

Retrofitting for Safety

Career implications for SH&E personnel

By Wayne C. Christensen

RETROFITTING—the practice of waiting until projects are essentially completed or nearly ready for market or implementation before conducting a safety review to identify deficiencies and make changes—can no longer be the norm. It is also not acceptable for a company to wait for the next serious accident to occur before addressing safety.

The correct approach is to ensure that prevention efforts and resolution of safety concerns are a prime focus in the design phase of facilities, equipment and products, and in process changes. Safety through design requires the integration of hazard analysis and risk assessment methods early in the design and engineering stages and mandates that actions be taken to reduce the risks of injury or damage to an acceptable level (Christensen & Manuele, 1999). The objective is to avoid making changes (retrofitting) after the project build or operate stages have been initiated, nearly completed or completed (Figure 1).

Consider these statements made decades ago that are still significant today:

- “To secure the highest efficiency in plant operations, provisions for workers’ safety must be included in the design and layout”(NSC, 1946).

- “When safety is properly inculcated in the planning of new operations or processes, there will be little need to secure management’s backing for incorporating safety features before operations are started”(NSC, 1955).

Safety must be a “pre-thought”—one embedded in the design phase—rather than an afterthought. Management, engineers and designers have little desire to spend time or money retrofitting for safety; consequently, waiting until the end of a cycle to make changes is an ineffective approach to reducing risk to an acceptable level.

However, SH&E professionals should not look for a CEO mandate that “safety must be involved.” Even with such backing, if SH&E professionals do not have the requisite knowledge to

work with engineers, these efforts will be frustrating. As Bahrain Petroleum Co. CEO Hussain Tadayon advises, SH&E practitioners must market themselves within the company, maintain their knowledge base and keep learning. “They should not wait to be asked but be there with answers, be creative, and they must know and understand the company’s needs” (Smith, 2004, p. 16). To help readers heed this advice, this article examines technology challenges and changes taking place, shares information on the knowledge needed to survive and explains how to acquire it.

Are Corporations Emphasizing Safety through Design?

Leading CEOs believe corporate reputation is a more important success measure than stock market performance, profitability or return on investment, according to a World Economic Forum—a point that can be used positively. On the other hand, a great concern is that other CEOs believe the key that drives change is profit (ISHN, 2004).

To be successful, SH&E professionals must link their work to measures important in their organization and must recognize that safe operations do not simply occur. This leads to a key question: Can a corporation that desires to be world-class yet fails to consider safety in the design stage really achieve world-class status?

The need to incorporate safety in design has been recognized for more than 60 years (NSC, 1946, 1955), yet the world is still waiting for business and industry leaders to emphasize safety in the design phase. While many have suggested that management’s attention is focused elsewhere, SH&E personnel must be more focused. Personal observations indicate that many corporate leaders voice concerns for safety, but demonstrate no effort to spur action in the design phase. In one case, a colleague reported that corporate auditing SH&E personnel were being replaced with less-experienced individuals. One might conclude that this company’s executives hoped fewer deficiencies would be identified as a result.

One should question management’s thinking and actions when plans are established to get a product

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to market or a facility into operation by some arbitrary date and management indicates that delays will not be permitted. Does this mean workplaces with unacceptable levels of risk will be tolerated? What if management states that the project or product cost package is fixed and that additional costs will not be approved? Does this mean unacceptable levels of risk will be tolerated and no funds will be available to eliminate hazards if fixes are not in the design? SH&E personnel who seek to retrofit would do well to wonder whether management might question where they were in the design phase and the value of their professional efforts.

