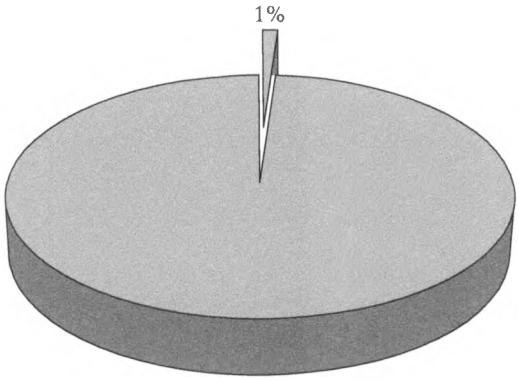
CHAPTER 6

Process Safety and Disaster Preparedness



Percentage of OSHA General Industry citations addressing this subject.

Of major impact on the field of safety and health management in the early 1990s was the promulgation by OSHA of the standard for Process Safety Management of Highly Hazardous Chemicals. The decade of the 1980s was witness to major tragedies involving explosions and catastrophic release of hazardous chemicals that resulted in numerous fatalities both to employees and to the general public. These tragedies were of such significance that they attracted worldwide attention.

The most prominent tragedy was the Bhopal, India, disaster that killed 2500 civilians in a single chemical company accident, as mentioned in Chapter 1. There is no doubt that this catastrophe affected national policy in the United States and influenced the development of the process safety standard. Another major tragedy was the Phillips Petrochemical Plant explosion in October 1989 in which an explosion and fire at a plant near Houston, Texas, killed 24 and injured another 128 workers. As might be expected, a substantial OSHA inspection was conducted at Phillips after this incident and a large fine was levied. However, this disaster

prompted OSHA to seek more than an after-the-fact approach with inspections and fines. The resulting OSHA Process Safety Standard sought to forestall such catastrophes in the future.

Some readers may be inclined at this point to skip this chapter as not applicable to their operation. "Process safety" seems to apply only to chemical plants and petroleum refineries, but the reader is cautioned that, in the early years of enforcement of the process safety standard, OSHA has been shown to adopt an aggressive definition of the word "process." Thus, a poultry processing plant, for example, can be seen to be covered by the process safety standard, because its process might employ chlorine for refrigeration, a dangerous chemical. Even a discrete-items manufacturing plant, might employ dangerous acids in its plating operations and thus fall under the scope of the process safety standard because it processes or stores a dangerous chemical in excess of a threshold amount.

PROCESS INFORMATION

In Chapter 5, the growing influence of information systems on the field of industrial safety and health was emphasized. This influence was evident in the content of OSHA's process safety standard. Before any analysis of the process is to begin, OSHA requires the employer to compile information on the highly hazardous chemicals to be used or produced by the process, the equipment to be used in the process, and the technology of the process itself. It is clear that OSHA's intent is for this information to be available to the union or other employee representative at the plant.

The safety and health manager (or whomever has been designated to deal with process safety hazards and standards) should first address the problem of where to find information about the chemicals used in the process. In Chapter 5, we studied the primary document of information regarding chemicals used within an industrial plant, and that document is the SDS. The SDS may provide all information necessary to comply with process safety requirements, but if it does not do this, the safety and health manager can turn to standard reference volumes on the properties of hazardous chemicals. The safety and health manager can win the confidence of the committees or teams of engineers, employees, and employee representatives assigned to analyze a hazardous process by knowing these standard reference volumes and relying on them when advising the analysis team. Following are a few of the popular standard references regarding hazardous chemicals:

- Irving Sax, *Dangerous Properties of Industrial Materials* (Sax, 1975)
- Robert E. Lenga, *Sigma-Aldrich Library of Chemical Safety Data*
- Gessner G. Hawley, *The Condensed Chemical Dictionary* (Hawley, 1975)
- *NIOSH Registry of Toxic Effects of Chemical Substances*

These references were used in the development of Case Study 6.1.

