CHAPTER 12

HIERARCHY OF CONTROLS: THE SAFETY DECISION HIERARCHY—SECTION 5.1.1

INTRODUCTION

Section 5.1.1 of ANSI/AIHA Z10-2005, the Occupational Health and Safety Management Systems Standard, is titled "Hierarchy of Controls." Here is the opening sentence in that section: "The organization shall implement and maintain a process for achieving feasible risk reduction based on the following order of controls." A prescribed hierarchy of controls immediately follows that provision.

The hierarchy presented in the standard is the basis for decision making when applying every section in Z10 that is intended to resolve occupational health and safety issues. Those issues are "defined as hazards, risks, management system deficiencies, and opportunities for improvement." This hierarchy is of such importance that a separate chapter in this book is devoted to it. This chapter will:

- Comment on the evolution of hierarchies of control
- Discuss the hierarchy of controls in Z10
- Provide guidelines on the application of a hierarchy of controls
- Establish the logic of taking steps in the hierarchy of controls in the order given
- Place the hierarchy of controls within good problem-solving techniques, as in The Safety Decision Hierarchy

- Relate Haddon's unwanted energy release concept to the hierarchy of controls
- Provide general design guidelines based on the unwanted energy release concept

EVOLUTION OF THE HIERARCHY OF CONTROLS

The hierarchy of controls in Z10 has six elements. Hierarchies in other published standards and guidelines may have three, four, or five elements. The version in Z10 is the outcome of the work of a large number of safety professionals over many years. All of its contributors cannot be recognized here. A limited review of the evolution of the hierarchy of controls is given, referencing:

- A three-step hierarchy in the National Safety Council's *Accident Prevention Manual*
- A four-step hierarchy in the U.S. government's system safety standard requirements
- Five-step hierarchies in recently issued standards and guidelines
- Six-step hierarchies in this author's writings and in a proposed revision of the U.S. government's system safety standard

AT THE NATIONAL SAFETY COUNCIL

The third edition of the National Safety Council's *Accident Prevention Manual* was published in 1955. Section 4 is titled "Removing the Hazard from the Job". It provides a three-step "order of effectiveness and preference." This is taken from the *Accident Prevention Manual*.

> The engineer should include in his planning and follow-through such measures as will attain one of the accident prevention goals listed as follows (in the order of effectiveness and preference):
>
> 1. Elimination of the hazard from the machine, method, material, or plant structure.
> 2. Guarding or otherwise minimizing the hazard at its source if the hazard cannot be eliminated.
> 3. Guarding the person of the operator through the use of personal protective equipment if the hazard cannot be eliminated or guarded at its source.
>
> Company policies should be such that safety can be designed and built into the job, rather than added after the job has been put into operation.

Establishing the concept that risk reduction actions should be taken in an order of effectiveness and preference was an important step in the evolution of the practice of safety. It implies that some steps in the process are preferable since they achieve greater risk reduction than others. Declaring that safety policies should require that safety be designed and built into the job rather than dealt with as an add-on is also a premise that influenced later versions of hierarchies of control.

MIL-STD-882-1969 and MIL-STD-882D-2000

The Department of Defense's Standard Practice for System Safety, MIL-STD-882, was first issued in 1969. It was a seminal document at that time. Three revisions of 882 have been issued over the span of the past 31 years. This standard has had considerable influence on the development of risk assessment, elimination, and amelioration concepts and methods. Much of the wording on risk assessments and hierarchies of control in safety standards and guidelines issued throughout the world is comparable to that in the various versions of 882.

The fourth edition, issued in February 2000, is designated MIL-STD-882D. It is available at http://www.dau.mil/educdept/mm_dept_resources/guidance/mil-std-882 d.doc and may be downloaded, for free. A "System safety design order of precedence" is outlined in 882D. Precedence means: priority in order, rank or importance. As was the case in previous versions of the standard, the design order of preference contains four elements:

1. Eliminate hazards through design selection
2. Incorporate safety devices
3. Provide warning devices
4. Develop procedures and training

As of this writing, 882D is the applicable document. Work is in progress to produce an extended and superior version. Comments are made later in this chapter on a December 1, 2005, draft designated MIL-STD-882E. It extends the four-step hierarchy to six steps.

