Session 653

The Future of the Safety Engineering Profession in the United States

John W. Mroszczyk, Ph.D., P.E., CSP
Northeast Consulting Engineers, Inc.
Danvers, MA 01923

Introduction

The field of *safety* is difficult to define. The *safety profession* has grown to include health, fire protection, insurance, management, systems, law enforcement, environmental, legal, industrial hygiene, engineering, disease control, and well as other functions. Safety professionals come from many different backgrounds.

The term *safety engineer* is even more difficult to define since it is frequently used to describe many safety functions that may or may not involve engineering. Many safety professionals use the title of *safety engineer* even though they may not have any engineering training. The majority of the membership of the American Society of Safety Engineers (ASSE) are not engineers. There is also discussion within the engineering community. Are all engineers “safety engineers”? Is *safety engineering* a separate engineering discipline? What are the educational and licensure requirements for safety engineers?

While the definition of *safety*, *safety professional* and *safety engineer* may be unclear, it is clear that the safety engineering profession has the knowledge, skill, experience, and insight to reduce hazards in almost every facet of the society. Safety engineers can be effective in reducing or eliminating workplace injuries, fatalities, and disease. The same safety engineering principles can be applied to consumer safety as well.

The Safety Professional

Safety is a multi-disciplinary field requiring a broad knowledge in areas such as the physical, chemical, biological, and behavioral sciences, mathematics, and engineering. *Safety professionals* come from a wide variety of undergraduate/graduate degree programs such as biology, chemistry, management, psychology, occupational safety and health, and engineering. The Board of Certified Safety Professionals (BCSP) defines a *safety professional* as:

“A safety professional is a person engaged in the prevention of accidents, incidents, and events that harm people, property, or the environment. They use qualitative and quantitative analysis of simple and complex products, systems, operations, and activities to identify hazards. They evaluate the hazards to identify what events can occur and the likelihood of occurrence, severity of results, risk (a combination of probability and severity), and cost. They identify what controls are appropriate and their cost and effectiveness. Safety professionals make recommendations to managers, designers, employers, government agencies, and others. Controls may involve administrative controls (such as plans, policies, procedures, training, etc.) and engineering controls (such as safety features and systems, fail-safe features, barriers, and other forms of protection). Safety professionals may manage and implement controls.

Besides knowledge of a wide range of hazards, controls, and safety assessment methods, safety professionals must have knowledge of physical, chemical, biological and behavioral sciences, mathematics, business, training and educational techniques, engineering concepts, and particular kinds of operations (construction, manufacturing, transportation, etc.)"

The American Society of Safety Engineers (ASSE) safety curriculum guidelines include courses in occupational safety, safety management, training methodologies, industrial hygiene, fire safety, hazardous materials, ergonomics, accident investigation and analysis, and legal aspects, in addition to mathematics and basic sciences. The Accreditation Board for Engineering and Technology (ABET) has accredited programs in safety science, occupational safety and health, safety technology, and safety management. There are no licensure requirements for becoming a s*afety professional*. The predominant certification is the Certified Safety Professional (CSP) offered by the Board of Certified Safety Professionals (BCSP).

The Safety Engineer

A *safety engineer* is different from a *safety professional*. First, to be an *engineer*, one must have an engineering degree. A typical engineering curriculum includes courses in mathematics, basic sciences, engineering sciences, and engineering design. Engineering sciences have their basis in mathematics and basic sciences but are oriented towards practical and creative applications. The National Society of Professional Engineers (NSPE, 2001) defines *engineer* as,

"The engineer applies knowledge of the mathematical and natural sciences gained by study, experience, and practice to develop ways to economically utilize the materials and forces of nature for the benefit of mankind

The NCEES Model Law (NCEES, 2003) defines an *engineer* as follows,

"A person who is qualified to practice engineering by reason of special knowledge and use of the mathematical, physical, and engineering sciences and the principles and methods of engineering analysis and design, acquired by engineering education and engineering experience.

One difference between safety professionals and engineers is that engineers are trained in design. The Accreditation Board for Engineering and Technology (ABET, 2007) defines *engineering* design as,

> "Engineering design is the process of devising a system, component, or process to meet desired needs. It is a decision-making process (often iterative), in which the basic sciences, mathematics, and the engineering sciences are applied to convert resources optimally to meet these stated needs

A *licensed professional engineer* (PE) differs from an *engineer*. A PE has achieved a level of competency by first earning a four-year degree in engineering from an accredited university, passing a Fundamentals of Engineering exam, completing four years of engineering experience under the direction of a PE, and passing a Principles and Practice of Engineering Exam. Only a licensed engineer may prepare, sign, seal, and submit engineering plans and drawings to a public authority for approval, interpret building codes and other state and federal regulations related to safety, or seal engineering work for public and private clients. Safety professionals are not allowed to do this work. Most if not all state boards of registration include the words "shall hold paramount the safety, health and welfare of the public in the performance of their professional duties" in their codes of professional conduct for licensed professional engineers.