CASE STUDY 6.1

HAZARDOUS CHEMICAL INFORMATION FOR PROCESS SAFETY ANALYSIS

Name of chemical	Phosphorus chloride (PCl_3), sometimes known as *phosphorus trichloride*
Toxicity information	Poison by inhalation. Moderately toxic by ingestion. A corrosive irritant to skin, eyes (at 2 parts per million (ppm)), and mucous membranes
	Lethal dose (for 50% of population):
	Rats (oral): 550 mg/kg
	Lethal concentrations for inhalation (for 50% of population):
	Rats: 104 ppm for 4 hours
	Guinea pigs: 50 ppm for 4 hours
Permissible exposure limits	OSHA PEL: 8-hour time-weighted average (TWA): 0.5 ppm
Physical data	Clear, colorless, fuming liquid
	Melting point: −111.8°C
	Boiling point: 76°C
	Density: 1.574 at 21°C
	Vapor pressure: 100 mm of mercury at 21°C
	Vapor density: 4.75
Reactivity data	Highly reactive with a variety of acids, oxidizers, and even water or steam. Fire and explosion hazard
Corrosivity data	Department of Transportation Classification: corrosive material
Thermal and chemical stability	Dangerous; when heated to decomposition, it emits highly toxic fumes of chlorides and PO_x. Can react with oxidizing materials
Hazardous mixing	Potentially explosive with nitric acid, sodium peroxide, oxygen (above 100°C). Violent reaction with water evolves hydrogen chloride and diphosphane gas, which then ignite. Will react with water, steam, or acids to produce heat and toxic corrosive fumes

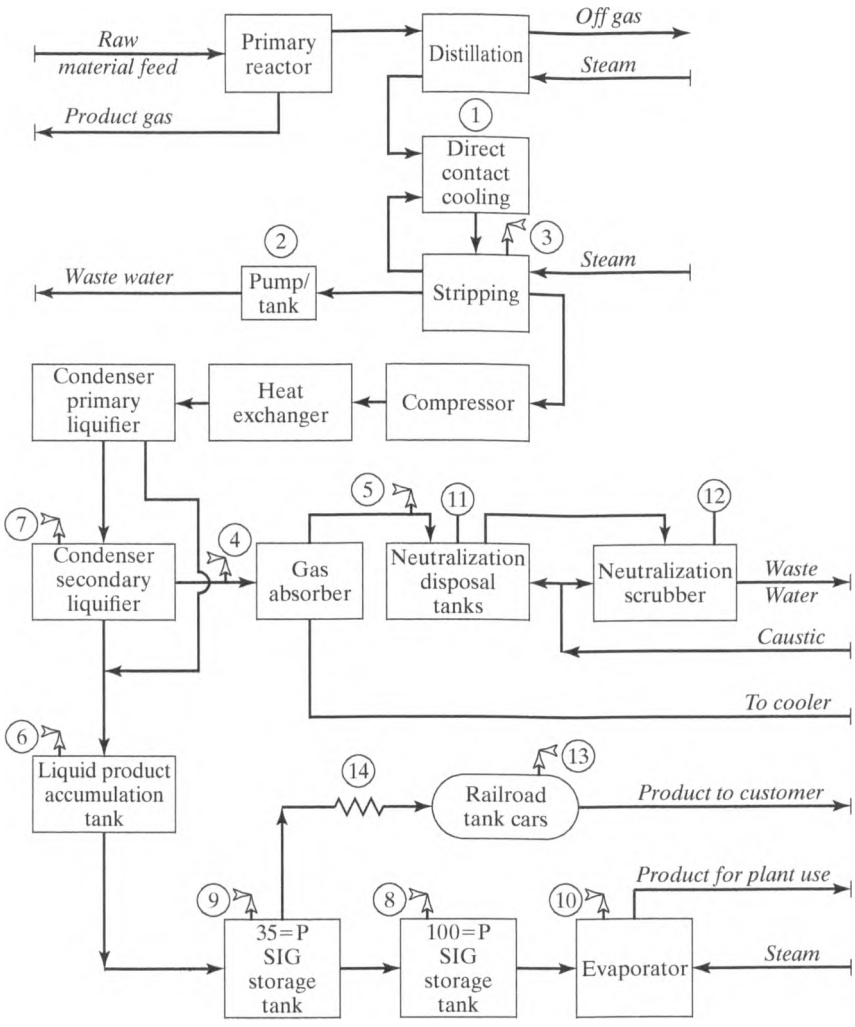


FIGURE 6.1

Example of a block flow diagram (*Source:* OSHA Standard 1910.119).

Case Study 6.1 was used to show how published data in chemical reference volumes can be used to provide the data necessary for analysis of hazardous processes. Not all data contained in reference volumes are required. For instance, in Case Study 6.1 under the category "hazardous mixing," only those materials that could foreseeably be inadvertently mixed with the hazardous chemical in the process under study are included.