ANSI/RIA R15.06-1999

The American National Standard for Industrial Robots and Robot Systems—Safety Requirements, ANSI/RIA B15006-1999, was issued in 1999. Its five-step "hierarchy of safeguarding controls" follows:

1. Elimination or substitution
2. Engineering controls (safeguarding technology)
3. Awareness means
4. Training and procedures (administrative controls)
5. Personal protective equipment

Note that this hierarchy of controls, as does that in Z10, includes substituting less hazardous methods or materials as a means of attaining acceptable risk levels. Also, its provisions are close to those in MIL-STD-882D. Providing personal protection equipment, Step 5 in the preceding hierarchy, is incorporated as an option in Step 4 of 882D. – Develop procedures and training.

ANSI/PMMI B155.1-2006

The Packaging Machinery Manufacturers Institute is the secretariat for the standard *Safety Requirements for Packaging and Packaging-Related Converting Machinery*. A revision of B155.1 was approved by ANSI in July 2006; it replaced the version issued in 2000. In part, this is the guidance given on the use of the "The Hazard Control Hierarchy," a five-step process:

> In selecting the most appropriate protective measures, apply the following principles in the order in which they appear.
>
> 1. Eliminate by design
> 2. Guards and safeguarding devices
> 3. Awareness devices
> 4. Procedures and training
> 5. Personal protective equipment

This hierarchy of controls repeats the elements enumerated within the hierarchies of other standards. Again, they closely resemble the provisions in MIL-STD-882D.

This Author's Writings

In *Innovations in Safety Management: Addressing Career Knowledge Needs*, published in 2003, the following hierarchy of controls was encompassed within The Safety Decision Hierarchy, which is to be discussed later. It may also be found in two articles written by this author: "Risk Assessment and Hierarchies of Control" and "Achieving Risk Reduction, Effectively."

1. Eliminate or reduce risks in the design processes.
2. Reduce risks by substituting less hazardous methods or materials.
3. Incorporate safety devices.
4. Provide warning systems.
5. Apply administrative controls (work methods, training, etc.).
6. Provide personal protective equipment.

Because of my observations with respect to the application of risk reduction methods in which differing levels of effectiveness have been achieved, I chose to separate "substituting less hazardous methods or materials" from the "elimination" step. That was a departure from the structure of hierarchies of control that had been previously published. An example supporting that decision is given in "The Logic of Taking Action in the Descending Order Given," a later section in this chapter. In Z10, the same two provisions are also separated.

December 2005 Draft of MIL-STD-882E

Mention was made previously of the work in progress to replace MIL-STD-882D. Because of the importance of the revisions proposed in the standard's "order of preference," we excerpt material from the draft version of 882E:

> Section 4, General Requirements, in 882E "delineates the minimum mandatory requirements for an acceptable system safety program." Section 4.1.4, as follows, gives the steps to be taken in reducing risk, in an "order of precedence."
>
> 4.1.4 Element 4—risk reduction.
>
> 4.1.4.1 System safety mitigation order of precedence.
>
> In reducing risk, the cost, feasibility, and effectiveness of candidate mitigation methods should be considered. In evaluating mitigation effectiveness, an order of precedence generally applies as follows.
>
> 4.1.4.1.1 Eliminate hazard through design selection.
>
> Ideally, the risk of a hazard should be eliminated. This is often done by selecting a design alternative that removes the hazard altogether.
>
> 4.1.4.1.2 Reduce mishap risk through design alteration.
>
> If the risk of a hazard cannot be eliminated by adopting an alternative design, design changes should be considered that reduce the severity and/or the probability of a harmful outcome.
>
> 4.1.4.1.3 Incorporate engineered safety features (ESF).
>
> If unable to eliminate or adequately mitigate the risk of a hazard through a design alteration, reduce the risk using an ESF that actively interrupts the mishap sequence.
>
> 4.1.4.1.4 Incorporate safety devices.
>
> If unable to eliminate or adequately mitigate the hazard through design or ESFs, reduce mishap risk by using protective safety features or devices.
>
> 4.1.4.1.5 Provide warning devices.
>
> If design selection, ESFs, or safety devices do not adequately mitigate the risk of a hazard, include a detection and warning system to alert personnel to the presence of a hazardous condition or occurrence of a hazardous event.
>
> 4.1.4.1.6 Develop procedures and training.
>
> Where other risk reduction methods cannot adequately mitigate the risk from a hazard, incorporate special procedures and training. Procedures may prescribe the use of personal protective equipment.

