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Risk Reduction Strategies

Past, present and future

By Roger C. Jensen

SEVERAL RESPECTED AUTHORS have proposed short lists of all strategies for controlling hazards or reducing risks from hazards. This article reviews those attempts and proposes an improved list of nine risk reduction strategies.

Why should the safety profession want a list of risk reduction strategies? The first and most obvious reason is to help identify options for addressing recognized hazards. This is a fundamental step taken by design teams following a systematic risk assessment methodology. The four processes in risk assessment are: identify hazards; assess risks; reduce risks; and document the results (Main, 2004). Much has been written about how a design team can effectively perform the first, second and fourth processes (Bahr, 1997; Main, 2004; Manuele, 2005; Piampiano & Rizzo, 2006). But when it comes to the third process—reducing risks—most authors and standards limit advice to telling the design team to follow a hierarchy of controls (Bahr, 1997; Main, 2004; Manuele, 2005). Hierarchy lists consist of three to six general approaches to hazard control (Manuele, 2005). Design teams could benefit from more-specific options. Strategies fill the gap between the broad approaches found in hierarchies of control and the more concrete applications or tactics.

A second reason for having a list of risk reduction strategies is to contribute to the evolving development of a scientific foundation for the practice of safety. William Haddon Jr. (1973a), a great innovator in the injury control movement, wrote of the value of classification for a scientific field, "An important landmark is reached in the evolution of a scientific field when classification of its subject matter is based on relevant, fundamental processes involved rather than on descriptions of the appearances of the phenomenon of interest."

Haddon was an advocate for elevating safety from a technology to a scientific field. He recognized that classification of fundamental processes is an essential part of all scientific fields. He proposed a comprehensive list of risk reduction strategies based on fundamental processes in order to help elevate safety from its origins as a rule-based technology to its future as a science-based profession.

Previous Hazard Control Strategies

Haddon proposed a set of 10 strategies for reducing damage of all kinds. His original set was based on an energy transfer model (Haddon, 1973a, 1973b). He later extended his thinking beyond that model (Haddon, 1980). This generic set of 10 strategies was intended to encompass all of the various strategies for preventing injury, mitigating the damage from injurious events, and rehabilitating or restoring the damaged person or thing. His strategies encompass a broad concept of injury, including personal injury caused by traumatic events, damage to health through long-term exposures and harm to the environment:

1) Prevent the creation of the hazard in the first place.

2) Reduce the amount of the hazard brought into being.

3) Prevent the release of a hazard that already exists.

4) Modify the rate or spatial distribution of the hazard from its source.

5) Separate in time or in space the hazard and that which is to be protected.

6) Separate the hazard and that which is to be protected by interposition of a material barrier.

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7) Modify relevant basic qualities of the hazard.

8) Make that to be protected more resistant to damage from the hazard.

9) Begin to counter the damage done by the environment.

10) Stabilize, repair and rehabilitate the object of the damage (Haddon, 1973a, 1973b).

Other respected authors have proposed different strategy lists, shown in the sidebar at right ("Previously Proposed"). Johnson (1975) developed a list of strategies for the Management Oversight and Risk Tree methodology. Like Haddon's original list, it was founded on the energy transfer model. Manuele (2003) critically examined the earlier lists and proposed a list of nine strategies. His emphasis was on the process of designing systems for safety. Asfahl (2004) provided a similar list of engineering design principles to reduce or eliminate industrial hazards.

The strategies provided by these authors share many concepts, but differences are also evident. To reconcile the differences, the various sources of hazards need clarification.

Previously Proposed Hazard Control Strategies

After Haddon, several respected authors have proposed different hazard control strategy lists.

Johnson (1975)

1) Limit energy.
2) Substitute a safer energy form.
3) Prevent energy buildup.
4) Prevent release of energy.
5) Provide for slow release of energy.
6) Channel energy release away.
7) Have barriers on the energy source.
8) Have barriers between energy source and persons or objects to be protected.
9) Have barriers on human objects.
10) Raise the injury or damage threshold.
11) Ameliorate once the energy is released.
12) Rehabilitate.