Not all engineers are required to be licensed. There are exemptions for engineers working in private industry or the government. Licensure exemptions present a real dilemma for engineers. Other licensed professionals such as medical doctors, lawyers, and nurses cannot practice unless they are licensed by their respective boards, regardless of where they work. In the engineering profession, generally speaking, it is only consulting engineers and engineers in private practice that seek licensure.

There is considerable discussion on what it means to be a *safety engineer* (Haight, et al, 2005). Safety engineering has been defined as the application of scientific and engineering principles to the elimination of hazards (Brauer, 1990). Safety engineering, like safety, is multi-disciplinary. Safety engineers must have a knowledge of safety <u>and</u> the engineering disciplines.

Most if not all engineering societies include the word "safety" in their code of ethics. For example, the American Institute of Chemical Engineers (AIChE, 2003) require that their members,

> "Hold paramount the safety, health and welfare of the public and protect the environment in performance of their professional duties

The Institute of Electrical and Electronics Engineers (IEEE, 2006) code of ethics requires their members to,

> "accept responsibility in making decisions consistent with the safety, health and welfare of the public, and to disclose promptly factors that might endanger the public or the environment

One of the fundamental canons adopted by the American Society of Mechanical Engineers (ASME, 2006) is, "Engineers shall hold paramount the safety, health and welfare of the public in the performance of their professional duties

The American Society of Civil Engineers (ASCE) includes as one of their fundamental canons,

"Engineers shall hold paramount the safety, health and welfare of the public and shall strive to comply with the principles of sustainable development in the performance of their professional duties

The National Society of Professional Engineers (NSPE) also includes in their code of ethics,

"Hold paramount the safety, health, and welfare of the public

Regardless of whether an engineer is licensed, all engineers must be knowledgeable in safety in order to conduct their professional duties. Like mathematics, all engineers must have a knowledge of safety. In this sense all engineers are "safety engineers". Under this view, safety engineering is not a separate, culturally distinct engineering discipline. It cuts horizontally across all engineering disciplines. It is a sub-field within the engineering field.

If safety engineering is to be thought of as a separate discipline there has to be a safety engineering curriculum. ABET accredited engineering curricula include mechanical, civil, electrical, mining, industrial, petroleum, ocean, manufacturing, and materials. Currently, there are no ABET accredited engineering curricula in safety engineering.

Besides educational disciplines there are also licensure disciplines. The National Council of Examiners for Engineering and Surveying (NCEES) administers licensure examinations in engineering throughout the United States. Examinations include mechanical, civil, electrical, mining, industrial, petroleum, fire protection, environmental, nuclear engineering, and others. The NCEES will not offer a specialty examination unless there is at least one accredited program in that specialty. The NCEES currently does not offer a specialty examination in safety engineering.

The road to establishing an ABET accredited safety engineering curriculum and an NCEES specialty licensure exam is a long one. However, a separate designation of *safety engineer* can be achieved under the current engineering licensure framework using the licensure/post-licensure certification model (Boykin, 2007). Under this model an engineer would obtain a PE license under the current system, then seek post-licensure certification in safety. The BCSP currently offers certification in safety. A licensed engineer that has a BCSP certification could have the designation of "safety engineer".

Design for Safety

Safety engineers have known that the most effective way to prevent injuries and fatalities in the workplace is to address hazards in the design phase rather than attempting to manage hazards after the fact. The exact origins of design interventions in preventing injuries and fatalities is not known. Gallagher (1991) cites several sources from 1907 and 1926 that mention the concept of controlling hazards through engineering means. This approach to safety has more recently been known under several names: Design for Safety (DFS), Safety Through design, or Safety in Design.

The first step in any design is to put forward a preliminary design. The Design for Safety process (DFS) begins with an assessment of the hazards and the associated risks. This includes an analysis of the potential failure modes taking into account foreseeable use, foreseeable misuse, the environment, the capabilities and known behaviors of the user, human error, installation, assembly, maintenance, lack of maintenance, degradation over time, and quality issues. Once the hazards have been identified, the Design for Safety (DFS) methodology is then applied in the order of precedence as listed below. For some situations a combination may apply.

1. Design out the hazard or reduce the risk to an acceptable level
2. Incorporate safety devices
3. Provide warning devices
4. Institute administrative procedures such as training and/or operating procedures
5. Personal protective equipment

Hazard control or elimination by designing out the hazard or incorporating safety devices should always take precedence. Behavioral remedies should maintain their proper place in the hierarchy of controls.