The "system safety design order of precedence" in 882D contains four elements: Eliminate hazards through design selection; Incorporate safety devices; Provide warning devices; and Develop procedures and training. Those four steps have been expanded to six in 882E. For each of the first two elements in 882D, two options are given in 882E. This is a significant development, based on the knowledge derived from practical applications of the order of precedence. The descriptive material in 882E for the six elements in the "System safety mitigation order of precedence" is recommended reading.

THE HIERARCHY OF CONTROLS IN Z10

I said in Chapter 1 that although Z10 is a management system standard and not a specification standard, the provisions pertaining to a hierarchy of controls are the exception. Rather than presenting a performance statement that relates to the outcomes to be achieved through a risk reduction process, a specifically defined hierarchy of controls is outlined. This is the hierarchy of controls—the order of controls—in Z10:

A. Elimination
B. Substitution of less hazardous materials, processes, operations, or equipment
C. Engineering controls
D. Warnings
E. Administrative controls
F. Personal protective equipment

Note that this hierarchy of controls contains six elements. The first step, Elimination is separated from the Substitution element. The logic for doing so is discussed later.

HIERARCHIES OF CONTROL: PREMISES AND GOALS

A hierarchy is a system of persons or things ranked one above the other. The hierarchy of controls in Z10 provides a systematic way of thinking, considering steps in a ranked and sequential order, to choose the most effective means of eliminating or reducing hazards and the risks that derive from them. Acknowledging that premise—that risk reduction measures should be considered and taken in a prescribed order—represents an important step in the evolution of the practice of safety.

A model of hierarchies of control may give examples of the types of actions to be taken for each of its elements, as does Appendix G in Z10. However, little is written about the purpose of and the goals to be achieved in applying a hierarchy of controls. An attempt to do so follows.

A major premise to be considered in applying a hierarchy of controls is that the outcome of the actions taken is to be an acceptable risk level, defined as follows:

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

That definition requires taking into consideration the practicable minimization of each of the two distinct aspects of risk as risk reduction actions are decided on:

- Avoiding, eliminating, or reducing the *probability* of a hazards-related incident or exposure occurring
- Reducing the *severity* of harm or damage that may result, if an incident or exposure occurs

Such a definition also requires reflection on the feasibility and effectiveness of the risk reduction measures to be taken, and their costs, in relation to the amount of risk reduction to be achieved. Decision makers should understand that, with respect to the six levels of action shown within the hierarchy of controls in Z10:

- The ameliorating actions described in the first, second, and third levels are more effective because they
  - Are *preventive* actions that eliminate or reduce risk by design, substitution, and engineering measures
  - Rely the least on personnel performance
  - Are less defeatable by supervisors or workers
- Actions described in the fourth, fifth, and sixth levels are *contingent* actions and rely greatly on the performance of personnel.

What Kepner and Tregoe write in *The New Rational Manager* about taking preventive and contingent actions in the problem-solving process fits precisely with the risk elimination and amelioration concepts set forth here:

> Two kinds of actions are available to anyone conducting a Potential Problem Analysis: preventive actions and contingent actions. The effect of preventive actions is to remove, partially or totally, the likely cause of a potential problem. The effectiveness of a contingent action is to reduce the impact of a problem that cannot be prevented. Preventive actions, if they can be taken, are obviously more efficient than contingent actions.

