Safety Engineering

The future of the profession in the U.S.

By John Mroszczyk

Abstract: *Safety engineering has been defined as the application of scientific and engineering principles and methods to the elimination of hazards. In the U.S., there has been some debate regarding the practice of safety engineering, particularly regarding whether it is a distinct engineering discipline, the differences between a safety engineer and a safety professional, and the educational requirements for becoming a safety engineer. This article examines these issues and looks at new opportunities in the future.*

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THE FIELD OF SAFETY is difficult to define. The safety profession has grown to include health, fire protection, insurance, behavior, management, systems, law enforcement, environmental, legal, industrial hygiene, engineering, disease control and other functions. Safety professionals come from many different backgrounds.

Considerable discussion has surrounded what it means to be a safety engineer (Haight, Brauer, Stickle, et al., 2005). The term *safety engineer* is also difficult to define because it is frequently used to describe many safety functions that may or may not involve engineering. Safety engineering has also been defined as the application of scientific and engineering principles to the elimination of hazards (Brauer, 1990).

Many safety professionals use the title of safety engineer even though they may not have engineering training. Some within the engineering community also debate whether all engineers are safety engineers and whether safety engineering is a separate engineering discipline. Educational and licensure requirements for safety engineers are also a topic of much discussion.

While the definition of safety, safety professional and safety engineer may be unclear, it is clear that the safety engineering profession has the knowledge, skills, experience and insight to advance a national/global strategy to control hazards both inside and outside the workplace through engineering design.

NIOSH has a national Prevention Through Design (PtD) initiative aimed at reducing/eliminating workplace injuries, fatalities and disease. In addition, the OSHA Alliance Program has been working on Design for Construction Safety, an initiative to reduce construction injuries and fatalities through engineering design. The same safety engineering principles being promoted by these efforts can be applied to consumer safety as well.

The Safety Professional

Safety is a multidisciplinary field requiring 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 and graduate degree programs, including biology, chemistry, management, psychology, occupational safety and health, and engineering. However, a large percentage of safety professionals are not engineers nor do they have engineering training. [Editor's note: About 1,250 of ASSE's 30,000 members report that they have a P.E. license.]

Board of Certified Safety Professionals (BCSP, 2008) defines a safety professional as:

> . . . 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.).

ASSE's (2006) 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. ABET (2007) has accredited programs in safety science, occupational safety and health, safety technology and safety management. Currently, there are no licensure requirements for becoming a safety professional, and the predominant certification in the field is the CSP offered by BCSP.

The fundamental canons of engineering practice indicate that engineers have an inherent responsibility and focus on safety.

The Safety Engineer

A safety engineer is different from a safety professional. While a safety professional may not have engineering training, 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 toward practical and creative applications. The National Society of Professional Engineers (NSPE, 2001) defines engineer as follows:

> 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 National Council of Examiners for Engineering and Surveying (NCEES) Model Law (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.

Another difference between safety professionals and engineers is that engineers are trained in design. ABET (2007) defines engineering design as follows:

> 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 (P.E.) differs from an engineer. A P.E. has achieved a level of competency by first earning a 4-year degree in engineering from an accredited university, passing a fundamentals of engineering exam, completing 4 years of engineering experience under the direction of a P.E., 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 perform this work. Therefore, P.E.s have an inherent responsibility and focus on safety.

Most 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 P.E.s.

Not all engineers are required to be licensed. There are exemptions for engineers working in private industry or the government. Such exemptions create a paradox. 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, however, only consulting engineers and engineers in private practice generally seek licensure.

However, even unlicensed engineers have a responsibility to consider safety when performing their professional duties. Most engineering societies include the word *safety* in their code of ethics. For example, American Institute of Chemical Engineers (AIChE, 2003) requires that its members "hold paramount the safety, health and welfare of the public and protect the environment in performance of their professional duties."

Institute of Electrical and Electronics Engineers' (IEEE, 2006) code of ethics requires its 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 fundamental canon adopted by 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."

One fundamental canon of American Society of Civil Engineers (ASCE, 2006) states, "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." In its code of ethics, NSPE requires its members to "hold paramount the safety, health and welfare of the public."

