CHAPTER 9

GENERAL PRINCIPLES OF HAZARD CONTROL

9-1 INTRODUCTION

In this chapter, basic concepts for controlling hazards are developed. Hazard control begins with recognition. It ends with implementation of a control for a hazard selected from one or more options. In the steps from recognition to control, one must apply several principles that are important.

This chapter presents several approaches for recognizing hazards and selecting controls. There are helpful constructs for thinking through hazard recognition and considering the use environment in which they occur. These aids are useful to envision a use environment and other factors that can contribute to an incident or its severity.

9-2 MURPHY'S LAW

Yes, things do go wrong. Despite one's best efforts to prevent undesired events, errors, misunderstandings, and incidents do occur. Murphy's law captures the idea "whatever can possibly go wrong, will."

The origin of Murphy's law is ascribed to an Air Force engineer, Captain Ed Murphy, and his colleagues, who were conducting crash tests in 1949. Finding a strain gage bridge wired incorrectly, Captain Murphy declared, "If there is any way the technician can do it wrong, he will." To this a colleague ascribed the name Murphy's law.

Captain Murphy and his colleagues achieved an excellent safety record. During several years of crash testing, they ascribed their results to a firm belief in Murphy's law and a concerted effort to prevent its fulfillment. When this claim was announced at a press conference by Colonel Stapp, the project director, Murphy's law quickly became a part of our vocabulary.[1] Variations and corollaries have been added as people applied Murphy's law to different fields. Table 9-1 lists a few applicable to safety engineering.

One goal in safety engineering is to prevent fulfillment of Murphy's law. For many engineers who have a role in products, equipment, processes, and environments, the goal is to reduce hazards. Through planning, design, and analysis of production and operations, factors that contribute to incidents can be eliminated or reduced.

Safety and Health for Engineers, Second Edition, by Roger L. Brauer

TABLE 9-1 Safety Engineering Corollaries of Murphy's Law

A car and truck approaching each other on an otherwise deserted road will meet at the narrow bridge.
Most projects require three hands.
Hindsight is an exact science.
Only God can make a random selection.
When all else fails, read the instructions.
Any system that depends on human reliability is unreliable.
If a test installation functions perfectly, all subsequent systems will malfunction.
In any calculation, any error which can creep in will do so. Any error in any calculation will be in the direction of most harm.
A fail-safe circuit will destroy others.
A failure will not appear until a unit has passed final inspection.

From A. Block, *Murphy's Law and Other Reasons Why Things Go Wrong* and *Murphy's Law Book Two*, Price/Stern/Sloan Publishers. Inc., Los Angeles. CA, 1977, 1980.

9-3 HAZARDS AND HAZARD CONTROL DEFINED

A hazard is "a condition or changing set of circumstances that presents a potential for injury, illness or property damage." It is the "potential or inherent characteristics of an activity, condition or circumstance which can produce adverse or harmful consequences."[2] Hazard control is any means of eliminating or reducing the risk resulting from a hazard. Hazard recognition is perceiving or being aware that a hazard does or can exist.

9-4 SOURCES OF HAZARDS

There are many sources for hazards. Some hazards are introduced by people. All too often hazards arise from engineering activities, such as planning, design, production, operations, and maintenance. Hazards are seldom introduced by engineers or others deliberately; more likely, they are created inadvertently, unknowingly, or unintentionally. Many factors may contribute to the introduction of hazards: pressure to meet design or production schedules, job stress, poor communication, and lack of knowledge may influence hazard recognition and control. Also important are lack of instruction, personnel, funds, management concern, and assistance from safety and health specialists.

Planning and Design

Planning is the process of developing a method for achieving something, formulating a program of action, or structuring an orderly arrangement of parts. Designing is an extension of planning. More detail and specific information is incorporated into a method, program of action, or physical object. In planning and design activities, engineers may create hazards in sites, buildings, facilities, equipment, operations, and environments. A hazard may result from a computational error, failure to envision the use environment, making poor assumptions, or not envisioning how things will actually work.

There are many examples of planning and design errors. A few will suffice. A common computational problem for engineers is converting units of measure. For example, failure to convert square inches to square feet will produce a large error in a load calculation. Failure to include a factor of safety in a structural calculation can be disastrous. Using the wrong factor of safety can introduce a hazard.