Confined Spaces & Construction Offer Examples

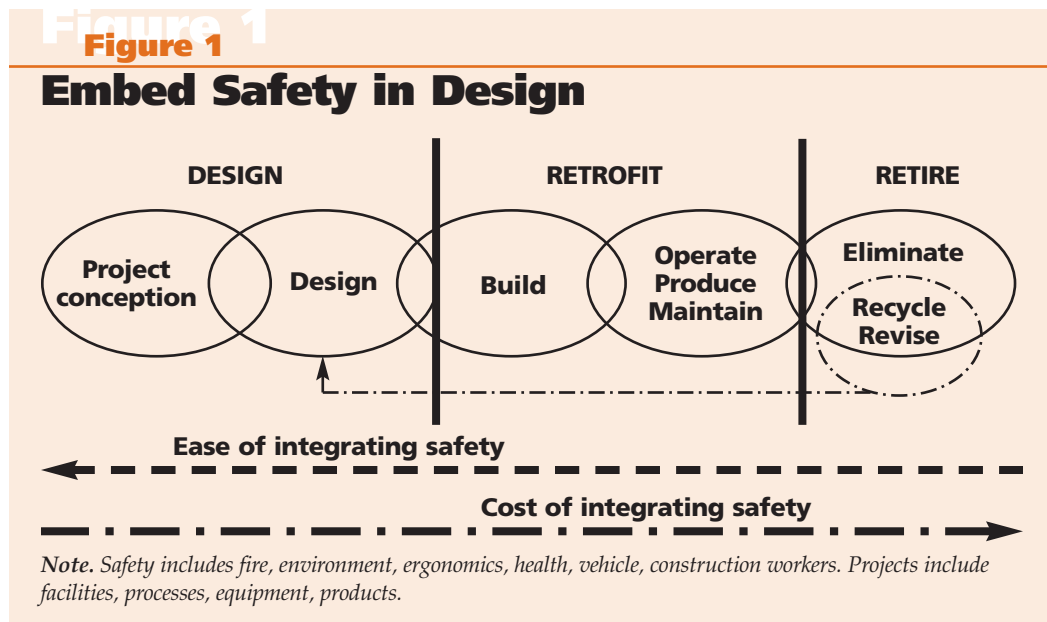
Continued failure to include hazard recognition and risk assessment when designing is evident in articles and checklists found in safety literature. Consider, for example, confined spaces. Confined spaces continue to result in a significant number of fatalities and injuries, and substantial dollars are spent on entry and rescue training and equipment. Yet, designers function with no specific objective to eliminate or design out confined spaces or the need to enter them. If the spaces cannot be eliminated, the need for entry could be removed, for example, through designs that use remote controls, self-cleaning apparatuses or vibration equipment to eliminate bridging or caking.

A major engineering company's conceptual phase design checklist (which was shared with the author by a colleague) revealed early concern for confined spaces, yet gave no consideration to eliminating the spaces or the need to enter them. Instead, the checklist questions essentially addressed when an entry was to be made—certainly not adequate to create modifications in the design.

Safety through design is rare in the U.S. (Gomez, 2004).

This directive [EU Control of Hazards on Temporary and Mobile Construction Sites] required all member countries to enact regulations to require owners, designers and contractors to consider safety issues from design to the execution of construction projects. This "safety in design" approach is only rarely discussed in U.S. circles, and, to my knowledge, it has never received any serious attention as a possible regulatory approach.

Lack of such consideration is further emphasized by Hecker, Gambatese and Weinstein (2005): "While designing for construction safety has become



increasingly common in Europe and Australia, until recently, few, if any, large-scale design-for-safety initiatives have been launched in the U.S."

Both statements are strong charges against U.S. industry's desire for safe operations. While these comments focus on construction safety, observations indicating an absence of safety through design programs in general industry were evident in researching the book *Safety Through Design* (Christensen & Manuele, 1999). Hopefully, industry leaders will heed these words: "Good business leaders understand human nature, care about each worker's well-being and recognize that a company's employees are its greatest asset, for them, employee safety is nonnegotiable, uncompromising [and] permanent" (McMillan, 2005). If they do, safety through design should be a focus.

Other Influences: ANSI Z10 & Innovation

Another significant development in this area is ANSI/AIHA Z10, Occupational Health and Safety Management Systems. Z10 has strong requirements for management, including the need to consider safety in the design phase if management is going to be found in compliance during an audit (see "ANSI/AIHA Z10" sidebar on p. 38). The standard also contains major implications with respect to increased knowledge requirements for SH&E personnel if they are to interpret, lead and participate in company efforts from the design stage forward. The full impact of this standard will be determined by management and perhaps OSHA in the next few years.

SH&E professionals also can look to building designers for an example of a proactive approach to design. These designers currently are making changes to strengthen the safety of structures without awaiting code changes. The reconstruction of World Trade Center Building #7 is a case in point. The building is being "designed with evacuation in mind, the stairs are 20% wider than required by the building code, allowing two people to pass side by side or go down

Abstract: This article examines how the practice of retrofitting impacts SH&E personnel. The article stresses the need for safety through design and offers suggestions for how SH&E professionals can expand their involvement in and knowledge of the design process.

them together. . . . Two feet thick, the core is made of reinforced concrete, which is more impact-resistant than steel with dry wall" (Flynn, 2005). These safety measures reflect innovative, proactive thinking—and show that waiting for code changes to enhance safety is not always an option.

ANSI/AIHA Z10 on Safety in Design

Section 5.1.2 Design Review & Management of Change

The organization shall establish and implement processes to identify, and take the appropriate steps to prevent or otherwise control hazards and reduce potential risks associated with:

- a) new processes or operations at the design stage; and
- b) changes to its existing operations, products, services or suppliers.