Beyond the properties of the chemicals used in the process, OSHA wants employers to document the technology of the process, including at least a block flow diagram (Figure 6.1) or a simplified flow process diagram (Figure 6.2). In addition, process

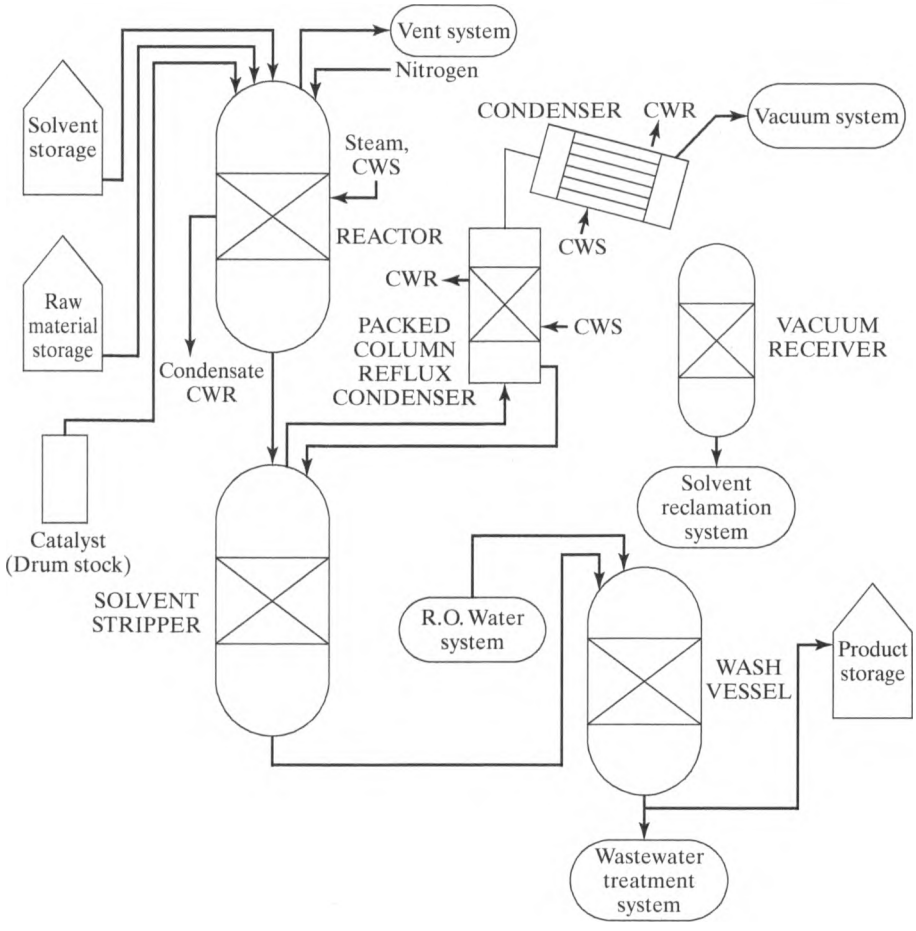


FIGURE 6.2

Example of a flow process diagram (*Source:* OSHA Standard 1910.119).

chemistry data, maximum intended inventory, and safe upper and lower limits for temperatures, pressures, flows, or compositions must be provided. Any deviations from the standards of the process that might affect the safety and health of employees must be evaluated to consider consequences. These data may already be available, but if they are not, they can be developed in the process hazard analysis explained in the next section.

The process equipment must also be documented and described with such details as materials of construction and piping and instrument diagrams. Particular interest is placed on safety features, such as relief system design, ventilation, design codes and standards, material and energy balances, and safety systems, such as interlocks, detection, and suppression systems. The federal standards require that process equipment comply with "recognized and generally accepted good engineering practices." Especially with regard to equipment purchased prior to the process safety standard, it may

be advisable to utilize a registered professional engineer to make a "good engineering practices" evaluation of process equipment.

Considering the scope of the information required by OSHA to be compiled for chemicals, processes, and process equipment, there is a need for the employer to develop a strategy for complying with the standard. It might seem straightforward to gather all of the required information into a file drawer, but there are problems with this approach. Different departments have responsibilities for different parts of the problem. For instance, plant maintenance might be responsible for proper functioning of process equipment, but documentation of the properties of the chemicals processed might fall within the responsibility of engineering or operations. It would be nice to be able to show the OSHA inspector what he or she probably would like to see: a file drawer of information all in one place that complies with every provision of the standard. However, this is usually not a practical solution. Especially with regard to changes and updates, keeping the central file up to date could become a nightmare. What the employer does not want the OSHA inspector to find is a nice, central file that is later shown to have incorrect or obsolete information about the process because responsible departments have made changes. A more practical solution to the problem is what Lastowka (Lastowka, 1997) has referred to as the *road-map approach*. This approach leaves required documents in their respective departments of responsibility. In a central file, convenient to the OSHA inspector, employee representatives, and other interested parties, is a "road map" that identifies each documentation requirement of the process safety standard and tells precisely where within the entire plant to find the pertinent detailed information required. Another possibility is to have a computerized information system with controlled access. Persons who need to have access to information can be so authorized; others who have responsibility for content can be authorized to alter the data when changes must be made.