From "The Management Oversight and Risk Tree," by W.G. Johnson, 1975, Journal of Safety Research, *7(1), pp. 4-15.*

Asfahl (2004)

1) Eliminate the process or cause of the hazard.
2) Substitute an alternate process or material.
3) Guard personnel from exposure to the hazard.
4) Install barriers to keep personnel out of the area.
5) Warn personnel with visible or audible alarms.
6) Use warning labels to inform/remind personnel of a hazard.
7) Use filters to remove exposure to hazardous effluents.
8) Design exhaust ventilation systems to deal with process effluents.
9) Consider the human interface.

From Industrial Safety and Health Management *(pp. 57-58), by C.R. Asfahl, 2004, Upper Saddle River, NJ: Pearson Prentice Hall.*

Manuele (2003)

1) Avoid introduction of the hazard.
2) Limit the amount of energy or hazardous material.
3) Substitute, using the less hazardous.
4) Prevent unwanted energy or hazardous material buildup.
5) Prevent unwanted energy of hazardous material release.
6) Slow down the release of energy or hazardous material.
7) Separate in space or time, or both, the release of energy or hazardous materials from that which is exposed to harm.
8) Interpose barriers to protect the people, property or the environment exposed to an unwanted energy or hazardous material release.
9) Modify the shock-concentrating surfaces.

From On the Practice of Safety *(pp. 311-313), by F.A. Manuele, 2003, Hoboken, NJ: John Wiley & Sons.*

Hazards

Lists of hazards by other authors were consulted and compared (Bahr, 1997, pp. 235-238; Hoes, 2001). The result of this analysis was the following list of hazard sources.

- conditions;
- energies;
- chemicals;
- inherent properties;
- musculoskeletal stressors;
- biologic agents;
- weather events;
- geologic events;
- outrageous conduct;
- compromised hazard controls.

Most of these are self-explanatory, but some deserve comment. The "musculoskeletal stressors" category contains those hazards associated with manual labor that have potential to overstress a person's anatomy. Some authors refer to these as ergonomic hazards. The "inherent properties" category refers to things that have utility because of an essential property which makes it hazardous (e.g., sharp teeth of a saw blade, dynamite, automobiles). For items with inherent hazards, the strategy to eliminate the hazard is impractical because it would make the product useless.

The "outrageous conduct" category comes from a term from workers' compensation law defined as "conduct so extreme that it exceeds reasonable bounds of human decency" (Garner & Black, 1999). It captures rare, but very dangerous situations created when, for example, terrorists hijack an airplane, armed robbers hold up a bank or an inebriated worker attempts to operate a crane. Weather events and geologic events are included to capture infrequent, high-energy events such as tornadoes and earthquakes.

The "compromised hazard controls" category includes those dangers that arise when a normally effective control is compromised. Some examples include continuing to use an extension cord with damaged insulation, using equipment with an inoperable safety device or not following a safety-critical procedure. Some hazards could logically be categorized into more than one of these types of hazard sources.

Safety professionals can easily recognize that such a range of hazards requires a corresponding variety of hazard controls. Specific hazard control tactics are so diverse and numerous that it would be overwhelming to attempt to list them. But strategies are broader and less numerous. The attempts by the cited authors have demonstrated the feasibility of developing meaningful categories for strategies. The following proposal is an attempt to build on the strengths of their lists and fill in gaps where appropriate.

Abstract: *In 1973, Haddon proposed a list of 10 strategies for preventing and mitigating hazards of all kinds. This article reviews subsequent refinements and alternate proposals. It also proposes a new list consisting of one strategy for eliminating the hazard and eight for mitigating risks associated with the hazard. Each strategy is illustrated by several examples. The nine risk reduction strategies are shown to fit logically into a three-level hierarchy of controls that could be used by design teams employing a risk assessment process.*

Table 1

Relationships among Proposed & Previous Strategy Lists

This table shows how the proposed nine strategies encompass those of from Haddon, Johnson, Asfahl and Manuele.