Failure to envision the use environment can introduce hazards. For example, the force required by an operator to push or pull an object may be adequate when a floor is dry. The task may be hazardous when the floor is wet or shoes are muddy. The visibility of a display may be excellent for the designer, but obscured for an operator who is taller or shorter. An opening or access for servicing equipment may be large enough for a bare arm, but inadequate when a mechanic wears heavy clothing in cold weather. A skylight on a roof may not be strong enough to stand on or its strength may diminish with continued exposure to sunlight. It becomes a dangerous stepping stool when placed adjacent to a refrigeration unit that must be serviced.

Making inadequate assumptions is another way hazards are introduced. Assuming that a load is static when it is really dynamic may result in failure. Football stands may not be capable of rhythmic loading as the crowd sways and stomps to the music of the band. We may make bad assumptions when we fail to obtain the best possible data from literature, user testing, or input from specialists. One may assume that a product will be used one way for a function whereas in practice, there may be other ways in which a product is used. There may also be misuses that are not envisioned.

Selection of materials can introduce hazards during design. A material may be attractive, but may produce toxic substances if it catches on fire. A material may have adequate strength, but may have other properties, like creep or brittleness, that can lead to disaster. A material may quickly lose its strength when exposed to sunlight or dampness found in some use environments.

Failing to consider the life of a product can introduce hazards during design and planning. A product may be safe when new, but may become dangerous during use. Use factors, such as heat, chemicals, weather, vibration, freezing, wear, abrasion, or other adverse conditions, can shorten product life.

Production and Distribution

Hazards also can result from production and distribution activities that engineers plan or manage. It is not always possible to construct or produce items the way they are drawn or described on paper. Changing fasteners or connectors because those specified are not available could weaken a structural joint. Replacing one chemical with another may introduce toxic or flammable hazards. Poor packaging design may contribute to the introduction of hazards during handling and shipping. Inadequate packaging could result in a release of hazardous materials to handlers, distributors, or buyers.

Maintenance and Repair

Hazards may come from insufficient, delayed, and improper maintenance and repair. Controlling hazards related to normal use is not sufficient. Many designs fail to recognize hazards during setup, maintenance, and cleaning activities. For example, poor access to service points or the need to carry out servicing with high levels of energy present can be dangerous. Hazards during or resulting from maintenance, repair, or cleaning, not just normal operation or use, must be recognized.

Failure to provide manual power or inching controls for powered equipment may make service and setup activities dangerous. Failure to tighten a bolt or tightening it too much may create a hazard. Failure to lock out or provide lockout capabilities for electrical, steam, or mechanical power or fuel sources during maintenance creates hazards. Failure to clean up work areas before, during, or after servicing and repair can introduce hazards. Errors in maintenance procedures or poorly written procedures can cause hazards.

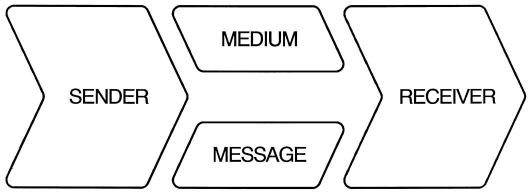

Figure 9-1. The four components of communication.

Failure to block areas undergoing maintenance activities may allow unqualified or unaware individuals into dangerous areas.

Communication

Poor communication or failures in communications can introduce hazards. Hazards can be introduced when changes in design, operations, and procedures are not communicated adequately to those impacted by them. The way information is communicated and the knowledge and understanding of receivers is important. Instructions and user manuals need the knowledge of the designer and others. Too often, instructions are descriptions of how an item works, rather than a series of actions one must take to make something work correctly. Poor communication leads to errors, incidents, and losses.

The four components of communication are essential in safety engineering. The four components are sender, receiver, media, and message (see Figure 9-1).

Designers, safety engineers, and other specialists have important roles in communications. They need to communicate designs, specifications, and procedures involving safe operations, use, maintenance, setup, and cleaning. They should even participate in preparation of advertising materials. If hazards or controls are not communicated to users or if protection is not illustrated in advertising, results may be disastrous.

9-5 PRINCIPLES OF HAZARD CONTROL

To minimize hazards, one must be able to

1. recognize them
2. define and select preventive actions
3. assign responsibility for implementing preventive actions
4. provide a means for measuring effectiveness

Together, these four steps achieve hazard control. A number of methods are available to accomplish these steps systematically. Part Five of this book details several methods.

