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 MSDS. The MSDS 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

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 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

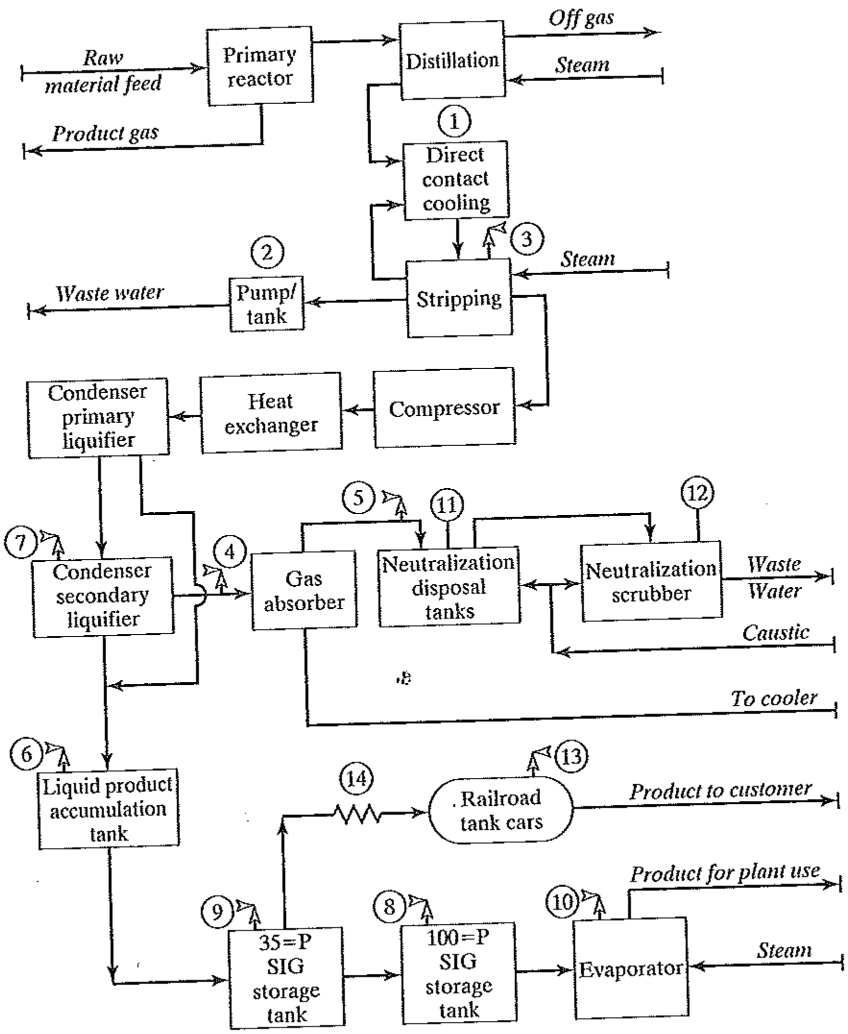

FIGURE 6.1

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

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

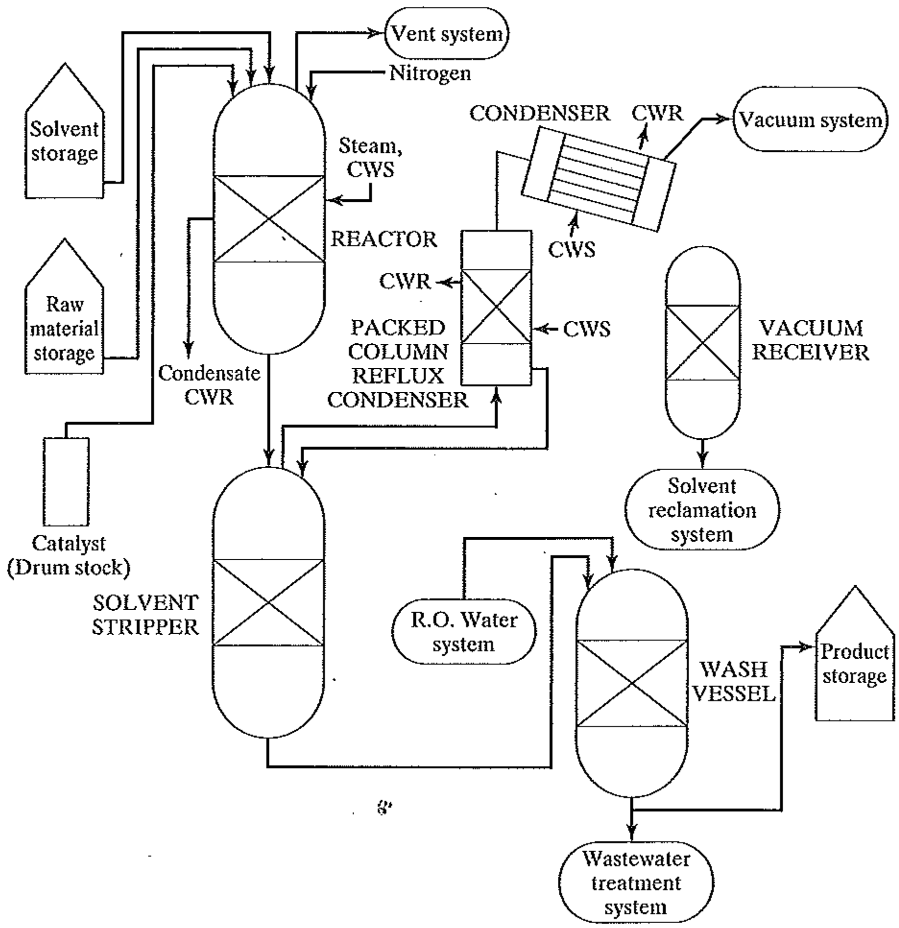

FIGURE 6.2

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

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.

ERATING 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.

INING

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 devel opment of the process safety standard. In the 1989 Phillips Petroleum catastrophe, som 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 includ some language to protect contractor personnel in the new process safety standarc which was under preparation at that time. OSHA already had knowledge that a signifi cant number of petrochemical and other companies were using outside contractors t