Like safety, safety engineering is multidisciplinary, but in several respects. Safety engineers must be knowledgeable not only in safety, but also in the engineering disciplines. The fundamental canons of engineering practice indicate that engineers have an inherent responsibility and focus on safety, whether licensed or not.

Like mathematics, safety is a core engineering subject. In this sense, all engineers are "safety" engineers. Under this view, safety engineering is not a separate, culturally distinct engineering discipline. Instead, it cuts horizontally across all engineering disciplines. It is a subfield within the engineering field.

If safety engineering is to be thought of as a separate discipline, there must be a safety engineering curriculum. ABET-accredited engineering programs include mechanical, civil, electrical, mining, industrial, petroleum, ocean, manufacturing and materials. There is not one in safety engineering. The accreditation process cannot even begin until curriculum criteria are established for a safety engineering degree. ABET procedures also require that a professional society serve as the lead organization for the proposed specialty field. No professional society has yet taken on this responsibility (Brauer, 2000).

Once the curriculum has been developed, a college or university would have to be convinced that there is enough student interest to offer the classes (Haight, 2005).

Besides educational disciplines there are also licensure disciplines. NCEES administers licensure examinations in engineering throughout the U.S. Examinations include mechanical, civil, electrical, mining, industrial, petroleum, fire protection, environmental, nuclear engineering and others. NCEES will not offer a specialty examination unless there is at least one accredited program in that specialty. Thus, 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 P.E. license under the current system, then seek post-licensure certification in safety. BCSP currently offers certification in safety. A P.E. who has a BCSP certification could then be designated a safety engineer.

Design for Safety

As illustrated by the well-known hierarchy of controls, 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 them after the fact. The origins of this concept are 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 and safety in design.

The first step in any design is to create a preliminary design. The DFS process begins with an assessment of hazards and their associated risks. This includes an analysis of the potential failure modes, taking into account intended use, foreseeable misuse, the environment, the capabilities and known behaviors of users, human error, installation, assembly, maintenance, lack of maintenance, degradation over time and quality issues.

Once hazards are identified, the DFS methodology is applied in the following order of precedence:

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) Provide PPE.

Hazard control or elimination by designing out the hazard or incorporating safety devices should always take precedence, while behavioral remedies should maintain their proper place in the hierarchy of controls. However, this hierarchy is not always followed by industry or by engineers. Instead, warnings, administrative procedures, training and the use of PPE are often relied on rather than eliminating the hazard by engineering design.

In practice, warnings, administrative procedures, training and the use of PPE are often relied on rather than eliminating the hazard by engineering design.

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 pose no 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 doors.

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. However, 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 must be trained in the proper use of the equipment. Lockout/tagout is an example of a special operating procedure generally used when equipment is being serviced.

Designing for Safety Around the Globe

The DFS concept has been known and applied in many industries in the U.S. and around the world. What has been lacking is an alignment and harmonization of DFS within the U.S. and globally. The U.S. currently lags behind the European Union, the U.K. and Australia in efforts to reduce occupational injuries and fatalities by engineering design.

For example, in 1994, the U.K. codified the Construction Design and Management Regulations. These regulations define the role of designers in addressing construction worker safety and health. The Australian government has concluded that design-related issues were involved in 40% of incidents in mining, transportation, agriculture, construction, trade and manu-

Photo 1 (above): An example of a machine interlock. The access panel is electrically interlocked so that the machine cannot be started when the panel is opened.

Photo 3 (above): Guardrails along a mezzanine. Guardrails prevent fall injuries when working near open-sided floors or platforms.

Photo 5 (below): Spring-loaded totes can reduce back injuries in the retail industry because the bottom adjusts to the amount of clothes in the tote. Workers do not have to bend over and reach in when removing clothes.

Photo 4 (left): Patient lifting devices can reduce back injuries in the healthcare industry.

Photo 2: A loader equipped with a rollover protection structure (ROPS).

facturing. The government is working to integrate safe design principles into all projects and products from the planning onward (Driscoll, Harrison, Bradley, et al., 2005). The 2002-12 National OHS Strategy endorsed by Australia's Workplace Relations Ministers Council includes the elimination of hazards in the design stage.

