolis/methods/incident_html on the Internet, you will find a bulletin on Ergonomics Methods and Tools titled "Task Analysis Methods: Critical Incident Technique." Note that the authors say utilizing a critical incident system is "inexpensive and provides rich information."

> The critical incident technique is inexpensive and provides rich information. This technique is helpful in emphasizing the features that will make a system particularly vulnerable.

This is what William G. Johnson says about Incident Recall in *MORT Safety Assurance Systems*:

> Incident recall is an information gathering technique whereby employees (participants) describe situations they have personally witnessed involving good and bad practices and safe and unsafe conditions. Such studies, whether by interview or questionnaire, have a proven capacity to generate a greater quantity of relevant, useful reports than other monitoring techniques, so much so as to suggest that their presence is an indispensable criterion of an excellent safety program.

A system that seeks to identify causal factors before their potentials are realized would serve well in attempting to avoid low-probability/serious-consequence events. The National Safety Council's *Accident Prevention Manual: Administration & Programs*, 12th Edition, is good reference on the critical incident technique. Additional resources are listed in the references at the end of this chapter.

Improve Incident Investigation

There are three major elements in the practice of safety:

- Pre-operational (in the design process)
- In the operation mode (integrated within a process of continuous improvement)
- Post-incident (after a hazards-related incident has occurred)

In this third and important element of safety management, thorough investigations of hazards-related incidents are vital as organizations try to attain superior results. Safety professionals should consider assessing the quality of incident investigations and develop a process for improvement so that investigations address the reality of causal factors, particularly when incidents, including "near misses," have serious injury potential.

For emphasis, I again state that thorough investigations can be a source for selecting leading indicators as respects safety management systems that need improvement. Safety professionals may conclude that obtaining the desired improvements in incident investigation will require a long-term effort, equivalent to a change in culture.

CONCLUSION

Incident frequency is down, but severity has not decreased proportionately. That requires a review, by safety professionals and the managements they influence, of the premises on which safety management systems are built. The result should be the elimination of the myths, if they exist, that addressing frequency also encompasses severity and that worker unsafe acts are the principle causal factors for injuries, and adopting a mind-set, in any case, that gives proper attention to serious injury reduction.

Did Dr. Lawrence Berra not get it right? "If you keep doing what you did, you will keep getting what you got."

The major theme of this chapter is encouraging safety professionals to identify the characteristics of the "vital few" incidents that result in serious injury and to propose the management actions necessary for minimizing the potential for their occurrence. Although the trending for incidents resulting in serious injuries has negative implications, it also provides opportunities.

On several occasions in this chapter, I say that achieving greater effectiveness in reducing serious injury potential may require changes in an organization's safety culture. Understandably, that will not be easy to do. However, safety professionals are obligated to try. If that gets done, the beneficial results may be substantial.

One other notable source has also suggested that the focus of safety management efforts should be on the more significant risks. In August 2006 such a bulletin was issued in the United Kingdom; it can be found at http://www.hse.gov.uk/risk:

London The Health and Safety Commission (HSC) in the United Kingdom is urging people to focus on real risks—those that cause real harm and suffering—and to stop concentrating on trivial risks, launching a set of key principles and practical actions it believes sensible risk management should, and should not, be about.

REFERENCES

Accident Prevention Manual for Industrial Operations: Administration and Programs, 8th ed. Itasca, IL: National Safety Council, 1980.

Accident Prevention Manual for Industrial Operations: Administration & Programs, 12 ed. Itasca, IL: National Safety Council, 2001.

Bureau of Labor Statistics. "Lost-Worktime Injuries and Illnesses: Characteristics and Resulting Time Away From Work." http://www.bls.gov/iif.

Columbia Accident Investigation Report, Vol. 1. Washington, DC: NASA, August 2003. Also available at http://www.nasa.gov/columbia/home/CAIB_Vol1.html.

DNV Consulting. "Leading Indicators for Major Accident Hazards—An Invitation to Industry Partners." http://www.Robin.Pitblado@dnv.com.

Employers Insurance of Wansau. "Pareto's Law and the Vital Few."

Heinrich, H. W. *Industrial Accident Prevention*, 4th ed. New York: McGraw-Hill, 1959.

Inflation Data. http://www.InflationData.com.

Injury Facts, 2003 Edition. Itasca, IL: National Safety Council, 2003.

Johnson, James. Managing director, Liberty Mutual Insurance Company. Presentation at the 2004 Behavioral Safety Now Conference Reno, Nevada.

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

Manuele, Fred A. "Injury Ratios." *Professional Safety*, February 2003.

Manuele, Fred A. *Innovations in Safety Management: Addressing Career Knowledge Needs*. Hoboken, NJ: John Wiley & Sons, 2001.

Manuele, Fred A. "Is a Major Accident About to Occur in Your Operations?" *Professional Safety*, May 2004.

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

Mealy, Dennis. "State of the Line." *National Council on Compensation Insurance News Bulletin*, 2005 and 2006. http://www.ncci.com.

Mirer, Franklin. Director, UAW Health and Safety Department. April 2004, presentation in Detroit, MI.

Norman, Donald A. *The Psychology of Everyday Things*. New York: Basic Books, 1988.

Petersen, Dan. *Safety Management*, 2nd ed. Des Plaines, IL: American Society of Safety Engineers, 1998.

Reason, James. *Managing the Risks of Organizational Accidents*. Burlington, VT: Ashgate Publishing Company, 1997.

Reason, James, and Alan Hobbs. *Managing Maintenance Error: A Practical Guide*. Burlington, VT: Ashgate Publishing Company, 2003.

Simon, Steven I., and Patrick R. Frazee. "Building a Better Safety Vehicle: Leadership-Driven Culture Change at General Motors." *Professional Safety*, January 2005.

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

Advanced Safety Management Focusing on Z10 and Serious Injury Prevention, by Fred A. Manuele

> 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 is 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 that 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.

Hammer, Willie. *Handbook of System and Product Safety*. Englewood, NJ: Prentice Hall, 1972.

Johnson, W. *Human Error, Safety and Systems Development*. Norwell, MA: Kluwer Academic Publishers, 2004.

Kletz, Trevor. *An Engineer's View of Human Error*, 2nd ed. Rugby, Warwickshire, UK: Institution of Chemical Engineers, 1991.

Krause, Thomas A. "Moving to the 2nd Generation in Behavior-Based Safety". ASSE Professional Development Conference, orlando, Florida, June 2000.

Krause, Thomas A. "Moving to the 2nd Generation in Behavior-Based Safety." *Professional Safety*, May 2001.

Krause, Thomas A. "Improving the Working Interface." *Occupational Hazards*, June 2001.

Krause, Thomas A. "Influencing the Behavior of Senior Leadership." *Professional Safety*, June 2004.

Krause, Thomas R. *Leading with Safety*. Hoboken, NJ: John Wiley & Sons, 2005.

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

Norman, Donald A. *The Psychology of Everyday Things*. New York: Basic Books, 1988.

Reason, James. *Human Error*. Cambridge, UK: Cambridge University Press, 1990.

Reason, James. *Managing the Risks of Organizational Accidents*. Burlington, VT: Ashgate Publishing Company, 1997.

Rothblum, Anita A. "Human Error and Marine Safety." U.S. Coast Guard Research & Development Center. http://www.uscg.mil/hq/g-m/risk/e-guidelines/RBDM/html/vol4/Volume4/Gen_Rec/HumanErr.htm.

Strater, Oliver. *Cognition and Safety: An Integrated Approach to Systems Design and Assessment*. Burlington, VT: Ashgate Publishing Company, 2005.

Swain, A. D. *A Method of Performing a Human Reliability Analysis*. Monograph SCR-685. Albuquerque, NM: Sandia National Laboratories, 1963.

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

CHAPTER 5

MANAGEMENT LEADERSHIP AND EMPLOYEE PARTICIPATION — SECTION 3.0

INTRODUCTION

In Chapter 1, this author stated that Section 3.0, "Management Leadership and Employee Participation," is the most important section in the Occupational Health and Safety Management Systems Standard. Having superior management leadership is an absolute requirement—a sine qua non—if the goal is to achieve superior results. In Section 3.1.1, Z10 asserts that "Top management shall direct the organization to establish, implement and maintain an occupational health and safety management system." With respect to this very important section of Z10, this chapter:

- Discusses the significance of management direction with respect to an organization's safety culture
- Comments on the role of safety professionals with respect to the safety culture
- Sets forth the absolutes needed in management leadership to attain stellar results
- Acknowledges the impact that the current business environment may have on achieving or maintaining a superior safety culture

Advanced Safety Management Focusing on Z10 and Serious Injury Prevention, by Fred A. Manuele

- Comments on the specific elements in Section 3.0:
  - Policy Statement, Section 3.12
  - Responsibility and Authority, Section 3.1.3
  - Employee Participation, Section 3.2
- Relates management leadership to serious injury prevention
- Describes cases of inadequate management leadership and employee participation that resulted in catastrophes
- Proposes that an internal analysis of the safety culture be made, gives an outline for such an analysis, and comments on a case study

THE SIGNIFICANCE OF ORGANIZATIONAL CULTURE

As top management makes decisions directing the organization, the outcomes of those decisions establish its safety culture. Safety is culture-driven, and management establishes the culture. An organization's culture consists of its values, beliefs, legends, rituals, mission, goals, performance measures, and sense of responsibility to its employees, to its customers, and to its community—all of which translate into a *system of expected behavior*. The injury and illness experience that results is a direct reflection of an organization's safety culture.

I give strong emphasis to the phrase "*a system of expected behavior*" because it defines what a staff believes, in reality, management wants done. Although organizations issue safety policies, manuals, and standard operating procedures, their staffs' perception of what is expected of them and the performance by which they will be measured—the *system of expected behavior*—may differ from what is officially documented. Colleagues remind me of having written years ago that what management does, rather than what management says, defines the actuality of an organization's safety culture and its commitment or noncommitment to safety, and that often a difference exists between what management says and what management does.

To achieve superior results, only top management can provide the leadership and direction needed to "establish, implement and maintain an occupational health and safety management system." Major improvements in safety will be achieved only if a change in culture takes place—only if major changes occur in the *system of expected behavior*.

THE ROLE OF SAFETY AND HEALTH PROFESSIONALS WITH RESPECT TO THE SAFETY CULTURE

What is the safety and health professional's role with respect to the safety culture? In an organization where safety is a core value and management at all levels walks-the-talk and demonstrates by its actions that it expects the safety culture to be superior, the role of the safety and health professional is easier as he or she gives advice that supports and maintains the culture.

In a large majority of organizations, an advanced safety culture does not exist. Then, the principle role of the safety and health professional is to influence management to move toward achieving a superior culture. The possibility of being successful in that endeavor is enhanced if the safety professional attains the status of an integral member of the business team. That will result from giving well-supported, substantial, and convincing risk reduction advice that serves the business interests. Admittedly, convincing management that safety should be one of the organization's core values may not be easily achieved.

ABSOLUTES FOR MANAGEMENT TO ATTAIN SUPERIOR RESULTS

During a review of statements made in annual reports on safety, health, and environmental controls issued by five companies that consistently achieve outstanding results, a pattern became evident that defines the absolutes necessary to attain such results:

- Safety considerations are incorporated within the company's culture, within its expressed vision, values, beliefs, core values, and *system of expected behavior*.
- The board of directors and senior management lead the safety initiative and make clear by their actions that safety is a fundamental within the organization's culture.
- There is a passion for, and a sense of urgency to generate, superior safety results.
- Safety considerations permeate all business decision making, from the concept stage for the design of facilities and equipment, through their disposal.
- An effective performance measurement system is in place.
- All levels of personnel are held accountable for results.

Whatever the size of an organization—10 employees or 100,000—the foregoing principles apply to achieving superior results. Safety is culture-driven, and the board of directors and senior management define the culture and the system of expected behavior. When a passion for superior results exists, management will insist that its hazard and risk problems be identified and resolved.

Robert I. Sutton is a professor of management science and engineering at Stanford University and a prolific author on management practices. A statement he makes in one paper (http://www.bobsutton.typepad.com) relates well to what companies with superior results want done with respect to hazards and risks:

> Last week, I was talking to an executive from a big software company about the virtues of evidence-based management. I argued that, when you dig into how some of the best companies operate, you see that there is a commitment to finding, facing, and acting on the facts—no matter how unpleasant those facts might be.

For superior results to be achieved, management must establish open communication so that knowledge about hazards and risks flows upward to decision makers.

Proof of management's wanting to know about problems is demonstrated by the actions they take to eliminate or control hazards and risks.

Sutton's statement describes a necessity for superior results to be achieved. And safety professionals should be working toward influencing management that it is in their best interest to put processes in place to uncover, confront, and address hazards and the risks that derive from them. Never the less, realism with respect to the management practices in some companies must be acknowledged, as is discussed in the next section. Unfortunately, what R. B. Whittingham wrote in the Preface to *The Blame Machine: Why Human Error Causes Accidents* speaks to what is sometimes actuality:

> Organizations, and sometimes whole industries, become unwilling to look closely at the system faults which caused the error. Instead the attention is focused on the individual who made the error and blame is brought into the equation.

You will not find a statement in this book indicating that the role of the safety professional in favorably influencing an organization's culture is easily fulfilled. Yet, the endeavor remains worthwhile and attaining positive results, perhaps in small steps, can be rewarding.

THE BUSINESS ENVIRONMENT

It is possible that the prevailing business environment makes it more difficult for safety professionals in some organizations to favorably influence their safety culture. Consider this excerpt from a 2005 report by the International Organization for Economic Cooperation and Development (OECD) based in Paris:

> The concept of "drift" as defined by Rasmussen as "the systematic organisational performance deteriorating under competitive pressure, resulting in operation outside the design envelope where preconditions for safe operation are being systematically violated" was generally agreed as being a far too common occurrence in the current business environment.

This OECD report also includes comments taken from *The Japan Times* that are attributed to Norika Hama, a professor of international economics at Doshisha University Business School, at the February 27, 2004, Economic and Structural Reforms in Japan and Germany Symposium (jointly sponsored by the Japanese-German Center of Berlin and Japan's Keizai Koho Center.):

> **Japan Times article**
>
> Another offshoot of deflation that is particularly worrying, she said, has manifested itself in a series of major accidents that have hit the plants of Japan's industrial giants in recent years. The examples cited by Hama included a fire that destroyed a tire factory of Bridgestone Corp. in Kuroiso, Tochigi Prefecture and a fire and explosion at Nippon Steel Corp.'s Nagoya ironworks, both of which happened last September.

> In their bid to make profit under deflationary pressures, those companies have been restructuring their operations and trying to cut costs, and are compelled to continue using facilities and equipment that normally would have been replaced and renewed years ago, thereby raising the risk of accidents, Hama said. Also because of job cuts, the firms do not have sufficient numbers of workers who can repair and keep the old equipment in proper condition, she said.
>
> The operation of Japan's manufacturing industries was once looked upon as a global standard, but the fact that major companies that are supposed to symbolize that standard have been hit by serious accidents shows deflation has damaged the nation's industrial base, Hama observed.

There are other references in the OECD report indicating that the effects of pressures to maintain high profit levels and reduce costs may be among the root causal factors for incidents that have low probability but serious consequences. In such cases, safety is compromised and the safety culture deteriorates. Although the OECD report pertains to the chemical process industries, similar observations may be made with respect to the negative impact of bottom-line pressures in other industries.

Later in this chapter, comments are made on a catastrophe in which the management acknowledged in its own internally prepared report that its safety culture, over time, had been allowed to deteriorate. In Chapter 14, "Lean Concepts: Opportunities for Safety Professionals," reference is made to safety levels being diminished as lean concepts are applied. In discussions with several safety directors, it has been readily established that everyone is expected to do more with less and that bottom-line pressures weigh heavily.

It is appropriate to acknowledge then that when the business environment results in management decision making that negatively impacts on the safety culture, convincing management that safety should be one of the organization's core values will not be easily achieved. However, the safety professional has an obligation to be professional, factual, and complete in the recommendations that he or she makes to keep risks at an acceptable level.

POLICY STATEMENT, SECTION 3.1.2

Z10 states that "The organization's top management shall establish a documented occupational health and safety policy." Three sample policy statements are provided in the standard's Annex A. They are good references. An organization's policy statement should be specially tailored to reflect top management's beliefs and written in the language that the issuer would normally use. The policy statement also has to be believable. In drafting a policy statement, considering the following may be helpful. The policy statement should:

1. Clearly state management's position on safety, health, and the environment, and indicate that avoiding injury and illness to employees and to the public

from operations or from products sold, and damage to the environmental is an organizational value.

2. Bear the signature of the senior executive or manager.
3. Be appropriate to the nature of the organization's operations and their scope.
4. Be current, reviewed at least annually, and prominently displayed.
5. State a commitment to comply with all applicable legislation and standards.
6. Affirm that issued safety, health, and environmental policies are to be followed.
7. Make clear that employees are to actively participate in all elements of the safety and health management system.
8. Pledge to a continual improvement process to further reduce risks.

If additional examples of policy statements are desired, they may be found in the safety, health, and environmental reports issued by Bayer at http://www.bayerUSA.com; DuPont at http://www.dupont.com; Intel at http://www.intel.com; and Johnson & Johnson at http://www.jnj.com.

RESPONSIBILITY AND AUTHORITY, SECTION 3.1.3

This section of Z10 requires that management define roles, assign responsibilities and authority, provide the necessary resources (financial and human), and, I emphasize, establish accountability. If a management accountability system for safety, health, and environmental results is not in place, management commitment to attaining superior results is questionable. Accountability without consequences is not accountability.

In the Introduction to Z10, it is made clear that it was drafted to be compatible with other business processes. That thought is reinforced in Section 3.1.3. Management is to provide the leadership and assume responsibility for "integrating the occupational health and safety management system into the organization's other business systems and processes." Doing so is a goal worthy of achievement. It will interweave safety and health processes into, and be supportive of, the organization's endeavors.

While management has leadership responsibilities for safety, so too do employees. As the standard indicates, "Employees shall assume responsibility for aspects of health and safety over which they have control."

Appendix B, Roles and Responsibilities, is an excellent reference from which excerpts may be taken to "define roles, assign responsibilities, establish accountabilities, and delegate authority" as suitable to an entity's needs. The data cover the following employment categories: President, Chief Executive Officer, Owner; Executive Officers, Vice Presidents, and other Senior Leadership; Directors, Managers, and Department Heads; Supervisors; Employees; and Health and Safety Department.

Defining responsibilities and establishing accountabilities is an important step. It must be done for safety and health management systems to be effective and to provide a basis for performance and accountability reviews.

EMPLOYEE PARTICIPATION, SECTION 3.2

Not only are employees to assume responsibility for aspects of health and safety over which they have control, but they are also to have opportunity to participate in every aspect of the occupational health and safety management system. And they are to have the mechanisms, time, and resources necessary to participate.

A statement made in Z10's advisory column next to employee participation is close to one I have often made and which I believe to be fundamentally true. If an employer does not take advantage of the knowledge, skills, and experience of the workers close to the hazards and risks, opportunities to improve safety management systems and reduce injury and illness potential may be missed.

Employers improve their prevention efforts if they recognize the insight and creativity of their workers. The task of reducing risk is well served if the culture makes it clear that worker's knowledge is valued and respected and that they are to participate in ownership of the safety management system.

Two examples of outstanding contributions to risk reduction made by hourly workers come to mind. At a plant manufacturing heavy machinery, the innovations of tool and die makers in redesigning work situations to reduce ergonomics risks were so creative that visitors were often shown their inventions as a matter of pride. In a space industry company, it became standard practice for the design engineers to seek the opinions of hourly workers before proceeding to manufacture what had been designed. They learned through experience that the suggestions made by hourly workers avoided risks, particularly human factors design errors, and resulted in improved efficiency during the production process.

This section of Z10 also requires that employers provide employees with relative occupational health and safety information, and identify and remove obstacles or barriers to employee participation. Examples given in the advisory column on obstacles or barriers to meaningful employee participation are lack of response to suggestions for risk reduction and reprisals for bringing hazards to the attention of supervisors. Both of these examples define a negative safety culture.

Appendix C, Employee Participation, is an excellent reference. It covers these topics: Encouraging employee participation; Example methods for establishing a participative culture; Examples of employee participation; Time and Resources; and Communications.

RELATING MANAGEMENT LEADERSHIP TO SERIOUS INJURY PREVENTION

Analyses I made resulting from reviews of over 1,200 incident investigation reports indicates that:

- A large proportion of incidents resulting in severe injury occur in unusual and nonroutine work, in nonproduction activities, and where sources of high energy are present. Also, they occur in what may be called at-plant construction operations. (At-plant construction encompasses work such as this: A motor is to be replaced. It weighs 800 pounds, and sits on a platform 15 feet above the floor. The work is to be done by in-house personnel.)
- Causal factors for low-probability/high-consequence events are seldom represented in the analytical data on accidents that occur frequently. (Some ergonomics-related incidents are the exception.)
- Many incidents resulting in serious injury are unique and singular events, having multiple and complex causal factors that may have technical, operational systems, or cultural origins.

My studies reveal that very often, over time, there had been an accumulation of shortcomings in safety and health management decision making that reflected adversely on management leadership and the safety culture. Other writers have reported similar findings.

Incidents that result in serious injuries are often low-probability events that result from what James Reason refers to as an accumulation of latent technical conditions and operating practices that are built into a system and shape an organization's culture. He discusses the long-term impact of a continuum of less-than-adequate management leadership and decision making in *Managing the Risks of Organizational Accidents*:

> 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.

As the impact of less-than-adequate decision making by management spreads throughout the organization, employees at all levels respond to the negative safety culture that develops and risky work practices become common. Such a situation, once recognized, presents a challenge to safety professionals in that giving advice to reduce the probability of incidents occurring that result in serious injuries must become a principle goal.

While not easy to do, safety professionals must prepare the data that may convince management to recognize the possible systemic causal factors which have accumulated and to take action to reduce them. Thus, to achieve a significant reduction in the potential for low-probability/severe-consequence incidents occurring, a different mind-set and change in culture have to be achieved. All this relates to Management Leadership and Employee Participation.

CASES: INADEQUATE MANAGEMENT LEADERSHIP AND EMPLOYEE PARTICIPATION

Data follow with respect to two situations in which deterioration in safety management leadership and employee participation resulted in catastrophic incidents. Negative safety decision making resulted in a deteriorating safety culture, failure to adequately involve employees in the safety process, and poor communication.

A positive safety culture results from management leadership and direction that produce the opposite of what is described in the following cases. I suggest that readers ask whether similar situations ever occur in the operations to which they give counsel.

Catastrophe in Texas City, March 2005

On March 23, 2005, at a BP Products North America-owned and -operated refinery, a fire and explosion resulted in 15 deaths, 170 injuries, and extensive property damage. An investigation team led by BP employee J. Mogford released a report titled *Fatal Accident Investigation Report, Isomerization Unit Explosion Final Report, Texas City, Texas, USA*. The 192 page report may be accessed at the website listed in the end-of-chapter references.

The report's Executive Summary highlights its content. As you read the following excerpts from the summary, keep the safety culture, management leadership, accountability, and employee participation implications in mind:

> [The] underlying causes are identified as follows:
>
> - Over the years, the working environment had eroded to one characterized by resistance to change, and lacking of trust, motivation, and a sense of purpose. Coupled with unclear expectations around supervisory and management behaviors this meant that rules were not consistently followed, rigor was lacking and individuals felt disempowered from suggesting or initiating improvements. Process safety, operations performance and systematic risk reduction priorities had not been set and consistently reinforced by management.
> - Many changes in a complex organization had led to the lack of clear accountabilities and poor communication, which together resulted in confusion in the workforce over roles and responsibilities.
> - A poor level of hazard awareness and understanding of process safety on the site resulted in people accepting levels of risk that are considerably higher than comparable installations. One consequence was that temporary office trailers were placed within 150 feet of a blowdown stack which vented heavier than air hydrocarbons to the atmosphere without questioning the established industry practice.
> - Given the poor vertical communication and performance management process, there was neither adequate early warning system of problems, nor any independent means of understanding the deteriorating standards in the plant.

A statement in the first bulleted item is significant in understanding the positive development of, or the deterioration in, a safety culture. Changes in a safety culture, for better or worse, do not occur quickly. Note that in the Texas City refinery: "Over the years, the working environment had eroded to one characterized by resistance to change, and lacking of trust, motivation, and a sense of purpose." The time factor is further recognized in the Executive Summary:

> It is evident that [the causal factors] had been many years in the making and will require concerted and committed actions to address.

The excerpts that follow are taken from the body of the report. They relate specifically to inadequate participation by the hourly workforce, poor motivation, a safety culture that accepted high risk taking, and the failure of senior management to hold people accountable for following the "defined processes/procedures." I repeat: that all of these factors are acknowledged in an internally produced report by BP personnel:

- The principal gaps were the ad hoc nature of trending and analysis, and the lack of engagement of the hourly workforce in development of procedures and periodic self-assessments.
- When risks were identified, management and the workforce appeared to tolerate a high level of risk. The investigation team observed many examples of a high level of risk being accepted within the site.
- There was a failure by leadership to hold employees at all levels accountable for executing defined processes/procedures. A workplace environment characterized by poor motivation, unclear expectations around supervisory/management behaviors, no clear system of reward and consequences, and high distrust between leadership and the workforce, had developed over a number of years within the site. The working relationships between leadership and workers, and employees and contractors were poor.

To describe a positive safety culture that results from good management leadership and employee participation, start by turning the negatives of the foregoing into affirmatives.

Columbia Space Vehicle Disaster, February 2003

The importance of a sound safety culture was made manifest when the factors surrounding the loss of a NASA space orbiter and its crew on February 1, 2003 were examined. The *Columbia Accident Investigation Report*, issued in August of that same year, is deeply disturbing. I recommend that you review the report in its entirety.

The highlights of the report provide a basis for review by operations managers and safety professionals to assess whether there have been similar shortcomings in past decision making with respect to safety in their operations. Such a review should

explore whether management system shortcomings have resulted in an accumulation of latent conditions and operating practices that have serious injury potential. It should also result in an assessment of the organization's safety culture. From the Columbia report:

- The physical cause of the loss of Columbia and its crew was a breach in the Thermal Protection System on the leading edge of the left wing. In our view, the NASA organizational culture had as much to do with this accident as the foam. At the most basic level, organizational culture defines the assumptions that employees make as they carry out their work. It is a powerful force that can persist through reorganizations and the change of key personnel. It can be a positive or a negative force.
- Leaders create culture. It is their responsibility to change it. Top administrators must take responsibility for risk, failure, and safety by remaining alert to the effects their decisions have on the system. Leaders are responsible for establishing the conditions that lead to their subordinates' successes or failures.
- At the time of the launch of [the shuttle], NASA retained too many negative (and also many positive) aspects of its traditional culture: "Flawed decision making, self-deception, introversion and a diminished curiosity about the world outside the perfect place."
- After the accident, Program managers stated privately and publicly that if engineers had a safety concern, they were obligated to communicate their concerns to management. Managers did not seem to understand that as leaders they had a corresponding and perhaps greater obligation to create viable routes for the engineering community to express their views and receive information.
- Safety personnel were present [at meetings] but passive and did not serve as a channel for the voicing of concerns or dissenting views. The silence of Program-level safety processes undermined oversight; when they did not speak up, safety personnel could not fulfill their stated mission to provide "checks and balances."
- Management decisions made during Columbia's final flight reflect missed opportunities, blocked or ineffective communications channels, flawed analysis, and ineffective leadership.

PROPOSING AN INTERNAL ANALYSIS OF THE SAFETY CULTURE

Assume that management responded favorably to a suggestion made by a safety professional that an internally conducted survey of the organization's safety culture would be beneficial. The purpose would be to gather the perceptions of all levels of employment on the quality of the safety management system in place. It should be understood that for those who participate in the exercise, their perceptions are their reality. The result of such an exercise will be a culture survey.

The self-analysis would provide data on the positive and negative effects of management leadership, the extent of employee participation, and whether an

accumulation of latent technical conditions and operating practices has developed that could be the causal factors for low-probability incidents having severe consequences.

For such a self-analysis, a survey mechanism is necessary. An outline of a basic survey guide follows. For the survey mechanism to relate to the hazards and risks in a particular operation, it is necessary that management, assisted by a safety professional, add or delete items. Also, a scoring system for each item, compatible with practices in the organization, should be included in any revision of the guide so that a compilation of results can be made. In many situations, a simple "yes", "no", and "not applicable" scoring system will suffice. I must emphasize—this guide is not offered as a one-size-fits-all mechanism.

A Safety Management System Survey Guide

1. Is the safety management system in place in our organization effective?
2. Does management demonstrate by what it does that safety is a core value in our organization?
3. Is there a significant gap between what management says and what management does?
4. Has the staff reporting directly to the senior manager been held accountable, in reality, for a high level of safety decision making?
5. Is this a safe place to work?
6. Are you asked to effectively participate in safety discussions and meetings?
7. Are you asked to provide input on safety matters that affect you directly?
8. Is your input on safety matters respected and considered valuable?
9. Do you believe that some of the equipment you operate or the work methods you are required to follow are hazardous and overly risky?
10. Do you believe you are free to report hazardous conditions and practices without reprimand?
11. Are you encouraged to report hazardous conditions and practices?
12. Does your supervisor effectively give safety a high priority?
13. Is accident investigation of sufficient depth to identify the reality of causal factors (organizational, cultural, design and engineering, technical, procedural)?
14. Is there a broadly held belief that the unsafe acts of workers are the principle causes of accidents?
15. Is safety often relegated to a lower status and overlooked when there are production pressures?
16. Have you been given adequate training on hazards, risks, and safe operating procedures?
17. Does the organization's culture accept gradually escalating risk?
18. Does the organizational structure enhance or dissuade adequate safety decision making?

19. Are there organizational barriers that prevent effective communication on safety, up and down?
20. Have streamlining and downsizing conveyed a message that efficiency and being on schedule are paramount, and that safety considerations can be overlooked?
21. Is staffing adequate in your group so that work can be done safely?
22. Are you discouraged to report injuries?
23. Have technical and operational safety standards been at a sufficiently high level?
24. Has it been the practice to accept safety performance at a lesser level than the prescribed standard operation procedures?
25. Have known safety problems, over time, been relegated to a "not of concern" status and, thereby, become "acceptable risks"?
26. Has safety-related hardware or software become obsolete?
27. Are certain operations continued with the knowledge they are unduly hazardous?
28. Have budget constraints had a negative effect on safety decision making?
29. Has inadequate maintenance resulted in an accumulation of hazardous situations that have gone attended. (e.g., Is the detection equipment adequate, maintained, and operable? Are basic safety-related repairs unduly postponed?)
30. Has adequate attention been paid to "near miss" incidents that could, under other circumstances, result in a major accident?
31. Are safety personnel encouraged to be aggressive when expressing their views on hazards and risks, even though their views may differ from those held by others?
32. Has there been an overreliance on outside contractors (outsourcing) to do what they cannot do effectively with respect to safety?
33. Are purchasing and contracting procedures in place to limit bringing hazards into the workplace?

A CASE STUDY

A safety director in a very large municipal organization with about 13,000 employees read an article this author wrote in which the necessity of having a positive safety culture to achieve superior performance levels was emphasized. That organization's work is considered high-hazard and fatalities and serious injuries often occur. The safety director had concluded that the senior executive in his organization, to whom he reported, was somewhat removed from the leadership necessary to further reduce fatalities and serious injuries, and that he did not hold the staff reporting to him accountable for their incident experience.

The safety director sought help. During our discussions, it was agreed that he would approach his boss to convince him that the organization would be well served if the opinions of the staff were solicited on the quality of the safety management system in place. He did so, and it worked.

A safety management system survey guide comparable to that just presented here was sent to the safety director. He worked up a version of it that fit the high-hazard operation with which he was involved. The survey guide was sent to a statistically adequate sampling of the staff—at all employment levels. Over 70% of the guide's recipients responded; they took the survey seriously.

When the safety director analyzed the results, he found that the same shortcomings in the safety management system were recorded, largely, by all levels of employment. And there were many shortcomings. However, most important, some of the staff members reporting directly to the senior executive who authorized the survey indicated that, for the department as a whole, safety was not a high-level value.

During a meeting I attended with the safety director, his boss, and other interested persons, the senior executive was well prepared with questions about how superior safety results had been achieved elsewhere. He was surprised by the results of the culture survey. He learned that every level of the organization had asserted they wanted safety to be given a higher status.

As the discussions proceeded, I asked the senior executive to draw an organizational chart showing the positions of all personnel who reported to him. He soon acknowledged that if the risks of injury and fatalities were to be reduced, he would have to provide strong leadership and hold the staff reporting to him accountable for results.

As this is written, the author has learned that the senior executive convened his staff and spelled out what he expected of them. A communication was issued throughout the organization setting forth the safety policy and the procedures to implement it. Safety is now an agenda item for several levels of management meetings, division heads are holding the staffs reporting to them accountable for results, and management is encouraging input and involvement from all levels of employees. Communication downward and upward has improved. Safety-related suggestions receive attention quicker than had formerly been the case.

CONCLUSION

Management Leadership and Employee Participation is the most important section in Z10. Safety is culture-driven, and leaders create the culture. It is the responsibility of leadership to change the safety culture when it is deficient. Top administrators must take responsibility for risk management by remaining alert to the effects their decisions have on the work system. Leaders are responsible for establishing the conditions and the atmosphere that lead to their subordinates successes or failures.

As top management makes decisions directing the organization, its safety culture is established and that culture is translated into a *system of expected behavior*.

When safety management systems are most effective, there is a commitment to ascertaining the facts about hazards and risks, regardless of any unpleasantness that may arise during the discovery process, and taking actions to achieve acceptable risk levels.

A safety culture is unsound if employees do not have opportunities to participate in every aspect of the occupational health and safety management system and if they do not have the mechanisms, time, and resources necessary to participate. Furthermore, if an employer does not take advantage of the knowledge, skills, and experience of the workers close to the hazards and risks, opportunities are missed to reduce injury and illness potential and to improve safety and health management systems. Too much cannot be made of the importance of concentrating on minimizing the hazards and risks at what James Reason calls "the sharp end," meaning where the work gets done.

In Section 4.0, the Planning section, Z10 provides a focus for all that is expected of management and employees. The planning process goal is to identify occupational health and safety management issues, which are defined as "hazards, risks, management system deficiencies, and opportunities for improvement." Consider this premise: The entirety of purpose of those responsible for safety, regardless of their titles, is to manage their endeavors with respect to hazards so that the risks deriving from those hazards are at an acceptable level.

REFERENCES

Bayer Corporation. *Health, Safety and Environment Report*. http://www.bayerUSA.com.

British Petroleum. *Fatal Accident Investigation Report, Isomerization Unit Explosion Final Report, Texas City, Texas, USA*. http://www.bp.com/liveassets/bp_internet/globalbp/STAGING/global_assets/downloads/T/texas_city_investigation_report.pdf#search='Fatal%20Accident%20Investigation%20Report%2C%20BP'.

Columbia Accident Investigation Board Report, Vol. 1. Washington, DC: NASA, August 2003. Also available at http://www.nasa.gov/columbia/home/AIB_Vol1.html.

DuPont. *Sustainable Growth 2004 Progress Report—Safety, Health & Environmental Section*. http://www.dupont.com.

Hama, Norika. Speech at a symposium "Economic and structural Refarms in Japan and Germany." Tokyo, Japan, February 2004.

Intel Corporation. *Environmental, Health and Safety Report 2004*. http://www.intel.com.

Johnson & Johnson. *2004 Sustainability Report*. http://www.jnj.com.

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

Petersen, Dan. "Understanding Human Error: It's Safety's next frontier." ASSE Symposium on Human Error in Occupational Safety Symposium Atlanta, GA, 2003.

Petersen, Dan. "Human Error". Des Plaines. IL: American Society of Safety Engineer Magazine Professional Safety, December 2003.

Report of the OECD Workshop on Lessons Learned from Chemical Accidents and Incident, 21–23 September 2004, Karlskoga, Sweden. Paris: Organization for Economic

Cooperation and Development, 2005. Also available at http://appli1.oecd.org/olis/2005doc.nsf/43bb6130e5e86e5fc12569fa005d004c/e6de9b632c0d0368c1256fd400348fa5/$FILE/JT00182564.PDF.

Reason, James. *Managing the Risks of Organizational Accidents*. Burlington, VT: Ashgate Publishing Company, 2001.

Sutton, Robert I. http://www.bobsutton.typepad.com. Comments made "Bobsutton work matters".

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

CHAPTER 6

ACHIEVING ACCEPTABLE RISK LEVELS: THE OPERATIONAL GOAL

INTRODUCTION

The Occupational Health and Safety Management Systems Standard, ANSI/AIHA Z10-2005, tersely and clearly states its purpose in Section 1.2:

> The primary purpose of this standard is to provide a management tool to reduce the risk of occupational injuries, illnesses, and fatalities.

Note the phrase "reduce the risk." This question logically follows. What risk reduction level is to be achieved? Safety and health professionals understand that setting a goal to achieve a zero risk level may seem laudable, but doing so results in chasing a myth. No facility, thing or activity is risk-free.

This chapter will answer the question: What risk level is to be achieved? That answer will provide a basis for thought when considering and acting on occupational health and safety management system issues. In Z10, those issues are "defined as hazards, risks, management system deficiencies, and opportunities for improvement."

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Z10 IMPLIES THAT ACCEPTABLE RISK LEVELS ARE TO BE ATTAINED

The term "acceptable risk" does not appear in the "shall" requirements of Z10. But, by implication, the outcome of identifying and analyzing hazards, making risk assessments, and taking risk reduction measures is to attain acceptable risk levels. For example, this is how Section 5.1.2, Design Review and Management of Change, begins: "The organization shall establish and implement processes to identify, and take appropriate steps to prevent or otherwise control hazards and reduce potential risks." Hazards and risks are to be prevented or controlled—presumably to an acceptable level.

The term "acceptable level" appears in one place in the standard's "should" column (the advisory column), where advice is given on the hierarchy of controls process. The term also exists in Appendix E, which gives advice on Assessment and Prioritization. Section 5.1.1, Hierarchy of Controls, requires that "The organization shall implement and maintain a process for achieving feasible risk reduction." In the "should" column, the following appears:

> Often, a combination of controls is most effective. In cases where the higher order of controls (elimination, substitution, and implementation of engineering controls) does not reduce the risk to an acceptable level, lower order controls may be necessary.

Appendix E contains a Hazard Analysis and Risk Assessment Guide. After the early steps in the Guide are taken, through which hazards are identified and analyzed and the risks are assessed, the decision makers are to make an acceptability determination. This is how Step 7 in the Guide reads: "The organization must then determine if the level of risk is acceptable or unacceptable."

RESIDUAL RISK

The language on residual risk in Appendix E, as in the following, clearly indicates that the intent is to achieve acceptable risk levels:

> *Residual risk*: Risk can never be eliminated entirely, though it can be substantially reduced through application of the hierarchy of controls. Residual risk is defined as the remaining risk after controls have been implemented. It is the organization's responsibility to determine whether the residual risk is acceptable for each task and associated hazard. Where the residual risk is not acceptable, further actions must be taken to reduce risk.

ZERO RISK LEVELS CANNOT BE ATTAINED

It is a given that a zero risk level cannot be attained if a facility or thing exists or an activity proceeds. Therefore, in all employment situations there will be some

residual risk. That risk is to be acceptable. An often quoted author on acceptable risk is William W. Lowrance, who wrote *Of Acceptable Risk: Science and the Determination of Safety*. One of his central themes is that attaining a risk-free environment, a zero risk level, is not possible. Lowrance writes:

> Nothing can be absolutely free of risk. One can't think of anything that isn't, under some circumstance, able to cause harm. Because nothing can be absolutely free of risk, nothing can be said to be absolutely safe. There are degrees of risk, and consequently there are degrees of safety.

Recognizing that there are degrees of risk and safety, the logical and desirable outcome in applying the provisions in Z10 and improving safety and health management systems is to achieve the maximum degree of safety practicable.

ATTAINING ACCEPTABLE RISK LEVELS: A CULTURAL VALUE

In organizations with advanced safety management systems, that idea—achieving minimum, practicable, and acceptable risk levels throughout all operations—is a cultural value. I suggest that safety and health professionals adopt the concept of attaining acceptable risk levels as a goal to be embedded in every risk reduction action proposed. In achieving that goal, it will be necessary to educate others on the beneficial effects of applying the concept.

Note that the standard's purpose identifies occupational fatalities, specifically, as a type of injury or illness to be reduced. That puts fatalities in a special category. It is obvious in this book that I emphasize giving particular attention to preventing incidents that result in serious injuries or illnesses, which encompass fatalities.

To repeat: My analyses indicate that many incidents resulting in serious consequences are unique and singular events and that they have multiple and complex causal factors having organizational, operational systems, technical, or cultural origins. Fewer incidents resulting in serious injury or illness or fatality will occur if attaining acceptable risk levels is a foundational concept and a cultural value when applying the processes required by Z10.

A FAILED ATTEMPT AT DEFINING ACCEPTABLE RISK

How would I define acceptable risk? Not easily. Some time ago, I realized that it was common, during the question period following a speaker's presentation, for members of the audience to emphasize their opposition to the speaker's use of the term "acceptable risk." Some safety practitioners took strong positions as they expressed their beliefs that no risk was acceptable in the workplace. (Some still do.)

In recognition of the educational need those beliefs presented, I tried to develop a definition of acceptable risk that was precise, terse, and possibly numerical, which could be universally applicable to all risk situations. I failed. Bruce Main, president of design safety engineering, joined me in researching and authoring a paper titled

"On Acceptable Risk," published in *Occupational Hazards* in January 2002. A longer version of that treatise became a chapter on Acceptable Risk in *On The Practice Of Safety*.

RISK ACCEPTANCE IS SITUATIONAL

As our research progressed, we had to accept that risk acceptance is situational, meaning that the variations of acceptable and tolerable risk levels in given situations are exceptionally broad. Consider this example. In the February 14, 2001, issue of the *Chicago Tribune*, a good deal of space was given to the risks in Indy-style auto racing. The coverage followed the death of Dale Earnhardt, a well-known race car driver.

A history of the fatalities and serious injuries in auto racing appeared in the newspaper, as well as the notable measures taken over the years to make racing less risky. Without a doubt, to this date, auto racing is still a risky occupation. The number of fatalities and serious injuries that occur in auto racing in relation to the number of drivers involved would be unacceptable in most other employment settings. Richard Petty, also a racing driver, was quoted in the *Tribune* as often admonishing his wife: "If I get killed, if you ever sue anybody, I will haunt you. I know the risk. I take all the responsibility."

How situational is occupational risk acceptance? What variations does society tolerate in risky occupational exposures? The Bureau of Labor Statistics (BLS) report titled *National Census of Fatal Occupational Injuries in 2005* states that "the rate at which fatal work injuries occurred in 2005 was 4.0 per 100,000 workers." The data in Table 1 gives the fatality rates for the five occupations having the highest fatality rates in 2005.

TABLE 1 Fatality Rates-Five Occupations, from BLS Report

Occupation	Fatality Rate Per 100,000 Persons Employed
Fishers and related fishing workers	118.4
Logging workers	92.9
Aircraft pilots and flight engineers	66.9
Structural iron and steel workers	55.6
Refuse and recyclable material collectors	43.8

Compared to a national average of 4.0 fatalities per 100,000 persons employed, it is obvious that the inherent risks in the occupations shown above are very high. For each of these occupations, studies have been conducted to determine how the risks can be reduced, and they have been reduced. Nevertheless, even after preventive measures are taken, the residual risks are considerable, and they are societally acceptable. Society wants fish and the fishers provide fish. Society tolerates the residual risks.

Judgments for arriving at an acceptable risk level are influenced by many factors, and the results vary considerably across industries. Even within a company, acceptable risk levels can vary substantially by location. A country's culture also plays an important role in risk acceptability, as has been experienced by our colleagues who work in companies with global operations. Risk acceptability is also time-dependent, in that what is acceptable today may not be acceptable tomorrow, next year, or the following decade.

Furthermore, safety professionals need to understand that decisions made with respect to risk acceptance or reduction may not always be based on logic. Sometimes, workers have perceptions about risk levels in a given situation that are unrealistically high. Although their perceptions may not be well founded, they have to be addressed in an attempt to diminish their fears. Companies have found that spending a little money to counter unreasonable perceptions of risk may be a good investment if employees are relieved of their fears and production slowdowns or interruptions are avoided.

THE CONCLUSION TO OUR FAILED ATTEMPT

As we proceeded with our studies, we found that developing a distinct, perhaps statistical, universally applicable definition of acceptable risk that did not contain general and judgmentally interpretive terms is not possible. But, with a studied understanding of risk, and risk taking, and the concept of As Low as Reasonably Practicable (ALARP), I dare to offer a practical definition of acceptable risk that can be effectively applied when dealing with workplace hazards, risks, and deficiencies in safety and health management systems.

DETERMINING ACCEPTABLE RISK LEVELS IS LARGELY JUDGMENTAL

In establishing a risk level, two judgmental estimates must be made: of the probability of a hazard-related incident or exposure occurring, and of the severity of harm or damage that may result. Rarely will precise incident or exposure probability data be available, and the differences in the estimates made by risk assessors of the severity of harm or damage that can occur in a given situation may be very large.

Some risk assessment systems include numerical categories for probability and severity levels and computations are made to arrive at a number that determines the risk level. Arriving at those numerical categories is entirely judgmental. Some of those numerical risk assessment systems are discussed in Chapter 10, "Three- and Four-Dimensional Numerical Risk-Scoring Systems."

Safety professionals must understand that risk assessment is as much art as science and that judgments—educated, to be sure—are made on incident or exposure probability and the severity of the incident or exposure outcome to arrive at a risk category. Also, they need to be able to work through the greatly differing views

people can have about probability, severity, and risk levels. In arriving at acceptable risk levels where the hazard/risk scenarios are complex, it is best to gather a team of experienced personnel for their contributions and for their buy-in to the conclusions.

POINTS TO CONSIDER IN DEFINING ACCEPTABLE RISK

Z10 is an Occupational Health and Safety Management Systems (OHSMS) standard. A good and terse definition of safety (interpreted here to encompass both occupational health and safety) can be found in ISO/IEC Guide 51, *Safety Aspects—Guidelines for Their Inclusion in Standards*, compiled by the International Organization for Standardization (ISO) and International Electrotechnical Commission (IEC). Safety is defined as freedom from unacceptable risk. And the Guide defines tolerable risk as that risk "which is accepted in a given context based on the current values of society."

Thus, safety is achieved in the workplace if the workers are free from unacceptable risk. That risk level must be defined, at least in general terms. But note in the definition given above that tolerable risk is that risk which is accepted in a given context. In a workable definition of risk, as we found, the context in which the work is being done must be considered.

We have already established that, in the real world, attaining a zero risk level is not feasible. Nevertheless, the residual risk remaining after risk avoidance, elimination, or reduction measures are taken should be acceptable and tolerable as judged by the decision makers for the work situation being considered.

The concept of ALARP helps with respect to the economic considerations necessary in risk decision making. A good and easily understood definition of ALARP may be found in the draft of MIL-STD-882E, the Department of Defense Standard Practice for System Safety:

> ALARP is that level of risk which can be further lowered only by an increment in resource expenditure that cannot be justified by the resulting decrement of risk.

In the real world, considering the amount of risk reduction expected and the costs to achieve those reductions becomes an important factor in risk decision making. When resources are limited, as they always are, spending an inordinate amount of money to only minimally reduce the risk through costly engineering and redesign methods is inappropriate, particularly if that money could be spent to significantly reduce other risks. In situations of that sort, applying additional administrative controls, as described in Chapter 12, "Hierarchy of Controls: The Safety Decision Hierarchy," may represent the better judgment.

ALARP is a sound concept. It promotes a management review that should result in achieving acceptable risk levels. Practical economic and risk trade-offs are frequent and necessary in the benefit/cost deliberations that take place when determining whether the costs to reduce risks further can be justified "by the resulting decrement in risk."

Nonetheless, it should not be assumed that a risk level as low as reasonably practicable will always be acceptable. On a few occasions, that will not be so. For instance, designing an air cooling system at a risk level that the designer considers to be as low as reasonably practicable and that uses Freon as the refrigerant is not acceptable. In the design of a steam-generating plant, an insulation system for steam piping that uses asbestos, although designed as low as reasonably practicable, is not acceptable.

DEFINING ACCEPTABLE RISK

A sound and workable definition of acceptable risk must encompass hazards, risks, probability, severity, and economic considerations. Also, in the following definition, it is made clear that a risk level as low as reasonably practicable must also be tolerable:

> Acceptable risk is that risk for which the probability of a hazards-related incident or exposure occurring and the severity of harm or damage that may result are as low as reasonably practicable, and tolerable in the situation being considered.

The risk assessment matrices shown in Chapter 8, "A Primer on Hazard Analysis and Risk Assessment," and the discussions of risk categories there will help in determining acceptable and tolerable risk levels.

EXAMPLES OF SPECIFICALLY DEFINED RISK ACCEPTANCE LEVELS

In some organizations, risk levels that are acceptable or tolerable are defined in terms of degree of injury or damage to property. The following examples will give safety professionals a basis from which they can develop probability and severity levels, and thus risk levels, that are acceptable to the operations for which they give counsel:

1. NASA-STD-8719.7, the *Facilities System Safety Handbook*, defines acceptable risk as follows: Loss of life as a result of hazards in this facility is unlikely. Hazards may result in:
   - No lost workday injuries or no restricted duty cases
   - Loss of facility operational capability of less than 1 day
   - Damage to equipment or property less than $25,000
2. For a major manufacturer of heavy mobile equipment, if it may be reasonably assumed that a user of the equipment, a customer, can lose a day's work, the risk situation must be addressed through equipment redesign or by strengthening the operations manual, thus alerting users to the hazard's potential and providing appropriate instructions.

3. In a smaller operation, the design and operation standard for acceptable risk to employees requires that if a hazard presents the potential for injury that may require medical treatment beyond first aid, the risk deriving from that hazard must be reduced.

4. In ANSI/RIA 15.06, the american national standard for Industrial Robots and Robot Systems-Safety Requirements, a provision requires that risk reduction measures be taken if a serious injury, defined as an injury that requires more than first aid, can be foreseen.

5. In ANSI/PMMI B155.1-2006, the American National Standard for Packaging Machinery and Packaging-Related Converting Machinery, the following definition is given:

> Acceptable risk—risk that is accepted for a given task or hazard. For the purpose of this standard the terms "acceptable risk" and "tolerable risk" are considered synonymous.

This note follows the definition above: "The expression 'acceptable risk' refers to the level at which further risk reduction will not result in significant reduction in risk; or additional expenditure will not result in significant advantages of increased safety."

RELATING TO PRODUCT SAFETY

Safety professionals who are also involved in product liability prevention will recognize that strong similarities exist between the acceptable risk concept applied in an occupational setting and the reasonably safe legal concept applicable in product liability determinations.

Products must be designed so that they are not unreasonably dangerous. The term "unreasonably dangerous" implies that there may be some residual risk. Inherent in this aspect of the U.S. legal system—that the design of products may not be unreasonably dangerous but that some residual risk may exist—is the implication that some non-zero level of residual risk is acceptable.

DESIGNING BEYOND STANDARDS

Many authors have written on the need, sometimes, to set design specifications exceeding the requirements of published standards to achieve acceptable risk levels. Complying with consensus or governmental standards will not necessarily achieve an acceptable risk level.

A learned colleague has frequently reminded us that complying with the National Electrical Safety Code or the applicable OSHA lockout/tagout standard will not necessarily ensure that a non-error-provocative lockout/tagout system has been put in place. Neither of those standards requires that disconnects be placed close to where the work is being done and thereby be conducive to employee use.

Workers may consider the inconvenience of traveling a distance to power disconnects excessive and a reason for them to not shut off the electric power, even

though standard operating procedure states they should. When the design of the lockout/tagout system is error-provocative, it is a near certainty that errors resulting in injuries and illnesses will occur. Although the design of the system may comply with the standards, the residual risk is unacceptable if it is error-provocative.

Ergonomic design practices offer another example of how an accepted design criteria for the workplace results in residual risk that may not be tolerable for some workers. A common ergonomic design practice is to develop designs that accommodate the 5th to 95th percentile target users. Examples include stature, reach, strength, etc. Typically, ergonomics design and operations standards that address the dimensions and capabilities of this 90% of the work population are considered acceptable. As a result, there will be some residual ergonomics risks, questionable in a given situation, with respect to those workers in the lower and upper fifth of the population.

Furthermore, consider OSHA's permissible exposure limits for hazardous substances or the guidelines issued by the American Conference of Governmental Industrial Hygienists. Although exposure limits are established, it is not presumed that all persons will be illness-free at those levels. Thus, in some companies, say their safety directors, the intent is to achieve exposure limits considerably less than world standards. These companies have set a goal to achieve superior, world-class safety records and have recognized that to do so they must operate at exposure levels lower than the standards. However, they also recognize that even at these improved levels, some small amount of residual risk remains.

CONCLUSION

This chapter establishes a concept that should be an operational goal to be achieved in applying every element in Z10. That goal is to arrive at acceptable risk levels so that the risk of harm is at a practicable and tolerable minimum. To achieve that goal, understanding the concept of acceptable risk is necessary. Fewer incidents resulting in serious injury or illness or fatality will occur if attaining acceptable risk levels is a foundational concept when putting in place the processes required by Z10.

REFERENCES

ALARP "at a Glance." London, UK: *Health and Safety Executive*. Also available at http://www.hse.gov.uk/risk/theory/alarpglance.htm.

ANSI/PMMI B155.1-2006. Safety Requirements for Packaging Machinery and Packaging-Related Converting Machinery Standard. Arlington, VA: Packaging Machinery Manufacturers Institute, 2006.

ANSI/RIA R15.06-1999. *Safety Requirements for Industrial Robots and Robot Systems Standard*. http://www.robotics.org.

ISO/IEC Guide 51. *Safety Aspects—Guidelines for Their Inclusion in Standards.* Geneva, Switzerland: International Organization for Standardization, 1999.

Lowrance, William F. *Of Acceptable Risk: Science and the Determination of Safety.* Los Altos, CA: William Kaufman, Inc., 1976.

Manuele, Fred A., and Bruce Main. "On Acceptable Risk." *Occupational Hazards*, January 2002.

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

MIL-STD 882E, Standard Practice for System Safety. Washington, DC: Department of Defense, a works in progress

NASA-STD-8719.7. *Facilities System Safety Handbook*. Washington, DC: NASA, January 1998.

USDL 05-1598. *National Census of Fatal Occupational Injuries in 2005*. Washington, DC: Bureau of Labor Statistics, U.S. Department of Labor, 2006.

CHAPTER 7

PLANNING — SECTION 4.0

INTRODUCTION

In the Plan-Do-Check-Act (PDCA) model, the Plan step requires that problems be identified and analyzed. In some PDCA models, the first action to be taken in applying the Do step is to develop solutions for the problems identified. Establishing and implementing the processes set forth in the planning section of Z10 will serve problem identification and analysis purposes as well as the development of solutions and implementation plans with respect to the problems identified.

As is stated in the standard, the "planning process goal is to identify and prioritize occupational health and safety management system issues." Those issues are "defined as hazards, risks, management system deficiencies, and opportunities for improvement." Also, objectives are to be established that offer the greatest opportunities for improvement and risk reduction, and plans are to be formulated to accomplish the prioritized objectives.

INITIAL AND ONGOING REVIEWS

Section 4.1 indicates that both initial and ongoing reviews of the safety management systems in place are to be made to "identify OHSMS issues." These reviews will fulfill the problem identification and analysis steps and solution consideration steps

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of the PDCA concept. Information gathered on hazards, risks, and deficiencies in safety management systems have to be analyzed so that an organization can put processes in place that "improve its management system and achieve conformance with this standard."

For this section of Z10 to be accomplished successfully, an organization must demonstrate by its culture—its *system of expected behavior*—that management is committed to being informed on the facts about hazards, risks, and deficiencies in its safety management systems, regardless of any unpleasantries that may arise during the discovery process, and to taking actions to achieve acceptable risk levels.

INITIAL REVIEWS

Initial reviews of the safety management systems in place are addressed in Section 4.1.1. In the advisory comments, this initial review is referred to as a baseline or gap analysis. Making a gap analysis in which the provisions in an existing safety and health management system are compared with the processes required by Z10 is highly recommended.

Since very few organizations meet all the requirements of Z10—a state-of-the-art standard—it is a near certainty that shortcomings in existing systems will be identified. The result should be prioritizing the shortcomings and developing action plans to improve the existing safety and health management system. For the initial review process, the standard suggests taking into consideration the relevant business management systems: hazards, risks and controls; resources (funding, personnel, equipment); regulations and standards; assessments; and other relevant activities.

ONGOING REVIEWS

Processes for making ongoing reviews are the subject of Section 4.1.2. The ongoing review process is to be supplemented by information arising from the application of other sections in the standard, such as Implementation and Operation, Evaluation and Corrective Action, and Management Reviews. To move forward on continual improvement, information is to flow to the decision makers on how the elements in the safety and health management systems can be improved. That knowledge flow is necessary to meet the needs of the Management Review process outlined in Section 7.0.

EXPECTED SHORTCOMINGS TO BE FOUND IN THE REVIEW PROCESSES

When making the initial and ongoing reviews required by Z10, it is suggested that particular emphasis be given to those processes in Section 5.0, Implementation and Operation, for which most organizations will be found wanting. Those processes include:

- Safety design reviews
- Risk assessments
- Management of change
- A prescribed hierarchy of controls
- Including safety specifications in purchasing documents

ASSESSMENT AND PRIORITIZATION

Section 4.2 outlines the Assessment and Prioritization provisions. Processes are to be in place to assess and prioritize the occupational health and safety management issues identified in the initial and ongoing review processes. The intent is to "Assess the impact on health and safety of OHSMS issues and assess the level of risk for identified hazards" and to "Establish priorities based on factors such as the level of risk, etc." Risk assessment and prioritization is a process that is not often found in typical safety and health management systems.

In addition, the processes shall "Identify the underlying causes and other contributing factors related to system deficiencies that lead to hazards and risks." As the "system deficiencies that lead to hazards and risks" are identified and planning is commenced to eliminate them, consideration must be given to the possibility that the system deficiencies define safety culture inadequacies. If so, culture change mechanisms would be applied.

The risk assessment requirements in Section 4.2 are highly significant. They are so noteworthy that three chapters pertaining to them directly follow:

- Chapter 8, "A Primer on Hazard Analysis and Risk Assessment"
- Chapter 9, "Including Risk Assessment Provisions in Standards and Guidelines: A Trend"
- Chapter 10, "Three- and Four-Dimensional Numerical Risk-Scoring Systems"

The goal of the risk assessment and prioritization process is to provide input for decision makers as they attempt to develop an occupational environment in which the risks are judged to be acceptable.

Safety professionals must recognize the real world of economics with respect to resource allocation and setting priorities so as to achieve the best probable good from the expenditure of those resources. In that context, Prioritization merits special comment:

- Some risks are more significant than others and safety professionals must be capable of distinguishing the more important risks from the less important.
- Resources will always be limited, and staffing and money are never adequate to address all risks.
- The greatest good to employees, employers, and society in general is attained if the available resources are applied to effectively and economically obtain the greatest probable risk reduction.

- On a priority basis, consideration has to be given first to those risks that have the greatest potential for serious harm or damage.

Section 4.3, Objectives, and Section 4.4, Implementation Plans and Allocation of Resources, logically follow the assessment and prioritization requirements. They require that processes be established and implemented to:

- Set documented objectives based on the priorities developed with respect to the hazards and risks identified and the shortcomings found in the safety and health management system (Section 4.3).
- Establish a documented implementation plan to achieve those objectives. That plan is to define resources, responsibilities, timeframes, and appropriate measures of progress (Section 4.4).

CONCLUSION

The success of an occupational health and safety management system is largely contingent on how thoroughly the provisions in the Planning process are applied. They are to identify and prioritize the issues that are "defined as hazards, risks, management system deficiencies, and opportunities for improvement." As that process moves forward, it should be understood that the entirety of purpose of those responsible for safety, regardless of their titles, is to manage their endeavors with respect to hazards so that the risks deriving from those hazards are acceptable.

This Planning section requires that shortcomings in existing safety management systems be identified, in relation to the requirements of Z10. The existence of hazards and risks is evidence of those shortcomings. Once such inadequacies are known, priorities are to be set, objectives are to be established for improved risk control, and actions are to be outlined in a documented plan for continual improvement. Those processes represent good management as respects applying the PDCA concept.

CHAPTER 8

A PRIMER ON HAZARD ANALYSIS AND RISK ASSESSMENT — SECTION 4.2

INTRODUCTION

Safety professionals can expect that being able to make documented risk assessments will be necessary for their job retention and career enhancement. That premise has acquired weight because of the more frequent inclusion of risk assessment provisions in safety standards and guidelines. ANSI/AIHA Z10–2005 is an example. Other standards and guidelines requiring such provisions are discussed in Chapter 9, "Including Risk Assessment Provisions in Standards and Guidelines: A Trend."

Since safety professionals need to be able to analyze hazards and assess the risks that derive from them, this question logically follows: What do they need to know? The intent here is to provide a primer that will serve many of the hazard analysis and risk assessment needs that safety professionals will encounter. This chapter:

- Defines the terms that must be understood in the hazard analysis and risk assessment process.
- Establishes the parameters for a hazard analysis.
- Indicates how a hazard analysis is extended into a risk assessment.

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- Includes A Hazard Analysis and Risk Assessment Guide.
- Gives examples of the terms used in risk assessment matrices and the variations in their meanings.
- Presents examples of basic, two-dimensional risk assessment matrices.
- Describes several of the most commonly used hazard analysis and risk assessment techniques.

DEFINING HAZARD, HAZARD ANALYSIS, RISK, AND RISK ASSESSMENT

When a safety professional identifies a hazard and its potential for harm or damage and decides on the probability that an injurious or damaging incident can occur, a risk assessment has been subjectively made. In doing so, for the simpler and less complex hazards and risks, the assessment may be based entirely on a priori knowledge and experience, without documentation. Making informal risk assessments has been an integral part of the practice of safety and health professionals from time immemorial.

Recent developments take the risk assessment subject to a higher level within the practice of safety. By formalizing the hazard analysis and risk assessment process, a better appreciation of the significance of individual risks is achieved. As risks levels are categorized and prioritized, more intelligent decisions can be made with respect to their elimination or reduction. For the hazard analysis and risk assessment process, it is necessary to arrive at definitions of hazards, hazards analyses, risks, and risk assessments.

ANSI/AIHA Z10 is an occupational health and safety management standard and its definitions of hazard and risk are, understandably, worker injury and illness related. They do not include considerations for possible damage to the environment or damage to property or business downtime. This chapter has a broader purpose, as will be seen.

- A hazard is defined, broadly, as the potential for harm to people, property, or the environment. If there is no potential for harm, injury or damage cannot occur. (In Z10, a hazard is defined as a condition, set of circumstances, or inherent property that can cause injury, illness, or death.) The dual nature of hazards must be understood. Hazards encompass all aspects of technology or activity that produce risk. Hazards include the characteristics of things (equipment, dusts, etc.) and the actions or inactions of people.
- A hazard analysis is made to estimate the severity of harm or damage that could result from a hazards-related incident or exposure. The hazard analysis process need not include an estimate of incident or exposure probability. Examples of hazards analyses that do not include probability indicators are the estimates made by fire protection engineers of Maximum Foreseeable Loss

or Maximum Probable Loss for insurance purposes, and the hazard analysis requirements of the *OSHA Rule for Process Safety Management of Highly Hazardous Chemicals,* 29 CFR 1910.119.

- Whether hazardous situations are simple or complex, the process for making a hazard analysis will address the following questions:
  1. Is there potential for harm, deriving from aspects of the technology or activity, the characteristics of things, or the actions or inactions of people?
  2. Can the potential be realized?
  3. Who and what are exposed to harm or damage?
  4. What is the frequency of endangerment?
  5. What will the consequences be, that is, the severity of harm or damage if the potential is realized?

  Making a hazard analysis is necessary to and precedes making a risk assessment. William Johnson said this about hazard analysis in *MORT Safety Assurance Systems*: "Hazard analysis is the most important safety process in that, if that fails, all other processes are likely to be ineffective." Johnson's premise is sound: Hazard analysis is one of the most significant fundamentals in the practice of safety and will be elaborated on here.
- Risk is defined as an estimate of the probability of a hazards-related incident or exposure occurring and the severity of harm or damage that could result. [Z10 defines risk as an estimate of the combination of the likelihood of an occurrence of a hazardous event or exposure(s), and the severity of injury or illness that may be caused by the event or exposures.]
- Probability is defined as the likelihood of a hazard being realized and initiating an incident or exposure that could result in harm or damage—for a selected unit of time, events, population, items, or activity being considered.
- Severity is defined as the extent of harm or damage that could result from a hazards-related incident or exposures.
- Risk assessment is a process that commences with hazard identification and analysis, through which the probable severity of harm or damage is established, and concludes with an estimate of the probability of the incident or exposure occurring.

In a statement indicating risk level, both probability of occurrence and severity of outcome must be included. After determining the severity of expected damage or harm through a hazard analysis, estimating the probability of an incident or exposure occurring is the additional and necessary step in concluding a risk assessment.

These excerpts from the *Framework for Environmental Health Risk Management* issued by the Presidential/Congressional Commission on Risk Assessment and Risk Management are an indication of the widespread adoption of the foregoing definitions:

What Is "Risk"

Risk is defined as the probability that a substance or situation will produce harm under specified conditions. Risk is a combination of two factors:

- The **probability** that an adverse event will occur;
- The **consequences** of the adverse event.

Risk encompasses impacts on public health and on the environment, and arises from exposure and hazard. Risk does not exist if exposure to a harmful substance or situation does not or will not occur. Hazard is determined by whether a particular substance or situation has the potential to cause harmful effects.

MAKING A HAZARD ANALYSIS AND RISK ASSESSMENT

For many hazards and the risks that derive from them, knowledge gained by safety practitioners through education and experience will lead to proper conclusions on how to attain an acceptable risk level without bringing teams of people together for discussion. For more complex situations, it is vital to seek the counsel of experienced personnel who are close to the work or process. Reaching group consensus is a highly desirable goal. Sometimes, for what a safety professional considers obvious, achieving consensus is still desirable so that buy-in is obtained for the actions to be taken. A general guide follows on how to make a hazard analysis and how to extend the process into a risk assessment.

Whatever the simplicity or complexity of the hazard/risk situation, and whatever analysis method is used, the following thought and action process is applicable.

A Hazard Analysis and Risk Assessment Guide

1. *Establish the Analysis Parameters.* Select a manageable task, system, process, or product to be analyzed; establish its boundaries and operating phase (standard operation, maintenance, startup); and define its interface with other tasks or systems, if appropriate. Determine the scope of the analysis in terms of what can be harmed or damaged: people (the public, employees); property; equipment; productivity; the environment.

2. *Identify the Hazards.* A frame of thinking should be adopted that gets to the bases of causal factors, which are hazards. These questions should be asked: What are the aspects of technology or activity that produce risk? What are the characteristics of things or the actions or inactions of people that present the potential for harm. Depending on the complexity of the hazardous situation, some or all of the following may apply:

- Use intuitive engineering and operational sense. This is paramount throughout.
- Examine system specifications and expectations.

- Review codes, regulations, and consensus standards.
- Interview current or intended system users or operators.
- Consult checklists.
- Review studies from other similar systems.
- Consider the potential for unwanted energy releases
- Take into account possible exposures to hazardous environments.
- Review the historical data: industry experience, incident investigation reports, OSHA and National Safety Council data, manufacturer's literature.
- Brainstorm.

3. *Consider the Failure Modes.* Define the possible failure modes that would result in the realization of the potentials of hazards. What circumstances can arise that would result in the occurrence of an undesirable event? What controls are in place that mitigate against the occurrence of such an event or exposure?

4. *Determine the Frequency and Duration of Exposure.* For each harm or damage category selected for the scope of the analysis (people, property, business interruption, etc.), estimate the frequency and duration of exposure to the hazard. This is a very important part of the exercise. For instance, in a workplace situation, ask how often a task is performed, how long the exposure period is, and how many people are exposed.

5. *Assess the Severity of Consequences.* The purpose is to determine the magnitude of harm or damage that could result. Informed speculations are made to establish the consequences of an incident or exposure: the number of injuries or illnesses and their severity, and fatalities; the value of property or equipment damaged; the time during which productivity will be lost; and the extent of environmental damage. Historical data can be of great value as a baseline. On a subjective basis, the goal is to decide on the worst credible consequences should an incident occur, not the worst conceivable consequence.

When the severity of the outcome of a hazards-related incident or exposure is determined, a hazard analysis has been completed.