Proposed strategies	Haddon[a]	Johnson[b]	Asfahl[c]	Manuele[d]
1) Eliminate the hazard	1	---	1	1
2) Moderate the hazard	2, 7	1, 2, 3	2	2, 3, 4, 9
3) Avoid releasing the hazard	3	4	---	5
4) Modify release of the hazard	4	5, 6	7, 8	6
5) Separate the hazard from that which needs to be protected	5, 6	7, 8	3, 4	7, 8
6) Help people perform safely	---	---	5, 6, 9	---
7) Use PPE	6	9	---	8
8) Improve the resistance of that which needs to be protected	8	10	---	---
9) Expedite recovery	9, 10	11, 12	---	---

[a]*From "The Basic Strategies for Reducing Damage from Hazards of All Kinds," by W.J. Haddon, 1980,* Hazard Prevention, 16*(5), pp. 8-12.* [b]*From "The Management Oversight and Risk Tree," by W.G. Johnson, 1975,* Journal of Safety Research, *7(1), pp. 4-15.* [c]*From* Industrial Safety and Health Management *(pp. 57-58), by C.R. Asfahl, 2004, Upper Saddle River, NJ: Pearson Prentice Hall.* [d]*From* On the Practice of Safety *(pp. 311-313), by F.A. Manuele, 2003, Hoboken, NJ: John Wiley & Sons.*

Proposed Risk Reduction Strategies

The author has developed a list of nine strategies for reducing one or more of the three components of risk (probability of a harmful incident; foreseeable severity of harm from an incident or exposure; and level of exposure to a health hazard). Table 1 indicates how the nine strategies encompass those from Haddon (1980), Johnson (1975), Asfahl (2004) and Manuele (2003). Tactical examples of each strategy are provided to clarify the meaning and illustrate the range of applications. The proposed strategies are as follows:

1) Eliminate the hazard.
2) Moderate the hazard.
3) Avoid releasing the hazard.
4) Modify release of the hazard.
5) Separate the hazard from that which needs to be protected.
6) Help people perform safely.
7) Use PPE.
8) Improve the resistance of that which needs to be protected.
9) Expedite recovery.

Examples of Each Strategy

Two or three examples of each strategy are provided. The tactical examples are described by presenting information in the following order: 1) a concise description of the hazard and situation; 2) that which needs protection; and 3) the actual tactic. Additional examples are given in the sidebars on pages 27-29). The tactics presented are common applications described in numerous books (e.g., Asfahl, 2004; Hammer & Price, 2001; National Safety Council, 1997).

In reading these examples, understand that specific tactics are not meant to be the complete approach for reducing risks for the hazard. Often, to effectively control a given hazard requires multiple tactics. For example, a room containing some amount of flammable vapor may use multiple tactics such as room ventilation to maintain the concentration below the flammable range, rules to avoid ignition sources, air monitors to detect whether the concentration rises above an acceptable level, and an automated fire suppression system.

1) Eliminate the Hazard

This strategy captures all tactics that avoid creating a hazard in the first place or that eliminate an existing hazard. Eliminating an existing hazard can be a permanent fix with 100% reliability, or it may be a solution that removes the hazard nearly all of the time, but lacks 100% reliability.

Example 1. The hazard is gravitational energy while working on top of a tank car setting up the feed hose for filling. The person is at risk of falling. To avoid creating the hazard, replace top-loading tank cars with bottom-loading tank cars.

Example 2. The hazard is musculoskeletal stress from manually lifting a patient from a wheelchair to a chair on a weight scale. The person doing the lifting is at risk. To avoid creating the hazard, obtain a scale with a larger platform and ramp to enable weighing the patient while in the wheelchair.