Prevention Through Design

The two major DFS initiatives being pursued in the U.S. will require the skills of safety engineers—engineers trained to identify hazards, assess the risk, then apply their design skills to reduce or eliminate the risk. NIOSH's 7-year PtD initiative is focused on preventing and controlling occupational injuries, illnesses and fatalities by addressing hazards early in the design process. The PtD concept is defined as follows:

> Addressing occupational safety and health needs in the design process to prevent or minimize the work-related hazards and risks associated with the construction, manufacture, use, maintenance and disposal of facilities, materials and equipment.

NIOSH has partnered with AIHA, ASSE, Center to Protect Workers' Rights, Kaiser Permanente, Liberty Mutual, National Safety Council (NSC), OSHA, ORC Worldwide and the Regenstrief Center for Healthcare Engineering. The initiative is structured along eight key workplace sectors—agriculture/forestry/fishing, mining, construction, manufacturing, wholesale/retail, transportation/warehousing/utilities, services and healthcare/social assistance—and four functional areas—research, education, practice and policy.

The research functional area will learn what

DFS Suggestions for the Workplace

Suggestion 1: Interlock machine guards and machine access panels (McConnell, 2004).
Purpose: Machine guards and panels must be in place for machine to run. Machine cannot be started if worker has removed a guard or panel during maintenance.

Suggestion 2: Patient lift devices (NIOSH, 2003).
Purpose: Prevents back injuries because healthcare professionals do not have to manually lift patients.

Suggestion 3: Coated chain mining conveyor (NIOSH, 2008).
Purpose: Reduces noise levels.

Suggestion 4: Rack-netting for warehouse racks (Mroszczyk, 2002).
Purpose: Prevents injuries from falling merchandise.

Suggestion 5: Design conveyor system (Cal/OSHA, 2007).
Purpose: Eliminates the need for manual handling.

Suggestion 6: Design a vacuum lifter for lifting large boxes (Cal/OSHA, 2007).
Purpose: Eliminate the need to manually lift large containers.

Suggestion 7: Design shaft guards for exposed rotating shafts (NSC, 1993).
Purpose: Eliminates chance of employee getting a body part or clothing caught in rotating shaft.

Suggestion 8: Install surveillance mirrors and closed-circuit cameras (NIOSH, 2006).
Purpose: Reduces chance of a workplace violence incident.

Suggestion 9: Install guardrail along open-sided floors (Hagan, et al., 2001b).
Purpose: Eliminates risk of a worker falling over the edge.

Suggestion 10: Install barrier guards at machine nip points (Hagan, et al., 2001b).
Purpose: Eliminates risk of an amputation injury from reaching into machine.

works best. It will also assess knowledge gaps and barriers. The education area will work to inform business, professional schools, engineers, architects, textbook authors and licensure/certification. The practice area will develop tools, procedures, resources and implementation plans. The overall goal is to institutionalize PtD in business, government and other organizations.

Photos 1 through 5 provide several examples of how design interventions can influence safety in the workplace. Photo 1 shows a plastic grinding machine. An operator could be exposed to the moving parts of the machine if s/he forgets to turn the machine off before opening the cover to clear a jam. It is also foreseeable that someone could start the machine while the operator is working on it. The DFS solution is to interlock the access panel (the open cover) so that the machine will not operate if the panel is open.

Photo 2 shows a loader equipped with a rollover protection structure (ROPS). A loader could tip over on a construction site for various reasons. The DFS solution is to provide a roll bar cage surrounding the operator. When used with a seatbelt, the ROPS system will prevent an operator from being thrown and crushed if the loader overturns.

Photo 3 shows guardrails along the open side of a mezzanine. Fall injuries can occur if workers inadvertently step off or fall from the open side. Guardrails will prevent fall injuries when workers or maintenance personnel must go to the mezzanine to retrieve merchandise or equipment, or perform maintenance.

Many back injuries occur in the healthcare industry as a result of the manual lifting of patients. The DFS solution is to provide mechanical assist devices (Photo 4). Back injuries can also occur in the retail industry from bending over to remove clothing or other articles from the bottom of totes. Photo 5 shows a DFS solution. Spring-loaded totes can reduce back injuries because the bottom adjusts upward depending on the amount of clothes in the tote. Workers need not bend over and reach in when removing clothes. The sidebar at left lists several other design suggestions for the workplace. It should be noted that while the suggestions can achieve the stated purpose, various factors in a given situation could render them less effective.