Innovation has become an important factor in manufacturing operations as well. General Electric calls it "imaginative problem-solving"—encouraging people to think "what if" yet always with the aim of driving growth. When asked, "Do you feel you've become more innovative in the past few years?" GE CEO Jeff Immelt responded, "[It all] goes back to people—those who want to take swings. I tell people that you have to view these [new leadership] traits as critical to your long-term development. You have to change . . . or else you don't have a great future in this company" (O'Connell, 2005).

Innovation is great, but it must not allow hazards to enter the operation. Immelt's statement can be used to promote safety through design. It is also significant because if SH&E personnel continue the old way of doing things—uninterested in seeking new approaches and ways of carrying out responsibilities—many obstacles to accomplishing safety objectives may emerge, including extinction of the safety position.

Time to Market Is Decreasing, SH&E Personnel Must Keep Up

Technology continues to advance rapidly, with

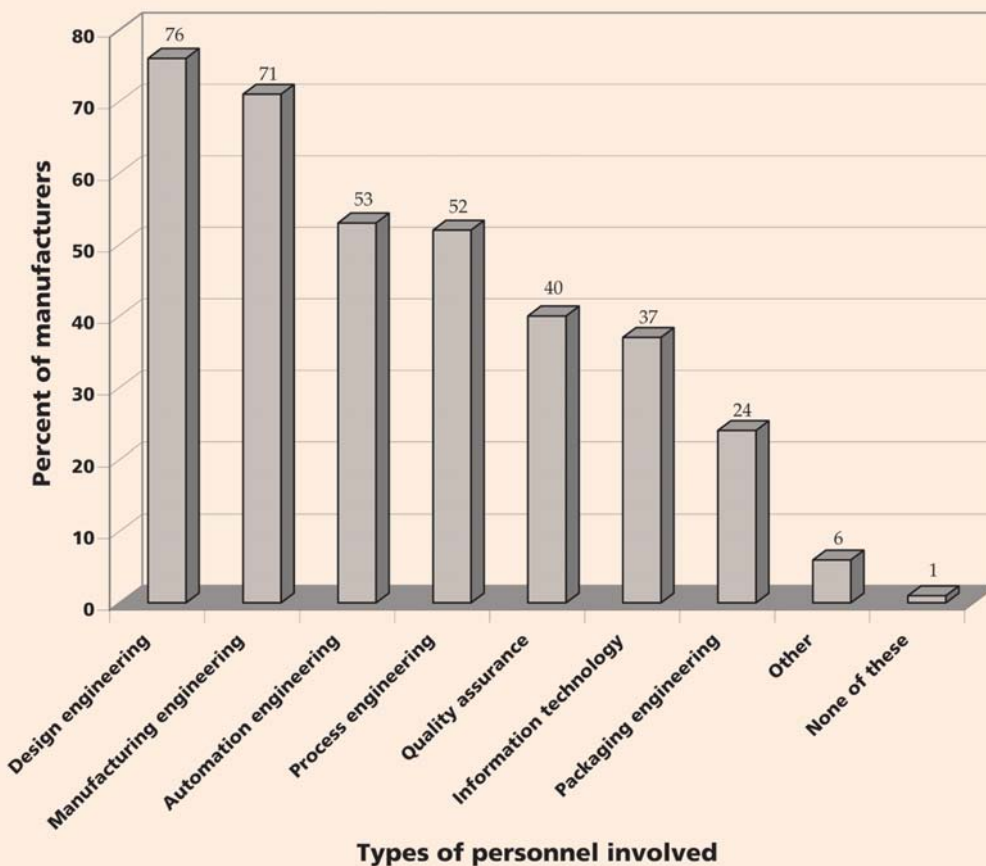
improvements announced almost daily. Some 3-D design software incorporates performance-based design objectives along with an ability to retain a history of all design changes. Engineers and designers can now design, assemble and test their projects on a computer, which eliminates the time and cost of models or prototypes. Since more codes and standards are becoming performance-based, SH&E practitioners must develop a competency in performance-based safety objectives and standards and must become less dependent on specification objectives and standards.

Software analysis tools such as finite element analysis (FEA) are increasingly part of the design process. Participating in their use requires specific knowledge and capability. Because designers must consider human factors such as ergonomics and an aging population, as well as physical limitations of employees and visitors, simulation tools are becoming a significant resource as well.

SH&E professionals must understand concepts and knowledge that can be used and stored in design software programs to:

Figure 2

What Personnel Do Manufacturers Involve in the Design Process?