2) Moderate the Hazard

This strategy applies to tactics that do something to the hazard in order to reduce its intensity, energy level, amount, concentration or inherent properties. Tactics that reduce a hazard by substituting something less hazardous are in this strategy.

Example 1. The hazard is heat emitted from an industrial furnace into an occupied room. Personnel in the room are exposed to heat stress. To avoid heat buildup, install local ventilation to draw away much of the hot air.

Example 2. Force required to handle a tool is concentrated on a small skin surface area. The tool user is at risk of damaging the nerves between skin and bone. The tactic is to change the sharp edges of the tool that contact the skin to gently rounded edges which will distribute the forces over a larger skin surface.

3) Avoid Releasing the Hazard

This strategy includes tactics used routinely to work safely with common energy and chemical hazards such as electricity, gravity, moving objects, fire and flammable materials.

Example 1. The hazard is unstable dirt walls of a trench in which someone must work. The worker is at risk of being buried by dirt if the wall collapses. The

wall can be prevented from releasing by installing proper shoring.

Example 2. The hazard is contact with electricity during equipment maintenance. The maintenance person is at risk. The electrical energy can be prevented from releasing by following a lockout procedure before starting the work.

4) Modify Release of the Hazard

This strategy is for dealing with a hazard that could be or has been released. The tactics modify the released hazard to avoid or reduce harmful effects. The examples illustrate the three mechanisms for implementing this strategy: 1) control the rate of release; 2) control the spatial distribution of the hazard; and 3) stop the released hazard before it causes significant harm.

Example 1. The hazard is a chemical in a high-pressure container. An increase in pressure could damage the container. A hazard control is a pressure-relief valve on the container.

Example 2. The hazard is the gravitational energy of old roof material being thrown from the roof to a truck bed below. The truck and personnel nearby need protection. The tactic is to provide a chute with a large opening at the top to channel materials into the smaller opening at the truck bed. This illustrates controlling the spatial distribution of the material.

Example 3. The hazard is using an electrically powered drill. The worker needs protection from electric shock in the event of a short circuit in the drill. A common control is to install a ground fault circuit interrupter (GFCI) in the circuit. If the current leaks through the short, the GFCI will cause the circuit to open, thereby protecting the worker from a harmful level of current.

5) Separate the Hazard from That which Needs to Be Protected

This strategy consists of the many common tactics that separate the hazard source from that which needs protection. Mechanisms for separation can be by distance, location or barrier. Tactics include employing barriers either around the hazard source (e.g., a machine guard) or between the hazard source and that which needs protection. (Barriers worn by a person are in Strategy 7.) Examples for this strategy illustrate separation by distance, location and barrier, respectively.

Example 1. The hazard is mechanical crushing force at the point of operation of a positive-clutch mechanical power press. The press operator needs protection. One engineering control is to provide two-hand actuator buttons to ensure that the operator's hands are a safe distance away when the stroke is tripped.

Example 2. The hazard is an in-running nip point at the roller of a conveyor. One way to control this is to install the conveyor so the roller is in a small room unoccupied by personnel. The room has engineering controls such as an interlocked door that stops the conveyor if someone opens the door.

Example 3. The hazard is the outrageous conduct of someone who attempts an armed robbery at a

Strategy 1: Eliminate the hazard.

Example 1. The hazard is carbon monoxide emitted from diesel engines of forklift trucks. Personnel are at risk. To avoid creating the hazard, replace diesel trucks with battery-powered trucks.

Example 2. The hazard is a rectangular floor mat with edges that could trip someone. Pedestrians are at risk of tripping. To avoid the hazardous condition, install a mat that is recessed into the floor to create a flush walking surface with no protrusions.

Strategy 2: Moderate the hazard.

Example 1. The hazard is musculoskeletal stress from manually lifting a load from the floor. The person lifting is at risk of musculoskeletal harm. To limit the amount of musculoskeletal stress, store the load on a shelf or platform so it can be lifted using a biomechanically less-stressful posture.