Knowledge and Recognition of Hazards

As noted earlier, no one individual can be fully knowledgeable about all hazards. Several disciplines and specialists may need to work together. Safety engineering requires a knowledge of hazards in many different topics. Safety engineering also requires a broad knowledge of engineering and systems. In contrast, many engineering disciplines provide in-depth knowledge of particular topics. Thus, the specialty of safety engineering requires knowledge of hazards and potential controls across many engineering disciplines.

TABLE 9-2 Most Frequently Cited OSHA Violations (2003)

Rank	Topic	No. of Citations
1	Scaffolding	8,682
2	Hazard communication	7,318
3	Fall protection	5,680
4	Lockout/tagout	4,304
5	Respiratory protection	4,302
6	Electrical-wiring	3,337
7	Machine guarding	3,245
8	Powered industrial trucks	3,130
9	Electrical systems	2,399
10	Mechanical power	2,321

After one has developed a knowledge of hazards, there is a need to develop skill at recognizing and understanding hazards. Sometimes one must anticipate hazards by knowing that bringing certain materials, activities, or conditions together produces hazards that otherwise are not present. One must consider the use environment and many different contexts. Only after hazards are recognized can one identify and select suitable controls.

Historical data often helps in identifying or anticipating hazards that may exist or potentially exist. For example, OSHA publishes annual statistics based on the frequency of citations of OSHA standards. Table 9-2 provides example data for 2003. The rate of citations may help identify hazards to look for and resolve. Internal company data from workers' compensation claims, OSHA or other logs of incidents, or company accident reports can help identify hazards that require attention.

Priorities

There is a set of priorities that many find helpful for selecting controls for hazards. Some refer to this list as "design order of precedence." The priorities, in order of importance, are:

1. eliminate the hazard
2. reduce the hazard level
3. provide safety devices
4. provide warnings
5. provide safety procedures (and protective equipment)

Many factors must be considered when selecting and implementing controls for hazards. Risk, cost, kind or severity of loss, practicality, and not introducing additional hazards are all important. For kind of loss, the first priority is to protect people and human life. Protection of property, environments, and operations follows. Haddon's energy release theory (Chapter 3) provides ideas for dealing with these priorities.

Eliminate the Hazard

The highest priority in hazard control is to eliminate or avoid the hazard. As soon as it is eliminated, the potential for harm or loss is gone. Hazards can be eliminated by making process or design changes or by substituting a nonhazardous material for a hazardous one. For example, elimination of manual handling steps in an operation will eliminate lifting hazards. A noncombustible material can replace a combustible one. Sharp corners can be rounded. Wastes can be removed.

Reduce the Hazard

If one cannot remove a hazard, the degree of hazard often can be reduced. Two approaches are reducing the degree of severity or reducing the probability of occurrence.

Reductions in degree of severity lead to less injury, illness, or damage. For example, moving a fire hazard where it is distant from people is a reduction in degree of severity. Fewer are likely to be injured. Placing hazards where there are few people reduces hazard severity. Using smaller quantities of flammable or toxic material or reducing energy levels at an occupied location is also a severity reduction. A sprinkler system does not prevent fires. It simply minimizes their severity.

Reducing the probability of occurrence means that a hazard is less likely to result in an incident. One means to accomplish this is to use parts that have a longer life. Designing for lower failure rates or using redundancy are others. Avoiding single point failures is another.

Redundancy The probability of error or failure can be reduced by providing redundancy in an operation or system. Redundancy means providing more than one means to accomplish something, where each means is independent of the other. There are several kinds of redundancy and ways to implement redundancy. One is to provide two or more parallel subsystems or components. For example, Figure 9-2(a) illustrates a circuit that will not operate if the single actuating switch is open or fails in an open position. The circuit in Figure 9-2(b) will operate when either switch A or switch B is closed, or when both A and B are closed. A failure of either switch alone will not disable the ability to energize the circuit.