Examples of eliminating a hazard by engineering design include using a ramp rather than a single step, using an irregular bolt pattern so that a critical bracket cannot be installed upside down, and making components of a child's toy large enough so that they are not a choking hazard. If a design alternative does not eliminate the hazard or provide adequate risk reduction, then a safety device should be considered. Examples of safety devices include "dead man" controls on lawnmowers and snow throwers, guards on table saws, and light beam obstruction detection sensors on automatic garage door openers.

In some cases it is not possible to achieve adequate risk reduction by a design change or by providing a suitable safety device. Under these circumstances warnings and/or written instructions should be provided. A warning can be either audible or visual. An example of an audible alarm would be a backup alarm on a construction vehicle. A "WATCH YOUR STEP" sign is an example of a visual warning. A warning should never be used in place of an alternative design or safety device. Administrative procedures such as training and/or special operating procedures should be implemented when warnings are not suitable. For example, forklift drivers need to be trained in the proper use of a fork lift truck. Lockout/tagout is an example of a special operation procedure generally used when equipment is being serviced.

Design for Safety in the Workplace

Several examples of how design interventions can influence safety in the workplace are shown in Exhibit 1 through 3. Exhibit 1 shows a photo of a plastic grinding machine. The access panel on this machine (the open cover) is interlocked so that the machine cannot be started if the operator has opened the panel to clear a jam or clean the machine. Access panels and guards should be interlocked. Exhibit 2 shows a loader equipped with a rollover protection structure (ROPS). ROPS is a roll bar cage surrounding the operator. When used with a seat belt, the ROPS system will prevent an operator from being thrown and crushed if the loader overturns. Exhibit 3 shows guardrails along the open side of a mezzanine. Guardrails will prevent fall injuries when workers or maintenance personnel have to go to the mezzanine to retrieve merchandise, equipment, or perform maintenance.

Exhibit 1. This photo shows an example of a machine interlock. The access panel is electrically interlocked so that the machine cannot be started when the panel is opened.

Exhibit 2. This photo shows a loader equipped with a rollover protection structure (ROPS).

Design for Safety in Construction

Construction is one of the most dangerous occupations. In the United States the number of construction fatalities is disproportionate to the size of the workforce. Construction makes up only 5.5% of the workforce, but has 21.5% of the fatalities. There are 1226 fatalities each year and 200,000 serious injuries. That's about 100 workers killed every month. For every worker killed there are about 160 workers injured (BLS, 2006). Some studies have shown that a fairly large percentage of construction accidents could have been eliminated, reduced, or avoided by making better choices in the design and planning stages of a project (Hecker, 2005). Addressing construction safety in the design and planning phase, therefore, can have a substantial impact on injuries and fatalities as well as the cost associated with safety related project delays.

Designing for construction safety (DfCS) is an application of DFS methods to construction projects. DfCS goes against the "traditional" approach to a construction project where safety is managed after the project is underway, long after the design professional has completed the plans and specifications. With this new approach to construction the designer's role is extended to include construction site safety, constructability, and maintenance in the design phase. DfCS will provide new opportunities for safety engineers and design professionals to apply their skills to reduce construction injuries and fatalities.

Exhibit 3. This photo shows guardrails along a mezzanine. Guardrails prevent fall injuries when working near open side floors or platforms.

The DfCS approach can best be described with several examples. The use of fall protection systems is not within the scope of DfCS. Where DfCS would come into play is to influence design decisions that could eliminate or significantly reduce the need for fall protection systems during construction and maintenance. Design specifications locating HVAC equipment on the ground or away from a roof edge would be a better choice no specification at all. The absence of such a design detail leaves it to the discretion of the install. Placing HVAC equipment close to a roof edge could lead to a fall injury or fatality if proper fall protection is not used during construction or maintenance.

Another example is the design of parapet walls. Building codes require that parapet walls be at least 30 inches high (IBC, 2003). If a designer chooses to specify the minimum 30 inch height, fall protection would be required during construction and maintenance because 30 inch high walls do not meet the guardrail height requirements under OSHA 1926. Workers would be subjected to a fall hazard if proper the fall protection measured are not taken. The designer can meet both the building code and OSHA requirements if a 42 inch high wall is specified. Then the risk of a worker falling because fall protection was not implemented, was not used, or was not used properly is eliminated.