- supplant knowledge loss when engineers retire or leave the company;

- make use of information from previous designs in new models;

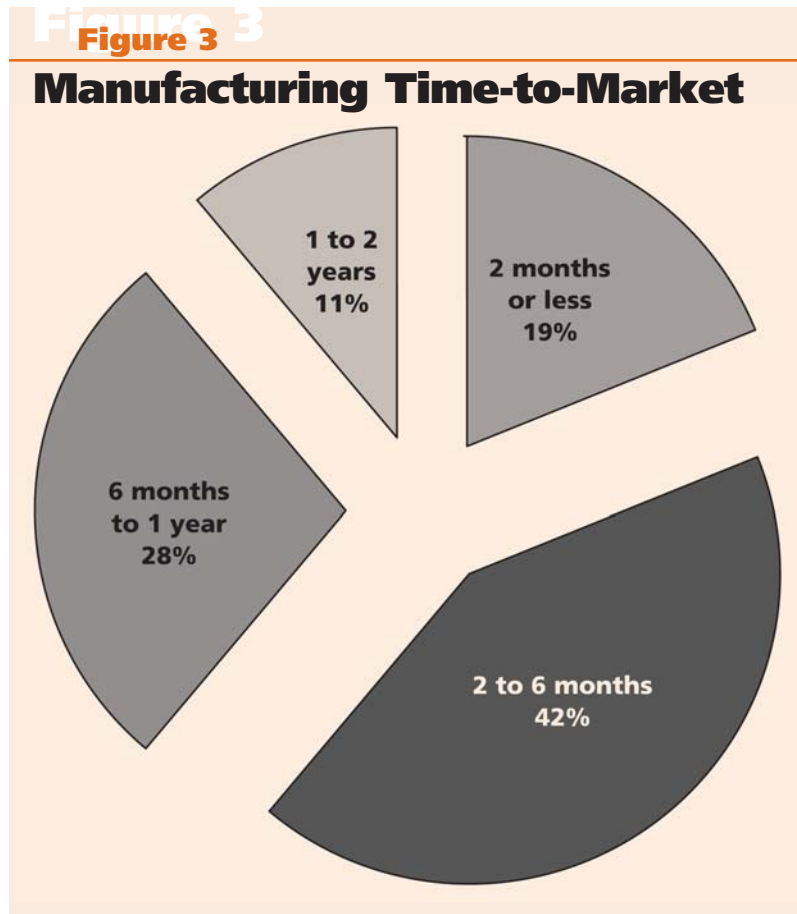
- achieve productivity goals, efficiency, quality consistency and reduced time-to-market.

Collaboration among design engineering, operations and other engineer groups has been identified as a key factor. Unfortunately, SH&E practitioners are often not part of this collaborative effort, as evident in the following quote:

In today's competitive environment, while it may take a village to raise a child, it takes an entire manufacturing organization to design a new product . . . approximately three-fourths of manufacturers involve both design and manufacturing engineers . . . more than half include automation and process engineers . . . quality assurance and information technology were . . . part . . . almost 40% (Gerold, 2004, p. 16).

Where is safety in this equation (Figure 2)? Is its absence an indication that SH&E personnel are resistant to being involved—or that engineers are resistant to their being involved?

The time required from product design to manu-



facture is already relatively compressed—and it continues to decrease. Some report speed-to-market is now a competitive factor. According to one survey (Gerold, 2004, p. 16), 61% accomplish this cycle in less than 6 months and 89% in less than 1 year (Figure 3). It is easy to understand why companies are not inclined to extend the design-to-manufacture cycle to undergo costly retrofitting. According to Greg Miliken, CEO of Alibre, “More than 70% of a product’s cost is committed in the earliest stages of the [design] process” (Rowe, 2006). Saving time results in cost savings; the decrease from months to weeks and from weeks to minutes can be readily recognized as cost savings—which likely will not be sacrificed to retrofit.

Clearly, innovation and technology are forcing dramatic reductions in time-to-market of projects and products. The declared need for safety to be included in design requires urgent consideration. It is not realistic to believe industry will wait so that SH&E professionals can retrofit when a prototype is ready or construction nearly complete.

The Society of Automotive Engineers’ seminar, “Designing for Safety and Developing Accurate Safety Specifications,” features topics that resemble a conference for SH&E practitioners, but it is a seminar for automotive and aerospace engineers to reduce safety recalls. Topics include safety in design concepts, theory of accidents, writing safety and interface specifications, minimizing accidents in

Design Terminology

- CAD = Computer-aided design
- CAE = Computer-aided engineering
- CAM = Computer-aided manufacturing
- CFD = Computational fluid dynamics. This involves predicting what will happen, quantitatively, when fluids flow, often with complications of: simultaneous flow of heat; mass transfer; phase change; chemical reaction; mechanical movement; or stresses in and displacement of immersed or surrounding solids.
- FEA = Finite element analysis. This provides detailed information about stresses/deflections inherent in a design. It is a mathematical model, an idealized/simple version of a physical situation. Thermal and structural analysis can be made. The designer tells what the model is made of, how fixed, and what forces act upon it. Graphics show where weak spots are likely.
- PLM = Project life cycle management

early and detail design, software safety design control technique. The promotional literature makes clear the premise—to prevent costly recalls.