As decisions are made in applying each step within the hierarchy of controls, the following should be considered as goals:

- Avoiding work methods that are overly stressful, taking into consideration worker capabilities and limitations
- Minimizing the probability of human error by assuring that work situations are not error-provocative, meaning that they do not (as in Chapanis's "The Error-Provocative Situation")
  - Violate operator expectations

  - Require performance beyond what an operator can deliver
  - Induce fatigue
  - Provide adequate facilities or information for the operator
  - Present unnecessarily difficult or unpleasant requirements
  - Include unnecessarily dangerous methods
- Designing systems so that human interaction with equipment and processes occurs at a practicable minimum
- Minimizing requirements for the use of personal protective equipment

THE LOGIC OF TAKING ACTION IN THE DESCENDING ORDER GIVEN

Comments follow on each of the action elements listed in Z10's hierarchy of controls, including the rationale for the order given. Taking actions in the prescribed order, as *feasible and practicable*, is the most effective means to achieve risk reduction.

A. Elimination

The use of the term "elimination" as the first step in applying a hierarchy of controls is a bit simplistic. My experience requires that I replace it with "Eliminate or reduce hazards and risks through system design and redesign." The theory is plainly stated. If the hazards are eliminated in the design and redesign processes, risks that derive from those hazards are also eliminated. However, elimination of hazards completely by modifying the design may not always be practicable. Then, the goal is to modify the design, within practicable limits, so that the:

- Probability of personnel making human errors because of design inadequacies is at a minimum
- Ability of personnel to defeat the work system and the work methods prescribed, as designed, is at a minimum

Examples would be designing to eliminate or reduce the risk from:

- Fall hazards
- Ergonomic hazards
- Confined space hazards
- Noise hazards
- Chemical hazards

Obviously, hazard elimination or reduction is the most effective way to remove or reduce risk. If a hazard is eliminated or reduced, the need to rely on worker behavior to avoid risk is diminished.

B. Substitution of Less Hazardous Materials, Processes, Operations, or Equipment Processes

Methods that illustrate substituting less hazardous methods, materials, or processes for that which is more hazardous include:

- Using automated material handling equipment rather than manual material handling
- Providing an automatic feed system to reduce machine hazards
- Using a less hazardous cleaning material
- Reducing speed, force, amperage
- Reducing pressure, temperature
- Replacing an ancient steam-heating system and its boiler explosion hazards with a hot air system

The substitution of a less hazardous method or material may or may not result in equivalent risk reduction in relation to what might occur if the hazards and risks were reduced to a minimum through system design or redesign.

Consider this example. Considerable manual material handling is often necessary in a mixing process for chemicals. A reaction takes place and an employee sustains serious chemical burns. There are identical operations at two of the company's locations. At one, the decision is made to redesign the operation so that it is completely enclosed, automatically fed, and operated by computer from a control panel, thus greatly eliminating operator exposure.

At the other location, funds for doing the same were not available. To reduce the risk, a substitution took place in this manner: It was arranged for the supplier to premix the chemicals before shipment. Some mechanical feed equipment for the chemicals was also installed. The risk reduction achieved by substitution was not equivalent to that attained by redesigning the operation.

C. Engineering Controls

When safety devices are incorporated in the system in the form of engineering controls, substantial risk reduction can be achieved. Engineered safety devices are intended to prevent workers' access to the hazard. They exist to separate hazardous energy from the worker and deter worker error. They include devices such as:

- Machine guards
- Interlock systems
- Circuit breakers
- Start-up alarms
- Presence-sensing devices
- Safety nets
- Ventilation systems

- Sound enclosures
- Fall prevention systems
- Lift tables, conveyors, and balancers

D. Warnings (Warning Systems)

Warning system effectiveness, and the effectiveness of instructions, signs, and warning labels, rely considerably on administrative controls, such as training, drills, the quality of maintenance, and the reactions of people. Furthermore, although vital in many situations, warning systems may be reactionary in that they alert persons only after a hazard's potential is in the process of being realized (e.g., a smoke alarm). Examples include:

- Smoke detectors
- Alarm systems
- Backup alarms
- Chemical detection systems
- Signs
- Alerts in operating procedures or manuals

A comment is necessary on my preferred use of the term "warning systems" over "warnings" or "warning signs." The terms "warnings" and "warning signs" appear in some published hierarchies of control, as is the case in Z10. The entire needs of a warning system must be considered, for which warning signs or warning devices alone may be inadequate.