PROCESS ANALYSIS

The preceding section showed that federal standards require documentation of a great deal of information about a process. The main thrust of the standards, however, is in the analysis of the data. The intent of the analysis is to go beyond equipment, chemicals, and how the process works to an investigation of what can go wrong in the process and how to deal with these hazards. The analysis requirements of the process safety standard recall the methods that were studied in Chapter 3, including fault-tree analysis and failure modes and effects analysis. Some analysts refer to "what-if" analyses and "what-if" checklists, which raise questions about process interactions and outside events in addition to failure modes of the process itself. Also to be included are analyses of past incidents that have had a potential for catastrophic consequences in the workplace.

The potential value of engineering control systems must be considered. Engineering control systems might include detection and early warning of impending catastrophic events. Such systems might consist of a computer-based process monitoring system with instrumentation and alarms. Of course, the computer monitoring the process might itself fail, and the consequences of this possibility must also be considered. Even the location of the site of the facility may enter into the analysis. For instance, if the facility

is located along a geologic fault, the possibility of earthquakes becomes a consideration. In addition, the human element must not be ignored. If human failure can contribute to the possibility of a catastrophe, the analysis must consider the human factor and how to mitigate any consequences of human failure. Human factors may enter the design decisions regarding the process.

Clearly, process safety analysis is an important subject, and the safety and health manager should be alert to recommend that top management take this responsibility seriously. Professional analysts with recognized credentials, assigned to the process analysis team, can go a long way in establishing the good faith of the employer in this endeavor. On the other hand, the opinions of the operators and maintenance personnel, who are intimately familiar with the process, can be even more valuable to the analysis.

Care should be taken in the documentation of the process hazard analysis to make sure that significant open-ended issues are not left unresolved, for example, without a documented strategy for alleviation of the issue. If the process has a serious hazard, the documentation of that hazard constitutes "recognition" of the hazard. Remember from Chapter 4 the importance of the word "recognized" in the wording of OSHA's General Duty Clause. Especially in the event of an accident or major incident, the OSHA inspector that makes the postaccident inspection can be expected to be looking for evidence that the company "recognized" the hazard that caused "serious physical harm" to employee(s).

Recognizing the comprehensive responsibility placed on employers to develop process hazard analyses, a phased approach was specified over a 5-year period after the effective date of the standard. Then, every 5 years, the initial analyses are to be updated and evaluated to be sure that the analysis is consistent with the current process. Of course, such actions must be documented, and records must be kept for the life of the process.

OPERATING PROCEDURES

After the process information has been gathered and analyzed, the conclusions reached must be transformed into operating procedures that assure that anticipated hazards are actually dealt with. Procedures depend on the phase of the operation being addressed. It is in keeping with good safety and health practice to recognize a difference between *temporary operations* and *normal operations*. It is sometimes necessary to bypass certain automatic protection systems during *temporary* or *initial startup* operations, but it is still necessary in some alternative fashion to address the hazards that are thus uncovered. In an emergency, some processes must continue to be operated in an *emergency operate* mode. Of particular interest is the need to know under what conditions an emergency shutdown becomes necessary, and if it does become necessary, what must be done.

A key feature in the safe operation of a process is the capability to recognize when something has gone wrong. For this, a process needs to have preset limits for the variables under control. For instance, a centrifugal pump on a pipeline operates normally with a prespecified minimum suction pressure and maximum discharge pressure. Any time the pressure dips below the prescribed minimum on the intake side of the pump, an automatic shutdown becomes necessary to protect the pump. Pressure on the discharge

side in excess of prescribed limits might exceed the design limits for the pipeline. Either of these conditions can be used to trigger emergency action to avert a more serious situation, especially when dealing with hazardous chemicals. The operating plan should tell workers what the consequences of control limit deviations are, as well as what to do to bring the process back under control. Rapid-response, on-line HELP display screens are a resource for providing such information in time to be of benefit in an emergency.

TRAINING

It is well known that operating procedures are often tucked away in some ring binder that no one reads or heeds. When catastrophic release of dangerous chemicals are at stake; however, "paper plans" for process safety are simply not good enough. There must be training for personnel who are required to execute the plan. An effective training plan has four ingredients:

1. Initial training for new operators or new processes
2. Refresher training at prescribed intervals, and in any event at least every 3 years
3. Verification or testing to prove that employees understand the process and safe procedures and are current
4. Documentation to confirm that the training and testing have been carried out

One method of documentation is to have employee cards that verify their currency in the process. The problem with this strategy is that employees may lose or fail to carry the cards. Federal standards do not say that the documentation must be carried on the employee's person; an employee record that verifies the training is more appropriately kept by the employer for each employee who works with the process.

In an accident case history that underlines the importance of employee training, Case Study 6.2 will illustrate a natural result of inadequate respiratory protection, inadequate operating procedures, and inadequate training of personnel to follow these procedures.