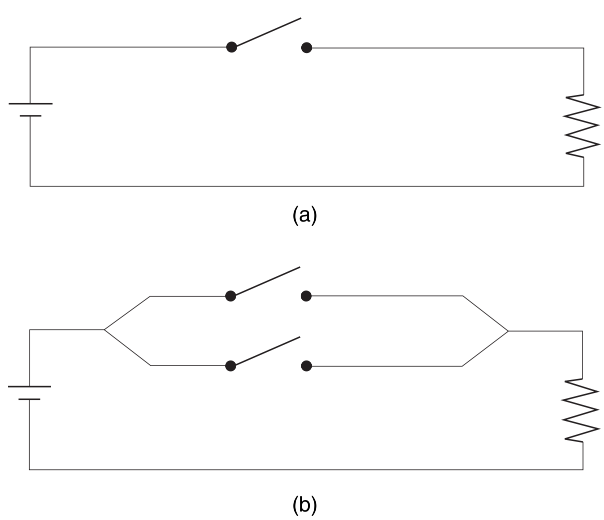

Figure 9-2. Circuit (a) has no redundancy in the switch that activates the circuit, whereas circuit (b) does by having two independent switches that can close the circuit.

Another way to provide redundancy is to use a backup system. For example, on some aircraft, the aileron control is activated by hydraulic devices. Some aircraft have as many as four separate hydraulic systems to minimize the chances of control failure. Failure in one system will actuate a second system. The second is not normally in operation until the first one fails. For example, having candles or lanterns available for use when the electricity goes off and lights are out is a form of backup system.

In some systems there is partial redundancy. Suppose there is only one pump supplying two sets of hydraulic lines to an actuating cylinder. The pump and cylinder have no redundancy, whereas the lines do. The system has only partial redundancy. A failure in the pump or cylinder would produce a failure of the system. A blockage failure in one of the lines would protect the system from failure because there is a second line. Running the hydraulic lines through the same location where damage to both is likely reduces the value of the redundant lines.

Redundancy can involve both human operators and automatic equipment. The cruise control on an automobile is an automatic device that keeps a car moving at a steady speed. The driver can also control the speed of the car by depressing the accelerator pedal. The driver and the speed control are redundant. The driver can fully override the speed control by disengaging it with a switch on the brake pedal or throwing a dashboard switch to deactivate it.

Redundancy also can be accomplished through the use of more than one person. In aircraft, a pilot and a copilot can perform the same function. If one is incapacitated, the other can take over (parallel redundancy). Another example (series redundancy) is a two-person press. Both operators face the hazard of getting caught in the machine when it is in motion. If each operator has a two-hand control, all four hands of the operators must be depressing a switch before the machine will operate. Another example is the use of two people for cleaning or repairing a closed container. After checking the container for hazards, only one person enters the enclosure. The other watches and provides help in case the first encounters some difficulty, but does not enter the enclosure without a replacement at the backup position.

Single Point Failure A single point failure is a failure of a component or subsystem that results in failure of the entire system. A broken starter switch or a dead battery in a car renders it inoperable. Single point failures must be avoided if a failure of the system can produce dangerous conditions.

Safety Devices

Safety devices can reduce hazards in many cases. Safety devices are features or controls that prevent people from being exposed to a hazard that exists. As soon as a safety device is in place, operating correctly, and properly maintained, it requires no action on the part of people. Safety devices are automatic devices. One must remember that safety devices do not remove a hazard. A major difficulty with safety devices is that they often are removed or are rendered inoperative, exposing someone to a hazard.

Machine guards are examples of safety devices. They prevent operators from entering a hazardous area. Fences, interlocks, shielding, and enclosures are all forms of safety devices.

Fail-safe devices are safety devices designed to prevent exposure to hazards. They also prevent injury or damage when a system or machine fails. Examples of fail-safe devices are automatic fire doors, air brakes on truck trailers, a dead-man switch on a powered hand tool, and safety cans with a spring-closing lid for flammable liquids. Fail-safe devices can be classified as fail-passive, fail-active, or fail-operational. A fail-passive device, such as an electrical circuit breaker or fuse, renders a system inoperative or deenergized until corrective action is taken. A fail-active device keeps a system energized but in a safe mode until corrective action is taken. A fail-operational device allows a system to function safely, even when the device fails.

Warning Devices

Another way to reduce hazards is to warn people. Warnings notify people of a hazard or danger. Warnings depend on people to take some action that will prevent them from being exposed to or injured by a hazard. Warnings do not remove a hazard. Warnings depend on human action to implement protection and are effective only when humans perceive and understand them and act correctly in response to them. Warning devices often rely on sensors to establish that a hazard exists for which a warning must be given.

