United States
Environmental Protection
Agency

Air and Energy Engineering
Research Laboratory
Research Triangle Park NC 27711

Research and Development

EPA/600/S8-87/034k Feb. 1988

EPA

Project Summary

Prevention Reference Manual: Chemical Specific, Volume 11: Control of Accidental Releases of Ammonia

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

The accidental release of a toxic chemical at Bhopal, India, in 1984 was a milestone in creating an increased public awareness of toxic release problems. As a result of other, perhaps less dramatic, incidents in the past, portions of the chemical industry were aware of this problem long before Bhopal. These same portions of the industry have made advances in this areas. Interest in reducing the probability and consequences of accidental toxic chemical releases that might harm workers within a process facility and people in the surrounding community prompted the preparation of a series of technical manuals addressing accidental releases of toxic chemicals. This manual is chemically specific for ammonia. The manual summarizes information to aid regulators and industry personnel in identifying and controlling release hazards associated with ammonia.

Reducing the risk associated with an accidental release of ammonia involves identifying some of the potential causes of accidental releases that apply to the process facilities that handle and store ammonia. In this manual, examples of potential causes are identified as are specific measures that may be taken to reduce the accidental release risk. Such measures include recommendations on: plant design practices; prevention, protection, and mitigation technologies; and operation and maintenance practices. Conceptual cost estimates of example prevention, protection, and mitigation measures are provided.

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

The accidental release of a toxic chemical, methyl isocyanate, in Bhopal, India, in 1984 was a milestone in creating an increased public awareness of toxic release problems. There have been other less dramatic incidents of toxic chemical releases in the past, and the chemical industry was aware of this problem long before this event. Safety and loss prevention has long been a standard part of industry activity, and over the years industry has made many advances in this area. There is renewed interest, however, in reviewing technology and procedures for preventing, protecting against, and mitigating accidental releases.

As an aid to regulators and industry personnel charged with reducing the probability and consequences of accidental toxic chemical releases, a series of technical manuals was prepared that addresses prevention, protection, and mitigation measures for release. This chemical specific manual on ammonia is part of that series.

Ammonia is a major commodity chemical in industry. The dominant use of this chemical is in the fertilizer industry which accounts for nearly 80% of all ammonia

produced. The direct application of ammonia to the soil is, in fact, the largest single use of the chemical. The primary industrial uses of ammonia are as a raw material in the manufacture of nitric acid and as the starting material in the production of a number of commercially important synthetic materials. In addition to the primary uses mentioned above, ammonia has many other minor uses in a wide variety of industries. Some of the more common uses include neutralization (especially the treatment of acidic wastes), extraction, refrigeration, water purification, the preparation of cleaners and detergents, pulp and paper manufacture, and food and beverage treatment.

Potential Causes of Releases

At atmospheric temperatures and pressures, anhydrous ammonia is a pungent, colorless gas that may easily be cooled to a colorless liquid. Because liquid anhydrous ammonia has a large coefficient of expansion, an overpressurization hazard exists if storage vessels have insufficient expansion space or if pipelines full of liquid ammonia are sealed at both ends. In these situations, thermal expansion of the liquid and an increase in temperature can result in containment failure from the hydrostatic pressure exerted by the liquid.

Failure leading to accidental releases may be caused by process, equipment, or operational problems. Most of the accidental releases of ammonia that have occurred in the past 15 years have resulted from pressurized pipeline ruptures, failed storage tanks, and road tanker accidents.

Possible process causes of an ammonia release include:

- Loss of feed composition control resulting in the formation of ammonia/air mixtures within the flammability limits;
- Backflow of process reactants to an ammonia feed tank;
- Excess feeds in any part of a process, leading to overfilling or overpressuring of equipment;
- Loss of condenser cooling in distillation columns;
- Overheating of reaction vessels and distillation columns; and
- Overpressure in ammonia storage vessels from overheating caused by exposure to fire, or from unrelieved overfilling.

Equipment causes of accidental releases result from hardware failures such as failure of feed control systems from a loss of power, clogged lines, jammed valves, or instrument failure; from excessive stress caused by improper fabrication, construction, or installation; from failure of pressure relief systems; from mechanical and thermal fatigue and shock; from corrosion of equipment constructed of high alloys; and from brittle fracture or creep failure. A significant concern for anhydrous ammonia is use of the proper alloy grade of steel. Certain grades of steel are prone to catastrophic failure due to cracking or embrittlement from anhydrous ammonia.