CASE STUDY 6.2

HYDROGEN SULFIDE POISONING—FATAL ACCIDENT

A pet food processing plant in Texarkana utilized a "hydrolyzer" in a process that processes chicken feathers and converts animal byproducts into pet food. Hydrogen sulfide gas, created by the process of decaying organic matter, leaked from the machine and was inhaled by an employee at the plant in a fatal accident that occurred in 2003. OSHA charged the firm with 25 alleged violations, including a willful violation resulting in the death of the employee. The citation charged that the employer failed to provide respiratory protection to employees working near the machine. The company also failed to label hazardous chemicals and to train workers to detect such chemicals in the event of exposure due to a leak. The OSHA proposed penalties for the violations totaled $436,000 (Roberts, 2009).

CONTRACTOR PERSONNEL

This chapter began with a discussion of some major catastrophes that led to the development of the process safety standard. In the 1989 Phillips Petroleum catastrophe, some of the dead and injured workers were employed by outside contractors, not Phillips. There is no question that this catastrophe triggered a response by OSHA to include some language to protect contractor personnel in the new process safety standard, which was under preparation at that time. OSHA already had knowledge that a significant number of petrochemical and other companies were using outside contractors to perform work at their plants. In the aftermath of the Phillips catastrophe, OSHA commissioned a study by the John Gray Institute of Lamar University to study safety and health issues as they relate to contract work in the petrochemical industry.

What emerged in the OSHA standard was a requirement for the prime employer to exert a measure of control over the contract operations and conduct of contract employees. Most employers already had procedures for controlling access to their facilities by contract personnel. However, the new process safety standard required employers to check into the safety record of prospective contractor firms before contract. Information known about process hazards must be communicated to contractors as well as applicable provisions of the prime employer's emergency action plan. In addition, the prime employer is required to perform periodic evaluations to assure that the contractor is doing the job with respect to OSHA process safety standards. Perhaps the most visible requirement of all is that prime employers are required to maintain an injury and illness log for contractor employees.

Notwithstanding the new responsibilities placed on the prime employers, the contract employers are still responsible for providing safe and healthful workplaces for their own employees. Training, for instance, must still be provided by contract employers for their employees. Even for safety rules originated by the prime employer for the hazardous process, the contract employers must assure that their own employees follow the prime employer's rules.

Historically, one management strategy for dealing with difficult safety and health matters has been simply to contract away the dangerous operations or dangerous parts of an operation. The rationale behind this strategy has been to pass the responsibility for safety and health along to the contractor or subcontractor. When the OSHA inspector visits the facility, the prime contractor could thus say that OSHA did not apply because his or her own employees were not exposed to the hazard. The process safety standard, however, has removed a large proportion of the incentive for pursuing this avenue of escape from responsibility for compliance with safety and health standards.

ACTS OF TERRORISM

This chapter and the OSHA process safety standard deal with disasters and major catastrophes and how to prevent them with process planning and design. There is no doubt that the type of catastrophe represented by Bhopal, India, and the Phillips explosion and fire can be prevented, or at least mitigated, by the measures described thus far in this chapter. On September 11, 2001, however, the world was changed forever when a new type of disaster surpassed the devastation of Bhopal and Phillips combined. The

deliberate attack on the twin towers of the World Trade Center in New York City and the Pentagon in Washington, D.C., on that fateful day killed more than 3000 people.

The world sees acts of terrorism daily and suicide bombings often, but September 11, 2001, brought an unprecedented new dimension to the perception of terrorism. The September 11 attacks consisted of multiple teams of terrorists, coordinated to act on the same day and strike within minutes of each other. The origins of the strike teams that morning were in different states, and each team had several members. All of the actual strike team members were committed to suicide in four separate groups, corresponding to the four commercial airline flights that were deliberately crashed that morning in the execution of the plan. The precision and coordination of the attacks and the similarity in execution made it clear that, in addition to the actual suicide teams, there were uncounted backup supporters who had some knowledge of the strategy and its execution. The September 11 attacks were obviously not isolated, impulsive strikes by a few fanatical extremists. Rather, they were a meticulously planned, broad assault on a nation by a large and well-supported organization. The reality of September 11 forced all Americans to grapple with the potential of further coordinated attacks and a general war against terrorism that would be fought primarily in the United States. In addition to the individual shock and response, employers were forced to plan for future acts of terrorism in the form of precautionary, preventive measures, as well as disaster plans to deal with actual occurrence of potential future catastrophes on their own premises.