6. *Determine Occurrence Probability.* Extending the hazard analysis into a risk assessment requires the one additional step of estimating the likelihood, the probability, of a hazardous event or exposure occurring. Unless empirical data are available, and that would be a rarity, the process of selecting incident or exposure probability is subjective. For the more complex hazardous situation, brainstorming with knowledgable people is necessary. To be meaningful, probability has to be related to an interval base of some sort, such as a unit of time or activity, events, units produced, or the life cycle of a facility, equipment, process, or product.

7. *Define the Risk.* Conclude with a statement that addresses the probability of a hazards-related incident or exposure occurring, the expected severity of adverse results, and a risk category (e.g., high, serious, moderate, or low). Using a risk assessment matrix for that purpose assists one in communicating on the risk level.

8. *Rank Risks in Priority Order.* A risk-ranking system should be adopted so that priorities can be established. Since the risk assessment exercise is subjective, the risk-ranking system would also be subjective. Prioritizing risks gives management the knowledge needed on the potentials risks have for harm or damage so that intelligent resource allocations can be made for their elimination or reduction.

9. *Develop Remediation Proposals.* When the results of the risk assessment indicate that risk elimination or reduction measures are to be taken, alternate proposals for the design and operational changes necessary to achieve an acceptable risk level would be recommended. In their order of effectiveness, the actions as shown in Chapter 12, "Hierarchy of Controls: The Safety Decision Hierarchy," would be the basis on which remedial proposals are made. For each proposal, the remediation cost would be determined and an estimate of its effectiveness in achieving risk reduction given. Risk elimination or reduction methods would then be selected and implemented.

10. *Follow Up on Actions Taken.* Although a hazard analysis and a risk assessment result from applying the steps in the preceding outline, good management requires that the remaining steps in "The Safety Decision Hierarchy" be taken: Measure the effectiveness of the actions taken; determine that the residual risk is acceptable or unacceptable; and start over if the risk is unacceptable. Follow-up activity would determine that the:

- Problem was resolved, only partially resolved, or not resolved.
- Actions taken did or did not create new hazards.

If new hazards are introduced, the risk is to be re-evaluated and other countermeasures proposed.

RESIDUAL RISK

Residual risk is defined as the risk remaining after preventive measures have been taken. No matter how effective the preventive actions, there will always be residual risk if an activity continues. Attaining zero risk is not possible. If the residual risk is not acceptable, the action outline set forth in the foregoing hazard analysis and risk assessment process would be applied again.

RISK ASSESSMENT MATRICES

A risk assessment matrix provides a method to categorize combinations of probability and severity, thus establishing risk levels. A matrix helps in communicating with decision makers and influencing their decisions on risks and the actions to be taken to ameliorate them. Also, risk assessment matrices can be used to compare and prioritize risks, and to effectively allocate mitigation resources.

Definitions of the levels of probability and severity used in risk assessment matrices vary greatly. This reflects the differences in the perceptions of risk that people have. Since a risk assessment matrix is a management decision tool, management personnel at the appropriate level must agree on the definitions of the terms to be used. In so doing, management establishes the levels of risk that require reduction and those that are acceptable.

To emphasize: Safety professionals must understand that the definitions of terms for incident probability and severity and for risk levels vary greatly. Thus, they should tailor a risk assessment matrix to suit the hazards and risks and the management tolerance for risk with which they deal. Examples of the definitions used for incident probability and severity are presented here, as well as definitions for risk categories and risk assessment matrices. They are intended to provide safety professionals with a broad base of information from which choices can be made in developing the matrix considered appropriate for their clients' needs.

The breadth of possibilities in drafting a risk assessment matrix is extensive. Matrices have been developed that display only one or a combination of several of the following injury or damage classes: employees, members of the public, facilities, equipment, product, operation downtime, and the environment.

For this primer, two-dimensional risk assessment matrices are discussed. They are displays of variations for two categories of terms: the *severity* of harm or damage that could result from a hazards-related incident or exposure, and the *probability* that the incident or exposure could occur. They also show the *risk levels* that derive from the various combinations of severity and probability. A review of three- and four-dimensional risk assessment systems is given in Chapter 10, "Three- and Four-Dimensional Numerical Risk-Scoring Systems."

DESCRIPTIONS: PROBABILITY AND SEVERITY

Examples follow in Tables 1–5 to show variations in the terms and their descriptions as used in a variety of applied risk assessment processes for the probability of occurrence and severity of consequence. There is no one right method in selecting probability and severity categories and their descriptions.

TABLE 1 Example A: Probability Descriptions

Descriptive Word	Probability Descriptions
Frequent	Likely to occur repeatedly.
Probable	Likely to occur several times.
Occasional	Likely to occur sometime.
Remote	Not likely to occur.
Improbable	So unlikely that one can assume occurrence will not be experienced.

TABLE 2 Example B: Probability Descriptions

Descriptive Word	Probability Descriptions
Frequent	Occurs often, continuously experienced.
Probable	Occurs several times.
Occasional	Occurs sporadically, occurs sometimes.
Seldom	Remote chance of occurrence; unlikely but could occur sometime.
Unlikely	Can assume incident will not occur.

TABLE 3 Example C: Probability Descriptions

Descriptive Word	Probability Descriptions
Frequent	Could occur annually.
Likely	Could occur once in 2 years.
Possible	Not more than once in 5 years.
Rare	Not more than once in 10 years.
Unlikely	Not more than once in 20 years.

TABLE 4 Exhibit A: Severity Descriptions for Multiple Harm and Damage Categories

Catastrophic	Death or permanent total disability, system loss, major property damage and business downtime.
Critical	Permanent, partial, or temporary disability in excess of 3 months, major system damage, significant property damage and downtime.
Marginal	Minor injury, lost workday accident, minor system damage, minor property damage, and little downtime.
Negligible	First aid or minor medical treatment, minor system impairment.

TABLE 5 Exhibit B: Severity Descriptions for Multiple Harm and Damage Categories

Catastrophic	One or more fatalities, total system loss, chemical release with lasting environmental or public health impact.
Critical	Disabling injury or illness, major property damage and business downtime, chemical release with temporary environmental or public health impact.
Marginal	Medical treatment or restricted work, minor subsystem loss or damage, chemical release triggering external reporting requirements.
Negligible	First aid only, nonserious equipment or facility damage, chemical release requiring only routine cleanup without reporting.

Table 6 shows how the severity of harm or damage categories can be related to several types of adverse consequences and levels of harm or damage.

TABLE 6 Relating Severity Categories to Kinds and Extent of Harm or Damage

Category: Descriptive Word	People: Employees, Public	Facilities, Product or Equipment Loss	Operations Down Time	Environmental Damage
Catastrophic	Fatality	Exceeds $3 M	Exceeds 6 Mos	Major event, requires more than 2 years for full recovery
Critical	Disabling injury or illness	500K to $3 M	4 Wks to 6 Mos	Significant event, requires 1 to 2 years for full recovery
Marginal	Minor injury or illness	50K to 500K	2 days to 4 wks	Recovery time is less than 1 year
Negligible	Injury requires only first aid	Less than 50K	Less than 2 days	Minor damage, easily repaired, little time for recovery

EXAMPLES OF RISK ASSESSMENT MATRICES

Five examples of risk assessment matrices follow. First, an adaptation is shown in Table 7 of the "Mishap risk categories and mishap acceptance levels" as in the working draft of MIL-STD-882E, the *Department of Defense Standard Practice For System Safety*. A comment in Appendix A of 882E is pertinent here: "A mishap assessment matrix allows classification by mishap severity and mishap probability and assists in managing the decision-making to achieve the necessary risk elimination or reduction to an acceptable level."

MIL-STD-882, first issued in 1969, is the grandfather of risk assessment matrices. All of the over 30 variations of matrices I have collected include the basics that came out of 882. They include event probability categories, severity of harm or damage ranges, and risk gradings.

This Second exhibit of a risk assessment matrix–Table 8—is a composite of matrices that include numerical values for probability and severity levels that are transposed into risk gradings. It is presented here for people who prefer to deal with numbers rather than qualitative indicators.

Take care, though–arriving at the values shown in this matrix is a qualitative exercise. And that is the case for all risk scoring systems that are not based on hard probability and severity numbers, which rarely are available.

TABLE 7 Risk Assessment Matrix

Occurrence Probability	Severity of Consequence			
	Catastrophic	Critical	Marginal	Negligible
Frequent	High	High	Serious	Medium
Probable	High	High	Serious	Medium
Occasional	High	Serious	Medium	Low
Remote	Serious	Medium	Medium	Low
Improbable	Medium	Medium	Medium	Low

TABLE 8 Risk Assessment Matrix: Numerical Gradings

Severity Levels and Values	Occurrence Probabilities and Values				
	Frequent (5)	Likely (4)	Occasional (3)	Seldom (2)	Unlikely (1)
Catastrophic (5)	25	20	15	10	5
Critical (4)	20	16	12	8	4
Marginal (3)	15	12	9	6	3
Negligible (2)	10	8	6	4	2
Insignificant (1)	5	4	3	2	1

Very high risk: 15 or greater. High risk: 9–14. Moderate risk: 4–8. Low risk: under 4.

The risk-scoring system in Table 9 appears in the American National Standard, Safety Requirements for Packaging Machinery and Packaging-Related Converting Machinery ANSI/PMMI B155.1-2006. It is shown here for two reasons. It is an indication of the validity of the concepts on which the risk assessment matrices in MIL-STD-882 are based and why so many developers of matrices use 882 as a reference. Although Table 9 is almost identical to the 882 version shown in Table 7, a slight difference exists: There is one variation for a risk severity category. As was said previously, people who develop risk assessment matrices work their own risk perceptions into them. And that is great. Table 10 shows a risk assessment matrix that combines types of severity categories and uses alpha risk gradings.

TABLE 9 Risk-Scoring System: ANSI/PMMI B155.1-2006

Probability Level	Severity Category			
	Catastrophic	Critical	Marginal	Negligible
Frequent	High	High	Serious	Medium
Probable	High	High	Serious	Medium
Occasional	High	Serious	Medium	Low
Remote	Serious	Medium	Medium	Low
Improbable	Medium	Medium	Low	Low

TABLE 10 Risk Assessment Matrix: Alpha Risk Level Indicators

Severity Categories	Probability That Something Will Go Wrong				
	Frequent (likely to occur immediately or soon: often)	Likely (quite likely to occur in time)	Occasional (may occur in time)	Seldom (not likely to occur, but possible)	Unlikely (unlikely to occur)
Catastrophic: death, multiple injuries, severe property or environmental damage	E	E	H	H	M
Critical: serious injuries, significant property or environmental damage	E	H	H	M	L
Marginal: may cause minor injuries, financial loss, negative publicity	H	M	M	L	L
Negligible: minimum threat to persons or damage to property	M	L	L	L	L

E: Extremely High Risk. H: High Risk. M: Moderate Risk. L: Low Risk.

Annex E in Z10 provides informative data concerning the standard's Assessment and Prioritization section. Table 11 is close to the risk assessment matrix shown in Annex E.

This author provided input on Annex E to the two people who drafted it: Jim Howe, vice chairman of the Z10 Accredited Standards Committee, representing the United Auto Workers International Union; and Kendall Crawford, who operates Kendall C. Crawford Associates and represented the American Petroleum Institute as a Z10 committee member. Howe and Crawford made revisions in what I provided so that its definitions and language were compatible with those of the standard itself. Crandall combined the separate risk assessment matrix and management decision levels I sent him into one matrix. Although the exhibit in Table 11 is close to the example given in Annex E, it is not an exact duplicate.

Crawford believed that my risk level categories were one step too high in two places on the bottom line of the matrix and he changed the matrix accordingly. He did not disagree with the other risk levels I suggested. What is the significance of this? Risk assessment is more art than science. Since establishing risk levels is largely a matter of judgment, people will come to different conclusions in a given

situation. Nevertheless, the ultimate goal needs to be kept in mind: satisfaction that the residual risk which exists after risk reduction measures are implemented is acceptable.

TABLE 11 Risk Assessment Matrix in Z10

Example of a Risk Assessment Matrix				
Likelihood of OCCURRENCE or EXPOSURE For selected Unit of Time or Activity	**Severity of Injury or Illness Consequence and Remedial Action**			
	CATASTROPHIC Death or permanent total disability	**CRITICAL** Disability in excess of 3 months	**MARGINAL** Minor injury, lost workday accident	**NEGLIGIBLE** First Aid or Minor Medical Treatment
Frequent Likely to Occur Repeatedly	**HIGH** Operation not permissible	**HIGH** Operation not permissible	**SERIOUS** High Priority Remedial action	**MEDIUM** Take Remedial action at appropriate time
Probable Likely to occur several times	**HIGH** Operation not permissible	**HIGH** Operation not permissible	**SERIOUS** High Priority Remedial action	**MEDIUM** Take Remedial action at appropriate time
Occasional Likely to occur sometime	**HIGH** Operation not permissible	**SERIOUS** High Priority Remedial action	**MEDIUM** Take Remedial action at appropriate time	**LOW** Risk Acceptable: Remedial Action Discretionary
Remote Not likely to occur	**SERIOUS** High Priority Remedial action	**MEDIUM** Take Remedial action at appropriate time	**MEDIUM** Take Remedial action at appropriate time	**LOW** Risk Acceptable: Remedial Action Discretionary
Improbable Very unlikely – may assume exposure will not happen	**MEDIUM** Take Remedial action at appropriate time	**LOW** Risk Acceptable: Remedial Action Discretionary	**LOW** Risk Acceptable: Remedial Action Discretionary	**LOW** Risk Acceptable: Remedial Action Discretionary

There are no restrictions or rules with respect to the terms used to establish qualitative risk levels. But a matrix, as a minimum, should illustrate probability and severity categories and risk gradings. Tables 7–11 show a general acceptance of a group of terms for incident probability and severity, and for risk categories. However, I repeat: Safety professionals should draft matrices with which they are comfortable. Since risk assessment matrices are valuable communication tools, the terms used in them must be agreed on and the education time necessary to achieve an understanding of them must be allocated.

ON ACCEPTABLE RISK

In Chapter 6, "Achieving Acceptable Risk Levels: The Operational Goal," I wrote that as every element of Z10 is applied, the outcome would be the achievement of acceptable risk levels so that the risk of harm remains at a practicable minimum. I also said that the risk assessment matrices in this chapter and the discussion of risk categories here will help in determining acceptable and tolerable risk levels.

The concept of As Low as Reasonably Practicable (ALARP) was recognized as a valuable tool in determining acceptable risk levels. However, a word of caution was offered: On occasion, achieving risk levels as low as reasonably practicable will not be acceptable. Prior to presenting the following definition, I said that a workable and sound definition of acceptable risk must encompass hazards, risks, probability, severity, and economics:

> Acceptable risk is that risk for which the probability of a hazards-related incident or exposure occurring and the severity of harm or damage that may result are as low as reasonably practicable, and tolerable in the situation being considered.

Thus far, this chapter has dealt with hazards, risks, probability, and severity. In applying the ALARP concept, economics is brought into the decision making. ALARP may be defined as follows: ALARP is that level of risk which can be further lowered by an increment in resource expenditure that cannot be justified by the resulting decrement of risk.

MANAGEMENT DECISION LEVELS

Remedial action or acceptance levels must be applied to the risk categories to permit intelligent decision making on the part of management. The remedial action levels shown in Table 12 served as the basis from which Ken Crawford, Jim Howe and I agreed on the entries to be made in the example of a risk assessment matrix included in Z10. Table 12 provides a basis for review and discussion. Others who craft risk assessment matrices may have other ideas about acceptable risk levels and the management actions to be taken in a given risk situation. Going through the exercise of creating and reaching agreement on a risk assessment matrix and the management decision levels adds to a safety professional's effectiveness in communicating about risks and obtaining consideration of the remedial actions recommended.

TABLE 12 Management Decision Levels

Risk Category	Remedial Action or Acceptance
High	Operation not permissible.
Serious	Remedial action to have high priority.
Medium	Remedial action to be taken within appropriate time.
Low	Risk is acceptable; remedial action discretionary.

In the discussion that follows of acceptable and tolerable risk levels and the management actions to be taken to achieve them, the Example of a Risk Assessment Matrix given in Table 11 serves as the foundation. Keep in mind that:

- An acceptable risk level must be tolerable in the situation being considered.

- Although economic considerations are part of the decision making, the risk level is to be as low as reasonably practicable and acceptable.
- Extra special consideration should to be given to preventing incidents resulting in serious injuries and illnesses, and fatalities.
- What follows is this author's opinion; others may have different views.

If the risk category for worker injury or illness is High, the risk is unacceptable and the operation should be stopped immediately. If it is determined that the cost to reduce the risk to a tolerably lower level is excessive in relation to the risk reduction benefit to be achieved, the operation should cease in all but rare situations (e.g., society accepts the risks of deep sea fishing, a high-hazard occupation).

If the risk category is Serious, the risk is not acceptable and action should be undertaken on a high-priority basis, meaning very soon, to lower the risk to a tolerable level. While arrangements are made to reduce the risk, an extra heavy application of the lower levels in the hierarchy of controls (warning systems, blocking off work areas, administrative controls, personal protective equipment) is in order. If it is determined that the cost to reduce the risk to a tolerably lower level is excessive in relation to the risk reduction benefit to be achieved, the operation should cease in all but rare situations.

When the risk category is Medium, even though the probability ratings for severe injury or illness are "Improbable" or "Remote," and the probability rating for minor injury is "Occasional," and the probability ratings for negligible injury are "Frequent" or "Probable," remedial action should be taken, in good time, to reduce the risk in accord with good economics. This is the risk category where the lower levels in the hierarchy of controls, if more extensively and effectively applied, may be sufficient to achieve acceptable and tolerable risk levels.

When the risk category is Low, the risk is considered acceptable. Nevertheless, there will be times when it is good business management and employee relations if attention is given to Low risks, if they are perceived to be more serious than they actually are. Remember, an employee's perception is his or her reality.

Some of the risk assessment matrices shown in this chapter combine elements pertaining to personal injury with the financial impact of an incident represented by the amount of property damage, business downtime, and time to recover from an environmental incident. Safety professionals who have made such combinations in their risk assessment matrices insist that they receive better management response to their proposals for risk reduction if they tie the severity of injury to avoiding operational property damage, downtime, business interruption, and environmental damage. That has been this author's experience.

DESCRIPTIONS OF HAZARDS ANALYSIS AND RISK ASSESSMENT TECHNIQUES

Over the past 40 years, a large and unwieldy number of hazard analysis and risk assessment techniques have been developed. For example, Pat Clemens gives brief

descriptions of 25 techniques in "A Compendium of Hazard Identification and Evaluation Techniques for System Safety Applications." In the *System Safety Analysis Handbook*, 101 methods are described. Brief descriptions will be given here of purposely selected hazard analysis techniques. If a safety professional understands all of them and is capable of bringing them to bear in resolving hazards and risk situations, he or she will be exceptionally well qualified to meet the risk assessment requirements in Z10.

As a practical matter, having knowledge of three risk assessment concepts will be sufficient to address most occupational safety and health risk situations: Preliminary Hazard Analysis, the What-If Checklist Analysis Methods, and Failure Mode and Effects and Analysis. It is important to understand that each of these techniques complements, rather than supplants, the others. Selecting the technique or a combination of techniques to be used to analyze a hazardous situation requires good judgment based on knowledge and experience. Qualitative rather than quantitative judgments will prevail. For all but complex risks, qualitative judgments will be sufficient.

Sound quantitative data on incident probabilities are seldom available. My associates skilled in system safety, a field in which quantitative risk assessments are routine, are not overly pleased when I say that most quantitative risk assessments are really qualitative risk assessments because so many judgments have to be made in the process to decide on the probability levels to be selected.

PRELIMINARY HAZARD ANALYSIS: HAZARD ANALYSIS AND RISK ASSESSMENT

The original use of the preliminary hazards analysis (PHA) technique was to identify and evaluate hazards in the early stages of the design process. However, in actual practice the technique has attained much broader use. The principles on which preliminary hazards analyses are based are used not only in the initial design process, but also in assessing the risks of existing products or operations.

For example, a European standard adopted by the International Organization for Standardization (ISO) requires that risk assessments be made for all machinery to go into a workplace within the European Community. That standard is ISO 12100-1, Safety of Machinery—Basic Concepts, General Principles for Design; Part 1, Basic Terminology, Methodology. The risk assessment process is outlined in ISO 14121, Safety of Machinery—Principles for Risk Assessments. These risk assessment requirements have been met in some companies by applying an adaptation of the PHA technique.

In reality, the PHA technique needs a new name, reflecting its broader usage. At A-P-T Research, Inc., the process is called Hazard Analysis and Risk Assessment, a designation they say is coming into greater usage since it is more descriptive of its purpose. (Also, take note of the following to avoid confusion: in the *OSHA Rule for Process Safety Management of Highly Hazardous Chemicals* and the EPA's *Risk Management Program for Chemical Accidental Release Prevention*, PHA stands for Process Hazard Analysis.)

The headings on preliminary hazard analysis forms will ask for the typical identifying data: date, names of evaluators, department, and location. The following information is usually included on a preliminary hazard analysis form:

- A hazard description, sometimes called a hazard scenario.
- A description of the task, operation, system, or product being analyzed.
- The exposures that are to be analyzed: people (employees, the public); facility, product, or equipment loss; operation downtime; environmental damage.
- The probability interval to be considered: unit of time or activity; events; units produced; life cycle.
- A numerical or alpha indicator for the severity of harm or damage that might result if the hazard's potential is realized.
- A numerical or alpha indicator for the occurrence probability.
- A risk assessment code, using the agreed on Risk Assessment Matrix.
- Remedial action to be taken, if risk reduction is needed.

A written communication accompanies the analysis, explaining the assumptions made and the rationale for them. Comments would then be made on the assignment of responsibilities for the remedial actions to be taken and when. A Hazard Analysis and Risk Assessment Worksheet (formerly called a Preliminary Hazard Analysis Worksheet) appears in Addendum A at the end of this chapter, courtesy of A-P-T Research, Inc. That form, and other similar forms, require entry of severity, probability, and risks codes before and after countermeasures are taken.

On Developing a Coding System

Assume that there are to be four severity categories, for which numerical codes are to be used: Catastrophic, 1; Critical, 2; Marginal, 3; Negligible, 4. Assume that there are to be five categories of occurrence probability, with alpha codes: Frequent, A; Probable, B; Occasional, C; Remote, D; Improbable, E. The foregoing is based on the Risk Assessment Matrix shown earlier in Table 7. Table 13 is an extension of Table 7. Alpha and numerical code indicators have been added to the matrix.

TABLE 13 Risk Assessment Matrix, Including Probability and Severity Codes

Occurrence Probability	Severity Categories			
	Catastrophic, 1	Critical, 2	Marginal, 3	Negligible, 4
Frequent, **A**	High	High	Serious	Medium
Probable, **B**	High	High	Serious	Medium
Occasional, **C**	High	Serious	Medium	Low
Remote, **D**	Serious	Medium	Medium	Low
Improbable, **E**	Medium	Medium	Medium	Low

Risk codes would then be as follows, taking into account the combinations of the severity and probability codes:

Combinations	Risk Category and Code	
A-1, A-2, B-1, B-2, C-1	High	H
A-3, B-3, C-2, D-1	Serious	S
A-4, B-4, C-3, D-2, D-3, E-1, E-2, E-3	Medium	M
C-4, D-4, E-4	Low	L

The foregoing is intended as an illustration from which suitable adaptations can be made by safety professionals.

WHAT-IF ANALYSIS

For a What-If Analysis, a group of people (as few as two, but often several more) use a brainstorming approach to identify hazards, hazard scenarios, how incidents can occur, and what their probable consequences might be. Questions posed during the brainstorming session may commence with "What-If," as in "What if the air conditioning fails in the computer room?" or may be expressions of more general concern, as in "I worry about the possibly of spillage and chemical contamination during truck offloading." All questions are recorded and assigned for investigation. Each subject of concern is then addressed by one or more team members. They would consider the potential of the hazardous situation and the adequacy or inadequacy of risk controls in effect, suggesting additional risk reduction measures if appropriate.

CHECKLIST ANALYSIS

Checklists are primarily adaptations from published standards, codes, and industry practices. There are many such checklists. They consist of lists of questions pertaining to the applicable standards and practices—usually with a "yes," "no," or "not applicable" response. Their purpose is to identify deviations from the expected and thereby possible hazards. A checklist analysis requires a walk-through of the area to be surveyed.

Checklists are easy to use and provide a cost-effective way to identify customarily recognized hazards. Nevertheless, the quality of checklists is dependent on the experience of the people who develop them. Furthermore, they must be crafted to suit particular needs. If a checklist is not complete, the analysis may not identify some hazardous situations. An example of a checklist for machinery design is provided in Addendum B at the end of this chapter. A checklist for general design purposes appears in Chapter 13, "Safety Design Reviews." Both serve as resources for those who choose to build their own checklists.

WHAT-IF/CHECKLIST ANALYSIS

A What-If/Checklist hazard analysis technique combines the creative, brainstorming aspects of the What-If method with the systematic approach of a Checklist. Combining the techniques can compensate for the weaknesses of each. The What-If part of the process, using a brainstorming method, can help the team identify hazards that have the potential to be the causal factors for incidents, even though no such incidents have yet occurred. The checklist provides a systematic approach for review that can serve as an idea generator during the brainstorming process. Usually, a team experienced in the design, operation, and maintenance of the operation performs the analysis. The number of people required depends, of course, on the operation's complexity.

HAZARD AND OPERABILITY ANALYSIS

The hazard and operability analysis (HAZOP) technique was developed to identify both hazards and operability problems in chemical process plants. An interdisciplinary team and an experienced team leader are required. In a HAZOP application, a process or operation is systematically reviewed to identify deviations from desired practices that could lead to adverse consequences. HAZOPs can be used at any stage in the life of a process.

HAZOPs usually require a series of meetings in which the team, using process drawings, systematically evaluates the impact of deviations from the desired practices. The team leader uses a set of guide words to develop discussions. As the team reviews each step in a process, they record any deviations, along with their causes, consequences, safeguards, and required actions, or the need for more information to evaluate the deviation.

FAILURE MODES AND EFFECTS ANALYSIS

In several industries, failure modes and effects analyses (FMEAs) have been the techniques of choice by design engineers for reliability and safety considerations. They are used to evaluate the ways in which equipment fails and the response of the system to those failures. Although an FMEA is typically made early in the design process, the technique can also serve well as an analysis tool throughout the life of equipment or a process.

An FMEA produces qualitative, systematic lists that include the failure modes, effects of each failure, safeguards that exist, and additional actions that may be necessary. For example, for a pump, the failure modes would include findings such as these: fails to stop when required; stops when required to run; seal leaks or ruptures; and pump case leaks or ruptures.

Both the immediate effects and the impact on other equipment would be recorded. Generally, when analyzing impacts, the probable worst case is assumed

and analysts would conclude that existing safeguards do or do not work. Although an FMEA can be made by one person, it is typical for a team to be appointed when there is complexity. In either case, the traditional process is similar:

1. Identify the item or function to be analyzed.
2. Define the failure modes.
3. Record the failure causes.
4. Determine the failure effects.
5. Enter a severity code and probability code for each effect.
6. Enter a risk code.
7. Record the actions required to reduce the risk to an acceptable level.

Note that the FMEA process described here requires the entry of probability, severity, and risk codes. The example of a risk assessment matrix shown in Table 13, and the Risk Category Codes, given in the nearby text fulfill the needs for traditional FMEA purposes. A Failure Modes and Effects Analysis form on which those codes would be entered is provided in Addendum C at the end of this chapter, courtesy of A-P-T Research, Inc.

FAULT TREE ANALYSIS

A Fault Tree Analysis (FTA) is a top-down, deductive logic model that traces the failure pathways for a predetermined, undesirable condition or event, called the TOP Event. An FTA can be carried out either quantitatively or subjectively. The FTA generates a fault tree (a symbolic logic model) entering failure probabilities for the combinations of equipment failures and human errors that can result in the accident. Each immediate causal factor is examined to determine its subordinate causal factors until the root causal factors are identified.

The strength of an FTA is its ability to identify combinations of basic equipment and human failures that can lead to an accident, allowing the analyst to focus preventive measures on significant basic causes. An FTA has particular value when analyzing highly redundant systems and high-energy systems in which high-severity events can occur. For systems vulnerable to single failures that can lead to accidents, the FMEA and HAZOP techniques are better suited. FTA is often used when another technique has identified a hazardous situation that requires more detailed analysis. Making a fault tree analysis of other than the simplest systems requires the talent of experienced analysts.

MANAGEMENT OVERSIGHT AND RISK TREE

As Clemens wrote in a previously cited paper, the Management Oversight and Risk Tree (MORT) technique applies “a pre-designed, systematized logic tree to

the identification of total system risks, both those inherent in physical equipment and processes and those which arise from operational/management inadequacies." MORT is an incident investigation and analysis technique. It is discussed here for a particular purpose.

There are three major elements in the practice of safety:

- In the design processes—preoperational
- In the operational mode—within a continuous improvement process
- Post incident—through investigation of hazards-related incidents for causal factor determination

All the hazard analysis and risk assessment techniques previously discussed relate principally to the design process or achieving risk reduction in the operational mode *before hazards-related incidents occur*. MORT was developed principally for incident investigations. In the Abstract for the *Guide To Use Of The Management Oversight And Risk Tree*, this is how MORT is described:

> MORT is a comprehensive analytical procedure that provides a disciplined method for determining the systemic causes and contributing factors of accidents. MORT directs the user to the hazards and risks deriving from both system design and procedural shortcomings.

MORT provides an excellent hazard analysis method for the post incident element of the practice of safety.

SOFTWARE

There are several software products available that assist in making hazards analyses and risk assessments. Comments follow on a select few.

1. *designsafe Risk Assessment Software.*[1] This program guides safety professionals and engineers through the risk assessment process. designsafe enables users to perform risk assessments conforming to many industry standards, including Z10; ISO 14121; the B11 series of standards on machine tools; the packaging industry standard B155.1; SEMI S10, a semiconductor industry standard; and others.

The software guides users to identify persons who interact with the system or machine, the tasks they perform, and the hazards associated with the tasks. Users are prompted to assess the risk of the task–hazard combinations and then reduce risk using safety control technology. The program provides documentation of the assessment quickly and easily. The system responds to the need of companies for speed and flexibility in performing risk assessments. An earlier version of designsafe was the platform for a wide variety of applications, including manufacturing and business processes, consumer products, etc.

[1]As described by the developer of the program, Bruce Main, president of design safety engineering.

The most recent (fifth) upgrade of designsafe incorporates these programs and allows greater flexibility, versatility, and speed in conducting risk assessments. It can be used for new or existing operations or products, equipment, systems, and processes. Companies also need to get Learn by eliminating waste, but not at the cost of increasing risk. designsafe enables users to perform value stream mapping to obtain optimum system design with the lowest waste at the lowest risk.

designsafe uses a checklist-driven format and comes preloaded with customized dictionaries for many industries, including general manufacturing; packaging machinery; robotics; medical devices; military equipment; construction; transportation, etc. This software is a guide—not an expert system. It walks users through the process. For a free demo version of designsafe, go to http://www.designsafe.com.

2. *Design for Safety Toolbox.* Assists in designing facilities with construction worker health and safety at the fore. It is available through the Construction Industries Institute at http://www.construction-institute.org

3. *SEMATECH Failure Modes and Effects Analysis (FMEA) Software Tool.* Provides just what the title indicates, a software tool to assist in making an FMEA. At http://www.sematech.org, look for Technology Transfer #92091302A-XFR.

4. *FaultrEase.* A graphic tool for creating, editing, and computing fault trees. A colleague who is skilled in fault tree analysis has made a remarkable comment about this tool: Its manual is readable. He has indicated that the program makes layout and pruning the tree relatively easy. It is available through ICF Consulting at http://www.icfconsulting.com/Markets/Environment/envmgmt05.asp.

ADDITIONAL RESOURCES

A Risk Assessment Tool, made available by the European Agency for Safety and Health at Work, may be found at http://hwi.osha.europa.eu/ra_tools_generic/. Parts I and II provide basic information on risk assessment. The subject matter is but eight pages long. Nevertheless, the document takes a reader through a basic hazard identification and risk assessment process. Part III provides checklists for hazard identification and the selection of preventive measures for 10 subjects, for example, moving machinery, electrical installations and equipment, fire, etc. Part IV consists of checklists for seven occupational settings, for example, office work, food processing, small-scale surface mining, etc.

In the United Kingdom, the Health and Safety Executive recently updated its "Five Steps to Risk Assessment." It may be accessed at http://www.hse.gov.uk/risk/fivesteps.htm. This is also a basic, uncomplicated system.

If a safety professional undertakes to inform supervisors and workers on the fundamentals of hazard identification and risk assessment, say, at safety meetings, the two foregoing resources will serve well in developing the presentations and any written material.

A particularly valuable reference is the *Guidelines for Hazard Evaluation Procedures, Second Edition With Worked Examples*. Although this text has been published by a chemical industry organization, it is largely generic.

The Basics of FMEA is a small-trim, 75-page book. It is a primer on the failure mode and effect analysis process.

In Chapter 10, "Three- and Four-Dimensional Numerical Risk-Scoring Systems," comment is made on FMEA publications issued for the semiconductor industry by International SEMATECH and for the auto industry by the Automotive Industry Action Group.

AVOIDING UNREALISTIC EXPECTATIONS

Making hazards analyses and risk assessments is both art and science. Whatever the methodology—the simplest or the most complicated—many judgments will be made in determining the severity potentials of hazards and the probably of incidents and exposures occurring. Even though the appliers of risk assessment methodologies make informed judgments, they may disagree on which hazards are most important because of their severity potential and which risks deserve the highest priority. One way to resolve those differences is to have qualified teams participate when the hazards and risks are considered significant, the intent being to reach a consensus.

Some who oppose the use of qualitative risk assessment techniques do so because the outcomes are not stated in absolutely assured, precise numbers. Such accuracy is not attainable because incident probability data are lacking and the severity of event outcomes is a best estimate. Expecting such results is unrealistic. Fortunately, recognition continues to grow that hazard analysis and risk assessment methods, although qualitative, add value to safety decision making.

CONCLUSION

This chapter is but a primer on hazard analysis and risk assessment. Its purpose is to provide a foundation for those who perceive that having additional knowledge in this aspect of safety and health management provides opportunity for professional growth, accomplishment, and recognition. Having that knowledge adds to one's ability to evaluate hazardous situations and make more convincing presentations to management for resource allocation to accomplish the risk reduction measures proposed.

Looking to the future, safety professionals can expect that being knowledgable about hazard analysis and risk assessment techniques will be required for job retention and career enhancement. Fortunately, it is not difficult to acquire the knowledge and skill required to fulfill almost all their needs.

As safety and health professionals become more involved in risk assessments, they will come to understand that professional safety practice requires attention to the two distinct aspects of risk:

- Avoiding, eliminating, or reducing the *probability* of a hazards-related incident or exposure occurring

- Minimizing the *severity* of harm or damage, anticipating that an incident or exposure may occur

Should a safety professional want to acquire an extensive and valuable text devoted entirely to applications in risk assessment, I suggest that he or she consider *Risk Assessment: Basics and Benchmarks* written by Bruce Main. With respect to risk assessment, Main has been a researcher, writer, consultant, software developer, instructor, and leader in standards development. To learn more about the book, go to http://www.designsafe.com.

REFERENCES

ANSI/AIHA Z10-2005. Occupational Health and Safety Management Systems Standard. Fairfax, VA: American Industrial Hygiene Association, 2005. Also available at http://www.aiha.org/marketplace.htm.

ANSI/PMMI B155.1-2006. Safety Requirements for Packaging Machinery and Packaging-Related Converting Machinery Standard. Arlington, VA: Packaging Machinery Manufacturers Institute, 2006.

Clemens, Pat. A Compendium of Hazard Identification and Evaluation Techniques for System Safety Application. *Hazard Prevention*, March/April 1982.

Failure Mode and Effects Analysis (FMEA): A Guide for Continuous Improvement for the Semiconductor Equipment Industry. Technology Transfer #92020963A-ENG. Austin, TX: International SEMATECH, 1992. Also available at http://www.sematech.org.

Framework for Environmental Health Risk Management, Final Report,Vol. 1. Washington, DC: The Presidential/Congressional Commission on Risk Assessment and Risk Management, 1997.

Guide to Use of the Management Oversight and Risk Tree—SSDC-103. Washington, DC: Department of Energy, 1994.

Guidelines for Hazard Evaluation Procedures, Second Edition with Worked Examples. New York: Center for Chemical Process Safety of the American Institute of Chemical Engineers, 1992.

ISO 12100-1. Safety of Machinery—Basic Concepts, General Principles for Design; Part 1. Basic Terminology, Methodology. Geneva, Switzerland: International Organization for Standardization, 2003.

ISO 12100-2. Safety of Machinery—Basic Concepts, General Principles for Design; Part 2. Technical Principles and Specification. Geneva, Switzerland: International Organization for Standardization, 2003.

ISO 14121. Safety of Machinery—Principles for Risk Assessment. Geneva, Switzerland: International Organization for Standardization, 1999.

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.

McDermott, Robin E., Raymond J. Mikulak, and Michael R. Beauregard. *The Basics of FMEA*. New York: Productivity Press, 1996.

MIL-STD-882D and E. *Standard Practice for System Safety*. Washington, DC: Department of Defense, 2000. Also available at http://www.safetycenter.navy.mil/instructions/osh/milstd882d.pdf#search = 'MILSTD882D'.

OSHAs Rule for Process Safety Management of Highly Hazardous Chemicals, 29 CFR 1910.119. Washington, DC: Department of Labor, Occupational Safety and Health Administration, 1992.

Potential Failure Mode and Effects Analysis: FMEA., 3rd ed. Southfield, MI: Automotive Industry Action Group (AIAG), 2001.

Stephans, R. A., and W. W. Talso. *System Safety Analysis Handbook*, 2nd ed. Albuquerque, NM: System Safety Society, 1997.

Additional Reading

Grose, Vernon L. *Managing Risk, Systematic Loss Prevention for Executives*. Englewood Cliffs, NJ: Prentice-Hall, 1987. Now available through Omega Systems Group, Arlington, VA.

Roland, Harold E., and Brian Moriarty. *System Safety Engineering and Management*, 2nd ed. New York: John Wiley & Sons, 1990.

Stevens, Richard A. *System Safety for the 21st Century*. Hoboken, NJ: John Wiley & Sons, 2004. (This is an updated version of *System Safety 2000* by Joe Stephenson.)

ADDENDUM A

HAZARD ANALYSIS AND RISK ASSESSMENT WORKSHEET

A·P·T Research, Inc,

Hazard Analysis and Risk Assessment

HAZARD No. Chem/Int-001 **HAZARD TITLE:** Flange Seal A-29 Leakage **REVISED:** 7/22/93

HAZARD DESCRIPTION

Flange Seal A-29 leakage, releasing pressurized $UnFo_3$ chemical intermediate from containment system, producing toxic vapors on contact with air attacking nearby equipment.

EXPOSURE INTERVAL 25 years **ACTIVITY/PROCESS PHASE:** Startup/Standard Operation/Stop/Emergency Shutdown

INITIAL RISK ASSESSMENT

(with existing of planned/designed-in countermeasures)

HAZARD TARGET(S): (check all applicable)	SEVERITY: (worst credible)	PROBABILITY: (for exposure interval)	RISK CODE: (from Matrix)
Personnel: X	I	D	2
Equipment: X	II	C	2
Downtime: X	III	C	3
Environment: X	II	C	2
Product: O			0

POST-COUNTERMEASURE RISK ASSESSMENT

(with additional countermeasures in place)

HAZARD TARGET(S): (check all applicable)	SEVERITY: (worst credible)	PROBABILITY: (for exposure interval)	RISK CODE: (from Matrix)
Personnel: X	I	E	3
Equipment: X	II	D	3
Downtime: X	III	D	3
Environment: X	III	D	3
Product: O			0

ADDITIONAL COUNTERMEASURES*

1) Surround flange with sealed annular stainless steel catchment housing, with gravity run-off conduit, led to Detecto-Box™ containing detector/alarm feature and chemical neutralizer (S/W).
2) Inspect flange at two-month intervals and re-gasket during annual plant maintenance shut-down (P).

***Mandatory for Risk Codes 1 & 2 unless permitted by Waiver.**
Personnel must not be exposed to Risk Code 1 or 2 hazards.

Code Each Countermeasure: (D) Design Alteration / (E) = Engineered Safety Features (S) = Safety Devices / (W) = Warning Devices / (P) = Procedures/Training

COMMENTS

BASIS: Dwg. No. IntPpRte H-47.d, Rev. 3, 15 June, '03, and in-plant survey.

Prepared by/Date: (Designer/Analyst)	Reviewed by/Date: (System Safety Manager)	Approved by: (Project Manager)

ADDENDUM B

EXAMPLES OF HAZARDS, HAZARDOUS SITUATIONS, AND HAZARDOUS EVENTS

This checklist is an adaptation of information that appears in the ISO's Safety of Machinery—Principles of Risk Assessment, Standard, ISO14121. The checklist is a guide for companies located throughout the world who design and manufacture machinery and equipment that would go into European workplaces. Although the checklist pertains to a broad range of equipment, those who use it as a reference must understand that it could not possibly include all hazards and all hazardous situations.

Mechanical Hazards

Due to machine parts or work pieces, for example,

- Shape
- Relative motion
- Mass and stability (potential energy of elements which may move under the effect of gravity)
- Mass and velocity (kinetic energy of elements in controlled and uncontrolled motion)
- Inadequacy of mechanical strength

Due to accumulation of energy inside the machinery, for example,

- Elastic elements (springs)

Advanced Safety Management Focusing on Z10 and Serious Injury Prevention, by Fred A. Manuele

- Liquids and gases under pressure
- The effect of vacuum

Mechanical Hazards due to the Potential for

- Crushing
- Shearing
- Cutting or severing
- Entanglement
- Drawing-in or trapping
- Impact
- Stabbing or puncture
- Friction or abrasion
- High-pressure fluid injection or ejection

Electrical Hazards due to

- Contact of persons with live parts (direct contact)
- Contact of persons with parts that have become live under faulty conditions (indirect contact)
- Approach to live parts under high voltage
- Electrostatic phenomena
- Thermal radiation or other phenomena such as the projection of molten particles and chemical effects from short circuits, overloads, etc.

Thermal Hazards Resulting in

- Burns, scalds, and other injuries by the possible contact of persons with objects or materials with an extreme high or low temperature, by flames or explosions, and also by the radiation of heat sources
- Damage to health by hot or cold working environment

Hazards Generated by Noise Resulting in

- Hearing loss (deafness), other physiological disorders (e.g., loss of balance, loss of awareness)
- Interference with speech communication, acoustic signals, etc.

Hazards Generated by Vibration

- Use of hand-held machines resulting in a variety of neurological and vascular disorders
- Whole-body vibration, particularly when combined with poor postures

Hazards Generated by Radiation

- Low-frequency, radio frequency radiation; microwaves
- Infrared, visible, and ultraviolet light

- X- and gamma rays
- Alpha or beta rays, electron or ion beams, neutrons
- Lasers

Hazards Generated by Materials and Substances (and Their Constituent Elements) Processed or Used by the Machinery

- Hazards from contact with or inhalation of harmful fluids, gases, mists, fumes, and dusts
- Fire or explosion hazards
- Biological or microbiological (viral or bacterial) hazards

Hazards Generated by Neglecting Ergonomic Principles in Machinery Design

- Unhealthy postures or excessive effort
- Hazardous situations due to lifting
- Inadequate consideration of hand-arm or foot-leg anatomy
- Neglected use of personal protection equipment
- Inadequate local lighting
- Mental overload and underload, stress
- Human error, human behavior
- Inadequate design, location, or identification of manual controls
- Inadequate design or location of visual display units

Hazards Deriving from Unexpected Start-up, Unexpected Overrun/Overspeed (or Any Similar Malfunction) from

- Failure/disorder of the control system
- Restoration of energy supply after an interruption
- External influences on electrical equipment
- Other external influences (gravity, wind, etc.)
- Errors in the software
- Errors made by the operator (due to mismatch of machinery with human characteristics and abilities)
- Impossibility of stopping the machine in the best possible conditions
- Variations in the rotational speed of tools
- Failure of the power supply
- Failure of the control circuit
- Errors of fitting
- Break-up during operation
- Falling of ejected objects or fluids
- Loss of stability/overturning machinery
- Slip, trip, and fall of persons related to machinery

Hazards, Hazardous Situations, and Hazardous Events due to Mobility

Relating to the traveling function

- Movement when starting the engine
- Movement without a driver in the driving position
- Movement without all parts in a safe position
- Excessive speed of pedestrian-controlled machinery
- Excessive oscillation when moving

Linked to the work position (including driving station) on the machine

- Fall of persons during access to (or at/from) the work position
- Exhaust gases/lack of oxygen at the work position
- Fire (flammability of the cab, lack of extinguishing means)
- Mechanical hazards at the work position:
  1. Contact with wheels
  2. Rollover
  3. Fall of objects, penetration by objects
  4. Break-up of parts
  5. Contact of persons with machine parts or tools (pedestrian-controlled machines)
- Insufficient visibility from the work position
- Inadequate lighting
- Inadequate seating
- Noise at the work position
- Vibration at the work position
- Insufficient means for evacuation/emergency

Due to the power source and to the transmission of power

- Hazards from the engine and batteries
- Hazards from transmission of power between machines
- Hazards from coupling and towing

From/to third persons

- Unauthorized start-up/use
- Drift of a part away from its stopping position
- Lack of or inadequacy of visual or acoustic warning means

Hazards, Hazardous Situations, and Hazardous Events due to Lifting

Mechanical hazards and hazardous events

- From load falls, collisions, machine tipping caused by:
  1. Lack of stability
  2. Uncontrolled loading, overloading, overturning moments exceeded
  3. Uncontrolled amplitude of movements
  4. Unexpected/unintended movement of loads
  5. Inadequate holding devices/accessories
  6. Collision of more than one machine
- From access of persons to load support
- From insufficient mechanical strength of parts
- From inadequate design of pulleys, drums

ADDENDUM C

FAILURE MODES AND EFFECTS ANALYSIS FORM

A·P·T Research, Inc,

FMEA No.: N/246.n
Project No.: Osh-004-92
Subsystem.: Illumination
System.: Headlamp Controls
Probability Interval.: 20 years

FAILURE MODES AND EFFECTS ANALYSIS

Sheet 11 of 44
Date.: 6 Feb '02
Prep. by.: R.R. Mohr
Rev. by.: S. Singleman
Approved by.: G. Roper

IDENT. No.	ITEM/ FUNCTIONAL IDENT.	FAILURE MODE	FAILURE CAUSE	FAILURE EFFECT	TARGET	RISK ASSESSMENT			ACTION REQUIRED/REMARKS
						SEV	PROB	Risk Code	
R/N.42	Relay K-28/ Contacts (normally open)	Open w/ command to close	Corrosion/or mfg.defect/or basic coil failure (open)	Loss of forward illumination/ Impairment of night vision/potential collision(s) w/unilluminated obstacles	**P** **E** **T** **M**	**I** **III** **I** **I**	**D** **D** **D** **D**	**2** **3** **2** **2**	Redesign headlamp circuit to produce headlamp fail-on, w / timed off feature to protect battery, or eliminate relay / use HD Sw. at panel.

P: Personnel / **E**: Equipment / **T**: Downtime / **M**: Mission / **V**: Environment

CHAPTER 9

INCLUDING RISK ASSESSMENT PROVISIONS IN STANDARDS AND GUIDELINES: A TREND

INTRODUCTION

It was stated in the preceding chapter that the ability of safety and health professionals to make risk assessments will be necessary for their job retention and career enhancement. That premise has acquired weight because of the more frequent inclusion of provisions requiring risk assessments in safety standards and guidelines. This significant trend will not only have an impact on the knowledge and skills that safety and health professionals are expected to have, but it will also provide career opportunities for them. To provide guidance for safety professionals, this chapter will:

- Give a review of the evolving trend by briefly commenting on significant undertakings in 2005 and 2006 relating to risk assessments.
- Comment more thoroughly on the hazard analysis and risk assessment provisions in several standards and guidelines.

VERY RECENT ACTIVITY

Concerning Maintenance

In the June 2006 issue of *Maintenance Technology*, Charles N. Bowers asserts that:

Advanced Safety Management Focusing on Z10 and Serious Injury Prevention, by Fred A. Manuele

> Risk management is not just a matter for your safety department or insurance carrier. Maintenance can use this powerful tool to help ensure the health and reliability of critical assets. Risk management was once thought to be the sole product of the site safety department. Maintenance and operations professionals, however, now understand the importance of a risk management process to aid in protecting, conserving and extending the reliability of critical assets.

Bowers (at Life Cycle Engineering, cbowerse@LCE.com) mentions the following risk assessment tools that can be employed to help preserve asset resources: Simplified Failure Mode Effects Analysis, Root Cause Failure Analysis, and Reliability-Centered Maintenance. Should safety and health professionals step forward to train maintenance managers in risk assessment concepts?

Concerning Natural and Man-Made Hazards

In June 2006 ASTM International circulated a draft titled *Standard Guide for Developing a Cost-Effective Risk Mitigation Plan* for ballot approval and comments. The standard outlines a framework of three steps: (1) risk assessment, (2) identification of alternatives, and (3) economic evaluation. This is a fascinating innovation. The guide presents a generic framework for developing a cost-effective risk mitigation plan for new and existing facilities exposed to risks deriving from natural and man-made hazards. (The working number for the standard is WK7175. ASTM at one time stood for the American Society for Testing and Materials.)

A good part of the standard relates to economic decision making following the risk assessments, as indicated by the following: "Several measures of economic performance are available for evaluating building-related investments. These measures include, but are not limited to, life-cycle cost, present value net savings, savings-to-investment ratio, and adjusted internal rate of return."

A course on how to apply the guide is work in progress at ASTM. The following appears in material describing the course, which is expected to be available date 2007 through ASTM. "The course includes a 45-minute on-line demonstration of how to access web-based resources that provide guidance on performing the risk assessment and risk management activities that underlie the economic evaluation." So, web-based resources on performing risk assessments are available. That is a very interesting development.

Concerning Fire Protection

The National Fire Protection Association (NFPA) engaged Battelle in 2006 to make a highly significant study with respect to risk assessment. The stated research objective is "To develop the technical basis and implementation strategy for the incorporation of risk assessment concepts into the NFPA codes and standards making system." In March 2007, Battelle delivered its report titled Guidance Document for Incorporating Risk Concepts into NFPA Codes and Standards. This is a grand undertaking with immense potential. Assume that all NFPA codes include provisions to apply risk assessment concepts. That would have an immense impact on

the knowledge needs of safety and health professionals because of the large number of NFPA codes that affect their work.

Generic Risk Assessment Provisions in a Packaging Machinery Standard

Comments in some detail will be made later on a revision of a standard that now contains risk assessment provisions: the Safety Requirements for Packaging Machinery and Packaging-Related Converting Machinery Standard, ANSI/PMMI B155.1/2006. The standard is a fairly recent development; it was approved in May 2006. Since the standard's risk assessment provisions are largely generic, others are examining that section to determine whether it can serve as the basis for a new ANSI standard on risk assessment alone.

Activity in Canada

In March 2006 the Canadian Standards Association (CSA) issued the first edition of CSA Z1000-6, the Occupational Health and Safety Management Standard. It is similar in many respects to ANSI/AIHA Z10-2005. Its Hazard and risk identification and assessment provision reads as follows: "The organization shall establish and maintain a process to identify and assess hazards and risks on an ongoing basis. The results of this process shall be used to set objectives and targets and to develop preventive and protective measures."

The Occupational Health and Safety Management Systems Standard, ANSI/AIHA Z10-2005, was approved in July 2005. Much is written in this book about its risk assessment and prioritization provisions.

Safety and health professionals, take note: The preceding data and the following reviews show that a trend exists with respect to risk assessment provisions being included more often in standards and guidelines.

Comments follow to inform safety professionals about specific safety and health standards and guidelines issued in the past several years that contain hazard analysis and risk assessment provisions. There are similarities and differences in the approaches taken by the drafters of these standards and guidelines. Some are industry-specific. Others apply across all industries. The message they give is clear: Safety and health professionals will be expected to have working knowledge of hazard analysis and risk assessment methods and how to apply them.

A SIGNIFICANT EVENT

A noteworthy first was achieved in the United States in June 1999 when ANSI/RIA R15.06-1999, the American National Standard for Industrial Robots and Robot Systems—Safety Requirements, was approved. The Robotic Industries Association (RIA) is the secretariat for the standard.

Why should safety generalists whose field of influence does not include robots pay attention to this standard? It was a precursor in form and content to other safety standards and guidelines that followed. ANSI/RIA R15.06-1999 was the first

occupational safety standard issued by the American National Standards Institute (ANSI) in which conducting a comprehensive risk assessment is presented as a means to determine the design requirements, the safeguarding to be applied, and the subsequent administrative controls that may be needed.

The robotic standard requires that a strategy be developed for identifying and controlling hazards and safeguarding personnel by either applying the prescribed guarding methods set forth in the standard or by conducting a comprehensive risk assessment to determine the safeguarding necessary. The standard is thorough on task and hazard identification, risk estimation, determining risk reduction categories in relation to the estimated risk, and the minimum required safeguard performance for each risk reduction category.

To assist users of the standard as they make risk assessments, a Robot Risk Assessment CD has been made available through the secretariat. Enter "Robotic Risk Assessment CD Version 2.0" into any search engine and clicking onto the result, this description will appear:

> This easy to navigate program helps you conduct a hazard analysis based on the application and the associated tasks the robot will be completing. It then leads you through the risk assessment where you will determine the severity of potential injuries and the frequency of exposure and likelihood of avoidance. Once the risk assessment is complete, the program provides for easy documentation.

ANSI/RIA R15.06 contains provisions to be applied by both the makers and users of robots and robot systems. ANSI standards are usually updated every 5 years and this standard was up for renewal in 2004. Rather than update R15.06, the Robotic Industries Association has become a member of the committee responsible for ISO 10218:1992, the Manipulating Industrial Robots—Safety Standard. (ISO is the designation for the International Organization for Standardization. It is the world's largest nongovernmental developer of standards, working with a network of the national standards institutes of 148 countries. The United States is represented at ISO by ANSI.)

The intent is to have an international standard on robots and robot systems that incorporates R15.06's provisions. That will be a major accomplishment. ISO 10218 would apply to both manufacturers of robots and robot equipment, and to purchasers and users. For ISO safety standards (and European Community safety standards), that will be a first since they apply only to machinery and equipment makers—not to purchasers and users, often meaning employers.

DEVELOPMENTS IN AVIATION GROUND SAFETY

One of the most interesting innovations regarding hazard analysis and risk assessment has been achieved by the International Air Transport Section of the National Safety Council. This section is truly international, having representation from all of the populated continents. Its *Aviation Ground Operation Safety Handbook* is used throughout the world.

A fifth edition of the handbook was published in July 2000; it includes new material titled "Risk Management Guide for the Aviation Industry." This excerpt is taken from the introduction to that material:

> Risk management takes aviation safety to the next level. It is a six-step logic-based, common approach to making calculated decisions on human, material, and environmental factors before, during and after operations. Risk management enables senior leaders, functional managers, supervisors and individuals to maximize opportunities for success while minimizing risks.

The air transport group has outlined a way of thinking about and dealing with hazards and risks, applying a logical and sequential methodology. It has developed a "process to detect, assess, and control risk." The steps in its "six-step logic based common sense approach" are shown in Table 1.

TABLE 1 The Risk Management Process

1. Identify the hazard.
2. Assess the risk.
3. Analyze risk control measures.
4. Make control decisions.
5. Implement risk controls.
6. Supervise and review.

In that text, the discussion of each step is extensive. Comments will be made here on the first two only. The remaining steps are addressed in Chapter 12, "Hierarchy of Controls: The Safety Decision Hierarchy." For Step 1,—Identify the hazards—the hazard analysis and risk assessment methodologies are as shown in Table 2.

TABLE 2 Hazard Analysis and Risk Assessment Methodologies

1. *Operations analysis:* Purpose—To understand the flow of events.
2. *Preliminary hazard analysis (PHA):* Purpose—To get a quick survey of all phases of an operation. In low hazard situations, the PHA may be the final hazard identification tool
3. *"What-If" tool:* Purpose—To capture the input of personnel in a brainstorming-like environment.
4. *Scenario process tool:* Purpose—To use imagination and visualizations to capture hazards.
5. *Change analysis:* Purpose—To detect the hazard implications of both planned and unplanned change.

For Step 2—Assess the Risks—a Risk Assessment Matrix is provided. Its configuration is unusual and it does not duplicate well. The terminology used in the matrix for probability and severity, and for the risk gradings, is identical to that in Table 10 in Chapter 8, "A Primer on Hazard Analysis and Risk Assessment," with one exception. In the Handbook, "M" is the designation for Medium Risk, rather than Moderate Risk. We here include Table 10 from Chapter 8 as Table 3.

The *Aviation Ground Operation Safety Handbook* is a good, thought-provoking, not overly complex resource document. (A sixth edition exists in draft form and its included for publication in the 4th quarter of 2007.)

TABLE 3 Risk Assessment Matrix: Alpha Risk Level Indicators

	Probability That Something Will Go Wrong				
Severity Categories	Frequent (likely to occur immediately or soon: often)	Likely (quite likely to occur in time)	Occasional (may occur in time)	Seldom (not likely to occur, but possible)	Unlikely (unlikely to occur)
Catastrophic: death, multiple injuries, severe property or environmental damage	E	E	H	H	M
Critical: serious injuries, significant property or environmental damage	E	H	H	M	L
Marginal: may cause minor injuries, financial loss, negative publicity	H	M	M	L	L
Negligible: minimum threat to persons or damage to property	M	L	L	L	L

E: Extremely High Risk. H: High Risk. M: Moderate Risk. L: Low Risk.

B11.TR3-2000

TR3 is the acronym for a technical report issued by the B11.TR3 Subcommittee formed by the Machine Tool Safety Standards Committee (B11) of ANSI. The subcommittee's work is available in *Risk Assessment and Reduction—A Guideline to Estimate, Evaluate and Reduce Risks Associated with Machine Tools*. The secretariat for this work is the Association for Manufacturing Technology. TR3 became a registered document at ANSI in November 2000.

The principles guiding the work of the TR3 subcommittee summarized are as follows:

- A simple, practical and generic hazard analysis and risk assessment process is to be developed that has the potential to be incorporated in all B11 standards.
- The process must apply to both suppliers and users.
- To the extent possible, the technical report is to be harmonized with European standards.

TR3 is part of the ANSI B11 series of reports and standards pertaining to the design, construction, care, and use of machine tools. It is a guideline, not a standard. However, the content of the guideline has been incorporated in over 75% of the 24 B11 ANSI standards, and work is in progress to amend the others. The impact of TR3 on the design, manufacture, and use of machinery is significant.

More important, over 90% of the guideline is generic. Thus, it is a basic document on hazard analysis and risk assessment providing guidance on reducing risks according to a prioritized procedure and on the selection of appropriate design and protective measures. When the process is complete, a tolerable risk level will be achieved.

It is significant that the TR3 document addresses the safety responsibilities of both designers and manufacturers, and of purchasers and users. Section 4 presents an Overview of risk assessment and risk reduction and includes the following General requirements:

In the design and use of a machine, use risk assessment and risk reduction to arrive at tolerable risk. The steps in the procedure to arrive at tolerable risk are:

a) gather the appropriate information to conduct this procedure
b) determine the limits of the machine
c) identify and document the hazards associated with the task to be performed over the life cycle of the machine
d) analyze the risk(s) associated with the identified individual tasks and related hazards for severity of injury/illness (harm) that can occur and the probability of such an occurrence
e) evaluate each risk to determine whether or not it is tolerable

If the risk is not initially tolerable, protective measures need to be applied which will either decrease the severity of harm or the probability of the occurrence of that harm until the associated risk is tolerable.

SEMI S10-1103 AND SEMI S2-0706

Safety-related guidelines issued by the semiconductor industry are another indication of recognition by a trade group of the value of using hazard analysis and risk assessment techniques to eliminate or control hazards and to attain acceptable risk levels. The manufacturers of machinery and equipment used in making semiconductors, and their customers (Intel, IBM, etc.), realized that they had mutual interests which would be well served if such equipment was designed to meet agreed on safety guidelines. Their trade association, Semiconductor Equipment and Materials International (SEMI), which has global participation, has issued several safety-related guidelines, among them SEMI S2-0706 and SEMI S10-1103.

Environmental, Health, and Safety Guideline for Semiconductor Manufacturing Equipment, SEMI S2-0706, was issued in July 2006. (It is an update of a 2003 guideline). This Guideline sets forth provisions for manufacturers of equipment to be used in the semiconductor industry. Several aspects of the Guideline's Safety Philosophy (Section 6) are pertinent to this chapter.

> 6.2 The assumption is made that operators, maintenance personnel, and service personnel are trained in the tasks that they are intended to perform.
>
> 6.4 This guideline should be applied during the design, construction, and evaluation of semiconductor equipment, in order to reduce the expense and disruptive effects of redesign and retrofit.
>
> 6.8 A hazard analysis should be performed to identify and evaluate hazards. The hazard analysis should be initiated early in the design phase, and updated as the design matures.
>
> 6.8.1 The hazard analysis should include consideration of:
>
> - the application or process
> - the hazards associated with each task
> - anticipated failure modes
> - the probability of occurrence and severity of harm
> - the level of expertise of exposed personnel and the frequency of exposure
> - the frequency and complexity of operating, servicing and maintenance tasks
> - safety critical parts

If the equipment is designed in accord with the Guideline and the prescribed hazards analyses are conducted, the responsibilities of users (employers) to meet Z10's design review provision are more easily accomplished. The hazard analysis is really a risk assessment since both occurrence probability and severity of harm are to be identified. This Guideline also gives employers assistance in meeting the Procurement provisions in Z10 that require including safety specifications in purchasing documents. Here is item 7.1 in the General Provisions: "This guideline should be incorporated by reference in equipment purchase specifications."

A supplementary and advisory document to SEMI S2-0706 is *Related Information 1—Equipment/Product Safety Program*. It makes an interesting statement

about the need to sometimes go beyond issued safety standards in the design process. It reflects my experience. It has to be understood that safety standards may set only minimum requirements, as does Z10:

> Compliance with design-based safety standards does not necessarily ensure adequate safety in complex or state-of-the-art systems. It often is necessary to perform hazard analyses to identify hazards that are specific with the system, and develop hazard control measures that adequately control the associated risk beyond those that are covered in existing design-based standards.

As one who promotes giving special attention to the prevention of incidents that result in serious injury or damage, I highlight the premise built into the Guideline requiring that equipment be readily accessible, defined as "capable of being reached for operation or inspection, without requiring climbing over or removing obstacles, or using ladders, chairs, etc."

Section 6.8.2 of SEMI S2 states that "the risks associated with hazards should be characterized using SEMI S10-1103," the Safety Guideline for Risk Assessment and Risk Evaluation Process. Here is the stated purpose of SEMI S10-1103:

> The purpose of this guideline is to establish general principles for risk assessment and to enable identification of hazards, risk estimation and risk evaluation in a consistent and practical manner. The document provides a framework for carrying out risk assessments on equipment in the semiconductor and similar industries and is intended for use by supplier and purchaser as a reference for EHS considerations.

The hazard identification and analysis processes shown in SEMI S10-1103 duplicate those in SEMI S2-0706. In the risk assessment process, the severity of outcome and likelihood of occurrence are to be identified and categorized. In Appendices, recommended categories for likelihood and severity are given, as well as matrices showing risk categories. The exhibits are comparable to those shown in Chapter 8, "A Primer on Hazard Analysis and Risk Assessment."

ANSI/ASSE Z244.1-2003

In July 2003 approval was given by ANSI to reissue the Control of Hazardous Energy—Lockout/Tagout and Alternative Methods Standard, ANSI/ASSE Z244.1/2003. This standard will have a broad impact in that it affects a huge number of locations. Section 5.4 discusses alternative methods of control, from which the following paraphrasing derives:

> When lockout/tagout is not used for tasks that are routine, repetitive, and integral to the production process, or traditional lockout/tagout prohibits the completion of those tasks, an alternative method of control shall be used. Selection of an alternative control method by the user shall be based on a risk assessment of the machine, equipment, or process.

The foregoing is significant because a risk assessment is required prior to selecting an alternative risk control method. ASSE is the secretariat.

ANSI/PMMI B155.1-2006

The Packaging Machinery Manufacturers Institute (PMMI) is the secretariat for the Safety Requirements for Packaging and Packaging-Related Converting Machinery Standard. A revision of this standard, B155.1, was approved by ANSI in July 2006 as an update of the 2000 version. The major changes to the original standard are indicative of the acceptance of the premise that hazard analysis and risk assessment provisions should be included in ANSI safety standards. Also, the standard is largely generic.

Safety professionals should not be surprised if the generic sections in B155.1 become models and appear in other standards. Section 6,—"The Risk Assessment Process," is an example of just how generic the standard's provisions are. It covers nearly eight pages in rather small print. Its key elements are:

6.0 The Risk Assessment Process.
- 6.1 General
- 6.2 Prepare for/set limits of the assessment
- 6.3 Identify hazards
- 6.4 Assess initial risk
- 6.5 Reduce risk
- 6.6 Assess residual risk
- 6.7 Achieve acceptable risk
- 6.8 Document the results

Note that in this sequence, risk reduction measures are to be taken, if necessary, after the initial risk assessment and that the resulting residual risk is also to be assessed. The goal of all this is to attain acceptable risk levels through a continual application of the process. That is a sound methodology.

B155.1's Subsection 6.4, "Assess Initial Risk," says that "risks shall be assessed using a risk scoring system." The Example Risk-Scoring System shown in the standard is taken from MIL-STD-882D. It is identical to the Risk Assessment Matrix depicted in Table 7 in Chapter 8, "A Primer on Hazard Analysis and Risk Assessment," and shown here as Table 4.

CSA STANDARD Z1000-6

Earlier in this chapter, I referred to the CSA's Occupational Health and Safety Management Standard, Z1000-6, first issued in March 2006. The standard's requirements for 'hazard and risk identification and assessment' are briefly, but adequately, stated in Section 4.3.4. "The organization shall establish and maintain a process

TABLE 4 Risk Assessment Matrix

Occurrence Probability	Severity of Consequence			
	Catastrophic	Critical	Marginal	Negligible
Frequent	High	High	Serious	Medium
Probable	High	High	Serious	Medium
Occasional	High	Serious	Medium	Low
Remote	Serious	Medium	Medium	Low
Improbable	Medium	Medium	Medium	Low

to identify and assess hazards and risks on an ongoing basis. The results of this process shall be used to set objectives and targets to develop preventive and protective measures."

The excerpt above is all that is said in the standard about hazard analysis and risk assessment. The subject is addressed further in Annex A which is informative. However, the intent of the hazard analysis and risk assessment provision is amplified in the "shall" provision Contained in Section 4.4.7, "Management of Change":

> The organization shall establish and maintain procedures to identify, assess, and eliminate or control occupational health and safety hazards and risks associated with
>
> (a) new processes or operations at the design stage
> (b) significant changes to its work procedures, equipment, or organizational structure, etc.

THE EUROPEAN INFLUENCE ON SAFETY AND HEALTH STANDARDS

These highly significant statements appear in the Foreword for B155.1-2006. They are indicators of the globalization of safety standards:

> This version of the standard has been harmonized with international (ISO) and European (EN) standards by the introduction of hazard identification and risk assessment as the principal method for analyzing hazards to personnel and achieving a level of acceptable risk. This version of the standard is a major revision that integrates the requirements of ISO parts 1 and 2 and ISO 14121, as well as U.S. standards. Suppliers meeting the requirements of ANSI/PMMI B155.1:2006 may simultaneously meet the requirements of these three ISO standards.

"Harmonized with international (ISO) and European (EN) standards" is a key phrase in the foregoing. Mention was made previously of the international implications of the on-going discussions on a robotics standard, of the goal to have TR3 in harmony with European standards, and of global participation in developing the semiconductor industry guidelines. Some of the impetus to revise standards and guidelines in the United States to include provisions for hazard analysis and risk

assessment arises from the provisions in standards that originated in Europe and which have become international.

ISO 12100-1, Safety of Machinery—Basic Concepts, General Principles for Design, Part 1: Basic Terminology, Methodology, requires that risk assessments be made of machinery going into a workplace. ISO 12100-2, Safety of Machinery—Basic Concepts, General Principles for Design; Part 2: Technical Principles, and Specifications, gives extensive details on "safety of machinery" design specifications. ISO 14121, Safety of Machinery—Principles of Risk Assessment sets forth the risk assessment concepts to be applied.

American manufacturers who export their products to Europe are required to place a "CE" mark on them to indicate that all operable European Community directives have been met, among which are the three standards mentioned above. It is obvious that the European influence on U.S. safety standards has been felt and will continue.

