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Project Summary

Prevention Reference Manual: Control Technologies. Volume 1: Prevention and Protection Technologies for Controlling Accidental Releases of Air Toxics

D. S. Davis, G. B. DeWolf, and J. D. Quass

The probability that an accidental release will occur depends on the extent to which deviations (in magnitude and duration) in the process can be tolerated before a loss of chemical containment occurs. Development of a satisfactory control system and equipment capable of withstanding deviations requires adherence to sound process and physical plant design principles and to appropirate procedures and management practices.

Control of a process is achieved by manipulating the variables of flow, temperature, pressure, composition, and quantity. A control system can be improved by improving the quality, specifications, and maintenance of physical components, and by duplicating components where warranted. Process changes that enhance control of the system will reduce the probability of a chemical release.

The probability that equipment will fail and cause a release can be reduced by considering various aspects of physical plant design. Whereas process design involves process operating conditions, physical plant design involves hardware, equipment components, and their placement within a unit or plant. A third way to reduce the probability of a release is to maintain proper management practices and personnel training procedures. Finally, protection system technologies such as flares, scrubbers, and enclosures offer a last line of defense against the occurrence of accidental toxic chemical releases.

Each of these areas is discussed in terms of its relation to categories of hazards, its effectiveness in reducing the probablity of a release, and its economics of application.

This Project Summary was developed by EPA's Air and Energy Engineering Research Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

Accidental toxic chemical releases, fire, and explosion are the three types of major accidents in chemical process plants. Toxic chemical releases can occur as a result of fire or explosion, but may also occur in their absence. The purpose of preventing toxic chemical releases is to prevent harm to human health and to the environment. An accidental toxic chemical release is the final event in a sequence of events leading to the release. This chain of events can be broken by preventing the initial event or any intermediate, enabling, event from occurring. Preventing a particular acci-

dental toxic release depends on correctly identifying individual events and event chains, on knowing the relative probability of the events, and on the skill and knowledge of the individuals charged with the problem.

Preventing accidental releases means preventing the loss of primary chemical containment. The general classes of equipment that contain chemicals are vessels, piping, and process machinery. To ensure containment, a process must operate in proper sequence under acceptable conditions of temperature, pressure, and composition. Equipment must be operated within design limits defined by specifications for pressure, temperature, chemical compatibility, mechanical stresses, and the physical limits imposed by the process system.

A toxic chemical release can occur when there has been a physical breakdown of equipment or a loss of process control that leads to a breach in primary containment. The problem requires consideration of process design, physical plant design, operation, and supervision and management.

Process Design

Modifications of fundamental process chemistry, operations, and equipment can reduce the severity of operating conditions, the quantities of toxic materials, and process complexity. Such modifications can increase process control, thereby reducing the probability of an accidental chemical release. Process changes involve the principles of addition, substitution, deletion, and duplication (or redundancy). Substitution, for example, might involve the replacement of a toxic chemical with one less toxic. Each process chemical, operation, or piece of equipment should be evaluated in terms of how changes based on these principles might reduce the probability of an accidental chemical release. Process changes involve such factors as: (1) control characteristics of the process, (2) process thermodynamics and chemistry, (3) flow measurement and control, (4) pressure measurement and control, (5) temperature measurement and control, (6) quantity measurement and control, (7) mixing systems, and (8) composition measurement and control.

Adequate control of a process means maintaining the prescribed conditions for all controlled variables within the process. These variables are in turn maintained through control system action on the manipulated variables of flow, temperature, pressure, composition, and quantity. These variables are controlled by manipulating the flow of some process stream. The specified value of the controlled variable in the process system is referred to as its set point. Since deviations in variable set points can cause deviations from acceptable process conditions, they are the fundamental source of process hazards. An assessment of the probability of a toxic chemical release depends on the extent to which deviations in magnitude and duration can be tolerated before a loss of chemical containment occurs. Once these limits of control are defined, appropriate modifications that enhance control can be planned.

Major control system components include: (1) sensing and measurement, (2) controllers, (3) final control elements, (4) switches and alarms, (5) emergency shutdown and interlock systems, and (6) computer control. The effectiveness of a process control system lies in its ability to minimize the magnitude and duration of deviations in the process variables of chemistry, flow, pressure, temperature, quantity, and composition.

Physical Plant Design

Physical plant design considerations address the specific hazards caused by hardware failure, the proper design and construction of equipment to reduce those hazards, and the siting and configuration of the equipment within the process plant. A plant's safety is often determined more by the quality of the basic design than by the addition of special safety features, though such features can make an important contribution to the safety of the plant. Specific hardware-related prevention measures can be identified for reducing the probability of accidental chemical releases.

Plant equipment must be designed to avoid fire, explosion, or accidental chemical release. Numerous industry codes and standards of practice have been developed by various organizations in response to knowledge gained from actual accidents in anticipation of operating and safety problems based on technical analysis. These standards and codes should be the starting point for plant design, although many specific situations may require more stringent specifications.

Siting (the location of the process plant within a community) and layout (the positioning of equipment within the process facility) are important aspects of release prevention and control. Certain siting conditions can influence the probability of a release, such as those affected by natural disasters and climate, and also by circumstances at neighboring facilities or transportation accidents. A facility in a flood-prone area, for example, may require different types of foundations for storage tanks or process equipment. Because an accidnetal release may affect the surrounding area, location of population centers, passing traffic, waterways, and nearby businesses must be taken into consideration. Prevailing wind speed and direction and climate must also be considered when designing a facility.

