Appendix C

Hazards of Ammonia Releases at Ammonia Refrigeration Facilities (Update)

August 2001
United States Environmental Protection Agency
Office of Solid Waste and Emergency Response (5104A)
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This Appendix is the complete EPA Alert document developed to assist and contribute to the protection of human health and to the prevention of ammonia releases to the environment.

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Chemical Safety
ALERT

Hazards of Ammonia Releases at Ammonia Refrigeration Facilities (Update)

The Environmental Protection Agency (EPA) is issuing this *Alert* as part of its ongoing effort to protect human health and the environment by preventing chemical accidents. We are striving to learn the causes and contributing factors associated with chemical accidents and to prevent their recurrence. Major chemical accidents cannot be prevented solely through regulatory requirements. Rather, understanding the fundamental root causes, widely disseminating the lessons learned, and integrating these lessons learned into safe operations are also required. EPA publishes *Alerts* to increase awareness of possible hazards. It is important that facilities, State Emergency Response Commissions (SERCs), Local Emergency Planning Committees (LEPCs), emergency responders, and others review this information and take appropriate steps to minimize risk. This document does not substitute for EPA's regulations, nor is it a regulation itself. It cannot and does not impose legally binding requirements on EPA, states, or the regulated community, and the measures it describes may not apply to a particular situation based upon the circumstances. This guidance does not represent final agency action and may change in the future, as appropriate.

Problem

Anhydrous ammonia is used as a refrigerant in mechanical compression systems at a large number of industrial facilities. Ammonia is a toxic gas under ambient conditions. Many parts of a refrigeration system contain ammonia liquefied under pressure. Releases of ammonia have the potential for harmful effects on workers and the public. If the ammonia is under pressure, risk of exposure increases since larger quantities of the refrigerant have the potential for rapid release into the air. Also, some explosions have been attributed to releases of ammonia contaminated with lubricating oil. This Alert further discusses these potential hazards and the steps that can be taken to minimize risks. This Alert should be reviewed by personnel who operate and maintain refrigeration systems, managers of facilities, and emergency responders (e.g., haz mat teams).

Accidents

A number of accidental releases of ammonia have occurred from refrigeration facilities in the past. Releases result from a number of situations that include plant upsets leading to over pressure conditions and lifting of pressure relief valves; seal leaks from rotating shafts and valve stems; refrigerant piping failures due to loss of mechanical integrity from corrosion; physical damage of system components from equipment collisions; hydraulic shock; and hose failures that occur during ammonia deliveries. Some of these incidents have led to injury and fatalities on-site as well as causing adverse off-site consequences. In addition to risks of personal injury, ammonia releases have the potential of causing significant collateral damage including: product loss due to ammonia contamination, interruption of refrigeration capacity, product loss due to refrigeration interruption, and potential for equipment and property damage resulting from the incident. In many cases, ammonia releases have resulted in multi-million dollar financial losses. The Factory Mutual Loss Prevention Data Bulletin 12-61 describes several incidents with property damage ranging from $100,000 to $1,000,000 per incident. The following describes several recent incidents in more detail.

One type of accident that is easily preventable is equipment failure due to physical impact. In a 1992 incident at a meat packing plant, a forklift struck and ruptured a pipe carrying ammonia for refrigeration. Workers were evacuated when the leak was detected. A short time later, an explosion occurred that caused extensive damage, including large holes in two sides of the building. The forklift was believed to be the source of ignition. In this incident, physical barriers would have provided mechanical protection to the refrigeration system and prevented a release.

Another incident highlights the need for an adequate preventive maintenance program and scheduling. In a 1996 incident involving a cold storage warehouse facility, compressor oil pressure progressively dropped during a long weekend. The low oil pressure cutout switch failed to shutdown the compressor leading to a catastrophic failure as the compressor tore itself apart. A significant release of ammonia ensued. Periodically testing all refrigeration-related safety cutout switches is absolutely necessary to minimize the likelihood of such incidents.