A MAJOR CONCEPT CHANGE

The quotation from the foreword of B155.1 previously given also includes this wording: "The introduction of hazard identification and risk assessment as the principal method for analyzing hazards to personnel and achieving a level of acceptable risk." That language presents an interesting and significant concept.

If all safety professionals accept the premise that hazard identification and risk assessment are to be the first steps in preventing injuries to personnel, a major concept change in the practice of safety will have been achieved. Adopting that premise takes the focus away from what have been called the unsafe acts of workers and redirects it to work system causal factors. This represents sound thinking.

MIL-STD-882D-2000 AND MIL-STD-882E

The Department of Defense's Standard Practice for System Safety, MIL-STD-882, was originally issued in 1969. It was a seminal document at that time, and three revisions of it have been issued over the span of 31 years. This standard has had considerable influence on the development of risk assessment, risk elimination, and risk control concepts and methods. Much of the wording on risk assessments and hierarchies of control in safety standards and guidelines issued throughout the world is comparable to that in the various versions of MIL-STD-882.

The fourth edition, issued in February 2000, is designated MIL-STD-882D. It is available at http://www.dau.mil/educdept/mm_dept_resources/guidance/mil-std-882 d.doc and may be downloaded for free.

As of this writing-882D remains the applicable document. Nonetheless, work is in progress to produce a superior version. A December 1, 2005, draft, MIL-STD-882E, extends 882D considerably. For example, the 882D version, including an Appendix, is 26 pages long. The 882E draft, including two Appendices, appears on 113 pages.

Since the 882E draft contains noteworthy revisions on the "System safety mitigation order of precedence," provides extended data on risk assessment matrices, includes general design requirements, and introduces the concept of ALARP as the risk mitigation level to be attained, comments are made here on that version. Section 4, "General Requirements," in 882E "delineates the minimum requirements for an acceptable system safety program." Section 4.1 outlines the System safety program elements, which number five. Abbreviated descriptions appear below:

> 4.1.1 Element 1—program initiation. The program manager and developer shall document the approved system safety engineering approach.
>
> 4.1.2 Element 2—hazard identification and tracking. System safety includes a complete identification of the hazards associated with a system.
>
> 4.1.3 Element 3—risk assessment. For each identified hazard, the mishap severity and probability or frequency are established. A mishap risk assessment matrix is used to assess and display the risks.
>
> 4.1.4 Element 4—risk reduction.*
>
> 4.1.5 Element 5—risk acceptance. Risk acceptance decisions should consider the risk of the individual hazard in context with the total system risk.

In 882E, Appendix A provides "Guidance For Implementation Of A System Safety Effort," It runs 43 pages long. It is good reading. Item A.4.1.2.1.3 speaks of "Mishap risk assessment matrix and scaling" as follows:

> The method of risk assessment and representation used by the program should be selected and tailored to fit practical program needs. For some programs a quantitative risk assessment matrix may be appropriate while others may require a qualitative (subjective) matrix.

To emphasize: It is not necessary to adopt a complicated and costly risk assessment system when the situations at hand can be resolved with a qualitative (subjective) and simpler system. Item A.7 in Appendix A, "Example Mishap Risk Assessment Matrices," is truly educational. In several places in this book, readers are advised to develop risk assessment matrices suitable to the hazards and risks with which they deal and to keep them simple. That idea is supported in A.7, where it is said that:

> Mishap risk assessment matrices should be tailored to each system or class of systems based on the expected range of severity of potential mishaps and the range of probability or frequency of these mishaps.

Item A.7 contains seven interesting examples of risk assessment matrices. They range from the basic to the highly complex.

*This section gives the steps in the risk reduction order of precedence. It relates to the Hierarchy of Controls outlined in Z10 and is discussed here in Chapter 12, "Hierarchy of Controls: The Safety Decision Hierarchy."

THE CHEMICAL INDUSTRY AND OSHA REQUIREMENTS

OSHA Rule for Process Safety Management of Highly Hazardous Chemicals, CFR 1910.119, issued in 1992, applies to employers at approximately 50,000 locations, many of which are not considered chemical companies. With respect to the requirements for hazards analyses included in standards, this OSHA rule merits a review by safety practitioners. It requires that:

> The employer shall perform an initial hazard analysis (hazard evaluation) on processes covered by this standard. The process hazard analysis shall be appropriate to the complexity of the process and shall identify, evaluate, and control the hazards involved in the process. The employer shall use one or more of the following methodologies that are appropriate to determine and evaluate the hazards of the process being analyzed:
>
> - What-If;
> - Checklist;
> - What-If/Checklist;
> - Hazard and Operability Study (HAZOP);
> - Failure Modes and Effect Analysis (FMEA);
> - Fault Tree Analysis; or
> - An appropriate equivalent methodology.
>
> Also, the hazard analysis shall address:
>
> - The hazards of the process;
> - The identification of any previous incident which had a likely potential for catastrophic consequences in the workplace;
> - Engineering and administrative controls applicable to the hazards and their interrelationships;
> - Consequences of failure of engineering and administrative controls;
> - Facility citing;
> - Human factors; and
> - A qualitative evaluation of a range of the possible safety and health effects of failure of controls on employees in the workplace.

Under the requirements for *Prestartup safety review*, for new facilities and for significant modifications, the employer is required to provide a process hazard analysis—among other considerations. In no place in the OSHA rule is there mention of occurrence probability. This appears in the preamble:

> OSHA has modified the paragraph (editorial note—paragraph on consequence analysis) to indicate that it did not intend employers to conduct probabilistic risk assessments to satisfy the requirement to perform a consequence analysis.

However, all risks are not equal. And managements do consider incident probability in their decision making when determining the priority levels for individual projects when allocating resources.

THE CHEMICAL INDUSTRY AND EPA REQUIREMENTS

The Environmental Protection Agency (EPA) and OSHA have different legal authority with respect to accidental releases of harmful substances. The concerns at EPA center on offsite consequences: that is, harm to the public and the environment. At OSHA, the legal authority pertains to on-site consequences.

On August 19, 1996, EPA issued *Risk Management Programs for Chemical Accidental Release Prevention*, 40 CFR, Part 68. The rule required risk management plans of location managements by June 21, 1999. Although the provisions of the rule are extensive, only the specifications for hazards analyses will be addressed here.

Processes subject to this rule are divided into three groups, labeled by EPA at Programs 1, 2, and 3. Program levels relate to the quantities and extent of exposure to toxic and flammable chemicals.

For locations qualifying for program levels 1 and 2, those with lesser exposure, EPA will accept hazard reviews done by qualified personnel using suitable checklists. Hazard reviews must be documented and show that problems have been addressed. In its literature, EPA comments on the desirability of using the "What-If" hazard identification and analysis process. EPA also proposes the use of more involved analytical techniques if findings suggest that may be desirable.

Hazard review requirement for Program level 3 locations are more specific and extensive. However, those locations that are compliant with the *OSHA Rule for Process Safety Management of Highly Hazardous Chemicals* will need to do little new, although they must extend their hazards analyses to consider the probability of harm to the public or to the environment. As with OSHA, a team must complete the process hazards analyses required by EPA. One member of the team, at least, should have experience with the process.

As might be expected at locations with more significant exposures, the process hazard analysis requirements are more extensive. They must be documented and include:

- Hazards of the process
- Identification of previous, potentially catastrophic incidents
- Engineering and administrative controls applicable to the hazards
- Siting
- Human factors
- Qualitative evaluation of health and safety impacts of control failure

For U.S. industries, EPA has obviously extended knowledge and skill requirements regarding hazard analysis techniques.

THE CHEMICAL INDUSTRY AND THE EXTENSIVE BODY OF INFORMATION

Completing hazards analyses was a common practice in the chemical industry many years before OSHA and EPA established requirements for them. Although

that practice is not of recent origin, it is mentioned here because of its extensive knowledge requirements. The body of information on hazard analysis available within the chemical industry is extensive. Here, we will refer to only one publication because of its particular significance.

The Center for Chemical Process Safety is a part of the American Institute of Chemical Engineers. One of its several publications is *Guidelines For Hazard Evaluation Procedures, Second Edition With Worked Examples*. The fact that this text was published by a chemically oriented group should not dissuade those who seek an education in the following evaluation techniques. Their descriptions are generic.

- Safety Review
- Checklist Analysis
- Relative Ranking
- Preliminary Hazard Analysis
- What-If analysis
- What-If Checklist Analysis
- Hazard and Operability Analysis
- Fault Tree Analysis
- Event Tree Analysis
- Cause-Consequence Analysis
- Human Reliability Analysis

These techniques are addressed broadly in the Guidelines within the chapters titled "Overview of Hazard Evaluation Techniques" and "Using Hazard Evaluation Techniques." Brief descriptions of some of those techniques are given in Chapter 8, "A Primer on Hazard analyses and Risk assessment."

CONCLUSION

The message is clear. The inclusion of provisions requiring hazards analyses and risk assessments in safety standards and guidelines is becoming ordinary. It is logical to assume that this trend will continue and that safety and health professionals will be expected to have the knowledge and skills necessary to give counsel on applying those provisions.

REFERENCES

ANSI/ASSE Z241.1-2003. Control of Hazardous Energy—Lockout/Tagout and Alternative Methods Standard. Des Plaines, IL: American Society of Safety Engineers, 2003.

ANSI/AIHA Z10-2005. Occupational Health and Safety Management Systems Standard. Fairfax, VA: American Industrial Hygiene Association, 2005.

ANSI/PMMI B155.1-2006. Safety Requirements for Packaging Machinery and Packaging-Related Converting Machinery Standard. Arlington, VA: Packaging Machinery Manufacturers Institute, 2006.

ANSI/RIA R15.06-1999. American National Standard for Industrial Robots and Robot Systems—Safety Requirements. Ann Arbor, MI: Robotics Industries Association, 1999.

ASTM. *Standard Guide for Developing a Cost-Effective Risk Mitigation Plan*. Working number WK7175. http://www.astm.org/cgi-bin/SoftCart.exe/index.shtml?E+mystore.

Aviation Ground Operation Safety Handbook, 5th ed. Itasca, IL: National Safety Council, 2000.

B11.TR3. *Risk Assessment and Reduction—A Guideline to Estimate, Evaluate and Reduce Risks Associated with Machine Tools*. McLean, VA: The Association for Manufacturing Technology, 2000.

Bowers, Charles N. The Risk Is in the Management. *Maintenance Technology*, June 2006.

CSA Standard Z1000-06. Occupational Health and Safety Management Standard. Mississauga, Ontario, Canada: Canadian Standards Association, 2006.

Guidance Document for Incorporating Risk Concepts into NFPA Codes and Standards. Quincy, MA: National Fire Protection Association, March 2007.

Guidelines for Hazard Evaluation Procedures, Second Edition with Worked Examples. New York: Center for Chemical Process Safety of the American Institute of Chemical Engineers, 1992.

ISO 10218:1992. Manipulating Industrial Robots—Safety Standard. Geneva, Switzerland: International Organization for Standardization, 1992. Also available at, http://www.iso.ch/iso/en/aboutiso/introduction/index.html.

ISO 12100-1. Safety of Machinery—Basic Concepts, General Principles for Design; Part 1: Basic Terminology, Methodology. Geneva, Switzerland: International Organization for Standardization, 2003.

ISO 12100-2. Safety of Machinery—Basic Concepts, General Principles for Design; Part 2: Technical Principles and Specifications. Geneva, Switzerland: International Organization for Standardization, 2003.

ISO 14121. Safety of Machinery—Principles for Risk Assessment Standard. Geneva, Switzerland: International Organization for Standardization, 1999.

MIL-STD-882D and MIL-STD-882E. Standard Practice for System Safety. Washington, DC: Department of Defense, 2000 and 2006.

OSHA Rule for Process Safety Management of Highly Hazardous Chemicals, CFR 1910.119. Washington, DC: Department of Labor, Occupational Safety and Health Administration, 1992.

Risk Management Programs for Chemical Accidental Release Prevention, 40 CFR, Part 68. Washington, DC: Environmental Protection Agency, 1996.

SEMI S2-0706. Environmental, Health, and Safety Guideline for Semiconductor Manufacturing Equipment. San Jose, CA: Semiconductor Equipment and Materials International, 2006. (*Related Information 1—Equipment/Product Safety Program* is an adjunct to these guidelines.)

SEMI S10-1103. Safety Guideline for Risk Assessment and Risk Evaluation Process. San Jose, CA: Semiconductor Equipment and Materials International, 2003.

CHAPTER 10

THREE AND FOUR DIMENSIONAL NUMERICAL RISK SCORING SYSTEMS

INTRODUCTION

In all the risk assessment matrices discussed in Chapter 8, "A Primer on Hazard Analysis and Risk Assessment," risk levels are based only on determinations of the *probability* of event occurrence and the *severity* of harm or damage that could result. Therefore, they are two-dimensional.

However, the world of risk assessment is in transition. Some systems now in use are three- or four-dimensional, and they require numerical risk scorings. Safety professionals can expect that variations of numerical risk scoring systems will proliferate. Nevertheless, it needs to be said that two-dimensional, qualitative risk assessment systems are not obsolete. Often, a two-dimensional system will be selected because it is sufficient for the hazards and risks encountered and it works well within an organization. This chapter will inform safety professionals on:

- Transitions in numerical risk assessment methods
- Cautions to be considered in using three- and four-dimensional systems
- Three-dimensional numerical risk scoring systems
- An extended three-dimensional numerical risk scoring system that includes a method to justify the risk amelioration costs in relation to the amount of risk reduction to be attained

Advanced Safety Management Focusing on Z10 and Serious Injury Prevention, by Fred A. Manuele

- A four-dimensional numerical risk scoring system
- A numerical risk-scoring system that this author developed

TRANSITIONS IN RISK ASSESSMENT

In the education of engineers, a passion for quantification and the application of numbers evolves. Engineers become comfortable with statistical measurements and expect things to be measured. Engineering texts still quote Lord Kelvin who wrote the following over 100 years ago:

> When you can measure what you are speaking about, and express it in numbers, you know something about it: but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meager and unsatisfactory kind.

Some practitioners in risk assessment disagree with Lord Kelvin's absolutist statement, such as Vernon L. Grose. In his *Managing Risk: Systematic Loss Prevention for Executives*, in which the above quote from Lord Kelvin may be found, Grose expressed concern over the use of "numerology" in making risk assessments, and cautions about the:

> . . . increasingly common abuse of mathematical statistics by "numericalizing without data" to obtain risk probabilities, and the deception-by-numbers that lulls executives into a false sense of security.

Nevertheless, the influence that engineers have had in developing risk assessment methods is obvious. Their passion for numerical precision encourages the use of quantitative methods. As an example, in at least two industries quantitative Failure Modes and Effects Analyses (FMEAs), rather than qualitative FMEAs, are now required to meet quality assurance requirements. Mostly, engineers make those FMEAs.

Similarly, some engineers are using numerical risk scoring systems to meet the risk assessment requirements placed on manufacturers who sell machinery to countries in the European Community. One such system in use for that purpose is four-dimensional. Also, a three-dimensional numerical risk-scoring system is in use in a segment of the heavy machinery manufacturing industry. It was introduced by engineering personnel to meet the demands for product safety.

A NEED FOR CAUTION AND PERCEPTIVE EVALUATION

Although three- and four-dimensional risk scoring systems are now more commonly used, there are several reasons to be inquisitive and cautious concerning their content, the meanings of the terms used in them, the numerical values applied to the gradations within elements to be scored, and how they are applied in determining risk levels.

- Creating numerical risk scorings begins with subjective judgments on the values to be given to the elements in the system, and those judgments are then translated into numbers. Thus, what starts out as judgmental observations become finite numbers, which then leads to an image of preciseness. Furthermore, those numbers are multiplied or totaled to produce a risk score, giving the risk assessment process a scientific appearance. The fact is that the risk assessment process is as much art as science.
- There are no universally applied rules to assign value numbers to elements to be scored. All values in all numerical risk scoring systems reflect the experience and views of those who create the systems.
- Frequency of exposure has, historically, been one of the elements considered in determining event probability. However, giving frequency of exposure its own multiplier, separate from and in addition to a probability multiplier, diminishes the needed emphasis on the severity of harm or damage that could result from an event.
- Meanings of the terms probability, likelihood, frequency of exposure or endangerment, and severity used in risk scoring systems are not consistent. Also, it may be that within a system, a term may appear more than once and have different usages, and consistency in the meanings of the terms used initially in the system may not be maintained.
- If risk scoring systems are applied rigidly whereby a higher score indicates a greater risk than a lower score, and the scores are not considered in light of the employee, community, social, and financial concerns, the best interests of the organization may not be well served. This applies especially to low probability events that may have severe consequences, for which risk scores may be low.

THREE-DIMENSIONAL NUMERICAL RISK-SCORING SYSTEMS

Substantial variations exist in the elements to be scored in the three-dimensional and the single four-dimensional numerical risk scoring systems to be reviewed here. To begin the discussion, excerpts are taken from the National Safety Council's (NSC's) *Accident Prevention Manual: Administration & Programs*, Twelfth Edition, and appear here with permission.

National Safety Council

The Council outlines a system for "Ranking Hazards by Risk (Severity, Probability, and Exposure)". The manual states that "Ranking provides a consistent guide for corrective action, specifying which hazards warrant immediate action, which have secondary priority, and which can be addressed in the future."

In the process, for each identified hazard, numerical scorings as follows are given to Severity, Exposure, and Probability. It is significant that they are totaled to arrive at a final rating, not multiplied in sequence as is the case in other three- and four-dimensional risk-scoring systems. Thus, the status of the severity

rating is not diminished as significantly. The following definitions, instructions, and Tables 1 through 3 are taken verbatim from the Council's Manual.

Severity Consider the potential losses or destructive and disruptive consequences that are most likely to occur if the job/task is performed improperly. Assumptions would be made as to the worst credible outcome of an incident in selecting a numerical rating for severity. Use the following point values.

TABLE 1 NSC Severity Descriptions and Point Values

1. Negligible	Probably no injury or illness; no production loss; no lost work days
2. Marginal	Minor injury or illness; minor property damage
3. Critical	Severe injury or occupational illness with lost time; major property damage; no permanent disability or fatality
4. Catastrophic	Permanent disability; loss of life; loss of facility or major process

Probability Consider the probability of loss that occurs each time the job is performed. The key question is, How likely is it that things will go wrong when this job is performed? The probability is influenced by a number of factors, such as the hazards associated with the task, difficulty in performing the job, the complexity of the job, and whether the work methods are error-provocative. Use the following point values.

TABLE 2 NSC Probability Descriptions and Point Values

1. Low probability of loss occurrence
2. Moderate probability of loss occurrence
3. High probability of loss occurrence

Exposure Consider the number of employees that perform the job, and how often. Use the following point values.

TABLE 3 NSC Exposure Descriptions and Point Values

1. One or a few employees perform the task up to a few times a day
2. One or a few employees perform the task frequently
3. Many employees perform the task frequently

After numerical point values are given to each job/task for severity, probability, and exposure, the point values are added to produce a total risk assessment code (RAC). A total score can be as low as 3 or as high as 10. Thus, each task is given

a risk ranking from which judgments can be made in setting priorities. Management can use these values to select particular jobs for analysis. The NSC's text clearly states that "The RAC rating scale is not intended to be used as an absolute measurement system."

In the NSC's system, there are four severity ratings, whereas probability and exposure each have three. Choosing to set up a system in this way and deciding on the numerical values to be assigned is entirely at the discretion of the system's creator. Other choices, reflecting an individual's experience, are equally valid. However, a variation of this system, or any other system, should keep severity, frequency of exposure, and probability considerations in balance so that disproportionate weightings are not given to any one of the categories.

Failure Mode and Effects Analysis (FMEA)

In at least two industries, extensions have been made to the basic qualitative FMEA method to make it a three-dimensional numerical process. Publications on FMEA by a consortium of automobile manufacturers and by a group of semiconductor equipment manufacturing companies add a detection criterion to the FMEA process. A discussion of their publications follows.

Automobile Industry FMEAs DaimlerChrysler, Ford, and General Motors are represented in the Automotive Industry Action Group (AIAG). FMEA teams in those companies, working under the auspices of the Automotive Division of the American Society for Quality (ASQC) and AIAG, developed a reference manual titled *Potential Failure Mode and Effects Analysis: FMEA*, currently in its third edition. Excerpts from the manual are reprinted here with permission from the *FMEA Manual (DaimlerChrysler, Ford, General Motors Supplier Quality Requirements Task Force)*.

Suppliers of parts and components that go into automobiles made by these three companies are required to apply the FMEA technique outlined in the reference manual. Thus, the impact of the auto industry requirement and the reference manual itself is immense. Throughout the manual, a prominent theme is that FMEAs are to be conducted by teams. Other than for very simple situations, that should be the standard practice. The criteria to be rated are Severity, Occurrence (probability), and Detection. This is how the criteria are defined:

- Severity is the rank associated with the most serious effect for a given failure mode.
- Occurrence is the likelihood that a specific cause/mechanism will occur during the design life.
- Detection is the rank associated with the best detection control listed in the design control.

Some professionals in risk assessment caution against having a large number of gradations within a system because of the inability of appliers of the system to differentiate between the gradations when making the judgments required. A list of the gradations appears in Tables 4–6.

TABLE 4 Suggested Design FMEA Severity Evaluation Criteria

Effect	Ranking
Hazardous: without warning	10
Hazardous: with warning	9
Very high	8
High	7
Moderate	6
Low	5
Very low	4
Minor	3
Very minor	2
None	1

TABLE 5 Suggested Design FMEA Detection Evaluation Criteria

Detection	Ranking
Absolute uncertainty	10
Very remote	9
Remote	8
Very low	7
Low	6
Moderate	5
Moderately high	4
High	3
Very high	2
Almost certain	1

TABLE 6 Suggested Design FMEA Occurrence Evaluation Criteria

Probability of Failure	Possible Failure Rates per Thousand Vehicles/Items	Ranking
Very high: persistent failure	$\geq$100	10
	50	9
High: frequent failures	20	8
	10	7
Moderate: occasional failures	5	6
	2	5
	1	4
Low: relatively few failures	0.5	3
	0.1	2
Remote: failure is unlikely	$\leq$0.010	1

In the AIAG reference manual, descriptions are given for each gradation to assist the raters as they draw conclusions. Nevertheless, in the foregoing, it is difficult to establish substantial distinctions between one gradation and a higher or lower gradation. After rankings are assigned to each of the criteria, a Risk Priority Number (RPN) is computed. It is the product of the Severity (S), Occurrence (O), and Detection (D) rankings.

$$\text{RPN} = (\text{S}) \times (\text{O}) \times (\text{D})$$

The following extract from the AIAG text is particularly significant because of its instruction for high-priority consideration when the Severity rating is high:

> Within the scope of the individual FMEA, this value (RPN) between 1 and 1000 can be used to rank order the concerns in the design. Engineering assessment for preventive/corrective action should be first directed to high severity, high RPN and other items designated by the team. The intent of any recommended action is to reduce ranking in the following order: severity, occurrence, and detection.
>
> In general practice, when the severity is 9 or 10, special attention must be given to ensure that the risk is addressed through existing design controls or preventive/corrective action(s), regardless of the RPN.

When one considers the current high cost of publications, the auto industry's FMEA manual is a real buy. It costs $36, plus shipping.

Semiconductor Manufacturing Companies FMEAs International SEMATECH is a consortium of semiconductor equipment manufacturing companies from seven countries. Its *Failure Mode and Effects Analysis (FMEA): A Guide for Continuous Improvement for the Semiconductor Equipment Industry* recommends another FMEA technique. This guidance is given in the Guide:

> In today's competitive world market, users of semiconductor equipment should require from their suppliers that FMEAs be initiated, to a minimum, at the functional level of new equipment design. This should allow for closer, long lasting user/supplier relationship.

Condensed adaptations of material from that publication appear here, with the permission of SEMATECH. There are similarities between this system and the one issued by the automobile manufacturing industry. However, the scope of the severity criteria encompasses all forms of harm, damage, or loss. Also, the value of counsel available from safety engineering personnel is recognized by including that designation—safety engineering—in the job titles of personnel who would form a team to conduct FMEAs.

In SEMATECH's FMEA, three criteria must be numerically ranked: Severity, Occurrence, and Detection. This is how they are defined in the Guide. As was stated earlier in this chapter, definitions of the terms used in risk-scoring systems vary, and the definitions in this system have their own unique characteristics.

- *Severity ranking criteria*—Customer satisfaction is key in determining the effect of a failure mode. Safety criticality is also determined at this time based on Environmental, Safety and Health (ES&H) levels. Based on this information, a severity ranking is used to determine criticality of the failure mode on the subassembly to the end effect. The end (global) effect of the failure mode is the one to be used for determining the severity ranking. Calculating the severity levels provides for a classification ranking that encompasses safety, production continuity, scrap loss, etc.
- *Occurrence ranking criteria*—The probability that a failure will occur during the expected life of the system can be described in potential occurrences per unit of time.
- *Detection ranking criteria*—This section provides a ranking based on an assessment of the probability that the failure mode will be detected given the controls that are in place.

Two scoring tables are given here for severity ranking: Table 7 lists five possible scoring levels and relates to the effect a failure may have on customer relations; Table 8 pertains to environmental, safety, and health levels and contains four possible scoring levels. Note that these tables enumerate abbreviated versions of the severity criteria, and that *for most of the scoring levels for the Severity, Occurrence and Detection criteria, two scoring possibilities are available for each narrative description*.

The following statement appears below the ES&H severity level definitions in the SEMATECH manual:

> ES&H severity levels are patterned after the industry standard, *SEMI S2-91-Product Safety Guidelines*. All equipment should be designed to level IV severity. Types I, II, III are considered unacceptable risks.

Thus, Type IV severity defines the acceptable risk level. It is well known that this industry has established high environmental, safety, and health standards for itself.

TABLE 7 SEMATACH Scoring Table for Severity Ranking: Customer-Related

Rank	Description
1–2	Failure is of such a minor nature that the customer (internal or external) will probably not detect the failure.
3–5	Failure will result in slight customer annoyance and/or slight deterioration of part or system performance.
6–7	Failure will result in customer dissatisfaction and annoyance and/or slight deterioration of part or system performance.
8–9	Failure will result in high degree of customer dissatisfaction and cause nonfunctionality of the system.
10	Failure will result in major customer dissatisfaction and cause non-system operation or non-compliance with government regulations.

TABLE 8 SEMATECH Scoring Table for Severity Ranking: ES&H Definitions

Rank	Severity Level	Description
10	Catastrophic I	A failure results in major injury or death of personnel.
7–9	Critical II	A failure results in minor injury to personnel, personnel exposure to harmful chemicals or radiation, a fire or a release of chemicals to the environment.
4–6	Major III	A failure results in a low level exposure to personnel, or activates facility alarm system.
1–3	Minor IV	A failure results in minor system damage but does not cause injury to personnel, allow any kind of exposure to operational or service personnel, or allow any release of chemicals into environment.

A slightly reduced listing of the Occurrence Ranking Criteria appears in Table 9. It interestingly relates probability to a time operating interval and expresses probability as a failure rate.

TABLE 9 SEMATECT Scoring Table for Occurrence Ranking Criteria

Rank	Description
1	An unlikely probability of occurrence during the item operating time interval. Unlikely is defined as a single failure mode (FM) probability < 0.001 of the overall probability of failure during the time operating interval.
2–3	A remote probability of occurrence during the item operating time interval (i.e. once every two months), defined as a single FM probability > 0.001 but < 0.01.
4–6	An occasional probability of occurrence during the item operating time interval (i.e. once a month), defined as a single FM probability > 0.01 but < 0.10.
7–9	A moderate probability of occurrence during the item time operating interval (i.e. once every two weeks), defined as a single FM probability > 0.10 but < 0.20.
10	A high probability of occurrence during the item time operating interval (i.e. once a week), defined as a single FM probability > 0.20.

Table 10 is a condensed version of the Detection ranking scale. It pertains to what the verification system and/or controls in place are expected to accomplish.

A Risk Priority Number (RPN) is calculated. RPN = Severity × Occurrence × Detection

$$\text{RPN} = \text{S} \times \text{O} \times \text{D}$$

In the decision-making process, however, a major difference exists in this system that is of particular interest to safety professionals. In the semiconductor industry's FMEA form, "Cr" appears at the top of a column. This is a Critical Failure Symbol. A "Y" is to be entered for "yes" if the failure potential is considered safety-critical.

TABLE 10 SEMATECH Scoring Table for Detection Ranking Criteria

Rank	Probability That the Defect Will Be Detected
1–2	Very high: almost certain
3–4	High: good chance
5–7	Moderate: likely
8–9	Low: not likely
10	Very low (or zero)

That gives importance to the Environmental, Safety and Health Severity Level Definitions previously shown. On the form, the instruction is that Critical Failures must be addressed when safety is an issue.

Although the SEMATECH FMEA manual was written for the semiconductor equipment industry, it is nevertheless recommended as a general reference. It is downloadable, for free, at http://www.sematech.org.

System Used by Some Heavy Equipment Manufacturers

Hazard analysis and risk assessment systems have been used for many years by certain heavy equipment manufacturers (HEM) in their design processes to achieve inherently safer products. Keep in mind that their principle concern in using the risk assessment method described here is product safety and the avoidance of injury to users of their equipment, or to bystanders. There are variations in the terms used in the several versions of this industry's Hazard Analysis System. In one version, these are the Risk Assessment Variables:

- Severity of the injury
- Frequency of exposure
- Probability that event results in injury and injury is not avoided

In another version, the parameters to be scored are severity, frequency, and vulnerability. This latter version and its definitions will be discussed here.

- *Severity* The most probable injury that would be expected from an accident.
- *Frequency* An estimate of how often a product user or bystander may be exposed to a hazard. The hazard may result from a machine part or system failure or from a man–machine interface failure.
- *Vulnerability* The degree of user or bystander susceptibility to injury when exposed to a hazard. The likelihood that personal injury will occur once exposure to a hazard has occurred, taking into consideration the detectability of

a hazard, risk assumptions, presence of environmental or stress conditions, skills, and attitudes, etc.

For each of these three variables, there are five possible ratings, all using identical numerics: 1, 3, 5, 7, and 9. Other selections are equally valid as long as they are proportional and do not give excessive consideration to one of the factors to be scored. The ratings follow in Tables 11–13.

TABLE 11 HEM Severity Scale, S

1. Minor first aid. Immediate return to work/activity.
3. Doctor's office or emergency room treatment. Up to 1 week lost time.
5. Hospitalization. Up to 1 month lost time. No loss in work capacity.
7. Permanent partial loss in work capacity. Increased work difficulty.
9. Death or complete disability.

TABLE 12 HEM Frequency Scale, F

1. Theoretically can occur, but highly unlikely during the life of the machine population.
3. Only once in the life of a small percentage (10%) of the product.
5. Once per use season or once annually.
7. Once daily.
9. Continuous exposure.

TABLE 13 HEM Vulnerability Scale, V

1. Practically impossible to complete injury sequence.
3. Remotely possible, but unlikely.
5. Some conditions favorable to completing the injury sequence.
7. Very possible, but not assured.
9. Almost certain to complete injury sequence.

The literature on the HEM system indicates the following:

- Hazards analyses and risk assessments are done by a team.
- Consensus is to be reached on risk scores.
- Risk scores are listed and ranked.
- High and low values would be examined, and actions for improvement developed when required.

This is the risk scoring system: Risk Score = Severity × Frequency × Vulnerability
Risk Score = S × F × V

This risk-scoring system gives equal weight to all variables. Thus, the needed emphasis on severity of injury is diminished when the risk score is produced. In a discussion with a user of this system, it was acknowledged that, with all variables being given equal weight, the significance of severity was subordinated. However, it was also stated that, in practice, the team gives the potential for severe injury due consideration when deciding on product improvement recommendations.

The William T. Fine System: A Three Dimension Numerical Risk Scoring Model

While at the Naval Ordinance Laboratory in White Oak, Maryland, William T. Fine submitted a 1971 report titled "Mathematical Evaluations for Controlling Hazards." Fine was an early proponent of determining whether the expenditure needed to substantially reduce risk could be justified after considering the amount of reduction to be attained.

In a sense, Fine's work was a precursor of the concept on which ALARP is based. ALARP is defined as that level of risk which can be further lowered by an increment in resource expenditure that cannot be justified by the resulting decrement in risk. Fine made this comment in his paper's Abstract:

> A formula has been devised which weighs the controlling factors and "calculates the risk" of a hazardous situation, giving a numerical evaluation to the urgency for remedial attention to the hazard. Calculated Risk Scores are then used to establish priorities for corrective action.
>
> An additional formula weighs the estimated cost and effectiveness of any contemplated corrective action against the Risk Score and gives a determination as to whether the cost is justified.

Fine's paper is thought-provoking, a valuable resource, and somewhat hard to find. For those who would like to explore a three-dimensional risk-scoring system to which an additional formula is applied to determine whether the risk reduction cost can be justified, an abbreviated version of Fine's paper may be found in the Addendum at the end of this chapter. The substance of the paper remains intact.

A FOUR-DIMENSIONAL NUMERICAL RISK-SCORING SYSTEM

Although reference will be made here to the four-dimensional risk-scoring system as it appears in Pilz's *Guide to Machinery Safety*, Sixth Edition, it should be understood that this system has appeared elsewhere and is in the public domain.

For example, it has been used with minor modification by at least one U.S. company to meet the European Community risk assessment requirements as set forth in ISO 14121, the Safety of Machinery—Principles for Risk Assessment Standard. As will be illustrated later, this risk-scoring system has major shortcomings.

In the Pilz text, early in Chapter 4.0 titled "Background to Risk Assessment," the following statement is made:

> In simple terms, there are only 2 real factors to consider:
>
> - The severity of foreseeable injuries (ranging from a bruise to a fatality)
> - The probability of their occurrence

As the Pilz text proceeds, however, the system becomes more complex. There are four elements to be scored:

- Likelihood of occurrence/contact with hazard (LO)
- Frequency of exposure to the hazard (FE)
- Degree of possible harm (DPH), taking into account the worst possible case
- Number of persons exposed to the hazard (NP)

This system has a particular focus. It applies only to personal injury, principally to employees, that could derive from machinery operation. As will be seen, all of the listings for "Degree of possible harm" involve personal injuries. There are no entries for possible damage to property or the environment. The terms used to establish gradations and scores in the Likelihood of occurrence and Frequency of exposure categories are comparable to those in previously cited risk assessment systems. They follow in Tables 14–16.

Note the position within the listings of "Even chance: could happen" in the Likelihood category and "Annually" in the Frequency of exposure category. A computation appears later in which these same ratings are used.

The fourth dimension in this system is Number of persons exposed to the hazard, as illustrated in Table 17.

TABLE 14 Likelihood of Occurrence (LO) and the Scores

Almost impossible: possible only under extreme circumstances	0.033
Highly unlikely: although conceivable	1
Unlikely: but could occur	1.5
Possible: but unusual	2
Even chance: could happen	5
Probable: not surprising	8
Likely: only to be expected	10
Certain: no doubt	15

TABLE 15 Frequency of Exposures to the Hazards (FE) and the Scores

Annually	0.5
Monthly	1
Weekly	1.5
Daily	2.5
Hourly	4
Constantly	5

TABLE 16 Degree of Possible Harm and the Scores

Scratch/bruise	0.1
Laceration/mild ill-effect	0.5
Break minor bone or minor illness (temporary)	2.0
Break major bone or major illness (temporary)	4.0
Loss of one limb, eye, hearing loss (permanent)	6.0
Loss of two limbs, eyes (permanent)	10.0
Fatality	15.0

TABLE 17 Number of Persons Exposed and the Scores

1–2 persons	1
3–7 persons	2
8–15 persons	4
16–50 persons	8
50+persons	12

Using the numerical ratings given to each element, the formula produces a Risk level by simple multiplication. The formula and the Risk levels follow, as in Table 18.

$$\text{LO} \times \text{FE} \times \text{DPH} \times \text{NP} = \text{Risk level}$$

TABLE 18 Risk Level

	Scoring Range
Negligible: presenting very little risk to health and safety	0–5
Low but significant: containing hazards that require controls	5–50
High: having potentially dangerous hazards, which require control measures to be implemented urgently	50–500
Unacceptable: continued operation in this state is unacceptable	500+

Assume that in a company's annual shutdown for retooling and maintenance, a task is to be performed for which the likelihood of occurrence of a hazardous event was rated as "Even chance: could happen" and the outcome would be Fatalities. In the illustration in Table 19, the ratings are purposely kept the same for likelihood of occurrence, frequency of exposure, and degree of possible harm. Ratings vary only for the number of people exposed.

TABLE 19 Usage of a Four-Dimensional Risk-Scoring System

	Number of Persons Exposed				
Ratings	2	7	15	50	51
Likelihood: even chance	5	5	5	5	5
Frequency of exposure: annual	0.5	0.5	0.5	0.5	0.5
Degree of possible harm: fatality	15	15	15	15	15
For: number of persons exposed	1	2	4	8	12
Risk levels	37.5 Low But Significant	75 High	150 High	300 High	450 High

For such a hazard scenario, the computations never fall within the Unacceptable risk level (500+), even when there is an even chance that 51 people will be killed. Score levels in this system are ill conceived. They greatly diminish the value of life. Nevertheless, the promotion of this risk-scoring system continues.

Using the number of persons exposed as a category in risk assessment requires careful consideration. In the Risk Assessment Matrix shown in Z10, and in other matrices shown in Chapter 8 here, a death or permanent total disability falls in the catastrophic category. In the FMEA system published by SEMATECH, a single fatality receives a Catastrophe rating. In the Fine system, a fatality that has an even chance of occurring and annual exposure falls in the unacceptable risk category. In the scenario previously described, 51 fatalities do not achieve the severity grading they deserve. Such a risk-scoring system is unacceptable.

A MODEL THREE-DIMENSIONAL NUMERICAL RISK-SCORING SYSTEM

One of the aims in this author's study of multidimensional numerical risk-scoring systems was to determine whether a model could be proposed that:

- Serves the needs of those who are more comfortable with statistics.
- Addresses the strong beliefs of those who want frequency of exposure given separate consideration in the risk assessment process, as is the case in Z10.
- Maintains credibility and efficacy.

As the work proceeded in crafting the numerical risk-scoring model presented here, the following guidelines emerged:

1. In a statistical risk-scoring system, all scores must meet a plausibility test. High risk scores must be produced for high risks; a lower-level risk should not fall in a high-risk category.
2. To create a focal point for the relative placement of other risk scores, it was assumed that for an incident having a severity outcome of one or more fatalities, with an even chance of occurring (50/50), and an annual frequency of exposure, the risk score must be High.
3. Frequency of exposure can be separately evaluated without negatively affecting the validity of risk determinations, provided that adequate weighting is given to severity of outcome in the scoring system.
4. Adaptations can be made of the risk assessment matrices shown in Chapter 8, "A Primer on Hazard Analysis and Risk Assessment," to develop a single risk-scoring model that addresses injury to people (employees and the public); facilities, product, or equipment loss; operations downtime; and chemical releases and environmental damage.
5. If the number of gradations for probability, frequency of exposure, or severity is excessive, distinctions between them are difficult to make. Five gradations were chosen for probability and frequency of exposure; for severity, there are four.
6. Although an attempt was made to not use a descriptive word more than once in the elements to be scored, it was not successful.

Definitions follow of the terms relevant to the numerical risk-scoring system presented here:

- *Hazard* The potential for harm to people, property, and the environment. The dual nature of hazards must be understood. Hazards encompass all aspects of technology or activity that produce risk. Hazards include the characteristics of things (equipment, dusts, etc.) and the actions or inactions of people.
- *Risk* An estimate of the probability of a hazards-related incident or exposure occurring and the severity of harm or damage that could result.
- *Probability* The likelihood of a hazard being realized and initiating an incident or exposure that could result in harm or damage—for the selected unit of time, events, population, items, or activity being considered.
- *Frequency of Exposure* The frequency and duration of exposure to the hazard, over time.
- *Severity* The extent of harm or damage that could result from a hazards-related incident or exposure.

The Risk Score Formula

Having decided to include frequency of exposure as a separate element to be scored, the question became how to assure that scoring computations, particularly for severity, are not adversely skewed. Thus, for this Risk Score Formula, the rating for frequency of exposure is not an equal multiplier. Rather, it is added to the rating for occurrence probability to produce a mid-level score that is then multiplied by the severity rating:

$$\text{Risk score} = (\text{Probability Rating} + \text{Frequency of Exposure Rating}) \times \text{Severity Rating}$$

$$\text{RS} = (\text{PR} + \text{FER}) \times \text{SR}$$

Gradation and Scoring Development

To achieve plausibility, a variety of scorings were tested until credible results were obtained. The gradations and ratings selected are shown in Table 20.

TABLE 20 Descriptive Words and Ratings

Probability		Frequency of Exposure		Severity	
Frequent (Fre)	15	Often (Of)	13	Catastrophic (Cat)	50
Likely (Lik)	9	Occasional (Oc)	10	Critical (Cri)	40
Occasional (Occ)	4	Infrequent (In)	7	Medium (Med)	25
Remote (Rem)	1	Seldom (Se)	4	Minimal (Min)	10
Improbable (Imp)	0.5				

What the Descriptive Words Mean

To give substance to the words used to establish gradations within the Probability, Severity, and Frequency of Exposure categories, their meanings as they are used in this risk-scoring system are presented in Tables 21–23.

TABLE 21 Incident Probability

Category: Descriptive Word	Definition: Applies for the Selected Unit of Time Events, Population, Items, Unit of Time, or Activity
Frequent	Likely to occur repeatedly, to even chance
Likely	Likely to occur several times
Occasional	Occurs sporadically, likely to occur sometimes
Remote	Not likely to occur, but could possibly occur
Improbable	So unlikely can assume occurrence will not be experienced

TABLE 22 Severity of Consequences

Category: Descriptive Word	People: Employees, Public	Facilities, Product, Equipment or Loss	Operations Downtime	Environmental Damage
Catastrophic	Fatality	Exceeds $2 M	Exceeds 6 months	Major event, requiring several years for recovery
Critical	Disabling injury or illness	$500K to $2 M	4 weeks to 6 months	Event requires 1–2 years for recovery
Marginal	Minor injury or illness	$50K to 500K	2 days to 4 weeks	Recovery time is less than 1 year
Negligible	No injury or illness	Less than $50K	Less than 2 days	Minor damage, easily repaired

TABLE 23 Frequency of Exposure

Category: Descriptive Word	Definition
Often	Continues to occur daily
Occasional	Daily to monthly
Infrequent	Monthly to yearly
Seldom	Less than yearly

Four risk categories were considered adequate: High, Serious, Moderate and Low. Risk scores for each category were assigned, as well as management decision indicators with respect to risk reduction actions to be taken or for risk acceptance. They are shown in Table 24.

TABLE 24 Risk Categories, Score Levels, and Action or Risk Acceptance Levels

Risk Category	Score Levels	Remedial Action or Acceptance
High	800 and above	Operation not permissible
Serious	500–799	Remedial actions to have high priority
Moderate	200–499	Remedial actions to be taken in appropriate time
Low	199 and below	Risk is acceptable, remedial action discretionary

It must be understood that the score levels provided in Table 25 were established through subjective judgments. They should be considered as advisory indicators and not as absolutes in management decision making. For example, in a real-world situation having high severity potential, remedial actions brought down the risk

score to 225, which is very close to 199, the level where the risk would be considered acceptable and not require further remedial action. The work proceeded, with close observation.

Table 25 displays The Risk Scoring System. It shows the various combinations with respect to incident probability, the frequency of exposure, and the severity of consequences; how probability and frequency ratings are totaled to become mid-scores; and the final score, arrived at by multiplying the severity score by the mid-score.

TABLE 25 The Risk-Scoring System

Probability Category & Rating	Frequency of Exposure & Rating		Mid-Score	Catastrophic	Final Score	Critical	Final Score	Medium	Final Score	Minimal	Final Score
Fre 15	Of	13	28	50	1,400	40	1,120	25	700	10	280
15	Oc	10	25	50	1,250	40	1,000	25	625	10	250
15	In	7	22	50	1,100	40	880	25	550	10	220
15	Se	4	19	50	950	40	760	25	475	10	190
Lik 9	Of	13	22	50	1,100	40	880	25	550	10	220
9	Oc	10	19	50	950	40	760	25	475	10	190
9	In	7	16	50	800	40	640	25	400	10	160
9	Se	4	13	50	650	40	520	25	325	10	130
Occ 4	Of	13	17	50	850	40	680	25	425	10	170
4	Oc	10	14	50	700	40	560	25	350	10	140
4	In	7	11	50	550	40	440	25	275	10	110
4	Se	4	8	50	400	40	320	25	200	10	80
Rem 1	Of	13	14	50	700	40	560	25	350	10	140
1	Oc	10	11	50	550	40	440	25	275	10	110
1	In	7	8	50	400	40	320	25	200	10	80
1	Se	4	5	50	250	40	200	25	125	10	50
Imp 0.5	Of	13	13.5	50	675	40	540	25	338	10	135
0.5	Oc	10	10.5	50	525	40	420	25	263	10	105
0.5	In	7	7.5	50	375	40	300	25	188	10	75
0.5	Se	4	4.5	50	225	40	180	25	113	10	45

The goal was to create a three-dimensional numerical risk-scoring system that serves the needs of those who are more comfortable with statistics in their risk assessments, addresses the strong beliefs of those who want frequency of exposure given separate consideration in the risk assessment process, and maintains credibility and efficacy. An example demonstrating how the risk-scoring system is applied appears in Table 26.

TABLE 26 Example of How the Risk Scoring System Is Applied

Probability of Occurrence	Score	Frequency of Exposure	Score	Severity	Score	Risk Score
Frequent	15	Often	13	Critical	40	$(15 + 13) \times 40 = 1{,}120$
Likely	9	Occasional	10	Critical	40	$(9 + 10) \times 50 = 760$
Occasional	4	Infrequent	7	Medium	25	$(4 + 7) \times 25 = 275$
Remote	1	Seldom	4	Minimal	10	$(1 + 4) \times 10 = 50$

CONCLUSION

Three-dimensional numerical risk-scoring systems can be crafted that have credibility. But, how should such systems be used? Numerical risk scores carry an image of precision that can influence decision making and priority setting. In reality, however, they should not be the sole or absolute determinant.

In gathering data for this chapter, one of the most interesting discussions about the real-world use of a numerical risk-scoring system took place with a person whose principle interest was the safety of the products his company produces. The risk determination system in that company requires that an independent facilitator serve as a discussion leader and that a risk review committee consisting of at least five to seven knowledgable people be appointed. Consensus on risk scores and recommendations for any necessary risk reduction actions must be reached.

In these deliberations, it is common for the severity scores for injuries to users or bystanders to be moved up a level or two. For example, an injury requiring a visit to a doctor but immediate return to work receives the lowest severity rating in the scoring system. However, when arriving at the recommendations to be made affecting product design or revising the operating procedures in instruction manuals, the review group regularly gives more weight to the injury than the scoring system indicates is necessary. Recommendations to achieve risk reduction are often influenced by the possible damage to corporate image, customer relations, and an assumed societal responsibility.

Numerical risk-scoring systems can serve a real need. Nevertheless, it should be remembered that they consist of numerics arrived at through subjective judgments. Risk assessment is still as much art as science.

REFERENCES

Accident Prevention Manual: Administration & Programs, 12th ed. Itasca, IL: National Safety Council, 2001.

Failure Mode and Effects Analysis (FMEA): A Guide for Continuous Improvement for the Semiconductor Equipment Industry. Technology Transfer #92020963A-ENG. Austin, TX: International SEMATECH, 1992. Also available at http://www.sematech.org.

Fine, William T. Mathematical Evaluations for Controlling Hazards. White Oak, MD: Naval Ordinance Laboratory, 1971.

Grose, Vernon L. *Managing Risk: Systematic Loss Prevention for Executives*. Originally published by Prentice-Hall, 1987. Now available through Omega Systems Group, Inc., Arlington, VA.

ISO 14121. Safety of Machinery—Principles for Risk Assessment Standard. Geneva, Switzerland: International Organization for Standardization, 1999.

Pilz. *Guide to Machinery Safety*, 6th ed. Farmington, MI: Pilz Automation Technology, 1999.

Potential Failure Mode and Effects Analysis: FMEA, 3rd ed. Southfield, MI: Automotive Industry Action Group, 2001.

ADDENDUM

MATHEMATICAL EVALUATIONS FOR CONTROLLING HAZARDS

What follows is an abbreviated version of a 1971 paper authored by William T. Fine, When he served at the Naval Ordinance Laboratory, White Oak, Md.

ABSTRACT

To facilitate expeditious control of hazards for accident prevention purposes, two great needs have been recognized. These are for:

(1) a method to determine the relative seriousness of all hazards for guidance in assigning priorities for preventive effort; and
(2) a method to give a definite determination as to whether the estimated cost of the contemplated corrective action to eliminate a hazard is justified.

To supply these needs, a formula has been devised which weighs the controlling factors and "calculates the risk" of a hazardous situation, giving a numerical evaluation to the urgency for remedial attention to the hazard. Calculated Risk Scores are then used to establish priorities for corrective effort. An additional formula weighs the estimated cost and effectiveness of any contemplated corrective action against the Risk Score and gives a determination as to whether the cost is justified.

Contents

Advanced Safety Management Focusing on Z10 and Serious Injury Prevention, by Fred A. Manuele

CHAPTER 1: INTRODUCTION

General The purpose of this chapter is to illustrate the need for quantitative evaluations to aid in the control of hazards and to explain the general plan of this report.

A problem frequently facing the head of any (field type) safety organization is to determine just how serious each known hazard is, and to decide to what extent he should concentrate his resources and strive to get each situation corrected. Normal safety routines such as inspections and investigations usually produce varying lists of hazards which cannot all be corrected at once. Decisions must be made as to which ones are the most urgent. On costly projects, management often asks whether the risk due to the hazard justifies the cost of the work required to eliminate it. Since budgets are limited, there is necessity to assign priorities for costly projects to eliminate hazards.

The question of whether a costly engineering project is justified is usually answered by a general opinion which may be little better than guesswork. Unfortunately in many cases, the decision to undertake any costly correction of a hazard depends to a great extent on the salesmanship of safety personnel. As a result, due to insufficient information, the cost of correcting a very serious hazard may be considered prohibitive by management, and the project postponed; or due to excellent selling jobs by Safety, highly expensive engineering or construction jobs may be approved when the risks involved really do not justify them.

In Chapter 2 of this report, a formula is presented to "calculate the risk" due to a hazard, or to quantitatively evaluate the potential severity of a hazardous situation. Use of this formula will provide a logical system for safety and management to determine priorities for attention to hazardous situations, and guidance for safety personnel in determining the areas where their efforts should be concentrated.

In Chapter 3 of this report, a formula is presented for determining whether or not the cost of eliminating a hazard is justified. Use of the formula will provide a solid foundation upon which safety personnel may base their recommendations for engineering-type corrective action. It will assure that projects which are not justified will not be recommended.

This report deals with justification of costs to eliminate hazards. This does not imply in anyway that a cost, no matter how great, is not worthwhile if it will prevent an accident and save a human life. However we must also consider accident prevention with reason and judgment. Budgets are not unlimited. Therefore the maximum possible benefit for safety must be derived from any expenditure for safety. When an analysis results in a decision that the cost of certain measures to eliminate a hazard "is not justified," we do not say or suggest that the hazard is not serious and may be ignored.

We do say that, based on evaluation of the controlling factors, the return on the investment, or in other words, the amount of accident prevention benefit, is below the standards we have established. The amount of money involved will no doubt provide greater safety benefit if used to alleviate other higher-risk hazards which this system will identify. As for the hazard in question, less costly preventive measures should be sought.

Definitions For the purpose of this presentation, three factors are defined as follows.

a. *Hazard.* Any unsafe condition or potential source of an accident. Examples are: an unguarded hole in the ground; defective brakes on a vehicle; a deteriorated wood ladder; a slippery road.
b. *Hazard-Event.* An undesirable occurrence; the combination of a hazard with some activity or person which could start a sequence of events to end in an accident. Examples of hazard events are: a person walking through a field which contains a hazard such as an unguarded well opening; a person not wearing eye protection while in an eye hazardous area; a person driving a vehicle that has defective brakes; a man climbing up a defective ladder; a vehicle being driven on a slippery road.
c. *Accident Sequence.* This chain of events or occurrences which take place starting with a "hazard-event" and ending with the consequences of an accident.
d. Additional definitions will be provided in later pages as needed.

CHAPTER 2: FORMULA FOR EVALUATING THE SERIOUSNESS OF THE RISK DUE TO A HAZARD

General The purpose of this chapter is to present a complete explanation of the method for quantitatively evaluating the seriousness of hazards, and some of the benefits that may be derived from such analyses.

The expression "a calculated risk" is often used as a catchall for any case when work is to be done without proper safety measures being taken. But usually such work is done without any actual calculation. By means of this formula, the risk is calculated. The seriousness of the risk due to a hazard is evaluated by considering the potential consequences of an accident, the exposure or frequency of occurrence of the hazard-event that could lead to the accident, and the probability that the hazard-event will result in the accident and consequences.

The formula is as follows:

$$\text{Risk Score} = \text{Consequences} \times \text{Exposure} \times \text{Probability}$$

$$\text{Abbreviated: } R = C \times E \times P$$

Definitions of the elements of the formula and numerical ratings for the varying degrees of the elements are given below.

a. Consequences C. The most probable result of a potential accident, including injuries and property damage. This is based on an appraisal of the entire situation surrounding the hazard, and accident experience. Classifications and ratings are:

	Description	Rating
(1)	Catastrophic: numerous fatalities; extensive damage (over $1,000,000), major disruption of activities of national significance	100
(2)	Multiple fatalities; damage $500,000 to $1,000,000	50
(3)	Fatality, damage $100,000 to $500,000	25
(4)	Extremely serious injury (amputation, permanent disability); damage $1,000 to $100,000	15
(5)	Disabling injuries; damage up to $1,000	5
(6)	Minor cuts, bruises, bumps, minor damage	1

b. Exposure E. *Frequency of occurrence of the hazard-event*—the undesired event which could star the accident-sequence. Classifications are below. Selection is based on observation, experience and knowledge of the activity concerned.

	Description	Rating
	The hazard event occurs:	
(1)	Continuously (or many times daily)	10
(2)	Frequently (approximately once daily)	6
(3)	Occasionally (from once per week to once per month)	3
(4)	Unusually (from once per month to once per year)	2
(5)	Rarely (it has been known to occur)	1
(6)	Very rarely (not known to have occurred but considered remotely possible)	0.5

c. Probability P. This is the likelihood that, once the hazard-event occurs, the complete accident-sequence of events will follow with the necessary timing and coincidence to result in the accident and consequences. This is determined by careful consideration of each step in the accident sequence all the way to the consequences, and based upon experience and knowledge of the activity, plus personal observations. Classifications and ratings follow:

	Description	Rating
	The accident-sequence, including the consequences:	
(1)	Is the most likely and expected result if the hazard-event takes place	10
(2)	Is quite possible, would not be unusual, has an even 50/50 chance	6
(3)	Would be an unusual sequence or coincidence	3
(4)	Would be a remotely possible coincidence. (It has happened here.)	1
(5)	Extremely remote but conceivably possible. (Has never happened after many years of exposure.)	0.5
(6)	Practically impossible sequence or coincidence; a "one in a million" possibility. (Has never happened in spite of exposure of many years.)	0.1

Examples The use of this formula is demonstrated by actual examples. Six widely different types of situations have been selected to illustrate the broad applicability of the formula. [*In this condensation of Fine's paper, three examples are given*.]

a. Example No. 1

(1) *Problem.* There is a quarter-mile stretch of two-lane road used frequently by both vehicles and pedestrians departing or entering the grounds. There is no sidewalk, so pedestrians frequently walk in the road, especially when the grass is wet or snow covered. There is little hazard to pedestrians when all the traffic is going in one direction only; but when vehicles are going in both directions and passing by each other, the vehicles require the entire width of the road, and pedestrians must then walk on the grass alongside the road: It is considered that an accidental fatality could occur if a pedestrian steps into the road, or remains in the road at a point where two vehicles are passing.

(2) *Steps to Use the Risk Score Formula.*

Step 1.

List the accident-sequence of events that could result in the undesired consequence

1. It is a wet or snowy day, making the grass along the road wet and uninviting to walk on.

2. At quitting time, a line of vehicles, and some pedestrians are leaving the grounds, using this road.
3. One pedestrian walks on the right side of this road, and he has an attitude which makes him oblivious to the traffic. (This is the hazard-event.)
4. Although traffic is "one way" out at this time, one vehicle comes from the opposing direction, causing the outgoing traffic line to move to the right edge of the road.
5. The pedestrian on the right side of the road fails to observe the vehicles, and he remains in the road.
6. The driver of one vehicle fails to notice the pedestrian and strikes him from the rear.
7. Pedestrian is killed.

Step 2.

Determine values for elements of formula:

Consequences. A fatality. Therefore C = 25.

- *Exposure*. The hazard-event is event 3 above, the pedestrian remaining in road and refusing to notice the line of traffic. It is considered that this type individual appears or is "created" by conditions occasionally. Therefore E = 3.
- *Probability* of all events of the accident sequence following the hazard-event is: "conceivably possible, although it has never happened in many years." Reasoning is as follows: events 4, 5, 6 and 7 are individually unlikely, so the combination of their occurring simultaneously is extremely remote.

Event 4 is unlikely because traffic is "one way" at quitting time.

Event 5 is unlikely because a number of drivers would undoubtedly sound their horns and force the pedestrian's attention.

Event 6 is unlikely because most drivers are not deliberately reckless.

Event 7, a fatality, is unlikely because vehicle speeds are not great on the road, and the most likely case would be a glancing blow and minor injury. Not even a minor injury has ever been reported here. In view of the above Probability, P = 0.5.

Step 3.

Substitute into formula and determine the Risk Score:

$$R = C \times E \times P = 25 \times 3 \times 0.5 = 37.5$$

(*Note:* The Risk Score or one case alone is meaningless. Additional hazardous situations must also be calculated for comparative purposes and a definite pattern. Additional cases are similarly calculated below.)

b. Example No. 2

(1) *Problem.* A 12,000 gallon propane storage tank is subject to two hazards. One hazard is the fact that the tank is located alongside a well-traveled road. The road slopes, and is occasionally slippery due to rain, snow or ice. It is considered possible that a vehicle (particularly a truck) could go out of control, leave the road, strike and rupture the tank, and cause a propane gas explosion and fire that could destroy several buildings, with consequences amounting to damage costing $200,000, plus a fatality.

The second hazard is the tank's location close to ultra-high compressed air lines and equipment. A high pressure pipeline explosion could result from a malfunctioning safety valve, a human error in operating the equipment, damage to a pipeline, or from other causes. Blast or flying debris could conceivably strike the propane tank, rupture it and cause it to explode with the same consequences as for a run-away vehicle.

(2) *Using the Risk Score Formula.* (*Note:* In this case there are two hazards, so the evaluation is done in two parts, one for each of the hazards, and the total scores are added.)

Step 1.

Consider—just the first hazard, that due to a vehicle. List the sequence of events that would result in an accident:

1. Many vehicles are driven down the hill alongside the storage tank
2. The road has suddenly become slippery due to an unexpected freezing rain.
3. One truck starts to slide on the slippery road as it goes down this hill. (*Note:* This is the "hazard-event" that starts the accident sequence.)
4. The driver loses his steering control at a point when he is uphill from and approaching the tank.
5. Brakes fail to stop the vehicle from sliding.
6. Vehicle heads out of control toward the tank.
7. Vehicle strikes the tank with enough force to rupture it and permit the propane gas to leak out.
8. A spark ignites the propane
9. Explosion and conflagration occur.
10. Building and equipment damage is $200,000, and one man is killed.

Step 2.

Substitute numerical values into formula:

- *Consequences.* One fatality and damage loss of $200,000. Therefore C = 25.
- *Exposure.* The hazard-event that would start the accident sequence is—the truck starting to slide on this road. This happened "rarely." Therefore E = 1.

- *Probability.* To decide on the likelihood that the complete accident-sequence will follow the occurrence of the hazard-event, we consider the probability of each event:
  a. Loss of steering control to occur at the precise point in the road approaching the tank is possible but would be a coincidence.
  b. Once the vehicle started to slide, if the road was ice covered, it would be expected that the brakes would fail to stop the slide.
  c. The vehicle heading toward the tank is highly unlikely. Momentum would cause the vehicle to continue straight down the road.
  d. The vehicle striking the tank with great force is extremely unlikely.

If a vehicle were sliding on an ice covered surface toward the tank, it would be easily diverted from its direction of travel by a number of obstructions between the road and the tank. When roads are slippery, travel is curtailed and drivers are cautioned to drive slowly. A slow rate of speed would be unlikely to produce enough force to damage the tank. The shape and position of the tank are such that a vehicle would tend to glance off it.

In summary, because of the highly unlikely nature of most of the events, this sequence has a one-in-a-million probability. It has never happened. But it is conceivable. Therefore $P = 0.5$.

Step 3.

Substitute in the formula.

$$\text{Risk Score} = 25 \times 1 \times 0.5 = 12.5$$

The entire process is to be repeated for the second hazard, which is the location near the high pressure air lines and equipment.

Step 1.

List the sequence of events.

1. Normal daily activities involve operation of equipment and pressuring of pipelines, some of which are in the vicinity of the propane storage tank.
2. A pipeline containing air compressed to 3,000 pounds per square inch, approximately 50 feet away from the storage tank has become deteriorated or damaged. (This is the hazard-event.)
3. The pipeline bursts.
4. Metal debris is thrown by the blast in all directions, several pieces flying and striking the propane tank with such force that the tank is ruptured.
5. Propane starts to leak out of the tank.
6. A spark ignites the propane fumes.

7. The propane and air mixture explodes.
8. Building damage is $200,000, and one man is killed.

Step 2.
Determine values and substitute in the formula.

- *Consequences.* One fatality and damage loss of $200,000. C = 25.
- *Exposure.* High pressure air lines have been known to have been neglected or damaged. Frequency of such occurrences is considered "unusual." Therefore E = 2.
- *Probability.* Now we estimate the likelihood that a damaged pipeline will explode and the explosion will occur close enough and with enough blast to throw debris and strike the propane tank with such force as to complete the accident sequence. Several bursts have occurred in the past few years, but none have damaged the propane tank. Few of the pipelines are close enough to endanger the tank. After careful consideration, the accident sequence is considered "very remotely possible." P = 0.5.

Step 3.
Substituting into the formula.

$$\text{Risk Score} = 25 \times 2 \times 0.5 = 25$$

$$\text{Totaling Risk Score} = 12.5 + 25 = 37.5$$

CHAPTER 3: FORMULA TO DETERMINE THE JUSTIFICATION FOR RECOMMENDED CORRECTIVE ACTIONS

General. The purpose of this chapter is to describe the method of determining whether the cost of corrective action to alleviate a hazard is justified. Once a hazard has been recognized, appropriate corrective action must be tentatively decided upon and its cost estimated. Now the "Justification" formula can be used to determine whether the estimated cost is justified.

The formula is as follows:

$$\text{Justification} = \text{Consequences} \times \text{Exposure} \times \frac{\text{Probability}}{\text{Cost Factor}} \times \text{Degree of Correction}$$

Elements are abbreviated

$$J = \frac{C \times E \times P}{CF \times DC}$$

It should be noted that the elements of the numerator of this formula are the same as the Risk Score formula described in Chapter 2. We have simply added a denominator made up of two additional elements which are as follows:

a. Cost Factor CF. A measure of the estimated dollar cost of the proposed corrective action. Classifications and ratings are:

Cost	Ratings
(1) Over $50,000	10
(2) $25,000 to $50,000	6
(3) $10,000 to $25,000	4
(4) $1,000 to $10,000	3
(5) $100 to $1,000	2
(6) $25 to $100	1
(7) Under $25	0.5

b. Degree of Correction DC. An estimate of the degree to which the proposed corrective action will eliminate or alleviate the hazard, forestall the hazard-event, or interrupt the accident sequence. This will be an opinion based on experience and knowledge of the activity concerned. Classifications and ratings are:

Description	Rating
(1) Hazard positively eliminated, 100%	1
(2) Hazard reduced at least 75%, but not completely	2
(3) Hazard reduced by 50 to 75%	3
(4) Hazard reduced by 25 to 50%	4
(5) Slight effect on hazard, less than 25%	6

Criteria for Justification. Values are substituted into the formula to determine the numerical value for Justification. The Critical Justification Rating is 10. For any rating over 10, the expenditure will be considered justified. For a score less than 10, the cost of the contemplated corrective action is not justified.

Note: The Critical Justification Rating has been arbitrarily set at 10, based on experience, judgment and the current budgetary situation. After extended experience at an individual organization, based on accident experience, budgetary situations, and appraisals of the safety status, it may be found desirable to raise or lower the critical score.

Examples. The use of the Justification formula will be illustrated by the use of the same six examples discussed in Chapter 2. (Three will be shown here.)

a. Example No. 1. The hazard of pedestrians and vehicles using the same road.

To reduce this risk, the corrective action being considered is to construct a sidewalk alongside the road, at an estimated cost of $1,500. The "J" formula is now used to determine whether this contemplated expenditure is justified.

(1) *Substitute Values in the "J" Formula.*

$$J = \frac{C \times E \times P}{CP \times DC}$$

(a) C, E, and P for this situation were discussed as Example No. 1 in Chapter 2 of this report and determined to be 25, 3, and 0.5, respectively.

(b) *Cost Factor*. The estimated cost factor is $1,500. Therefore CF is 3.

(c) *Degree of Correction*. The probability of the hazard-event occurring is considered to be reduced at least 75 percent, but 100 percent, by the construction of the sidewalk. Therefore DC = 2.

(d) *Justification Rating*.

$$J = \frac{25 \times 3 \times 0.5}{3 \times 2} = \frac{37.5}{6} = 6.25$$

(2) *Conclusion.* "J" is less than 10. Therefore the cost of construction of the sidewalk is not justified.

Note: This lack of sufficient justification evaluates the situation from the safety viewpoint only. Management could feel there is added justification for morale or other purposes.

(3) *Additional Consideration.* Since the Risk Score is still a substantial 37.5, other less costly corrective measures should be sought. This includes improved administrative controls to enforce one-way traffic, reduce speed, and encourage pedestrians to use another exit gate. This will reduce the Risk Score by reducing both Exposure and Probability.

b. Example No. 2. The hazard due to compressed air being used in a shop without proper pressure reduction nozzles.

The proposed corrective action is installation of proper pressure reducing nozzles on the 50 air hoses, at a cost of $8 each, or $400. To determine justification for the expenditure:

(1) *Determine Values for the Elements of the "J" Formula.*

(a) C, E, and P were discussed in Example No. 2 of Chapter 2 and evaluated at 5, 10, and 6, respectively.

(b) *Cost Factor*. The cost of the corrective action is $400, so CF = 2.

(c) *Degree of Correction*. The corrective action will reduce the hazard by at least 50 percent, so DC = 3.

(d) Substituting in the formula:

$$J = \frac{5 \times 10 \times 6}{2 \times 3} = \frac{300}{6} = 50$$

(2) *Conclusion.* "J" is well above 10. The cost of installing pressure reduction nozzles is strongly justified.

c. Example No. 3. The hazardous location of the 12,000 gallon propane storage tank.

The proposed corrective action is to relocate the tank to a place where it will be less likely to be damaged by any external source, at an estimated cost of $16,000.

(1) *Determine Values for Elements of the Formula.*

(a) C, E, and P were determined in Example No. 3 of Chapter 2 to be 25, 1, and 1.5 (the two hazards combined.)

(b) *Cost Factor*. Cost of relocation is $16,000. CF = 4.

(c) *Degree of Correction*. In the very best location available, there still remains a remote possibility o damage to the tank, so DC = 2.

(d) Substituting in the formula:

$$\mathrm{J} = \frac{25 \times 1 \times 1.5}{4 \times 2} = \frac{37.5}{8} = 4.7$$

(2) *Conclusion.* Based on the established criteria, the cost of relocation of the tank is not justified.

(3) It is emphasized that the conclusion in this case that the proposed corrective action is not justified does not mean that the hazard is of little or no significance. The Risk Score is still 37.5, and this remains of appreciable concern.

Since the potential consequences of an accident are quite severe, effort should be expended to reduce the risk, by reducing either the Exposure of the Probability, or devising other less costly corrective action. In this case, it is considered that an additional steel plate barrier could be erected to protect the tank from the compressed air activities, and one or two strong posts in the ground could minimize danger from the road. Thus, the Probability of serious damage to the truck, and the Risk Score, would be considerably lessened at a very nominal cost.