For example, the National Five Protection Association's Life Safety Code, NFPA 101, may require, among other factors: detectors for smoke and products of combustion; automatic and manual audible and visible alarms; lighted exit signs; designated, alternate, properly lit exit paths; adequate spacing for personnel at the end of the exit path; proper hardware for doors; and emergency power systems. Obviously, much more is needed than merely "warnings."

E. Administrative Controls

Administrative controls rely on the methods chosen being appropriate in relation to the needs, capabilities of people responsible for their delivery and application, quality of supervision, and expected performance of workers. Some administrative controls are:

- Personnel selection
- Developing appropriate work methods and procedures
- Training

- Supervision
- Motivation, behavior modifi
- Work scheduling
- Job rotation
- Scheduled rest periods
- Maintenance
- Management of change
- Investigations
- Inspections

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F. Provide Personal Protecti

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- Safety glasses
- Face shields
- Respirators
- Welding screens
- Safety shoes
- Gloves
- Hearing protection

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- Work scheduling
- Job rotation
- Scheduled rest periods
- Maintenance
- Management of change
- Investigations
- Inspections

Achieving a superior level of effectiveness in all these administrative methods is difficult and not often attained.

F. Provide Personal Protective Equipment

The proper use of personal protective equipment relies on an extensive series of supervisory and personnel actions, such as the identification of the type of equipment needed, its selection, fitting, training, inspection, maintenance, etc. Examples include:

- Safety glasses
- Face shields
- Respirators
- Welding screens
- Safety shoes
- Gloves
- Hearing protection

Although the use of personal protective equipment is common and necessary in many occupational situations, it is the least effective method to deal with hazards and risks. Systems put in place for their use can be defeated easily. In the design process, one of the goals should be to reduce reliance on personal protective equipment to a practical minimum.

For many risk situations, a combination of the risk management methods outlined in the hierarchy of controls is necessary to achieve acceptable risk levels. However, the expectation is that consideration will be given to each of the steps in a descending order, and that reasonable attempts will be made to eliminate or reduce hazards and their associated risks through steps higher in the hierarchy before lower steps are considered. A lower step in the hierarchy of controls is not to be chosen until practical applications of the preceding level or levels are exhausted.

THE SAFETY DECISION HIERARCHY

The following observations are a reflection of my experience—encompassing the design and engineering aspects, operational aspects, and post incident aspects of the practice of safety:

- Safety practitioners often recommend solutions to resolve hazard/risk situations before they define the problem—that is, before they identify the specifics of the hazards and assess the associated risks.
- Rarely are safety management systems in place to determine whether the preventive actions taken achieve the intended risk reduction.

These observations led to research into the feasibility of encompassing the hierarchy of controls within a sound problem-solving technique that:

- Commences with problem identification and analysis.
- Requires measurement of the results of actions taken to determine their effectiveness.
- Takes further preventive measures if the residual risk is not acceptable.

The initial step in my inquiry was to review several texts on problem solving. The problem-solving methods the authors of these texts propose have great similarity. A composite of those techniques follows in Table 1.

TABLE 1 Problem-Solving Methodology

1.	Identify the problem
2.	Analyze the problem
3.	Explore alternative solutions
4.	Select a plan and take action
5.	Examine the effects of the actions taken

In every problem-solving method reviewed, the first steps are to identify and analyze the problem. Also, they end with a provision requiring that evaluations be made of the effects of the actions taken. Figure 1, The Safety Decision Hierarchy, presents a logical sequence of actions that safety professionals should consider in resolving safety issues: identify and analyze the problem; consider the possible solutions; decide on and implement an action plan; and determine whether the actions taken achieved the intended risk reduction results. Note that such a sequence of actions also fits well with the PDCA concept.