Dramatic savings can occur through creative design practices that focus on inherent product risks very early in the design process, and on ways to minimize each risk factor. At a time when safety recalls are becoming increasingly costly and damaging . . . this seminar reveals how significant cost savings can be obtained by designing for safety. . . . [A]ttendees will . . . also discover risk-mitigation techniques that can be effectively implemented in their workplaces to prevent costly recalls (SAE, 2007).

Lean Manufacturing: Another Trend with Impact

With most companies involved in quality programs, including statistical process control in the last 2 decades, Weimer (2004) asks:

Well what about the \$10 billion that industry annually pays on warranties? . . . Make it right and there won't be any costs . . . what's missing to the tune of \$10 billion in manufacturing? A new methodology called lean quality has captured the attention of the automotive and transportation industry (p. 68).

Lean quality may be the next wave in industry. It is referred to as lean manufacturing by the Society of Manufacturing Engineers, which has a certification process. Safety must be included. To that point, the ANSI B11 Committee is developing a technical report (TR7) titled "Integrating Safety into Lean Manufacturing: A Guide on Integrating Safety and Lean Manufacturing Principles in the Use of Machines."

The Influence of Software

Software continues to influence the design process as well. Examples include the following:

- SolidWorks (CAD).

Delivers . . . features to make engineers faster, more accurate and . . . productive . . . for machine designers . . . library . . . on-screen . . . hundreds of pre-designed . . . parts users have created . . . for consumer product . . . design capabilities . . . enabling designers to make . . . attractive, functional products . . . quickly (www.solidworks.com).

- RULESTREAM (from the firm's case studies).

Engineering custom-built furniture in . . . one day—leading manufacturer . . . call centers and educational institution . . . product engineering time . . . down from several days . . . enables engineers, rather than programmers, to develop, manage and update design automation applications efficiently.

A power generation systems company indicates that "by transitioning to RULESTREAM, [the company] will continue to develop burner proposals in days instead of weeks" (www.rulestream.com).

- Product life cycle management (PLM). Eclipse Aviation Corp. wanted to build a small jet to sell for

under \$1 million and cost less than half of what it costs to operate today's smallest jet. Cost goals were accomplished. The firm was able to reduce assembly time for jets from months to days.

. . . management realized . . . that meeting its goals would require PLM technology. . . . Eclipse designers modeled . . . entire aircraft down to the last rivet . . . (software) permits visualization, digital mockup and validation capabilities . . . can import digital models of . . . aircraft to permit simulations of different factory layouts" (Waurzyniak, 2005, p. 53).

- Simulation. Bill Weyand, MSC Software's CEO, told attendees at a product development conference, "CAD is becoming outdated; it's computer-aided engineering and simulation software that is the direction the industry is heading" (www.connectpress.com).

"A big time-consumer in ergonomics simulation . . . (those) took 3 or 4 weeks to create originally (1997-98) now require only 3 or 4 days . . . aircraft assembly process, tooling and line workers involved in the production processes have all been simulated and tested prior to production."

Companies ask to "have simulator tool usable on . . . interface that will let them make updates to double check if adding new equipment will have an impact" (*Machine Design*, 2003, p. 10).

- FEA.

Verifies safety of radioactive waste container with . . . mechanical event simulation . . . a safe container was needed for disposal of radioactive waste (radioactive glovebox) . . . had to meet strict regulatory safety standards for shielding, containment and structural strength . . . FEA software (used) to verify the container's structural integrity including simulation of a 2-foot drop test as specified . . . faster . . . more economical than . . . physical prototype tests . . . saved significant time and money (www.algor.com).

SolidWorks offers a webcast, "FEA for the Rest of Us," which states "if you are not using FEA, you will . . . if you will not, you'll get left behind."

- VX CAD/CAM. Time-to-market is cut in half and safety is improved.

For some time, European manufacturers . . . more attuned to safety in product design. Whether . . . more stringent government regulations or . . . demands of consumers . . . products contain more safety features. Nowhere is . . . concern . . . more obvious than in . . . design of products for children . . . high standards of safety technology and quality are paramount . . . company mixes function and aesthetics . . . product time-to-market continues to be reduced while components are . . . ever more complex (www.vx.com).

SH&E personnel should share the following statement with designers and engineers:

You must start thinking safety early. One of . . . the most frequent mistakes designers make is thinking only of . . . production process . . . ignoring . . . [the] fact [that] . . . [the] system will be safeguarded . . . operators often find safeguards inhibit . . . ability to perform their jobs efficiently, resulting in reduced productivity . . . [the] safest systems are those where required safeguards are considered simultaneously with . . . [the] production system's design (Freedman, 2004, p. 126).