Two other incidents illustrate the potential for serious effects from accidental releases from ammonia refrigeration systems, although the causes of these releases were not reported. In a 1986 incident in a packing plant slaughterhouse, a refrigeration line ruptured, releasing ammonia. Eight workers were critically injured, suffering respiratory burns from ammonia inhalation, and 17 others were less severely hurt. A 1989 ammonia release in a frozen pizza plant led to the evacuation of nearly all of the 6,500 residents of the town where the plant was located. The release started when an end cap of a 16-inch suction line of the ammonia refrigeration system was knocked off. Up to 45,000 pounds of ammonia was released, forming a cloud 24 city blocks long. About 50 area residents were taken to hospitals, where they were treated with oxygen and released, while dozens of others were treated with oxygen at evacuation centers.

Hazard Awareness

Ammonia is used widely and in large quantities for a variety of purposes. More than 80% of ammonia produced is used for agricultural purposes; less than two percent is used for refrigeration. Ammonia can safely be used as a refrigerant provided the system is properly designed, constructed, operated, and maintained. It is important to recognize, however, that ammonia is toxic and can be a hazard to human health. It may be harmful if inhaled at high concentrations. The Occupational Safety and Health Administration (OSHA) Permissible Exposure Level (PEL) is 50 parts per million (ppm), 8-hour time-weighted average. Effects of inhalation of ammonia range from irritation to severe respiratory injuries, with possible fatality at higher concentrations. The National Institute of Occupational Safety and Health (NIOSH) has established an Immediately Dangerous to Life and Health (IDLH) level of 300 ppm for the purposes of respirator selection. Ammonia is corrosive and exposure will result in a chemical-type burn. Since ammonia is extremely hygroscopic, it readily migrates to moist areas of the body such as eyes, nose, throat, and moist skin areas. Exposure to liquid ammonia will also result in frostbite since its temperature at atmospheric pressure is –28°F.

The American Industrial Hygiene Association (AIHA) has developed Emergency Response Planning Guidelines (ERPGs) for a number of substances to assist in planning for catastrophic releases to the community. The ERPG-2 represents the concentration below which it is believed nearly all individuals could be exposed for up to one hour without irreversible or serious health effects. The ERPG-2 for ammonia is 200 ppm. EPA has adopted the ERPG-2 as the toxic endpoint for ammonia for the offsite consequence analysis required by the Risk Management Program (RMP) Rule under section 112(r) of the Clean Air Act.

In refrigeration systems, ammonia is liquefied under pressure. Any liquid ammonia released to the atmosphere will aerosolize producing a mixture of liquid and vapor at a temperature of –28°F. The released ammonia rapidly absorbs moisture in the air and forms a dense, visible white cloud of ammonium hydroxide. The dense mixture tends to travel along the ground rather than rapidly rising. This behavior may increase the potential for exposure of workers and the public.

Although pure ammonia vapors are not flammable at concentrations of less than 16%, they may be a fire and explosion hazard at concentrations between 16 and 25%. Mixtures involving ammonia contaminated with lubricating oil from the system, however, may have a much broader explosive range. A study conducted to determine the influence of oil on the flammability limits of ammonia found that oil reduced the lower flammability limit as low as 8%, depending on the type and concentration of oil (Fenton, et al., 1995).

An important property of ammonia is its pungent odor. The threshold concentration at which ammonia is detectable varies from person to person; however, ammonia can be usually detected at concentrations in the range of 5 ppm to 50 ppm. Concentrations above about 100 ppm are uncomfortable to most people; concentrations in the range of 300 to 500 ppm will cause people to leave the area immediately.