The safety decision hierarchy depicts a way of thinking about hazards and risks and establishes an effective order for risk elimination or amelioration. Why propose that safety practitioners adopt a safety decision hierarchy? This quote from *The New*

The Safety Decision Hierarchy

A. Problem identification and analysis—Plan

1. Identify and analyze hazards.
2. Assess the risks.

B. Consider these actions in their order of effectiveness—Plan

MOST EFFECTIVE ↓ LEAST EFFECTIVE

1. Eliminate or reduce risks in the design processes.
2. Reduce risks by substituting less hazardous methods or materials.
3. Incorporate safety devices.
4. Provide warning systems.
5. Apply administrative controls (work methods, training, etc.).
6. Provide personal protective equipment.

C. Select risk reduction measures and implement them—Do

D. Measure for effectiveness—Check

E. Accept the residual risk, or start over if it is unacceptable—Act

FIGURE 1

Rational Manager, reflecting the real-world observations of Kepner and Tregoe in advising many clients, makes the case:

> The most effective managers, from the announcement of a problem until its resolution, appeared to follow a clear formula in both the orderly sequence and the quality of their questions and actions.

It makes sense to apply a safety decision hierarchy encompassing an orderly sequence of effectiveness to resolve safety issues.

ON PROBLEM IDENTIFICATION AND ANALYSIS

In applying The Safety Decision Hierarchy, the goal in the problem identification and analysis phase is to identify and analyze the hazards and assess the risks. Hazard and risk problems cannot be intelligently addressed until the hazards are analyzed and assessments are made of the probability of incidents or exposures occurring and the possible severity of their consequences. Chapter 8, "A Primer on Hazard Analysis and Risk Assessment," is a resource for this problem identification and analysis phase.

EXPLORING ALTERNATIVE SOLUTIONS

The action steps shown in the section of The Safety Decision Hierarchy titled "Consider These Actions, in Their Order of Effectiveness" provide a basis for considering alternate risk elimination or reduction measures. They are similar to items A through F in the "preferred order of controls" outlined in Section 5.1.1, "Hierarchy of Controls," in Z10. The logic in support of those steps and the order in which they are listed was given previously in this chapter.

DECIDING AND TAKING ACTION

All facets of the safety decision hierarchy apply when considering the hazards and risks in a specific facility, process, system, piece of equipment, or a tool in its simplest form. Also, they are broadly applicable in all three major aspects of the practice of safety:

- In the design processes, preoperational, where the opportunities are greatest and the costs are lower for hazard avoidance, elimination, or control
- In the operational mode where, integrated within a continual improvement process, hazards are eliminated or controlled, before their potentials are realized and hazards-related incidents or exposures occur
- Post incident, through investigation of hazards-related incidents and exposures to determine and eliminate or control their causal factors

MEASURING FOR EFFECTIVENESS

Provisions in Section 7.1 of Z10, "Management Review Process," require that systems be in place to measure the effectiveness of the risk reduction measures taken. Those provisions are relative to the measurement of effectiveness and re-analyzing steps in The Safety Decision Hierarchy. Assuring that the actions taken accomplish what was intended is an integral step in the PDCA process. Followup activity would determine that the:

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

ACCEPT THE RESIDUAL RISK, OR START OVER IF IT IS UNACCEPTABLE

If the followup activity indicates that the residual risk is not acceptable, the thought process set forth in the safety decision hierarchy would again be applied, commencing with hazard identification and analysis.

HADDON'S UNWANTED ENERGY RELEASE CONCEPT

Dr. William Haddon was the first director of the National Highway Safety Bureau. He was the originator of the unwanted energy release theory. Haddon's concept is that unwanted transfers of energy can be harmful (and wasteful) and that a systematic approach to limiting the possibility of their occurrence should be taken. His work is considered seminal.