Design for Construction Safety

Construction is one of the most dangerous occupations in the U.S. The number of construction fatalities is disproportionate to the size of the workforce. Construction makes up only 5.5% of the workforce, yet experiences 21.5% of the fatalities. There are 1,226 fatalities and 200,000 serious injuries each year (BLS, 2006). That's about 100 workers killed and more than 16,000 injuries every month.

Some studies have shown that a fairly large percentage of construction accidents could have been prevented, reduced or avoided by making better choices in the design and planning stages of a project (Hecker, Gambatese & Weinstein, 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. This is another area where the skills of the safety engineer can be applied to reduce construction injuries and fatalities.

In October 2004, the OSHA Alliance Program formed a workgroup to develop and promote ways that designers could influence construction injuries and fatalities. The workgroup consisted of representatives from the ASCE Construction Institute, ASSE, Independent Electrical Contractors, International Association of Foundation Drilling, Laborers Health and Safety Fund of North America, Mason Contractors Association of America, NFPA, NIOSH, Sealant, Waterproofing and Restoration Institute, and Washington Group International. Designing for Construction Safety (DfCS) was one of the ideas put forward as a way to reduce construction injuries and fatalities.

The workgroup has since met more than a dozen times and has developed several work products. These products include a general DfCS presentation, a 2- to 4-hour DfCS course for design professionals and a case study. Members of the workgroup have given presentations at conferences sponsored by ASSE, NSC and Voluntary Protection Programs Participants Association. An OSHA 10-hour course for design professionals is also being developed.

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. Under DfCS, the designer's role is extended to include construction site safety, constructability and maintenance. It is anticipated that DfCS will provide new opportunities for safety engineers to apply their design skills to reduce construction injuries and fatalities.

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.

For example, design specifications locating HVAC equipment away from a roof edge would be a better choice than close to the edge or no specification at all. Installing equipment close to a roof edge could lead to a fall injury or fatality if fall protection is not used during construction or maintenance.

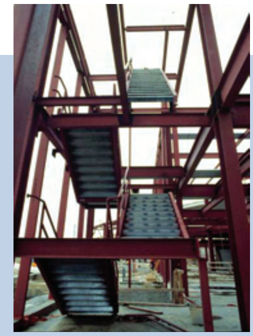

Photo 6: A set of prefabricated stairs. Prefabrication of building components reduces the number of work tasks that must be performed above the ground. Prefabricated stairs with railings installed early in a project preclude the need for ladders and temporary guardrails.

Photo 7: Permanent roof anchorage points. By designing fixed, structurally sound anchorage point workers will have convenient tie-offs during construction and future maintenance.

Another example is the design of parapet walls. Building codes require that parapet walls be at least 30 in. high (ICC, 2003). If a designer specifies the minimum 30-in. height, fall protection would be required during construction and maintenance because 30-in.-high walls do not meet the guardrail height requirements under OSHA 1926. Workers would be subjected to a fall hazard if proper fall protection measures were not taken. However, the designer can meet both building code and OSHA requirements if a 42-in.-high wall is specified. This eliminates the risk of a worker falling due to fall protection not being provided, used or used improperly.

Photos 6 and 7 (p. 37) provide additional examples of how design features can be implemented to eliminate or reduce the likelihood of fall injuries. Photo 6 shows a set of prefabricated stairs. These reduce work at elevation. Furthermore, prefabricated stairs with railing that are installed early in a project eliminate the need for ladders and temporary guardrails for other workers on the site.

Photo 7 shows permanent roof anchorage points. By designing fixed, structurally sound anchors, workers will have convenient tie-offs during construction and future maintenance. Another example is permanent guards over skylights, which provide protection when working on the roof. A concrete segmented bridge is an example of how prefabricating and lifting building systems into place can reduce fall injuries by reducing the time spent at elevation. The sidebar below lists other DfCS suggestions. Again, while the suggestions can achieve the intended purpose, various factors in a given situation could render them less effective.