Most warnings signal people through visual or auditory senses. Some common examples are signs, symbols, and visual or auditory alarms. Flags, labels, signs, flashing or changing lights, sirens, whistles, horns, and other means are used to notify people that a hazard exists. Because communication is a complex process, select and use warnings with care. Warnings can fail or be ineffective because of the complexities involved in their use. The following sequence is typically involved:

1. A hazard must be recognized during design by a designer or sensed by some sensor device.
2. The hazard must be differentiated from other hazards.
3. A warning must be actuated or presented.
4. The warning must operate.
5. The warning must be sensed by a receiving person.
6. The warning must be perceived as a warning relative to the background and its meaning understood.
7. The receiver must know what protective action should be taken.
8. The receiving person must take the appropriate protective action.
9. The correct action must be completed in a timely manner.

A warning is useless if any one of these steps is not completed. Table 7-1 identified 15 characteristics that warnings should have.

Warnings that seem similar can result in the incorrect action. For example, a fire horn in a school has a long continuous sound, whereas a tornado warning on the same system produces a sound that alternates between high- and low-pitch sounds. The appropriate actions in each case are opposite. For a fire, children must exit the building. For a tornado, they are to get down along the wall in a central corridor. An error in action can be deadly, as shown by the events in a Midwest grade school. The children exited when there was actually a tornado.

When several warnings are present at one time, they can be confusing, particularly if priorities among competing warnings are not clear. During the major loss of coolant incident at the Three Mile Island nuclear power plant, 500 or more audio and visual warnings went off during the first minute of the incident sequence; more than 800 went off by the end of the second minute.[3] Operators had a sensory and decision-making overload, which contributed to the overall severity of the incident.

Procedures

Another way to reduce the danger from hazards is by using procedures. Procedures are sets of actions that must be executed. People must learn to use safe procedures. Procedures must be developed and understood before they are used, must be safe, and must accomplish the desired goal in an efficient manner. One can establish procedures for efficiency, management control, and many other purposes beside safety. There are a number of methods (see Part Five) available for analyzing procedures to determine whether they are safe, sufficient, and effective.

One needs to design procedures to minimize danger to anyone using them. Procedures should not introduce unsafe practices and should not put someone in danger. People must be taught and develop skills in following safe procedures. People should learn why safe procedures exist and what hazards the procedures attempt to help them avoid.

People need to recognize hazards that may occur during the use of procedures and how to act if such contingencies occur. For example, people are often taught how to operate a machine. Then they start to use the machine and something unexpected occurs that their training did not include. Because the procedures did not cover such an event, the operator must use individual judgment to take the correct action. Too often the wrong action is taken. Because new and inexperienced operators are not familiar with the unexpected and how to protect themselves, the incident and injury rate for new employees is very high. Often new employees are not taught how to deal with nonroutine conditions.

Procedures are the lowest control on the priority list because they depend totally on human behavior to recognize the hazard and take appropriate corrective action. The hazard is still present. A person must be able to recognize the situation calling for a procedure, to know what procedure is correct for that situation, to recall the procedure, and to execute it correctly. The correct situation and procedure must be differentiated from all other similar ones. Skill is required in completing the procedure, and frequent practice may be necessary to retain the proper skill. The person must have the physical capabilities to perform it. All actions must occur in a timely manner. Failure in any one of these steps can result in inadequate protection.

Personal Protective Equipment

Personal protective equipment is sometimes needed if controls that are higher in the priority list cannot be implemented, but one must recognize that personal protective equipment is an element of a procedure. Wearing special equipment depends on human behavior and cooperation. Even if good fit and proper selection are accomplished, the use of equipment is not ensured. The hazard against which it provides protection is still present or likely to be present.

9-6 ENVIRONMENTAL HAZARDS

When dealing with hazards of environments, additional factors are important. Environments include such things as heat, light, noise, vibration, pressure, chemicals, and radiation (nonionizing and ionizing). One must consider the effects on people, how they occur, and how they are observed. We cannot observe most environmental hazards or assess them accurately without instrumentation and reference to standards. Therefore, procedures for determining whether a hazard exists are important.