The solution to this grave problem, which threatens every citizen whether in the workplace or elsewhere, is not an easy one. Similarly, it is difficult to conceive an appropriate governmental and regulatory response to this type of problem. The federal agency OSHA was faced with the dilemma of the threat to thousands of workers' lives, and yet there seemed to be no readily conceivable regulation or standard that could prevent recurrence of the bloodshed. For the first time in its history, OSHA was faced with a serious threat to workers' lives and had no response that seemed to have any potential to prevent or even mitigate this hazard. OSHA citation of employers seemed absurdly inappropriate. This is not to say that OSHA did not respond to this tragedy after the fact; indeed OSHA committed a tremendous amount of resources to the aftermath of the tragedy, including dispatching emergency crews of inspectors who worked round the clock to support the cleanup operations. OSHA issued over 100,000 respirators in the first year of the cleanup (OSHA's Role at the World Trade Center Emergency Project, 2002). They also issued gloves, hard hats, and other personal protective equipment. In addition, OSHA assessed hazards to cleanup workers, taking samples and testing atmospheres, and conducted fit testing for respirators. However, despite these efforts after the fact, virtually all of the casualties of this tragedy were already beyond anyone's ability to rescue them. No OSHA standard had addressed the hazard of terrorist attack, and nothing OSHA had done could prevent this most dramatic attack on the safety of the American worker. The devastation of this attack has changed the way Americans view safety and health priorities. A new Department of Homeland Security seemed more compelling than the traditional mission of OSHA.

During and immediately after the September 11 attacks, the cameras were on the emergency responders—police and firefighters—who encouraged the nation with their heroism and devotion to duty. Much analysis and aftermath investigation would use hindsight to suggest that the emergency responders were disorganized and ineffective.

However, the public would not tolerate the use of hindsight to blame any of the heroic responders for actions or inactions in the heat of the crisis. To the contrary, the public rallied around the police and firefighters, and there was an outpouring of moral and charitable public support from across the nation. Although the rescue workers in the trenches were honored, some blame fell upon their departments for failure to support the rank and file, saying that the separate departments had a history of political competition and reluctance to share resources.

More than a year after the disastrous attacks, ideas began to emerge from thinking safety and health professionals who have pieced together remedies and steps for preparing for the worst of nightmares that could be faced in a workplace. One such thinking professional is Dr. Mark A. Friend, CSP, professor of occupational safety in the Department of Environmental Health Sciences and Safety at East Carolina University in Greenville, North Carolina. Dr. Friend, accompanied by university student researchers, visited the disaster sites at the Pentagon and in New York, where they made observations and gathered information from witnesses. Dr. Friend summarized his findings of "Lessons Learned" in *Responder Safety* (Friend, 2002). Most of the recommendations dealt with national strategies for defense against terrorist attacks, but some were steps to be taken at the employer level.

One recommendation was to "limit building access." Although many such steps have been taken around government buildings and military bases, private companies could benefit from the planning of future buildings and parking lots. Parking lots that have close proximity to buildings facilitate car and truck bombing attacks. Subtle landscaping tricks can enhance the beauty and attractiveness of company buildings and facilities while protecting the buildings from explosive blasts from car or truck bombs. The protection can take the form of restrictions to the approach of vehicles or, as in landscape berms, in limiting the blast area. A more commonly seen temporary remedy has been the grim reminder rendered by huge portable, concrete barricade structures.

In times of crisis, often the large number of volunteers overwhelms the system charged with managing the effort. The September 11 experience has shown the need for what Dr. Friend calls "incident management." Volunteers may be naïve about requirements for personal protective equipment and how to use it properly. Untrained volunteers are at risk, and when they make mistakes, sometimes they put the professionals at risk as well. In addition, some of the so-called "volunteers" are really at the site out of curiosity and can interfere with the ongoing rescue work. Preparation for major disasters includes systems for screening persons authorized to be on site and the provision of a robust system of providing and checking credentials.

There is a subtle pitfall in the plan for a state-of-the-art communication system for appropriate command and control in times of crisis. The finest computer system in the world can lose its functionality if it is not used. Therefore, it is wise to find a way to integrate sophisticated emergency information systems into daily use so that they will be operational and ready to serve in times of crisis. There is no field in which obsolescence appears more rapidly than in the computer and information systems arena. To keep a computer system operational, it must be used and updated frequently. The same can be said of the people who use the computer system.

The tragedy of September 11 was more than could be fathomed at the time of the drafting of the OSHA process safety standard. Still, some of the same steps and

procedures recommended for chemical processes subject to the hazards of catastrophic release or explosion can be used to plan for dealing with terrorist attacks. A good example is the use of "what-if" analyses, discussed earlier in this chapter. In the basic planning for chemical processes themselves, a new hazard to be considered is possible sabotage of the process by terrorists.

It remains to be seen what long-range changes to the typical workplace and to society in general will emerge from the experience of September 11, 2001. Perhaps the architectural style represented by the high-rise office building will become obsolete in time. Workweek routines and styles will likely change also. Even before the September 11 attacks, many workers had gone to flex schedules and work-at-home plans. The reasons for these changes in work styles include the laptop computer, cell phones, fax, and other technology developments that were totally independent of the terrorist attacks. In short, the American workplace is in transition. The safety and health manager's job will undergo much change in this transition, and so will the role of government enforcement agencies.