Although Haddon stated in "On the Escape of Tigers: An Ecologic Note" that "the concern here is the reduction of damage produced by energy transfer," he also asserted that "the type of categorization here is similar to those used for dealing systematically with other environmental problems and their ecology." These excerpts are from Haddon's breakthrough paper:

> A major class of ecologic phenomena involves the transfer of energy in such ways and amounts, and at such rapid rates, that inanimate or animate structures are damaged. Several strategies, in one mix or another, are available for reducing the human and economic losses that make this class of phenomena of social concern. In their logical sequence, they are as follows:
>
> - prevent the marshaling of the form of energy;
> - reduce the amount of energy marshaled;
> - prevent the release of the energy;
> - modify the rate or spatial distribution of release of the energy from its source;
> - separate, in space or time, the energy being released from that which is susceptible to harm or damage;
> - separate, by interposing a material barrier (the energy released from that which is susceptible to harm or damage);
> - modify appropriately the contact surface, subsurface, or basic structure, as in eliminating, rounding, and softening corners, edges, and points with which people can, and therefore sooner or later do, come in contact;
> - strengthen the structure, living or non-living, that might otherwise be damaged by the energy transfer;
> - move rapidly in detection and evaluation of damage that has occurred or is occurring, and counter its continuation or extension; and
> - after the emergency period following the damaging energy exchange, stabilize the process.

All hazards are not addressed by the unwanted energy release concept. Such examples are the potential for asphyxiation from entering a confined space filled with inert gas, or inhalation of asbestos fibers. However, all hazards do fall within a goal that is to avoid both unwanted energy releases and exposures to hazardous environments.

Keeping Haddon's unwanted energy release concept in mind will be particularly beneficial as managements, supervisors, engineers, designers, and safety professionals consider applying these Z10 provisions: hierarchy of controls; design reviews; management of change; risk assessments; and including safety specifications in purchasing and acquisition papers.

To provide guidance to those applying The Safety Decision Hierarchy, we here reproduce "General Design Requirements: A Thought Process for Hazard Avoidance, Elimination, or Control," as it appeared in our earlier *On The Practice Of Safety*. This guideline is my extension of the incident and exposure prevention aspects of Haddon's work.

The Guideline gives advice on designing the workplace and the work methods. It addresses nine major subjects. Haddon listed 10 strategies, one of which is divided here into two parts, becoming items 2 and 3. Haddon's last two subjects pertain to recovery actions to be taken after an incident occurs. They relate to the Emergency Preparedness provisions in Section 5.1.5 of Z10 and are not addressed in this chapter. In no way is it suggested that my guideline addresses all hazard and risk elimination or amelioration possibilities. It can be helpful as a reference and as a teaching tool.

General Design Requirements: A Thought Process for Hazard Avoidance, Elimination, or Control

1. Avoid introduction of the hazard: Prevent buildup of the form of energy or hazardous materials.
    - Avoid producing or manufacturing the energy or the hazardous material
    - Use material handling equipment rather than manual means
    - Don't elevate persons or objects
2. Limit the amount of energy or hazardous material.
    - Seek ways to reduce actual or potential energy input
    - Use the minimum energy or material for the task (voltage, pressure, chemicals, fuel storage, heights)
    - Consider smaller weights in material handling
    - Store hazardous materials in smaller containers
    - Remove unneeded objects from overhead surfaces
3. Substitute, using the less hazardous.
    - Substitute a safer substance for a more hazardous one: when hazardous materials must be used, select those with the least risk throughout the life cycle of the system
    - Replace hazardous operations with less hazardous operations
    - Use designs needing less maintenance
    - Use designs that are easier to maintain, considering human factors
4. Prevent unwanted energy or hazardous material buildup.
    - Provide appropriate signals and controls
    - Use regulators, governors, and limit controls
    - Provide the required redundancy
    - Control accumulation of dusts, vapors, mists, etc.
    - Minimize storage to prevent excessive energy or hazardous material buildup

- Reduce operating speed (processes, equipment, vehicles)