Effects

Exposures to environments produce few traumatic injuries. Most often there are health effects, nontraumatic injuries, or cumulative effects. Thermal environments can cause burns. Exposure to extremely loud noise can cause injury to the eardrum. Exposure to high-intensity ultraviolet radiation can injure receptor cells in the eye. More often, environmental exposures lead to health disorders. Exposures to hot environments can produce various illnesses and physiological disorders. Exposures to noise can produce forms of stress and lower tolerance for others. Exposure to high levels of ionizing radiation can result in acute illness and death and exposures to low levels may lead to delayed illnesses, such as cancer.

Some effects of environmental exposures are delayed. The delay in manifestation of illness may be hours, days, or even years. The time between exposure and onset of symptoms is the latency period. Some cancers associated with exposures to certain materials and environmental conditions may not appear for years. The most extreme latency period is on the order of 30 to 40 years.

Some effects of environmental exposures appear as behavioral effects. A person changes the way he behaves. Some behavioral changes are easy to recognize. For example, consider the parents who are irritated by the constant blare of their teenager's stereo. They may feel tense and yell at their child as a result. Some chemicals affect nerve transmission or muscle action. A person exposed to such materials may exhibit noticeable reduction in motor skills. Other materials can cause loss of memory that affects a person's job skills. Often these behavioral changes are not associated immediately with some environmental exposure. The symptoms may result from many other causes as well. Sometimes treatment is initiated for the behavior problem and not the real cause. An example is "mad hatter's disease" or "Danbury shakes." Employees in the hat-making industry around Danbury, Connecticut, were exposed to mercury and became nervous and irritable and exhibited shaking.

There are significant differences among people in their physical, emotional, and behavioral response to environmental exposures. For example, some people burn easily in sunlight; others do not. Some people may experience a skin rash from contact with certain solvents, whereas others may not for the same exposure. In some cases, people become sensitized. For a long time they do not exhibit any effect when exposed to an environmental agent; then they do. After the first response is initiated, further exposures at even low levels will initiate the response.

Information Requirements

Exposures to environmental conditions and materials do not always produce effects. Not all exposures are harmful. Some are beneficial. For example, exposure to sunlight provides a means for acquiring vitamin D. Excessive exposure can lead to burns and skin cancer.

To determine if an environmental condition is hazardous, several items of information are needed. The information must be estimated for design purposes. When actual exposures are the concern, one needs to make measurements.

First, one must know the agent. Whereas it is easy to distinguish thermal conditions from noise, it is not so easy to tell what chemicals are present in the air and whether they are airborne solids or gases and vapors. For ionizing radiation, one must know what kind of radiation is present. For ultraviolet radiation, one needs to know the wavelengths present.

Second, one must know the values for attributes of an environmental condition. For thermal environments, for example, one needs the dry bulb air temperature, humidity, air velocity, and radiant heat load. For nonionizing radiation, one must know the intensity and wavelengths. For airborne chemicals, one must know the contaminants present and their concentrations.

Third, one must often know how long a person could be or has been exposed. The degree of hazard for many environmental agents is a function of the dose, determined in most cases from length of exposure and concentration.

Hazard Recognition

From knowledge about the presence of an agent, its form and intensity, and the potential or actual duration of exposure, one cannot establish if there is a hazard. For some agents, computations are needed to convert this information into some index value. In addition, the indices or measurements themselves must be compared with exposure standards, which establish what environmental conditions constitute a minimally acceptable exposure.

Instrumentation and Measurement

Special instruments are needed to determine the agents and their form and intensity present in an environment. Instruments may be grouped into two classes: laboratory instruments and field instruments.

Many times it is impractical or impossible to bring specialized instruments to the location where there is concern over an exposure. Laboratory instruments may not be portable or may require support systems that cannot be provided in field settings. Laboratory instruments may not be rugged enough to take the physical abuse and conditions found in the field. Laboratory instruments may be difficult to set up and calibrate when they are moved. Some instrumentation is difficult to read correctly, and an untrained user is likely to make errors.

There are two approaches for resolving these problems. One can use field instruments if they are available for the agents of concern. Field instruments overcome many limitations of laboratory instruments, although accuracy may be compromised in doing so. However, they may provide sufficiently accurate information so that decisions about exposures can be made in the field.

The second approach requires collecting samples and bringing them to a laboratory for analysis. Samples cannot be collected for all environmental agents. Some agents, like radioactive materials, decay with time. A delay from a sampling point to a laboratory may reduce the accuracy of readings.