Industry claims productivity improvements that also emphasize the need for safety in the design phase. The Boeing 787 Dreamliner is a multicompany project, with engines by GE and Rolls-Royce, nacelle system including thrust reverser by Goodrich Corp. and pylons provided by Boeing's Wichita Division. With this many participants in a small part of the entire project, if safety is not coordinated into design should anything less than chaos be expected?

Boeing reports that "factories are more efficient than at any time in history . . . (they) cut final assembly time of 737 in half to 11 days." For 777s, "final assembly line included more than 10,000 parts . . . digital 3-D models in . . . design phase helped reduce the number of changes, errors and rework by more than 50%" (Holmes & Arndt, 2004, p. 33).

According to safety engineers at Ford:

. . . software . . . has already proven to be an invaluable tool for increasing productivity and efficiency. . . [E]ngineers are now able to calculate head-impact targets—a process that used to take them a full week—in just 30 minutes. . . Ford expects . . . video analysis and validation software . . . can deliver significant cost savings to safety engineering programs by minimizing improper test setup . . . reducing . . . overall number of tests that need to be run (MTS Systems Corp., 2003).

Knowledge & Methodology Needs

Why aren't SH&E personnel involved in design? Lack of technical and software knowledge may be a factor—one that may cause engineers to not want their involvement. Because technology is driving manufacturing, SH&E staff must improve their value by becoming immersed in the design stage. A modicum of technical and design software knowledge is needed to function online and communicate with engineers. Those who wish to continue their careers in safety should consider changing their approach to the goal of safe and healthful workplaces, and recognize that it cannot be accomplished unless retrofitting is essentially eliminated by incorporating safety into design.

This need for involvement with engineers and designers becomes more apparent after reviewing an editorial which indicated that consideration must be given to the turnover of process designers in industry—and to the resulting loss of expertise on the process as designed (Speedy, 2004). This holds true for process engineering as well as for other engineering and maintenance functions.

The editorial continued, "We cannot continue to communicate in the same old way. New people are listening, with a new set of skills and expectations. We have to find new ways to convey our expertise" (Speedy, 2004, p. 16). These words are applicable to the safety field as well. They require that one be cognizant of the loss of engineering expertise when working with designers and engineers.

Process plant engineering jobs are draining away with some plants having only an engineering manager.

Fewer engineers are required due to productivity improvements enabled by automation and information technology. . . . *The impact to the plant is that only what absolutely needs to be done gets done.* . . . There is an extreme focus on cost reduction all the way around. . . . Plants no longer shut down for regular maintenance. Instead they run for years at a time as maintenance problems pile up and the *plant runs more and more inefficiently* (emphasis added) (Merritt, 2004, p. 32).

Readers most likely have observed or heard these concerns expressed, especially in recent major loss cases. Attention must be paid to minimizing maintenance requirements during design. This requires that substantial efforts be directed to recognizing hazards and performing risk assessments to reach an acceptable level of risk (ALOR).

For example, SH&E personnel must help designers realize that thousands of maintenance tasks are performed each year in individual facilities. They can serve as the bridge between maintenance personnel and engineers/designers by sharing information about the difficulties encountered in maintaining equipment, processes and facilities in a manner that will cause engineers to design with these factors in mind (Main, Cloutier, Manuele et al., 2003).

SH&E personnel must have foresight to move safety upstream, must have a positive impact and must embed safety in the design. This requires that they take the following actions:

- Develop methods to ensure a substantive interface with engineers and designers.
- Encourage engineering managers to seek design software that includes safety features, or to take advantage of opportunities to incorporate specific safety data, requirements and information in software used by the engineering group.



SH&E personnel should consider changing their approach to the goal of safe workplaces and should recognize that it cannot be accomplished unless retrofitting is essentially eliminated.

- Ensure that hazard analysis and risk assessment procedures are used to reach an ALOR.

- Involve multiple stakeholders in developing measurable design safety objectives such as usability with acceptable risk (UARs) (Christensen, 2003, p. 32).

Although the author is not advocating that SH&E practitioners become engineers, in order to work with engineers, some technical and design software knowledge would be valuable. (It should be noted that some knowledge requirements may be decreased since software advances have reduced the amount of technical information needed.)

In the past, many SH&E professionals had problems reading project blueprints. Transferring designs from the drafting table to computers did little to change that. However, thanks to the move from 2-D to 3-D design software and many other innovations, it is now easier to envision on-screen what designers are portraying. Still, one must recognize that engineers are not trained or educated in hazard recognition and risk assessment. Therefore, capable SH&E personnel must teach engineers or help them evaluate the simulation of the worker performing tasks, and ensure that hazards are identified and assessed, and that an ALOR is achieved.