Example 2. The hazard is gravitational energy of a welder working on the guardrail of a bridge. The welder is exposed. To limit the amount of gravitational energy, install nets under the bridge to reduce the potential distance of a fall as well as the intensity of deceleration forces upon impact.

Example 3. The hazard is flammable vapors in a room. People and property need protection from a fire. To prevent buildup of the flammable vapor concentration, maintain adequate room ventilation to keep the flammable vapor concentration well below the flammable range.

Example 4. The hazard is a stationary object with a sharp edge in an area for pedestrians. Pedestrians are at risk of impact injury. The tactic is to install padding on the stationary object. Another solution would be to change sharp edges to gently rounded edges.

Example 5. The hazard is a slippery floor adjacent to a floor with much higher coefficient of friction. Pedestrians are at risk of slipping when they step from a high- to low-friction surface. A tactic is to etch the more slippery floor to give it similar frictional properties to the adjacent floor.

Strategy 3: Avoid releasing the hazard.

Example 1. The hazard is a potentially flammable atmosphere in a work area. Personnel and property need protection from ignition. To prevent ignition of the hazardous atmosphere, provide only non-sparking tools for work within the area. Ventilating the area to keep the vapor concentration well below the lower flammable limit (Strategy 2) complements this tactic.

Example 2. The hazard is gravitational energy of a hand tool being used by workers on a scaffold. Persons below are at risk if the tool is dropped. The gravitational energy of the hand tool can be prevented from releasing onto the workers below if the workers on the scaffold tether the tool to a guardrail before using it.

Strategy 4: Modify release of the hazard.

Example 1. The hazard is gravitational energy of an elevator. Personnel who use it need protection. Elevators are designed to release their gravitational energy slowly through the use of counterweights and effective brakes.

Example 2. The hazard is a building containing explosive materials. The building needs protection. Controls for preventing an explosion in the first place belong in Strategy 3. A tactic that illustrates Strategy 4 is to design the building so, if an explosion occurs, doors and vents blow open to allow the rapidly expanding gases to disperse in the least harmful directions.

Example 3. The hazard is a fire in one room of a building. Other rooms in the building need protection. The tactic is to construct the building with fire walls separating internal rooms. This will both slow the spread of the fire and limit its spatial distribution.

Strategy 5: Separate the hazard from that which needs to be protected.

Example 1. The hazard is lightning. A wood structure needs protection from being ignited. The hazard control is to install protection that deflects lightning from the structure.

Example 2. The hazard is a moving conveyor located in a place where workers are tempted to cross over. Personnel need protection. One acceptable tactic is to build a pedestrian bridge over the conveyor to keep personnel separated from the hazard. A less-reliable tactic would be to use signs and work rules to direct personnel to always walk around the conveyor.

Example 3. The hazard is a laboratory technician mixing chemicals in a process that emits a nuisance gas. The tactic is to have the technician perform the mixing in a ventilation hood that separates the gas from the technician's breathing zone.

Example 4. The hazard is the point-of-operation of a press brake. A common tactic is to have the operator hold the work so his/her hands are a safe distance from the hazard during the downstroke.

Example 5. The hazard is gravitational energy of a load supported by a crane. Personnel below the load need protection in case the load is dropped. One tactic is to use signs and barriers to make the area underneath the planned load movement a no personnel zone.

Example 6. The hazard is gravitational energy of packaged materials on high shelves in a warehouse where forklifts operate. Forklift operators need protection. The tactic is to install a falling object protective structure on each forklift vehicle.

Example 7. The hazard is electrical energy in a power tool cord. The tool user needs protection. A control is to maintain the insulation on the electrical cord.

Example 8. The hazard is a radiological technician exposed to X-rays. The technician relies on a lead barrier within the wall separating the machine controls from the patient.