For each kind of chemical and physical exposure, there are accepted procedures and instruments for making measurements. Because this book cannot provide full details on instruments and measurement procedures, one should refer to current publications and regulations for accepted practices or seek assistance from occupational safety and health or industrial hygiene professionals.

Health Standards

Standards for environmental agents (physical and chemical) are updated regularly. The updates are necessary to incorporate new knowledge and new agents into standards. Often there is incomplete information about the exposures themselves, effects of exposures, and the mechanisms for illness or injury. Information about hazards of agents are derived primarily from incidental exposures and from testing. Testing most often involves animal or other studies. Occasionally, human volunteers participating in studies provide direct information on effects of environmental agents on humans. In general, standards are based on past events. The trend is to make them more restrictive because new experience indicates that past standards do not provide adequate protection.

The main sources of environmental standards are OSHA and EPA standards. OSHA sets workplace standards; the EPA sets standards for air and water quality for the general public. Other agencies, like the CPSC and the FDA, also set certain environmental standards as they pertain to products. For work environments, the American Conference of Governmental Industrial Hygienists publishes recommended standards of exposure for chemical and physical agents.[4]

9-7 HAZARD CONTROL MODELS

The complex relationships among people, machines, environments, and organizations can make hazard control difficult. Using only one means for control may not be sufficient. Consider the problem of protecting people from falling into an excavation. Barricades may be placed around a trench or hole. However, at night someone may not see the barricade, so a flashing light is mounted on the barricade for visibility. For blind people, the flashing light is useless. When appropriate, a beeper is added to the flashing unit. Children may ignore the warning devices and their features and crawl under or over the barricade and fall in. A strong wind could knock the barricades over. The battery for the light and beeper may fail. A warning sign in English may be installed, but someone may not be able to read or understand English. The complexities of a seemingly simple problem often make it difficult to eliminate or control a hazard.

In the process of hazard recognition and control, one must identify the complexities of contributing elements. One must consider the hazards in their use environment. A number of conceptual models have been proposed to help one think of the many elements that are involved in incidents. Individually, people, machines, environments, materials, and other factors may not create hazardous conditions. Taken together in certain situations, a hazardous condition may be created or a danger increased. The appropriateness of a control method can only be determined in light of the complex array of elements potentially present.

Four Ms

One conceptual model, illustrated in Figure 3-2, is the four Ms: man, media, machine, and management.[5] Media can be thought of as environment. The model helps one think of the many factors and their interrelationships that contribute to potential incidents.

Goal Accomplishment Model

Another conceptual model, the goal accomplishment model, is illustrated in Figure 9-3. It assumes that people and organizations are goal oriented. The model includes nine factors that are typically involved in accomplishing a goal. *People* (1) perform *activities* (2) and use *equipment* (3) to help them. People perform the activities in some *place* or *facility* (4) under constraints of *physical* (5), *social* (6), and *regulatory* (7) environments. There are *time* (8) and *cost* (9) limits for the activities. Each of these elements has many characteristics that can affect the achievement of the goal (see Table 9-3). One

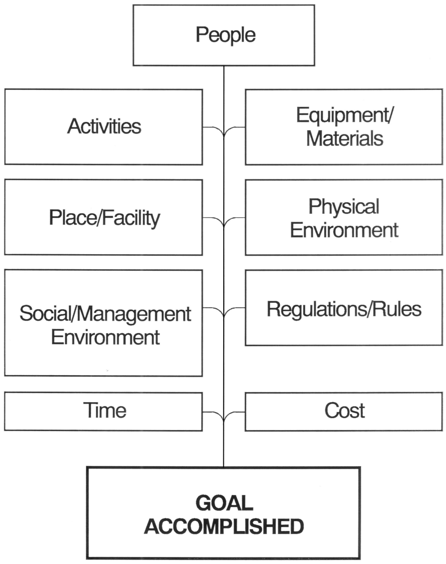

Figure 9-3. A goal accomplishment model for identifying and controlling hazards.