A properly designed plant layout reduces the potential for and consequences of an accidental release by making it easier to operate the plant and by segregating hazardous areas within the facility. Increased distances between process units, for instance, tend to reduce the potential for and/or the effects of an accidental release. Optimum spacing arrangements provide straight, unobstructed access ways that continue from one end of a unit to the other and that connect with roads surrounding the unit. Piping associated with various utilities and process units should be segregated, and more than one escape route should be available for any location within the plant. A safe control room, located in an area of minimum risk of exposure to fires, explosions, or toxic releases, should be designed to minimize the potential for injury to employees if an accident occurs. Storage facilities should be located on no more than two sides of a processing area. Storage tanks should be located as far from nearby population centers as possible, and large inventories of hazardous chemicals should not be allowed to accumulate.

Vessels, piping, machinery, and process instrumentation must be constructed of materials appropriate to the process characteristics. Process fluid characteristics such as alkalinity, acidity, abrasiveness, and reactivity must be considered in combination with pressure and temperature extremes.

Procedures and Practices

Quality hardware, contained mechanical equipment, and protective devices all increase plant safety; however, they must be supported by the safety policies of management and by constraints on their operation and maintenance. Management policies and procedures must be designed to match the level of risk in the facilities where they will be used

The effectiveness of any safety program is determined by a company's commitment to it, as shown by the safety performance measures established, the incentives provided for attaining safety goals, and the resources committed to safety and hazard control.

Because human error is a common cause of accidental chemical releases, personnel selection and training, and the maintenance of a qualified, experienced work force is a significant part of release prevention. Signal detection, signal filtering, probability estimation, manual control, and fault diagnosis are important operator skills. The qualifications and abilities of personnel in high-hazard facilities should be greater than for those in other process facilities. Management is responsible for ensuring that adequate descriptions of standard policy and safety procedures are available and also for supporting these procedures by means of staff training programs, and by establishing operating and maintenance practices for: handling upset and emergency conditions, using safety equipment, and performing plant audits.

Emergency training includes such topics as: (1) recognition of alarm signals, (2) performance of specific safety functions, (3) use of specific equipment, (4) evacuation instructions, (5) firefighting, and (6) rehearsal of emergency situations.

Proper plant maintenance and modification procedures are necessary to ensure the integrity of chemical processing equipment and more effective production. Since these activities are also a primary source of accidental releases, proper maintenance and modification practices are an important part of accidental release prevention. Accidents frequently happen when workers incorrectly identify the equipment needing maintenance. It is essential to have positive isolation of both process materials and moving parts during maintenance activities. Permit systems and up-to-date maintenance procedures reduce the potential for accidents during maintenance operations by specifying the work to be done, defining individual responsibilities, eliminating or protecting against hazards, and ensuring that appropriate inspection and testing procedures are followed.

The potential for an accidental chemical release may also be reduced by repairing or replacing equipment that seems headed for failure. Some of the most common tests for examining equipment conditions are (1) metal thickness and integrity testing, (2) vibration testing and monitoring, and (3) relief valve testing.

Protection Technologies

The technology of protection involves equipment and systems used to capture or destroy a toxic chemical that has escaped from primary containment. Such technologies include flares, scrubbers, enclosures, and incinerators, each of which represents an addition to the basic process system it protects. The appropriate application and proper design of these systems for toxic chemicals must be evaluated on a case-by-case basis.

Flares are routinely used in the chemical process industries to dispose of intermittent or emergency emissions of flammable waste gases because they can handle larger flow variations than can process combustion devices such as boilers. Many units include venting steps to the flare system during processing. Though flares can be a useful protection against accidental releases of toxic chemicals, because of potential secondary hazards their use requires a thorough analysis of each specific application.

Scrubbers, a traditional method of absorbing toxic gases from process streams, can be used for controlling toxic gas releases from vents and pressure relief discharges, from process equipment, or from secondary containment enclosures. Absorbers are useful for protecting against accidental releases of toxic chemicals, but there may be circumstances where their use is difficult. As with flare systems, it is important to determine that use of an absorber does not exacerbate the original problem. Absorbers differ from flares in that they are often dedicated to specific units because of the diverse nature of gas contaminants and the poor turndown ratio of absorbers. The types of absorbers most applicable to accidental chemical releases are spray towers, packed towers, and venturis.

Enclosures are containment structures that can capture toxic chemicals spilled or vented from storage or process equipment, thereby preventing their immediate discharge to the environment. Enclosures contain the spilled liquid or gas until it can be transferred to other containment, discharged at a controlled rate, or transferred at a controlled rate to scrubbers for neutralization. Enclosures can be constructed around individual equipment items, process units, and entire plants, depending on the nature of the hazard being controlled. The most common procedure involves directed ventilation; e.g., fume hoods, exhaust blowers, fans, and specialized heating and air-conditioning systems. Underground storage tanks can also be used for certain applications.

D. S. Davis, G. B. DeWolf, and J. D. Quass are with Radian Corporation, Austin, TX 78766.
***T. Kelly Janes** is the EPA Project Officer (see below).*
The complete report, entitled "Prevention Reference Manual: Control Technologies, Volume 1: Prevention and Protection Technologies for Controlling Accidental Releases of Air Toxics," (Order No. PB 87-228 656/AS; Cost: $24.95, subject to change) will be available only from:

National Technical Information Service
5285 Port Royal Road
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The EPA Officer can be contacted at:

Air and Energy Engineering Research Laboratory
U.S. Environmental Protection Agency
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