Procurement orders and design contracts also must have a comprehensive indication of the design safety requirements. Outsourcing is another reason for safety's early involvement in the design process. Despite the fact that the Association for Manufacturing Technologies reports that outsourcing may be replaced by "in-sourcing" as manufacturing makes its biggest comeback in 25 years (IMTS), engineering outsourcing will be significant. Giving contracts to engineers with no background in safety may produce a wide-ranging need for retrofitting, cause missed deadlines and lead to unacceptable levels of risk, particularly if safety is not incorporated in the design objectives, specifications and checklists. ANSI/AIHA Z10 includes sections on procurement and contractors (5.1.3 and 5.1.4).

Since retrofitting is costly and difficult, a question must be asked: Will retrofitting be completed or will unacceptable levels of risk be tolerated?

Positive Factors for SH&E Practitioners

- Design software provides greater opportunity to incorporate safety into design because it permits design data toolboxes, history of changes and significant specifications to be integrated into programs and carried from one design to another modification or model.

- Virtual engineering in 3-D eases technical requirements to participate online, increasing the opportunity for nonengineers to be included in the design process, no matter where in the world the designing is being done. In addition, animation permits visualization of workers performing tasks, which can help in identifying hazards, ergonomic issues and risk concerns during design.

- A growing number of U.S. and overseas standards and laws require hazard analysis and risk

assessment, making these design-stage functions critical. Examples include ANSI/AIHA Z10; B11 Machine Tool standards; Z244.1-2003, Control of Hazardous Energy (see Section 4: Design); and PMMI 155.1, Safety Requirements for Packaging Machinery and Packaging-Related Converting Machinery.

- Architects consider whole building design, recognizing that all systems are interdependent. As Autodesk software notes:

As owners, you are aware . . . decisions made during the design phase . . . often impact the building throughout its lifecycle. Architectural initial design through . . . construction and maintenance . . . can embed intelligence . . . so . . . structures know . . . things as HVAC ducts cannot interfere with them . . . a waste of time and money associated with reworking . . . (Autodesk, 2003).

Practitioners must expand their knowledge base in ways that will contribute to organization needs. This includes understanding the software used by their company or by outsourced designers and engineers. AutoCAD, Autodesk, CATIA, DELMIA, ProEngineer and SolidWorks are just a few of the many software programs available. The best approach is to identify those programs used, then check the developers' websites, which typically offer many opportunities to gain insight into the specific software. An SH&E professional need not be an expert, but simply knowledgeable enough to carry on a conversation with engineers and designers.

Being Proactive in Safety through Design

Participants in developing design objectives for a patient treatment center had a surprising realization concerning their task. Nurses, doctors and facility managers were teamed with designers, architects, social scientists and engineers. During the process, the organization realized "we are designing for human experiences, not buildings" (Nussbaum, 2004, p. 86). This emphasizes clearly the importance of selecting a cross-section of talent to establish UARs (measurable objectives) in the design objectives phase (Christensen, 2003, p. 32).

SH&E practitioners cannot sit next to designers and engineers all the time. If engineers and designers are able to embed safety in the design, based on knowledge, checklists and a toolbox, meeting design objectives and conducting design reviews will be much easier. (Note: Objectives is a term frequently used interchangeably with goals. Whichever term is used, it is important that they be measurable and meaningful, something more than an easily attained number such as 10% improvement is needed. Rather, an objective should focus on the elimination of a problem or a condition—for example, noise levels from equipment, process, facility or operation are maintained below 82 dB.)

The Center for Automotive Research conducted the study, "Best Practices in the Automotive Industry," and issued a report which stresses throughout that:

. . . some of the most important factors for future success revolve around collaboration and communication within and between organizations. While these two factors are not surprising, they are not inherently part of the psyche of automotive manufacturers, or at least haven't been (Rowe, 2005).

This likely applies to many other sectors of business and industry as well. Therefore, SH&E personnel must pay attention and have a greater involvement with designers and engineers to achieve operations with an acceptable level of risk.

SH&E practitioners can contribute to a company even before the design phase of a project. By sharing information with engineers and enhancing personal technical knowledge, greater value should be perceived. Following are nine thoughts for moving in that direction.

1) Help engineers develop knowledge of safety. This is not inherent in their education or experience, and it is a concern compounded by the fact that design software makes it easier for less-qualified individuals to perform. Engineers and designers must understand safety concerns, terminology and concepts, and must know how to apply the safety hierarchy. They must also understand that zero injuries is the objective, and that zero risk is not attainable.