TABLE 9-3 Factors in the Goal Accomplishment Model

Factor	Typical Characteristics
People	Age, gender, size, strength, training, knowledge, emotion, state of health, culture, attitudes
Activities	Sensory and motor skills, actions taken
Equipment	Machines, vehicles, systems, materials, supplies, containers
Place	Facility, building, land area, road, air space, waterways, and characteristics of them
Environment	Thermal, electrical, sound, chemical, illumination, radiological, biological
Social/management environment	Organizational and work climate, interpersonal relationships, communication, language
Regulatory/procedural environment	Laws, regulations, procedures, policies, work rules and practices, rules of the road, etc. (both written and unwritten)
Time	Time available, rates, shifts, work hours, changes in shifts
Cost	Initial cost, operating cost, rent, losses, medical cost, repair cost, replacement costs, demolition or decommissioning costs, etc.

can analyze situations for these elements to help identify what can go wrong in reaching the goal.

9-8 SOME BASICS

Housekeeping and sanitation are fundamental in preventing injuries and illnesses. When incidents do occur, first aid or emergency action can reduce the severity of losses. People often overlook these basics. Industrial workers fought hard to achieve some of these and some workers are still fighting for them. A few comments about them are needed. These fundamentals must not be overlooked.

Housecleaning and Housekeeping

One way to control hazards is through housecleaning and housekeeping. Housecleaning involves involves picking up, wiping up, and sweeping up. It includes removal of scrap and waste. Housekeeping reflects the adage “having a place for everything and everything in its place.” Not having proper storage places and storage equipment often is the problem. Some would delegate housecleaning and housekeeping to janitorial services, but everyone should share the responsibility for them.

Lack of housecleaning and housekeeping creates hazards. It is a symptom of unorganized, unplanned, and sloppy work and work management methods. In fact, many companies find that good planning and organization of work solves many housecleaning and housekeeping problems. At the same time, the planning creates profit. One can often tell how well an activity is planned and managed and how profitable it is by simply observing the housecleaning and housekeeping.

Sanitation

Sanitation is another important concept related to safety and health. Control of health hazards requires sanitation. Disease transmission and ingestion of toxic or hazardous materials are controlled through a variety of sanitation practices:

1. proper design and operation of sanitary and storm sewers
2. availability of safe drinking water and sanitary dispensing equipment
3. clean, operable toilet facilities
4. frequent garbage, scrap, and waste removal
5. sanitary food preparation, service, handling, and eating areas
6. insect and rodent control
7. sufficient and sanitary cleanup areas, locker rooms, and showers
8. use of appropriate personal protective equipment and clothing

First Aid and Emergency Action

Treating injuries immediately can reduce their severity and prevent further injury. Trained personnel, who know correct treatment, should administer first aid and maintain records of treatment. Adequate supplies and equipment should be available, and special equipment, such as deluge showers and eyewash fountains, should be provided at points where chemical hazards require them. Maintaining first aid supplies, equipment, and training is also important.

Emergency actions help mitigate the severity of an incident by limiting exposures of people, property, and the environment. Emergency actions may take several forms, such as evacuation, emergency communications, treatment, and recovery and may require the use of specially trained teams (fire brigades, spill response teams, etc.) and special equipment (fire protection systems, spill containment equipment, flood control equipment, communication systems, etc.). Chapter 29 discusses emergency actions in more detail.

EXERCISES

1. Identify hazards in your place of work or residence, applying the four Ms model and the goal accomplishment model.
2. Discuss the importance of communication for safety and cases of communication errors or failures with
   - **(a)** a communication specialist
   - **(b)** a safety professional
   - **(c)** an attorney

REVIEW QUESTIONS

1. What is Murphy's law?
2. What is a hazard?
3. What is hazard control?
4. What are the sources of hazards?
5. What are the four components of communication?
6. What are the priorities for hazard control?
7. What are the general effects of exposures to hazardous environmental conditions?
8. What is a latency period?
9. What range in time can a latency period cover for various exposures to hazardous environments?
10. Do all people exhibit the same response to exposures to environmental hazards? If not, why?
11. What three items of information does one need to evaluate an exposure to an environmental condition?
12. How does one know if an exposure is hazardous?
13. How does one acquire information about an exposure?
14. What are the elements in the four Ms model?
15. What are the elements in the goal accomplishment model?
16. How are housecleaning and housekeeping related to hazards?
17. Explain the following terms:
    - **(a)** redundancy
    - **(b)** single point failure
    - **(c)** safety device
    - **(d)** safety warning
18. Why do procedures have the lowest priority in the list of hazard controls?
19. Why is personal protective equipment included with procedures?

NOTES

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