RECOMMENDED PROCEDURE FOR USING THE "J" FORMULA

A convenient **"J"** Formula Worksheet is furnished for undertaking a hazard analysis to determine the Justification Rating. Once a hazard has been recognized, the following procedure is recommended:

a. State the problem briefly.

b. Decide on the most likely consequences of an accident due to the hazard.

c. Review all factors carefully, on the scene. List the actual step-by-step sequence of events that is most likely to result in the consequences chosen. You must be specific.

d. Decide on the most appropriate corrective action and obtain or make a rough estimate of its cost.
e. Consider carefully the effect of the proposed corrective action on the hazard, and estimate roughly the degree to which the dangerous situation will be alleviated.
f. If alternative corrective measures are possible, repeat steps (d) and (e) for them.
g. Select the hazard-event: the first undesirable occurrence that could start the accident sequence.
h. Consider the existing situation carefully to determine the frequency of the occurrence of the hazard-event: by on the scene observation, and then decide on the Exposure Rating. If in doubt between two ratings, interpolate.
i. For the Probability Rating, consider the likelihood of the occurrence of each event of the accident sequence, including the resulting injury and/or damage, and form an opinion based on the descriptive words. For example, if two unusual coincidences are required, this could be considered "remotely possible"; two "remotely possible" occurrences could be "conceivably possible," etc. If in doubt between two ratings, interpolate.
   Endeavor to be consistent. Consider the occurrence of only the same consequences which were decided on in step (b) above. For example, if you decided on consequences of a fatality, then in this step you may only consider the probability of a fatality. If you also wish to consider lesser injuries, a separate and additional computation must be made, since both the Consequences and Probability evaluations would be different. Scores should be added.
j. You have now obtained ratings for all the elements of the "J" formula. Substitute in the formula and compute the Justification Score.
k. If alternative corrective measures are being considered to alleviate the hazard, compute their Justification Scores also.
l. If there are alternative corrective measures which have acceptable Justification Scores, the most desirable from the Safety standpoint is the one which would make the greatest reduction in the Risk Score. Therefore, for each alternative, assume that the corrective measures are in effect and re-compute the Risk Score. Of course this selection may also be affected by external (non-safety) considerations such as the size of investment required, the relative effects on morale, esthetics, efficiency, convenience, ease of implementation, etc.

EXCEPTION TO RELIANCE ON THE "J" FORMULA

A highly hazardous situation may exist for which no corrective action that can be devised will give an acceptable Justification Score. Obviously in such a case, whatever corrective action is necessary to reduce the Risk Score should be taken, regardless of the Justification Score.

"J" FORMULA WORKSHEET

Problem:

Sequence of events or factors necessary for accident:

1.
2.
3.
4.
5.
6.
7.
8.

Formula Factors	*Rating*
C Consequences	
E Exposure	
P Probability	
CF Cost Factor	
DC Degree of Correction	

J Justification: $J = \dfrac{C \times E \times P}{CF \times DC} = \dfrac{X \quad X}{X}$

The estimated cost of corrective action is/is not justified.

CHAPTER 11

IMPLEMENTATION AND OPERATION — SECTION 5.0

INTRODUCTION

The provisions in the planning section (Section 4.0) of Z10 pertain to the first three steps in the Plan-Do-Check-Act (PDCA) process as shown below:

Plan:	Identify the problem.
Plan:	Analyze the problem.
Plan:	Develop solutions.
Do:	Implement solutions.
Check:	Evaluate the results.
Act:	Adopt the change, abandon it, or start over.

In the planning processes, occupational health and safety management systems issues are identified, analyzed, and prioritized. Those issues are defined in the standard as "hazards, risks, management system deficiencies and opportunities for improvement." After the identification and analysis process, objectives are then to be established that offer the greatest opportunities for improvement. The following steps are to draft a documented implementation plan to achieve the objectives and to allocate the necessary resources.

Applying the Implementation and Operating section of Z10 moves one into the 'Do' element of the PDCA process. The standard says that "This section

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(5.0) defines the operational elements that are required for implementation of an OHSMS" and that "these elements provide the backbone of an OHSMS and the means to pursue the objectives from the planning process."

I give particular emphasis to the 'Do' element. Although the application of all the sections in Z10 has significance with respect to achieving safety and health management system effectiveness, several Implementation and Operation requirements in Section 5.0 have particular significance. Only brief comments are made in this chapter on those elements of Section 5.0 that are extensively addressed in the occupational safety literature, commencing with Section 5.1.4, "Contractors."

Separate chapters follow on the Z10 requirements for which the literature is not at prevalent and which are vital in achieving superior results:

- Chapter 12, Hierarchy of Controls: The Safety Decision Hierarchy, Section 5.1.1
- Chapter 13, Safety Design Reviews, Section 5.1.2
- Chapter 15, Management of Change, Section 5.1.2
- Chapter 16, Procurement, Section 5.1.3

Applied lean concepts as discussed in this book in Chapter 14 relate to the safety design review provisions of Z10.

CONTRACTORS, SECTION 5.1.4

Relations with Contractors who work on an organization's site are addressed in the section following that on Procurement. An organization is to have processes in place to protect its employees from the risks that may be presented by the contractor's work or the activity of the contractor's employees, and to protect the contractor's employees from the organization's activities and operations. These requirements are briefly stated in Section 5.1.4.

A good reference on contractor selection procedures and the key safety, health, and environmental protection provisions to which contractors should adhere are discussed in the first chapter in *Construction Safety Management and Safety Engineering*. In addition, an Internet search (entering "contractor safety requirements" into any search engine) will yield a large number of downloadable procedures established by a variety of entities with respect to contractor selection and the safety performance expected of contractors while on an organization's premises.

Publications on contractor safety issued by three organizations are listed as resources in Z10's Appendix K, "Bibliography and Reference." Two standards issued by the American National Standards Institute (ANSI) are referenced in appendix K. One pertains to multiemployer projects; the other covers basic safety management elements in construction activities.

The American Petroleum Institute (API) reference listed in Z10's Appendix K gives guidance on how to implement a contractor safety and health program. The International Association of Oil and Gas Producers (OGP) publication provides guidelines on working together in a contract environment.

EMERGENCY PREPAREDNESS, SECTION 5.1.5

With respect to Emergency Preparedness, an organization is to have processes in place to "prevent, prepare for, and/or respond to emergencies." This is a subject that has been much written about since 9/11 and Hurricane Katrina. A good basic reference on the subject is Chapter 18, "Emergency Preparedness," in the National Safety Council's *Accident Prevention Manual: Administration & Programs*, Twelfth Edition.

Enter "emergency preparedness" into an Internet search engine and the resulting references available for review number well into the millions. In Z10's Appendix K, three references on Emergency Preparedness, and valuable resources, are given: documents prepared by the Federal Emergency Management Agency (FEMA), Department of Transportation (DOT), and the Occupational Safety and Health Administration (OSHA).

EDUCATION, TRAINING, AWARENESS, AND COMPETENCE, SECTION 5.2

For these subjects, an organization is to have processes in place to: establish competency needs for employees and contractors; see that they are educated and trained in a language they understand; and ensure that the trainers are competent. An Internet search will reveal millions of possible resources on training and awareness, but not as many on establishing competence levels. These chapters in the above-mentioned *Accident Prevention Manual* are helpful: Chapter 27, "Motivation," Chapter 28, "Safety and Health Training," and Chapter 30, "Safety Awareness Programs." Appendix K identifies publications that pertain to establishing competency levels. For example, a listed American Petroleum Institute (API) publication is titled "*1210 Trainer Competencies*." A publication issued by the International Association of Oil and Gas Producers (OGP) addresses "*Competence Assessment Training Guidelines*." Several other references pertain to training fundamentals.

COMMUNICATION, SECTION 5.3

Z10's communication provisions require that: all levels of the organization be informed about the OHSMS and implementation plan; injuries and illnesses be promptly reported; employees be encouraged to recommend improvements on safety and health matters; and any barriers to communication on hazards and risks and safety management deficiencies be eliminated.

DOCUMENT AND RECORD CONTROL PROCESS, SECTION 5.4

The organization is allowed some discretion with respect to its document and record control process. The following is stated in the advisory column: "The type

and amount of formal documentation that is necessary to effectively manage and OHSMS should be commensurate with the size, complexity and risks of an organization."

Nevertheless, records shall be kept to "demonstrate or assess performance with the requirements of this standard." In several provisions in Z10, statements are made indicating that documentation is necessary on, for example, health and safety policy, objectives, and the implementation plan. For many of Z10's other provisions, activity cannot be properly managed without adequate documents.

REFERENCES

Accident Prevention Manual: Administration & Programs, 12th ed. Itasca, IL: National Safety Council, 2001.

Hill, Darryl C., ed. *Construction Safety Management and Engineering*. Des Plaines, IL: American Society of Safety Engineers, 2004.

CHAPTER 12

HIERARCHY OF CONTROLS: THE SAFETY DECISION HIERARCHY — SECTION 5.1.1

INTRODUCTION

Section 5.1.1 of ANSI/AIHA Z10-2005, the Occupational Health and Safety Management Systems Standard, is titled "Hierarchy of Controls." Here is the opening sentence in that section: "The organization shall implement and maintain a process for achieving feasible risk reduction based on the following order of controls." A prescribed hierarchy of controls immediately follows that provision.

The hierarchy presented in the standard is the basis for decision making when applying every section in Z10 that is intended to resolve occupational health and safety issues. Those issues are "defined as hazards, risks, management system deficiencies, and opportunities for improvement." This hierarchy is of such importance that a separate chapter in this book is devoted to it. This chapter will:

- Comment on the evolution of hierarchies of control
- Discuss the hierarchy of controls in Z10
- Provide guidelines on the application of a hierarchy of controls
- Establish the logic of taking steps in the hierarchy of controls in the order given
- Place the hierarchy of controls within good problem-solving techniques, as in The Safety Decision Hierarchy

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- Relate Haddon's unwanted energy release concept to the hierarchy of controls
- Provide general design guidelines based on the unwanted energy release concept

EVOLUTION OF THE HIERARCHY OF CONTROLS

The hierarchy of controls in Z10 has six elements. Hierarchies in other published standards and guidelines may have three, four, or five elements. The version in Z10 is the outcome of the work of a large number of safety professionals over many years. All of its contributors cannot be recognized here. A limited review of the evolution of the hierarchy of controls is given, referencing:

- A three-step hierarchy in the National Safety Council's *Accident Prevention Manual*
- A four-step hierarchy in the U.S. government's system safety standard requirements
- Five-step hierarchies in recently issued standards and guidelines
- Six-step hierarchies in this author's writings and in a proposed revision of the U.S. government's system safety standard

AT THE NATIONAL SAFETY COUNCIL

The third edition of the National Safety Council's *Accident Prevention Manual* was published in 1955. Section 4 is titled "Removing the Hazard from the Job". It provides a three-step "order of effectiveness and preference." This is taken from the *Accident Prevention Manual*.

> The engineer should include in his planning and follow-through such measures as will attain one of the accident prevention goals listed as follows (in the order of effectiveness and preference):
>
> 1. Elimination of the hazard from the machine, method, material, or plant structure.
> 2. Guarding or otherwise minimizing the hazard at its source if the hazard cannot be eliminated.
> 3. Guarding the person of the operator through the use of personal protective equipment if the hazard cannot be eliminated or guarded at its source.
>
> Company policies should be such that safety can be designed and built into the job, rather than added after the job has been put into operation.

Establishing the concept that risk reduction actions should be taken in an order of effectiveness and preference was an important step in the evolution of the practice of safety. It implies that some steps in the process are preferable since they achieve greater risk reduction than others. Declaring that safety policies should require that

safety be designed and built into the job rather than dealt with as an add-on is also a premise that influenced later versions of hierarchies of control.

MIL-STD-882-1969 and MIL-STD-882D-2000

The Department of Defense's Standard Practice for System Safety, MIL-STD-882, was first issued in 1969. It was a seminal document at that time. Three revisions of 882 have been issued over the span of the past 31 years. This standard has had considerable influence on the development of risk assessment, elimination, and amelioration concepts and methods. Much of the wording on risk assessments and hierarchies of control in safety standards and guidelines issued throughout the world is comparable to that in the various versions of 882.

The fourth edition, issued in February 2000, is designated MIL-STD-882D. It is available at http://www.dau.mil/educdept/mm_dept_resources/guidance/mil-std-882 d.doc and may be downloaded, for free. A "System safety design order of precedence" is outlined in 882D. Precedence means: priority in order, rank or importance. As was the case in previous versions of the standard, the design order of preference contains four elements:

1. Eliminate hazards through design selection
2. Incorporate safety devices
3. Provide warning devices
4. Develop procedures and training

As of this writing, 882D is the applicable document. Work is in progress to produce an extended and superior version. Comments are made later in this chapter on a December 1, 2005, draft designated MIL-STD-882E. It extends the four-step hierarchy to six steps.

ANSI/RIA R15.06-1999

The American National Standard for Industrial Robots and Robot Systems—Safety Requirements, ANSI/RIA B15006-1999, was issued in 1999. Its five-step "hierarchy of safeguarding controls" follows:

1. Elimination or substitution
2. Engineering controls (safeguarding technology)
3. Awareness means
4. Training and procedures (administrative controls)
5. Personal protective equipment

Note that this hierarchy of controls, as does that in Z10, includes substituting less hazardous methods or materials as a means of attaining acceptable risk levels. Also, its provisions are close to those in MIL-STD-882D. Providing personal protection equipment, Step 5 in the preceding hierarchy, is incorporated as an option in Step 4 of 882D. – Develop procedures and training.

ANSI/PMMI B155.1-2006

The Packaging Machinery Manufacturers Institute is the secretariat for the standard *Safety Requirements for Packaging and Packaging-Related Converting Machinery*. A revision of B155.1 was approved by ANSI in July 2006; it replaced the version issued in 2000. In part, this is the guidance given on the use of the "The Hazard Control Hierarchy," a five-step process:

> In selecting the most appropriate protective measures, apply the following principles in the order in which they appear.

1. Eliminate by design
2. Guards and safeguarding devices
3. Awareness devices
4. Procedures and training
5. Personal protective equipment

This hierarchy of controls repeats the elements enumerated within the hierarchies of other standards. Again, they closely resemble the provisions in MIL-STD-882D.

This Author's Writings

In *Innovations in Safety Management: Addressing Career Knowledge Needs*, published in 2003, the following hierarchy of controls was encompassed within The Safety Decision Hierarchy, which is to be discussed later. It may also be found in two articles written by this author: "Risk Assessment and Hierarchies of Control" and "Achieving Risk Reduction, Effectively."

1. Eliminate or reduce risks in the design processes.
2. Reduce risks by substituting less hazardous methods or materials.
3. Incorporate safety devices.
4. Provide warning systems.
5. Apply administrative controls (work methods, training, etc.).
6. Provide personal protective equipment.

Because of my observations with respect to the application of risk reduction methods in which differing levels of effectiveness have been achieved, I chose to separate "substituting less hazardous methods or materials" from the "elimination" step. That was a departure from the structure of hierarchies of control that had been previously published. An example supporting that decision is given in "The Logic of Taking Action in the Descending Order Given," a later section in this chapter. In Z10, the same two provisions are also separated.

December 2005 Draft of MIL-STD-882E

Mention was made previously of the work in progress to replace MIL-STD-882D. Because of the importance of the revisions proposed in the standard's "order of preference," we excerpt material from the draft version of 882E:

> Section 4, General Requirements, in 882E "delineates the minimum mandatory requirements for an acceptable system safety program." Section 4.1.4, as follows, gives the steps to be taken in reducing risk, in an "order of precedence."
>
> 4.1.4 Element 4—risk reduction.
>
> 4.1.4.1 System safety mitigation order of precedence.
>
> In reducing risk, the cost, feasibility, and effectiveness of candidate mitigation methods should be considered. In evaluating mitigation effectiveness, an order of precedence generally applies as follows.
>
> 4.1.4.1.1 Eliminate hazard through design selection.
>
> Ideally, the risk of a hazard should be eliminated. This is often done by selecting a design alternative that removes the hazard altogether.
>
> 4.1.4.1.2 Reduce mishap risk through design alteration.
>
> If the risk of a hazard cannot be eliminated by adopting an alternative design, design changes should be considered that reduce the severity and/or the probability of a harmful outcome.
>
> 4.1.4.1.3 Incorporate engineered safety features (ESF).
>
> If unable to eliminate or adequately mitigate the risk of a hazard through a design alteration, reduce the risk using an ESF that actively interrupts the mishap sequence.
>
> 4.1.4.1.4 Incorporate safety devices.
>
> If unable to eliminate or adequately mitigate the hazard through design or ESFs, reduce mishap risk by using protective safety features or devices.
>
> 4.1.4.1.5 Provide warning devices.
>
> If design selection, ESFs, or safety devices do not adequately mitigate the risk of a hazard, include a detection and warning system to alert personnel to the presence of a hazardous condition or occurrence of a hazardous event.
>
> 4.1.4.1.6 Develop procedures and training.
>
> Where other risk reduction methods cannot adequately mitigate the risk from a hazard, incorporate special procedures and training. Procedures may prescribe the use of personal protective equipment.

The "system safety design order of precedence" in 882D contains four elements: Eliminate hazards through design selection; Incorporate safety devices; Provide warning devices; and Develop procedures and training. Those four steps have been expanded to six in 882E. For each of the first two elements in 882D, two options are given in 882E. This is a significant development, based on the knowledge derived

from practical applications of the order of precedence. The descriptive material in 882E for the six elements in the "System safety mitigation order of precedence" is recommended reading.

THE HIERARCHY OF CONTROLS IN Z10

I said in Chapter 1 that although Z10 is a management system standard and not a specification standard, the provisions pertaining to a hierarchy of controls are the exception. Rather than presenting a performance statement that relates to the outcomes to be achieved through a risk reduction process, a specifically defined hierarchy of controls is outlined. This is the hierarchy of controls—the order of controls—in Z10:

A. Elimination
B. Substitution of less hazardous materials, processes, operations, or equipment
C. Engineering controls
D. Warnings
E. Administrative controls
F. Personal protective equipment

Note that this hierarchy of controls contains six elements. The first step, Elimination is separated from the Substitution element. The logic for doing so is discussed later.

HIERARCHIES OF CONTROL: PREMISES AND GOALS

A hierarchy is a system of persons or things ranked one above the other. The hierarchy of controls in Z10 provides a systematic way of thinking, 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. Acknowledging that premise—that risk reduction measures should be considered and taken in a prescribed order—represents an important step in the evolution of the practice of safety.

A model of hierarchies of control may give examples of the types of actions to be taken for each of its elements, as does Appendix G in Z10. However, little is written about the purpose of and the goals to be achieved in applying a hierarchy of controls. An attempt to do so follows.

A major premise to be considered in applying a hierarchy of controls is that the outcome of the actions taken is to be an acceptable risk level, defined as follows:

> Acceptable risk is that risk for which the probability of a hazard-related incident or exposure occurring and the severity of harm or damage that could result are as low as reasonably practicable, and tolerable in the situation being considered.

That definition requires taking into consideration the practicable minimization of each of the two distinct aspects of risk as risk reduction actions are decided on:

- Avoiding, eliminating, or reducing the *probability* of a hazards-related incident or exposure occurring
- Reducing the *severity* of harm or damage that may result, if an incident or exposure occurs

Such a definition also requires reflection on the feasibility and effectiveness of the risk reduction measures to be taken, and their costs, in relation to the amount of risk reduction to be achieved. Decision makers should understand that, with respect to the six levels of action shown within the hierarchy of controls in Z10:

- The ameliorating actions described in the first, second, and third levels are more effective because they
  - Are *preventive* actions that eliminate or reduce risk by design, substitution, and engineering measures
  - Rely the least on personnel performance
  - Are less defeatable by supervisors or workers
- Actions described in the fourth, fifth, and sixth levels are *contingent* actions and rely greatly on the performance of personnel.

What Kepner and Tregoe write in *The New Rational Manager* about taking preventive and contingent actions in the problem-solving process fits precisely with the risk elimination and amelioration concepts set forth here:

> Two kinds of actions are available to anyone conducting a Potential Problem Analysis: preventive actions and contingent actions. The effect of preventive actions is to remove, partially or totally, the likely cause of a potential problem. The effectiveness of a contingent action is to reduce the impact of a problem that cannot be prevented. Preventive actions, if they can be taken, are obviously more efficient than contingent actions.

As decisions are made in applying each step within the hierarchy of controls, the following should be considered as goals:

- Avoiding work methods that are overly stressful, taking into consideration worker capabilities and limitations
- Minimizing the probability of human error by assuring that work situations are not error-provocative, meaning that they do not (as in Chapanis's "The Error-Provocative Situation")
  - Violate operator expectations

  - Require performance beyond what an operator can deliver
  - Induce fatigue
  - Provide adequate facilities or information for the operator
  - Present unnecessarily difficult or unpleasant requirements
  - Include unnecessarily dangerous methods
- Designing systems so that human interaction with equipment and processes occurs at a practicable minimum
- Minimizing requirements for the use of personal protective equipment

THE LOGIC OF TAKING ACTION IN THE DESCENDING ORDER GIVEN

Comments follow on each of the action elements listed in Z10's hierarchy of controls, including the rationale for the order given. Taking actions in the prescribed order, as *feasible and practicable*, is the most effective means to achieve risk reduction.

A. Elimination

The use of the term "elimination" as the first step in applying a hierarchy of controls is a bit simplistic. My experience requires that I replace it with "Eliminate or reduce hazards and risks through system design and redesign." The theory is plainly stated. If the hazards are eliminated in the design and redesign processes, risks that derive from those hazards are also eliminated. However, elimination of hazards completely by modifying the design may not always be practicable. Then, the goal is to modify the design, within practicable limits, so that the:

- Probability of personnel making human errors because of design inadequacies is at a minimum
- Ability of personnel to defeat the work system and the work methods prescribed, as designed, is at a minimum

Examples would be designing to eliminate or reduce the risk from:

- Fall hazards
- Ergonomic hazards
- Confined space hazards
- Noise hazards
- Chemical hazards

Obviously, hazard elimination or reduction is the most effective way to remove or reduce risk. If a hazard is eliminated or reduced, the need to rely on worker behavior to avoid risk is diminished.

B. Substitution of Less Hazardous Materials, Processes, Operations, or Equipment Processes

Methods that illustrate substituting less hazardous methods, materials, or processes for that which is more hazardous include:

- Using automated material handling equipment rather than manual material handling
- Providing an automatic feed system to reduce machine hazards
- Using a less hazardous cleaning material
- Reducing speed, force, amperage
- Reducing pressure, temperature
- Replacing an ancient steam-heating system and its boiler explosion hazards with a hot air system

The substitution of a less hazardous method or material may or may not result in equivalent risk reduction in relation to what might occur if the hazards and risks were reduced to a minimum through system design or redesign.

Consider this example. Considerable manual material handling is often necessary in a mixing process for chemicals. A reaction takes place and an employee sustains serious chemical burns. There are identical operations at two of the company's locations. At one, the decision is made to redesign the operation so that it is completely enclosed, automatically fed, and operated by computer from a control panel, thus greatly eliminating operator exposure.

At the other location, funds for doing the same were not available. To reduce the risk, a substitution took place in this manner: It was arranged for the supplier to premix the chemicals before shipment. Some mechanical feed equipment for the chemicals was also installed. The risk reduction achieved by substitution was not equivalent to that attained by redesigning the operation.

C. Engineering Controls

When safety devices are incorporated in the system in the form of engineering controls, substantial risk reduction can be achieved. Engineered safety devices are intended to prevent workers' access to the hazard. They exist to separate hazardous energy from the worker and deter worker error. They include devices such as:

- Machine guards
- Interlock systems
- Circuit breakers
- Start-up alarms
- Presence-sensing devices
- Safety nets
- Ventilation systems

- Sound enclosures
- Fall prevention systems
- Lift tables, conveyors, and balancers

D. Warnings (Warning Systems)

Warning system effectiveness, and the effectiveness of instructions, signs, and warning labels, rely considerably on administrative controls, such as training, drills, the quality of maintenance, and the reactions of people. Furthermore, although vital in many situations, warning systems may be reactionary in that they alert persons only after a hazard's potential is in the process of being realized (e.g., a smoke alarm). Examples include:

- Smoke detectors
- Alarm systems
- Backup alarms
- Chemical detection systems
- Signs
- Alerts in operating procedures or manuals

A comment is necessary on my preferred use of the term "warning systems" over "warnings" or "warning signs." The terms "warnings" and "warning signs" appear in some published hierarchies of control, as is the case in Z10. The entire needs of a warning system must be considered, for which warning signs or warning devices alone may be inadequate.

For example, the National Five Protection Association's Life Safety Code, NFPA 101, may require, among other factors: detectors for smoke and products of combustion; automatic and manual audible and visible alarms; lighted exit signs; designated, alternate, properly lit exit paths; adequate spacing for personnel at the end of the exit path; proper hardware for doors; and emergency power systems. Obviously, much more is needed than merely "warnings."

E. Administrative Controls

Administrative controls rely on the methods chosen being appropriate in relation to the needs, capabilities of people responsible for their delivery and application, quality of supervision, and expected performance of workers. Some administrative controls are:

- Personnel selection
- Developing appropriate work methods and procedures
- Training

- Supervision
- Motivation, behavior modification
- Work scheduling
- Job rotation
- Scheduled rest periods
- Maintenance
- Management of change
- Investigations
- Inspections

Achieving a superior level of effectiveness in all these administrative methods is difficult and not often attained.

F. Provide Personal Protective Equipment

The proper use of personal protective equipment relies on an extensive series of supervisory and personnel actions, such as the identification of the type of equipment needed, its selection, fitting, training, inspection, maintenance, etc. Examples include:

- Safety glasses
- Face shields
- Respirators
- Welding screens
- Safety shoes
- Gloves
- Hearing protection

Although the use of personal protective equipment is common and necessary in many occupational situations, it is the least effective method to deal with hazards and risks. Systems put in place for their use can be defeated easily. In the design process, one of the goals should be to reduce reliance on personal protective equipment to a practical minimum.

For many risk situations, a combination of the risk management methods outlined in the hierarchy of controls is necessary to achieve acceptable risk levels. However, the expectation is that consideration will be given to each of the steps in a descending order, and that reasonable attempts will be made to eliminate or reduce hazards and their associated risks through steps higher in the hierarchy before lower steps are considered. A lower step in the hierarchy of controls is not to be chosen until practical applications of the preceding level or levels are exhausted.

THE SAFETY DECISION HIERARCHY

The following observations are a reflection of my experience—encompassing the design and engineering aspects, operational aspects, and post incident aspects of the practice of safety:

- Safety practitioners often recommend solutions to resolve hazard/risk situations before they define the problem—that is, before they identify the specifics of the hazards and assess the associated risks.
- Rarely are safety management systems in place to determine whether the preventive actions taken achieve the intended risk reduction.

These observations led to research into the feasibility of encompassing the hierarchy of controls within a sound problem-solving technique that:

- Commences with problem identification and analysis.
- Requires measurement of the results of actions taken to determine their effectiveness.
- Takes further preventive measures if the residual risk is not acceptable.

The initial step in my inquiry was to review several texts on problem solving. The problem-solving methods the authors of these texts propose have great similarity. A composite of those techniques follows in Table 1.

TABLE 1 Problem-Solving Methodology

1. Identify the problem
2. Analyze the problem
3. Explore alternative solutions
4. Select a plan and take action
5. Examine the effects of the actions taken

In every problem-solving method reviewed, the first steps are to identify and analyze the problem. Also, they end with a provision requiring that evaluations be made of the effects of the actions taken. Figure 1, The Safety Decision Hierarchy, presents a logical sequence of actions that safety professionals should consider in resolving safety issues: identify and analyze the problem; consider the possible solutions; decide on and implement an action plan; and determine whether the actions taken achieved the intended risk reduction results. Note that such a sequence of actions also fits well with the PDCA concept.

The safety decision hierarchy depicts a way of thinking about hazards and risks and establishes an effective order for risk elimination or amelioration. Why propose that safety practitioners adopt a safety decision hierarchy? This quote from *The New*

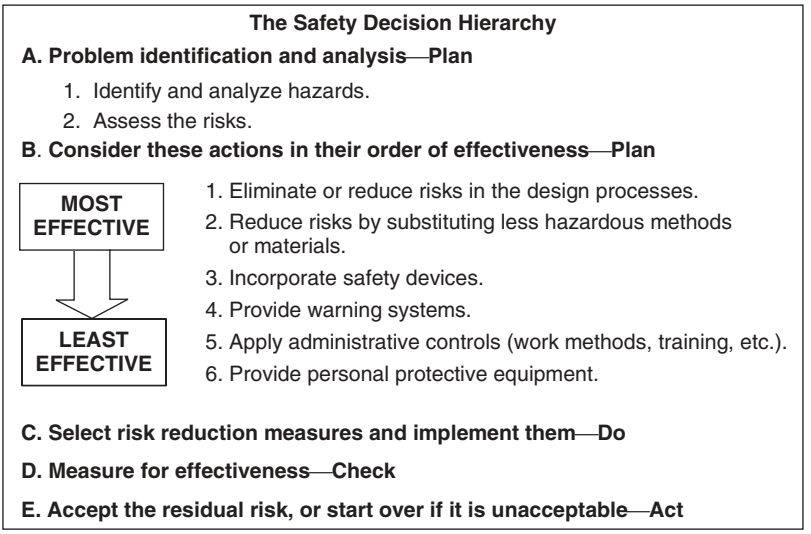

FIGURE 1

Rational Manager, reflecting the real-world observations of Kepner and Tregoe in advising many clients, makes the case:

> The most effective managers, from the announcement of a problem until its resolution, appeared to follow a clear formula in both the orderly sequence and the quality of their questions and actions.

It makes sense to apply a safety decision hierarchy encompassing an orderly sequence of effectiveness to resolve safety issues.

ON PROBLEM IDENTIFICATION AND ANALYSIS

In applying The Safety Decision Hierarchy, the goal in the problem identification and analysis phase is to identify and analyze the hazards and assess the risks. Hazard and risk problems cannot be intelligently addressed until the hazards are analyzed and assessments are made of the probability of incidents or exposures occurring and the possible severity of their consequences. Chapter 8, "A Primer on Hazard Analysis and Risk Assessment," is a resource for this problem identification and analysis phase.

EXPLORING ALTERNATIVE SOLUTIONS

The action steps shown in the section of The Safety Decision Hierarchy titled "Consider These Actions, in Their Order of Effectiveness" provide a basis for

considering alternate risk elimination or reduction measures. They are similar to items A through F in the "preferred order of controls" outlined in Section 5.1.1, "Hierarchy of Controls," in Z10. The logic in support of those steps and the order in which they are listed was given previously in this chapter.

DECIDING AND TAKING ACTION

All facets of the safety decision hierarchy apply when considering the hazards and risks in a specific facility, process, system, piece of equipment, or a tool in its simplest form. Also, they are broadly applicable in all three major aspects of the practice of safety:

- In the design processes, preoperational, where the opportunities are greatest and the costs are lower for hazard avoidance, elimination, or control
- In the operational mode where, integrated within a continual improvement process, hazards are eliminated or controlled, before their potentials are realized and hazards-related incidents or exposures occur
- Post incident, through investigation of hazards-related incidents and exposures to determine and eliminate or control their causal factors

MEASURING FOR EFFECTIVENESS

Provisions in Section 7.1 of Z10, "Management Review Process," require that systems be in place to measure the effectiveness of the risk reduction measures taken. Those provisions are relative to the measurement of effectiveness and re-analyzing steps in The Safety Decision Hierarchy. Assuring that the actions taken accomplish what was intended is an integral step in the PDCA process. Followup activity would determine that the:

- Problem was resolved, only partially resolved, or not resolved.
- Actions taken did or did not create new hazards.

ACCEPT THE RESIDUAL RISK, OR START OVER IF IT IS UNACCEPTABLE

If the followup activity indicates that the residual risk is not acceptable, the thought process set forth in the safety decision hierarchy would again be applied, commencing with hazard identification and analysis.

HADDON'S UNWANTED ENERGY RELEASE CONCEPT

Dr. William Haddon was the first director of the National Highway Safety Bureau. He was the originator of the unwanted energy release theory. Haddon's concept is that unwanted transfers of energy can be harmful (and wasteful) and that a systematic approach to limiting the possibility of their occurrence should be taken. His work is considered seminal.

Although Haddon stated in "On the Escape of Tigers: An Ecologic Note" that "the concern here is the reduction of damage produced by energy transfer," he also asserted that "the type of categorization here is similar to those used for dealing systematically with other environmental problems and their ecology." These excerpts are from Haddon's breakthrough paper:

> A major class of ecologic phenomena involves the transfer of energy in such ways and amounts, and at such rapid rates, that inanimate or animate structures are damaged. Several strategies, in one mix or another, are available for reducing the human and economic losses that make this class of phenomena of social concern. In their logical sequence, they are as follows:
>
> - prevent the marshaling of the form of energy;
> - reduce the amount of energy marshaled;
> - prevent the release of the energy;
> - modify the rate or spatial distribution of release of the energy from its source;
> - separate, in space or time, the energy being released from that which is susceptible to harm or damage;
> - separate, by interposing a material barrier (the energy released from that which is susceptible to harm or damage);
> - modify appropriately the contact surface, subsurface, or basic structure, as in eliminating, rounding, and softening corners, edges, and points with which people can, and therefore sooner or later do, come in contact;
> - strengthen the structure, living or non-living, that might otherwise be damaged by the energy transfer;
> - move rapidly in detection and evaluation of damage that has occurred or is occurring, and counter its continuation or extension; and
> - after the emergency period following the damaging energy exchange, stabilize the process.

All hazards are not addressed by the unwanted energy release concept. Such examples are the potential for asphyxiation from entering a confined space filled with inert gas, or inhalation of asbestos fibers. However, all hazards do fall within a goal that is to avoid both unwanted energy releases and exposures to hazardous environments.

Keeping Haddon's unwanted energy release concept in mind will be particularly beneficial as managements, supervisors, engineers, designers, and safety professionals

consider applying these Z10 provisions: hierarchy of controls; design reviews; management of change; risk assessments; and including safety specifications in purchasing and acquisition papers.

To provide guidance to those applying The Safety Decision Hierarchy, we here reproduce "General Design Requirements: A Thought Process for Hazard Avoidance, Elimination, or Control," as it appeared in our earlier *On The Practice Of Safety*. This guideline is my extension of the incident and exposure prevention aspects of Haddon's work.

The Guideline gives advice on designing the workplace and the work methods. It addresses nine major subjects. Haddon listed 10 strategies, one of which is divided here into two parts, becoming items 2 and 3. Haddon's last two subjects pertain to recovery actions to be taken after an incident occurs. They relate to the Emergency Preparedness provisions in Section 5.1.5 of Z10 and are not addressed in this chapter. In no way is it suggested that my guideline addresses all hazard and risk elimination or amelioration possibilities. It can be helpful as a reference and as a teaching tool.

General Design Requirements: A Thought Process for Hazard Avoidance, Elimination, or Control

1. Avoid introduction of the hazard: Prevent buildup of the form of energy or hazardous materials.
    - Avoid producing or manufacturing the energy or the hazardous material
    - Use material handling equipment rather than manual means
    - Don't elevate persons or objects
2. Limit the amount of energy or hazardous material.
    - Seek ways to reduce actual or potential energy input
    - Use the minimum energy or material for the task (voltage, pressure, chemicals, fuel storage, heights)
    - Consider smaller weights in material handling
    - Store hazardous materials in smaller containers
    - Remove unneeded objects from overhead surfaces
3. Substitute, using the less hazardous.
    - Substitute a safer substance for a more hazardous one: when hazardous materials must be used, select those with the least risk throughout the life cycle of the system
    - Replace hazardous operations with less hazardous operations
    - Use designs needing less maintenance
    - Use designs that are easier to maintain, considering human factors
4. Prevent unwanted energy or hazardous material buildup.
    - Provide appropriate signals and controls
    - Use regulators, governors, and limit controls
    - Provide the required redundancy
    - Control accumulation of dusts, vapors, mists, etc.
    - Minimize storage to prevent excessive energy or hazardous material buildup

- Reduce operating speed (processes, equipment, vehicles)

5. Prevent unwanted energy or hazardous material release.
   - Design containment vessels, structures, elevators, material handling equipment to appropriate safety factors
   - Consider the unexpected in the design process, to include avoiding the wrong input
   - Protect stored energy and hazardous material from possible shock
   - Provide fail-safe interlocks on equipment, doors, valves
   - Install railings on elevations
   - Provide non-slip working surfaces
   - Control traffic to avoid collisions
6. Slow down the release of energy or hazardous material.
   - Provide safety and bleed-off valves
   - Reduce the burning rate (using an inhibitor)
   - Reduce road grade
   - Provide error-forgiving road margins
7. Separate in space or time, or both, the release of energy or hazardous materials from that which is exposed to harm.
   - Isolate hazardous substances, components, and operations from other activities, areas, and incompatible materials, as well as from personnel
   - Locate equipment so that access during operations, maintenance, repair, or adjustment minimizes personnel exposure (e.g., hazardous chemicals, high voltage, electromagnetic radiation, cutting edges)
   - Arrange remote controls for hazardous operations
   - Eliminate two-way traffic
   - Separate vehicle from pedestrian traffic
   - Provide warning systems and time delays
8. Interpose barriers to protect the people, property, or the environment exposed to an unwanted energy or hazardous material release.
   - Insulation on electrical wiring
   - Guards on machines, enclosures, fences
   - Shock absorbers
   - Personal protective equipment
   - Directed venting
   - Walls and shields
   - Noise controls
   - Safety nets
9. Modify the shock concentrating surfaces.
   - Padding on low overheads
   - Rounded corners
   - Ergonomically designed tools
   - "Soft" areas under playground equipment

CONCLUSION

The hierarchy of controls in Z10 derives from work that has evolved over many years. It is a state-of-the-art and technically sound presentation. As management "implement(s) and maintain(s) a process for achieving feasible risk reduction," the hierarchy presents the actions to be considered in a logical order.

Encompassing a hierarchy of controls within a sound problem-solving technique furthers the ability of management and safety professionals to achieve effective risk reduction, and to meet the requirements of certain provisions in Z10. Adopting well-established problem-solving techniques to address hazard and risk situations is a fundamentally sound approach. That is the purpose of The Safety Decision Hierarchy.

REFERENCES

Accident Prevention Manual, 3rd ed. Itasca, IL: National Safety Council, 1955.

ANSI/AIHA Z10-2005. Occupational Health and Safety Management Systems Standard. Fairfax, VA: American Industrial Hygiene Association, 2005. Also available at, http://www.aiha.org/marketplace.htm.

ANSI/PMMI B155.1-2006. Safety Requirements for Packaging Machinery and Packaging—Related Converting Machinery Standard. Arlington, VA: Packaging Machinery Manufacturers Institute, 2006.

ANSI/RIA R15.06-1999. American National Standard for Industrial Robots and Robot Systems—Safety Requirements. Ann Arbor, MI: Robotics Industries Association, 1999.

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

Haddon, William J., Jr. "On the Escape of Tigers: An Ecological Note." *Technology Review*, May 1970.

Kepner, Charles H., and Benjamin B. Tregoe. *The New Rational Manager*. Princeton, NJ: Princeton Research Press, 1981.

Manuele, Fred A. "Achieving Risk Reduction, Effectively." *Process Safety and Environmental Protection*, May 2006.

Manuele, Fred A. *Innovations in Safety Management: Addressing Career Knowledge Needs*. Hoboken, NJ: John Wiley & Sons, 2001.

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

Manuele, Fred A. "Risk Assessment and Hierarchies of control." *Professional Safety*, May 2005.

MIL-STD-882D. Military Standard System Safety Program Requirements. Washington, DC: Department of Defense, 2000.

NFPA 101. Life Safety Code. Quincy, MA: National Fire Protection Association, 2006.

CHAPTER 13

SAFETY DESIGN REVIEWS — SECTION 5.1.2

INTRODUCTION

Requirements for Design Review and Management of Change are addressed jointly in one Part of Z10, Section 5.1.2. Although the subjects are interrelated, each has its own importance and uniqueness. Comments on the Management of Change concept and how to institute the management of change process are provided separately in the next chapter.

This chapter is devoted to design reviews only. Z10 requires that processes be in place to conduct design reviews to avoid bringing hazards into the workplace. Design reviews are to be made for new or modified equipment, technology, and design specifications; for new or revised procedures and work practices; and when new or revised safety and health standards are issued.

Having written and stressed that the most effective and economical way to minimize risks is to have the hazards from which they derive addressed in the design process, I commend the drafters of Z10 for including the safety design review provisions in the standard. If it becomes the norm for employers to include these provisions in their safety and health management systems, injuries and illnesses will be substantially reduced.

In a few entities, written procedures establish that safety professionals have a specified responsibility in capital expenditure proposal reviews, project design reviews, writing purchasing specifications for new equipment, and for signing off

Advanced Safety Management Focusing on Z10 and Serious Injury Prevention, by Fred A. Manuele

on new or altered equipment before it can be placed in operation. In other entities, such procedures are not documented but followed because safety professionals have been successful in convincing engineering personnel that their counsel can provide added value. In either case, safety professionals developed an expertise from which they could demonstrate meaningful participation and contribution.

The methods used to avoid bringing hazards and risks into the workplace will be broadly discussed here, with the hope that safety professionals can adopt from the materials presented to their advantage. To assist in applying the Z10 design review provisions, this chapter includes:

- A review of safety through design concepts and procedures
- Comments on how some safety professionals are engaged in activities that lessen the probability of hazards and risks being brought into the workplace
- A review of the procedures the auto industry and the United Auto Workers (UAW) have established for hazard and risk avoidance in the design process—for its significance and broad influence
- An edited composite of procedures in place in several companies to achieve hazard avoidance and control in the design process, and procedures to be followed before modified equipment is released for operation
- A general checklist as a reference from which a specifically tailored checklist can be developed for use in design reviews, and for equipment acceptance
- A company's equipment design philosophy as a model

SAFETY THROUGH DESIGN

The book *Safety Through Design* was the creation of the Institute for Safety Through Design, an entity at the National Safety Council (NSC). The Institute's vision was to achieve a future in which "Safety, health, and environmental considerations are integrated into the design and development of systems meant for human use." An advisory committee, the members of which were drawn from industry, organized labor, and academia, and others interested in the cause, agreed on the following definition for safety through design:

> The integration of hazard analysis and risk assessment methods early in the design and engineering stages and taking the actions necessary so that risks of injury or damage are at an acceptable level.

That definition serves well in developing an understanding of the Design Review requirements in Z10. The theme of *Safety Through Design* is that if decisions affecting safety, health, and the environment are integrated into the early stages of the design process:

- Productivity will be improved
- Operating costs will be reduced

- Expensive retrofitting to correct design shortcomings will be avoided
- Significant reductions in injuries, illnesses, and damage to the environment, and their attendant costs, will be achieved.

We also recognized the cost savings and the superior safety level that resulted from applying safety through design principles, as in the following:

> Hazards and the risks that derive from them are most effectively and economically avoided, eliminated, or controlled if they are considered early in the design process, and where necessary as the design progresses.

All of the foregoing derives from the following premises. Risks of injury derive from hazards. If hazards are addressed and eliminated or controlled in the design process so that the risks deriving from them are acceptable, the potential for harm or damage and operational waste is diminished. These premises tie in neatly with the reference in Z10 to addressing occupational health and safety management system issues, which are defined as "hazards, risks, management system deficiencies, and opportunities for improvement."

THE SAFETY DESIGN REVIEW PROCESS

A safety design review process will not be effective until the participants in the review team have acquired knowledge of hazards and risks and agreed on the risk assessment methods and risk assessment matrix to be used. Chapter 7, "A Primer on Hazard Analysis and Risk Assessment," serves as a basis for the education of team members. Also, a safety design review process can be successfully applied only if senior management has been convinced of its value.

Chapter 13 in *Safety Through Design* was written by Dr. Paul S. Adams, senior safety engineer and ergonomist at Applied Safety & Ergonomics. It commences as follows: "This chapter describes a process for integrating safety into the design process that is being implemented and used in a major manufacturing company." His updated comments on the safety design review process appear here with his permission.

> **The Safety Design Review Process**
>
> Formal safety design reviews may sound like tedious exercises, but they are effective processes for delivering inherently safer designs. Design reviews are systematic processes for carefully reviewing design attributes, applications, misapplications, energy control systems, and human interactions. Safety design reviews attempt to identify hazards and hazardous conditions that are foreseeable throughout the lifecycle of a product or process, and to develop mitigation strategies.
>
> In most cases, a design review is best conducted by a team comprised of stakeholders and at least one objective, disinterested engineer. Typical participants include representatives from Engineering, Production, Maintenance, and Health and Safety.

Both the system designer(s) and the review team share responsibility for the safety of the final design.

Safety design reviews should be approached as important problem-solving events. A spirit of cooperation, and even fun, can be maintained by restricting criticism to constructive debate on specific design features. Although the focus should always be on safety, review teams frequently identify additional opportunities to reduce costs and improve productivity. Constructability and maintainability issues often surface, and these alone can pay huge dividends for the comparatively short time invested in reviewing a project. While it is the role of the facilitator to assure that these topics do not derail or compromise the safety focus, such opportunities should obviously be captured as value-added by-products. Review sessions also provide some of the best possible training for both novice and experienced engineers, as collective knowledge and experience are openly shared.

A common approach for conducting a formal design safety review is to methodically work through a Design Safety Checklist. Some organizations use a generic checklist, supplemented with additional checklists for specific disciplines, such as electrical or chemical systems. For each system element, reviewers address the various forms of energy present and the steps taken to control unwanted or hazardous release.

A typical design safety review meeting proceeds as follows:

1. Project manager distributes drawings and copies of checklists.
2. Review team chooses a facilitator, often a disinterested engineer; i.e., an engineer not assigned to or intimately familiar with the project.
3. Project engineer/manager describes the project and its scope, and answers general questions about major areas of concern.
4. Project engineer/manager keeps notes; a.k.a. design punch list.
5. Facilitator leads a methodical review using a generic checklist, with team members asking detailed questions to ensure thorough consideration of hazards and their control. Checklist items and sections that are not applicable are so noted.
6. Additional discipline checklists are reviewed as appropriate.
7. A marked up copy of the checklists, along with signatures of the participants, is retained with project documents.

Specific deliverables from a design review typically include:

- A set of marked-up drawings and specifications.
- A list of design modifications requiring attention prior to release for bid or construction/fabrication.
- A list of specific items to be checked during installation and the final walk-down or post-fabrication inspection. (There are often items identified as potentially problematic that cannot be adequately assessed at the time of the review due to lack of detailed knowledge.)
- Assignments for resolving specific details or making design corrections.

Following the review, it is the responsibility of the project engineer/manager to follow up and ensure that all issues raised during the design safety review are resolved and appropriate revisions are completed. Verification through a post-construction/fabrication inspection should be completed prior to release of the product or system.

That is what a design safety review is all about. Done well, such reviews diminish the likelihood of bringing hazards and risks into the workplace. Having the right facilitator is important in the design review process. In one company, it is standard practice to engage a consultant facilitator to lead safety design reviews to assure that one individual's views do not dominate and that all participants are given an opportunity to be heard.

EMPHASIZING CONSIDERATION OF THE WORK METHODS IN THE DESIGN PROCESS

Much was made in Chapter 12, "Hierarchy of Controls: The Safety Decision Hierarchy," of the need to design work methods so that they were not error-provocative or overly stressful. Safety design reviews should not be limited to the facility, equipment, and processes, that is—the hardware. They should also limit the hazards and risks in the work methods prescribed, taking into consideration the capabilities and limitations of the workers so that the risks of injury and damage are at a practicable minimum.

I quote from a paper by Roy Brander titled "The Titanic and Risk Management." Brander writes this: "Safe design of the procedure is as important as design of the artifact." His point is important. It corresponds closely with my observation that, too often, inadequate attention is given to the hazards in the work methods, the result being that what the workers are expected to do is inherently risky.

HOW SOME SAFETY PROFESSIONALS ARE ENGAGED IN THE DESIGN PROCESS

To obtain information on how safety professionals are involved in activities to avoid bringing hazards and risks into the workplace, a request for comments on the subject was made through an Internet safety server. Here are some of the responses, the most unfortunate listed first. As they are reviewed, safety professionals may want to assess their place in the design process and look for hints on how they can improve their positions.

- From an industrial hygienist: "If the engineers would only let me into the design process, I know that many of the health hazards I deal with could be better controlled, we wouldn't need to do so much testing, and our operations would be more productive because we would reduce the amount of time employees spend on testing and on personal protective equipment usage."
- "We don't have any forms or established procedures for our getting into what engineers are designing, and there is no formal method for engineering to notify us of a project. We do get copies of the engineering weekly reports, and we read those carefully. Then, we invite ourselves into the discussion."

- "There was a lot of resistance by engineering to our getting into what they were designing because they had not recognized that we could be an asset. It took us a long time and quite a few money-saving successes to get it ingrained into their procedures that it was to their benefit to refer capital expenditure requests to us for our input. We don't have a written procedure, but it gets done."
- "Almost all of our engineering is done by outside firms. I haven't been successful in convincing the few engineers we have left that I can help them write specifications that will save them money. But I have convinced the manager of my plant that I am to have sign-off authority for new installations. My sign-off reviews can be embarrassing to the people who laid out the specs and I have to be very diplomatic in how I do what I need to do. But the plant manager gives me support now. He has been educated."
- This from a construction safety professional: "I request to see all drawings at the 10% level while changes are still easily incorporated. I get a schedule of all construction plans and visit contractor lay-down areas to inspect materials being used on the job. I attempt to educate quality assurance personnel on what to look for as safety indicators. I visit the engineering department and the contracting department on a daily basis when I'm in town. Yes, it is time-consuming but it saves money and lives as well as equipment. It took maximum effort on my part to get where I am."
- "In my company, it's in the capital expenditure procedure manual that all funding requests will receive a safety review. Managers have the same responsibility for safety as they do for productivity and quality, and when they approve the capital expenditure request, they are also signing off for safety. But, my name appears on the capital expenditure distribution list among the management people who have to sign off as approving the request. This isn't as burdensome as it was in the beginning because I have educated a fairly stable engineering and management staff on what it takes to get my approval."
- "Through our successes in ergonomics, engineering recognized our contributions not only for safety, but also for productivity. They now invite us into the design process in the idea stage. They make it plain that they look to us to see that they don't mess up. We learned the hard way over a lot of years that it is expensive to correct hazards that are in the machines and equipment we buy. We had to do some costly equipment modifications for employee safety and health, and for environmental situations after the installations were completed and in operation. Our engineers aren't easy on us. But that's okay. We had to accept the criticism from them that our ergonomics checklists were so general that they weren't helpful."
- "Our Facility Safety Manual includes extensive procedures for documented reviews for safety, health, environmental, and ergonomic standards before budget approval is obtained on a new project, and for equipment reviews before the equipment is released to normal production. As you will see from what I'm mailing to you, we are deep into specifications, and the signature of a safety specialist is required in the project and budget review procedures."

The involvement of safety professionals in the design processes, specification writing, purchasing, and sign-off processes varies from nothing to being required by written procedures. In all but one of the cases cited, there is some involvement by safety professionals. And, that came about because they took the initiative and proved their value.

A GOOD PLACE TO START

Safety professionals who are not involved in the design processes should consider ergonomics as fertile ground in which to get started. It is well established that successful ergonomics applications result not only in risk reduction, but also in improved productivity, lower costs, and waste reduction. Furthermore, musculoskeletal injuries represent a large segment of the spectrum of injuries and illnesses in all organizations. Since they are costly, reducing their frequency and severity will yield notable results.

Ergonomists know how to write specifications that result in the design of the workplace and work methods to fit the capabilities and limitations of workers. One company that has established detailed ergonomics design criteria is DaimlerChrysler. How their design criteria are used demonstrates that a close relationship exists between establishing safety design parameters and including safety specifications in purchasing documents. This is how the DaimlerChrysler Ergonomic Design Criteria are introduced:

> This document attempts to integrate new technology around the human infrastructure by providing uniform ergonomic design criteria for DaimlerChrysler's manufacturing, assembly, power train and components operations, as well as part distribution centers. These criteria supply distinct specifications for the Corporation, to be used by all DaimlerChrysler engineers, designers, builders, vendors, suppliers, contractors, etc. providing new or refurbished/rebuilt materials, services, tools, processes, facilities, task designs, packaging and product components to DaimlerChrysler.

In effect, the *Ergonomic Design Criteria* used internally at DaimlerChrysler also become the ergonomic specifications that vendors and suppliers are to meet. In the "Supplier Roles and Responsibilities" it is made clear that all suppliers are to "make all reasonable efforts to implement all of the criteria and requirements" of the *Ergonomic Design Criteria*. If a requirement is compromised, the supplier must inform DaimlerChrysler and the matter is reviewed to a conclusion by a DaimlerChrysler ergonomics representative.

DaimlerChrysler has given permission for its *Ergonomic Design Criteria* to appear in this book. Since the Criteria also serve as purchasing specifications and since examples of safety specifications being included in purchase orders and contracts are not easily acquired, the Criteria appear as an Addendum to Chapter 15, "The Procurement Process."

Taking into consideration what is now known about ergonomic design specifications, it is incomprehensible that employers continue to purchase equipment that is not ergonomically designed.

An example of how another company developed extensive General Design and Purchasing Guidelines that serve both as design requirements to be met by its engineering staff and as the company's purchasing specifications also appears as an addendum to the chapter on Procurement. My searching revealed that most companies consider their design and purchasing criteria to be proprietary and not distributable. However, one such document that includes general design parameters is in the public domain and can be cited here.

DECEMBER 2005 DRAFT OF MIL-STD-882E

Mention was made in Chapter 9, "Including Risk Assessment Provisions in Standards and Guidelines: A Trend," of a December 2005 draft of MIL-STD-882E, the Department of Defense's Standard Practice for System Safety. (The draft is a work in progress.) Item A.10 in its Appendix A is titled "Example Safety Design Requirements." A brief version of it is given here. It promotes thinking about, and gives guidance on, writing design specifications to fit the needs of a particular entity.

Example Safety Design Requirements

1. Hazardous material use is to be eliminated or minimized. After considering material selection and substitution of lesser hazardous materials, the remaining risks are to be reduced in the design process.
2. Hazardous substances, components, and operations are to be isolated from other activities, areas, personnel, and incompatible materials.
3. Equipment is to be located so that access during operations, servicing, repair, or adjustment minimizes personnel exposure to hazards (e.g., hazardous substances, high voltage, electromagnetic radiation, and cutting and puncturing surfaces).
4. Power sources, controls, and critical components of redundant subsystems are to be protected by physical separation or shielding, or by other acceptable methods.
5. For hazards that cannot be eliminated, consideration is to be given to safety devices that will minimize mishap risk (e.g., interlocks, redundancy, fail safe design, system protection, fire suppression, and protective measures such as clothing, equipment, devices, and procedures).
6. Provisions for the disposal of systems are to be considered in the design process.
7. Warning signals are to be standardized within like types of systems: they are to be designed to minimize the probability of incorrect personnel reaction to them.
8. Warning and cautionary notes are to be provided in assembly, operation, and maintenance instructions; and distinctive markings are to be provided on hazardous components, equipment, and facilities to ensure personnel and equipment protection when no alternate design approach can eliminate a hazard. Use standard warning and cautionary notations where multiple applications occur. Standardize notations in accordance with commonly accepted commercial practice. Warnings, cautions, or other written advisories are not to be used as the only risk reduction method for hazards assigned Catastrophic or Critical mishap severity categories.
9. If safety critical tasks require personnel to have specific proficiency, a certification process for that proficiency should be used.

10. In the design process, specific consideration should be given to the minimization of injury or damage to equipment or the environment as a result of a mishap.
11. Inadequate or overly restrictive safety requirements are not to be included the system design specifications.
12. Acceptable risk is mishap risk that is as low as reasonably practicable (ALARP) within the constraints of operational effectiveness, time, and cost.

Although the foregoing outline does not take up much space, it represents an extensive body of knowledge. The outline is basic and "right on."

A General Design Safety Checklist is provided later on in this chapter. Also, several other design guidelines and checklists that can be adapted for design review purposes appear in this book, such as the "General Design Requirements: A Thought Process for Hazard Avoidance, Elimination, or Control" that was provided in Chapter 12 as a reference in applying the hierarchy of controls.

AUTO INDUSTRY/UAW SAFETY DESIGN CONCEPTS AND THEIR IMPLICATIONS

The following excerpts are from a General Motors/United Auto Workers labor agreement. Similar wording appears in contracts with other automakers. Why cite this agreement? It outlines methods that serve to avoid bringing hazards and risks into the workplace. The agreed upon concepts begin with the design process and extend to the involvement of safety professionals at the plant level:

> . . . As early as possible and preferably in the zero phase of the planning in the design process . . . the parties agree to perform Task Based Risk Assessments on new equipment and manufacturing systems, and on existing equipment and manufacturing systems where locally agreed to and approved by the Plant Safety Review Board. A Task Based Risk Assessment will be performed after the detailed designs are completed. . . . A review of anticipated equipment and/or processes with the shop committee and the Local Joint Health and Safety Committee will be held.
>
> The local Joint Health and Safety Committee may be required to travel to vendors, plants, or other locations to participate in a Design Review of such equipment or processes as outlined in the Design for Health and Safety Specification. Machinery, equipment or processes will not be released for production without the written approval of the Plant Safety Administrator.

In summary, this agreement presents a near theoretical ideal. It indicates that:

- Design specifications for safety and health are in place
- Risk assessments are made as early as possible in the design phase
- Risk assessments are made on existing equipment
- Safety and health professionals visit vendor locations for design reviews
- Operation of machinery, equipment, or processes requires written approval by safety personnel before release into production

These provisions impact greatly on safety at GM locations, on the standards to be met by firms engaged by GM to do design and engineering, and on the vendors of equipment supplied to GM. They also expand the knowledge and skill requirements of safety professionals. A specification document sets forth the requirements for the design and redesign of equipment and systems to achieve a safe operating environment. This document requires that:

- Task-based risk assessments be made in the design process when new programs are initiated.
- A safety buy-off be performed before a builder or fabricator of equipment or systems ships equipment.
- A multidiscipline validation team assures that the desired level of safety has been met when the equipment or process is installed, using safety checklists and the task-based risk assessment summary—all to provide another look at the production system to verify that nothing has been missed.
- Task-based risk assessments be made of existing equipment, as directed by the Plant Safety Review Board.

How the System Works at a Plant Location

GM had undertaken a major "model change" on an auto production line at its Fairfax Assembly Plant located in Kansas City, Kansas. Dwayne Dunsmore, safety supervisor, representing GM, and Edward A. Neal, safety representative, representing the UAW, were very much involved. Together, Dunsmore and Neal have had about 80 years of experience in the auto industry.

They have observed the positive effects of safe tool and equipment design, construction, and installation on the cost of doing business as well as on the reduction of injuries and illnesses. The following is part of their analysis:

> **On the Prevention of Serious Injuries by Utilization of Design Reviews Prior to Build, and Sign-off Requirements at Various Stages of Build**
>
> For the major operational changes to be made at the Fairfax facility, extensive safety design specifications were established early on by the National Joint Parties, Health and Safety UAW/GM. These design specifications, including design reviews and stage buy off were jointly developed and implemented. It was understood that GM engineers, contract engineering firms, and build shops were obligated to comply with them.
>
> Safety design reviews were conducted from the very beginning of the process. These design reviews were part and parcel of the process. Local Joint Health and Safety Committee members and Ergonomics personnel participated in the reviews from the beginning at the concept stage. Plant engineers, industrial engineers, vendors and UAW workers, experienced in the process being designed, were included as needed. GM and UAW personnel recognized many years ago the need for good safety design reviews to be made early in the design development process so that a higher safety level could be achieved and the great expense of retrofitting could be avoided.

Risk assessment tools designed by UAW/GM were used during the safety design reviews. Open issues, arising from GM or UAW observations, were followed through to a satisfactory conclusion. During the safety design reviews, Excel spreadsheets were used to check compliance with safety design specifications and to track tasks and hazards. The risk management process depended on detailed safety design analysis and task-based risk assessments (TABRAs). The Hierarchy of Safety Controls was vigorously applied to reduce or eliminate risks with emphasis on elimination of the risk.

Crucial to the success of the UAW-GM joint process was the inclusion of the hourly skilled trades and production personnel, who were extensively involved in the task-based risk assessments. This involvement was based on the premise that the person who does a job every day has intimate knowledge of it and can make meaningful contributions on how a job or process can be changed to make it safer. (The TABRA process has matured: now, internally developed computer-based software is used in the safety design review process and for recordkeeping.)

GM and UAW safety personnel had the responsibility to perform a safety "Buy off" on equipment at the vendor's place of business. Their purpose was to validate that the vendor was meeting the safety design specifications in the equipment being built. Implementation of this process drove compliance in the early design stages.

Plant Health and Safety and Ergonomics personnel were sent to build shops about fifty times for visits for one production build program. Individual vendors were visited an average of three times to resolve safety issues on the equipment they were building. It was necessary to visit some vendors as many as eight times to reach resolution on safety design issues. Some vendors and engineers were obviously more "switched on" or cooperative than others.

Validation with respect to meeting safety design specifications was also performed after equipment was installed in the auto assembly plant. Even with the rigid controls in place during the design process and the validations made at vendor locations, a number of safety issues arose during the validation process after tools were installed on the plant floor and integrated with other equipment, existing or new.

We don't want to create the impression that getting to the stage of effectiveness described here on establishing safety design specifications, conducting safety design reviews and making risk assessments was easily accomplished. Implementation of the processes several years ago met with resistance from some engineers and some equipment manufacturers. Some of this resistance may have been based on the pride designers or tool builders have regarding their work. Some resistance may have been based on lack of safety knowledge. (Neal asked a Professor at a major university who headed the Engineering Department, "How many safety specific hours were required in the curricula." The answer was "None.")

We came to the conclusion that engineers and build shop personnel are not bad people. They just need a lot of help along the way. They need to learn how to design and build equipment in a fashion that reduces the likelihood of personal injury, illness or death.

It is not suggested that by following the procedures just previously recorded that the system will work perfectly. However, if what is written in the auto industry/UAW contracts became the norm throughout all of U.S. business, a giant step

forward will have been taken for worker safety. Safety professionals who are looking for additional ideas may find them in these agreements and the procedures put in place to implement them. Although the reference here is to a union-employer contract, the concepts and methods defined are universally applicable and compatible with the emerging emphasis on safety through design.

A SAFETY DESIGN REVIEW AND OPERATIONS REQUIREMENTS GUIDE

A composite is provided here of the procedures in place in three companies for design reviews and for a safety sign-off before new or modified equipment can be released into normal operations. These procedures serve to avoid bringing hazards and risks into the workplace. In a way, these requirements represent culture statements: Managements have decided that hazards and risks are to be dealt with as equipment is designed, and before it can be placed in operation. This composite presents a basis for thought as safety professional pursue the adoption of similar concepts and procedures.

Requirements: Equipment and Process Design Safety Reviews

A. Purpose To establish procedures to ensure that hazards are analyzed and that risks are at an acceptable level when considering new, redesigned, and relocated equipment or processes.

B. Scope These procedures apply to all equipment and processes that may present risks of injury to people or damage to property or the environment. They pertain to the design or redesign of all new, transferred, and relocated equipment and processes. For all aspects of these procedures, documentation shall be appropriate to the activity.

> Safety, as the term is used here, encompasses risks of injury or damage to personnel (employees and the public), property, and the environment.

C. Responsibilities

Location Manager The ultimate responsibility for safety rests with the location manager.

Project Manager The project manager is responsible for assuring that:

- Corporate safety requirements are met
- Safety documentation to accompany capital expenditure requests is prepared
- Preliminary and subsequent design safety reviews are conducted

- Appropriate coordination and communication take place with outside design and engineering firms to assure that specifications are met
- Proper consideration is given to any safety problems identified by the staff during their visits to vendors and design and engineering firms prior to delivery of equipment

Design Engineers The principle responsibility of design engineers is to design inherently safer equipment and processes. Whether employees or contractors, design engineers shall assure that the considerations necessary for safety have been outlined during the design process. They will provide the Project Manager and the Safety Review Team with documentation, including:

- Detailed equipment design drawings
- Equipment installation, operation, preventive maintenance, and test instructions
- Details of and documentation for codes and design specifications
- Requirements and information needed to establish regulatory permitting and/or registrations

Safety Review Team This team will conduct preliminary and subsequent design safety reviews for equipment and processes, or have design reviews made by outside consultants for particular needs. In addition to the Project Manager, members will include the project design engineers, production and maintenance personnel, the facilities engineer, selected disinterested engineers, the safety professional, and other personnel (from financial or purchasing) as needed.

The Safety Review Team will also be responsible for:

- Arranging and conducting safety walk-downs of new projects
- Determining when visits are to be made at vendor design and engineering locations, and selecting the personnel with the necessary skills to make the visit

Safety Professional The safety professional will:

- Serve as a member of the Safety Review Team and assist in identifying and evaluating hazards in the design process and provide counsel as to their avoidance, elimination, or control
- Visit design engineering firms and other vendors, when so requested by the Safety Review Team, to assure that safety problems are identified and corrected prior to shipment of equipment
- Be a signatory on an Equipment Acceptance–Safety Review Form (Figure 1) prior to newly installed or altered equipment or processes being released to normal production.

Equipment Acceptance–Safety review form

Dept._____ Control No._____

Equipment Description_____

This form must be completed prior to equipment being released to normal production. It is applicable to:

1. All newly installed equipment or processes
2. Changes made in the use of equipment or processes
3. Modifications of existing equipment or processes

Preliminary approval indicates that the equipment is ready for initial production trials, but needs additional work for safety as listed in a memo attachment titled "Safety Items Needing Attention." Final approval indicates that the preliminary findings have been addressed satisfactorily and that the equipment can be released to normal production.

	Preliminary	*Final*
Signed:_____	_____	_____
Engineer-in-charge	Date	Date
Signed:_____	_____	_____
Dept. Mgr. or Supervisor	Date	Date
Signed:_____	_____	_____
Safety Manager	Date	Date

The original copy of this form shall be retained by the Department Manager or Supervisor. The Engineer-in-charge and the Safety Manager will retain copies. The company's file retention policy shall apply.

FIGURE 1

Department Managers and Supervisory Personnel Department managers and supervisors will give support to the project manager for the activities that come under their jurisdiction. They will be signatories, along with engineering personnel and the safety professional, on sign-off forms before newly installed or altered equipment is released for normal operation.

D. Initial Capital Expenditure Safety Review Capital expenditure requests at financial levels requiring divisional or corporate approval must be accompanied by a Preliminary Safety Review, completed by the Safety Review Team and including as many of the subjects applicable as outlined in Table 1. Comments would be included giving assurance that the hazards and risks identified can be properly addressed.

For new or altered equipment, or processes at a financial level not requiring divisional or corporate approval, formal Preliminary Safety Reviews are to be made at the discretion of the Safety Review Team.

TABLE 1 Topics to Be Considered: Preliminary Design Safety Review

Ergonomics	Material handling
Machine guarding	Illumination needs
Fire protection	Means of egress
Walking and working surfaces	Confined spaces
Use of hoists, cranes, etc.	Work at heights
Electrical potentials	Lockout/tagout
Confined spaces	Temperature extremes
Hazardous or toxic materials	Noise or vibration
Personal protective equipment	Non-ionization emitters
Environmental concerns	Sanitation

E. Design Reviews When designs have been completed and drawings and specifications are available, the Safety Review Team will hold one or more design review meetings to:

- Identify hazards not given appropriate attention, and recommend solutions to attain acceptable risk levels
- Assure that corporate safety requirements are being met
- Avoid the cost of risk reduction retrofitting as the project moves forward
- Assure compliance with applicable regulations, codes, and standards

F. Safety Walk-Downs When a project reaches completion at an approximately 70% level, the Safety Review Team will arrange and conduct a safety walk-down to provide an opportunity to:

- Assure that specifications have been met
- Determine that hazards identified in the preliminary safety review and the subsequent design review have been properly addressed
- Identify hazards that may have been built inadvertently into the project, and to arrange for the necessary action to be taken

Similarly, a final safety walk-down will be arranged as the project nears completion.

H. Equipment and Process Release Requirements For newly purchased, redesigned, or relocated equipment or processes—before release for normal production:

- Task analyses shall be made to identify hazards and risks, and the hazards identified are to be properly dealt with

- Any revisions necessary in the written job procedures shall be made
- Retraining as required shall be given
- An Equipment Acceptance-Safety Review Form shall be completed, the signatories to which shall be the engineer-in-charge, the department manager or supervisor, and the safety professional

I. Design Reviews at Vendor and Design Engineering Locations When considered advantageous by the Safety Review Team, arrangements will be made for personnel with the appropriate skills to visit vendors and design engineering firms to:

- Assure that vendors are building equipment to specifications
- Determine whether hazards exist that were not identified in the design review process, or by the vendor or design engineering firm, which need attention
- Avoid the high cost of retrofitting for safety matters during installation, testing, and debugging

For these reviews, a specifically tailored Vendor/Design Engineering Review Form is to be created from sections of the General Design Safety Checklist appropriate to the task. Reports must be made available to the Safety Review Team and Project Manager.