WORKPLACE SECURITY

The principal focus of this book and the traditional role of the safety and health manager have been on hazards that are accidental or at least unintended. However, Chapter 2 introduced the hazard of workplace violence and recognized the possibility that some workplace injuries might be caused by voluntary intent. Indeed, workplace violence has grown to become a leading cause of workplace fatalities. This chapter has introduced the threat of mass terrorism, a presence that can never be denied after the disastrous events of September 11, 2001. Similarly, the safety and health manager in today's world cannot deny the impact of these voluntary acts upon the safety and health of employees in the workplace. A comprehensive safety and health management plan will include steps to mitigate the hazards of intentional acts by inside employees or outside terrorists. Acts of mass terrorism result in general disasters that call for strategies similar to those recommended for process safety disasters, both in the preparation and prevention of such disasters and in the emergency and cleanup procedures that come in the aftermath of these events. The problem can also be approached from a different direction—the identification and control of persons with malevolent intent and the restriction of access by unauthorized persons, a field that is commonly known as *security*.

Is workplace security a function of safety and health management? To an increasing extent, safety and health managers are being delegated that authority, and they are responding by assuming that responsibility. A title, such as "Manager of Safety and Security," may reflect that component of the job. Responsibility for security enlarges the mission of the safety and health manager beyond the objectives of safety and health. Security encompasses protection of the company's resources, information systems, and records, in addition to protecting employees and property.

Industrial workplace security is receiving attention, but the most dramatic shooting tragedies have occurred in colleges and schools, not industrial plants. Shocking tragedies have prompted educational administrators and even state governments to place emphasis on security at college and high school campuses throughout the country. As stated in Chapter 2, the Virginia Tech tragedy was the worst in history. Other

tragic incidents were the Columbine High School shootings in Colorado, April 20, 1999 (15 dead), and the University of Texas tower shootings in Austin, Texas, on August 1, 1966 (17 dead). Colleges and schools are workplaces too, and these tragic events have served to elevate the mission of workplace security to one of prominence equal to that of workplace safety.

ACTIVE SHOOTER INCIDENTS

Much work has been done to address the topic of workplace security. From 1966 to 2012, there have been 324 active shooter incidents in the United States (Active Shooter Recommendations and Analysis for Risk Mitigation, 2012). Of these, the majority resulted in an average of 3.1 deaths and 3.9 people wounded. All but 16% of these incidents ended through application of force or attacker suicide/attempted suicide. Over recent years, anecdotal evidence suggests that incidents are increasing in number and severity.

According to a report by several leading industry groups and the Department of Homeland Security, most workplace incidents are over within 10–15 minutes and before law enforcement arrives (Active Shooter How to Respond, 2008). That means the key to surviving an incident is preparation, training, and action. The safety and health manager should have an emergency action plan that identifies how incidents are to be reported, what evacuation paths and procedures should be followed, and how to react when help arrives. This plan should be practiced regularly with training on what to do in the event of an actual incident.

Employees should be trained in the three recommended reactions to an Active Shooter Incident: evacuating the area, hiding out, and acting against the shooter as a last resort (Active Shooter How to Respond, 2008). The best way to do this training is through a simulation or drill. Employees should be taught to first attempt to use the exit. If they are unable to exit, they should find a room or area they can barricade themselves into. The key here is to remain out of sight of a potential attacker and await rescue. If this is not possible, employees should act against the shooter. It is critical that when doing so, employees take on a survival mindset and commit to their actions to incapacitate the shooter.

OSHA has stated that if conditions exist for the potential for workplace violence, the employer is responsible to recognize the hazard and put in place a program to mitigate and address the hazard. Workplace violence and active shooters are a recognized workplace hazard and cannot be ignored.

SUMMARY

Major industrial catastrophes—the shocking Bhopal disaster being the worst—alerted the world to the hazards of processes dealing with chemicals dangerous not only to plant workers, but to the general public as well. OSHA responded in the early 1990s with the Process Safety Management of Highly Hazardous Chemicals standard, which has had a major impact on industrial America, especially on chemical plants. The standard prescribes a systematic approach that includes gathering information about dangerous processes and analyzing that information to anticipate catastrophes and

deal with them in advance. The analysis draws on recognized principles of safety engineering and analysis and on chemical engineering tools such as block flow diagrams and flow process charts. Once the analysis is complete, operating procedures must be developed and a training program instituted to assure that the fruits of the analysis are implemented.