DFS Suggestions for Construction

Suggestion 1: Design prefab units that can be built on the ground and erected in place (CDM, 2004).
Purpose: Reduce worker exposure to falls and being struck by falling objects.

Suggestion 2: Allow adequate clearance between structure and power lines (Behm, 2005).
Purpose: Overhead power lines are hazardous when operating cranes.

Suggestion 3: Design 42-in. parapet walls (Behm, 2005).
Purpose: Eliminate need for fall protection.

Suggestion 4: Design permanent anchorage points (Weinstein, Gambatese & Hecker, 2005).
Purpose: Provide fall protection anchorage during construction and future maintenance.

Suggestion 5: Specify primers, sealers and other coatings that do not emit noxious vapors (Weinstein, 2005).
Purpose: Reduce noxious vapors.

Suggestion 6: Design permanent anchorage points for residential roofs (Behm, 2005).
Purpose: Provide fall protection anchorage for roofing contractors during future maintenance.

Suggestion 7: Design cable type lifeline system for tower structures (Behm, 2005).
Purpose: Allows workers to hook onto the structure and move up and down during future maintenance.

Suggestion 8: Design window sills to be 42 in. above floor (Gambatese, Behm & Hinze, 2005).
Purpose: Eliminate need for fall protection during construction and future maintenance.

Suggestion 9: Design permanent guardrails around skylights (Behm, 2005).
Purpose: Prevent workers from falling through skylights.

Suggestion 10: Walkable ceiling above clean room (Hecker, et al., 2005).
Purpose: Provides access to mechanical equipment withoutrequiring fall protection.

Design for Consumer Safety

Outside the workplace is the world of the ordinary consumer. Consumer safety is important for at least three reasons. First, every year thousands of consumers 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 U.S. $700 billion annually (CPSC, 2007).

Second, consumer safety fits into a broader view that non-work-related hazards are another factor in worker lost time, safety and health (Schulte, 2006). Third, it would be strange logic to believe that the skills of safety engineers should stop at the workplace doors. 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.

Consumer Product Safety Commission (CPSC) is the federal regulatory agency charged with protecting the public from risks of serious injury or death from consumer products. CPSC has jurisdiction over many products, including toys, cribs, power tools, cigarette lighters, household chemicals, automatic-drip coffeemakers and lawnmowers. The agency 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.

National Highway Traffic Safety Administration (NHTSA) has jurisdiction over ground-based vehicles such as cars, trucks, bicycles and motorcycles, as well as accessories such as child car safety 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. NHTSA also issues the Federal Motor Vehicle Safety Standards, which cover motorcycle helmets, fuel system integrity, school bus rollover protection, tires, occupant crash protection and seatbelts.

Both 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

Photo 8: 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.

Photo 9: A single step presents a subtle change in elevation that is not easily recognized. A warning cone can help provide some visual cue to patrons.

Photo 10: Toggle or rocker-powered car window switches can pose a hazard to children left unattended in a car. The pull-up/push-down switch pictured here significantly reduces this hazard.

years—to implement. The result is that consumer hazards are too often managed after the fact through recalls and other policy procedures.

Therefore, consumer safety provides another opportunity for safety engineers to apply their skills to reduce injuries and fatalities by designing out hazards before the product reaches the shelves (Mroszczyk, 2003). Photos 8 through 11 show several examples of how safety engineers can influence consumer safety using DFS principles. Photo 8 shows a merchandise display with display hooks. These hooks are dangerous because the sharp-pointed ends can cause eye or facial injuries (Hagan, Montgomery & O'Reilly, 2001b). Safety loops or guarded hooks should be used instead.

Photo 9 shows a single step. Single steps are hazardous because the subtle change in elevation is not easily recognized. This hazard is usually compounded by the absence of visual cues. The DFS solution would be to use a ramp or a full set of stairs. When this is not possible, prominent handrails, step lights, contrasting colors, contrasting textures and warning signs should be used (Cote & Harrington, 2006).

Toggle or rocker-powered window switches can pose a hazard when children are left unattended in a car, even briefly, with the key in the ignition in the *on* or *accessory* position and the window down. A child can be strangled by standing or leaning on the switch to look out the window. An automotive pull-up/push-down power window switch found in many modern cars (Photo 10) significantly reduces the likelihood of this happening.