EQUIPMENT ACCEPTANCE–SAFETY REVIEW FORMS

Drafting acceptance–safety review forms that are specific to every piece of equipment or process would be a mammoth undertaking. Nevertheless, industry-specific safety review checklists do exist and they should be used when applicable.

The example of an Equipment Acceptance–Safety Review Form shown in Figure 1 assumes the existence of a General Design Safety Checklist that can serve as a foundation for the review process. Also, the example presumes two levels of review: a preliminary review to identify items needing attention and a final sign-off.

PRELIMINARY SAFETY DESIGN REVIEW

A Preliminary Safety Design Review goes by several names. In one company, its purpose is to meet “Fitness for Use Criteria”. In another company, it is referred to as a “Hazards Screening Analysis”. A Preliminary Safety Review Form is a listing of subjects pertaining to equipment, facilities, or processes that aids reviewers in identifying hazards and risks that must be addressed. Completion of the form produces, in effect, an early design review. The review team indicates whether a subject needs further consideration. No one list is suitable for all needs. In drafting such a list, a safety professional will use the General Design Safety Checklist as a reference and include some, all, or more than the subjects listed in Table 1.

COMPOSITE GENERAL DESIGN SAFETY CHECKLIST

A detailed, specifically referenced design checklist covering all workplace safety needs would fill thousands of pages. The General Design Safety Checklist presented here is a brief composite derived from several sources. Some safety professionals will view it as excessive; others will find that it does not address all their needs. Those who use it as a reference should be aware that there are many subject-specific and industry-specific checklists to which they should also refer. For example:

- The *Guidelines for Hazard Evaluation Procedures*, Second Edition, issued by the Center for Chemical Process Safety, includes a checklist-questionnaire for chemical operations that fills 45 pages.
- The checklist in Addendum B at the conclusion of Chapter 8 is adapted from ISO 14121, the Safety of Machinery—Principles of Risk Assessment Standard. It is to serve as a guide for those who design and manufacture equipment and machinery that goes into European workplaces.

This General Design Safety Checklist is intentionally presented as a list of questions without the separating boxes and lines typical of most checklists. Also, the customay boxes to the right of a design checklist where users would enter checkmarks for "yes," "no," and "not applicable" have been eliminated.

General Design Safety Checklist

Preface This checklist begins with a preface that brings attention to Haddon's unwanted energy release theory, which modified and extended for workplace use, is this: For all injuries or illnesses, an unwanted and harmful transfer of energy or exposure to a harmful environment is a factor.

Dr. William Haddon espoused the theory that unwanted transfers of energy can be harmful (and wasteful) and that a systematic approach to limiting their possibility should be taken. Thus, it is proposed that "a systematic approach" be taken in the design process to limit harmful transfers of energy and exposures to harmful environments. Excerpts from "On the Escape of Tigers," one of Haddon's papers in which the energy release theory is presented, appear in Chapter 12, "Hierarchy of Controls: The Safety Decision Hierarchy."

The questions in Section A, "Introduction: Basic Considerations" relate to Haddon's theory and are presented as general concepts to be considered when using the checklist, for which yes or no answers are to be obtained. They emphasize that the two distinct aspects of risk are to be considered in the design process:

- Avoiding, eliminating, or reducing the *probability* of a hazards-related incident or exposure occurring
- Minimizing the *severity* of harm or damage if an incident occurs

A. Introduction: Basic Considerations

1. Can the production of hazardous materials or energy be eliminated?
2. Will the amount of the hazardous materials or energy be limited?
3. Can less hazardous materials be substituted?
4. Can hazardous material or energy buildup be prevented?
5. Can the release of hazardous materials or energy be slowed down?
6. Can unwanted energy release be separated in space or time from that which is susceptible to harm or damage?
7. Can barriers be interposed to separate unwanted energy release from that which is susceptible to harm or damage?
8. Will surfaces with which people come in contact be modified to reduce the risk of injury?

B. Designing for Those with Disabilities

1. Do the designs take into consideration the requirements of the Americans With Disabilities Act (ADA)?
2. Are reasonable accommodations made for the disabled?

C. Confined Spaces

1. Have confined spaces been eliminated by design when possible?
2. Do any confined spaces require a permit? Refer to 1910.146(c)(1).
3. Have confined spaces been designed for easy ingress, prompt egress, and, where possible, elimination of hazardous atmospheres?
4. Can confined spaces be designed with multiple, large accesses?
5. Are accesses provided with platforms that will support all required personnel and equipment?
6. Will access ports be large enough to permit entry when personnel are using personal protective equipment?
7. Will pipes or ducts limit entry to access ports?
8. Are the locations of ladders and scaffolds in the space identified?
9. Are fall protection needs fulfilled (such as anchorage points)?
10. Can the necessary equipment be moved through accesses?
11. Does the design provide for isolation of the confined space from hazardous energy (i.e., electrical, chemical, etc.)?
12. Does the design provide for isolation by valve blocking, spools, double blocks and bleeds, flanges, and flushing connections?
13. Can spaces be designed so that maintenance and inspection may be performed from outside or by self-cleaning systems?

D. Electrical Safety

1. Overall, will the electrical system meet OSHA/NEC standards?
2. Will the system be sufficiently flexible to allow for future expansion?
3. Will emergency power be provided for critical systems?
4. Is grounding adequate?
5. Are ground fault interrupter circuits to be installed where needed? Refer to 1910.304(f)(7).
6. Are grounding connections to piping and conduits eliminated to prevent accumulation of static electricity?
7. Is grounding provided for protection from lightning on all structures?
8. Are accommodations made for special-purpose or hazardous locations? Refer to 1910.307.
9. Is the design adequate where there may be combustible gases or vapors?
10. Is high-voltage equipment isolated by enclosures such as vaults, security fences, lockable doors, and gates?
11. Are nonisolated conductors such as bus bars on switchboards or high-voltage equipment connections that are located in accessible areas protected to minimize hazards for maintenance and inspection personnel?
12. Where injury to an operator may occur if motors were to restart after power failure, are provisions made to prevent automatic restarting upon restoration of power? Refer to 1910.262(c)(1).
13. Are electrical disconnect switches lockable, readily accessible, and labeled? Refer to 1910.303(f).
14. Are breakers/fuses properly sized? Refer to 1910.303(b).
15. Has the polarity of all circuits been checked? Refer to 1910.403(a)(2).
16. Do electrical cabinets and boxes have appropriate clearances? Refer to 1910.303(g) and (h).
17. Are exposed live electrical parts operating at 50 volts or more guarded against accidental contact by approved cabinets or enclosures, by location, or by limiting access to qualified persons? Refer to 1910.303(g)(2)(i).
18. Are rooms or enclosures containing live parts or conductors operating at over 600 volts, nominal, designed to be kept locked, or have provisions been made to keep them under the observation of a qualified person at all times? Refer to 1910.303(h)(2).
19. Are the electrical wiring and equipment located in hazardous (classified) locations intrinsically safe, approved for the hazardous location, or safe for the hazardous location? Refer to 1910.307(b)(1–3).

E. Emergency Safety Systems — Means of Egress

1. Are means of egress adequate in number, remote from each other, properly designated, marked, lighted, and easily recognized?

2. Has emergency lighting be provided for means of egress, and elsewhere where needed?
3. Does the design contemplate emergency lighting where workers may have to remain to shut down equipment?
4. Do means of egress exit directly to the street or open space?
5. Are doors, passageways, or stairways that do not lead to an exit marked by signs reading "not an exit" or by a sign indicating actual use?
6. Does the design provide internal refuge areas for workers who cannot escape?
7. Will reliable emergency power be provided for critical and life support systems?
8. Will emergency safety showers and eyewash stations be adequate and properly placed?
9. Will adequate first aid stations, spill carts, and emergency stations be provided?

F. Environmental Considerations (Some Are Operational, Beyond Design)

1. Have waste products been identified and a means of disposal established?
2. Will provisions be made for responding to chemical spills (containment, cleanup, disposal)?
3. Is there an existing spill control plan for chemicals?
4. Have all waste streams been identified?
5. Are adequate pretreatment facilities provided to process waste streams?
6. Will an adequate storage area be available for wastes held prior to treatment or disposal?
7. Will waste storage areas have adequate isolation or containment for spills?
8. Will hazardous wastes be disposed of at approved treatment, storage, and disposal facilities?
9. Is special equipment or specially trained personnel provided for treatment operations?
10. Has the acquisition of permits been addressed for the treatment or disposal of waste streams?
11. Have state or local requirements for permitting been evaluated and factored into the project?
12. Can the facility meet regulations for reporting spills or the storage of chemicals?
13. Have adequate provisions been made for cleaning the process equipment?
14. Have provisions been made for a catastrophic release of chemicals?
15. Have provisions been made for any necessary demolition and the resulting waste?

16. Have requirements for remediation at the site prior to construction been addressed?
17. Will all feasible measures for waste minimization be implemented?
18. Have the processes that generate air pollution been evaluated for minimization potential?
19. Will adequate air pollution controls be installed (scrubbers, fume hoods, dust collectors)?
20. Have the handling and cleaning of air pollution control systems been addressed?
21. Have the processes that generate wastewater been evaluated for minimization potential?
22. Will indoor spills be protected from reaching drains?
23. Will outdoor spills be protected from reaching storm water drains and sewer manholes?
24. Are adequate water disposal systems available?
25. Will pretreatment methods be necessary and provided?
26. Will the discharges of domestic and industrial wastewater be in accord with regulations?

G. Ergonomics — Work Station and Work Methods Design

1. Generally, have material handling designs considered worker capabilities and limitations, to accommodate the employee population at the 95% level?
2. Do material handling designs promote the use of mechanical material handling equipment, such as conveyors, cranes, hoists, scissor jacks, and drum carts?
3. Do design layouts minimize:
   a. constant lifting?
   b. twisting and turning of the back when moving an object?
   c. crouching, crawling, and kneeling?
   d. lifting objects from floor level?
   e. static muscle loading?
   f. finger pinch grips?
   g. work with elbows raised above waist level?
   h. twisting motions of hands, wrists, or elbows?
   i. hyper-extension or hyper-flexion of wrists?
   j. repetitive motion?
   k. awkward postures?
4. Are work stations designed to provide:
   a. adequate support for the back and legs?
   b. adjustable work surfaces that are easily manipulated?

   c. delivery bins and tables to accommodate height and reach limitations?
   d. work platforms that elevate and descend, as needed?
   e. powered assists and suspension devices to reduce the use of force?
5. Has adequate attention been given to:
   a. lighting (to Illuminating Engineering Society requirements)?
   b. heat?
   c. cold?
   d. noise?
   e. vibration?
6. Does the design accommodate the hazards inherent in servicing, maintenance, and inspection?
7. Will there be adequate clearance and ready access to equipment for servicing?
8. Will controls be efficiently located in a logical and sequential order?
9. Will indicators be easy to read, either by themselves, or in combination with others?

H. Fall Avoidance

1. Overall, has the design minimized the need for ladders and stairs?
2. Where works must be done at heights, has adequate consideration been given to providing work platforms or fixed ladders?
3. Are parapets or guardrails provided at roof edges?
4. Is the equipment designed to minimize fall hazards during maintenance, inspection, and cleaning?
5. Does the design provide for fall arrest measures, such as anchorage points and fall-restraining systems?

I. Fire Protection

1. Overall, in the design, will national and local fire codes, and insurance requirements be met?
2. Will fire pumps, water tanks/ponds, and fire hydrants be adequate?
3. Will risers and post valves be accessible and protected from damage?
4. Will small hose standpipes be adequate?
5. Will sufficient hose racks be provided?
6. Will special fire suppression systems be provided?
7. Has the containment of fire suppression water been addressed?
8. Will there be adequate external fire zones?
9. Will emergency vehicle access be adequate?

10. Will flame arresters be installed where needed on equipment vents?
11. Will fire extinguishers be of appropriate types, adequate, and mounted for easy access?
12. Will the design for the location of flammables be appropriate?
13. For flammables, will storage rooms and cabinets meet national fire codes and insurance requirements?
14. For flammable liquid dispensing, will grounding, bonding, and ventilation be adequate?
15. Will fire sensors, pull stations, and alarms be adequate?
16. Are flooding systems designed to provide a predischarge alarm that can be perceived above ambient light or noise levels before the system discharges, giving workers time to exit from the discharge area?
17. Has the project been reviewed by insurance personnel?

J. Hazardous and Toxic Materials

1. In the design process, have all materials in this category been identified?
2. Have the physical properties of the individual chemicals been identified?
3. Have the most conservative exposure limits been established as the design criteria?
4. Has a determination been made to use intrinsically safe equipment?
5. Have material safety data sheets been obtained for all materials?
6. Are the reactive properties known for chemicals that will be combined or mixed?
7. Have measures been taken to eliminate, substitute for, or minimize the quantities of hazardous chemicals?
8. Does the design emphasize closed process systems?
9. Will the design properly address all occupational illness potentials, and minimize the need for monitoring, testing, and personal protective equipment?
10. Are storage facilities designed to separate hazardous from nonhazardous substances?
11. Does the design consider the chemical compatibility issues?
12. Have adequate provisions been made for chemical release, fire, explosion, or reaction?
13. Have provisions been made to contain water used in hazardous release control?
14. Are ventilation systems adequate to handle an emergency release?
15. Is the storage of hazardous chemicals below ground avoided?
16. Is storage tank location such as to minimize facility damage or damage to the public in a catastrophic event?
17. Are adequate storage tank dikes provided?

18. Will emergency ventilation be provided for accidental releases?
19. For extraordinary releases, will special ventilation, relief, and deluge systems be provided?
20. Will the normal use of chemicals allow operating without personal protective equipment?
21. Will the design of bulk loading/unloading facilities contain anticipated leaks and spills?

K. Lockout/Tagout — Energy Controls

1. In the design process, has adequate attention been given to lockout/tagout requirements to prevent hazardous releases from these energy sources:
   a. electrical?
   b. mechanical?
   c. hydraulic?
   d. pneumatic?
   e. chemical?
   f. thermal?
   g. nonionizing radiation?
   h. ionizing radiation?
2. Are lockout/tagout devices adequate in design and number, readily accessible, and operable?
3. Are lockout/tagout devices standard throughout the facility?

L. Machine Guarding

1. Overall, do the designs prevent workers hands, arms, and other body parts from making contact with dangerous moving parts? Refer to 1910.212(a)(3).
2. Have the requirements of all applicable machine guarding standards of ANSI been identified and met?
3. Are safeguards firmly secured and not easily removed? Refer to 1910.212 (a)(2).
4. Do safeguards ensure that no object will fall into moving parts? Refer to 1910(a)(1).
5. Do safeguards permit safe, comfortable, and relatively easy operation of the machine? Refer to 1910.212(a)(2).
6. Can the machine be oiled without removing safeguards? Refer to 1910.212 (a)(2).
7. Does the design include a system that requires shutting down machinery before safeguards are removed?
8. Are fixed machines soundly anchored?

9. Are in-running nip points properly guarded? Refer to 1910.212(a)(1).
10. Will the design properly address point-of-operation exposure? Refer to 1910.212(a)(3).
11. Are all reciprocating parts properly guarded? Refer to 1910.212(a)(3)(iv).
12. Are all rotating parts properly guarded? Refer to 1910.212(a)(3)(iv).
13. Are all shear points properly guarded? Refer to 1910.212(a)(3)(iv).
14. Are exposed set screws, keyways, collars, etc., properly guarded? Refer to 1910.212(a)(3)(iv).
15. Does the design eliminate the potential for flying chips? Refer to 1910.212 (a)(i).
16. Has the potential for any sparking been eliminated? Refer to 1910.212(a)(i).
17. If robots are to be used, have they been designed to ANSI/RIA R15.06-1999, the American National Standard for Industrial Robots and Robot Systems—Safety Requirements?

M. Noise Control

1. In the design process, have maximum noise levels been established that are to be stipulated in specifications for new equipment?
2. Is emphasis given to controlling noise levels through engineering measures?
3. Are the size or shape of rooms and proposed layout of equipment, work stations, and break areas to be evaluated for noise levels?
4. Will workers be separated from noise by the greatest feasible distance?
5. Will barriers be installed between noise sources and workers?
6. Are enclosed control rooms provided for operators in areas where the noise is above trigger levels?
7. Will lower-noise-level processes be selected when feasible?
8. Have equipment and work stations been located so that the greatest sources of noise are not facing operators?

N. Pressure Vessels

1. Will all pressure vessels be designed to ASME and insurance company requirements?
2. Will pressure vessels containing flammables or combustibles meet OSHA 1910.106 and NFC standards?
3. Will pressure relief valves be:
   a. correctly sized and set?
   b. suitable for intended use?
   c. directed to discharge safely?

O. Ventilation

1. Have all sources of emission been identified and their hazards characterized?
2. Have ways to reduce personnel interaction with the emission sources (location, work practices) been considered in the design process?
3. Have assessments been made with respect to incompatible emission streams (cyanides and acids, etc.)?
4. Has consideration been given to weather conditions and seasonal variations?
5. Will the design requirements of the ANSI Z9 series, ACGIH Ventilation Manual, ASHRAE guidelines, and NFPA 45 and 90 be met?
6. Will local ventilation effectively capture contaminants at the point of discharge?
7. Will room static pressures be progressively more negative as the operation becomes "dirtier"?
8. Will the ventilation system provide a margin of safety if a system fails?
9. Will emergency power and lighting be provided on critical units?
10. Will the ventilation equipment be remote and/or "quiet"?
11. Will spray booths and degreasers meet OSHA standards?
12. Will laboratory or contaminated air be totally exhausted?
13. If contaminated air is cleaned and reused, will it meet good safety requirements?
14. Will the makeup air to hoods be clean and adequate?
15. Have flow patterns been established to prevent exposure to personnel?
16. Does the design provide for proper gauging and alarm systems with respect to a sudden pressure drop?
17. Are ventilation controls easily accessible to operators?

P. Walking and Working Surfaces, Floor and Wall Openings, Fixed Stairs and Ladders

1. Will aisles, loading docks, and the areas through doorways have enough clearance to allow safe turns when material handling equipment is used? Refer to 1910.22(b)(1).
2. In the aisles, are people and vehicles adequately separated?
3. Are permanent aisles to be marked with lines on the floor? Refer to 1910.22 (b)(2).
4. Does the design provide for floors, aisles, and passageways being free from obstruction? Refer to 1910.22(b)(1).
5. Has a logistics study been made to provide the safe and efficient flow of people and materials?
6. Will the construction texture of walking surfaces be nonslip?

7. Will the floors be designed to stay dry?
8. Will water and process flows be designed to keep off the walkway?
9. Will the floors be sloped and drained?
10. Will utilities and other obstructions be routed off the walking surfaces?
11. Will the design allow future utility expansion, with added facilities not having to be above and thereby cross floors, and be obstructive?
12. Will the designs for floor and wall openings meet the requirements of OSHA 1910.23?
13. Do the designs for fixed stairs and ladders meet the requirements of OSHA 1910.23, .24, .27?

RESOURCES

For some sections in Z10, very good resource material is provided in the Appendices. However, there is no Appendix on the Design Review provisions. In Appendix I, which pertains to Audits, Design Review and Management of change are briefly mentioned. In Appendix K, the Bibliography and References, one resource is listed under the heading "Design Guidelines." That is the National Safety Council publication *Safety Through Design*, for which Wayne C. Christensen and Fred A. Manuele were the coeditors.

Bruce W. Main is the president of design safety engineering, inc.; he is a practitioner in risk assessment and design reviews. His *Risk Assessment: Basics and Benchmarks* contains a chapter titled "Design Reviews." It addresses: the Purpose of a Design Review; Types of Design Reviews; Timing of a Design Review; Design Review Mechanics; The Decision-Making Process; Separating Analysis and Review; Types of Safety Analyses for Design Reviews; and Practical Considerations. Safety professionals who are interested in honing their knowledge and skills with respect to risk assessment and safety design reviews will find this book most interesting.

Chapter 14, "Lean Concepts: Opportunities for Safety Professionals," discusses how a company merged lean concepts into its design process. Design reviews are made at several stages as the design progresses.

An Internet search on design reviews will yield many results, but only a few address safety considerations. Enter safety design reviews into any search engine, and you will find that the literature on safety design reviews is scarce. That is one reason why outlines of several safety design processes as they are applied by individual companies or a combination of companies are included in this chapter.

CONCLUSION

Since I have been a strong proponent of addressing hazards and the risks that derive from them early in the design process, I logically recommend that safety professionals move toward including the design review element in Z10 in the safety

management systems they develop or can influence. I stand by the premise that hazards and the risks that derive from them are most effectively and economically avoided, eliminated, or controlled if they are considered early in the design process, and when necessary as the design progresses. Furthermore, the risks of injury, illness, or damage are significantly reduced if processes are in place to avoid bringing hazards and risks into the workplace.

Intel is one company that has implemented extensive procedures to avoid bringing hazards and risks into the workplace. An Addendum to this chapter, reprinted here with permission, is an adaptation of Intel's Equipment Design Philosophy, a practical management guide. This material is highly recommended reading.

REFERENCES

ANSI/AIHA Z10-2005. Occupational Health and Safety Management Systems Standard. Fairfax, VA: American Industrial Hygiene Association, 2005. Also available at http://www.aiha.org/marketplace.htm.

Brander, Roy. *The Titanic and Risk Management*. http://www.cuug.ab.ca/~brander/titanic/NDIA/NDIA_lecture.html.

Christensen, Wayne C., and Fred A. Manuele, eds. *Safety Through Design*. Itasca, IL: National Safety Council, 1999.

Design for EHS: Equipment Design Philosophy. Chandler, AZ: Intel Corporation, 1999.

Ergonomic Design Criteria. DaimlerChrysler. https://gsp.extra.daimlerchrysler.com/mfg/amedd/tooldesign/textsection15.htm.

Guidelines for Hazard Evaluation Procedures, 2nd ed. New York: Center for Chemical Process Safety of the American Institute of Chemical Engineers, 1992.

Haddon, William, Jr. "On the Escape of Tigers: An Ecologic Note." *Technical Review*, May 1970.

ISO 14121. Safety of Machinery—Principles for Risk Assessment. Standard Geneva, Switzerland, International Organization for Standardization, 2003.

Main, Bruce W. *Risk Assessment: Basics and Benchmarks*. Ann Arbor, MI: design safety engineering, inc., 2004.

ADDENDUM

DESIGN FOR EHS: EQUIPMENT DESIGN PHILOSOPHY

What follows is an adaptation of a management guide issued by Intel Corporation, Corporate Equipment EHS/Capital Equipment Development, in June 1999.

MANAGEMENT SUMMARY

Achieving cost-effective compliance with environmental, health, and safety requirements has become increasingly difficult with the rapid pace of modern technology cycles and continued globalization within the semiconductor industry. Many companies within the semiconductor industry have worked to create a common set of requirements through the use of SEMI standards such as S2-93 and S8-95.

Unfortunately, significant financial resources continue to be consumed to modify equipment designs because such standards are treated as the basis for EHS compliance audits rather than as design criteria. Companies lose additional financial resources when they must respond to incidents that result from insufficient EHS training or inadequate evaluations during the design and development phases. This document introduces the key aspects of the "Design for EHS" strategy and its benefits.

DFEHS Concept Integrate EHS requirements and analyses into the tool development cycle, starting at the design concept phase and continuing through each subsequent phase. The system must be closed loop so that lessons learned from previous tool generations are incorporated into new designs and new EHS requirements can be introduced.

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Purpose No aspect of the tool's design, development, installation, operation, maintenance, or service should place any person, facility, or the environment in jeopardy. Equipment manufacturers should assume exclusive ownership for developing and implementing a comprehensive EHS strategy that achieves this purpose. If the DFEHS strategy is properly applied, the equipment manufacturer will address all EHS concerns during the design and development phases, establish safe work practices during equipment development, and automatically document all end user EHS requirements prior to product release.

Competitive Advantages of a "Design for EHS" Model

I. Lowers cost of EHS compliance by almost 60%, improving overall tool development cost.
II. Enables an Incident & Injury Free manufacturing environment
III. Reduces duration of tool installation and qualification by providing accurate documentation on facility preparation and equipment installation during the customer's project planning
IV. Drives global regulatory compliance
V. Reduces manufacturer's product liability exposure
VI. Reduces manufacturer's time to market for new equipment models

TECHNICAL DISCUSSION

Management's commitment to the Design for EHS strategy and participation in ensuring a comprehensive EHS program is critical in achieving a company culture that integrates EHS as a top priority. A culture that emphasizes good EHS practices should produce measurable improvements in the designs of products that employees produce as well as the manner that they work, both on the company's property and at the customer's site.

Management must define the expectations that project managers, engineers, and other personnel are to use when making decisions on EHS compliance. Each employee must accept the responsibility to ensure the work he or she performs does not lead to a hazardous condition. Several key considerations for developing a Design for EHS program are outlined below.

A basic equipment development model showing recommended tasks for each of the primary development phases follows the technical discussion.

Implementation Keys for a Successful Design for EHS Program

I. Management accepts accountability for the program's success
II. Single point of contact responsible for implementation across all divisions, product lines, etc. This individual is thoroughly linked to management as

well as organizations responsible for engineering, quality assurance, reliability, field service, training, etc.

III. Equipment design engineers held responsible for application of the Design for EHS process.

IV. Engineering and Field Service personnel trained to work safely as well as identify and investigate EHS issues at the customer's site.

V. DFEHS model applied to full life cycle of the company's products, projects & programs.

VI. DFEHS process documents knowledge gained during all projects, product life cycles, etc.

Fundamental Components of a Design for EHS Program

I. Documented EHS programs

II. Documented equipment development procedure integrating EHS milestones
   A. Defined Roles & Responsibilities
   B. Reference library (e.g.-standards, codes, checklists, & other design "tools" for engineers)
   C. Established milestones within the development cycle (e.g.-EHS Roadmap, design reviews)
   D. Consistent hazard analysis techniques (e.g.-Failure Modes and Effects Analysis)
   E. Consistent risk assessment techniques (e.g.-SEW S10-1296)
   F. Established hazard control hierarchies (e.g.: personnel safety, pollution prevention)
   G. Company policy defining EHS documentation expected from project teams
   H. Database where lessons learned from other equipment models are documented 1. Project updates to a management review board (monitors status, reviews key decisions, etc.)
   I. Process checks

III. Internal program audits

BASIC DESIGN FOR ENVIRONMENTAL, HEALTH AND SAFETY MODEL: TASKS FOR EACH PHASE OF EQUIPMENT LIFE CYCLE

Concept Phase

- Evaluate new product idea.
- Compare functionality needs against available technologies.
- Determine critical components & subsystems required.

- Identify environmental, health, and safety risks associated with the proposed technology.
- Prepare list of design options with the suitable EHS characteristics for evaluation during feasibility study.

Concept Feasibility

- Review design options against EHS database to ensure lessons learned in previous generations are given proper consideration.
- Evaluate the quantity of chemicals and natural resources expected to be consumed by the process technology.
- Establish EHS requirements necessary to meet goals for EHS performance and code compliance.
- Conduct an initial hazard survey to identify potential EHS issues during installation, operation, maintenance, service, and decommissioning.
- Make design recommendations to project team.
- Develop EHS roadmap which integrates EHS requirements as key milestones in the equipment development schedule.

Development of Enabling Hardware

- Communicate to the design engineers how the EHS roadmap fits into the equipment development schedule.
- Provide the design team with training on EHS requirements.
- Integrate EHS requirements into project success criteria.
- Comprehend impact of variations in customer configurations, facility designs, and jurisdictional requirements.
- Conduct preliminary hazard review and code analysis: ergonomics, safety, electrical, clearance zones, materials of construction, etc.
- Evaluate methods to reduce the consumption of chemicals and other natural resources.
- Include EHS in project design reviews. Add any lessons learned to EHS database.
- Inform suppliers of components and subsystems of the EHS requirements and integrate them into purchasing specifications.
- Develop procedures to safely control all hazards associated with operation, maintenance and service and prepare first draft of manuals. Add any lessons learned to EHS database.
- Develop EHS Test Plan.

Development of Pilot Tool

- Evaluate and test all interfaces, subsystems, components, schematics, interlocks, and emergency systems according to EHS test plan.
- Conduct detailed hazard analysis of facilitation, installation, operation, calibration/testing, and maintenance activities.
- Develop documentation for facility preparation & equipment installation.
- Update EHS information in the manuals for operation, maintenance and service based on evaluation of results.
- Collect environmental emissions & utilities data and assess against goals.
- Define training requirements for all job functions.
- Perform EHS and code compliance evaluation.
- Implement design modifications and revise documentation as necessary to achieve EHS and code compliance goals.
- Track all issues to closure.

Manufacturing Readiness

- Develop training courses for internal and end user personnel.
- Validate closure of EHS roadmap and all identified compliance issues.
- All components and subsystems are listed or recognized by Nationally Recognized Testing Laboratory (NRTL) and/or validated by third party review.
- Define standard equipment configuration (may impact tool installation and jurisdictional requirements, or vice versa).
- Evaluate all configuration options against EHS requirements to ensure full compliance. Correct design(s) as necessary.
- Comprehensive EHS evaluation by qualified professionals (internal or third party), including operations & service manuals.
- Access any discrepancies identified and take corrective action.
- Obtain all compliance documentation and supporting data: Technical Construction File (TCF), SEMI S2/S8 reports, compliance letters, tool manuals, required certifications, etc.

Product Release/Full Manufacturing

- Conduct a final comprehensive EHS systems check and update environmental emissions data.
- Make final revisions to installation documentation and associated safety procedures.

- Notify customer of install, layout and facilitation requirements needed to maintain EHS compliance and meet customer's special requirements.
- Publish final revisions of operating and maintenance manuals.
- Offer training courses to internal and end user personnel.
- Conduct postmortem of project & add lessons learned to EHS database.

Installation, Operation and Maintenance

- Establish closed loop feedback system with field service personnel and customers to ensure quick and proper disposition of newly discovered EHS issues.
- Engineering and Customer Support must give priority to investigating all EHS issues and implementing corrective action.
- Establish a proactive product safety notification system for all customers.
- Change control procedures must be established to review and implement corrective actions in a controlled manner when EHS issues are discovered.
- Lessons learned from EHS issues discovered during the tool's operational life should be added to the EHS database for use in design projects.

Equipment Decommissioning

- Identify and assess safety & health hazards resulting from equipment demolition.
- Identify hazardous or regulated wastes, contaminated components, etc., which present potential environmental issues.
- Determine the environmental regulations which apply to the situation and specify best known treatment/disposal methods.
- Provide customers with procedures to safely perform demolition, decontamination, and disposal of equipment and any associated waste.
- Capture lessons learned during decommissioning in the EHS database for use in designing the next generation tool.

CHAPTER 14

LEAN CONCEPTS: OPPORTUNITIES FOR SAFETY PROFESSIONALS

INTRODUCTION

Applying lean concepts to eliminate waste, improve efficiency, and lower production costs has become popular with senior-level managements. Minimizing waste is the foundation on which the lean concept is built. In a lean endeavor, activities or processes that consume resources, add cost, or require unproductive time without creating value are eliminated. The lean concept can be described as striving for excellence in operations in which each employee seeks to eliminate waste and participates in the smooth flow of value to the customer.

For safety professionals, "lean" spells opportunity to make substantial contributions to the business process. Tactfully but forcefully safety professionals must bring to management's attention the fact that an element of waste which should be addressed in the lean process is the waste arising from the direct and ancillary costs of accidents.

Direct accident costs are substantial and those costs are a form of waste. Ancillary costs, such as those deriving from the interruption of work, facility and equipment repair, idle time of workers, training of replacements, and investigation and report preparation time, may represent an amount of waste greater than the direct costs. For incidents resulting in severe injury, particularly when property damage and business interruption are extensive, the ancillary cost and accompanying waste can be significant.

Advanced Safety Management Focusing on Z10 and Serious Injury Prevention, by Fred A. Manuele

To encourage safety and health professionals to seek meaningful involvement in lean initiatives, this chapter will:

- Discuss the origin of lean concepts and how broadly they are being applied.
- List the definitions pertinent to lean and relate them to injury and illness prevention.
- Discuss a successful merging of lean concepts and design concepts to show how safety, health, and environmental professionals can be extensively involved.
- Illustrate how the 5S concept (a program that focuses on organization, cleanliness, and standardization to improve profitability, efficiency, service and safety) is foundational in a lean application and how hazards and risks are reduced through 5S applications.
- Comment on lean implementations in which hazards and risks were not addressed, the result being greater risks of injury and illness.
- Explore the absence of references to waste elimination that results from incident prevention in the lean literature.
- Discuss a major work in progress that will be educational for safety and health professionals.

ORIGIN OF THE LEAN CONCEPT

In much of the literature on lean, Taiichi Ohno, while at Toyota, is recognized as the originator of the concept—about 50 years ago. And Toyota has been a highly successful applier of the concept. Nevertheless, reference is made occasionally in the literature to: the concepts applied in the early 1900s by Henry Ford, who created the first "lean" auto production line; Frank Bunker Gilbreth, who was a proponent of scientific management and motion study; Walter Shewhart, a pioneer in statistical control; and W. Edwards Deming, who achieved world renown for his work in quality management. Whatever the origins of the pieces in lean, the leaders at Toyota—as they strove for operational excellence—combined, refined, and converted them with great success into what is called lean in the United States.

LEAN CONCEPTS ARE BROADLY APPLICABLE

Although the original literature on lean describes applications in manufacturing, the concepts have been adopted to minimize waste in a variety of situations—for accounting systems, a large spectrum of service businesses, transportation companies, warehousing, construction, health care facilities (including entities as small as group physician practices), product quality improvement, environmental management, and the elimination of non-value-added emails. How broadly have lean concepts been applied? A search for "lean concepts" on any search engine yields

over 11,000,000 results. In particular, safety and health professionals who have environmental management responsibilities may want to look into the EPA entry available on the Internet: *Lean and Environment Toolkit*. A major section in the *Toolkit* is titled "How to Incorporate Environmental Considerations into Value Stream Mapping."

DEFINITIONS

Understandably, several terms associated with the lean concept are Japanese. Condensed definitions of these terms follow, a since they are applied in the design process discussed later in this chapter, as well as some other definitions that need to be understood.

Flow, as a goal in the lean process, is achieved after waste is removed from the system and the improved process (value stream) runs smoothly and efficiently with a minimum of waste in the work of personnel or in equipment downtime.

Jidoka specifically refers to machines or the production line itself being able to stop automatically when abnormal conditions arise—for example, when one machine breaks down, when heat rises beyond a set limit. *Jidoka* applications do not allow defective parts or products to go from one workstation to another.

Kaizen means "change for the better." In American English, the term has come to mean continual improvement. For the purpose of this chapter, the emphasis in applying the continual improvement process is to eliminate waste, meaning those activities that add to costs but do not provide value.

Muda encompasses all activities that wastefully consume resources but do not add value. Seven types of waste were identified at Toyota for which continual reduction is to be obtained. They are as follows:

The Seven Wastes

Defects in products or services are obviously wasteful in that they consume material and require additional production and correction time.

Overproduction is the excess production or acquisition of items beyond what is actually needed. When overproduction occurs, additional capital investment is necessary, and costs are increased without adding value since more storage space and material handling are necessary. Overproduction that results in excessive material handling adds to risks.

Transportation wastes are those that require the additional and unproductive moving of a product in process. Each time a product is moved, there is added risk of damage to the product, equipment, and facilities, and harm to personnel. In the moving process, the product fills valuable space and requires time expenditures without adding value.

Waiting refers to both the unproductive time spent by workers waiting for the material or components in process to arrive and the time required for excess production to flow through the system. An additional example is material or

information waiting to be worked on to complete a customer order. Similar wastes occur when incidents happen that could result in injury.

Inventory buildup in excess of what is needed requires an additional capital outlay and produces waste because of the need for additional storage space and handling time. Frequent handling of the inventory adds to the risk of injury.

Motion refers to unproductive time and movement on the part of workers when the process is cumbersome, inefficient, and wasteful. This implies that the process may also be hazardous.

Overprocessing means using a more expensive or otherwise valuable resource than is needed for the task. Overprocessing also includes costly rework.

Poka yoke means mistake-proofing or fool-proofing, the purpose being to design work and processes so that it is nearly impossible for workers to make mistakes. An example is designing hose connections or electrical connections so that they can be joined together in only one way, thereby reducing risk. This is an important but often neglected concept with respect to employee and product safety.

Mura pertains to unevenness in the work flow: The goal is steady work flow.

Muri relates to avoiding overburdening equipment or employees: The goal is to reduce the work load to acceptable levels. For equipment, this might mean operating at 80% of the maximum specified limit; for employees, designing work methods that are overly stressful and working excessive hours are to be avoided.

Pull defines the operational situation after which much has been accomplished in applying the lean process and inventories can be maintained in relation to the "pull" as represented by customer orders. Waste from having excessive product in inventory, and all that implies, is minimized—for example, the cost of excess space, the financing of excess inventory, the cost and risk of additional handling of inventory, etc.

Total Productive Maintenance assures that all equipment used in a process is able to perform its tasks, always, so that production or work processes will not be interrupted.

MERGING LEAN AND DESIGN CONCEPTS

All but one of the applications of lean concepts with which I have become familiar are to remove waste from existing operating systems. In the one exception, a pharmaceutical company merged lean concepts into the original design considerations for a major project in which new equipment was to be acquired and installed in an existing facility. In lean language, that would be a "brownfield" application. When design engineers incorporate lean concepts into the design of an entirely new facility, that is a "greenfield" application.

What this pharmaceutical company has done is an excellent example of how lean and safety can be addressed concurrently in the design process. The concept has

been applied elsewhere. For example, James P. Womack and Daniel T. Jones state in *Lean Thinking: Banish Waste and Create Wealth in Your Corporations*, Second Edition, that lean concepts were applied in the design of Toyota auto manufacturing plants built in the United States.

In addition, this pharmaceutical company's initiative is particularly noteworthy in that it incorporates the relative provisions of ANSI/AIHA Z10-2005, the Occupational Health and Safety Management Systems Standard:

Provision in Z10	Section Designation
Risk assessments	4.2
Hierarchy of controls	5.1.1
Design reviews	5.1.2
Management of change	5.1.2
Procurement	5.1.3

Practical application of the process has been demonstrated in the company that developed it. All operations personnel at this location have had lean training. An abbreviated version of this company's process follows. It is close to the theoretical ideal. Safety and health professionals can learn from it.

CRITERIA FOR APPLYING THE LEAN DESIGN PROCESS IN THE EXAMPLE PHARMACEUTICAL COMPANY

In the example company that developed this lean design process, its use commences when an assumption is made that a project is of such magnitude that it will require following the steps outlined in its Request for Capital Expenditure Procedure. For purchases below the capital expenditure request level, the basics in the process are applied, but not as extensively. For example, if the machine shop supervisor submits a request to purchase a metal cutting saw, safety considerations would be established and they would have to be reviewed by environmental, health, and safety professionals as well as more than one level of management. Those safety requirements would be included in the purchase order. After receipt and installation of the equipment, a safety validation would be made.

THE EXAMPLE COMPANY'S LEAN DESIGN PROCESS

1. *The Concept Stage* From any source—research and development, engineering, any operations department, a cross-functional group, maintenance, individual workers—a suggestion for process improvement may be proposed. A broad range of brainstorming by the team takes place. If it is concluded that the idea should be moved forward and its expenditure level requires following the organization's request for capital expenditure procedure, review and tentative approval are sought at the senior management level. A project manager is assigned.

2. *Capital Expenditure Request and Element Champion Review* The capital expenditure request would describe the design objectives of the project in general, make the business case for it, and request the necessary funding. In this pharmaceutical company, each of the 26 elements in its safety management system is assigned to a "champion," most often at an upper management level. For instance, the chief executive officer assumes the responsibility for the direction and accomplishment of two of those elements; four are assigned to another senior manufacturing executive. At this stage, all the safety management system element champions have become aware of the project and sign-off by each of them is required.

3. *Identify the Customers/Users* A customer/user in this context means every employee who may be affected by the process revision being proposed. It, in fact, means everyone. The purpose is to assure that all persons who could be affected are aware of the proposed process change and can provide input as the activity proceeds. Identifying the customers/users is considered an important step in the lean process.

With respect to external customers, the characteristics of the products manufactured have been agreed on, close estimates made of the product amounts that will be purchased and over what time spans, inventories are kept under tight control, and the delivery methods and times of delivery arranged.

4. *Project Customers/Users Requirement Specification* At this point, a senior-level manager prepares a document expanding on the original idea. The document contains enough detail to specify the outcomes expected and some criteria are established. Customers/users (employees) may submit their specifications and suggestions on how waste can be eliminated.

5. *Value Stream Map* A value stream map is now created. It is a preliminary flowchart that includes every step of the production process, as conceived of at this time. It is an important stage in the design in that it documents the processes to be considered in the waste elimination process.

Value Stream Mapping is the written or computer-based identification of the sequence of activities and information flows to produce a product or deliver a service. This represents a vital step in the lean concept because it provides the opportunity for team brainstorming to identify activities that do not add value. Lean practitioners use value stream mapping to: identify major sources of non-value-added time in a value stream; envision a less wasteful future state; and develop an implementation plan for future lean activities. An Addendum providing a Simplified Initial Value Stream Map appears at the end of this chapter.

6. *Project Conceptual Design* All that preceded this step in the process influences the drafting of the project's conceptual design. It shows the proposed layout, and building and utility impacts, and contains specifics on the major equipment needed. Environmental, health, and safety considerations are addressed at this conceptual stage. All of the following personnel review and sign off on the concept's design: operation executives; subject matter experts; environmental, health, and safety professionals; engineering; maintenance personnel; the building manager.

7. *Change Control Provisions* This company operates under the regulations of several governmental entities. Therefore, a rigid change control system is in place to assure that all quality, safety, and environmental requirements are met. At a senior management level, a change control document is produced requiring approval by all department heads. At this juncture, the head of the compliance group is particularly interested in seeing that all regulations are met. In Z10, the comparable requirement is to have a management of change process in place.

8. *Project Safety Clearance and Lean Review* This is a summation step with respect to all of the foregoing. The design document is reviewed by the environmental, health, and safety group and by the compliance group. Determinations are made with respect to the need for further safety analysis in individual parts of the process or because of their interrelationships. Safety specifications are expanded and become more specific.

Although lean considerations have been an aspect of this process from the beginning, the project manager now stresses more rigorously the application of lean concepts. The purpose is error-proofing, waste elimination, to have the process stop when equipment recognizes a fault, and the avoidance of rejects. All or some of the lean systems previously mentioned—*poka yoke*, *jidoka*, *kaizen*, or *muda*—may be brought into play. But, *muda* concepts prevail throughout. Waste is to be at a minimum.

In addition, since this company has been a meticulous applier of the 5S system (defined in their usage as—Sorting, Simplification, Systematic Cleaning, Standardization, and Sustaining), its concepts are overriding in the lean process. It was said by a senior executive at the company location that "If the staff has not been educated in 5S concepts and believe that their substance is a core value, you can forget about Lean. You must have established a stable environment in which waste elimination is fundamental to move into the next step to accomplish Lean."

9. *Drafting Vendor Specifications* Engineering personnel draft vendor specifications although manufacturing, environmental, health, and safety, and operating personnel may also be involved. At this stage, communication commences with the vendor selected. Subject matter experts employed by the vendor may assist in drafting specifications for the project.

10. *Conceptual Design Risk Assessment* This review takes place at the concept and drawing level. Formal risk assessment methods, qualitative or quantitative, are used as required. The risk assessments are documented and approved by a multifunction team, of which the environmental, health, and safety personnel are a part. An independent reviewer, not a member of the project team, must also sign off on the risk assessments. Several people at this location have been trained to do Failure Mode and Effects Analyses.

11. *The Preliminary Design* Project team members work with the vendor to assure that the users' (in-house personnel's) requirements are met. The receivables from the vendor include schematics, flow diagrams, drawings, specifications for further components, and operating procedures and training manuals.

12. *Additional Value Stream Map: Waste Scavenger Hunt* (Muda *Check*) A value stream map was created when the project was in the concept stage. At this developmental phase, an additional flowchart is made to depict the proposed design. *Muda*, as previously stated, encompasses all activity that wastefully consumes resources but does not add value.

A *Muda* check takes place as a waste scavenger hunt to further minimize the possibilities of product defects, overproduction, excessive product handling, idle and waiting time by operating personnel, and excessive inventory; and to improve efficiency in processing and encourage the best possible use of employee skills. All levels of personnel are involved.

13. *Proposed Design Safety/Risk Assessment: Create System Drawings* Now that a proposed design is available, additional risk assessments are made—prior to system build. The environmental, health, and safety staff is prominently active in the risk assessments, along with other involved personnel. The use of formal risk assessment methods is more frequent at this stage. A final sign-off by the independent reviewer is also necessary.

At this point, the design is frozen, the vendor creates system drawings, and the vendor builds to drawings.

14. *Safety, Operational, and Lean Review* At the vendor's location, before shipment of the equipment can be made, the purchaser's environmental, health, and safety personnel assure that all safety-related specifications have been met. Factory acceptance testing takes place and members of the review team (engineering, operations, maintenance, validation, etc.) determine that the equipment operates as expected and that waste occurs at a minimum. This is a large part of the approval process prior to shipment of the equipment. The staff has found that testing at this level at the vendor's location has avoided many issues which would have to be resolved later on its shop floor. Review by maintenance is especially important here as their sign-off impacts on the company's ability to apply the Total Preventive Maintenance initiative. With approval, the equipment may be shipped to the purchaser.

15. *Standard Operating Procedures* In reality, this function is done in parallel with the previous steps. It involves writing standard operating procedures, developing training modules, defining record-keeping needs, drafting production records, etc.

16. *Facility Review and Approval* After installation, with which the vendor is extensively involved, site acceptance tests are performed. Approval is needed by the project team, including environmental, health, and safety personnel, before acceptance. The purpose of this step is to validate that the equipment performs as intended, that the quality level expected has been achieved and that environmental, health, and safety specifications have been met.

17. *In Production* At this stage, *kaizen*—continual improvement—is the governing concept. Superior quality is maintained. Adherence to standard operating procedures, including safe practices, is the norm. Waste is constantly searched for and eliminated.

18. *5S Review* Since this organization has made applying the 5S system a core value, a final review is made to assure that all five of its key elements have

been maintained: Sorting, Simplifying, Systematic Cleaning, Standardization, and Sustaining.

THE 5S CONCEPT

The originators of the lean design process were asked to critique this chapter for technical accuracy. One of them made this comment: "We have found that 5S is one of the foundations of lean. As far as safety is concerned, nothing makes hazardous conditions and practices stick out more than a well-organized facility. You should expand on 5S and how it can help improve safety performance."

His premise required further inquiry into how the 5S program operates in his facility. How well does it work at this location? They say that their 5S program is an underlying reason for their receiving a bundle of awards on employee safety, environmental affairs management, and product quality. Other applications of 5S concepts may not be precisely the same as what takes place at this location, either for lean or safety purposes. Nevertheless, personnel critiquing this chapter have affirmed that the 5S concept can have a solid impact on worker safety and that it is folly to expect good work practices and outstanding performance from workers if the work environment is dismal and disordered, and operational discipline is lacking.

Sorting The first step in a 5S application is to get rid of everything not needed, all the clutter, and to achieve an atmosphere of orderliness. When that orderliness has been achieved in operational and storage areas—both for work in process and equipment needed to do the work—efficiency and housekeeping are improved, hazards and risks are reduced, and time wasted searching for work items is eliminated.

Simplifying Is the next step in the 5S process. If there is a place for everything retained, and those places are well marked and labeled and known to the staff, it is easier to find tools, parts and the equipment needed to do a job and to keep things orderly. Simplifying in a disciplined manner promotes the identification of hazardous situations and makes it easier to complete tasks with less risk.

Systematic Cleaning Is the third step in 5S. Everyone is to be involved in the systematic cleaning endeavor. Workers in a unit are assigned ownership of, and responsibility for, the cleaning tasks. The purpose is to produce orderliness: dirt, disorder, items stored in aisles, and getting in the way or stored in a manner that makes their recovery hazardous are not tolerated. The cleaning processes add to operational efficiency, eliminate waste, and reduce risk.

Standardization The fourth step in 5S adopts the best practices for equipment and machinery layout, and the design of equipment and work practices for productivity, mistake-proofing and continual improvement. Workers at all levels have opportunities for input into the standardization procedure. Comments are sought on the design of the work methods to maximize efficiency as well as to minimize risks.

Since at this location, accidents are recognized as a form of waste, safety is an integral part of the standardization process. Performance standards and expectations for predictable results are set. A minimum of operational breakdowns is expected. Root causal factors for operating problems are studied and largely eliminated on an anticipatory basis. Up front prevention is the thinking. Methods to identify possible breakdowns and how to respond with a minimum of waste when they occur are a part of the standardization procedure. For maintenance personnel, that makes their work easier: they are exposed to fewer hazardous situations; jerry-rigging for unusual work is not condoned. It is emphasized that maintaining tight control over the management of change procedures is an integral part of the standardization element in 5S.

Sustaining The fifth step in the 5S process involves maintaining what has been accomplished in the four previous steps. This, they say, is the most difficult step. It is expected that some workers might revert to previous practices, particularly with respect to cluttering the workplace and avoiding cleanliness. Sustaining the 5S concept can be achieved only by continuous management leadership.

The CEO in this company says that he knows he has to continuously and personally embrace the 5S concept and both talk the talk and walk the talk, repeatedly. He holds his staff accountable for sustaining what they have achieved—an orderly and stable work environment in which efficiency is at a high level, waste occurs at a minimum, and hazards and risks are at an acceptable level.

THE BENEFIT OF ADDRESSING HAZARDS AND RISKS EARLY IN THE LEAN PROCESS

Since the goal in applying the lean concept is to minimize waste and reduce costs, it is logical to address safety considerations early in the process, rather than as an afterthought. Unfortunately, many attempts at achieving lean have not included safety considerations. Worse yet, the record indicates that safety needs have been compromised in some lean applications and the hazards and the risks that derive from them are thus increased. Retrofitting for the correction of hazards that arise as the drive for lean is pursued is wasteful and expensive. I have observed situations similar to those against which Kevin Newman and Theodore Braun offer caution in "Advice on Incorporating Ergonomic Safety Initiatives into Your Continuous Improvement Process":

> Unfortunately, Lean doesn't necessarily mean safer though the two should go hand in hand. After all, a poorly designed task that requires a worker to reach excessively is not only inefficient, requiring more time and motion than needed, but is also likely to cause injury. Similarly, a worker lifting materials beyond his or her own capabilities takes more time and energy to perform the task and runs the risk of overexertion.
>
> In the worst-case scenario, an overzealous company may implement extreme Lean Manufacturing strategies where safety is not merely overlooked, but compromised. In

the end, increasing efficiency without incorporating safety will cost far more than it saves.

Minimizing handling and storing materials and work in process, and avoiding interruptions in the flow of work processes, are central in the lean process. Although all hazards and risks should be addressed in the lean concept, applying ergonomics principles, particularly, fits well as the Lean process moves forward.

ON THE LEAN LITERATURE

There is plenty to read on lean. However, there is a dearth of information in the lean literature on how the waste deriving from accidents should be addressed. For safety professionals, that scarcity describes both a problem and an opportunity to make their presence felt. An example of such scarcity is the previously mentioned and widely sold Womack and Jones text. Although a clearly popular book, it contains little reference to accidents as a waste factor.

Progressive safety professionals will recognize this shortcoming—the nonrecognition of accidents as a source of waste by the appliers of lean concepts—as an opportunity to educate management on the advantage of including safety considerations as the lean process is applied.

A MAJOR WORK IN PROGRESS

Other safety professionals have recognized the dearth of information in the lean literature on how both safety and lean might be integrated. They have also encountered situations where safety concepts and lean applications were in conflict, with the results being far from satisfactory.

The Association for Manufacturing Technology (AMT) established a committee to develop a Technical Report titled *Designing for Safety and Lean Manufacturing: A Guide on Integrating Safety and Lean Manufacturing Principles in the Use of Machinery* (TR7). Although its purpose is to address lean and safety concepts in the use of machinery, this Technical Report will be valuable to all safety professionals who become involved in lean. Its content is largely generic and the principles apply to all enterprises. TR7 provides guidance on how the lowest waste at the lowest risk level can be achieved and helps fill the gap on lean in the technical literature. TR7 has been approved and is available through AMT.

> Lean manufacturing includes a variety of initiatives, technologies and methods used to improve productivity (better and faster) throughput by reducing waste, costs and complexity from manufacturing processes. However, the effort to get lean has too frequently led to the misapplication of lean manufacturing principles in ways that result in significant risk to worker safety and to the goal of lean manufacturing. Safety is a critical element in the lean manufacturing effort. This document provides guidance for persons interested in how to concurrently address lean manufacturing

concepts and safety concerns of machinery. A brief overview of lean manufacturing concepts is presented and examples demonstrate situations where this has not occurred.

A process model for safety and lean is presented and examples demonstrate situations where this has not occured. A risk assessment framework is outlined that demonstrates how lean manufacturing concepts and safety can be implemented concurrently. Examples of where safety and lean have been successfully applied are shared. This document also provides design guidelines on how to meet lean objectives without compromising safety.

This Technical Report is an excellent resource for safety professionals who want to understand how the lean process and safety principles can be melded to serve waste reduction purposes while maintaining acceptable risk levels. It provides guidance from the initial concept stage for design and redesign and addresses operational waste reduction applications.

CONCLUSION

Because of the foundation on which the lean concept has been built—removing waste from a system—applying the notion will probably have staying power. Since accidents and their consequences are so fundamentally wasteful, preventing them should be an integral part of lean applications. From the very beginning, when an organization commences discussion of adopting lean concepts, safety professionals should step forward to become members of the lean team. Opportunity exists to address hazards and the risks that derive from them as processes are designed and redesigned. To be meaningful participants, safety professionals must become familiar with lean concepts. Several helpful resources on lean are listed in the references.

In addition, an Internet search will reveal that several courses on the lean concept are available. For example, the Society of Manufacturing Engineers (SME) has developed courses that award lean certificates at three different levels of expertise. Each progressive level of lean certification requires continuing education—either academic coursework or structural classroom training. Information about the SME courses and the related "Lean Certification Body of Knowledge" can be accessed at http://www.sme.org. As the SME literature says, "Lean thinking requires Lean learning."

REFERENCES

Dennis, Pascal. *Lean Production Simplified: A Plain-Language Guide to the World's Most Powerful Production System*. Shelton, CT: Productivity Press, 2002.

Designing for Safety and Lean Manufacturing: A Guide on Integrating Safety and Lean Manufacturing Principles in the Use of Machinery, TR7. McLean, VA: Association for Manufacturing Technology, expected a Technical Report in progress with third qualter 2007 publication.

EPA. *Lean and Environment Toolkit*. "How to Incorporate Environmental Considerations into Value Stream Mapping." http://www.epa.gov/epainnov/lean/toolkit/ch3.htm#definition.

Imai, Masaaki. Gemba Kaizen: *A Commonsense Low-Cost Approach to Management*. New York: McGraw-Hill, 1997.

Newman, Kevin, and Theodore Braun. "Advice on Incorporating Ergonomic Safety Initiatives into Your Continuous Improvement Process." *Occupational Hazards*, August 2 2005.

Rother, Mike, and John Shook. *Learning to See: Value Stream Mapping to Create Value and Eliminate* Muda. Cambridge, MA: Lean Enterprise Institute, 2003.

Womack, James P., and Daniel T. Jones. *Lean Thinking: Banish Waste and Create Wealth in Your Corporations*, 2nd ed. Northampton, MA: Free Press, 2003.

ADDENDUM

A SIMPLIFIED INITIAL VALUE STREAM MAP: TO IDENTIFY WASTE (*MUDA*) AND OPPORTUNITIES FOR CONTINUOUS IMPROVEMENT (*KAIZEN*)

A **B** **C** **D** **E** **F**

Defects The machinery at Station A is old and worn. Regardless of the amount of tinkering, it cannot achieve a quality defect level lower that 3 parts per 10,000. Producing defects at that level, below some customer specifications, is wasteful.

Motion Adjustments of the machinery at Station A and die changes must be made frequently. That is wasteful motion and adds risk. Also, the lockout/tagout device is over 100 feet from the machine. An arrangement of that sort is error-provocative and promotes risk taking. Getting to and from the device wastes time.

Because of customer specifications, all parts processed at Station A are inspected at Station B. Parts are moved to Station B in carts. Since the casters on the carts are too small, moving them is cumbersome and time-consuming, and they are prone to tipping. They have tipped over, injuring workers and damaging parts. This inspection motion is expensive, wasteful, boring, and adds elements of risk.

Overproduction At Station C, the machinery processes parts faster than can be handled by the remainder of the production line. Thus, materials in progress get stacked in aisles until they are transferred to a storage area. Having excess materials in process is wasteful. An additional result is overly stressful manual material handling and the ergonomic risks that implies.

Transportation Station D represents the wastes deriving from the additional storage space and material handling needed because of overproduction at Station C.

Advanced Safety Management Focusing on Z10 and Serious Injury Prevention, by Fred A. Manuele

The storage configuration is not conducive to efficiency. Aisles are narrow. Powered vehicles have collided, have struck workers, and goods have been damaged.

Waiting Although overproduction occurs at Station C, personnel at Station E often are not fully occupied, and waste occurs while they are waiting for other components to be delivered. Inventory controls are inadequate, and the motorized delivery system is inefficient and risky.

Inventory The inventory at Station D is greater than needed, and thereby wasteful. Excessive material handling is necessary.

Overprocessing Because the quality level achieved at Station A is inadequate for some customers, considerable parts re-work is necessary at Station F. That wastes resources, and use of the machinery in the process adds risk.

CHAPTER 15

MANAGEMENT OF CHANGE — SECTION 5.1.2

INTRODUCTION

In ANSI/AIHA Z10-2005, the Occupational Health and Safety Management Systems standard, Section 5.1.2 is titled "Design Review and Management of Change." As was stated in Chapter 13, "Safety Design Reviews," the processes for design reviews and for management of change have considerable significance in a safety and health management system. Although they have some common characteristics, they are implemented through distinctively separate management processes.

One of the reasons that the management of change process in addressed separately is to promote a broad understanding and application of the change analysis concept that is at its base. This chapter will:

- Define the purpose and methodology of a management of change system, and relate it to the change analysis concept.
- Establish its significance as a method to prevent serious injuries and incidents involving major property damage.
- Outline management of change procedures, keeping in mind the staffing limitations at moderate sized locations and their need to avoid burdensome paperwork.

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PURPOSE OF A MANAGEMENT OF CHANGE SYSTEM

Although the term "management of change" is not defined in Z10, its purpose is clearly established. The objective of a management of change process is to prevent the introduction of new hazards and risks into the work environment when changes are made in technology, equipment, facilities, work practices and procedures, design specifications, raw materials, organizational or staffing changes impacting on skill capabilities, and standards or regulations. Applying the change analysis concept is essential within a management of change process. A change analysis is to assure that:

- The hazards and risks that may arise when a change is to be made have been identified and assessed and that appropriate control measures are taken.
- New hazards are not created by the change.
- The change does not impact negatively on previously resolved hazards.
- The change does not make the potential for harm of an existing hazard more severe.

ON CHANGE ANALYSIS

Change analysis is a commonly used process. An Internet search will reveal that the literature on change analysis is abundant. A few examples follow. OSHA says this about change analysis in its *Safety & Health Management System eTool—Worksite Analysis*:

> Anytime something new is brought into the workplace, whether it be a piece of equipment, different materials, a new process, or an entirely new building, new hazards may unintentionally be introduced. Before considering a change for a worksite, it should be analyzed thoroughly beforehand. Change analysis helps in heading off a problem before it develops.

In the *Aviation Ground Operations Safety Handbook*, change analysis is listed among the "Tools to Aid in Hazard Identification" section as a method "to detect the hazard implications of both planned and unplanned change."

In *MORT Safety Assurance Systems*, William Johnson makes references to change analysis throughout the book as he discusses applying the "Management Oversight and Risk Tree (MORT). "Richard Stephens's *System Safety for the 21st Century*" Contains a chapter titled "Change Analysis."

Provisions for design reviews and management of change are also contained in other standards, perhaps by other names. For example, in the Quality Management Systems—Requirements Standard, ANSI/ASQ Q9001-2000, Section 7.3.7 is titled "Control of Design and Development Changes." It reads as follows:

> Design and development changes shall be identified and records maintained. The changes shall be reviewed, verified and validated, as appropriate, and approved before implementation. The review of design and development changes shall include evaluation of the effect of the changes on constituent parts and product already delivered. Records of the results of the review of changes and any necessary actions shall be maintained.

The management of change provisions in Z10 brings the practice of safety in line with the requirements of ISO 9000.

RELATING CHANGE ANALYSIS TO PREVENTING SERIOUS INJURIES

I have recorded the results of my research into the characteristics of incidents resulting in serious injuries in Chapter 3, "Serious Injury Prevention." I wrote that a large proportion of incidents resulting in serious injury occur when workers are engaged in out-of-the-ordinary tasks, meaning when changes are taking place, such as:

- In nonproduction activities
- When nonroutine and unusual work is performed
- When high sources of energy are present
- During in-plant construction operations (e.g., replacement of a large motor)

I strongly recommend that, when drafting a management of change process, definitions of the types of activities to which it is to be applied include the work categories that are known to result in serious injuries.

THE MANAGEMENT OF CHANGE PROCESS

As is the case with all management systems, an administrative procedure must be written to communicate what the management of change system is to encompass and how it is intended to operate. The system must be designed to fit the organization's structure, culture, and work force. Although brevity is the goal, the procedure document should:

- Define the purpose of the management of change system.
- Establish accountability levels.
- Specify the criteria that are to trigger the initiation of formal change requests.
- Make clear how personnel are to make change requests, and specify the change request form to be used.
- Outline the criteria for request reviews and responsibilities for reviews.
- Indicate that a change analysis is to be made encompassing:
  - The risks to the workers who are to do the work and other employees who may be affected.

  - Possible damage to the property and environment.
  - The procedures to accomplish the change.
  - How the results will be evaluated.
- Assign responsibility for acceptance or declination of the change request, in accord with the results of the change analysis, and include a management of change approval form.
- Outline a method to determine the management actions needed as a result of the actions taken on approved changes (e.g., additional training of operators and maintenance workers; revision of standard operating procedures and drawings; communications to employees and contractors; updating emergency plans).
- Indicate that after changes are made, a final review will take place before startup of operations.

RESPONSIBILITY LEVELS

In drafting a management of change procedure, responsibility levels must be defined; they must also be in accord with an entity's organizational structure. In an entity where even minor changes in a process are considered critical as respects employee injury and illness potential, possible environmental contamination, and the quality of the product, the levels of responsibility can be many. Examples of levels of responsibility, as outlined in an organization where the inherent hazards require close control, are shown here as reference points for safety professionals who undertake the drafting of management of change procedures.

Initiator The initiator owns the change and is responsible for initiating the change request form. If required by the complexity of the proposed change, the initiator's responsibilities may be reassigned at any time during the change process. The initiator will fully describe and justify changes, ensure that all appropriate departments have assessed the changes, manage the execution of the change request, and ensure that the changes are implemented properly.

Department Supervisor The department supervisor is responsible for assigning qualified personnel to initiate change requests. The change control process is critical to the safety of employees, avoiding environmental contamination, and the quality of final products. The departmental supervisor is responsible for ensuring that the change request is feasible and adequately presented for review.

Document Reviewers Document reviewers will review and approve change request forms. The review/approval activities include review of the document for accuracy and adequacy with respect to the proposed changes.

Approvers Department managers will select pre-approvers with expertise related to the nature of the proposed change. Each reviewer will be responsible for evaluating and assessing the impact of the proposed change on existing processes in his or her area of expertise. The reviewers must also review and approve the change request form and the implementation plan to evaluate the change and assure that the steps for implementation are appropriate. This is the final review before the proposed change is implemented.

Post implementation Approvers Department managers will select post implementation approvers who are to assure that the change has been appropriately implemented as indicated when approval for the requested change was given. This process is to also assure that only the changes as shown on the change request form have been implemented.

WHEN TO INITIATE THE MANAGEMENT OF CHANGE PROCESS

There are no specific instructions in Z10 indicating when the management of change provisions are to be applied. However, employers are permitted to make "a determination of the appropriate scope and degree of the design review and management of change" process. This provision gives the employer an opportunity to arrange for a level of review that is commensurate with the hazards and risks and to avoid overburdening costs that are not warranted by the risk levels. This represents good business practice. But, in making those judgments, management should not overlook the opportunity to reduce serious injury potential when the work is being done to achieve changes.

Adopting an exception for a category of work such as that permitted in OSHA's Rule for Process Safety Management of Highly Hazardous Chemicals, 29 CFR 1910.119, is strongly opposed. That standard States:

> The employer shall establish and implement procedures to manage changes (except for "replacement in kind"), etc.

With emphasis, I say that excluding "replacement in kind" work from the management of change process may reduce the probability of avoiding incidents that result in serious injuries.

To highlight this point, I repeat the example of in-plant construction given in Chapter 3, "Serious Injury Prevention." A motor weighing 800 pounds is to be replaced. Assume that it is a "replacement in kind." It sits on a platform 15 feet above the floor. The work is to be done by in-plant personnel. Work of that sort should not be excluded when a management of change procedure is drafted.

Keeping in mind the hazard and risk complexities of a particular employment situation and the desirability of establishing a management of change system which is adequate but not overly complex, a guideline follows from which a safety professional can choose, or add to, in writing a procedure which defines the situations

for which a change analysis is to be made. The list commences with the types of activities in which serious injuries often occur and is extended to include the particulars listed in Z10 that should trigger a management of change process.

1. Nonroutine and unusual work is to be performed.
2. The work exposes employees to sources of high energy.
3. Types of maintenance operations for which pre-job planning and safety reviews would be beneficial because of inherent hazards.
4. Substantial equipment replacement work is needed, including "replacement in kind" projects.
5. New or modified technology is introduced, including software.
6. Modifications are made in equipment, facilities, or processes.
7. New or revised work practices or procedures are introduced.
8. Design specifications or standards are changed.
9. Different raw materials are to be used.
10. Modifications to existing health and safety devices and equipment will be made.
11. Significant changes to the site's organizational structure will be made.
12. Staffing changes are made, requiring a review of skill levels.
13. A change in the use of contractors is made.

Guidelines on the content of a Management of Change Request Form and a sample form follow.

MANAGEMENT OF CHANGE REQUEST FORM

If creating a Management of Change Request Form, consideration should be given to including as much of the following as needed.

- Name of person making the request
- Date of request
- Department, section, or area
- The equipment, facility, or process affected
- Brief description of the proposed change and what it will accomplish
- Potential performance, safety, health, and environmental considerations
- Titles for personnel who need to review the change and space to enter their names
- Effect the change may have on standard operating procedures, maintenance, and training, etc.
- Space for reviewers to enter special conditions or requirements
- Approvals and authorizations

- Routing indicators or provisions for copies to be sent to personnel responsible for training and updating operating procedures, drawings, etc.

A sample Management of Change Request Form is shown in Figure 1. The form should be revised to suit an entity's needs and perhaps saved electronically to allow flexibility when descriptive data and comments are added.

Management of change request form

General Information

Date _____ Originator _____ Department _____

Sent to _____

Equipment, facility, or process affected _____

Urgency of change: _____ Emergency _____ Priority _____ Routine

Basis for the Change (Check those that are applicable.)

_____ Improved safety—risk reduction

_____ Improved performance—efficiency

_____ Pollution prevention—waste minimization

_____ Essential to operation

_____ Other

Description of Proposed Change and Potential Hazards

Summarize the technical basis for the proposed change and any potential safety, health, or environmental impacts from the proposed change. Describe how the change will affect SOPs, maintenance, training, etc. State the change start and end dates.

_____

_____

_____ Approved or disapproved by

Name and date _____ Organization/Position _____

_____ _____

_____ _____

Comments

_____

_____

_____

_____

_____

_____

FIGURE 1

FORMALIZING THE MANAGEMENT OF CHANGE PROCESS

A Management of Change Policy and Procedure as detailed as appropriate to fit an organization's needs should be written and understood by all levels of employment. Addendum A in this chapter is a composite of issued policies and procedures governing management of change. Its purpose is to establish "a process for evaluating occupational safety and health and environmental exposures when operational changes are made so as to control the internal risks during the change process and to avoid bringing new hazards and risks into the workplace."

Organizations that issued the management of change policies and procedures which served as the basis from which Addendum A was created recognized that control of their change procedures was vital because of the complexity of their operations and because of the high level of inherent risks in their processes. In that Addendum, the responsibilities of the management of change "champion" are outlined. Someone has to be given responsibility to supervise the work being done to accomplish the change and follow it through to an appropriate conclusion, as in the Plan-Do-Check-Act (PDCA) model.