5. Prevent unwanted energy or hazardous material release.
   - Design containment vessels, structures, elevators, material handling equipment to appropriate safety factors
   - Consider the unexpected in the design process, to include avoiding the wrong input
   - Protect stored energy and hazardous material from possible shock
   - Provide fail-safe interlocks on equipment, doors, valves
   - Install railings on elevations
   - Provide non-slip working surfaces
   - Control traffic to avoid collisions
6. Slow down the release of energy or hazardous material.
   - Provide safety and bleed-off valves
   - Reduce the burning rate (using an inhibitor)
   - Reduce road grade
   - Provide error-forgiving road margins
7. Separate in space or time, or both, the release of energy or hazardous materials from that which is exposed to harm.
   - Isolate hazardous substances, components, and operations from other activities, areas, and incompatible materials, as well as from personnel
   - Locate equipment so that access during operations, maintenance, repair, or adjustment minimizes personnel exposure (e.g., hazardous chemicals, high voltage, electromagnetic radiation, cutting edges)
   - Arrange remote controls for hazardous operations
   - Eliminate two-way traffic
   - Separate vehicle from pedestrian traffic
   - Provide warning systems and time delays
8. Interpose barriers to protect the people, property, or the environment exposed to an unwanted energy or hazardous material release.
   - Insulation on electrical wiring
   - Guards on machines, enclosures, fences
   - Shock absorbers
   - Personal protective equipment
   - Directed venting
   - Walls and shields
   - Noise controls
   - Safety nets
9. Modify the shock concentrating surfaces.
   - Padding on low overheads
   - Rounded corners
   - Ergonomically designed tools
   - "Soft" areas under playground equipment

CONCLUSION

The hierarchy of controls in Z10 derives from work that has evolved over many years. It is a state-of-the-art and technically sound presentation. As management "implement(s) and maintain(s) a process for achieving feasible risk reduction," the hierarchy presents the actions to be considered in a logical order.

Encompassing a hierarchy of controls within a sound problem-solving technique furthers the ability of management and safety professionals to achieve effective risk reduction, and to meet the requirements of certain provisions in Z10. Adopting well-established problem-solving techniques to address hazard and risk situations is a fundamentally sound approach. That is the purpose of The Safety Decision Hierarchy.

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CHAPTER 13

SAFETY DESIGN
SECTION 5.1.2

INTRODUCTION

Requirements for Design Review ar
in one Part of Z10, Section 5.1.2. A
own importance and uniqueness. C
and how to institute the manageme
the next chapter.

This chapter is devoted to desig
in place to conduct design reviews
Design reviews are to be made fo
design specifications; for new or re
new or revised safety and health s

Having written and stressed th
minimize risks is to have the hazard
process, I commend the drafters
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provisions in their safety and hea
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In a few entities, written proc
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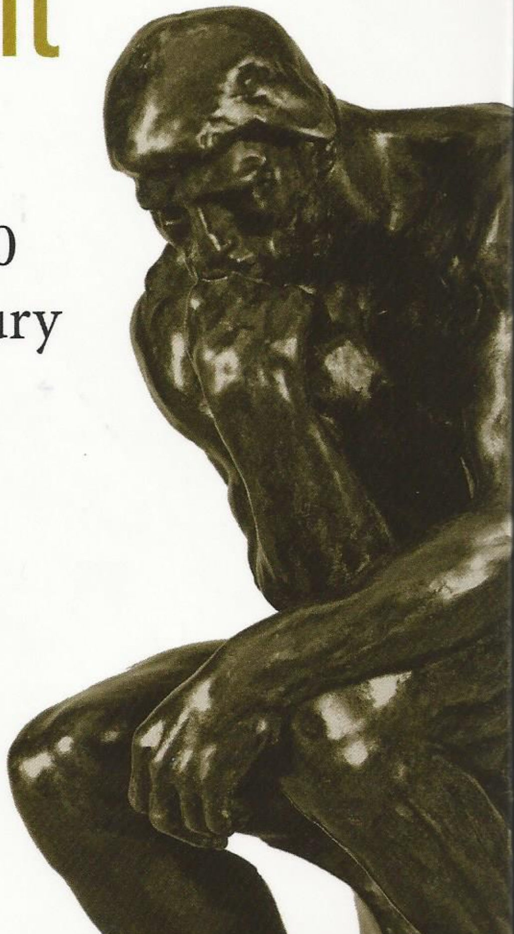
Advanced Safety Management

Focusing on Z10 and Serious Injury Prevention



Fred A. Manuele