Several examples are shown in Exhibit 4 and 5. Any work that can be done on the ground then lifted into place is a better design choice than doing the work at elevation worker could fall. Exhibit 4 shows a set of pre-fabricated stairs. In this case not only is work at elevation reduced, pre-fabricated stairs with railings that are installed early in a project preclude the need for ladders and temporary guardrails for other workers on the site. Exhibit 5 shows permanent roof anchorage points. By designing fixed, structurally sound anchors workers will have convenient tie-offs during construction and future maintenance.

Exhibit 4. This photo shows a set of pre-fabricated stairs. Pre-fabrication of building components reduces the number of work tasks that must be performed above the ground. Pre-fabricated stairs with railings installed early in a project preclude the need for ladders and temporary guardrails.

Consumer Safety

Outside the workplace there is the world of the ordinary consumer. Consumer safety is important for at least three reasons. First, every year thousands of consumers (men, women, and children) and are injured or killed by defective products. Others may be injured or killed in retail establishments. Deaths, injuries, and property damage related to defective products cost the United States $700 billion annually (CPSC, 2007). Second, consumer safety fits into a broader view that non-work related hazards play an important part in lost time and worker safety and health (Shulte 2006).Third, it would be strange logic that the skills of safety engineers should stop with the workplace. It only makes sense that the same safety engineering and DFS principles be applied to consumer products, retail establishments, public places, playgrounds, recreational areas, and other areas.

Exhibit 5. This photo shows permanent roof anchorage points. By designing fixed, structurally sound anchorage point workers will have convenient tie-offs during construction and future maintenance.

The U.S. Consumer Product Safety Commission is the federal regulatory agency that is charged with protecting the public from risks of serious injury or death from consumer products. The CPSC has jurisdiction over a number of products such as toys, cribs, power tools, cigarette lighters, household chemicals, automatic-drip coffee makers, and lawnmowers. The CPSC works with industry to develop voluntary standards, issues mandatory standards, bans products in some cases, issues recalls for defective products, and conducts research on potential product hazards.

The National Highway Traffic Safety Administration (NHTSA) was established by the Highway Safety Act of 1970. NHTSA has jurisdiction over ground based vehicles such as cars, trucks, bicycles, and motorcycles, and, accessories such as child car seats. Like its consumer product counterpart, NHTSA writes standards for vehicles and vehicle components, receives consumer complaints, and has the authority to recall vehicles if there is a defect. The Federal Motor Vehicle Safety Standards are issued by NHTSA. These standards include but are not limited to motorcycle helmets, fuel system integrity, school bus rollover protection, tires, occupant crash protection, and seat belts.

Both the CPSC and NHSTA play important roles in reducing injuries and property damage resulting from vehicles, vehicle related components, and consumer products. However, voluntary standards and government regulations take time, sometimes years, to implement. The result is that consumer hazards are too often managed after the fact through recalls and other policy procedures.

Consumer safety therefore provides another opportunity for safety engineers to apply their skills to reduce consumer injuries and fatalities by designing out hazards before the product reaches the shelves (Mroszczyk, 2003). Toggle or rocker powered window switches are dangerous when children are left unattended in a car, even briefly, with the key “on” or in “accessory” and the window is down. A child can be strangled by standing or leaning on the switch to look out the window. Exhibit 6 shows an automotive pull-up/push-down power window switch which significantly reduces the likelihood of this happening. Exhibit 7 shows a typical merchandise display found in many retail stores. The display hooks are dangerous because the pointed end can cause eye or facial injuries. Safety loops or guarded hooks should be used.

Exhibit 6.This photo shows an automotive pull-up/push-down power window switch.

Summary

The discussion regarding safety engineering as a separate, distinct engineering discipline will go on. What is clear, however, is that the responsibility to consider safety applies to all engineers, licensed and unlicensed. Professional engineers in particular are bound to protect the health, safety, and welfare of the public. All engineers, therefore, must be knowledgeable in safety engineering, just as all engineers must be knowledgeable in mathematics and engineering analysis. In this sense, all engineers are “safety engineers”.

Engineering is a learned profession. Like other learned professions, medicine and law, professional engineers (PE) are bound by professional ethics requiring high standards of honesty, integrity and fairness. To keep up with the ever expanding body of knowledge, engineers should obtain continuing education. ASSE and other professional safety organizations are in the best position to provide continuing education courses in safety engineering to train or update practicing engineers.

The safety engineering profession has the knowledge, skill, experience, and insight to make a significant impact on injuries, illnesses, and fatalities resulting from work and non-work related hazards by applying Design for Safety (DFS) principles. DFS principles can be implemented to reduce injuries and fatalities in the workplace including construction. The same principles can be applied to consumer products as well.

Exhibit 7. This photo shows a typical merchandise display used in many retail stores. The display hooks are dangerous because the pointed end can cause eye or facial injuries. Safety loops or guarded hooks should be used.

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