Example 9. The hazard is outrageous conduct in which an equipment operator shows up for work while under the influence of a narcotic or alcohol. Other personnel need protection. A recognized tactic is to train supervisors to recognize signs of drug and alcohol use, and a process for keeping the operator off the job while not fit for duty, thereby separating in time and space those who need protection from the outrageous conduct.

casino. The cashier needs protection. A tactic is to provide a bullet-resistant barrier between the cashier and customers.

6) Help People Perform Safely

This strategy consists of all tactics aimed at helping personnel perform their jobs safely. In the human factors literature, these tactics are referred to as facilitators (Peacock & Laux, 2005). Some are grouped under the umbrella of administrative controls, such as establishing standard operating procedures and training employees to perform work according to those procedures. Some are warnings that activate only when needed, such as alarms and flashing lights. Some are warning signs on walls, doors and equipment. Facilitators include designing human/machine interfaces to maximize correct performance and minimize errors, as well as efforts aimed at matching job demands with employee mental and physical capabilities.

Example 1. The hazard is the movement of industrial forklift vehicles in a warehouse. One tactic, involving two parts, is to establish operating rules and provide high-quality training to operators.

Example 2. The hazard is mechanical crushing force at the point of operation of a machine set up for actuation by foot switch. Experience indicates that on occasion employees inadvertently step on the foot switch (Trump & Etherton, 1985). The mistimed activation can destroy the workpiece and injure the operator. A common tactic is to provide a foot pedal with a cover. (See Barnett, 1997 for a discussion of the pros and cons of different foot pedal designs.)

Example 3. The hazard is musculoskeletal stress from sustained assembly work at a workstation that is set up too low for the employee. To see the work, the employee must lean his/her head forward, causing the muscle at the back of the neck (trapezius) to be in constant tension while the muscle is extended. The hazard control tactic is to provide an adjustable-height workbench and to educate the employee on the importance of adjusting it properly.

7) Use PPE

This strategy involves barriers worn by a person to protect him/herself. Common forms are devices for protecting the head, eyes, face, lungs, hands, knees and toes. A surgeon's mask has a different purpose—to protect the patient from microorganisms in the surgeon's breath. Therefore, surgical masks are barriers associated with the source of the hazard, and belong in Strategy 5.

Example 1. The hazard is kinetic energy of small objects falling from overhead. The heads of personnel need protection. A tactic is wearing hardhats.

Example 2. The hazard is a toxic gas that might be released from a storage container while being handled at a disposal site. Personnel need protection. The tactic is to provide each worker with an SCBA, air-supplied respirator or filter respirator for the specific toxic chemical. This example could also include wearing a full-body chemical-impermeable suit.

8) Improve the Resistance of That which Needs to Be Protected

This strategy includes tactics aimed at improving resistance of people, property and the environment to encounters with hazards. This strategy provides the best fit for designing and constructing structures to withstand hazardous weather and geologic events.

Example 1. The hazard is an earthquake. A building or bridge can be designed to be more resistant to earthquake damage.

Example 2. The hazard is the blood of a hospital patient infected with hepatitis B. Nurses and other care providers need protection. The tactic is to vaccinate all employees potentially exposed to patients' blood.

Example 3. The hazard is hot working conditions. Those assigned to work in the area are at risk of a heat disorder. The tactic is to implement an acclimatization program to ensure that workers are fit for such work.

9) Expedite Recovery

Tactics in this strategy involve planning and preparation of actions to take in the event that some harm occurs. The examples are specific instances of common safety functions performed by responsible employers, such as being prepared to promptly administer first aid, get medical care for someone in need and respond to a HazMat spill. Medical moni-

toring for early detection of a developing disease is also part of this strategy.

Example 1. The hazard is a chemical in a tanker truck being transported on a roadway. A wreck could result in spilling the chemical onto the roadway and adjacent soil, with the potential to seep into groundwater. The tactic is to establish, before any such incident, a response plan to ensure prompt cleanup in order to limit severity of harm to the environment.