Hazard Reduction

The Chemical Accident Prevention Group of EPA's Region III (Pennsylvania, Maryland, Virginia, West Virginia, Delaware, and the District of Columbia) has been evaluating facilities in Region III with ammonia refrigeration systems to gather information on safety practices and technologies and to share its knowledge with these facilities. Region III has conducted more than 135 chemical safety audits from 1995 to the present of both large and small facilities using ammonia for refrigeration. In addition, over the past 2 years, Region III has conducted 32 Risk Management Program (RMP) audits of ammonia refrigeration systems to ensure compliance with the RMP rule and 17 General Duty Clause inspections of systems that are not covered by the RMP regulation but had a near miss incident. (A brief explanation of the General Duty Clause and the RMP Rule is found in the Statutes and Regulations Section of this *Alert*). To share their findings from the audits, including both the deficiencies observed and the actions that facilities are taking to increase safety, Region III has made presentations to the Refrigerating Engineers and Technicians Association (RETA). This Alert is intended to communicate these findings to a wider audience.

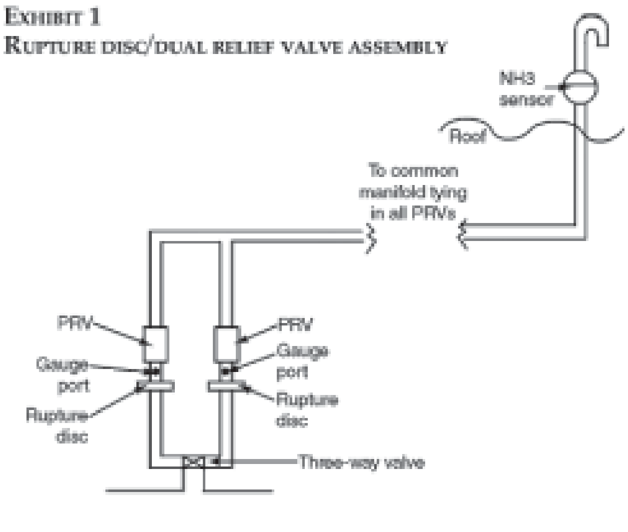
Ammonia refrigeration facilities should be aware of the potential hazards of ammonia releases and of the steps that can be taken to prevent such releases. They should be prepared to respond appropriately if releases do occur. Here are steps that ammonia refrigeration facilities could take to prevent releases and reduce the severity of releases that do occur:

- Establish training programs to ensure that the ammonia refrigeration system is operated and maintained by knowledgeable personnel. Some organizations that provide ammonia refrigeration education and training are listed in the Training Resources Section of this *Alert*.

- Consider using a spring-loaded ball valve (dead-man valve) in conjunction with the oil drain valve on all oil out pots (used to collect oil that migrates into system components) as an emergency stop valve.
- Develop and require refrigeration maintenance personnel to follow written, standard procedures for maintaining the system including such routine procedures as oil draining. Consider developing in-house checklists to guide maintenance personnel while they execute these procedures.
- Remove refrigeration oil from the refrigeration system on a regular basis. Never remove oil directly from the refrigeration system without pumping down and properly isolating that component.
- Provide barriers to protect refrigeration equipment, i.e., lines, valves, and refrigeration coils, from impact in areas where forklifts are used. Consider integrating ammonia refrigeration awareness and discussion of the risks of forklift accidents that can lead to ammonia releases as part of a formal forklift driver training program.
- Develop and maintain a written preventive maintenance program and schedule based on the manufacturers recommendations for all of the refrigeration equipment. The preventive maintenance program should include, but not be limited to:
    - a) compressors
    - b) pumps
    - c) evaporators
    - d) condensers
    - e) control valves
    - f) all electrical safety(s), including
        - 1) high pressure cutouts
        - 2) high temperature cutouts
        - 3) low pressure cutouts
        - 4) low temperature cutouts
        - 5) low oil pressure cutouts
        - 6) automatic purge systems
    - g) ammonia detectors
    - h) emergency response equipment, including,
        - 1) air monitoring equipment
        - 2) self-contained breathing apparatus (SCBA)
        - 3) level A suit
        - 4) air- purifying respirators.
- Perform regular vibration testing on compressors. Document and analyze results for trends.
- Maintain a leak-free ammonia refrigeration system. Investigate all reports of an ammonia odor and repair all leaks immediately. Leak test all piping, valves, seals, flanges, etc., at least four times a year. Some methods which can be used for leak testing are sulfur sticks, litmus paper, or a portable monitor equipped with a flexible probe.
- Consider installing ammonia detectors in areas where a substantial leak could occur or if the facility is not manned 24 hours/day. The ammonia detectors should be monitored by a local alarm company or tied into a call-down system. Ensure that the ammonia detectors are calibrated regularly against a known standard. Check the operation of ammonia sensors and alarms regularly.