Addendum A is to serve as a reference only as each organization needs to craft its own formal management of change process. For moderate-sized locations, implementing the policy may be accomplished by instituting a not overly complex pre-job planning and safety analysis system.

PRE-JOB PLANNING AND SAFETY ANALYSES

For moderate-sized locations, I strongly recommend that safety professionals consider drafting and proposing the implementation of a pre-job planning and safety analysis system as the implementation method to fulfill the Management of Change Policy and Procedures drafted to meet the requirements in Z10. The purpose of a pre-job planning and safety analysis system is to provide a means for supervisors and their staffs to determine how the work is to be done and to study the hazards and risks that may be encountered—before the work commerces.

Implementing such a system would occur after a Management of Change Request Form is received and approved. Addendum B in this chapter provides a framework from which a pre-job review system can be developed. It should not be adopted as presented. For example, revisions will almost always be necessary in Item 9, which is purposely an extensive list of hazards.

Establishing the planning and analysis concept is emphasized here, with a caution against creating burdensome procedures and reports for simplistic non-routine jobs. For those jobs, if it became the accepted practice that workers think through the job to be done and plan the work methods, discuss the hazards and risks, and determine whether the risks are or are not acceptable, that would be a highly favorable accomplishment.

IMPLEMENTING THE MANAGEMENT OF CHANGE PROCESS

Safety professionals must appreciate the magnitude of the task to be undertaken as they move toward achieving a successful implementation of a management of change system. In almost all companies, putting a management of change procedure in place requires a culture change. Egos get in the way, territorial prerogatives are maintained, and the expected resistance to change can be huge since the people affected will have had little or no experience with the administrative systems being proposed. To be successful, the management of change process requires team building and cooperative effort from each team member.

Safety professionals should base the case for instituting a management of change system primarily on accident and injury experience in the entity for which counsel is being given but also borrowing from the experience of the industry group of which it is a part. Basing a proposal for adoption of a system solely on the requirements of Z10 will require masterful preparation and persuasion. However, that case can be made, at least sometimes.

Except for the chemical and allied industries, decision makers have not been educated through their business literature on the benefits of having a management of change system in place for safety purposes. That should be taken into consideration as safety professionals develop their proposal.

Earlier in this text, it was stated that the management of change procedures presented here would keep in mind the needs and capabilities of moderate-sized organizations. That commitment is recognized in the following suggestions on how to successfully implement management of change procedures:

- Keep the procedures simple: Make sure they fit well with the entity's hazards and risks. A modest system that works is better than an elegant one that does not.
- As is the case with all elements in a safety management system, management commitment and leadership must be obtained and demonstrated. That means providing the personal direction and involvement in initiating the procedures, providing adequate resources, and making the necessary decisions in favor of safety when disagreement occurs during the change review process.
- Obtain widespread acceptance and commitment. Solicit input from the affected employees and respect their perspectives and concerns when developing a system.
- Provide adequate training. All affected personnel must be appropriately educated on the rationale for instituting the management of change system, the procedures to be followed, and their roles and responsibilities.
- Field-test the system prior to its official implementation. Debugging it early will pay off in the long run.
- Monitor the progress and performance of the system through periodic audits and through the informal inquiry of employees on their perspectives. A management system that is never reviewed and improved will eventually degrade.

ACHIEVING THE NECESSARY CULTURE CHANGE

Achieving the culture change necessary to incorporate the management of change process requires support from all levels of management and from line workers. Furthermore, such a culture change cannot be attained without a training program that helps workers understand the concepts to be applied. How that got done is illustrated in the following example.

At a location where the serious injury experience was considered excessive for non-routine work, safety professionals decided that something had to be done about it. As they prepared a course of action and talked it up at all personnel levels, from top management down to the worker level, they encountered the usual negatives: For example, it would be time-consuming, the workers would never buy into the program, and the supervisors would resist the change. The safety professionals considered the negatives as normal expressions of resistance to change.

Their program consisted, in effect, of indoctrinating management and the workforce on the benefits to be obtained by doing a pre-job review that encompassed how to get the job done effectively and in good time, and job hazard analysis and risk assessment. Eventually, management and the line workers agreed that classroom training sessions could be held. Subsequently, the safety professionals stressed that the classroom sessions were vital to their success.

At the beginning of those sessions, an outline was distributed to the attendees that set forth the fundamentals of the pre-job review system being proposed. After a discussion of the procedures enumerated in the outline, attendees were divided into groups to plan actual maintenance jobs that were described in scenarios that had been previously prepared. The discussion outline given to the participants was comparable to that shown in Addendum B in this chapter. It is a composite of pre-job planning and safety analysis systems.

At this location, supervisors took to the idea of pre-job planning and safety analysis when they recognized that such a system made their jobs easier, improved productivity, and reduced the risks. As one safety professional said: “Our supervisors have become real believers in the system.” Thus, a culture change had been achieved.

DOCUMENTATION

Z10 states that “the organization shall establish and implement processes” to fulfill the management of change requirements. This implies having written procedures outlining the processes. Maintaining records of the changes made is recommended in the advisory comments of Z10 and a reference is made there to an explanatory statement in E5.4. The advice given in E5.4, as in the following, is sound and should be taken into consideration as management of change procedures are drafted:

> The type and amount of formal documentation necessary to effectively manage an Occupational Health and Safety Management system should be commensurate with

> the size, complexity and risks of an organization. Large organizations commonly use substantial formal documentation and consider it value-added. Small organizations, on the other hand, may often be able to fulfill this requirement through more informal mechanisms that still clearly and effectively define roles and responsibilities and assure continuity of the processes.

Although Z10 does not require the use of a Management of Change Request Form, it is difficult to comprehend having an effective management of change system without one. Such a form defines good management practice and is educational. Also, when a pre-job planning and safety analysis procedure is in place, the work described in the request form is accomplished more efficiently and with better risk control.

The importance of maintaining a history of the changes made needs emphasis. It is important that all modifications be recorded in drawings, prints, and the appropriate files. They become the historical records that have to be reviewed and considered in the decision making, later on, when changes in other equipment, systems, or methods are to be made. They also should be available when safety audits are made.

Comments on ***changes made that went unrecorded*** in drawings, prints, and records such as the following are found too often in reports on incidents resulting in serious injury, property damage, business interruption, or environmental contamination: The system was rewired; a blank was put in the line; control instruments were disconnected; relief valves of lesser capacity had been installed; and sewer line sensors to detect hazardous waste were removed.

CONCLUSION

It is the intent of this chapter to provide a primer for safety professionals who have little or no experience with formal management of change procedures from which they can craft a process suitable for the entities to which they give counsel. The focus is on the needs of moderate-sized locations.

The management of change provision in Z10 is soundly based. Having a change analysis system in place for revisions that require pre-study because they may impact on safety, productivity, and environmental controls is good risk management. Management of change is one of the subjects for which the annexes in Z10 provide no help. Except for the chemical process industries, formally adopted management of change systems are untypical. And all of the training programs on management of change advertised on the Internet that this author has located have a chemical orientation.

However, some help on the content of a management of change system suitable for general application is provided in Addendum A to this chapter. It is a composite of real-world applications. Nevertheless, a safety professional should modify it to suit the needs of the entities to which counsel is given.

REFERENCES

ANSI/ASQ Q9001-2000. Quality Management Systems—Requirements Standard. Milwaukee, WI: American Society for Quality, 2000.

Aviation Ground Operations Safety Handbook, 5th ed. Itasca, IL: National Safety Council, 2000.

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

OSHA Rule for Process Safety Management of Highly Hazardous Chemicals, 29 CFR 1910.119. Washington, DC: U.S. Department of Labor, 1992.

Process Safety Management Guideline for Compliance, 1910.119. *OSHA Bulletin 3133*. http://www.osha.gov/Publications/osha3133.html.

Safety & Health Management System eTool—Worksite Analysis. Washington, DC: U.S. Department of Labor, OSHA. Also available at http://www.osha.gov/SLTC/etools/safetyhealth/comp2.html.

Stephens, Richard A. *System Safety for the 21st Century*. Hoboken, NJ: John Wiley & Sons, 2004.

ADDENDUM A

MANAGEMENT OF CHANGE POLICY AND PROCEDURES: OCCUPATIONAL SAFETY AND HEALTH AND ENVIRONMENTAL CONSIDERATIONS

1.0 ***Overview*** This policy defines the requirements for a Management of Change process with respect to occupational safety and health and environmental considerations.

2.0 ***Purpose***

2.1 This policy establishes a process for evaluating occupational safety and health and environmental exposures when operational changes are made so as to control the internal risks during the change process and to avoid bringing new hazards and risks into the workplace.

3.0 ***Scope***

3.1 This policy applies to all operations at this location: there are no exceptions.

4.0 ***Responsibility***

4.1 The Management Executive Committee, with counsel from the senior safety professional, is responsible for establishing processes to determine when these management of change procedures shall apply, how they are to be implemented and by whom, and to follow the processes through to an effective conclusion.

4.2 Facility management is responsible for ensuring that these processes and procedures to address the safety, health and environmental implications of operational changes are implemented within their areas of responsibility.

4.3 Employees at all levels—division managers, supervisors, line operators and ancillary personnel—after receiving training on this policy and process, are

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responsible within their domains of influence for initiating communications on operational changes that may impact on safety, health and environmental considerations and for the implementation of this policy and process.

4.4 All safety professionals have responsibility to identify operational changes that require study as to hazard and risk potential and to bring their observations to management's attention through their organizational structures.

5.0 ***Application***

5.1 This policy applies to all operational changes that may potentially impact on the safety and health of employees and on our environmental controls.

5.2 This policy will be implemented as an adjunct to all issued Safety, Health and Environmental policies and procedures, but particularly to our Design and Procurement of Equipment and Facilities Procedure.

5.3 The senior safety professional, and other safety professionals with particular skills, shall participate routinely in management staff meetings when operational changes are discussed.

5.4 A safety professional will sign off on the change plans considering the provisions of our Design and Procurement of Equipment and Facilities Procedure and on the New Product Development process.

5.5 Examples of operational changes to which this policy and process may apply include:

- Unusual, non-routine, non-production work, work where high energy exposures are contemplated, and maintenance projects for which the scope of the work requires a determination that pre-job planning and safety analysis would be beneficial
- Revisions in operating methods and procedures
- Revised production goals
- Plans to lower operating costs
- Revisions in staffing levels, upward or downward
- Organizational restructuring
- Revisions in the environmental management system
- New product development
- Adoption of new information technology that has an impact on operations
- Changes in safety, health or environmental regulations
- Acquisitions, mergers, expansions, relocations or divestitures

6.0 ***The Management of Change System***

6.1 When an operational change is identified that requires study in respect to its impact on occupational safety, health or environmental controls, a person at an appropriate management level shall be appointed the Management of Change Champion to chaperone the review process to a conclusion.

6.2 That person, having obtained counsel from safety professionals, will determine how extensive the review procedure will be and decide on whether:

- Completion of a Management of Change Request Form is necessary [Figure 1 in this chapter] within which the accountability and sign-off levels are set forth.
- Multidisciplinary group discussions are to be held to encompass the content of the Pre-Job Planning and Safety Analysis Outline (Addendum B in this chapter).
- The hazards and risks that may result as the operational change moves forward are of greater significance and require appointment of an ad hoc Management of Change Committee to oversee the project. Safety professionals having the necessary skills are to be members of such committees.
- Our Capital Expenditure Request Procedure is to be initiated.

6.4 ***The Management of Change Champion shall:***

- Assure that input on the operational change has been obtained from all who might be impacted.
- Arrange for resources, staffing and scheduling to accomplish the change.
- Schedule the necessary risk assessments.
- Obtain comments from line operating personnel on their views on how the hazards and risks can be ameliorated, and their concerns.
- Get a sign-off from safety personnel.
- Follow the review process to a logical conclusion.
- Arrange a final review of the changes made to assure that hazards and risks have been properly addressed.
- Determine that residual risks, after the risk reduction and control measures have been taken, are acceptable.
- See that documentation is appropriate.
- Have Standard Operating Procedures modified as necessary.

6.5 ***Documentation*** The Management of Change Champion is to give emphasis to documenting all changes made that should be recorded in prints and appropriate files so that persons who make further changes at a later date will know precisely what was done. In making decisions on what documentation is to be made, this principle is to apply: be super cautious and consider later needs. Risk assessments are to be retained.

7.0 ***Standard Operating Procedures*** Revisions are to be made in Standard Operating Procedures as necessary, and a determination will be made as to any additional training necessary.

8.0 ***Training***

8.1 Personnel responsible for safety, health and environmental training at management, supervisory, line worker, and ancillary personnel levels shall incorporate this policy and process into the training curricula.

8.2 Employees impacted by the changes made shall receive training on the revised Standard Operating Procedures before changes are finalized.

8.3 In the training process, employees will be properly informed with respect to their assuming responsibility for the aspects of safety, health and environmental matters over which they have control.

ADDENDUM B

PRE-JOB PLANNING AND SAFETY ANALYSIS OUTLINE

1. Review the work to be done. Consider both productivity and safety:
   a. Break the job down into manageable tasks.
   b. How is each task to be done?
   c. In what order are tasks to be done?
   d. What equipment or materials are needed?
   e. Are any particular skills required?
2. Clearly assign responsibilities.
3. Who is to perform the pre-use of equipment tests?
4. Will the work require: a hot work permit; a confined entry permit; lock-out/tagout (of what equipment or machinery)?
5. Will it be necessary to barricade for clear work zones?
6. Will aerial lifts be required?
7. What personal protective equipment will be needed?
8. Will fall protection be required?
9. What are the hazards in each task? Consider:

Access	Work at heights	Work at depths	Fall hazards
Worker position	Worker posture	Twisting, bending	Weight of objects
Elevated loads	Welding	Fire	Explosion
Electricity	Chemicals	Dusts	Noise
Weather	Sharp objects	Steam	Vibration
Stored energy	Tools dropping	Pressure	Hot objects
Forklift trucks	Conveyors	Moving equipment	Machine guarding

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10. Of the hazards identified, do any present severe risk of injury?
11. Develop hazard control measures, applying the Safety Decision Hierarchy.
12. Is special contingency planning necessary (people, procedures)?
13. What communication devices will be needed (two-way, hand signals)?
14. Review and test the communication system to notify the emergency team (phone number, responsibilities, etc.).
15. What are the workers to do if the work doesn't go as planned?
16. Considering all of the foregoing, are the risks acceptable? If not, what action should be taken?

Upon Job Completion

17. Account for all personnel
18. Replace guards
19. Remove safety locks
20. Restore energy as appropriate
21. Remove barriers/devices to secure area
22. Account for tools
23. Turn in permits
24. Clean the area
25. Communicate to others affected that the job is done
26. Document all modifications to prints and appropriate files
27. Do a startup safety review

CHAPTER 16

THE PROCUREMENT PROCESS SECTION 5.1.3

INTRODUCTION

Although the requirements for the Procurement processes are plainly stated in Z10 and easily understood, they are brief in relation to the enormity of what will be required to implement them. As is the case for the provisions in Z10 on safety design reviews, the purpose of the Procurement processes is to avoid bringing hazards and risks into the workplace.

The standard requires that processes be in place so that reviews are made of purchased products, materials and other goods, and related services to identify and evaluate health and safety risks—before their possible introduction into the work environment. To fulfill the Procurement provisions, safety specifications must be included in purchase orders and contracts. To assist safety professionals as they give advice on implementing those provisions, this chapter will:

- Comment briefly on prevalent purchasing practices.
- Establish the significance of the procurement processes.
- Discuss the pre-work necessary to include safety specifications in the procurement process.
- Provide some resources.

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- Comment on the paucity of publicly available occupational health and safety purchasing specifications.
- Remark on the need, sometimes, to set specifications above published standards.
- Give examples of design specifications that become purchasing specifications.

FACING THE REAL WORLD OF PURCHASING PRACTICES

Unfortunately, the practice in many companies during the bid process for acquiring machinery, equipment, and materials is that the purchasing department will choose the lowest bidder. For many years, safety professionals have told stories about how purchasing personnel accepted the lowest bid on safety-related products or materials only to find, after their receipt, that they did not fulfill operational expectations, and safety needs were not met. Expensive retrofitting for safety purposes then became necessary.

Retrofitting to accommodate safety needs starts with evaluating the deficiencies in the equipment as it is—that is, identifying what was overlooked in the design process. The resulting level of risk when safety requirements are addressed through retrofitting may be higher than would be the case if safety specifications were included in the bid or purchasing papers. As retrofitting proceeds, it is easy for the decision makers to rationalize the acceptance of higher risk levels.

Influencing managements and purchasing personnel to adopt the Procurement provisions in Z10 will not be easy. Safety professionals who propose adding the Procurement provisions as an element in their safety and health management systems and to have safety specifications included in a company's purchasing practices should expect the typical resistance to change. In most places, a culture change will be necessary.

An oblique interpretation of the procurement requirements could be that, as safety and health professionals, you are assigned the responsibility to convince managements and purchasing agents that, in the long term, it can be very expensive to buy cheap.

SIGNIFICANCE OF THE PROCUREMENT PROVISIONS

I place great emphasis on having the Procurement provisions in Z10 become an element in safety and health management systems because doing so prevents the introduction of hazards and risks into the workplace. Here is the basis for my thinking. Risks of injury derive from hazards. If hazards are properly addressed and eliminated or brought under control in the design process so that the risks deriving from them are at an acceptable level, the potential for harm or damage and operational waste is minimized. The logical extension of addressing hazards and risks in the design process is to have the design specifications on which the organization decides included in purchase orders and contracts so that suppliers and

vendors know what safety specifications are to be met. That reduces the possibility of bringing hazards into the workplace.

Although having safety specifications included in purchase orders or contracts is not a broadly applied practice, safety professionals are encouraged to consider the benefits to be achieved if they are. If the ideal is attained in the purchasing process and hazards and risks brought into the workplace are at a practical minimum, significant risk reduction results, which means fewer injuries.

PRE-WORK NECESSARY FOR PROCUREMENT APPLICATIONS

As was stated in Chapter 13, "Safety Design Reviews," there is a close relationship between establishing safety design specifications and including safety specifications in procurement documents. The latter cannot be successfully achieved until the former has been accomplished. Once safety design specifications are established, the first step is to apply them internally. An appropriate extension then is to incorporate them in purchase orders and contract language.

It is the common practice for vendors and suppliers of equipment to design to their own, and possibly inadequate, safety specifications if the purchaser has not established its requirements. That ends up being costly for the purchaser, especially if production schedules are delayed and the retrofitting expense to get systems operating as designed and for safety purposes is substantial.

RESOURCES

Although the "shall" Procurement provisions, that is, the mandatory provisions, are precisely and clearly stated in Z10, no assistance is provided in the standard's annexes on how the provisions should be applied. In Annex F, "Objectives/Implementation Plans," the following objectives are outlined for the Procurement provision: distribute approved policy; train on policy and procurement procedure; and distribute safety requirements to be included in standard contracts.

Such a scenario presumes that a Procurement policy and safety requirements have been established and distributed and that training on their implementation will be given. Procedurally, that is good and recommended practice. These comments are informative, but not very helpful with respect to specifics on how the procedures are to be implemented.

Procurement is listed in Appendix I, of Z10 "Audit," as one of the subjects to be reviewed when a safety audit is made. Documents to be examined for objective evidence of the adequacy of the procurement provisions are those addressing safe operating procedure(s) and supplier selection, evaluation, and management.

Again, it is assumed that Safe Operating Procedures for Procurement have been established and that a Supplier Selection, Evaluation, and Management procedure is in place. All are good and necessary procedures to have. Put together the two previous references and they provide a basis for thought and action, but not much else.

Several safety texts were reviewed to determine whether they give guidance on including safety specifications in the Procurement process. They do not. Searching the Internet is minimally productive, but this author directs safety professionals to one particular resource.

At http://www.jnj.com/community/health_safety/programs/Machine_Safety.htm, Johnson & Johnson has posted its machine safeguarding program titled "Johnson & Johnson Zero Access." My understanding is that these safeguarding requirements are included in purchasing specifications. Also, Johnson & Johnson indicates that its machine safeguarding is a "Beyond Compliance" initiative. More about that later.

Examples of some safety-related purchasing specifications posted on the Internet follow. There are others.

- Washington State University, "Terms and Conditions for Purchase Orders," at http://www.wsu.edu/purchase/termscond.htm. Item 21 addresses OSHA /WISHA requirements.
- Bechtel BWXT Idaho, LLC, "General Provisions for Non-Construction Subcontracts and Purchase Orders," at http://www.inl.gov/procurement/docs /proc-183.pdf#search = 'Bechtel%20BWXT%20Idaho%2 C%20LLC%20General%20Provisions%20for%20NonConstruction%20Subcontractors'. Item B.4 pertains to Environmental Safety and Health.
- NC State University Environmental Health & Public Safety Center, "Design Specifications for Class IV Laser Laboratories," at http://www2 .ncsu.edu/ehs/laser/index.htm.
- Yale University, Procedure 3220, "Purchases of Restricted Items," at http: //www.yale.edu/ppdev/policy/3220/3220.pdf, which addresses among other factors:

  Hazardous Materials Materials that present special safety risks during transport, storage, use, or disposal. These include, but are not limited to, certain highly toxic, reactive, or otherwise hazardous chemicals, gases, and biological agents.

  Safety-Critical Equipment Equipment that can present safety hazards to users (e.g., X-ray and laser equipment) as well as equipment used to control exposures to recognized hazards, and whose improper use could subject users to harm (e.g., fume hoods, biological safety cabinets, respirators, automated film processors).

THE PAUCITY OF AVAILABLE HEALTH AND SAFETY PURCHASING SPECIFICATIONS

Applications of safety-related design standards that become purchasing specifications are not easily acquired. Most companies consider their specifications proprietary and do not freely make them available to others. For the moderate-sized company with a limited engineering staff, writing design and purchasing specifications will not be easy to do.

It seems appropriate to suggest that organizations prevail on the business associations of which they are members to undertake writing generic design and purchasing specifications that relate to the hazards and risks inherent in their operations. Nevertheless, two examples of design specifications that are also purchasing specifications are presented at the end of this chapter.

OPPORTUNITIES IN ERGONOMICS

As is the case with Z10's safety design review provisions, safety professionals who are not involved in the design or purchasing processes should consider ergonomics as fertile ground in which to get started. Some of the comments made in Chapter 13, "Safety Design Reviews," are repeated here because they apply equally to Z10's design and procurement provisions.

Musculoskeletal injuries, ergonomically related, are a large segment of the spectrum of injuries and illnesses in all industries and businesses. Since they are costly, reducing their frequency and severity will yield notable results. Furthermore, it is well established that successful ergonomics applications result not only in risk reduction, but also in improved productivity, lower costs, and waste reduction.

Ergonomists know how to write design specifications for work methods and the workplace that take into consideration the capabilities and limitations of workers. A company that has established detailed ergonomics design criteria, to be followed by its own engineers and by its vendors and suppliers, is DaimlerChrysler. The following introduction in DaimlerChrysler's *Ergonomic Design Criteria* demonstrates the relationship between writing design specifications and then including them in purchasing requirements:

> This document attempts to integrate new technology around the human infrastructure by providing uniform ergonomic design criteria for DaimlerChrysler's manufacturing, assembly, power train and components operations, as well as part distribution centers. These criteria supply distinct specifications for the Corporation, to be used by all DaimlerChrysler engineers, designers, builders, vendors, suppliers, contractors, etc., providing new or refurbished/rebuilt materials, services, tools, processes, facilities, task designs, packaging and product components to DaimlerChrysler.

In effect, the ergonomic design criteria to be used internally at DaimlerChrysler also become the ergonomic specifications that vendors and suppliers are to meet. In a Section titled "Supplier Roles and Responsibilities," it is made clear that all suppliers are to "make all reasonable efforts to implement all of the criteria and requirements" of the ergonomic design criteria. If a design requirement is compromised, the supplier is to so inform DaimlerChrysler and the matter is reviewed to a conclusion by a DaimlerChrysler ergonomics representative.

DaimlerChrysler has given permission for its *Ergonomic Design Criteria* to be duplicated in this book. Since the design criteria established also serve as purchasing specifications, they appear as Addendum A at the conclusion of this chapter.

GENERAL DESIGN AND PURCHASING GUIDELINES

Addendum B in this chapter is a compilation of design and purchasing guidelines currently in use. Note again that design specifications were developed that became purchasing specifications. Addendum B is presented here as a reference from which engineering personnel and safety professionals can make selections and add, subtract, or alter items to suit location needs. It would be inappropriate to implement these Guidelines without study and adjustment to reflect the hazards and risks inherent in a particular entity.

The adoption of modified or customized version of these Guidelines will usually require persuasive discussion with the purchasing staff. Developing a procurement process as outlined in the Guidelines applied will require a culture change in all but a few organizations. Safety professionals must understand the enormity of what is being undertaken when they move to have safety specifications included in purchasing documents when that has not been the current practice. Nevertheless, the productivity, risk reduction, and waste-saving benefits of a process that avoids bringing hazards and risks into the workplace cannot be refuted.

The Guidelines in Addendum B commence with Sections on General Safety Requirements, Machine Guarding, Industrial Hygiene, Ergonomics, Machine and Process Controls, and Environmental Impact/Hazard Evaluation. Section 8 sets forth a Procedure with the following instruction: "Use this document as a guide whenever purchasing new (or modifying existing) equipment." The Major parts of this Section are titled "Codes and Standards"; "Equipment/Fixture Design"; "Mechanical—Design and Construction"; "Electrical—Design and Construction"; "Pneumatics—Design and Construction"; "Software"; and "Machine Guarding."

These Guidelines are quite broad. They relate to occupational safety and health, environmental concerns, productivity, and avoiding events that result in business interruption.

DESIGNING AND WRITING SAFETY SPECIFICATIONS BEYOND THE LEVEL OF STANDARDS

Johnson & Johnson says that its machine safeguarding is a "Beyond Compliance" initiative. In the safety standards writing process, it is common for contributions to be made by many participants, and compromises are made as they deliberate to accommodate the variety of views expressed on the subject being considered. The result often is a standard that includes minimum requirements, as is the case in Z10. In Chapter 9, "Including Risk Assessment Provisions in Standards and Guidelines: A Trend" this appears.

> A supplementary and advisory document to SEMI S2 *(Environmental, Health, and Safety Guideline for Semiconductor Manufacturing Equipment)* is titled *Related Information 1 – Equipment/Product Safety Program*. It makes an interesting statement, cited below, about the need, sometimes, to go beyond issued safety standards in

the design [and purchasing] process. That also reflects my experience. It has to be understood that safety standards may set only minimum requirements, as does Z10.

> Compliance with design-based safety standards does not necessarily ensure adequate safety in complex or state-of-the-art systems. It often is necessary to perform hazard analyses to identify hazards that are specific with the system, and develop hazard control measures that adequately control the associated risk beyond those that are covered in existing design-based standards.

Two subjects come to mind that encourage designing beyond compliance standards. Systems designed in accord with OSHA's lockout/tagout and confined space standards may be error-provocative.

- Assume that an electrical system is designed to OSHA lockout/tagout requirements and to the requirements of the National Electrical Code but that the distance workers have to travel to lockout stations is, in their view, too far and burdensome. You can be sure that sometimes workers will not follow the written Standard Operating Procedures. If a system's design and purchasing contract merely say "Meet OSHA Requirements," the result could be an error-provocative system.
- Stating in purchasing (construction) contracts that confined spaces should be designed to meet OSHA's standard may also result in error-provocative situations. An appropriate goal is to try to design out confined spaces, first, and then consider the safety entry and exit needs in the design process where confined spaces must exist.

CONCLUSION

Too much emphasis cannot be placed on the significance of the Procurement provisions in Z10 and the benefits that will derive from their implementation. It stands to reason that if the purchasing process limits bringing hazards and risks into the workplace, the probability of incidents resulting in injury or illness will be diminished. That is what Z10 is all about: "To reduce the risk of occupational injuries, illnesses, and fatalities."

Since very few organizations have processes in place that comply with Z10's Procurement provisions, safety professionals are faced with an enormous task when they attempt to convince managements to adopt such provisions. Surely, undertaking to do so is a worthy and noble task.

Although the addenda to this chapter are lengthy, I recommend that safety professionals read them to gain an appreciation of how extensive design and purchasing specifications can be and how they may help a company or entity avoid bringing hazards and risks into the workplace. Also, it must be understood that design engineers may not agree with some of the specifics included in the Guidelines suggested here and would write different safety-related specifications.

REFERENCES

ANSI/AIHA Z10-2005. Occupational Health and Safety Management Systems Standard. Fairfax, VA: American Industrial Hygiene Association, 2005. Also available at, http://www.aiha.org/marketplace.htm.

Ergonomic Design Criteria. DaimlerChrysler. https://gsp.extra.daimlerchrysler.com/mfg/amedd/tooldesign/textsection15.htm.

Johnson & Johnson. *"Zero Access"*. http://www.jnj.com/community/health_safety/programs/Machine_Safety.htm.

SEMI S2-0706. Environmental, Health, and Safety Guideline for Semiconductor Manufacturing Equipment. San Jose, CA: Semiconductor Equipment and Materials International, 2006. (*Related Information 1—Equipment/Product Safety Program* is an adjunct to these *Guidelines*.)

ADDENDUM A

DAIMLERCHRYSLER ERGONOMIC DESIGN CRITERIA FOR ENGINEERS, DESIGNERS, BUILDERS, VENDORS, SUPPLIERS AND CONTRACTORS

Presented Here With Permission

Do's & Don'ts Rev. 7-1-06

SECTION 15 (In a series of Guidelines)

15.0 Ergonomic Design Criteria

This document attempts to integrate new technology around the human infrastructure by providing uniform ergonomic design criteria for DaimlerChrysler's manufacturing, assembly, power train and components operations, as well as part distribution centers. These criteria supply distinct specifications for the Corporation, to be used by all DaimlerChrysler engineers, designers, builders, vendors, suppliers, contractors etc. providing new or refurbished/rebuilt materials, services, tools, processes, facilities, task designs, packaging and product components to DaimlerChrysler.

The ergonomic review of a workstation must consider backup provisions and maintenance access and activities. This document is to be used as a trigger point in determining if an ergonomic assessment of a particular workstation is required.

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15.1 Manual Material Handling Design Criteria

15.1.1 Force Requirements/Load

15.1.1.1 Example

For production tasks the maximum cyclic two handed lift is 9 kg (20 lbs.). New requisitions for lift assists require prior approval from a DaimlerChrysler MAP Ergonomics representative (refer to Table 1).

15.1.1.2 Example

The maximum cyclic two handed push/pull force is 196 N (44 lbs.) initial and 107 N (24 lbs.) sustained. The force measurement must reflect appropriate acceleration rates that would be used by the manufacturing plant based on their cycle time.

15.1.1.3 Example

For production tasks the maximum cyclic two handed carry is 14 kg (30 lbs.).

15.1.1.4 Example

For new or refurbished manually handled packages, the maximum weight guideline of a small lot container (including container and contents) is 14 kg (30 lbs). All small lot packaging which exceeds 14 kg (30 lbs) should be reviewed by an ergonomic specialist using a quantitative ergonomic analysis.

15.1.1.5 Example

Maximum lateral force applied horizontally at full arm's extension in front of a body is 67 N (15 lbs.).

15.1.1.6 Example

For production tasks, the maximum cyclic one handed lift is 4.5 kg (10 lb).

15.1.2 Material Handling Methods and Task Geometry

15.1.2.1 Example

For production tasks the maximum cyclic horizontal carry distance is 6 m (20 ft.).

15.1.2.2 Example

Minimize the horizontal distance of any push, pull or carry.

15.1.2.3 Example

Maximum horizontal reach measured from the edge of any barrier (tool, fixture, vehicle, etc.) between the worker and the task when lifting is 51 cm (20″). This specification assumes compliance with 15.3.5.4 and 15.3.1.12.

15.1.2.4 Example

Minimize the horizontal reach distance at the origin and the destination of lift or lower.

15.1.2.5 Example

Minimize the vertical travel distance of the hands between the destination and the origin of lift or lower.

15.1.2.6 Example

Minimize the frequency of lifts or lowers.

15.1.2.7 Example

Minimize overhead weight manually supported and its duration.

15.1.2.8 Example

Minimize the need to push or pull. Use gravity to move material whenever possible. (Use conveyors, power trucks, lift tables, turn tables, or gravity slides/chutes whenever possible).

15.1.2.9

15.1.2.10 Example

Convert lift/lower combined with a carry to a push or pull using facilities including powered and non powered conveyors, ball roller tables and hand carts.

15.1.2.11 Example

Replace a carry with a push or pull using facilities including conveyors (all kinds), tables and slides between work stations, carts, and lift trucks where applicable.

15.1.2.12 Example

Replace a pull with a push whenever possible.

15.1.2.13 Example

Minimize the distance between the center of gravity of the part and the operator. Provide part supports/guides to minimize torque on the upper extremities.

15.1.3 Dunnage/Material Racks

15.1.3.1 Example

Design material packaging such that the parts are easy to grasp and manipulate with one hand using no grasping tools and without the need to flip or rotate the

part. Material packaging design should allow the operator to grasp parts with either a power grip or a hook grasp as opposed to a pinch grip. Orient parts in dunnage or racks to match fixture or point of operation loading. Material rack designs must also facilitate the use of lift assists for material loading and unloading as required.

15.1.3.2 Example

The operator should not be assigned to step up or down incoming material racks to obtain material. Appropriate material display platforms must be provided.

15.1.3.3 Example

Material handling racks must have lightweight returnable dunnage and/or dunnage bars with a lifting effort not to exceed 14 kg (30 lbs). Lifting effort should be reduced by the utilization of lightweight bars, a mechanical apparatus on the rack to counteract the lift force, or a mechanical lineside lift assist in the loading and unloading areas.

15.1.3.4 Example

Returnable dunnage should have interchangeable cap and base.

15.1.3.5 Example

Dunnage layer separators that require rotation for high density stacking returns are not recommended.

15.1.3.6 Example

Where ever a lift assist is provided, and dunnage layers weigh more than 14 kg (30 lb), provide a pick up point on the dunnage layers, located at the center of gravity, that will allow the same end effector to lift both the parts and the empty dunnage layers.

15.1.3.7 Example

Design material handling racks to avoid tight nesting of parts where a tool is required to pry the parts from one another.

15.1.4 Material Handling Devices

15.1.4.1 Example

Minimize the manual handling of materials. Use initiatives including lift tables, articulating arms, lift trucks, hoists, conveyors, gravity dumps or chutes, palletized material and bulk handling.

15.1.4.2 Example

Ensure that articulating arm and lift device designs include consideration of the product, dunnage, production rate, shop floor layout, AME Tool Design Do's and Don'ts, and test trials of actual plant conditions.

15.1.4.3 Example

Maximize all push cart caster diameters. Provide push handles between 91.5 - 112 cm (36 to 44″) above the floor. Consider using 25.5 cm (10″) diameter very low starting and rolling resistance casters such as Chrysler part numbers: NPM 35-185-0053 (rigid caster) and NPM 35-187-0106 (swivel caster).

15.1.5 Handles

15.1.5.1 Example

One handed cut out handles shall have a minimum of 13 cm (5″) in width with a 6 cm (2.5″) hand clearance.

15.1.5.2 Example

Two handed cut out handles shall have a minimum of 25.5 cm (10″) in width with a 6 cm (2.5″) hand clearance.

15.1.5.3 Example

The maximum handle diameter for full encirclement by the hand is 38 mm (1.5″).

15.1.5.4 Example

The minimum handle diameter for comfort is 6.5 mm (0.25″) for loads up to 7 kg (15 lbs.); 13 mm (0.5″) for loads between 7 – 9 kg (15-20 lbs).; and 19 mm (0.75″) for loads over 9 kg (20 lbs.). Make handle diameters as close as possible to 38 mm (1.5″).

15.1.5.5 Example

Handles should be located at or above the line passing through the center of gravity of the load.

15.1.5.6 Example

Loads weighing more than 4.5 kg (10 lbs.) must have good hand coupling. Refer to 15.2.2.4 for proper handle designs style and dimensions that enhance coupling.

15.1.5.7 Example

Manually lifted bulky or unstable loads weighing more than 18 kg (40 lbs.) must have a good hand coupling for multiple person lifting.

15.1.5.8 Example

Handles shall have surface material that has a high coefficient of friction to reduce slippage and the required grip force.

15.1.6 Ergonomic Assist Arms

15.1.6.1 Example

All efforts are to be made to design parts, assemblies, tools, equipment, and workstations conforming to all sections of the ergonomic guidelines to eliminate the need for an ergonomic assist arm.

15.1.6.2

All requirements for ergonomic assist arms are to be authorized by the platform MAP Ergonomics representative.

15.1.6.3 Example

Arms are to provide the means to accomplish tasks as quickly as possible, faster than manual methods if possible. This can be accomplished by designing arms that perform multiple tasks. Tasks can include securing the part(s) to the end-effector, locating them on the vehicle, and fastening them into place. In addition, walking distances and changes in direction while manipulating loads shall be minimized. After moving and releasing, the load arm should safely return to its point of origin when released wherever possible.

15.1.6.4 Example

Arms are to be designed as compact and lightweight as possible. Arm design is to put the operator as close to the point of operation as possible.

15.1.6.5 Example

Arms are to be designed so the operator can stand in a neutral posture and be able to view target alignment points and critical load and unload points without risk of bumping into the structure of the lift assist arm. An operator is in a neutral posture when standing upright without any twisting or tilting of the back or neck.

15.1.6.6 Example

Targets and locating/alignment points are to be made as large as possible. Guides and wipers are to be provided where appropriate.

15.1.6.7 Example

Arms are to be synchronized to the speed of the assembly line wherever possible.

15.1.6.8 Example

The manual force required to push, pull, raise and lower the arm and the part are to be minimized, and are not to exceed limits established in section 15.1.

15.1.6.9 Example

Handles are to be easily adjustable in height, width, and handle orientation. Additional adjustment provisions may be required depending on the configuration of the arm. Arms are to be delivered with the handles set at a height of 104 cm (41″), distance between handles of 46 cm (18″), and are to be tilted inward at a 30 degree angle. Required vertical hand movements are to remain within the criteria established in section 15.3.3. This may require a second set of handles.

15.1.6.10

Handle design is to be within criteria established in section 15.2.2.

15.1.6.11 Example

Controls, such as up, down, load, and unload, activated while the operator is moving the arm, are to be located so they can be activated while holding onto the handles. They may be buttons, or require the motion of the handle to activate. Button activation forces are to remain within the criteria established in section 15.2.1.2.

15.1.6.12 Example

The end effector shall be designed to provide an easy, errorproof way of loading the part.

15.1.6.13

15.2 Tool Design Criteria

15.2.1 Manual Force

15.2.1.1 Example

The maximum pinch force is 9 N (2 lbs.).

15.2.1.2 Example

Maximum finger-activated push button force is 13 N (3 lbs.). Maximum thumb-activated push button force is 22 N (5 lbs.). When these forces are applied to hoist pendant controls, functional grip span must not exceed 9.5 cm (3.7″).

15.2.1.3 Example

Eliminate palm buttons where possible. When necessary, select REES low force 8.5 N (1.9 lb.) palm buttons # 04957-012, DaimlerChrysler NPM 22-452-1510 for palm buttons cycle initiation applications. The spacing between the palm buttons should not exceed 61 cm (24″). Static force application to palm buttons should be minimized and must not exceed 4 seconds in duration per cycle. Button boxes should not increase the reach distance from the operator to load the point. Ring guards are required for each horizontal palm button.

15.2.1.4 Example

Maximum hand crank control forces are 22 N (5 lbs.).

15.2.1.5 Example

Eliminate hand tool feed force. (Consider using weld nuts and the use of hex or torx head rather than slotted or Phillips head screws.)

15.2.1.6 Example

Make levers as long as practical to maximize mechanical advantage. The maximum manual lever force requirement is 129 N (29 lbs.).

15.2.1.7 Example

The maximum force to rotate an object using the hand in a flexion/extension motion is 2.11 Nm (1.6 ft.lb.).

15.2.2 Tool Handle and Activation

15.2.2.1 Example

The sealer or paint gun trigger grip force is 5 - 25 N (1 - 6 lbs.). Two finger activation triggers are preferred over one finger triggers. Thumb trigger activation devices are not recommended for repetitive operations. Articulating surfaces such as cycle buttons, levers or triggers shall be designed to minimize contact stress on the skin surfaces while providing positive off — on differentiation sensory feedback.

15.2.2.2 Example

Maximum grip strength is achieved with a hand tool grip span between 7.5 – 8 cm (2.9″ to 3.1″). The maximum grip force is 45 N (10 lbs.).

15.2.2.3 Example

Manual hand tooling with hinged design such as pliers must be equipped with appropriate spring loaded return assist mechanisms, when assigned to be used on a frequent cyclic basis.

15.2.2.4 Example

Make the tool handle diameters as close as possible to 4 cm (1.5″) with a minimum of 11.5 cm (4.5″) in length. Surface materials must have a high coefficient of friction to minimize the required grip force. The holding and controlling surface of the tools should be designed without deep grooves, sharp edges or fluted finger surfaces. For a tool used with a power grip, the tool must be designed, whenever possible, with an oval shaped handle 3 cm by 4.5 cm (1.25″ by 1.75″) in diameter. If an oval shaped handle cannot be used, select a circular handle of at least 4 cm (1.5″) in diameter. Tool handles should be equipped with a flange to prevent the tool from slipping out of the hand. Tools in which an axial force is applied such as punches

should be equipped with a 15 mm (0.6″) flanges to prevent the hand from slipping off the handle and to guard the hand from hammer contact and collision with a rigid surface.

15.2.2.5 Example

Tool handles must extend beyond the palm of the hand with a minimum length of 11.5 cm (4.5″).

15.2.2.6 Example

Provide padded and rounded surfaces on hand tools and fixtures.

15.2.2.7 Example

Use four finger throttle on right angled, crow foot and tube nut runner power tools. Locate the power tool throttle opposite the torque reaction force for non reversing tools or opposite the work task on reversing tools. For example if a reversing tool is used overhead the throttle should be facing downward. Consult your Corporate power tool specialist for further assistance.

15.2.3 Tool Selection

15.2.3.1 Example

Use only DaimlerChrysler Corporate approved power tools.

15.2.3.2 Example

Minimize the weight of manually handled hand / power tools and fixtures. Ensure that all tools are appropriately balanced and in the "in-use" position, to avoid additional manipulation of the tool.

15.2.3.3 Example

Select hand tools with minimal vibration. Power tool vibration levels must not exceed 4 m/s^2 using the testing protocol defined in ISO 5349.2. Ensure that all power tool attachments such as sanding disks, extension, sockets etc. . . are balanced and mechanically secure to minimize the avoidable vibration.

15.2.3.4 Example

Pulse tools are preferred. Mandatory tools should be lightweight, low force, fitted to the hand and designed for one handed use.

15.2.3.5 Example

Provide air line swivel couplings between at the power tool / hose interface, particularly where more than one position or posture per cycle will be used.

15.2.3.6 Example

Pneumatic air tool exhausts must be adjusted to direct exhaust air away from the worker.

15.2.3.7 Example

Equipment must be designed so that convenient accessibility is provided for maintenance facilities and tools must be designed such that maintenance related service controls, instruments, lube points, shut off valves etc. are visible and fully accessible from the shop floor in a convenient location outside of machine guarding.

15.2.4 Reaction Torque Control

15.2.4.1 Example

Pneumatic nut runners shall be equipped with an automatic shut-off to achieve a pre-set torque with greater precision while minimizing the torque reaction stress on the operator.

15.2.4.2 Example

Right angled, tube nut runner and crowfoot hand held continuous drive power tools with shut off mechanisms exceeding 50 Nm (37 ft. lbs.) must have torque controlled utilizing a pulse tool, reactionary device or tool arm.

15.2.4.3 Example

Pistol grip continuous drive power hand tools with shut off mechanisms exceeding 3 Nm (26 in. lbs.) must have torque controlled utilizing a pulse tool, reactionary device or tool arm.

15.2.4.4 Example

In line continuous drive hand held power tools exceeding 1.6 Nm (14 in. lbs.) must have torque controlled utilizing a pulse tool, reactionary device or tool arm.

15.2.5 Tool Support

15.2.5.1 Example

Use a lift assist/balancer to support the weight of tools or fixtures when they weigh > 3 kg (7 lbs.) and are used on work elements performed frequently; or weigh > 11 kg (25 lbs.) and are used on work elements performed infrequently. The tool support attachment location should be located at the tool's center of gravity when all connection devices are attached.

15.2.6 Controls and Displays

15.2.6.1 Example

Minimize the total number of operator controls. The location of the controls and indicators shall take into account their importance, frequency and sequence of use.

The arrangement of controls should be compatible with their associated displays or machine functions. Controls should be located close to the associated display and arranged in a logical manner with respect to displays. Controls should be positioned to allow equipment and machinery operations with the upper limb joints in neutral position between 91.5 – 123 cm (36″ and 48″) above the worker supporting surface. Controls spacing and clearances should be adequate for an operator wearing gloves or other necessary protective equipment. Sensitivity gain relationships of controls should be appropriate for the task as described below:

Up (Right)	Down (Left)	Up (Right)	Down (Left)
on	off	up	down
high	low	faster	slower
open	close	increase	decrease
in	out	start	stop
raise	lower	accelerate	decelerate

15.2.6.2 Example

Locate controls/indicators according to their importance, frequency and sequence of use. Use digital display when precise values are needed. Analog displays, such as dials should be used to monitor rate of changes and for comparison within defined limits. Analog dial pointers should be aligned to indicate normal functioning. Color coded dials should be provided to indicate operating conditions. Appropriate character sizes on the dials should be provided for effective inspection.

Optimal indicator character height (mm) = horizontal distance (mm)/200

15.3 Workstation Design Criteria

15.3.1 Task Design

15.3.1.1 Example

Design a job with a variety of muscles and postures used in every cycle.

15.3.1.2 Example

Design a job such that both hands can be used.

15.3.1.3 Example

Whole body vibration levels must be minimized. Critical whole body resonance frequencies are between 2-200 Hz.

15.3.1.4 Example

Minimize the need for workers to be inside of the vehicle during assembly. Articulated arm seated personnel carriers should be considered as an alternative for inside of vehicle assembly tasks.

15.3.1.5 Example

Minimize twisting and deviated work postures in the task design (work in front of the body).

15.3.1.6 Example

Minimize the need for operators to walk backwards with extended reaches. Utilize skillets with lifts, moving sidewalks, synchronous carriers or reverse the direction of flow of the vehicle during assembly to avoid these conditions.

15.3.1.7 Example

The maximum two handed cyclic vertical downward pull force is 107 N (24 lbs.).

15.3.1.8 Example

Ensure the worker's hands are in line with their forearms (i.e. keep wrists straight).

15.3.1.9 Example

Keep the worker's palms facing each other (not facing up or down).

15.3.1.10 Example

Keep the worker's upper arms hanging near vertical to the sides of the body.

15.3.1.11 Example

Consider automating or Purchased in Assembly (P.I.A.) of highly repetitive tasks.

15.3.1.12 Example

Seated work is not usually an acceptable approach for manufacturing operations where movement of the lower body is required. Approved seated workstations must be provided with a horizontal leg clearance of 66 cm (26″) and a work surface height of 76 cm (30″) above the supporting surface and a DaimlerChrysler Corporate approved chair. If inadequate leg clearance is available, the workstation must be designed for the operator to perform the work in a standing posture. Articulating arm personnel carriers offering seated postures for vehicle interior assembly are acceptable and can be a preferred process alternative on specific assembly tasks to the awkward postures often assumed by the workers assigned to perform assembly tasks on the interior of the vehicles.

15.3.2 Workstation Layout

15.3.2.1 Example

Keep tools and work in front of the worker.

15.3.2.2 Example

Eliminate reaching behind the worker.

15.3.2.3 Example

Place more frequently used objects closer to the worker.

15.3.2.4 Example

Place heavier objects closer to the worker.

15.3.2.5 Example

During the normal work cycle, the operator should not be assigned to step up or down between workstation elevations when manually handling large parts where visibility may be reduced and/or when walking backwards over the elevation change. Appropriate level workstation platforms must be provided for these conditions. If a work assignment includes stepping up and down off a platform, increased metabolic demands must meet the requirements of 15.5.2.

15.3.2.6 Example

Video display tube heights should be adjustable with the center between 122 – 152 cm (48″ – 60″) above worker support surface for standing work stations.

15.3.3 Working Height

15.3.3.1 Example

For standing workstations the optimal task height (location of hands when working) is 104 cm (41″) above the worker support surface.

15.3.3.2 Example

The recommended work envelope (location of hands when working) is between 91 – 122 cm (36″ – 48″) above the standing support surface.

15.3.3.3 Example

Provide fixtures or a surface area to support objects being worked on.

15.3.3.4 Example

If the workstation cannot be lowered, consider the use of platforms.

15.3.4 Reach Distance

15.3.4.1 Example

Reach envelopes should consider the smallest users (i.e. 5th percentile females). The anthropometric data referenced should be an appropriate approximation of the working population that will be using the workstation.

15.3.4.2 Example

Minimize horizontal reach distances to perform manual task. The maximum horizontal reach distance measured from the edge of any barrier (tool, fixture, vehicle,

etc.) between the worker and the task is 51 cm (20″). Tooling and conveyor infrastructures such as air lines, electrical conduits, machine guarding, structural supports and emergency stop cables shall not be located between the worker and the manual tasks in such a way that the reaches are increased by their physical presence. Design tooling/fixtures that prevent lowering of the part away from the operator.

15.3.4.3 Example

Place frequently used tools and parts within 38 cm (15″) of the worker and minimize horizontal non lifting reaches > 51 cm (20″).

15.3.4.4 Example

Platforms with belly bars may be used to achieve reaches greater than 51 cm (20″). When designing a belly bar, the angled portion of the rail should begin at a vertical height of 76 cm (30″), and end at a vertical height of 91 cm (36″), with a maximum angle of 30° from vertical. If the belly bar is located on a platform, the toe plate should be located outboard of the rails to maximize toe clearance.

15.3.5 Clearances

15.3.5.1 Example

Clearance allowances should consider the largest users (e.g. 95th percentile males). The anthropometry data referenced should be an appropriate approximation of the working population that will be using the workstation.

15.3.5.2 Example

Use a minimum clearance of 46 cm (18″) torso clearance between powered moving objects and fixed structures and 10 cm (4″) hand clearance between manually moved objects and fixed structures. Refer to 16.12.1.9 for complete clearance requirements associated with motion hazards.

15.3.5.3 Example

Use a minimum of 203 cm (80″) above the floor for overhead clearance for standing workstations.

15.3.5.4 Example

Provide standing workstation foot clearance along the length of that workstation with 15 cm (6″) depth and 10 cm (4″) height clearance.

15.3.5.5 Example

The minimum width for clearance in areas where workers are required to walk is 71 cm (28″).

15.3.5.6 Example

Provide an unobstructed work space having a three dimensional cylindrical shape with a minimum of 122 cm (48″) in diameter when manual material handling is required.

15.3.5.7 Example

The minimum dynamic work space per person for upper extremity motions has a three dimensional cylindrical shape with a diameter of 69 cm (27″).

15.3.6 Auditory Signals

15.3.6.1 Example

Use auditory signals when a quick response is critical.

15.3.6.2 Example

Alarms for low hazard or non-hazard purposes such as "End of Travel" and "In-the-Hole" alarms should be set at 6 dBA above background, but shall not exceed 10 dBA above background. Alarms intended to alert of dangerous conditions such as fire/tornado alarms, railcars entering the building, and putting a machine into automatic cycle should be set at 10 dBA above background, but shall not exceed 15 dBA above background.

15.3.6.3

Please refer to the DaimlerChrysler Sound Level Specification for Industrial Machinery and Equipment for noise control design guidelines. This specification may be found at: http://intranet.chrysler.com/admin/osha/indhg/Web/Default.htm.

15.3.7 Visual Considerations

15.3.7.1 Example

Consider vision systems for repetitive complex inspection tasks.

15.3.7.2 Example

Provide artificial lights with minimum shadows and glare if required.

15.3.7.3 Example

The normal viewing distance is 46 cm (18″) with a minimum of 33 cm (13″) and a maximum of 71 cm (28″).

15.3.7.4 Example

Design tooling/fixtures and assembly tasks to minimize blind or hidden loading/assembly requirements.

15.3.8 Synchronous Material and Tool Carriers (Line Side Limos)

15.3.8.1 Example

Carriers are to be designed so employee hand height is between 91 – 122 cm (36″ – 48″), with a target height of 104 cm (41″) per section 15.3.3.2. When all parts cannot be located at 104 cm (41″) due to space limitations, heaviest parts shall be at that height. If elevation changes are used to accomplish this, operations at similar heights shall be grouped together to reduce the number of elevations changes required.

15.3.8.2 Example

Parts are to located in close proximity to where they will be installed. Parts should also be in assembly position to eliminate unnecessary rotating or flipping of parts.

15.3.8.3 Example

Tool holders on carriers are to be within height criteria of section 15.3.3.2 and are to be located in close proximity to, and in the same orientation to, where the tool is used.

15.3.8.4 Example

The structure of the carrier should not interfere with the load or unload path of parts or tools.

15.3.8.5 Example

The carrier should be designed to provide clear access to the point of operation per section 15.3.5.

15.3.8.6 Example

Reach distances are to be minimized and kept with the criteria of section 15.3.3.2 and section 15.3.4.2.

15.3.8.7 Example

Part holders are to hold the part only. Dunnage (expendable or returnable) shall not be loaded onto the carrier with the part.

15.3.8.8 Example

The design of the carrier should allow easy adjustment of height and location of shelves and other features, to allow for product changes, process changes, and continuous improvement. The carrier should allow adjustments to be made with standard hand tools.

15.3.8.9 Example

Carrier speed should be synchronized with the line speed.

15.3.8.10 Example

The carrier should automatically return to home position after its associated operations are completed.

15.4 Process Driven Design Criteria

DaimlerChrysler employees may refer to the appropriate MAP Ergonomics representative to obtain a copy of the Process Driven Design Specifications.

15.5 Digital Human Modeling Criteria

15.5.1

Select the Safework human model and the Delmia digital manufacturing simulation software. The digital design criteria must accommodate 90% of the manufacturing population at the specific geographical region where task designs are being prepared.

15.5.2

Maximum acceptable time weighted average metabolic energy consumption is 4.5 Kcal/minute.

15.5.3

Manual material handling tasks must be acceptable to 75% of the female population using the published paper authored by Stover Snook and Vincent Ciriello (Ergonomics, 1991, Vol. 34, No. 9, 1197-1213).

15.5.4

DaimlerChrysler Corporation will undertake to conduct digital assembly mock up simulations as DaimlerChrysler requires.

15.5.5

The Manager of MAP Virtual Assembly will develop and implement advanced digital human simulations of worker interfaces within corporate engineering to eliminate, reduce and remove manual assembly task risk factors for DaimlerChrysler.

15.6 Ergonomic Review Procedures

15.6.1 Supplier Roles and Responsibilities

Designers, builders, vendors, suppliers, contractors,etc. (which will be referred to as Supplier) who provide new and refurbished materials, services, tools, processes, facilities, task designs, and product components to DaimlerChrysler shall:

- make all reasonable efforts to implement all of the criteria and requirements of Section 15 of the DaimlerChrysler Tool Design Standards Do's and Don'ts,

- integrate Section 15 into their decision making process as early as possible in the engineering design phases,
- identify compromises to the requirements of Section 15, make every effort to implement effective, low cost engineering controls and solutions to accommodate the requirements of Section 15, and earn approval of deviations to the requirements of Section 15 as required.

What To Do When A Requirement Is Compromised

- undertake to obtain professional ergonomic guidance and direction from a competent Certified Professional Ergonomist (CPE) or equivalent as required to evaluate and assess compromised requirements,
- electronically inform (via e-mail) the DaimlerChrysler Process representative and the DaimlerChrysler MAP Ergonomics representative when new and refurbished materials, services, tools, processes, facilities, task designs or product components compromise the requirements of Section 15,
- electronically (via e-mail) request the attendance of the appropriate DaimlerChrysler MAP Ergonomics representative at a meeting to review any deviations to Section 15 on the design plans at the engineering concept phase and at the 40% process design review. The request for attendance must be accompanied by an appropriate ergonomic assessment with recommendations by the Supplier's competent ergonomist for the specific requirement being compromised in Section 15. A minimum of 10 days lead time notification should be provided to the DaimlerChrysler MAP Ergonomics representative when setting up these meetings. Appropriate local directions and contact information must also be provided in the electronic meeting invitation.
- If the compromised requirement is not excessive based upon an objective ergonomic analysis, the DaimlerChrysler MAP Ergonomics representative will grant approval of a deviation of the specific requirement using form 15.6.2.
- By accepting a contract which references the DaimlerChrysler Tool Design Standards Do's and Don'ts, the Supplier accepts total responsibility for compliance with Section 15 of the Do's and Don'ts, and for the lack there of.
- The DaimlerChrysler MAP Ergonomics representative will reserve the right to contribute to the optimization of worker interfaces and to verify compliance with Section 15 of the DaimlerChrysler Tool Design Standards Do's and Don'ts.

15.6.2

DaimlerChrysler Corporation Ergonomics Deviation Review Form

ADDENDUM B

GENERAL DESIGN AND PURCHASING GUIDELINES

1. **Purpose**
   1.1 This document provides general technical requirements and guidelines for the design, build and purchase of equipment and fixtures.
2. **Scope**
   2.1 This document applies to the Arlington manufacturing facility in Campbell, IL.
3. **References**
   3.1 AR-15—General Safety Standards
   3.2 AR-19—Procedure for Processing Purchase Requisitions and Purchase Orders
4. **Definitions**
   4.1 None.
5. **Material and Equipment**
   5.1 Any relevant material or equipment as needed.
6. **Responsibilities**
   6.1 All Arlington associates in the Campbell manufacturing facility must adhere to the guidelines provided in this document when purchasing new equipment or modifying existing equipment.
7. **Requirements**
   7.1 Purchasing—Follow the guidelines for purchasing as found in AR-19.
   7.2 Safety
      7.2.1 Machine Guarding—Refer to AR-57, Machine Guarding Procedure for Safety.

Advanced Safety Management Focusing on Z10 and Serious Injury Prevention, by Fred A. Manuele

7.2.2 Guarding for Construction—Follow AR-62.

7.2.2.1 Give consideration to the best appropriate finish of all parts including functionality and aesthetic purposes.

7.2.2.2 Use stainless steel or ceramics for parts that contact the product. Approval of any parts/material which contact product must be obtained on a case by case basis.

7.2.2.3 Anodize aluminum parts.

7.2.2.4 Use industrial paint or primer when the painting of steel is necessary.

7.2.2.5 Finish all surfaces to prevent corrosion.

7.2.2.6 Consider material compatibility for long component life and the prevention of corrosion.

7.2.2.7 Allow no direct contact of the product with aluminum, bronze, lead, or oil.

7.2.2.8 Use steel or aluminum framing for large transparent doors in high stress or vibration areas.

7.2.2.9 Use only polycarbonate materials such as RAND or a similar material for transparent doors and guards since Plexiglas materials often become brittle and shatter upon impact.

7.2.2.10 Make all exposed edges (i.e., where contact with a body part may occur during operation of equipment) with a 3/16″ radius (minimum).

7.2.2.11 Method of fastening panels to framework:

1. Use only "TORX" screws.
2. Use through bolt, flat washers, and anti-vibratory nut, if possible—Tapping into transparent panels is NOT ACCEPTABLE.
3. Place bolts spaced not more than 6″ center to center.
4. Use hinged panels with captive style fastener for the latch.

7.2.3 Signage—Clearly identify all controls and devices with appropriate warning signs, labels and tags.

7.3 Industrial Hygiene

7.3.1 Noise

7.3.1.1 Make the maximum noise level of the equipment 80 dBA, 8 Hour Time Weighted Average when measured on the "A" scale of a standard sound level meter or noise dosimeter within 3 feet of the equipment.

7.3.1.2 Make the maximum peak noise level 115 dBA when measured on the "C" scale of a standard sound level meter, within 3 feet of the equipment.

7.3.2 Ventilation—Use a systematic approach when designing or modifying exhaust ventilation systems.

7.3.2.1 Refer to "Industrial Ventilation—A Manual of Recommended Practices," published by the American Conference of Governmental Industrial Hygienists (ACGIH), Section 6.0, which presents a systematic approach for designing or modifying exhaust ventilation systems.

7.3.2.2 As a baseline, design to a minimum of 90 fpm and a maximum of 150 fpm face velocity at point source of exhaust.

7.3.2.3 Equip each exhaust flow vent system with a continuous air flow monitoring device to detect any loss in air flow: Tie the system into the site emergency power system.

7.3.3 OSHA Hazard Communication

7.3.3.1 Submit a Material Safety Data Sheet to site safety representative for approval prior to design and build of any new or upgraded equipment or process that requires the use of solvents, chemicals or other fluids.

7.3.3.2 An investigation will be conducted to determine if the equipment or process will pose any physical or health hazard.

7.3.3.3 Measures will then be recommended to minimize the risk. This includes descriptions of features and safeguards protecting the operator from direct or fugitive exposure to chemicals, solvents or generated waste streams.

7.4 Ergonomics

7.4.1 General Workstation Design—Consider the following ergonomic guidelines for general workstation design as optimal dimensions and are not intended to restrict or limit your ability to design effective workstations. Above all, general workstation design should factor in the amount of risk employees will be subjected to when using workstations.

7.4.1.1 Typical risk factors associated with industrial designs include but are not limited to:

1. excessive forces
2. poor body postures
3. high repetition
4. vibration

7.4.1.2 Design workstations, when possible, to allow operators to work in both sitting and/or standing positions.

7.4.1.3 Make work surface height for a sit/stand station 38″ to 40″.

7.4.1.4 Design "seated only" work surface height shall be 28-30″ (28″ is preferred) when "sit/stand" workstation is not feasible.

7.4.1.5 Minimize work surface thickness, including underside support members (1″ preferred, 2″ maximum).

7.4.1.6 Design work fixtures to allow hands to be positioned no higher than 4″ above the work surface. The total dimension from the underside of the workstation to the point where the work is performed should not exceed 6″. If visual requirements necessitate higher work positioning, arm rests should be provided.

7.4.1.7 Provide unobstructed legroom for the operator to sit comfortably (24″ wide, 26″ from the floor to the underside of work surface, 18″ deep from the front edge of work surface).

7.4.1.8 Allow a 4″ × 4″ toe cut-out at the bottom of the station when Standing Stations are used.

7.4.1.9 Design equipment/fixtures to be adaptable for convenient use by right or left handed operators, wherever possible.

7.4.1.10 Round all leading edges which the operator may come into direct contact with whenever possible. Try to recess the external hardware like hinges, door pulls, knobs, etc., as much as possible to avoid contacting the operator.

7.4.1.11 Minimize equipment/fixture size to limit forward bending or reaching, as much as possible to allow for tote pans and/or parts trays to be positioned in front of the operator. All operator/equipment interaction issues must be considered.

7.4.1.12 When fixed (non-adjustable) features are included into the design, the following principles are important to remember:

1. Design clearance dimensions for a tall operator (74″ in height).
2. Design reaching dimensions for a short operator (60″ in height).
3. Design fixed height dimensions designed for an average operator (66″ in height).

7.5 Machine and Process Control

7.5.1 Master Control Relay—Provide Master Control Relay for emergency shutdown.

7.5.1.1 Hardwire emergency Stop pushbuttons and all Safety Switches in series to the Master Control Relay.

7.5.1.2 If any of these devices opens, the Master Control Relay should de-energize and remove power from the control circuit.

7.5.2 Emergency Stop—Provide Emergency Stop pushbuttons in an obvious location and within easy reach of either hand of the operator.

7.5.2.1 Design the E-stop such that to restart after Emergency shutdown it is necessary to pull out the E-STOP button and then press the appropriate buttons to initiate normal operation.

7.5.2.2 Design the E-STOP to interrupt power from the outputs, drives and other powered devices.

7.5.3 Interrupt DC Power Supply—Use DC power supply, interrupted on the DC side for faster response.

7.5.4 PLC Power—Wire power to the PLC outputs through a set of master control relay contacts.

7.5.5 Interlocks—Design machine to not be capable of running in continuous RUN mode with interlocked guards out of position or removed.

7.5.6 Mechanical Design:

1. No sharp edges or corners.
2. No shear points or pinch points.
3. Design turntable machines to not catch arms, hands, fingers or clothes and with filled internest areas.
4. Consider torque or force limiting devices for any part-moving device such as turntables, carriages and slide assemblies, etc. (For instance, magnetic couplings used for emergency breakaway on linear shuttle assemblies.)
5. Use four-way, spring-centered, pneumatic valves for equipment working off of two hand controls.

7.6 Environmental Impact/Hazard Evaluation

7.6.1 Have materials used for all new or upgraded equipment and processes that are to be located in the facility evaluated to assure that they comply with Arlington's Policy and Governmental Regulations concerning such materials. This applies particularly to chemicals and generated waste streams.

7.6.1.1 Environmental Impact—Have any equipment or process which may release any chemicals to the environment evaluated for environmental impact. All information necessary for this impact study must be submitted to the site environmental coordinator early enough in the development stage to avoid costly rework or delays.

7.6.1.2 Material Safety Data Sheets—Have any chemical proposed for a new process approved by the site safety

representative. A Material Safety Data Sheet (MSDS) and any other hazard data information must be submitted for evaluation prior to release of any purchase order for new equipment.

8. **Procedure**

8.1 Use this document as a guide whenever purchasing new (or modifying existing) equipment.

8.2 Codes and Standards

8.2.1 At a minimum, all equipment shall comply with the latest revisions of the applicable specifications, codes and standards. When deemed applicable by Engineering, documentation/labeling of said compliance shall be provided. *Note:* In case of conflicting specifications, the more stringent shall apply.

8.3 Equipment/Fixture Design

8.3.1 Make sure all surfaces that may come into contact with the operator's body are free of sharp edges and corners (minimum 3/16″ radius).

8.3.2 Tilt or orient fixtures to allow the operator to perform all work with a neutral body posture.

8.3.2.1 A general guideline is to tilt the fixture 15° toward the operator to enhance access and visibility, and to minimize awkward postures.

8.3.2.2 Specific recommendations will be made upon review of the job function in question.

8.3.3 Locate frequently accessed controls in front of and close to the operator to minimize reach distances.

8.3.4 Minimize repetitive reaches in front of the body to never exceed 16″.

8.3.5 Repetitive reaches above chest height, below work surface height or behind the body are not acceptable.

8.3.6 Design repetitively used control buttons (e.g., cycle start buttons) to require nominal activation of one pound or less. Where possible, it is also desirable for the pushbutton to be 2–3″ in diameter.

8.3.7 Provide control knobs and handles with a nominal diameter of 1-1/4″. Clearance must be provided in equipment to avoid bumping the fingers or hands when parts are being positioned.

8.4 Mechanical—Design and Construction

8.4.1 Design equipment in a manner to prevent operator mistakes. *Note:* This includes preventing incorrect installation of tooling for set-up, incorrect loading of parts, installing wrong parts or incomplete parts. The goal is to make the machine capable of producing zero defects without relying on correct operational procedure.

8.4.2 Materials/Finishes

8.4.2.1 Materials "IN" Contact with the Product

Approval of any parts/material which contact product must be obtained on a case by case basis. Listed below are some guidelines to aid in choosing a material:

1. Use nonabrasive and nonmarring materials.
2. Use Stainless Steel—300 series is preferred, 400 series in specific applications. Passivation and/or electropolish finish.
3. Use Aluminum—hard anodize only.
4. Use Plastics—fluorocarbons, polycarbonates, acrylics, ABS, polypropylenes, polyethylenes and nylons, with approval of site project coordinator.

8.4.2.2 Materials "NOT" in Contact with the Product

1. Use Carbon Steels—properly prepared and painted, flash chromed or electroless nickel plated.
2. Use Stainless Steels—anodize.
3. Use Aluminum—anodize.

8.4.2.3 Miscellaneous Finishes

1. Cover any table top surface or equipment that comes in contact with product with either stainless steel or laminate (see specifications for requirements). Approval of any parts/material which contact product must be obtained on a case by case basis.
2. Do not use Wood Products in the manufacturing area.

8.4.3 Equipment Size and Weight Restrictions

8.4.3.1 Free Standing Equipment—No restriction

8.4.4 Tooling Requirements

8.4.4.1 Locating Datum—Dimension all tooling from and locate the part from the primary datum of the component part. Features—Design tooling with the following features:

1. Interchangeability—Use dowels, bushings, and standard dowel patterns for locating to the equipment, when practical, all like tooling.
2. Quickchange—Use quickchange features on tooling to accomplish the changeover within the time requirement and in a repeatable manner. Quickchange techniques or devices such as single fastener size, quarter turn fasteners, locking knobs, slotted holes, setup blocks, special tools, etc., may be used.
3. Adjustment/Installation—Design tooling to be fixed and not adjustable to the equipment. Adjustment features should be incorporated into

the equipment (locking slide) rather than the tooling (slotted holes) if possible.