Example 2. The hazard is musculoskeletal stress from repetitive labor. One tactic for minimizing harm to personnel is to conduct a symptom survey. Individuals reporting significant pain in a body part are referred to a physician. An ergonomist may also examine the workstation to determine whether the pain is related to the job. This tactic aims to identify a potential cumulative trauma disorder in an early stage so changes can be made to facilitate recovery.

Discussion

Classification Issue

While developing the nine strategies, two issues arose that warrant discussion. One involves making structures more resistant to hazards, the other involves PPE use.

Categorizing structural design features under a particular strategy proved complex. Designing a structure to withstand extreme weather events or an earthquake fits most naturally into Strategy 8—improve the resistance of that which needs protection. However, numerous examples are less clear, for example, the dikes that protected New Orleans until damaged by Hurricane Katrina. If the dike is regarded as "that which needs protection," then reinforcing it fits into Strategy 8. However, if the city itself is regarded as "that which needs protection," then the dike is a barrier, and Strategy 5 applies.

Another gray area involves engineered venting of a building in case of an internal explosion. The venting tactic involves controlling release of the hazard (Strategy 4), as well as making the building more resistant to damage (Strategy 8). Similarly, coating structural beams with heat-insulating materials to separate the beams from the hazardous heat of a fire could be regarded as a barrier (Strategy 5) or making the structure more resistant to damage (Strategy 8). As these examples illustrate, some hazard control tactics can fit logically into more than one of the nine strategies.

The PPE issue involved choosing between three options. One option was to classify PPE as a barrier between the hazard and the person (Strategy 5). Both Haddon (1980) and Manuele (2003) consider PPE a barrier strategy. A second option was to regard PPE as a method for increasing the person's capability to resist harm from a hazard (Strategy 8). The third option was to create a separate strategy for PPE. The first and second options can be supported through rational argument, and are not considered wrong. However, the third option was selected in order to make it easier to reconcile the list of risk reduction strategies with the prevailing hierarchies of control,

Strategy 6: Help people perform safely.

Example 1. The hazard is carbon monoxide in an occupied building. The hazard control tactic, consisting of two parts, is to 1) place carbon monoxide detectors in selected areas of the facility; and 2) train personnel to recognize the sound of the alarm and evacuate the area. When carbon monoxide rises above a normal level, an audible alarm activates. Employees who have been trained will have an opportunity to minimize their exposure to the gas.

Example 2. The hazard is rotating gears in a machine. Placing a warning sign on the cover of the opening provides a visual notice not to open the cover unless proper lockout/tagout procedures are followed.

Example 3. The hazard is an extremely low workload for a power plant control room operator during the night shift. The minimal stimulation from the job demands, combined with working through the night, creates an elevated risk of dozing off, making an error of omission or losing situation awareness. A tactic is to assign the operator some stimulating work to perform during the night shift. If more stimulation is needed, allow the operator to periodically walk outside the control room.

Example 4. The hazard is musculoskeletal stress from assembly line work. One type of administrative control, involving three parts, is to 1) conduct a body part discomfort survey at the beginning and end of a shift to uncover possible mismatches between individual workers and their workstations; 2) evaluate the workstations of those who have noticeable increases in discomfort; and 3) make appropriate changes to the workstation or reassign the worker to a more appropriate workstation.

Strategy 7: Use PPE.

Example 1. The hazard is loud noise energy in the workplace. One tactic is to provide those exposed with personal hearing protection.

Strategy 8: Improve the resistance of that which needs to be protected.

Example 1. The hazard is musculoskeletal stress experienced by a construction laborer. One element of some ergonomics programs involves having employees perform stretching activities at the beginning of the shift. It is quite reasonable to hypothesize that stretching activities will improve workers' ability to resist soft-tissue injuries, although studies have neither proved nor disproved efficacy (McGorry & Courtney, 2006).