Operational causes of accidental releases result from incorrect procedures and human error. These include: overfilled storage vessels; improper process control system operation; errors inloading and unloading; poor quality control of replacement parts; inadequate maintenance, especially of pressure relief systems and other preventive and protection devices; and lack of inspection and nondestructive testing of vessels and piping to detect weakening from corrosion.

Hazard Prevention and Control

Prevention of accidental releases relies on the proper design, construction, and operation of facilities where ammonia is stored and used and on the protective systems that guard against an accidental release.

Process design involves the basic chemistry of a process and how this chemistry is affected by the variables of flow, pressure, temperature, composition, and quantity. Any aspect of a process may be modified to enhance the integrity of the system. Such changes could involve the quantities of materials, process pressures and temperatures, the sequence of operations, process control strategies, and the instrumentation used.

The most important consideration for systems containing ammonia is the prevention of overheating and/or overpressuring. In addition to overpressure, overheating can also weaken process equipment and increase the probability of leaks developing at joints and valves.

Physical plant design covers equipment, siting and layout, and transfer/transport facilities. Dry ammonia is noncorrosive to most common metals; however, moist ammonia corrodes copper, tin, zinc, and many alloys, especially copper alloys. Only specific grades of steel, recommended for ammonia service, should be used due to the cracking or embrittlement problem mentioned previously. Certain aluminum alloys can be used in parts of ammonia systems. Metallic and nonmetallic gasket materials (e.g., compressed asbestos, graphited asbestos, carbon steel or stainless steel spiral-wound asbestos, and aluminum) are considered suitable for ammonia service based on current industry practice.

The siting and layout of any facility handling ammonia and of individual equipment should be designed to reduce personnel exposure in the event of a release. Siting should allow ready ingress and egress and take advantage of barriers that reduce release exposures. Considerable distance between large inventories and sensitive receptors is desirable. The ground under process equipment and storage vessels should be sloped so that fire water and liquid spillages flow away from equipment into drains. Storage facilities should be located in cool, dry, well-ventilated areas.

Because heat causes significant thermal expansion of ammonia, piping, storage vessels, and other equipment should not be located adjacent to piping containing flammable materials, hot process piping and equipment, or other sources of direct or radiant heat. Special consideration should be given to the location of furnaces and other permanent sources of ignition in the plant.

Two types of protection technologies for containment and neutralization include enclosures and scrubbers. Enclosures would capture ammonia spilled or vented from storage or process equipment, containing the spilled liquid or gas until it could be transferred to other containment and discharged at a controlled rate or to water scrubbers for absorption.

Scrubbers can also be used for controlling ammonia releases. Because of its high solubility, ammonia discharges can be absorbed in water in scrubbing devices such as spray towers, packed bed scrubbers, and venturis.

If an accidental release occurs, mitigation technologies can reduce the consequences. Such measures include physical barriers, water sprays and fogs, and foams that will divert, limit, or disperse the released chemical to the atmosphere. In spite of the lower specific gravity of pure ammonia vapor relative to air, large accidental releases of ammonia have often formed ammonia/air mixtures that are denser than the surrounding atmosphere. The primary means of dispersing and removing ammonia vapor from the air is with water sprays or fogs. A "capture zone" can be created downwind of the release into which the ammonia vapor will drift and be absorbed.

Since accidental releases of toxic materials result not only from deficiencies of design but also from deficiencies of operation, safe operation of plants using ammonia requires competent, experienced managers and staff trained in the proper way to handle and store ammonia.

D. Davis, G. DeWolf, J. Quass, and M. Stohs are with Radian Corporation, Austin, TX 78766.
***T. Kelly Janes** is the EPA Project Officer (see below).*
The complete report, entitled "Prevention Reference Manual: Chemical Specific, Volume 11. Control of Accidental Releases of Ammonia," (Order No. PB 87-231262/AS; Cost: $18.95, subject to change) will be available only from:
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650
The EPA Officer can be contacted at:
Air And Energy Engineering Research Laboratory
U.S. Environmental Protection Agency
Research Triangle Park, NC 27711

United States
Environmental Protection
Agency

Center for Environmental Research
Information
Cincinnati OH 45268

U.S. OFFICIAL MAIL
U.S. POSTAGE

Official Business
Penalty for Private Use $300

EPA/600/S8-87/034k

0000329 PS

U S ENVIR PROTECTION AGENCY
REGION 5 LIBRARY
230 S DEARBORN STREET
CHICAGO IL 60604