2) Develop a system to ensure that all engineers and designers (including contractors) in the organization performing similar functions can recognize hazards, perform risk assessments and identify hazard-mitigation techniques. Types of safety knowledge may vary with the design group, so one should verify that all have accumulated the perceived safety knowledge for their functions. Various online training/knowledge acquisition resources are available to help SH&E personnel develop media resources for engineers/designers; these include the American Society for Training and Development (www.astd.org); the Hammond Communications Group (www.hammondcg.com); Computer Graphics magazine (www.cgw.com); and eLearn Magazine (www.elearnmag.org).

3) Provide guidance concerning company requirements for safety—not just policy and procedures, but details of standards to be used in designs. It is not enough to require compliance with OSHA, ANSI, ASTM or company standards. Such standards often reflect only minimal requirements and compliance with them may not achieve desired levels of safety. For example, compliance with ANSI 14.3 (fixed ladders) would meet OSHA requirements, but will that result in the level of safety desired? Where tools and equipment are frequently carried up the ladder, it is necessary to decide whether ladder safety devices are required rather than cages or whether alternating stair ladders with handrails would provide a greater degree of safety on heights below ANSI 14.3 requirements.

Many safety items that should be standardized in the operation can be incorporated into engineering software toolboxes (such as alternating stairs, ladder

safety devices, and eyewash and shower equipment). In addition, a system is needed to ensure that engineers and designers receive information about changes in safety standards, including the impact on future designs and consideration of design and contractual requirements of ANSI/AIHA Z10.

4) Provide engineers with incident-cause data based on root-cause incident investigations and analysis from the company's actual incidents, near-hits, product cases or complaints. Saying that an operation has a "large number" of slips and falls does not contribute to prevention, since location and other root-cause data are not indicated, nor is it known whether the falls resulted from factors such as materials or liquids in the work space or aisle; elevations or equipment; or incidents outside the building.

5) Prepare design checklists specifically for engineers/designers and ensure that these tools relate to prevention in the design phase. They should not be merely a compilation of checklists currently used for operational inspections. Working with engineers/designers using a freshly drafted design checklist may proceed more effectively if a specific project is considered when the list is used the first time. Experience indicates that in ensuing discussions, engineers can see the value of items on the list.

6) Encourage management involvement. This means more than simply allotting money or introducing a policy that may be perceived as "flavor of the month." Widespread demonstration of management interest and involvement, especially with engineers and designers, should be expected. A trickle-down approach lacks assurance that all parties observe such demonstrations. SH&E personnel must recognize that management attitude and involvement may improve as a result of the safety staff's support, work and actions, not by demanding attention or policies making safety a priority.

7) Identify future action potential by determining what SH&E colleagues inside or outside the company/facility would identify as problems that should be addressed if they were to be involved in design of a new process, equipment, product or facility. Useful insights may be gained from their personal experience.

8) Enable and support teamwork. Several software platforms (such as CoCreate and Adobe Acrobat 3-D) permit collaboration among multiple users looking at the same drawings, at the same



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By sharing information with engineers and enhancing personal technical knowledge, SH&E personnel can increase their perceived value to their organizations.

time, perhaps hundreds of miles apart.

9) Become familiar with software analytical functions such as CFD, FEA, simulation and animation that are used extensively to design, and analyze or revise designs. These systems aid materially in reducing design time and are ushering in a new world where design, manufacture and repair will be completed in the virtual world before the facility, equipment or process is built, or product is made. (For additional details on key factors in instituting a safety through design program see Christensen, 2003 and Christensen and Manuele, 1999.)

Conclusion

Industry has been slow to recognize and require consideration of safety through design. In addition, management has focused primarily

on reducing time to market and increasing profits. Industry has not demanded incorporation of safety features into design software. Until this occurs, software companies will not voluntarily incorporate such information.

Given these trends, safe work environments will not result unless retrofitting is eliminated. SH&E professionals would do well to recognize this need and avoid a potential impact on their careers. Many activities can help enhance the standing of SH&E practitioners with engineers and designers.

SH&E personnel must provide engineers and designers with education and various tools. To be most effective, SH&E professionals must expand their technical and software knowledge. As Bahrain Petroleum's Tadayon advised, SH&E professionals "should not wait to be asked but be there with answers, be creative . . . know and understand the company's needs" (Smith, 2004, p. 16). Darryl Hill (2002) says it another way: "Safety has operated under an outdated set of principles for too long. The warning signs are clear, the current issues have been defined, now the transformation must begin to ensure future prosperity."

SH&E professionals must develop stature and credibility; must be innovative and proactive in making safety through design a way of life; and must contribute to corporate objectives and a safe work environment. As GE's Immelt said, "You have to change . . . or else you don't have a great future." Sound advice worth remembering in the continuing efforts to eliminate retrofitting. ■

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