4. Design tooling to assure the correct installation of the tooling onto the equipment, using asymmetrical dowel patterns or a similar feature.

8.4.5 Hardware Items

8.4.5.1 Include one (1) resettable stroke counter and one (1) non-resettable stroke counter with each piece of automatic equipment.

8.4.6 Working Environment

8.4.6.1 Design all equipment to operate in a Class 100,000 working environment unless otherwise specified.

8.4.7 Preferred Mechanical Components

8.4.7.1 The following Preferred Components are listed in two groups, "A" and "B." "A" components are preferred as "first choice" and "B" components as "second choice." *[In a resource to this addendum, a chart lists equipment items and brand names categorized in the aforementioned groups "A" and "B." It is not reprinted here.]*

8.4.7.2 Use of "B" components shall require the approval of the Equipment Engineer.

8.4.7.3 Use Preferred Components except when their use is not practical or jeopardizes project delivery.

8.4.7.4 Obtain approval from Equipment Engineer prior to substitution for Preferred Components.

8.4.7.5 Use standard commercially available components wherever possible.

8.4.7.6 General Equipment and Machinery

8.5 Electrical—Design and Construction

8.5.1 Enclosures

8.5.1.1 Use enclosures properly rated for the environment to which they will be exposed.

8.5.1.2 Equip the main control enclosure with a fusible and lockable disconnect. Alternately, if appropriate, a fusible lockable disconnect may be provided directly upstream of the main control enclosure. It shall be readily accessible as stated in the NEC.

8.5.1.3 *If any live circuit should exist by design in the system after opening the main disconnect, the main disconnect and the enclosure(s) containing that live circuit shall be obviously labeled stating this condition and the source and voltage of the live circuit*.

8.5.1.4 Provide spare space in the electrical enclosure for future additions:

1. Allow for panels less than 500 square inches; a minimum of 40% spare capacity shall be provided.
2. Allow for panels greater than 500 square inches; a minimum of 15% spare capacity shall be provided.

8.5.1.5 Do not mount control equipment on the door or sides of the enclosure except devices such as pushbuttons, pilot lights, selector switches, meters and instruments.

8.5.1.6 Mount terminal strips on inside enclosure sides and door, when appropriate. All terminal strips must be permanently, mechanically affixed—not glued or attached with a sticky strip.

8.5.1.7 Appropriately protect all wiring against excessive flex and pinching as a result of enclosure door operation.

8.5.1.8 During operation, the control enclosure interior temperature shall not experience a rise in temperature greater than 40° Fahrenheit over ambient temperature. Should the installed equipment cause this condition to occur in a static environment, filtered forced air shall be provided to maintain this temperature requirement. Appropriate alarms on this air flow must be provided.

8.5.2 Transformers

8.5.2.1 Use control transformers, where applicable, sized for 10% to 25% spare capacity (but not less than 100 VA). Transformers 2 KVA and larger shall be of the dry type and shall be mounted externally.

8.5.2.2 Supply Source for the main control transformer shall be taken from the load side of the main disconnecting device. The isolated secondary of the main control transformer shall provide, nominally 120 VAC, single phase and shall provide a bonded ground.

8.5.2.3 Fusing—Provide on primary and secondary.

8.5.3 Component Mounting

8.5.3.1 Use meters and operating controls placed so as to conform with Arlington ergonomic and AR-19 methods. Discuss with the electrical engineering representative.

8.5.3.2 Make all panel mounted components removable without having to remove the control panel.

8.5.3.3 Identify control equipment mounted on the machine by use of engraved Lamicoid type labels. Labels shall be permanently secured to the machine in order to facilitate their identification and location on wiring diagrams.

8.5.3.4 Identify control equipment mounted internal to the control cabinet by Brady labels or its equivalent. Dymo type labels shall not be used.

8.5.3.5 Permanently label all components (relays, transformers, fuses, terminal blocks, etc.) mounted on the equipment and in the control enclosures according to a scheme agreed upon by an electrical engineering representative. Labels must be affixed so that replacing parts does not remove or change the intended identification.

8.5.4 Pushbuttons

8.5.4.1 Use "Start" of the fully guarded momentary contact type on equipment or operations sensitive or very dangerous in the event of inadvertent start-up. Otherwise, flush momentary type buttons shall be used.

8.5.4.2 Use Normal "Stop" buttons of the extended momentary contact type.

8.5.4.3 Locate the "Stop" button near the start pushbutton.

8.5.4.4 Use Emergency stop pushbuttons of the illuminated, maintained type when depressed.

1. Arrange the circuit so that depressing an emergency stop pushbutton will inhibit all machine motions and drop out the hard wired start/stop circuit. The E-stop light will be wired independent of other E-stop lights so that any depressed E-stop can be identified regardless of the position of any other E-stop pushbutton.

8.5.4.5 Pushbutton Colors

Color	Typical Function	Example
Red	Stop Emergency Stop	Stop motors Master stop
Green	On/Start Autocycle	Start of a cycle or motor
Black	Inch, Jog Horn Silence	Inching Jogging
Yellow	Return, Reset	Return of machine to safe or normal condition
White	By approval only	
Gray	By approval only	
Blue	By approval only	
Orange	By approval only	

8.5.5 Position Sensors—Digital: Solid-state optical or proximity sensors are preferred to electromechanical limit switches. Sensors with built-in status indicating lights are preferred to those without.

8.5.6 Sensors/Signal Conditioners—Analog: Use solid-state sensors or signal conditioners with a 4–20 mA DC output.

8.5.7 Power Distribution

8.5.7.1 Power Supply Protection—Provide suitable power supply protection/conditioning equipment if the equipment is susceptible to power brownouts, voltage surges/spikes, or line conducted electromagnetic interference.

8.5.7.2 Surge Suppression—Include an MOV or diode in parallel located as close to the load as practical on all inductive loads—motor starters, solenoids, relays, transformers, etc.

8.5.7.3 Overloads—Use overloads of the manual reset type. Overload reset buttons shall be installed in the panel enclosures to allow manual reset, unless specifically provided for in separate motor starter control boxes.

8.5.8 Wiring Practices

8.5.8.1 Remote Interlocks—See Section 8.5.13.1 for labeling and Section 8.5.11 for color coding, for installations and equipment containing different sources of power.

8.5.8.2 Failsafe Operation—Utilize sensors, controls and logic in such a manner that their failure or loss of power would produce the least undesirable consequences. In case of power failure, circuits must be manually re-energized to restart. The overall start and stop function must be hardwired, which eliminates the dependence on an electronic device or controller.

8.5.8.3 Push-to-Test Devices—Use pilot lights of the push-to-test type. However, if they are originating from a programmable logic controller (PLC) output, then a dedicated pushbutton input to the PLC shall be utilized to test all of such PLC output pilot lights. All other devices such as displays and horns must be tested by a push-to-test function, should be wired to the dedicated push-to-test button where possible.

8.5.8.4 Interconnections/Terminals

1. Provide all components such as sensors, temperature sensors, heaters, and small motors which require frequent replacement with an appropriately designed quick disconnecting means. Terminals are one acceptable means.
2. Package and terminate all panel-mounted solid-state devices and/or components (resistors, diodes, etc.) to be easily removable with the use of hand tools. They must be installed to allow easy access for troubleshooting and testing. They shall not be mounted near large heat-producing

components such as transformers. They shall not be soldered and/or "butt-spliced."

3. Calibrate critical process control variables on a regular basis. Where applicable and practicable, provide banana jacks/switches or accessible quick disconnects to allow convenient access for calibration. Discuss calibration requirements with the Electrical Engineer or an Instrument Mechanic. A calibration label shall be affixed to the device (or in close proximity), indicating the equipment I.D., calibration date, calibrator, and calibration due date.
4. Terminate devices external to any control enclosure at a terminal block in the control enclosure. Wiring from external devices shall not be connected directly to a device in the control enclosure. However, 440 volt motors may be wired directly to the motor starter. Thermocouples and similar very low-voltage signal-carrying conductors may be terminated directly on the device to which it interfaces. If terminals are used, they must be of a special type appropriate to signals being conducted. One terminated and identified wire shall be returned for test purposes from a connection between limit switches, pushbuttons or other devices connected in series. This test point termination may be in field junction boxes where easily accessible if appropriate.
5. Wire control circuit voltage reference points to a terminal in each terminal enclosure external to the control panel. All terminals shall be marked to correspond with terminal markings as specified on wiring diagrams.
6. Protect sensor devices with cord leads such that the leads cannot be damaged. Open wiring is not permitted.
7. Do not make electrical connection to control devices with soldered connections or wire nuts. Sensors shall be terminated on terminals in a junction box. A field junction box should be mounted to provide terminals if necessary.
8. Use terminal blocks with terminal clamp screws with no more than two wires under one screw.
9. Wire terminal blocks and mount so that internal and external wiring does not cross over the terminals.

10. Provide spare terminals in each terminal enclosure including enclosures external to the control panel. The number shall be at least ten percent of the total in use or a minimum of 6, whichever is greater. If fewer than 10 terminals are used and space prohibits, then less than 6 spares are adequate. There shall be spares appropriately spaced on each terminal block. A general rule would be to include 2 to 3 spares for each 10 terminals.
11. While maintaining functional appearance, placement of conduit and sealtite runs shall not restrict access for repair or replacement of machine parts. All conduit and sealtite shall be secured to permanent fixtures, walls, or bracing to avoid loose and damageable runs.

8.5.9 Circuit Installation

8.5.9.1 Separate AC wiring from DC wiring on both inside control panels and in wire runs, and signal wiring shall be separated from power wiring. Signal wiring shall be properly shielded. Thermocouple wiring shall be run separately unless shielded in which case it may be run with signal wiring. Where AC and DC wiring must be crossed, the wires or wire bundles shall cross at 90° to each other.

8.5.9.2 Sufficiently loop wiring to components mounted on doors to allow easy opening of the door and protect form excessive flex or pinching.

8.5.9.3 Use stranded copper of type MTW or THHN on all control wiring.

8.5.9.4 Wireways, sealtight and conduit must meet NEC requirements and provide for adequate spares without overfilling. Conduit or sealtight is required for machine wiring.

8.5.9.5 Use appropriately sized cable/wire anchors that are permanently affixed to the surface. Self-adhesive anchors are not acceptable unless mounted by screws.

8.5.9.6 All cable/wire straps shall be appropriately sized, spaced and tensioned to avoid cable/wire insulation deformation/damage and provide adequate support.

8.5.9.10 Replace nicked or cracked wire insulation.

8.5.9.11 Use a plug type removable terminal block at all locations to be separated for shipment where large equipment with interconnecting control panels are required, in order to minimize installation wiring.

8.5.9.12 Protect all wiring running alongside or over sharp edges.

8.5.9.13 Shield and ground all low voltage DC (signal) wires and cable to prevent noise interference.

8.5.9.14 Utilize a ground fault circuit Interrupter (GFCI) whenever the process is a wet process. (See the NEC.)

8.5.10 Maintenance Considerations

8.5.10.1 *Give consideration to accessing electrical equipment for maintenance troubleshooting*. This may involve maintenance bypass switches for certain interlocks. However, the machine should not be allowed to run production in the maintenance bypass mode. The equipment should be so designed to provide access to sensors, switches, and motors, etc., for preventive maintenance procedures performed on a regular basis.

8.5.10.2 Provide all wiring with a service loop sufficient to re-make the connection at least three times.

8.5.10.3 Label all wire ends as indicated on the wiring diagrams. Where no wiring label is indicated, a to/from designation shall be used. Jacketed power wiring which is color coded can have the labeling on the jacket.

8.5.11 Wire Colors

8.5.11.1 Three-Phase Power and Motor Wiring

Volts	A = L1	B = L2	C = L3	Neutral	G = Ground
480	Brown	Orange	Yellow	Gray	Green
240	Black	Red	Blue	White	Green
208	Black	Black	Black	White	Green

8.5.11.2 One-Phase Power and Motor Wiring

Volts	Phase	N = Neutral	G = Ground
480(277)	APP Phase	Gray	Green
240(120)	APP Phase	White	Green
208(120)	APP Phase	White	Green
120	Black	White	Green

8.5.11.3 AC Control Wiring

Volts	Phase	N = Neutral	G = Ground
5 to 60	Pink	White/pink	Green
61 to 120	Red	White/red	Green

8.5.11.4 DC Control Wiring and DC Motor Leads

Volts	(+)	(−)
0 to 11	Purple	White/Blue
5 to 60	Blue	White/Blue
61 to 120	Blue/Black	White/Blue

8.5.11.5 Use green or green w/yellow tracer for grounding circuits ONLY.

8.5.11.6 Cable sheathing and noise suppression conductors do not suffice for fault carrying conductors. A separate ground shall be used.

8.5.11.7 For external power or control wiring which is not de-energized when the equipment main disconnect is opened, color code is as follows: use a wire with a yellow tracer—the base color being that which corresponds to the circuit voltage in use.

8.5.11.8 Make any temporary wiring or jumpers yellow or orange and installed in a manner indicating that this is obviously the purpose.

8.5.11.9 Select appropriate conductor and jacket insulation for the environment and the service intended. All low voltage conductor insulation shall be 300 V minimum while high voltage conductor insulation shall be 5X the nominal conductor voltage or 600 V minimum. The insulation shall be appropriately selected to withstand the minimum bend radii expected and the effects of the environment (UV, ozone, oil, etc.).

8.5.11.10 "HI-POT" test all power wiring should be at the appropriate voltage/duration for the nominal conductor voltage carried.

8.5.11.11 Allowed Exceptions

1. Intrinsically safe wiring may require all conductors to be blue. Under certain conditions, sheathing may be the acceptable fault current conductor in intrinsically safe wiring. (See the NEC.)
2. If AC and AC neutrals or AC and DC neutrals are tied together, then the color of the corresponding AC neutral of the highest voltage will be used on all those common neutrals.
3. Wiring on devices purchased completely wired.
4. Where insulation is used that is not available in the colors specified.
5. Equipment for use outside of the United States when the above color coding is not in agreement with the established local electrical codes.

8.5.12 Methods of Grounding

8.5.12.1 Use a separate grounding conductor for grounding of equipment. A stranded or braided copper conductor shall be used for grounding where subject to vibration.

8.5.12.2 Grounding by attaching the device enclosure to the machine with bolts or other approved means shall be considered satisfactory if all paint and dirt are removed from joint surfaces. Moving machine parts having metal-to-metal bearing surfaces shall not be considered as a grounding conductor.

8.5.12.3 Do not use the grounded neutral conductor of a circuit for the grounding of equipment. No neutral shall be grounded, unless electrically isolated from the plant power distribution system in or immediately adjacent to the equipment in question. This is to prevent current imbalances in the power distribution system which would affect ground fault detection.

8.5.12.4 Do not mix signal and power grounds.

8.5.12.5 Terminate signal grounds at one central location whenever possible to eliminate ground loops and noise.

8.5.13 Remote Interlocks

8.5.13.1 Attach caution labels, for installations and equipment containing different sources of power, adjacent to the main disconnects stating:

CAUTION: THIS PANEL CONTAINS MORE THAN ONE SOURCE OF POWER.

DISCONNECT THE FOLLOWING SOURCES BEFORE SERVICING:

[Identity and location of all disconnects shall be shown on the label.]

8.5.13.2 Use labels of red Lamicoid with white lettering or of equivalent quality, secured in place by screws or rivets. Where practical, the remote sources of power shall be interlocked with the disconnect means. If not, a manual means shall be provided to quickly disconnect these sources.

8.5.13.3 Make all ungrounded wiring which contains remote sources of power yellow throughout the control panel.

8.5.14 Operator Interface—Apply Human Engineering criteria (Ergonomics) to the design of the operator interface. Except on the smallest systems, message board type status and alarm indicators are preferred to an array of indicator lights and associated nameplates.

8.5.15 Variable Speed Motor drives—Above 1/4 HP, solid-state variable frequency AC motor drives are preferred to solid-state variable voltage DC motor drives. Below 1/4 HP stepper motor drives are preferred to variable voltage DC drives. The selection should be discussed with xxxxx electrical engineering representative to provide standardization when possible.

8.5.16 Programmable Controllers

8.5.16.1 Discuss the type of PLC, CPU version, and I/O selection with xxxxx electrical engineering representative.

8.5.16.2 Insure that the supplier follows all design criteria established by the PLC manufacturer for installation of PLCs.

8.5.16.3 Ground I/O cards according to function (i.e., DC inputs, AC input, AC outputs, etc.), and spare slots should be left between these function groupings.

8.5.16.4 At least one hard-wired Emergency Stop function shall be generated to create an emergency shutdown independent of the PLC and shall function even if a component of the PLC fails. The Emergency Stop function shall be interlocked in to the PLC software. The E-Stop hardwiring shall open appropriate power circuits to PLC outputs.

8.5.16.5 Shield low voltage DC wiring with the following: Below 15 volts which interfaces to I/O modules, sink or source currents less than 8 MA, or input signal delay times less than 10 MA.

8.5.16.6 Maintain the shield continuity throughout the system when shielded cable is used.

8.5.16.7 Provide a minimum of 20% spare slots for future expansion.

8.5.16.9 PLC Digital Inputs—Use input modules of 110 VAC or 24 V (first preference is for AC, with DC being the second preference). Discuss with the xxxxx representative.

8.5.16.10 PLC Digital Outputs—Use 24 V for indicator lights and alarms. AC is first preference, DC is second preference. For pneumatic or hydraulic solenoids and motor starters, 115 V AC modules can be used. Solenoids should be rated for continuous duty.

8.5.16.11 PLC Analog Inputs/Outputs—The preference is 4–20 MA DC. Should 1–5 VDC input/output be required, precision 250 OHM resistors (1%) shall be used and installed at the terminating location.

8.5.16.12 Communication—In order to achieve the goal of integrating manufacturing machine raw data, components and process parameters should be shareable to the higher level of the computer system, a communication system shall be provided. It includes an interface module, communication software, and communication ports. Coaxial cable and twisted pair wire are common for the communication media; however, the optic fiber cable is preferred for the working environment with high electrical noise.

8.5.17 Instrumentation—All instruments and measuring devices used must be approved by an electrical engineering and/or instrumentation technician prior to use. Special considerations must be given to standardization, precision and accuracy, calibration requirements and maintenance. All original manuals and specifications shall be provided.

8.5.18 Machine Installation Drawings

8.5.18.1 General—Include an installation drawing showing physical dimensions for mechanical, electrical and service requirements with respect to the space needed for proper installation for each machine that is to be installed.

8.5.18.2 Service Requirements—Clearly indicate the appropriate electrical service (i.e., 480 V, 3 phase) for operation on the drawing.

8.5.19 Machine Documentation

8.5.19.1 ANSI/USAS Y32.10-1967 drawing symbols should be used. The electrical designation and descriptions on related pneumatic/hydraulic piping diagrams shall match those on the electrical diagrams.

8.5.19.2 Provide a P & ID diagram if appropriate.

8.5.19.3 Provide electrical control drawings in AUTOCAD in all cases. Formats, numbering systems, symbology, details, annotation to be discussed with xxxxx electrical engineering representative. Examples will be provided. Standard symbols generally follow standard ABCD.

8.5.19.4 All programs for drives, PLCs, etc., shall be sufficiently annotated and correspond accurately to electrical drawings.

8.5.19.5 Include all original manuals for components with machinery such as the following: motor drive manuals, operator interfaces, special programming devices, message displays, etc.

8.5.19.6 Provide a Bill of Materials with detailed parts description, manufacturer, and part number. The format should be discussed with xxxxx electrical engineering representative. Examples can be provided.

8.5.20 Preferred Electrical Components

8.5.20.1 The following Preferred Components are listed in two groups, "A" and "B." "A" components are preferred as "first choice" and "B" components as "second choice" if no "A" components are applicable.

8.5.20.2 Use of "B" components shall require the approval of the equipment engineer.

8.5.20.3 Obtain approval for substitution of Preferred Components from the equipment engineer.

8.5.20.4 Electrical Components

[In the original document, this section contains a list of electrical components and brand names for "A" and "B" choices. It is not reprinted here.]

8.6 Pneumatics—Design and Construction

8.6.1 Air Supply—Operate equipment from a single incoming air supply drop. Maximum Supply Pressure, 110 psig. Design Pressure, 60 psig recommended where possible.

8.6.2 Hardware/Circuit

8.6.2.1 Non-Lubricated System—Use pneumatic devices and circuits which do not require lubrication.

8.6.2.2 Disconnect—Design equipment/fixture to operate from a single quick disconnect (with exhausting, locking valve).

8.6.2.3 Cylinders

1. Use ports with lockable flow control valves.
2. Cylinders used in the vertical orientation and which could pose a hazard to the operator during an air dump shall have a pilot operated check valve in the

exhausting port to keep the cylinder from lowering during an air dump.
3. Use cylinders of the permanently lubricated type.
4. Adjustable cushioning at both ends is preferred.
5. Use rods with self-aligning rod end coupling.

8.6.2.4 Exhaust—To be reclassified, filtered and directed away from the operator and conform to Class 100,000 working environment.

8.6.2.5 Directional Valves—Modular packages or manifold style are preferred.

8.6.2.6 Do not use Air Over Oil or Air Pressure Intensifiers.

8.6.2.7 Fittings—Use plastic, stainless or brass.

8.6.2.8 Ports—Make all ports NPT wherever possible. If NPT is not available, then BSP shall be used. Devices with ports other than NPT shall be labeled to indicate the port type.

8.6.3 Labels—Clearly identify all devices. Labels shall be located on the structure of the equipment next to the device so that the label remains when the device is changed. Bilingual labeling considerations are to be addressed at the discretion of Site Project Coordinator.

8.6.4 Preferred Pneumatic Components

8.6.4.1 The following Preferred Components are listed in two groups, "A" and "B." "A" components are preferred as "first choice" and "B" components as "second choice" if no "A" components are applicable.

8.6.4.2 Use of "B" components shall require the approval of the equipment engineer.

8.6.4.3 Use Preferred Components except when their use is not practical or jeopardizes project delivery.

8.6.4.4 Obtain approval for substitution of preferred components from the equipment engineer.

8.6.4.5 Use standard commercially available components (ISO Standard Preferred) wherever possible.

8.6.4.6 Pneumatic Components

[In the original document, this section lists pneumatic components and the names of "A" and "B" supplier companies. It is not reprinted here.]

8.7 Software

8.7.1 PLC Software Control Philosophies

8.7.1.1 Logic Location/Recovery—Locate all start/stop logic and equipment control logic in the PLC. This logic shall be retained in PLC memory while the system is down due to normal or emergency stop, or due to power failure. The goal of the PLC logic will be

zero recovery; i.e., after a failure has been corrected, restarting the system shall be accomplished by pushing the "start" button.

8.7.1.2 Event Driven—Write software to sequence on events (switch closures) rather than time. Counters, Timers, and One-Shots shall be used only if necessary. If they are used, use as many conditions as practical.

8.7.1.3 Structure—Write PLC software in modules, using tables wherever possible, and arranged in the following order:

1. System start-up
2. Non-motion logic (lights, horns, alarms)
3. Motion logic (solenoids, motors)
4. CIM/HMI interface logic

8.7.1.4 All alarms shall be latched. Alarms shall be cleared by use of an acknowledge button.

8.7.2 Testing Objectives—Test software to ensure proper operation in the following areas.

8.7.2.1 The system performs in compliance with the statement of requirements.

8.7.2.2 The software is error free and executes correctly as defined by the process specifications.

8.7.2.3 That operating faults, alarms, interlocks and error conditions are detected and recover as specified.

8.7.2.4 That automatic and manual abort and recovery functions perform as specified.

8.7.2.5 That operator interfaces are correct as specified.

8.8 Machine Guarding

8.8.1 Refer to MG2468-18 for guarding requirements and suggested types.

9. Appendices

9.1 Appendix I—Operation and Maintenance Manual

9.2 Appendix II—Codes and Standards

Appendix I Operation and Maintenance Manual [to be provided by the equipment supplier]. An Operation Maintenance Manual is required for all Automatic Equipment to the extent appropriate to communicate proper operation and maintenance activities. The scope of the manual may range from one page of instructions for simple equipment to a full comprehensive manual for complex equipment.

Appendix II This appendix lists certain Codes and Standards to which the supplier is to adhere.

CHAPTER 17

EVALUATION AND CORRECTIVE ACTION — SECTION 6.0

INTRODUCTION

In applying the Plan-Do-Check-Act (PDCA) concept with respect to occupational health and safety management, after the issues (hazards, risks, management system deficiencies, and opportunities for improvement) are identified and analyzed, and solutions for improvement are developed and implemented, the next step is to evaluate the results and take remedial action when shortcomings have been found. That sequence is shown in the following depiction of the PDCA process:

	Plan-Do-Check-Act
Plan:	Identify the problem
Plan:	Analyze the problem
Plan:	Develop solutions
Do:	Implement solutions
Check:	Evaluate the results
Act:	Adopt the change, abandon it, or start over

Putting in place the processes outlined in Section 6.0 of Z10 results in an evaluation of the effectiveness of health and safety management systems. Through this evaluation stage, shortcomings are identified, decisions are made on the actions necessary to overcome the deficiencies, and corrective action is taken. Communication on the

Advanced Safety Management Focusing on Z10 and Serious Injury Prevention, by Fred A. Manuele

lessons learned through the Evaluation and Corrective Action processes is fed back into the Planning and Management Review initiatives.

Monitoring, Measurement, and Assessment methods are listed in Section 6.1 of Z10. The methods listed include workplace inspections, exposure assessments, incident tracking, employee input, occupational health assessment, and procedures for addressing other needs as required by the employer's occupational health and safety management system. Findings deriving from such processes are to be communicated to interested parties.

The literature on workplace inspections is abundant. Thus, that subject is not further addressed here. Measurements of effectiveness with respect to injury exposure assessments and occupational health assessments determine how well the requirements for the assessment and prioritization processes as set forth in Section 4.2 of Z10 have been fulfilled. They require that organizations have processes in place to assess the risks pertaining to health and safety exposures. Those processes are addressed in Chapters 8–10 here.

Monitoring for incident tracking relates to measures of performance. Although establishing performance measures is not one of the subjects listed in the "shall" provisions of Section 6.0, one advisory comment is this: "Organizations should develop measures of performance that enable them to see how they are doing in preventing injuries and illnesses." To have statistical validity, the performance measures adopted should consider the extent of the exposures (perhaps hours worked) as well as evaluations of the effectiveness of safety and health management systems. Although Z10's advisory information refers to occupational injury and illness rates as performance measures, a caution is given indicating that such rates should not be the sole or primary measurement tool. For a discussion of performance measures suitable for organizations of various sizes, see the chapter titled "Measurement of Safety Performance" in *On The Practice Of Safety*.

The effectiveness of the processes outlined in Z10's Section 3.0, "Management Leadership and Employee Participation," would be the basis of performance measurements on employee input. The provisions in Section 3.2, "Employee Participation," states that "The organization shall establish and implement processes to ensure effective participation in the occupational health and safety management system by its employees at all levels of the organization, including those working closest to the hazard(s)."

Section 6.2 of Z10 lists the requirements for Incident Investigation. Since I now give greater emphasis to the importance of incident investigation within the spectrum of safety and health management systems, a separate chapter on the subject appears here. Incident investigations, well made, can be a good source to identify cultural, operational, and technical causal factors, particularly for incidents resulting in serious injury or damage.

Making safety and health management system audits to determine their effectiveness and to identify opportunities for improvement is the subject of Section 6.3 in Z10. The goal of a safety audit is to provide management with an assessment of the reality of the safety culture in place and to provide recommendations on how

that culture might be improved. This important measurement process is also the subject of a separate chapter here.

Section 6.4 of Z10 pertains to Corrective and Preventive Actions. Although requirements are set forth briefly, the importance of this section should not be minimized. To fulfill its requirements, employers are to have processes in place so that corrective actions are expeditiously taken on: the deficiencies in occupational safety and health management systems; inadequately controlled hazards; and newly created hazards that have been identified during the monitoring process.

Section 6.5, "Feedback to the Planning Process," is a lessons learned and communication mechanism. This is an important feature of the continual improvement process. Its purpose is to assure that hazards, risks, and safety and health management system deficiencies observed during the monitoring, measurement, audit, incident investigation, corrective, and preventive action activities are communicated to the appropriate parties and considered in the ongoing planning and management review process. As a result of such communication, objectives are to be revised and modifications made to implementation plans to achieve a more effective health and safety management system.

CONCLUSION

When applying the PDCA continual improvement process, an important step is to determine whether the management systems put in place achieve what is intended. That is the purpose of Z10's Section 6.0—to provide an evaluation mechanism so that deficiencies in the systems may be identified and acted on. This is an important continual improvement function.

CHAPTER 18

INCIDENT INVESTIGATION — SECTION 6.2

INTRODUCTION

In Chapter 3, "Serious Injury Prevention," I commented on studies made of over 1200 incident investigation reports to assess the effectiveness of the incident investigation systems in place. I said that on a scale of 10, with 10 being best, some companies scored a 2, that causal factor determination was poor, and that opportunities to re-adjust the focus of preventive efforts to the benefit of workers and employers were lost. Observations were not made in that chapter on a rationale that may explain why incident investigations are often superficial.

As a result of those studies, I concluded that safety professionals would better serve their clients' interests:

- If they viewed incident investigation as a prime source for selecting leading indicators for improvements in safety management systems. Because—If incident investigation is done well, the reality of the technical, organizational, methods of operation, and cultural causal factors for incidents and exposures that result in serious injuries and illnesses will be revealed.
- If they adopted a different mind set and sought to have incident investigation given a much higher place within all the elements of a safety management system. Because—The quality of incident investigation is one of the principal markers in evaluating an organization's safety culture.

Advanced Safety Management Focusing on Z10 and Serious Injury Prevention, by Fred A. Manuele

In Chapter 4, "Human Error Reduction," I encouraged safety professionals to enfold human error reduction concepts into every facet of safety management systems and to focus on system deficiencies resulting from human errors that occur above the worker level.

Having so written, guidance is now given to those safety professionals who choose to promote improvement in the incident investigation process. This chapter will:

- Discuss the Incident Investigation processes required in Z10.
- Comment on the cultural difficulties facing safety professionals who try to have incident investigations improved if an organization has condoned a low quality of incident investigation.
- Suggest studies of needs and opportunities.
- Explain why supervisors who complete incident investigations may not be adequately qualified.
- Review the content of a good incident investigation form.
- Provide materials and resources to assist a safety professional in crafting an incident investigation procedure suitable to an organization's culture.
- Promote root causal factor identification, analysis and resolution systems.

INCIDENT INVESTIGATION PROVISIONS IN Z10

The requirements for incident investigation are concisely set forth in Section 6.2. They are contained in one paragraph, with no subsections. To fulfill the standard's requirements, organizations are to establish and implement processes to investigate and analyze hazardous incidents in a timely manner so as to identify occupational health and safety management issues (hazards, risks, management system deficiencies, and opportunities for improvement), and other possible incident causal factors.

That is the whole of it—one brief paragraph on incident investigation sets forth the requirements for this very important subject. It might seem as if this significant safety management process is dealt with too briefly. On the other hand, within an ANSI management system standard, all that needs to be said is said.

Advisory comments on incident investigation are more extensive. They indicate that: incidents should be viewed as possible symptoms of problems in the occupational health and safety management system; the goal is to identify and correct hazards and system deficiencies before incidents occur; experience shows that incident investigations should be commenced as soon as practical; and lessons learned from investigations are to be fed back into the planning and corrective action processes.

POSSIBLE EXPLANATIONS FOR POOR INCIDENT INVESTIGATION

Two additional opportunities arose in the latter half of 2006 for me to evaluate the quality of a total of 102 incident investigation reports completed on serious

injuries in two companies. The results of those evaluations agree with my previous studies. In both cases, headquarters safety professionals selected incident investigation reports for my review using their (sometimes differing) definitions of a serious injury.

On a scale of 1 to 10, with 10 representing the best, the first company was given a score of a 3.5: The other a score of 3.2. At the first company, 63% of the serious injuries occurred to ancillary personnel; at the other, 67% of serious injuries occurred to personnel described "as not making product."

These relatively poor scores were again troubling and prompted inquiry into what really occurs in the investigation process that might be a barrier to in-depth causal factor determinations. Such reviews provided an opportunity to explore the reasons why this important safety management function is often done superficially.

An examination of the incident investigation process leads to the conclusion that it can be considered a means of negative finger-pointing at one's self. If the culture does not require thorough incident investigations, those individuals responsible for completing the investigations may be allowed to avoid what they perceive to be a self-incriminating, personal performance and accountability review. First-line supervisors may also want to avoid recording comments that may be considered accusatory at management levels above them.

Assume that the safety culture does not require effective incident investigation. Consider the following examples, limited to seven, of statements that could be made legitimately in investigation reports, but may be perceived as self-incriminating or accusatory of management levels above the first-line supervisor:

1. "Hazards were not properly considered in the design process, and the way we do the work is risky."
2. "The equipment is being run beyond its normal life cycle, and the risks in operating it are high."
3. "What we are asking our people to do is error-inducive and exhausting and they make mistakes."
4. "We haven't had time to write an SOP for this job."
5. "It was the kind of a rush situation that often happens and sometimes the workers don't follow the SOP."
6. "We have had work orders in maintenance for 2 months to fix the wiring on this equipment."
7. "The stuff purchasing bought is cheaply made and it falls apart."

Where the safety culture so requires, a thorough incident investigation may:reflect on the hazard and risk decision making by upper management; identify the human errors made above the worker and supervisor level; and indicate that the work methods prescribed are unacceptable. Thus, resistance to carrying out the incident investigation process is normal behavior in organizations where management does not require that hazard and risk problems be identified and acted on. Situations of this sort define safety culture problems.

It has been my experience that these obvious and human performance limitations are overcome only when safety is truly a core value within an organization and when the safety culture, led by senior management, requires that the example points of inquiry listed above, as well as others, be addressed realistically. Senior management informs the staff by its own actions, by the system of expected behavior it puts in place, and by its insistence, when incidents occur, that the facts be realistically determined and acted on.

If a safety professional attempts to promote improving the quality of incident investigation, the safety culture in place must be evaluated and accurately defined as an action plan for improvement is formulated.

CULTURAL IMPLICATIONS THAT MAY IMPEDE GOOD INCIDENT INVESTIGATIONS

Throughout this book, I have emphasized the significance of an organization's safety culture and how it impacts favorably or unfavorably on safety-related decision making. Since I believe that effective incident investigation and analysis are vital to obtaining superior safety results, I continue—with compassion—to encourage safety professionals to undertake improvements in the investigation process. Condoning inadequate incident investigation defines a safety culture problem, one that will not be easily overcome.

A relevant, and all-too-truthful, paragraph on the Cultural Aspects of Data Collection System Design appears in *Guidelines for Preventing Human Error in Process Safety*:

> A company's culture can make or break even a well-designed data collection system. Essential requirements are minimal use of blame, freedom from fear of reprisals, and feedback which indicates that the information being generated is being used to make changes that will be beneficial to everybody. All three factors are vital for the success of a data collection system and are all, to a certain extent, under the control of management.

In relation to the foregoing, the title of R. B. Whittingham's book *The Blame Machine: Why Human Error Causes Accidents* is particularly appropriate. Whittingham says that his research shows that, in some organizations, a "blame culture" has evolved whereby the focus of their investigations is on individual human error and the corrective action stops at that level. This approach avoids collecting data on and improving the management systems that may have enabled the human error.

What Whittingham describes is indicative of an inadequate safety culture. As an example of one aspect of a negative safety culture, consider the following scenario. It represents a culture of fear.

> An electrocution occurred. As required in that organization, the corporate safety director visited the location to expand on the investigation. During discussion with the deceased employee's immediate supervisor, it became apparent that the supervisor

> knew of the design shortcomings in the lockout/tagout system, of which there were many at the location. When asked why the design shortcomings were not recorded as causal factors in the investigation report, the supervisor's response was: "Are you crazy? I would get fired if I did that. Correcting all these lockout/tagout problems will cost money and my boss doesn't want to hear about things like that."

This culture of fear arose from the system of expected behavior that management created. The supervisor completed the investigation report in accord with what he believed to be management's expectations. He recorded the causal factor as "employee failed to follow the lockout/tagout procedure" and the investigation stopped there. Overcoming such a culture of fear in the process of improving incident investigation processes, wherever and to what extent it exists, will require careful analysis and much persuasive diplomacy.

Recall Whittingham's findings: In many organizations, and sometimes in whole industries, there is an unwillingness to look closely into error-provocative system faults. For an incident investigation system to be effective, management must demonstrate by its actions that it *wants to know* what the root causal factors are.

However, the record is clear—incident investigations can be done effectively. In some companies, incident investigation is done well because the safety culture will not tolerate anything other than superior performance. In the studies I made of the quality of investigations, some companies scored an 8 out of a possible 10. (More than one safety director has accused me of being a hard marker.)

In the companies that scored well, the positive safety culture is driven by senior executives, and in some instances, by the board of directors. At those levels, incident experience is reviewed and personnel are held accountable for results. An example of how the absence of executive and board interest in safety was transformed into positive and active leadership may be found in "Building a Better Safety Vehicle: Leadership-driven Culture Change at General Motors":

> Safety culture change at GM was driven from the top and realized through the commitment and engagement of the leadership at every level. What follows is the story of how this was accomplished.
>
> Paul O'Neill, chair at Alcoa, joined the GM board of directors in 1993. His commitment to worker safety was key to the dramatic turnaround at Alcoa, where he not only improved safety, but also generated quantifiable bottom-line results. So perhaps GM's directors should not have been surprised when, as they prepared to adjourn the first board meeting O'Neill attended, he asked, "Where's the safety report?" There was none. O'Neill's question—and its exposure of the status of safety at the company—would become a watershed in GM's history. The President's Council. . . . decided to meet the challenge and take a close look at GM's safety performance and do whatever was necessary to improve it.

What interpretation can be given to the foregoing? For this important aspect of safety management—incident investigation—a champion at the senior executive level is needed to drive improvement. In every company with which I am familiar that has achieved stellar safety results, incident experience is regularly reviewed at

the chief executive officer level. One senior executive at a location that continues to attain outstanding records recently said:

> I find that what I talk about repeatedly, and I emphasize repeatedly, conveys to my staff the areas in which I mean to have superior results. They know by what I do that we are not to have employee injuries, environmental spills, customer complaints about product quality, or transportation accidents. I thoroughly review every such incident. Fortunately, there haven't been many of them.

ON THE WAY TO IMPROVEMENT, START WITH A SELF-EVALUATION OF THE CULTURE

Safety professionals who undertake to improve the quality of incident investigation should commence with the first step of the Plan-Do-Check-Act (PDCA) process—define the problem. They should begin with an evaluation of a sampling of completed incident investigation reports. In my studies, what I called the identification entries in incident investigation forms (such as name, department, location of the accident, shift, time, occupation, age, etc.) received relatively high scores for thoroughness of completion. Thus, it is suggested that the evaluation concentrate on the incident descriptions, causal factor determination, and the corrective actions taken. A safety professional, with efficient time usage in mind, may want to limit the evaluation's scope to include only incidents resulting in serious injury or illness, as he or she defines seriousness.

In Chapter 3, "Serious Injury Prevention," an outline for such a study was presented under the heading "Proposing a Study of Serious Injuries." Such a study will not be time-consuming since the data to be collected and analyzed should already exist or can be obtained easily. To assist in such a study, two addenda are provided at the conclusion of this chapter. Both are reprinted from the third edition of *On The Practice Of Safety:* Addendum A, "A Systemic Causation Model for Hazards-Related Incidents," and Addendum B, "Reference for Causal Factors and Corrective Actions." Another good reference when completing this evaluation, in terms of its comments on human errors that may be made above the worker level, is Chapter 4 here.

A safety professional who undertakes such a study should keep in mind that its outcome is to be an analysis of the:

- Activities in which serious injuries occur, for which concentrated prevention efforts will be beneficial
- Quality of causal factor determination and corrective action taking
- Culture that has been established over time with respect to good or not so good causal factor determination and corrective action taking
- Organization levels that are to be influenced if improvements are to be made.

From that analysis, a plan of action would be drafted to influence the safety culture, to the extent that is necessary. In so doing, the intent is to favorably influence the

system of expected behavior. The organization's safety culture with respect to the quality of incident investigation cannot be changed without the support of senior management.

Thus, the plan of action must be well crafted to convince management of the value of making the changes proposed—avoiding injuries to employees, good business, waste reduction (think lean), personnel relations, and fulfilling community responsibility. It is much, much easier for me to write all this than it will be for safety professionals to get it done. Changes in culture are not easily accomplished. They require considerable time and patience, and may only be achieved in small steps.

OTHER SUBJECTS REQUIRING REVIEW

As a part of the improvement endeavor, other evaluations should be made, such as—what is being taught about incident investigation, what guidance is given in procedure manuals, and whether the content and structure of the incident investigation form assist or hinder thorough investigations. The following define real-world situations as discovered in my studies. Suppose:

- In the courses being taught on incident investigation, the instructor leads attendees to conclude that 80–90% of accidents are principally caused by the unsafe acts of workers and that the corrective actions proposed should focus on worker behavior.
- In the incident investigation procedure manual, the same thought is conveyed and little guidance is given on root causal factors at levels above that of the worker.
- In the incident investigation form, the first instruction after a description of the incident is to identify the unsafe act committed by the worker.

When there is a lack of understanding about the fundamentals of incident causation and the need to identify root causal factors, supervisors, upper levels of management, and safety professionals sign off on incident reports when the reality is that those investigations were shallow and of little value. Making the additional reviews proposed here will help a safety professional define the extent of any problem and assist in crafting a course of action for improvement.

HAVING COMPASSION FOR THE SUPERVISOR

Published investigation procedures typically state that the first-line supervisor is best qualified to complete incident investigations because he or she is closest to the work and knows the most about the hazards and risks. That premise needs rethinking. A safety professional should ask the following: How much training with respect to hazards and risks do supervisors receive, does the training make them

knowledgable and technically qualified, and how often is training provided? The answers will help determine whether the training is sufficient to support the premise that supervisors are the best persons qualified to make good incident investigations.

The following question also needs to be asked: How often do supervisors complete incident investigations and do the forms and procedure manuals provide adequate support? It is unusual for a supervisor to complete two or three incident investigations in a year. Consideration needs to be given to the time lapse between the supervisor's attending a training session and completing an incident investigation form (or between completing investigations), and how long the knowledge gained in any training session would be retained without frequent use. Supervisors should be provided with a readily available, up-to-date document or manual, the content of which should be comparable to that of this chapter's two Addenda.

INCIDENT INVESTIGATION FORMS

Appendix H in Z10 consists of a brief dissertation on the value and outcome of an incident investigation—to prevent similar incidents from occurring—and a sample investigation form that an organization can adopt or modify to suit its needs. The form presents a good basic outline and its content should be considered a minimum. It has several positive characteristics that safety professionals should consider as they draft or revise investigation forms:

1. No entry is required that would lead an investigator to focus on what the worker did or did not do, to the exclusion of other causal factors.
2. Observations concerning the incident may be entered at three levels: supervisor; witnesses; and employees with insight.
3. Determining possible causal factors is facilitated by listing major categories: Equipment; Tools; Environment; Procedure; and Personnel.
4. Recommended corrective actions are to be listed, along with the originator's name. Whether those proposed actions have been accepted or rejected must be marked or recorded, as well as the completion date(s) for those actions.
5. The Responsible/Approving Department Manager/Process Owner must sign off on the form.
6. The report concludes with the investigator's signature and a record of the personnel to whom the report will be sent.

TAKING A STEP FORWARD

As incident investigation procedures are improved, the long-term goal is to have root causal factors determined and properly acted on. As a beginning step, it is suggested that a problem-solving process be considered for which training and administrative requirements are not extensive: the "5 Why" technique. Highly

skilled incident investigators may insist that the 5 Why process is inadequate because it does not promote the identification of root causal factors resulting from decisions made at a senior executive level. Nevertheless, achieving competence in applying the 5 Why concept will be a major step forward in many organizations.

The origin of the 5 Why process is attributed to Taiichi Ohno when he was employed at Toyota. He developed and promoted the practice of asking "why" five times to determine what caused a problem so that root causal factors can be identified and effective countermeasures can be implemented. The 5 Why process is applied in a large number of settings for a huge variety of problems.

Since the premise on which the 5 Why concept is based is uncomplicated, it can be adopted easily in the incident investigation process, as some safety professionals have discovered. For the occasionally encountered complex incident situation, starting the investigation with the 5 Why approach may lead to the eventual use of Event Trees, Fishbone Diagrams, or more sophisticated investigation systems.

Given an incident description, the investigator would ask "why" five times to get to the root causal factors and outline any necessary corrective actions. A not overly complex example follows:

> The written incident description says that a tool-carrying wheeled cart tipped over and onto an employee while she was trying to move it. She was seriously injured.
>
> 1. Why did the cart tip over? *The diameter of the casters is too small and the carts are prone to tipping*.
> 2. Why is the diameter of the casters too small? *They were made that way in the fabrication shop*.
> 3. Why did the fabrication shop make carts with casters that are too small? *They followed the dimensions given to them by engineering*.
> 4. Why did engineering give fabrication dimensions for casters that have been proven to be too small? *Engineering did not consider the hazards and risks that would result from using small casters*.
> 5. Why did engineering not consider those hazards and risks? *It never occurred to the designer that the use of small casters would create hazardous situations*.
>
> ***Conclusion:***
>
> I [the department manager] have made engineering aware of the design problem. In that process, an educational discussion took place in respect to the need to focus on hazards and risks in the design process. Also, engineering was asked to study the matter and has given new design parameters to fabrication: the caster diameter is to be tripled. On a high-priority basis, fabrication is to replace all casters on similar carts. A 30-day completion date for that work was set.
>
> I have also alerted supervisors to the problem in areas where carts of that design are used. They have been advised to gather all personnel who use the carts and instruct them that larger casters are being placed on tool carts and that, until that is done, moving the carts is to be a two-person effort. I have asked our safety director to alert her associates at other locations of this situation and how we are handling it.

Sometimes, asking "why" as few as three times gets to the root of a problem, on other occasions, asking "why" six times may be necessary. Having analyzed incident reports in which the 5 Why system was used, I offer these cautions:

- Management commitment to identifying the reality of root causal factors is an absolute necessity.
- Take care that the first "why" is really a why, and not a "what" or a diversionary symptom.
- Expect that the repetition of 5 Why exercises will be necessary to get the idea across: Doing so in group meetings at several levels, but particularly at the management level, is a good idea.
- Be sure that management is prepared to act on the systemic causal factors identified as skill is developed in applying the 5 Why process, particularly those factors that arise from human errors made above the worker level.

WHAT THIS CHAPTER IS NOT

Since the literature giving guidance on incident investigation techniques is abundant, comments are not being made here on such as: Investigation criteria; Immediate actions to be taken; Fact determination; Objectivity; Interviewing witnesses; Developing incident investigation teams; Action plans, etc. The chapter titled "Designer Incident Investigation" in *On The Practice Of Safety*, Third Edition, gives a detailed review of the methodology. Similar incident investigation procedure outlines appear within the resources listed in the next section. For safety professionals who choose to become educated on more sophisticated incident investigation methods, these same resources will provide information on Barrier analysis; Change analysis; Event tree analyses; Failure mode and effects analysis; and Fishbone *(Ishikawa)* diagrams.

INCIDENT INVESTIGATION RESOURCES

Since the names of the authors and publishers for each of the resources listed here are shown, as well as the websites for many of them, they are not listed again in the Additional Resources list at the end of this chapter. The first five resources enumerated here are highly recommended for their content; they are also available on the Internet and may be downloaded, for free.

Accident Prevention. Washington, DC: U.S. Department of Labor, OSHA. Also available at http://www.osha.gov/SLTC/smallbusiness/sec6.html.

> This accident investigation guide was written for small businesses. As suggested by its length—seven pages—it is a basic document from which excerpts may be taken for the instruction of supervisors. Supplements include "Discussion/Overheads" and "Student Handouts."

ESandH manual, Environmental, Safety, and Health, Document 4.6, Incident Analysis Manual. Washington, DC: U.S. Department of Energy, 2005. Also available at http://www.llnl.gov/es_and_h/hsm/doc_4.06/doc4-06.pdf#search = 'incident%20analysis%20manual'.

This is an update of an earlier Department of Energy publication. It represents the thinking, as of its March 2005 publication date, of the environmental, safety, and health personnel that assembled it. It is a good basic investigation document. Also, it emphasizes forming incident investigation and analysis committees and explains how they should operate. Appendix E presents an interesting Root Cause Mini-MORT Analysis system. Reading its 50 pages will be time well spent.

Root Cause Analysis Guidance Document. DOE-NE-STD-1004-92. Washington, DC: Us Department of Energy, 1982. Also available at http://www.eh.doe.gov/techstds/standard/nst1004/nst1004.pdf#search = 'DOENESTD1004'.

This is a 69-page, highly informative document, an instructive read. Various incident investigation techniques are discussed in an "Overview of Occurrence Investigation." Thus, it is a resource on Events and Causal Factor Analysis; Change Analysis; Barrier Analysis; Management Oversight and Risk Tree (MORT); Human Performance Evaluation; and Kepner–Tregoe Problem Solving and Decision Making.

MORT User's Manual—For Use with the Management Oversight and Risk Tree Analytical Logic Diagram. DOE-76/45-4, SSDC-4, Revision 3. Washington, DC: Department of Energy, 1992. Also available at http://www.eh.doe.gov/analysis/trac/SSDC_doc/10003.txt.

These statements appear in the Abstract: "MORT is a comprehensive analytical procedure that provides a disciplined method for determining the causes and contributing factors of major accidents. Alternatively, it serves as a tool to evaluate the quality of an existing [safety management] system." This "MORT User's Manual" is a 57-page paper issued in 1992. The concepts on which MORT is built have staying power, as is evidenced by the following reference published a decade later.

NRI MORT User's Manual—A Generic Edition for Use with the Management Oversight and Risk Tree Analytical Logic Diagram. NRI-I (2002) is published by The Noordwijk Risk Initiative Foundation in the Netherlands.

In a discussion under the heading "What Is MORT," these comments are made: "By virtue of public domain documentation, MORT has spawned several variants, many of them translations of the *MORT User's Manual* into other languages. The durability of MORT is a testament to its construction and content; it is a highly logical expression of the functions required for an organization to manage risks effectively." It is stated that this 2002 version of the *MORT User's Manual* aims to:

- Rephrase its questions in British English
- Improve guidance on the investigative application of MORT

- Restore "freshness" to the 1992 MORT question set
- Simplify the system of transfers in the chart
- Remove DOE-specific references
- Help users tailor the question set to their own organizations

I believe that the authors of this revision accomplished their purposes—to improve guidance on the investigation application, restore 'freshness,' and simplify the system. What they have done is fascinating. The 69-page document is available at http://www.nri.eu.com/NRI1.pdf#search = 'NRI%20Mort%20User%27s%20Manual'. I recommend that safety professionals who want to identify the reality of root causal factors acquire an understanding of the thinking on which MORT is based.

A review of the forementioned documents will provide an inexpensive and valuable education. Now, to extend the resource list, five books on incident investigation and root causal factor identification and analysis and one Manual are referenced. There are other resources.

Accident Investigation, Second Edition. Itasca, IL: National Safety Council, 1995.

This 51-page, rather inexpensive duplication manual provides a highly recommended "systematic approach to accident investigation, identification of causal factors, and implementation of corrective actions." It provides an extensive Guide for Identifying Causal Factors and Corrective Actions. Causal factors are listed under four categories: Equipment; Environment; People; and Management. Possible corrective actions are suggested for each causal factor. Sample forms and case studies are also included.

Ammerman, Max. *The Root Cause Analysis Handbook*. New York: Productivity Press, 1998.

This is a 135-page book devoted principally to root cause analysis. It offers what the cover says it will: "A simplified Approach to Identifying, Correcting, and Reporting Workplace Errors." In addition to addressing incident investigation in a general context, it also briefly covers Task Analysis; Change Analysis; Control Barrier Analysis; Event and Causal Factor Charting; and Determining Root Cause.

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

This is a highly recommended text. Chapter 6 is titled "Data Collection and Incident Analysis Methods." Elsewhere, comments are made on types of human error causal factors, their nature, and how to identify and analyze them.

Hendrick, Kingsley, and Ludwig Benner, Jr. *Investigating Accidents With STEP*. New York: Marcel Dekker, 1987.

Hendrick and Benner have developed an incident investigation system called Sequentially Timed Events Plotting (STEP). Several authors refer to this thought-provoking system.

Oakley, Jeffrey. *Accident Investigation Techniques: Basic Theories, Analytical Methods and Applications*. Des Plaines, IL: American Society of Safety Engineers, 2003.

This is a relatively brief and inexpensive book that comments on the general incident investigation process, and on several investigation and analytical techniques, such as Events and Causal Factors Analysis; Change Analysis; Tree Analysis; and Specialized Computerized Techniques.

Although an Internet search will reveal a large number of companies offering consulting services on root causal factor analysis, I am listing two that have published books on the subject, whose authors have a known history with respect to occupational safety and health:

Gano, Dean L. *Apollo Root Cause Analysis—A New Way of Thinking*. Portland, OR: Appollonian Publications, 1999.

Dean Gano has been a consultant in root cause analysis for many years. His technique and writings are well regarded.

TapRoot Manual. Knoxville, TN: System Improvements, Inc.

This book describes the root cause identification and analysis methods developed by the staff at Systems Improvements, Inc., which has provided consulting services on these subjects for several years.

ROOT CAUSAL FACTOR DETERMINATION AND ANALYSIS

Whatever incident investigation system is adopted, its goal is to identify, analyze, and resolve root causal factors. An Internet search will reveal that root causal factor identification and analysis is a broadly used problem resolution method. For the practice of safety, my interpretation of the premise on which the concept is based is that getting to the underlying, systemic sources of problems, rather than just addressing their symptoms, is a more effective means of preventing the recurrence of similar problems. Furthermore, proper application of the technique achieves an ancillary benefit in that it expands knowledge at all decision-making levels with respect to needed improvements in safety management systems.

CONCLUSION

My studies of incident investigation prompt the conclusion that significant risk reduction can be achieved if investigations are done well. If incident investigations are thorough, the reality of the technical, organizational, methods of operation, and cultural root causal factors will be revealed. If a safety professional wanted to select leading indicators for safety management system improvement, he or she would have good source data for that purpose if incident investigation reports identify root causal factors. I now believe that the quality of incident investigation is one of the principal markers in evaluating an organization's safety culture.

If a safety professional undertakes to improve the quality of incident investigation, I propose that the following comments about incident investigation as excerpted from the August 2003 *Report of the Columbia Accident Investigation Board* be kept in mind as a base for reflection throughout the endeavor. The Report pertains to the Columbia Space Shuttle disaster. It is accessed at http://caib.nasa.gov/news/press_releases/pr031028.html):

> Many accident investigations do not go far enough. They identify the technical cause of the accident, and then connect it to a variant of "operator error." But this is seldom the entire issue. When the determinations of the causal chain are limited to the technical flaw and individual failure, typically the actions taken to prevent a similar event in the future are also limited: fix the technical problem and replace or retrain the individual responsible. Putting these corrections in place leads to another mistake—the belief that the problem is solved.
>
> Too often, accident investigations blame a failure only on the last step in a complex process, when a more comprehensive understanding of that process could reveal that earlier steps might be equally or even more culpable. In this Board's opinion, unless the technical, organizational, and cultural recommendations made in this report are implemented, little will have been accomplished to lessen the chance that another accident will follow.

For emphasis, I paraphrase: If the cultural, technical, organizational, and methods of operation causal factors are not identified, analyzed, and resolved, little will be done to prevent the recurrence of similar incidents.

ADDITIONAL RESOURCES

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

Manuele, Fred A. *On the Practice Of Safety*. Hoboken, NJ: John Wiley & Sons, 2003.

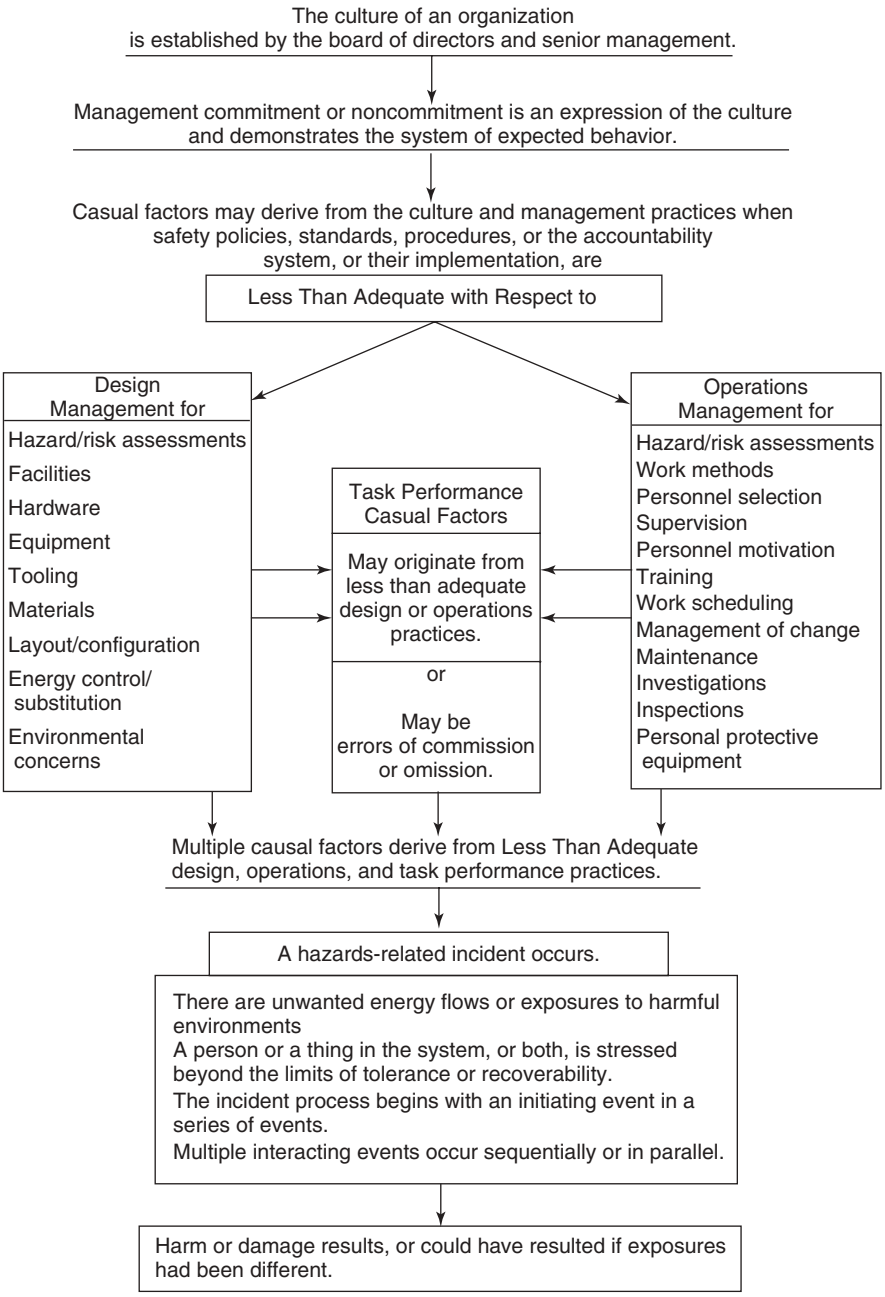
Simon, Steven I., and Patrick R. Frazee. "Building a Better Safety Vehicle: Leadership-driven culture change at General Motors." *Professional Safety*, January 2005.

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

ADDENDUM A

A SYSTEMIC CAUSATION MODEL FOR HAZARDS-RELATED OCCUPATIONAL INCIDENTS

A SYSTEMIC CAUSATION MODEL FOR HAZARDS-RELATED OCCUPATIONAL INCIDENTS



ADDENDUM B

A REFERENCE FOR THE SELECTION OF CAUSAL FACTORS AND CORRECTIVE ACTIONS FOR INCIDENT INVESTIGATION PROCEDURES AND REPORTS

Designers of incident investigation systems should understand that the causal factors and corrective actions included within investigation forms or as separate informational documents must be appropriate to the operations being conducted. The material presented here should not be used without modification to suit specific needs.

Workplace Design Considerations

1. Hazards derive from the basic design of facilities, hardware, equipment, or tooling.
2. Hazardous materials need attention.
3. Layout or position of hardware or equipment presents hazards.
4. Environmental factors (heat, cold, noise, lighting, vibration, ventilation, etc.) present hazards.
5. Workspace for operation, maintenance, or storage is insufficient.
6. Accessibility for maintenance work is hazardous.

Work Methods Considerations

1. Work methods are overly stressful.
2. Work methods are error-provocative.
3. Job is overly difficult, unpleasant, or dangerous.
4. Job requires performance beyond what an operator can deliver.
5. Job induces fatigue.

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6. Immediate work situation encouraged riskier actions than prescribed work methods.
7. Workflow is hazardous.
8. Positioning of employees in relation to equipment and materials is hazardous.

Job Procedure Particulars

1. No written or known job procedure.
2. Job procedures existed but did not address the hazards.
3. Job procedures existed but employees did not know of them.
4. Employee knew job procedures but deviated from them.
5. Deviation from job procedure not observed by supervision.
6. Employee was not capable of doing this job (physically, in terms of work habits, or behaviorally).
7. Correct equipment, tools, or materials were not used.
8. Proper equipment, tools, or materials were not available.
9. Employee did not know where to obtain proper equipment, tools, or materials.
10. Employee used substitute equipment, tools, or materials.
11. Defective or worn-out tools were used.

Hazardous Conditions

1. Hazardous condition had not been recognized.
2. Hazardous condition was recognized but not reported.
3. Hazardous condition was reported but not corrected.
4. Hazardous condition was recognized but employees were not informed of the appropriate interim job procedure.

Personal Protective Equipment

1. Proper personal protective equipment (PPE) not specified for job.
2. PPE specified for job but not available.
3. PPE specified for job, but employee did not know requirements.
4. PPE specified for job, but employees did not know how to use or maintain.
5. PPE not used properly.
6. PPE inadequate.

Management and Supervisory Aspects

1. General inspection program is ineffective.
2. Inspection procedure did not detect the hazards.
3. Training as respects identified hazards not provided, inadequate, or didn't take.
4. Maintenance with respect to identified hazards is inadequate.

5. Review not made of hazards and right methods before commencing work for a job done infrequently.
6. This job requires a job hazard/task/ergonomics analysis.
7. Supervisory responsibility and accountability not defined or understood.
8. Supervisors not adequately trained for assigned safety responsibility.
9. Emergency equipment not specified, not readily available, not used, or did not function properly.

Corrective Actions to Be Considered

1. Job study to be recommended: job hazard/task/ergonomics analysis needed.
2. Work methods to be revised to make them more compatible with worker capabilities and limitations.
3. Job procedures to be changed to reduce risk.
4. Changes are to be proposed in work space, equipment location or work flow.
5. Improvement is to be recommended for environmental conditions.
6. Proper tools to be provided along with information on obtaining them and their use.
7. Instruction to be given on the hazards of using improper or defective tools.
8. Job procedure to be written or amended.
9. Additional training to be given concerning hazard avoidance on this job.
10. Necessary employee counseling will be provided.
11. Disciplinary actions deemed necessary, and will be taken.
12. Action is to be recommended with respect to employee who cannot become suited to the work.
13. For infrequently performed jobs, it is to be reinforced that a pre-job review of hazards and procedures is to take place.
14. Particular physical hazards discovered will be eliminated.
15. Improvement in inspection procedures to be initiated or proposed.
16. Maintenance inadequacies are to be addressed.
17. Personal protective equipment shortcomings to be corrected.

CHAPTER 19

AUDIT REQUIREMENTS — SECTION 6.3

INTRODUCTION

Provisions requiring that periodic audits be made of the effectiveness of an organization's safety and health management systems are outlined in Z10's Section 6.3. Having audits made is a part of the Evaluation and Corrective Action processes. As is the case with every aspect of an organization's endeavors, making a periodic review of progress with respect to stated goals is good business practice. Stated goals, in this instance, would be to have processes in place that meet the requirements of Z10.

Safety audits perform a valuable function in that they determine the effectiveness or ineffectiveness of the organization's safety and health management systems. In accord with the audit requirements of Z10, deficiencies noted during safety audits are to be documented and communicated to those who can take action to eliminate them. The deficiencies are to be prioritized for orderly consideration.

In addition, hazardous situations observed during an audit that might be the causal factors for serious injuries, illnesses, or fatalities are to be immediately communicated to the appropriate decision makers so that actions may be taken on a high-priority basis. This is in concert with one of the principal themes in this book—serious injury prevention.

In the advisory column of Z10 opposite the Audit requirements, two particularly important statements are made:

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1. The safety audits required are not to be merely "compliance" oriented, meaning that they are not limited to determining compliance with laws, standards, or regulations. Although compliance may be considered during the audit process, the intent is for the audit to be "system" oriented so as to evaluate the effectiveness of the standard's management processes.
2. To promote objectivity, audits are to be conducted by persons independent of the activities being audited. However, it is made clear that this advisory does not mean audits must be made by persons "external to the organization."

To assist safety professionals in crafting or recrafting safety and health audit systems to meet the requirements of Z10, this chapter will:

- Establish the purpose of an audit
- Discuss the implications of observed hazardous situations
- Explore management's expectations with respect to audits
- Establish an understanding that safety auditors will also be audited during the audit process
- Comment on auditor qualifications
- Discuss the need to have safety and health management system audit guides tailored to the operations at the location being audited
- Provide information and resources for the development of suitable audit guides

THE PRINCIPLE PURPOSE OF A SAFETY AUDIT: TO IMPROVE THE SAFETY CULTURE

Throughout this book, I have emphasized that safety is culture driven. Results achieved with respect to safety and health are a direct reflection of an organization's culture. In *Safety Auditing: A Management Tool*, Donald W. Kase and Kay J. Wiese state early in a chapter titled "Successful Auditing" that:

> Success of a safety auditing program can only be measured in terms of the change it effects on the overall culture of the operation, and enterprise that it audits.

The Kase and Wiese observation can be supported easily. The paramount goal of a safety and health management system audit is to have a beneficial effect on an organization's decision-making processes that determine the quality of safety obtained.

A safety audit report provides an assessment of the outcomes of the safety-related decisions made by management over the long term. Those outcomes are determined by evaluating the adequacy of what really takes place with respect to the application of existing safety policies, standards, procedures, and operating processes. A safety audit report serves as the basis for improvement of an organization's safety culture.

SIGNIFICANCE OF OBSERVED HAZARDOUS SITUATIONS

Physical or operational hazardous situations observed during a safety audit should be viewed principally as indicators of inadequacies in the safety management processes that allowed them to exist. Assume that management takes corrective action to eliminate every hazardous situation noted in an audit report. Still, little will be gained if no change is made in the overall decision making to improve the management systems that allowed the hazardous situations to arise and continue.

REASONABLE MANAGEMENT EXPECTATIONS: THE EXIT INTERVIEW

Safety auditing is an exceptionally valuable process, but time-consuming and expensive. Safety professionals should not be surprised if informed managements expect substantial results from the audit process that benefit their operations. Safety and health professionals conducting audits should prepare well for their exit interviews. This means:

- Having been objective in their evaluations of management systems
- Having good justification for their findings
- Being able to support the proposed prioritization of management system improvements.

In an exit interview with informed management personnel, the auditor or audit team should anticipate, and prepare beforehand to respond to, questions comparable to the following:

1. What are the most significant risks?
2. What improvements in our management systems do we need to make?
3. In what priority should we approach what you propose?
4. Are there alternative risk reduction solutions that we might consider?
5. Will you work with us to determine that the actions we take and the money we spend attain sufficient risk reduction?

Audit systems fail if they do not recognize management needs and if they are not looked upon as assisting management in achieving its operational goals. Safety auditors will not be perceived favorably if their work is not considered an asset to managements who seek to improve their safety and health management systems and their safety culture.

Unfortunately, safety auditors cannot absolutely assure managements that every hazard and risk has been identified. Some hazard/risk situations remain obscure, and humans have not yet developed the perfection necessary to identify all of them. For example, the negative impact of less-than-adequate decisions affecting design and engineering, purchasing and maintenance may not be easily observable

because their effect may not be felt for several years. It should be made clear to management that applied safety auditing is based on a sampling technique and that it is patently impossible to identify 100% of the hazard/risk situations and shortcomings in safety management systems.

EVALUATIONS OF AUDITORS BY THOSE AUDITED

Safety and health professionals should also recognize that the time spent by auditors, the impressions they create, and the time expenditures required of personnel at the location being audited are also under evaluation. Speculate on the nature of the negative comments made upward to executive management for this situation, which actually occurred.