Example 2. The hazard is extreme forces from waves striking dikes such as those in New Orleans. The hazard may be regarded as the dike structure. The hazard control is to design and construct dikes to withstand forces expected in a Category 5 hurricane.

Example 3. The hazard is a forest fire. The forest environment can be made more resistant to fire spread by thinning out the trees and removing some of the easily flammable materials on the forest floor.

Strategy 9: Expedite recovery.

Example 1. The hazard is workplace exposure to airborne lead. The primary strategy is to limit exposure. A secondary strategy is to implement medical monitoring in order to identify and remove from exposure anyone with a level above an acceptable range.

Example 2. The hazard is the sharp edge of a cutting tool used for a particular task. The worker can lacerate his/her skin. A tactic is to be prepared to render prompt and effective first aid in order to minimize harm.

Example 3. The hazard is a worksite where temperatures are high and where people perform manual labor. One tactic for heat disorders is to maintain capability for prompt treatment. With proper treatment, a case of heat exhaustion will not develop into heat stroke. Similarly, a victim of heat stroke may be saved from coma or death by prompt action.

Figure 1

Nine Strategies Integrated into Three-Level Hierarchy of Control

Priority 1: Control by eliminating the hazard.
- **Strategy 1—Eliminate the hazard.**

Priority 2: Control by designing for effectiveness with minimal human effort.
- **Strategy 2—Moderate the hazard.**
- **Strategy 3—Avoid releasing the hazard.**
- **Strategy 4—Modify release of the hazard.**
- **Strategy 5—Separate the hazard from that which needs to be protected.**

Priority 3: Control through human effort and behavior.
- **Strategy 6—Help people perform safely.**
- **Strategy 7—Use PPE.**
- **Strategy 8—Improve the resistance of that which needs to be protected.**
- **Strategy 9—Expedite recovery.**

which typically list PPE as a separate approach at or near the end of the list. This becomes important to design teams using a risk assessment process.

Contribution to Design Teams

In the course of performing a risk assessment, the process of selecting an appropriate hazard control tactic requires stepping through a hierarchy of controls. Most hierarchy lists are so general that they offer little to spark creative thinking among design team members. The value of strategies to design teams will be enhanced by integrating the strategies into an appropriate hierarchy of controls. A simple, three-level hierarchy is proposed for design teams.

The hierarchy consists of 1) control by eliminating the hazard; 2) control by designing for effectiveness with minimal human effort; and 3) control through human effort and behavior. Figure 1 depicts the integration of the nine strategies into the three-level hierarchy. Within each priority category, the strategies are in no particular order; a design or redesign team should simply consider whichever strategies appear feasible for the particular hazard. The graphic of the three priorities and nine strategies could help a design team not only step through the hierarchies/priorities, but also identify options for reducing risk.

Contribution to the Safety Profession

This article proposes a modification to the risk reduction strategies previously proposed by Haddon, Johnson, Manuele and Asfahl. The list of strategies has several desirable features. First, it applies to a diverse range of hazards as documented by the numerous tactics mentioned. Second, by building on the proposals of previous authors, the list is more complete than the previous lists. Third, the nine strategies can be grouped into three general hazard control approaches that follow a logical order of preference. Fourth, the nine strategies are based on fundamental processes, consisting of one to eliminate the hazard and eight to mitigate the risk. Mitigation strategies involve reducing the probability of the hazard causing harm, reducing the potential severity of the harm or reducing the level of exposure to a health hazard.

Compared to some long-standing professions and scientific fields, the safety profession is less developed. The safety profession is not yet near a point of agreeing on many fundamental concepts and aspects of the practice (Stephans, 2004). Advancing the safety profession requires a continuous improvement philosophy that includes critically examining and clarifying the basic concepts as well as standardizing common methodologies. The ideas presented in this article are offered to contribute to the process of continuously improving the safety profession. ■

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