Recognizing the role of contractor personnel in chemical process tragedies that have already occurred, prime employers are being held to greater responsibility for contractor personnel as well. This facet of the process safety standard whittles away at the employer excuse that the safety of subcontract employees is not their responsibility.

In the aftermath of September 11, 2001, disasters from runaway, unsafe chemical processes have been overshadowed by the threat of terrorist attacks. Some of the precautionary steps in preparation for chemical process disasters are likewise recommended for dealing with the threat of terrorism.

EXERCISES AND STUDY QUESTIONS

6.1 What two major catastrophes in the 1980s affected national policy with respect to process safety?

6.2 When developing the database of information regarding hazardous chemical processes, what is the primary source of information regarding the chemicals themselves?

6.3 Name two types of diagrams that are recognized methods of documenting the technology of a hazardous process.

6.4 List some example hardware details of engineering designs that might be included in a documentation of process technology.

6.5 What form of analysis would be appropriate when planning for a natural disaster, such as an earthquake or tornado?

6.6 Give an example of how plant location can affect the analysis for process safety.

6.7 How is the human element considered in process safety analysis?

6.8 How would an employer benefit from employing professional analysts to analyze the safety of a process?

6.9 What is the principal advantage of using in-house operators and maintenance personnel on the process analysis team?

6.10 How can a safety and health manager win the confidence of technical committees or teams?

6.11 A company is replacing certain aspects of their manufacturing process with robotic assistance. At this point, safety measures at times are disabled. What phase of operations is occurring and what are important considerations?

6.12 Is it ever legal to bypass automatic process safety systems? If so, give an example.

6.13 Is it sometimes advisable to continue to operate a dangerous process in an emergency? Does OSHA prohibit this?

6.14 Explain how a control system can recognize when danger with a process has developed.

6.15 List the four ingredients of an effective training program for process safety.

6.16 What disadvantage is associated with an employee-held card system for documenting training for process safety?

6.17 The traditional role of prime employer and subcontractor is that the prime employer is responsible for hazards to prime employees, and subcontractors are responsible for

hazards to their own employees. How has the process safety standard changed this relationship?

6.18 Under what circumstances might an employer need to maintain an OSHA injury/illness log for persons other than their own employees?

6.19 What popular strategy have employers used to dodge responsibility for the safety and health of their employees? How has the process safety standard limited this strategy?

6.20 How has the process safety standard strengthened OSHA's ability to cite the General Duty Clause?

6.21 What is the "road-map" approach to compliance with the process safety standard and what is its principal advantage?

6.22 How might a poultry processing plant fall under the scope of the process safety standard? How might a discrete item manufacturing plant need to comply with the process safety standard?

6.23 How might a manufacturer of wrenches and tools fall under the scope of the process safety standard?

6.24 What pitfall lies in the documentation of process hazard analyses that leave significant issues open ended?

6.25 Under what circumstances might it be especially important to employ the services of a registered professional engineer in the evaluation of process equipment?

6.26 Identify the three recommended defenses against a potential shooter attack in the workplace. Which of these three should be used as a last resort?

6.27 What is the historical percentage of active shooter attacks that have ended in application of force against the shooter or in the attacker's suicide/attempted suicide?

6.28 What method is recommended for training employees to deal with attackers in the workplace?

6.29 What elements should be included in an emergency action plan for dealing with a shooter in the workplace?

6.30 What is the requirement for employers for keeping their employees safe from an active shooter?

RESEARCH EXERCISES

6.31 Check out the Internet for details regarding the Phillips Petroleum disaster in October 1989.

6.32 Study international disasters, such as Chernobyl and Bhopal. Which was worse? Are these the worst industrial disasters ever? Why or why not?

6.33 Use library resources and the format of Case Study 6.1 to gather information from standard chemical references to document the dangers associated with hydrochloric acid.

6.34 The Texas City Oil Refinery was an example of multiple process safety failures. Review the Chemical Safety Board findings and identify where these process safety failures occurred and how could they be rectified?

6.35 The Deep Water Horizon explosion had multiple causes during the startup phase of operations. What were some of these causes and how do they confirm the importance of sound operating procedures in all aspects of operations?

6.36 What were some of the process safety lessons learned from the Imperial Sugar explosion?

STANDARDS RESEARCH QUESTIONS

6.37 Identify (by OSHA standard number) the OSHA General Industry standard for Process Safety Management of Highly Hazardous Chemicals. Search the database on the

Companion Website to determine its frequency of citation. What percentage of the citations are designated as "serious?"

6.38 Search the OSHA General Industry standard for process safety for the term *training*. Determine whether training provisions of this standard are among the more frequently cited parts of the standard.

6.39 Search the General Industry standard for process safety to determine what roles for the employee or employee representative are specified in the standard. Have these provisions been cited by OSHA? If so, are any of the citations designated as "serious?"