> Four safety and health auditors spent a week making an audit of a 37 employee location. After the second day, employees complained that the auditors were being disruptive because of the amount of their time that the auditors consumed. To make matters worse, during the third day the lead auditor told the location manager that the scorings being given to safety and health management systems by the auditors were higher than usual and that the auditors would have to delve further into operations so that they could report on management system shortcomings that need attention.
>
> Employees at the location became more irritated and complained because of the repetitive, valueless and duplicatory interference in their work.

AUDITOR COMPETENCY

Throughout Z10, there is an emphasis on identifying, prioritizing, and acting on occupational health and safety management system issues. Those issues are defined in the standard as "hazards, risks, management system deficiencies, and opportunities for improvement." To be able to identify and evaluate those issues as they exist in the operation being audited, the safety and health professionals conducting the audit must have the necessary qualifications and competency developed through experience. Managements have often said that auditors had little knowledge of the technical aspects of the hazards and risks at their sites, and that the audit report was superficial and of little value.

If safety and health audits are to be perceived as having value, the auditors must have the professional qualifications to make them. Safety professionals conducting audits need to consider how well they are prepared for the situation at hand and how best to approach the management personnel in the organization to be audited. Similarly, if persons external to an organization are engaged to make safety audits, the safety professionals hiring them should examine their credentials carefully.

Excerpts from a paper titled "Auditor Competency for Assessing Occupational Health & Safety Management Systems" will help in this regard. That paper (available on the Internet) was jointly issued by the American Society of Safety

Engineers, the American Industrial Hygiene Association and the American Board of Industrial Hygiene in August 2005. They say that:

> Several studies have raised questions about the value of quality, environmental and occupational health and safety management system certification [audits]. Many of the concerns raised in these studies have focused on the competency of the auditors performing conformity assessment audits. [Author's note: The foregoing comments pertain principally to audits made for management system certifications with respect to quality, environmental, and occupational safety and health by persons external to an organization. Nevertheless, similar questions have been raised for many years about the value of comparable audits made by in-house personnel.]

The paper also contains an extensive listing under the heading "Specific Knowledge and Skills of Occupational Health and Safety Management System Auditors." The excepts here are to serve safety professionals in making a preliminary review of their own capabilities as auditors and in assessing the qualifications of auditors external to their organizations whom they may hire.

> Occupational safety and health management system auditors should have knowledge and skills in occupational health and safety management principles and methods and their application, and related science and technology to enable them to examine occupational health and safety management systems and to generate appropriate audit findings and conclusions. Specific knowledge and skills should include:
>
> - Occupational health and safety management tools (including hazard identification and risk assessment, selection and implementation of appropriate hazard controls, developing proactive and reactive performance measures, understanding techniques to encourage employee participation and evaluation of work-related accidents and incidents)
> - An understanding of the physical, chemical, and biological hazards and other workplace factors affecting human well-being
> - The potential interactions of humans, machines, processes and the work environment
> - Methodologies for exposure monitoring and assessment
> - Medical surveillance methodologies for monitoring human health and well-being
> - Methodologies for accident and incident investigations
> - Methodologies used to monitor occupational safety and health performance
> - Sector-specific education, experience, and knowledge of operational hazards, risks, processes, products and services to enable auditors to comprehend and evaluate how the organization's activities, raw materials, production methods and equipment, products, byproducts, and business management systems may impact occupational health and safety performance in the workplace

This list, although abbreviated, provides a good foundation on which a safety and health professional can make a self-evaluation with respect to competency in relation to a particular audit undertaking.

ONE SIZE DOES NOT FIT ALL

Many of the statements made in Dan Petersen's "What Measures Should We Use, and Why?" concur with this author's own experience. This is what I wrote about his article in *On The Practice Of Safety:*

> Petersen questions the value of "packaged audits," giving examples of studies that show that audit results did not always correlate to a firm's accident experience. There is a history of that sort of thing with respect to "packaged audits" in which an audit guide is used that may not be sufficiently relative to the actual safety practices and needs in the entity being audited. Petersen concluded that "the self-built audit—one that accurately measures performance of a firm's own safety system—was viewed as the answer." To construct such an audit, Petersen says, a firm must define:
>
> 1. Safety system elements
> 2. The relative importance of each (weighting)
> 3. Questions to determine what is happening
>
> This is meaty stuff. All elements in a safety management system, while necessary, do not equally impact on those hazards that present the greatest potential for harm, whether measured by incident frequency or severity of injury. Obviously, the safety management elements included, and those emphasized, in an audit system should relate to the hazards that an entity really has to deal with. Keep in mind that hazards include both the characteristics of things and the actions or inactions of people.
>
> To determine what is really happening, an auditor must explore the safety management systems in place, what is expected of them, and which systems are effective or ineffective in controlling an entity's risks. That, in effect, results in a culture appraisal.

In the preceding listing of qualifications for safety and health management system auditors, one of the items pertains to "Sector-specific" knowledge of operational hazards, risks, processes, etc. When drafting an audit guide and in selecting the elements to be emphasized, much should be made of sector-specific hazards and risks—meaning those inherent in the operations at the site.

All hazards are not equal: Neither are the risks deriving from them equal. In a chemicals operation where the inherent fire and explosion hazards are significant, the processes in place and their effectiveness with respect to design and engineering, control of fire and explosion potential, occupational health exposures, training, inspection, management of change, and procurement require much greater attention than a warehouse where the only chemicals used are for cleaning purposes. Similarly, provisions to avoid auto accidents are more significant in the operation of a distribution center than an operation where driving is only incidental.

In some organizations, the same audit guide is used for all locations and the audit system requires that numerical or alpha scorings be recorded for each element being evaluated. The weightings for the elements are the same, regardless of their significance at the location being audited. Such a practice is questionable.

This book emphasizes serious injury prevention. When the audit system requires that identical weightings be given to elements regardless of the nature of the operations being audited, the greater import of a particular management system within the operation may be overlooked. Also, the additional probing necessary into that management system to identify those hazards that may be the causal factors for low-probability/serious-consequence events may be less-than-adequate.

It seems that greater effectiveness can be achieved if the audit guide is structured so that modifications may be made to suit the hazards and risks at the location being audited. In our communications age, it is appropriate to suggest that safety professionals who craft audit systems consider using a flexible computer-based system in which the descriptive content of the elements to be audited can be abbreviated or expanded and their weightings varied to suit the exposures at individual locations. That would truly be a self-built audit system.

GUIDELINES FOR AN AUDIT SYSTEM

Appendix I of Z10 gives guidance on how to comply with the standard's audit requirements. The appendix lists all the sections in Z10 in tabular form and includes suggestions on how their implementation might be objectively evaluated. Comments concerning the adaptation of Appendix I support avoiding the development and implementation of a "packaged" audit system—a one-size-fits-all model:

> The degree of detail in this table may not be needed for every organization, but may be used as a template that can be modified to match the culture and needs of each organization.

Therefore, modifications are to be made to fit the culture and the inherent hazards and risks in an organization. For example, is it necessary that there be a "documented occupational health and safety policy," as Z10 requires for every location? Or, is it appropriate to recognize that for a small operation having as few as 10 employees, a verbal and demonstrated commitment by management to achieving superior control of hazards and risks is sufficient?

An example of such a practical adjustment in a safety and health evaluation system may be found in OSHA's "Safety and Health Management Systems eTool—Safety and Health Assessment Worksheet." In OSHA's assessment process, an entry is to be made for this item: *There is a written (or oral, where appropriate) policy*. The implication is that, at times, an orally established safety policy is acceptable.

Appendix I in Z10 also includes "suggestions for the objective type of evidence that can be used while conducting an OHSMS audit." They include the types of documents and records to be examined, the titles of the persons to be interviewed, and the activities to be observed. Trying to be objective during a safety and health audit is vital to achieving good results.

The guidance given on objectivity is comparable to the instructions given in the VPP Site Worksheet that is completed to determine whether a location meets the

requirements of OSHA's Voluntary Protection Program (VPP). OSHA evaluators are to support their conclusions as they evaluate system elements by indicating that they derive from interviews, observations, or documentation.

Since it is proposed that safety professionals not develop a one-size-fits-all audit system, a specific audit guide to meet Z10 requirements is not recommended or presented here. Nevertheless, to create or improve an audit guide, it is suggested that the reader refer to both the example audit plan in Appendix I and the VPP Site Worksheet used by OSHA auditors when they determine whether an organization meets its VPP requirements. The VPP Site Worksheet is available as Appendix E of Section C, OSHA's Comprehensive Safety and Health Management System Requirements. Although it can be accessed at http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=DIRECTIVES&p_id=2976, downloading it in a usable format is not easily done. To encourage its use as a foundation in developing a customized audit system, a version of the VPP Site Worksheet appears as an addendum to this chapter.

The Worksheet is, in a sense, an audit form. As will be shown in Chapter 21, "Z10, Other Safety Standards and Guidelines, and VPP Certification," the VPP safety management system requirements have great similarity with the Z10 provisions. However, there are differences. Some of the VPP requirements are not as specific as comparable provisions in Z10. Those provisions are identified below along with cross-references to the relevant chapter in this text:

Subject	Reference
Risk assessment	Chapter 8, "A Primer on Hazard Analysis and Risk Assessment," and Chapter 9, "Including Risk Assessment Provisions in Standards and Guidelines: A Trend"
Design Reviews	Chapter 13, "Safety Design Reviews"
Management of Change	Chapter 15, "Management of Change"
Procurement	Chapter 16, "The Procurement Process"

Similarly, certain VPP requirements are not addressed in the Z10 provisions. During a VPP site review, evaluations are made to determine:

- More specifically, the adequacy of the "Occupational Health Care Program and Recordkeeping"
- Whether "Access to experts (for example, Certified Industrial Hygienists, Certified Safety Professionals, Occupational Nurses, or Engineers) is reasonably available to the site, based upon the nature, conditions, complexity, and hazards of the site?"

Safety and health professionals would give appropriate consideration to "the nature, conditions, complexity, and hazards of the site" as stated above to determine whether the need exists to include comparable provisions in any audit guide they are drafting.

Two other valuable resources that relate closely to the content of the VPP Site Worksheet and to many of the provisions in Z10 are available on the Internet. Both are OSHA publications: one is the previously mentioned "Safety and Health Management Systems eTool—Safety and Health Assessment Worksheet" and the other is "The Program Evaluation Profile (PEP)."

Both of these publications have another feature that will interest some safety and health professionals. They include numerical scoring systems for the individual elements being evaluated. OSHA's Safety and Health Assessment Worksheet includes a four-element scoring system; the PEP form allows five scores to be recorded. If a numerical or alpha scoring system is to be used, the single, correct scoring system is the one with which the auditors and personnel who review and act on the audit reports are comfortable.

CONCLUSION

Auditing performance with respect to established operational goals is good business practice. The audit requirements in Z10 are to meet that purpose. Professionally done, safety audits provide valuable information to decision makers who wish to achieve superior safety and health results.

It is suggested that safety professionals who propose that organizations meet Z10's audit requirements start with a gap analysis. The result would be comparisons between the elements in the safety and health management systems in place with the provisions in Z10. Since the Z10 standard is a state-of-the-art document, it is not surprising that many organizations do not have management systems in place which meet all of its provisions. For a very large percent of organizations, a gap analysis will reveal shortcomings with respect to: design reviews; management of change; risk assessments; a hierarchy of controls; and procurement practices.

After the gap analysis is made, a safety and health professional would assist management in formulating an action plan to fulfill Z10 requirements. As progress is made, the content of audit guides would be adjusted accordingly. They should be flexible and relate to the inherent hazards and risks at the location being audited.

Over time, Z10 will become the benchmark against which the adequacy of occupational safety and health management systems will be measured. Societal expectations of employers with respect to their safety and health management systems will be defined by the standard's provisions. The audit system put in place should assist management in moving closer to compliance with the provisions in Z10.

REFERENCES

"Auditor Competency for Assessing Occupational Health & Safety Management Systems." The American Society of Safety Engineers, the American Industrial Hygiene Association, and the American Board of Industrial Hygiene, August 2005. http://www.aiha.org/1documents/Governmentaffairs/p_auditor%20position%paper_8-25-05.pdf

Kase, Donald W., and Kay J. Wiese. *Safety Auditing: A Management Tool*. New York: John Wiley & Sons, 1990.

Manuele, Fred A. *On The Practice Of Safety*. Hoboken, NJ: John Wiley & Sons, 2003.

Petersen, Dan. "What Measures Should We Use, and Why?" *Professional Safety*, October 1998.

"The Program Evaluation Profile (PEP)." U.S. Department of Labor, OSHA. http://www.osha.gov/SLTC/safetyhealth/pep.html.

"Safety and Health Management Systems eTool—Safety and Health Assessment Worksheet." U.S. Department of Labor, OSHA. http://www.osha.gov/SLTC/etools/safetyhealth/asmnt_worksheet.html.

VPP Site Worksheet. Appendix E, Section C, Comprehensive Safety and Health Management System Requirements. In CSP 03-01-002-TED 8.4—*Voluntary Protection Programs (VPP): Policies and Procedures Manual*, Chapter III, Requirements for Star, Merit, Resident Contractor, Construction Industry, and Federal Agency Worksites. http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=DIRECTIVES&p_id=2976.

ADDENDUM

VPP SITE REPORT

What follows is an adaptation of the VPP Site Worksheet issued by OSHA.

Section I: Management Leadership and Employee Involvement

A. Written Safety and Health Management System
   - A1. Are all the elements (such as Management Leadership and Employee Involvement, Worksite Analysis, Hazard Prevention and Control, and Safety and Health Training) and subelements of a basic safety and health management system part of a signed, written document?
   - A2. Have all VPP elements and subelements been in place at least 1 year?
   - A3. Is the written safety and health management system at least minimally effective to address the scope and complexity of the hazards at the site?
   - A4. Have any VPP documentation requirements been waived?

B. Management Commitment and Leadership
   - B1. Does management overall demonstrate at least minimally effective, visible leadership with respect to the safety and health program?
   - B2. How has the site communicated established policies and results-oriented goals and objectives for worker safety to employees?
   - B3. Do employees understand the goals and objectives for the safety and health program?

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B4. Are the safety and health program goals and objectives meaningful and attainable? Provide examples supporting the meaningfulness and attainability (or lack there of if answer is no) of the goal(s).

B5. How does the site measure its progress toward the safety and health program goals and objectives?

C. Planning

C1. How does the site integrate planning for safety and health with its overall management planning process (e.g., budget development, resource allocation, or training)?

C2. Are safety and health effectively integrated into the site's overall management planning process?

D. Authority and Line Accountability

D1. Does top management accept ultimate responsibility for safety and health in the organization? (Top management acknowledges ultimate responsibility even if some safety and health functions are delegated to others.)

D2. How is the assignment of authority and responsibility documented and communicated (e.g., organization charts, job descriptions)?

D3. Do the individuals assigned responsibility for safety and health have the authority to ensure that hazards are corrected or necessary changes to the safety and health management system made?

D4. How are managers, supervisors, and employees held accountable for meeting their responsibilities for workplace safety and health? (Annual performance evaluations for managers and supervisors are required.)

D5. Are adequate resources (equipment, budget, or experts) dedicated to ensuring workplace safety and health?

D6. Is access to experts (e.g., Certified Industrial Hygienists, Certified Safety Professionals, Occupational Nurses, or Engineers), reasonably available to the site, based upon the nature, conditions, complexity, and hazards of the site?

E. Contract Workers

E1. Does the site utilize contractors? Please explain.

E2. Were there contractors onsite at the time of the evaluation?

E3. When selecting onsite contractors, how does the site evaluate the contractor's safety and health programs and performance (including rates)?

E4. Are contractors and subcontractors at the site to maintain effective safety and health programs and to comply with all applicable OSHA and company safety and health rules and regulations?

E5. Does the site's contractor program cover the prompt correction and control of hazards in the event that the contractor fails to correct or control such hazards?

E6. How does the site document and communicate oversight, coordination, and enforcement of safety and health expectations to contractors?
E7. Have the contract provisions specifying penalties for safety and health issues been enforced, when appropriate?
E8. How does the site monitor the quality of the safety and health protection of its contract employees?
E9. If the contractors' injury and illness rates are above the average for their industries, does the site have procedures that ensure all employees are provided effective protection on the worksite?
E10. Do contract provisions for contractors require the periodic review and analysis of injury and illness data?
E11. Based on your answers to the above items, is the contract oversight minimally effective for the nature of the site? (Inadequate oversight is indicated by significant hazards created by the contractor, employees exposed to hazards, or a lack of host audits.)

F. Employee Involvement
F1. How were employees selected to be interviewed by the VPP team?
F2. How many employees were interviewed formally? How many were interviewed informally?
F3. Do employees support the site's participation in the VPP Process?
F4. Do employees feel free to participate in the safety and health management system without fear of discrimination or reprisal?
F5. Please describe at least three ways in which employees are meaningfully involved in the problem identification and resolution, or evaluation of the safety and health program (beyond hazard reporting).
F6. Are employees knowledgable about the site's safety and health management system?
F7. Are employees knowledgable about the VPP program?
F8. Are the employees knowledgable about OSHA rights and responsibilities?
F9. Do employees have access to results of self-inspection, accident investigation, appropriate medical records, and personal sampling data on request?

Section II: Worksite Analysis

A. Baseline Hazard Analysis
A1. Has the site been at least minimally effective at identifying and documenting the common safety and health hazards associated with the site (such as those found in OSHA regulations, building standards, etc., and for which existing controls are well known)?
A2. What methods are used in the baseline hazard analysis to identify health hazards?
A3. Does the site have a documented sampling strategy used to identify health hazards and assess employees' exposure (including duration,

route, and frequency of exposure), and the number of exposed employees?

A4. Do sampling, testing, and analysis follow nationally recognized procedures?

A5. Does the site compare sampling results to the minimum exposure limits or are more restrictive exposure limits (PELs, TLVs, etc.) used?

A6. Does the baseline hazard analysis adequately identify hazards (including health) that need further analysis?

A7. Do industrial hygiene sampling data, such as initial screening or full shift sampling data, indicate that records are being kept in logical order and include all sampling information (e.g., sampling time, date, employee, job title, concentrated measures, and calculations)?

B. Hazard Analysis of Significant Changes

B1. When purchasing new materials or equipment, or implementing new processes, what types of analyses are performed to determine their impact on safety and health? Is it adequate?

B2. When implementing/introducing nonroutine tasks, materials or equipment, or modifying processes, what types of analyses are performed to determine their impact on safety and health? Is it adequate?

C. Hazard Analysis of Routine Activities

C1. Is there at least a minimally effective hazard analysis system in place for routine operations and activities?

C2. Does hazard identification and analysis address both safety and health hazards, if appropriate?

C3. What hazard analysis technique(s) are employed for routine operations and activities (e.g., job hazard analysis, HAZOPs, fault trees)? Are they adequate?

C4. Are the results of the hazard analysis of routine activities adequately documented?

D. Routine Inspections

D1. Does the site have a minimally effective system for performing safety and health inspections (i.e., a minimally effective system identifies hazards associated with normal operations)?

D2. Are routine safety and health inspections conducted monthly, with the entire site covered at least quarterly (for construction, the entire site weekly)?

D3. How do inspections use information discovered through the baseline hazards analysis, job hazard analysis, accident/incident analysis, employee concerns, sampling results, etc.?

D4. Are those personnel conducting inspections adequately trained in hazard identification?

D5. Is the routine inspection system written, including documentation of results?

D6. Do the written routine inspection reports clearly indicate what needs to be corrected, by whom, and by when?

D7. Did the VPP team find hazards that should have been found through self-inspection?

E. Hazard Reporting
- E1. Does the site have a reliable system for employees to notify appropriate management personnel in writing about safety and health concerns?
- E2. Do the employees agree that they have an effective system for reporting safety and health concerns?
- E3. Is there a minimally effective means for employees to report hazards and have them addressed?

F. Hazard Tracking
- F1. Does the hazard-tracking system address hazards found by employees, hazard analysis of routine and nonroutine activities, inspections, and accident or incident investigations?
- F2. Does the tracking system result in hazards being corrected and provide feedback to employees for hazards they have reported?
- F3. Does the tracking system result in timely correction of hazards with interim protection established when needed?
- F4. Does a minimally effective tracking system exist that results in hazards being controlled?

G. Accident/Incident Investigations
- G1. Is there a minimally effective system for conducting accident/incident investigations, including near-misses?
- G2. Are those conducting the investigations trained in accident/incident investigation techniques?
- G3. Describe how investigations discover and document all the contributing factors that led to an accident/incident.
- G4. Were any hazards discovered during the investigation previously addressed in any prior hazard analyses (e.g., baseline, self-inspection)?

H. Safety and Health Program Evaluation
- H1. Briefly describe the system in place for conducting an annual evaluation.
- H2. Does the annual evaluation cover the aspects of the safety and health program, including the elements described in the Federal Register?
- H3. Does the annual evaluation include written recommendations in a narrative format?
- H4. Is the annual evaluation an effective tool for assessing the success of the site's safety and health system?
- H5. What evidence demonstrates that the site responded adequately to the recommendations made in the annual evaluation?

H. Trend Analysis
- I1. Does the site have a minimally effective means for identifying and assessing trends?

I2. Have there been any injury and/or illness trends over the last three years?
I3. If there have been injury and/or illness trends, what courses of action have been taken?
I4. Does the site assess trends utilizing data from hazard reports or accident/incident investigations to determine the potential for injuries and illnesses?

Section III: Hazard Prevention and Control

A. Hazard Prevention and Control
A1. Does the site select at least minimally effective controls to prevent exposing employees to hazards?
A2. When the site selects hazard controls, does it follow the preferred hierarchy (engineering controls, administrative controls, work practice controls [e.g. lockout/tag out, bloodborne pathogens, and confined space programs], and personal protective equipment) to eliminate or control hazards?
A3. Describe any administrative controls used at the site to limit employee exposure to hazards (e.g., job rotation).
A4. Do the work practice controls and administrative controls adequately address those hazards not covered by engineering or administrative controls?
A5. Are the work practice controls (e.g. lockout/tag out, bloodborne pathogens, and confined space programs) recommended by hazard analyses implemented at the site?
A6. Are followup studies (where appropriate) conducted to ensure that hazard controls were adequate?
A7. Are hazard controls documented and addressed in appropriate procedures, safety and health rules, inspections, training, etc.?
A8. Are there written worker safety procedures including a disciplinary system?
A9. Has the disciplinary system been enforced equally for both management and employees, when appropriate?
A10. Does the site have minimally effective written procedures for emergencies?
A11. Are emergency drills held at least annually?
A12. Does the site have a written preventive/predictive maintenance system?
A13. Did the hazard identification and analysis (including manufacturers' recommendations) identify hazards that could result if equipment is not maintained properly?
A14. Does the preventive maintenance system adequately detect hazardous failures before they occur?
A15. How does the site select Personal Protective Equipment (PPE)?

A16. Do employees understand the limitations and uses of PPE?
A17. Did the team observe employees using, storing, and maintaining PPE properly?
A18. Is the site covered by the Process Safety Management Standard (29 CFR 1910.119)? If not, skip to section B.
A19. Which chemicals that trigger the Process Safety Management (PSM) standard are present?
A20. Please describe the PSM elements in place at the site (do not duplicate if included elsewhere in the report, such as under contractors, preventive maintenance, emergency response, or hazard analysis).

B. Occupational Health Care Program and Recordkeeping
B1. Describe the occupational health care program (including availability of physician services, first aid, and CPR/AED) and special programs such as audiograms or other medical tests used.
B2. How are licensed occupational health professionals used in the site's hazard identification and analysis, early recognition and treatment of illness and injury, and the system for limiting the severity of harm that might result from workplace illness or injury?
B3. Is the occupational health program adequate for the size and location of the site, as well as the nature of hazards found here?

Section IV: Safety and Health Training

A. Safety and Health Training
A1. What are the safety and health training requirements for managers, supervisors, employees, and contractors?
A2. Who delivers the training?
A3. How are the safety and health training needs for employees determined?
A4. Does the site provide minimally effective training to educate employees regarding the known hazards of the site and their controls?
A5. What system is in place to ensure that all employees and contractors have received and understand the appropriate training?
A6. Who is trained in hazard identification and analysis?
A7. Is training in hazard identification and analysis adequate for the conditions and hazards of the site?
A8. Does management have a thorough understanding of the hazards of the site?

CHAPTER 20

MANAGEMENT REVIEW — SECTION 7.0

The importance of the Management Review requirements in Z10 is inverse to the length of this brief chapter. It was said in Chapter 1 that Section 3.0, "Management Leadership and Employee Participation," is the most important section in Z10. Top management leadership is vital because it establisher the organization's safety culture and because continual improvement processes cannot be successful without effective top management direction. To achieve superior results, top management must repeatedly walk the talk.

It was also stated in Chapter 1 that Section 7.0, the Management Review section, was a close second in importance. Maintaining superior management leadership requires that evaluations be made of the effectiveness of safety processes so that improvements can be made where necessary. The Management Review provisions in Z10 require gathering, at least annually, the data necessary to assess "The performance of the occupational health and safety management systems relative to expectations." Action items for improvement are to be drafted as that performance assessment is made.

As shown below, the management review process commences with the Check step in the Plan-Do-Check Act (PDCA) model and provides input to senior management so that processes previously put in place may be accepted as satisfactory or revised, as in the Act step:

Advanced Safety Management Focusing on Z10 and Serious Injury Prevention, by Fred A. Manuele

Plan:	Identify the problem
Plan:	Analyze the problem
Plan:	Develop solutions
Do:	Implement solutions
Check:	Evaluate the results
Act:	Adopt the change, abandon it, or start over

The writers of the Z10 standard should appreciate the widespread recognition of the significance of the standard, particularly this Management Review section. On March 23, 2005, a serious workplace disaster occurred at the BP Texas City refinery. It resulted in 15 deaths and more than 170 injuries. A blue ribbon panel, consisting mostly of known experts, was created for the sole purpose of assessing the safety culture at U.S. refineries operated by BP.

The *Report of the BP U.S. Refineries Independent Safety Review Panel* was made public in January 2007; it has become known in occupational safety and health circles as the Baker Report. The panel's chair was James A. Baker, III, who has served in senior government positions under three U.S. presidents.

Several references are made in the Report to sections in Z10 as recommended practices. Those references, and by inference the Z10 standard itself, are testimony that they represent the state-of-the-art in safety and health management systems. In the Report, the most extensive references to Z10 processes concern Management Reviews. A very large part of Z10's Section 7.0 is quoted, close to verbatim. The following, as it appears in The Baker Report, is close to a duplicate of the "shall" provisions in Section 7.0.

> According to the ANSI Z10 standard for occupational health and safety management systems, the management review process should include consideration of the following eight inputs:
>
> - progress in the reduction of risk;
> - effectiveness of processes to identify, assess, and prioritize risk and system deficiencies;
> - effectiveness in addressing underlying causes of risks and system deficiencies;
> - input from employees and employee representatives;
> - status of corrective and preventive actions and changing circumstances;
> - follow-up actions from system audits and previous management reviews;
> - the extent to which objectives have been met; and
> - the performance of the system relative to expectations, taking into consideration changing circumstances, resource needs, alignment of the business plan, and consistency with policy.

The Baker Report continued with these slightly modified excerpts from the advisory column for Section 7.0. Where we have inserted [safety management system] here, the actual designation in Section 7.0 is OHSMS.

The related commentary to the ANSI Z10 standard provides a useful description of the role of and purpose for management reviews:

> Management reviews are a critical part of the continual improvement of the [safety management system]. The purpose of reviews is for top management, with the participation of [safety management system] leaders and process owners, to do a strategic and critical evaluation of the performance of the [safety management system], and to recommend improvements. This review is not just a presentation or a non-critical review of the system, but should focus on results and opportunities for continual improvement. It is up to the organization to determine appropriate measures of [safety management system] effectiveness. They should also evaluate how well the safety management system] is integrated with other business management systems, so it supports both health and safety goals and business needs and strategies.
>
> Reviews by top management are required because they have the authority to make the necessary decisions about actions and resources, although it may also be appropriate to include other employee and management levels in the process. To be effective, the review process should ensure that the necessary information is available for top management to evaluate the continuing suitability, adequacy, and effectiveness of the [safety management system]. . . . Reviews should present results (for example, a scorecard) to focus top management on the [safety management system] elements most in need [of] their attention. . . .
>
> At the conclusion of the reviews, top management should make decisions, give direction, and commit resources to implement the decisions. The management review should include an assessment of the current [safety management system] to address if the system is encompassing all of the risks to which the organization is exposed. This portion of the review should include a review of major risk exposures and ask the question, "Are there any holes" in the current [safety management system] that could allow a risk that might not be considered within the [safety management system].

What The Baker Review Panel excerpted from Z10's Section 7.0 gives the requirements added credibility. Also, it is difficult to improve on what the writers of the standard said about the Management Review Process.

Section 3.0, "Management Leadership and Employee Participation," and Section 7.0, "Management Review," are vital and integrated parts of a whole. An organization cannot achieve superior results if its performance in these two sections is not stellar.

A Management Review is to result in a documentation of the action items necessary to achieve continual improvement in occupational health and safety management systems, the assignment of responsibility for the actions to be taken, completion dates, and requirements for periodic reporting on progress made. One test of the organization's safety culture is whether resources are made available to achieve the improvements decided upon.

Appendix J intends to help managements fulfill the Z10 Management Review requirements. It consists principally of a scorecard, the purpose of which is to focus "top management's attention on the parts of the occupational health and safety management system that most need their attention and direction." The scorecard

lists the major items in Z10 on one page and asks the user to enter colors indicating the implementation status of each of the provisions. Colors represent the following performance categories:

- Blue: World-class OHS performance
- Green: Strong. Conforming/complete, may have minor gaps with/action plans
- Yellow: Moderate. Scattered nonconformances need to be addressed, positive trends/major elements in place
- Violet: Significant nonconformances exist, still needs focus
- Red: Major Effort Required. Major systematic nonconformances exist.

The foregoing color scheme is recorded here as an example of how performance gradations may be expressed. The writers of Z10's Appendix J properly recognized that a variety of evaluation systems may be used—qualitative or quantitative. They also made an important statement when they stated that Management Review reports should suit the organization's "size, operations, services, or culture." A summary report will be more readily accepted if it fits the organization's style and culture.

This Management Review section gives safety and health professionals a meaningful opportunity to assist in providing objective summary reports on the status of occupational health and safety management systems and to present managements with proposals to overcome shortcomings. Such reports will have greater value if a section addresses serious injury potential and risk reduction measures.

In accord with the PDCA concept, the overriding theme of the Management Review is to achieve continual improvement. Thus, the development of action items for improvement in the review process, and follow through, is vital.

In many companies, a major Management Review process is conducted annually and a summary progress report carrying the signature of the chief executive officer is published. Such reports may be made available broadly, such as on the Internet. Publication of the reports serves the purposes of good community relations as well as good employee relations.

REFERENCES

ANSI/AIHA Z10-2005. Occupational Health and Safety Management Systems Standard. Fairfax, VA: American Industrial Hygiene Association, 2005. Also available at http://www.aiha.org/marketplace.htm.

Report of the BP U.S. Refineries Independent Safety Review Panel. http://www.safetyreviewpanel.com/index.php.

CHAPTER 21

Z10, OTHER SAFETY STANDARDS AND GUIDELINES, AND VPP CERTIFICATION

INTRODUCTION

Often, after I have given a speech on the provisions in Z10 or had a conversation with a colleague about them, questions are asked about how Z10 compares to other safety and health management systems standards and guidelines and whether compliance with Z10 will meet "certification" requirements. Thus, this chapter:

- Provides a response to the question on comparison
- Comments on certification
- Discusses the certification available through OSHA's Voluntary Protection Program (VPP)
- Explores the similarities and differences in Z10 and VPP
- Encourages organizations to seek VPP certification as a step toward meeting Z10 requirements
- Duplicates the VPP requirements for the Star Designation

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COMPARISONS

An attempt was made to compare the provisions in Z10 to the following selected and well-known safety guidelines and standards:

- *OHSAS 18001:1999, Occupational Health and Safety Management Systems—Specification:* A guideline issued by the British Standards Institute, commonly known as 18001
- *ILO-OSH 2001, Guidelines on Occupational Safety and Health Management Systems:* An International Labor Organization publication that deserves the good reviews it has received
- *BS 8800-2004, Occupational Health and Safety Management Systems—Guide:* An updated and comprehensive British standard issued by the British Standards Institute
- *OSHA's Voluntary Protection Program (VPP):* As described in the *Policies and Procedures Manual* posted on the Internet in 2003

A MESS OF FALSE POSITIVES

The comparison exercise was not fruitful. Subjective judgments were necessary on the intent of the provisions in the standards and guidelines reviewed that used similar words but that were determined not to be substantially the same. That, of itself, required questioning the value of the effort. Placing the provisions of Z10 in columnar form and recording alpha and numerical references for questionably comparable sections in other standards and guidelines resulted in an inaccurate, bewildering, and cumbersome output. Furthermore, such a chart should not influence what a safety and health professional proposes or what management adopts.

A safety professional is obligated to be cognizant of the state-of-the-art as the practice of safety evolves. The source of an innovation in safety and health management is irrelevant. If applying an innovation serves to reduce risk, a safety and health professional is compelled to promote its adoption, regardless of the standard or guideline in which it first appears.

Z10 IS STATE-OF THE-ART

Interesting findings did result from the review exercise. There are no management system or process provisions in the standards and guidelines reviewed that are not addressed in Z10. Since Z10 was approved as an ANSI standard in July 2005, its issue date is later than that of the others. Z10 is state-of-the-art and encompasses the best in the world.

If an organization's occupational health and safety management system meets the requirements of Z10, its system will surpass the provisions in the standards and guidelines reviewed and, in particular, exceed the certification requirements for 18001 and for OSHA's Voluntary Protection Program.

ON CERTIFICATION

The British Standards Institute (BSI) is a major player in certification and seems to have made a financial success of it. Both 18001 and BS 8800-2004 are published by BSI. A bit of a mystery exists here. BSI is a standards developer in the United Kingdom. Yet it runs a profitable fee-based business providing certification of health and safety management systems based on the 18001 guideline. It should be understood that 18001 is a guideline, not a standard. It is not equivalent to BS 8800, a standard that was updated and reissued in 2004.

Requiring certification for quality management (ISO 9000 series) and environmental management (14000 series) is common. Sometimes, particularly in a competitive business deal in Asia, the providers of goods or services are required to present documents indicating that their occupational safety and health management systems are also certified. And, the certifying entities meet that requirement. Comments made by colleagues reflecting their experiences with certifying agencies stand at extremes:

- "They did a thorough and valuable job. They identified improvements in our safety processes that needed to be made."
- "The certification process was a paper exercise. A review of our safety and health manual was made in our office. It did us no operational good at all. But, since we needed the certificate in a competitive situation, we didn't complain."

Nevertheless, it seems that companies which have attained superior safety results more often want their achievements recognized by some sort of certification. That will be demonstrated in the statistics shown later with respect to the growth in the number of companies attaining VPP recognition. For superior performers in the United States, VPP certification has become a mark of distinction.

To emphasize, the focus of this book is on injury and illness prevention, with an emphasis on avoiding serious injuries and illnesses. That purpose will be advanced if, as a company seeks and meets the requirements for certification, its safety and health management system is improved and moves closer to complying with the provisions in Z10. Such a form of certification is available through OSHA, which administers the VPP programs. OSHA does not require that a fee be paid to attain VPP status.

THE VPP PROGRAM

On July 2, 1982, OSHA announced the establishment of Voluntary Protection Programs to recognize and promote effective worksite-based safety and health management systems. Granting the VPP designation is OSHA's "official recognition of the outstanding efforts of employers and employees who have created exemplary worksite safety and health management systems."

OSHA states this about VPP in an Internet publication titled "VPP—Recognizing Excellence in Safety and Health:"

> Using one set of flexible, performance-based criteria, the VPP process emphasizes holding managers accountable for worker safety and health, the continual identification and elimination of hazards, and the active involvement of employees in their own protection. These criteria work for the full range of industries, union and non-union, and for employers large and small, private and public.
>
> The VPP places significant reliance on the cooperation and trust inherent in partnership. Sites choosing to apply for VPP recognition show their commitment to effective worker protection by inviting a government regulator into their workplace. In return, OSHA removes them from programmed inspection lists and does not issue them citations for standards violations that are promptly corrected.
>
> Sites qualifying for VPP attain Star, Merit, or Demonstration status. Star participants meet all VPP requirements. Merit participants have demonstrated the potential and willingness to achieve Star status, but some aspects of their programs need improvement. Demonstration participants test alternative ways to achieve safety and health excellence that may lead to changes in VPP criteria.
>
> Statistical evidence for VPP's success is impressive. Consistently, the average VPP worksite has had an incidence rate for days away from work, restricted work activity, and/or job transfer that is at least 50 percent below the average for its industry!
>
> In VPP:
>
> - Management commits to operating an effective occupational safety and health management system characterized by four basic elements: management leadership and employee involvement, worksite analysis, hazard prevention and control, and safety and health training.
> - Employees agree to participate in the program and work with management to ensure a safe and healthful workplace.
> - The site submits an application to OSHA that describes its system of worker protection.
> - OSHA evaluates the application. If OSHA accepts it, the agency then conducts an onsite review to verify that the safety and health management system meets VPP requirements. With approval comes OSHA's public recognition of the applicant's exemplary safety and health management system.
> - OSHA also periodically reevaluates the participant to confirm its continuing qualification for VPP. Onsite evaluations are every $2\frac{1}{2}$ to 5 years for Star, 12 to 18 months for Demonstration, and 18 to 24 months for Merit.
> - OSHA removes VPP participants from its programmed inspection lists.
> - OSHA enforcement personnel will investigate workplace complaints, any fatality or catastrophe, and other significant events. After such events, VPP personnel may also review a participant's continuing eligibility for VPP.

Incidence Experience Requirement

To qualify for the Star designation, an entity must show that its 3-year illness and injury Total Case Incidence Rate (TCIR) and its 3-year Days Away from Work, Restricted Work Activity, and Job Transfer Rate (DART) fall below the entity's industry average. That suggests exclusivity and deserved recognition for those companies which have superior safety and health management systems and stellar performance.

Certification

An approval ceremony follows the attainment of Star recognition. Usually, an OSHA representative visits the site to recognize its achievements, presents the VPP certificate or plaque, and also gives the site a VPP flag. Therefore, the desired certification is achieved.

The VPP Corporate Pilot Program

In April 2004 OSHA offered corporations that have made a commitment to achieving VPP status a streamlined application and onsite evaluation process called the VPP Corporate Pilot Program. One purpose is to reduce duplication of effort for employers that implement standardized safety management systems throughout their organizations. Being admitted to the program fosters cooperation with OSHA and forms a kind of partnership that should result in more locations within a company achieving Star status.

This program continues to attract participants. An August 25, 2006, newswire release reported that General Electric Company an organization with more than 100 VPP star sites, was admitted into the VPP Corporate Pilot Program. The release also indicated that GE was the sixth organization to be thus inducted, joining Georgia-Pacific, International Paper, the U.S. Postal Service, Dow Chemical, and the Washington Group National. An additional 25 or more companies have since expressed interest in the Program.

OSHA Needs to Embrace Recent Developments

OSHA has built its VPP program around four basic safety management system elements:

- Management leadership and employee involvement
- Worksite analysis
- Hazard prevention and control
- Safety and health training

A 1989 OSHA publication titled "Safety and Health Program Management Guidelines" is also based on those same four basic elements. From the inception of the VPP program in 1982 and through the years following the 1989 publication of the Guidelines, those four elements were considered sound and largely sufficient. This author has distributed a large number of excerpts from the Guidelines.

In light of recent developments, the Guidelines need reconsideration. At least one other person has similarly concluded. Updating the Guidelines is one of the proposals Frank White, Senior Vice President of ORC Worldwide, made in an April 2006 letter to Assistant Secretary for Labor Edwin G. Foulke, Jr. Members of ORC, about 140 mostly Fortune 500 corporations, strive for excellence in safety and health performance. White's comments are pertinent to this chapter:

> In early 1989, OSHA issued what has become landmark guidance on the key elements of an effective occupational safety and health management "program." Since that time, OSHA has made its Voluntary Protection Program, which has at its core the implementation of a management systems approach, a centerpiece of the agency's efforts to improve workplace safety through voluntary programs. Several recent developments provide a powerful strategic opportunity for OSHA to update its 1989 guidance and, in so doing, to exercise strong leadership and direction on a fundamental issue.
>
> In particular, the recently issued American National Standards Institute (ANSI) Occupational Health and Safety Management Systems (OHSMS) Standard, ANSI Z10-2005, provides a new national benchmark for what constitutes an effective OHSMS and is the work product of a broad cross-section of stakeholders.

Indeed, OSHA's "Safety and Health Program Management Guidelines" achieved landmark status when they were issued in 1989. However, the time has come to open up the discussion of the Guidelines and extend them to encompass the provisions of Z10, the "new national benchmark." As that happens, the requirements for VPP star status would draw yet closer to the provisions of Z10.

GROWING INTEREST IN ACHIEVING VPP RECOGNITION

It is common at safety conferences and meetings that safety directors whose companies have obtained VPP recognition let others know about their achievements. Attaining VPP Star status has become a mark of distinction. It provides entities with better than average performance a certification that they are in a superior class. Many of these companies have certifications for their quality management and environmental management systems, and obtaining certification for their safety and health management systems adds to their prestige.

Recall that OSHA described its granting of the VPP designation as its "official recognition of the outstanding efforts of employers and employees who have created exemplary worksite safety and health management systems." And, the upward trend with respect to attaining that recognition is notable, as shown in Table 1. The source of this data is OSHA's Office of Partnership and Recognition.

TABLE 1 Growth of Federal and State VPP Recognitions as of July 3, 2006

Year	VPP Sites
2000	678
2001	777
2002	879
2003	1,043
2004	1,223
2005	1,424
2006	1,550

SIMILARITIES AND DIFFERENCES

There are remarkable similarities and differences between the provisions in Z10 and the requirements to achieve Star status in the VPP program. The major differences relate to safety management system elements that are now given greater significance because of what has been learned in the past several years and that are more specifically defined in Z10. Although substantial similarities exist, only the differences are highlighted here.

Risk Assessment

Comments are made in Chapter 8 "A Primer on Hazard Analysis and Risk Assessment" and in chapter 9, "Including Risk Assessment Provisions in Standards and Guidelines: A Trend" on the significance now given throughout the world to having risk assessment processes in place as an integral part of a safety and health management system. That is a fairly recent development.

To repeat, VPP requirements are based on concepts that were appropriate in their time. The emphasis in VPP is on hazard identification and analysis. The term "hazard" is not defined. But, the wording with respect to hazards in the VPP requirements puts a heavy emphasis on conditions, and it is limiting. The only place in the VPP requirements where risk is mentioned is in the opening paragraph of the section on Worksite Analysis:

> A hazard identification and analysis system must be implemented to systematically identify basic and unforeseen safety and health hazards, evaluate their risks, and prioritize and recommend methods to eliminate or control hazards to an acceptable level of risk. Through this system, management must gain a thorough knowledge of the safety and health hazards and employee risks.

Hazard identification and analysis is a vital process. The outcome establishes the severity of harm that can result from an incident. However, event probability must also be considered to properly assess, prioritize, and act on risks. When making

risk assessments, a mind set must be adopted that focuses on both the probability of incident occurrence and the severity of harm or damage that may result. It is now commonly accepted that safety professionals are obligated to consider both aspects of risk—probability and severity—as they give counsel on attaining acceptable risk levels.

Z10 says that risk assessments "shall" be made and offers comments in an advisory column on what should be considered in the process. Further guidance is given in a three-page Appendix on Assessment and Prioritization. Z10 emphasizes prioritizing risks—an important step in these economic times where risk reduction resources are limited.

In VPP, the section on "Tracking of Hazard Correction" states the following: "This system must include methods for: Recording and prioritizing hazards; and Assigning responsibilities, timeframes for correction, interim protection, and follow-up to ensure abatement." Note that it is hazards that are to be prioritized. That cannot be properly done if the probability of an incident occurring because a hazard's potential has been realized is not considered.

Design Reviews and Procurement

There are two provisions in Z10 that are but briefly mentioned in the VPP Star requirements. These provisions serve to avoid bringing hazards into the workplace, a concept that is gaining recognition as an important element in safety management systems. Some companies have applied these provisions with good success. Z10 says that processes "shall" be in place to have:

- Safety design reviews made
- Safety specifications included in purchasing orders, agreements, and contracts

The idea is that if a safety management system includes processes that minimize bringing hazards into the workplace, the risks deriving from those hazards are also minimized, and resources do not have to be allocated in retrofitting equipment to achieve acceptable risk levels. Retrofitting can be costly, and is often less effective than eliminating or controlling risks in the design process and including safety specifications in procurement documents.

The VPP requirements are not quite as precise. They do say, in "Pre-use analysis," that the safety and health impact of new equipment, etc., must be assessed and that the "practice *should* [emphasis added] be integrated in the procurement/design phase to maximize the opportunity for proactive hazard controls."

Management of Change

This author believes that having an effective management of change system is vital for safety management system effectiveness, particularly with respect to serious injury prevention. Since only a few companies have good management of change systems in place, OSHA will better serve the country by giving greater emphasis to this provision. The VPP provision in "Hazard Analysis of Significant Changes" does very briefly state that hazard analyses must be made of significant changes.

Audits

Both Z10 and VPP require that annual evaluations be made of the safety and health management system. Z10 also requires that processes "shall" be in place to conduct periodic audits. Such audits are not required by VPP. In the "should" column of Z10, the following is stated: "Audits should be conducted by individuals independent of the activities being examined." Making independent and periodic audits is a good safety management practice.

Requirements in VPP Not Similarly Addressed in Z10

There are two subjects for which VPP requirements differ considerably from Z10 provisions:

- The VPP section on industrial hygiene is extensive. "A written IH program is required."
- VPP states, in a section titled "Certified Professional Resources," that "Access to certified safety and health professionals and other licensed health care professionals is required. They may be provided by offsite sources such as corporate headquarters, insurance companies, or private contractors. OSHA will accept certification from any recognized accrediting organization."

Z10 does not give separate treatment to occupational health exposures. Hazards and risks pertaining to injuries and illnesses are treated as parts of a whole. Also, although no provision requiring access to certified professional resources exists in Z10, applying many of the provisions in Z10 will require the counsel of highly qualified professionals.

VPP REQUIREMENTS FOR THE STAR DESIGNATION

OSHA's *Voluntary Protection Programs (VPP): Policies and Procedures Manual* covers all aspects of the VPP programs. Chapter III in the Manual sets forth the Requirements for Star, Merit, Resident Contractor, Construction Industry, and Federal Agency Worksites. Safety and health management system requirements for Star status are outlined in Section C of Chapter III. They are presented here in an Addendum in their entirety to provide a sound basis for review. This author suggests that safety and health management systems be brought up to VPP status as a step toward meeting Z10 requirements.

CONCLUSION

The focus of this book is on preventing incidents that result in injuries and illnesses, with an emphasis on serious injury and illness avoidance. That purpose

will be advanced if companies analyze their safety and health management systems and develop action plans to achieve VPP recognition. In addition to obtaining certification as superior performers, they will be taking a major step forward toward meeting Z10 requirements. Z10 is state-of-the-art and, understandably, few companies have systems in place that meet all its requirements. The Z10 standard and its annexes, and the VPP requirements spelled out in this chapter, serve as excellent resources in making the analysis proposed.

This author strongly believes that having safety and health management systems in place that meet Z10 requirements will result in significant reductions in injuries and illnesses. Since Z10 is state-of-the-art and represents best practices, its existence places special responsibilities on safety professionals to be familiar with and promote the adoption of its provisions. Regardless of where an innovation appears in a safety standard or guideline, safety professionals are obligated to be cognizant of the state-of-the-art as the practice of safety evolves and give counsel on best practices and how to apply the available resources to achieve acceptable risk levels.

REFERENCES

ANSI/AIHA Z10-2005. Occupational Health and Safety Management Systems Standard. Fairfax, VA: American Industrial Hygiene Association, 2005. Also available at http://www.aiha.org.

BS 8800-2004. Occupational Health and Safety Management Systems—Guide. London: British Standards Institute, 2004.

"Growth of VPP." http://www.osha.gov/dcsp/vpp/charts/html.

ILO-OSH 2001. Guidelines on Occupational Safety and Health Management Systems. Geneva, Switzerland: International Labor Organization, 2001.

OSHA. *Voluntary Protection Programs (VPP): Policies and Procedures Manual*, CSP 03-01-002—TED 8.4. http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=DIRECTIVES&p_id=2976.

OSHA. *VPP Corporate Pilot Program.* www.Osha.gov/OshDOC/data_General_facts/vpp-corporate-pilot.

"OSHA's VPP Corporate Pilot Program. General Electric and Others Admitted." http://www.releases.usnewswire.com/printing.asp?id=71265).

OHSAS 18001:1999. Occupational Health and Safety Management Systems—Specification. London: British Standards Institute, 1999.

"Safety and Health Program Management Guidelines." Occupational Safety and Health Administration, *Federal Register*, January 26, 1989.

"VPP—Recognizing Excellence in Safety and Health." http://www.osha.gov/Publications/VPP/vpp_kit.html.

ADDENDUM

REQUIREMENTS FOR STAR RECOGNITION IN OSHA'S VPP PROGRAM

The following material is excerpted from Chapter III of OSHA's *Voluntary Protection Programs (VPP): Policies and Procedures Manual*, CSP 03-01-002—TED 8.4.

C. Comprehensive Safety and Health Management System Requirements

The following safety and health management system elements and sub-elements must be implemented [for Star recognition.] For small sites, at the discretion of the onsite team, some of the requirements may be implemented and documented less formally.

1. Management Leadership and Employee Involvement

a. *Management Commitment.* Management demonstrates its commitment by:

- Establishing, documenting, and communicating to employees and contractors clear goals that are attainable and measurable, objectives that are relevant to workplace hazards and trends of injury and illness, and policies and procedures that indicate how to accomplish the objectives and meet the goals.
- Signing a statement of commitment to safety and health.
- Meeting and maintaining VPP requirements.
- Maintaining a written safety and health management system that documents the elements and sub-elements, procedures for implementing the elements, and other safety and health programs including those required by OSHA standards.

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- Identifying persons whose responsibilities for safety and health include carrying out safety and health goals and objectives, and clearly defining and communicating their responsibilities in their written job descriptions.
- Assigning adequate authority to those persons who are responsible for safety and health, so they are able to carry out their responsibilities.
- Providing and directing adequate resources (including time, funding, training, personnel, etc.) to those responsible for safety and health, so they are able to carry out their responsibilities.
- Holding those assigned responsibility for safety and health accountable for meeting their responsibilities through a documented performance standards and appraisal system.
- Planning for typical as well as unusual/emergency safety and health expenditures in the budget, including funding for prompt correction of uncontrolled hazards.
- Integrating safety and health into other aspects of planning, such as planning for new equipment, processes, buildings, etc.
- Establishing lines of communication with employees and allowing for reasonable employee access to top management at the site.
- Setting an example by following the rules, wearing any required personal protective equipment, reporting hazards, reporting injuries and illnesses, and basically doing anything that they expect employees to do.
- Ensuring that all workers (including contract workers) are provided equal, high-quality safety and health protection.
- Conducting an annual evaluation of the safety and health management system in order to:
  - Maintain knowledge of the hazards of the site.
  - Maintain knowledge of the effectiveness of system elements.
  - Ensure completion of the previous years' recommendations.
  - Modify goals, policies, and procedures.

b. *Employee Involvement.* Employees must be involved in the safety and health management system in at least three meaningful, constructive ways in addition to their right to report a hazard. Avenues for employees to have input into safety and health decisions include participation in audits, accident/incident investigations, self-inspections, suggestion programs, planning, training, job hazard analyses, and appropriate safety and health committees and teams. Employees do not meet this requirement by participating in incentive programs or simply working in a safe manner.
   - Employees must be trained for the task(s) they will perform. For example, they must be trained in hazard recognition to participate in self-inspections.
   - Employees must receive feedback on any suggestions, ideas, reports of hazards, etc., that they bring to management's attention. A site must provide documented evidence that employees' suggestions were followed up and implemented when appropriate and feasible.

- All employees, including new hires, must be notified about the site's participation in VPP and employees' rights (such as the right to file a complaint) under the OSH Act. Orientation-training curriculum must include this information.
- Employees and contractors must demonstrate an understanding of and be able to describe the fundamental principles of VPP.

c. *Contract Worker Coverage.* Contract workers must be provided with safety and health protection equal in quality to that provided to employees.
   - All contractors, whether regularly involved in routine site operations or engaged in temporary projects such as construction or repair, must follow the safety and health rules of the host site.
   - VPP participants must have in place a documented oversight and management system covering applicable contractors. Such a system must:
     - Ensure that safety and health considerations are addressed during the process of selecting contractors and when contractors are onsite.
     - Encourage contractors to develop and operate effective safety and health management systems.
     - Include provisions for timely identification, correction, and tracking of uncontrolled hazards in contractor work areas.
     - Include a provision for removing a contractor or contractor's employees from the site for safety or health violations. *Note*: A site may have been operating effectively for 1 year without actually invoking this provision if just cause to remove a contractor or contractor's employee did not occur.
   - **Injury and Illness Data Requirements**
     - Nested contractors (such as contracted maintenance workers) and temporary employees who are supervised by host site management are governed by the site's safety and health management system and are therefore included in the host site's rates.
     - Site management must maintain copies of the TCIR (total case incident rate) and DART (three year day away, restricted, and/or transfer case incident) rate data for all applicable contractors based on hours worked at the site. . . .
     - Sites must report all applicable contractors' TCIR and DART rate data to OSHA annually.
   - **Training**. Managers, supervisors, and non-supervisory employees of contract employers must be made aware of:
     - The hazards they may encounter while on the site.
     - How to recognize hazardous conditions and the signs and symptoms of workplace-related illnesses and injuries.
     - The implemented hazard controls, including safe work procedures.
     - Emergency procedures.

d. *Safety and Health Management System Annual Evaluation.* There must be a system and written procedures in place to annually evaluate the safety and health management system. The annual evaluation must be a critical review and assessment of the effectiveness of all elements and sub-elements of a comprehensive safety and health management system. An annual evaluation that is merely a workplace inspection with a brief report pointing out hazards or a general statement of the sufficiency of the system is inadequate for purposes of VPP qualification.
   - The written annual evaluation must identify the strengths and weaknesses of the safety and health management system and must contain specific recommendations, timelines, and assignment of responsibility for making improvements. It must also document actions taken to satisfy the recommendations.
   - The annual evaluation may be conducted by site employees with managers, qualified corporate staff, or outside sources who are trained in conducting such evaluations.
   - At least one annual evaluation and demonstrated corrective action must be completed before VPP approval.
   - The annual evaluation must be included with the participant's annual submission to OSHA. . . .

2. Worksite Analysis A hazard identification and analysis system must be implemented to systematically identify basic and unforeseen safety and health hazards, evaluate their risks, and prioritize and recommend methods to eliminate or control hazards to an acceptable level of risk.

Through this system, management must gain a thorough knowledge of the safety and health hazards and employee risks. The required methods of hazard identification and analysis are described below.

a. *Baseline Safety and Industrial Hygiene Hazard Analysis.* A baseline survey and analysis is a first attempt at understanding the hazards at a worksite. It establishes initial levels of exposure (baselines) for comparison to future levels, so that changes can be recognized. Systems for identifying safety and industrial hygiene hazards, while often integrated, may be evaluated separately. Baseline surveys must:
   - Identify and document common safety hazards associated with the site (such as those found in OSHA regulations or building standards, for which existing controls are well known), and how they are controlled.
   - Identify and document common health hazards (usually by initial screening using direct-reading instruments) and determine if further sampling (such as full-shift dosimetry) is needed.
   - Identify and document safety and health hazards that need further study.

- Cover the entire work site, indicate who conducted the survey, and when it was completed.

The original baseline hazard analysis need not be repeated subsequently unless warranted by changes in processes, equipment, hazard controls, etc.

b. *Hazard Analysis of Routine Jobs, Tasks, and Processes.* Task-based or system/process hazard analyses must be performed to identify hazards of routine jobs, tasks, and processes in order to recommend adequate hazard controls. Acceptable techniques include, but are not limited to: Job Hazard Analysis (JHA), and Process Hazard Analysis (PrHA).
   - Hazard analyses should be conducted on routine jobs, tasks and proces ses that:
     - Have written procedures.
     - Have had injuries/illnesses associated with them or have experienced significant incidents or near-misses.
     - Are perceived as high-hazard tasks, i.e., they could result in a catastrophic explosion, electrocution, or chemical over-exposure.
     - Have been recommended by other studies and analyses for more in-depth analysis.
     - Are required by a regulation or standard.
     - Any other instance when the VPP applicant or participant determines that hazard analysis is warranted.

c. *Hazard Analysis of Significant Changes.* Hazard analysis of significant changes, including but not limited to non-routine tasks (such as those performed less than once a year), new processes, materials, equipment and facilities, must be conducted to identify uncontrolled hazards prior to the activity or use, and must lead to hazard elimination or control.
   If a non-routine or new task is eventually to be done on a routine basis, then a hazard analysis of this routine task should subsequently be developed.

d. *Pre-use Analysis.* When a site is considering new equipment, chemicals, facilities, or significantly different operations or procedures, the safety and health impact to the employees must be reviewed. The level of detail of the analysis should be commensurate with the perceived risk and number of employees affected.
   This practice should be integrated in the procurement/design phase to maximize the opportunity for proactive hazard controls.

e. *Documentation and Use of Hazard Analyses.* Hazard analyses performed to meet the requirements of c. or d. above must be documented and must:
   - Consider both health and safety hazards.
   - Identify the steps of the task or procedure being analyzed, hazard controls currently in place, recommendations for needed additional or more effective hazard controls, dates conducted, and responsible parties.
   - Be used in training in safe job procedures, in modifying workstations, equipment or materials, and in future planning efforts.

- Be easily understood.
- Be updated as the environment, procedures, or equipment change, or errors are found that invalidate the most recent hazard analyses.

f. *Routine Self-Inspections.* A system is required to ensure routinely scheduled self-inspections of the workplace. It must include written procedures that determine the frequency of inspection and areas covered, those responsible for conducting the inspections, recording of findings, responsibility for abatement, and tracking of identified hazards for timely correction. Findings and corrections must be documented.
   - Inspections must be made at least monthly, with the actual inspection schedule being determined by the types and severity of hazards.
   - The entire worksite must be covered at least once each quarter.
   - Top management and others, including employees who have knowledge of the written procedures and hazard recognition, may participate in the inspection process.
   - Personnel qualified to recognize workplace hazards, particularly hazards peculiar to their industry, must conduct inspections.
   - Documentation of inspections must evidence thoroughness beyond the perfunctory use of checklists.

g. *Hazard Reporting System for Employees.* The site must operate a reliable system that enables employees to notify appropriate management personnel in writing—without fear of reprisal—about conditions that appear hazardous, and to receive timely and appropriate responses. The system can be anonymous and must include timely responses to employees and tracking of hazard elimination or control to completion.

h. *Industrial Hygiene (IH) Program.* A written IH program is required. The program must establish procedures and methods for identification, analysis, and control of health hazards for prevention of occupational disease.
   - *IH Surveys.* Additional expertise, time, technical equipment, and analysis beyond the baseline survey may be required to determine which environmental contaminants (whether physical, biological, or chemical) are present in the workplace, and to quantify exposure so that proper controls can be implemented.
   - *Sampling Strategy* The written program must address sampling protocols and methods implemented to accurately assess employees' exposure to health hazards. Sampling should be conducted when:
     - Performing baseline hazard analysis, such as initial screening and grab sampling.
     - Baseline hazard analysis suggests that more in-depth exposure analysis, such as full-shift sampling, is needed.
     - Particularly hazardous substances (as indicated by an OSHA standard, chemical inventory, material safety data sheet, etc.) are being used or could be generated by the work process.

- Employees have complained of signs of illness.
- Exposure incidents or near-misses have occurred.
- It is required by a standard or other legal requirement.
- Changes have occurred in such things as the processes, equipment, or chemicals used.
- Controls have been implemented and their effectiveness needs to be determined.
- Any other instance when the VPP applicant or participant determines that sampling is warranted.

- *Sampling Results* Sampling results must be analyzed and compared to at least OSHA permissible exposure limits (PELs) to determine employees' exposure and possible overexposure. Comparison to more restrictive levels, such as action levels, threshold limit values (TLVs), or self-imposed standards, is encouraged to reduce exposures to the lowest feasible level.
  - *Documentation* The results of sampling must be documented and must include a description of the work process, controls in place, sampling time, exposure calculations, duration, route, and frequency of exposure, and number of exposed employees.
  - *Communication* Sampling results must be communicated to employees and management.
  - *Use of Results* Sampling results must be used to identify areas for additional, more in-depth study, to select hazard controls, and to determine if existing controls are adequate.
- *IH Expertise* IH sampling should be performed by an industrial hygienist, but initial sampling, full-shift sampling, or both may be performed by safety staff members with special training in the specific procedures for the suspected or identified health hazards in the workplace.
  - *Procedures* Standard, nationally recognized procedures must be used for surveying and sampling as well as for testing and analysis.
  - *Use of Contractors* If an outside contractor conducts industrial hygiene surveys, the contractor's report must include all sampling information listed above and must be effectively communicated to site management. Any recommendations contained in the report should be considered and implemented where appropriate. Use of contractors does not remove responsibility for the IH program, including identification and control of health hazards, from the VPP applicant or participant.

i. *Investigation of Accidents and Near-Misses* The site must investigate all accidents and near-misses and must maintain written reports of the investigations. Accident and near-miss investigations must:
   - Be conducted by personnel trained in accident investigation techniques. Personnel who were not involved in the accident or who do not supervise the injured employee(s) should conduct the investigation to minimize potential conflicts of interest.

- Document the entire sequence of relevant events.
- Identify all contributing factors, emphasizing failure or lack of hazard controls.
- Determine whether the safety and health management system was effective, and where it was not, provide recommendations to prevent recurrence.
- Not place undue blame or reprisal on employees, although human error can be a contributing factor.
- Assign priority, timeframes, and responsibility for implementing recommended controls.
- The results of investigations (to include, at a minimum, a description of the incident and the corrections made to avoid recurrence) must be made available to employees on request, although the actual investigation records need not be provided.

j. *Trend Analysis* The process must include analysis of information such as injury/illness history, hazards identified during inspections, employee reports of hazards, and accident and near-miss investigations for the purpose of detecting trends. The results of trend analysis must be shared with employees and management and utilized to direct resources; prioritize hazard controls; and determine or modify goals, objectives, and training to address the trends.

3. Hazard Prevention and Control Management must ensure the effective implementation of systems for hazard prevention and control and ensure that necessary resources are available, including the following:

a. *Certified Professional Resources* Access to certified safety and health professionals and other licensed health care professionals is required. They may be provided by offsite sources such as corporate headquarters, insurance companies, or private contractors. OSHA will accept certification from any recognized accrediting organization.

b. *Hazard Elimination and Control Methods* The types of hazards employees are exposed to, the severity of the hazards, and the risk the hazards pose to employees should all be considered in determining methods of hazard prevention, elimination, and control. In general, the following hierarchy should be followed in determining hazard elimination and control methods.
When engineering controls have been studied, investigated, and implemented, yet still do not bring employees' exposure levels to below OSHA permissible exposure limits; or when engineering controls are determined to be infeasible, then a combination of controls may be used. Whichever controls a site chooses to employ, the controls must be understood and followed by all affected parties; appropriate to the site's hazards; equitably enforced through the disciplinary system; written, implemented, and updated by management as needed; used by employees; and incorporated in training, positive reinforcement, and correction programs.

- *Engineering* Engineering controls directly eliminate a hazard by such means as substituting a less hazardous substance, by isolating the hazard, or by ventilating the workspace. These are the most reliable and effective controls.
  - *Protective Safety Devices* Although not as reliable as true engineering controls, such methods include interlocks, redundancy, failsafe design, system protection, fire suppression, and warning and caution notes.
- *Administrative* Administrative controls significantly limit daily exposure to hazards by control or manipulation of the work schedule or work habits. Job rotation is a type of administrative control.
- *Work Practices* These controls include workplace rules, safe and healthful work practices, personal hygiene, housekeeping and maintenance, and procedures for specific operations.
- *Personal Protective Equipment (PPE)* PPE to be used are determined by hazards identified in hazard analysis. PPE should only be used when all other hazard controls have been exhausted or more significant hazard controls are not feasible.

c. *Hazard Control Programs* Applicants and participants must be in compliance with any hazard control program required by an OSHA standard, such as PPE, Respiratory Protection, Lockout/Tagout, Confined Space Entry, Process Safety Management, or Bloodborne Pathogens. VPP applicants and participants must periodically review these programs (most OSHA standards require an annual review) to ensure they are up to date.

d. *Occupational Health Care Program*

- Licensed health care professionals must be available to assess employee health status for prevention, early recognition, and treatment of illness and injury.
- Arrangements for needed health services such as pre-placement physicals, audiograms, and lung function tests must be included.
- Employees trained in first aid, CPR providers, physician care, and emergency medical care must be available for all shifts within a reasonable time and distance. The applicant or participant may consider, based on site conditions, providing Automated External Defibrillators (AEDs) and training in their use.
- Emergency procedures and services including provisions for ambulances, emergency medical technicians, emergency clinics or hospital emergency rooms should be available and explained to employees on all shifts. Also see paragraph h.below.

e. *Preventive Maintenance of Equipment* A written preventive and predictive maintenance system must be in place for monitoring and maintaining workplace equipment. Equipment must be replaced or repaired on a schedule, following manufacturers' recommendations, to prevent it from failing and creating a hazard. Documented records of maintenance and repairs must

be kept. The system must include maintenance of hazard controls such as machine guards, exhaust ventilation, mufflers, etc.

f. *Tracking of Hazard Correction* A documented system must be in place to ensure that hazards identified by any means (self-inspections, accident investigations, employee hazard reports, preventive maintenance, injury/illness trends, etc.) are assigned to a responsible party and corrected in a timely fashion. This system must include methods for:
   - Recording and prioritizing hazards, and
   - Assigning responsibility, timeframes for correction, interim protection, and follow-up to ensure abatement.

g. *Disciplinary System* A documented disciplinary system must be in place. The system must include enforcement of appropriate action for violations of the safety and health policies, procedures, and rules. The disciplinary policy must be clearly communicated and equitably enforced to employees and management. The disciplinary system for safety and health can be a sub-part of an all-encompassing disciplinary system.

h. *Emergency Preparedness and Response* Written procedures for response to all types of emergencies (fire, chemical spill, accident, terrorist threat, natural disaster, etc.) on all shifts must be established, must follow OSHA standards, must be communicated to all employees, and must be practiced at least annually. These procedures must list requirements or provisions for:
   - Assessment of the emergency.
   - Assignment of responsibilities (such as incident commander).
   - First aid.
   - Medical care.
   - Routine and emergency exits.
   - Emergency telephone numbers.
   - Emergency meeting places.
   - Training drills, minimally including annual evacuation drills. Drills must be conducted at times appropriate to the performance of work so as not to create additional hazards. Coverage of critical operations must be provided so that all employees have an opportunity to participate in evacuation drills.
   - Documentation and critique of evacuation drills and recommendations for improvement.
   - Personal protective equipment where needed.

4. Safety and Health Training

a. Training must be provided so that managers, supervisors, non-supervisory employees, and contractors are knowledgeable of the hazards in the workplace, how to recognize hazardous conditions, signs and symptoms of workplace-related illnesses, and safe work procedures.

b. Training required by OSHA standards must be provided in accordance with the particular standard.
c. Managers and supervisors must understand their safety and health responsibilities and how to carry them out effectively.
d. New employee orientation/training must include, at a minimum, discussion of hazards at the site, protective measures, emergency evacuation, employee rights under the OSH Act, and VPP.
e. Training should be provided for all employees regarding their responsibilities for each type of emergency. Managers, supervisors, and non-supervisory employees, including contractors and visitors, must understand what to do in emergency situations.
f. Persons responsible for conducting hazard analysis, including self-inspections, accident./incident investigations, job hazard analysis, etc., must receive training to carry out these responsibilities, e.g., hazard recognition training, accident investigation techniques, etc.
g. Training attendance must be documented. Training frequency must meet OSHA standards, or for non-OSHA required training, be provided at adequate intervals. Additional training must be provided when changes in work processes, new equipment, new procedures, etc., occur.
h. Training curricula must be up-to-date, specific to worksite operations, and modified when needed to reflect changes and/or new workplace procedures, trends, hazards and controls identified by hazard analysis. Training curricula must be understandable for all employees.
i. Persons who have specific knowledge or expertise in the subject area must conduct training.
j. Where personal protective equipment (PPE) is required, employees must understand that it is required, why it is required, its limitations, how to use it, and maintenance.

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