Garage doors powered by automatic openers present an entrapment hazard if a person is in the line of the door as it is closing. Children have been reported to play a dangerous game in which they activate the door then run under it as it is closing (CPSC, 1985). A DFS solution would be a noncontact obstruction detection device. Photo 11 (p. 40) shows an automatic garage door operator infrared beam sensor. An object under the leading edge of a down-

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Photo 11: An automatic garage door operator infrared beam sensor. An object under the leading edge of a downward traveling door will break the beam and reverse the door. This system prevents entrapment injuries and fatalities.

ward-travelling door will break the beam and reverse the door. This system prevents entrapment injuries and fatalities, particularly with young children, by sensing the presence of an object without actually contacting the object.

Many children's items and toys are the subject of CPSC recalls because they present choking hazards, even though design specifications have existed since at least 1990 (CPSC, 1990). To better control these hazards, CPSC developed the small parts cylinder test. Children's items and toy parts that extend outside of this cylinder should not pose a choking hazard. The sidebar below lists several other design suggestions for consumer safety. Keep in mind that factors in a given situation could render the design solution less effective.

DFS Suggestions for Consumers

Suggestion 1: Avoid single steps (Cote & Harrington, 2006).
Purpose: Single steps are tripping/fall hazards.

Suggestion 2: Install safety vaccum release system in pools and spas (CPSC, 2005).
Purpose: Reduces likelihood of drowning from pump entrapment by automatically shutting off pump if blockage is detected.

Suggestion 3: Design merchandise displays that are at least 3 ft high. (Hagan, et al., 2001b).
Purpose: Avoid tripping/fall hazard.

Suggestion 4: Use spotters when forklift trucks operate on sales floor (Mroszczyk, 2002).
Purpose: Consumers are kept out of the travel path of the forklift truck.

Suggestion 5: Shift interlock for vehicles (NHTSA, 2008).
Purpose: Driver must step on brake to move shifter out of park. Prevents inadvertent shift into drive.

Suggestion 6: Design handrails for stairways (Cote & Harrington, 2006).
Purpose: Provides support and a means to arrest a fall.

Suggestion 7: Design pull-up/push-down switches for powered windows in cars (NHTSA, 2008).
Purpose: Eliminates power window strangulation if child stands or leans on window control switch.

Suggestion 8: Design toys and children's articles to comply with CPSC small parts cylinder test (CPSC, 1990).
Purpose: Eliminates choking hazard.

Suggestion 9: "Dead-man" blade control for power lawnmowers (CPSC, 1988).
Purpose: Prevents blade from operating unless operator is at controls.

Suggestion 10: Design consumer products that do not have sharp protrusions, corners or edge (Woodson, Tillman & Tillman, 1992).
Purpose: Eliminates puncture and laceration injuries.

Conclusion

The debate regarding safety engineering as a separate, distinct engineering discipline will continue. What is clear, however, is that the responsibility to consider safety applies to all engineers, licensed and unlicensed. In this sense, all engineers are safety engineers. In the interim, the safety engineering profession could move forward under the present educational and licensure structure using the licensure/postlicensure certification model. Under this model a licensed engineer could obtain a separate designation as a safety engineer by obtaining a post-licensure BCSP certification.

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 DFS principles.

Much work remains to be done in moving a national DFS agenda forward. First, there must be a fundamental shift in how engineers approach hazard mitigation. DFS principles must be uniformly applied in the workplace, in construction and in the consumer world. U.S. colleges and universities need to include safety training in engineering curriculum. Standards and regulations must be developed, and building codes must include provisions for considering the safety of construction workers.

The first step in standardizing the DFS process has already been taken in the form of several interim guidelines for addressing occupational risks using DFS principles (Manuele, 2008). The time is right. The growing interest in this concept will require professionals trained and focused on safety and design—namely, safety engineers.

The long history of designing out hazards can now be aligned with two major national initiatives in the U.S.—NIOSH's PTD and OSHA Alliance Program's DfCS. The same effort can also be extended to consumer safety. The harmonization between the U.S. and global efforts could help strengthen and standardize approaches to hazard control in a global economy. ■

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