- Replace pressure relief valves (PRVs) on a regular schedule (consult ANSI/IIAR Standard 2 — Equipment, Design, and Installation of Ammonia Mechanical Refrigerating Systems); document replacement dates by stamping the replacement date onto each unit's tag.
- Replace single PRVs with dual relief valve installations. A dual relief valve installation consists of one three-way shut-off valve with two pressure safety relief valves. The required use of dual relief valves (based on the size of the vessel to be protected) is outlined in ASHRAE Standard 15 — Safety Code for Mechanical Refrigeration. Consider how the use of dual relief valve installations may facilitate the replacement, servicing, or testing of PRVs on a regular schedule — a three-way valve allows one PRV to be isolated while the other remains on-line to protect the vessel. This setup allows each PRV to be serviced, tested or replaced on a regular basis without the need to pump down the system.
- For large systems with many PRVs, consider using the arrangement shown in Exhibit 1 for detecting leakage. This arrangement includes installation of a rupture disc upstream of each PRV with a gauge port or transducer in between the disc and PRV and installation of an ammonia sensor in the PRV common manifold. In case of leakage from a PRV, the sensor would set off an alarm. A check of either the pressure gauge or transducer signal would permit easy identification of which PRV has popped.
- Ensure that the ammonia refrigeration system is routinely monitored. Consider using a daily engine room log, recording process parameters (e.g., temperature and pressure levels) and reviewing the log on a regular basis. Consider having the chief engineer and the refrigeration technician sign the daily engine room log. In designing new systems or retrofitting existing systems, consider the use of computer controls to monitor the process parameters.

Exhibit 1
Rupture disc/dual relief valve assembly



- Keep an accurate record of the amount of ammonia that is purchased for the initial charge to the refrigeration system(s) and the amount that is replaced. Consider keeping a record of the amount of lubricating oil added to the system and removed from the system.
- Ensure that good housekeeping procedures are followed in the compressor/recycle rooms.

- Ensure that refrigeration system lines and valves are adequately identified (e.g., by color coding or labeling) by using an inhouse system.
- Properly post ammonia placards (i.e. NFPA 704 NH3 diamond) and warning signs in areas where ammonia is being used as a refrigerant or being stored (for example, compressor room doors). Properly identify the chemicals within the piping system(s); label all process piping, i.e. piping containing ammonia, as “AMMONIA.” Label must use black letters with yellow background. (This requirement is not the same as the in-house color coding system.)
- Periodically inspect all ammonia refrigeration piping for failed insulation/ vapor barrier, rust, and corrosion. Inspect any ammonia refrigeration piping underneath any failed insulation systems for rust and corrosion. Replace all deteriorated refrigeration piping as needed. Protect all un-insulated refrigeration piping from rust and/or corrosion by cleaning, priming, and painting with an appropriate coating.
- Carry out regular inspections of emergency equipment and keep respirators, including air-purifying and self-contained breathing apparatus (SCBA), and other equipment in good shape; ensure that personnel are trained in proper use of this equipment. For SCBA, it is important to ensure that air is bone dry. For air-purifying respirators, replace cartridges as needed and check expiration dates.
- Consider using the compressor room ammonia detector to control the ventilation fans.
- Identify the king valve and other emergency isolation valves with a large placard so that they can easily be identified by emergency responders, in case of an emergency. These valves should be clearly indicated on the piping and instrumentation diagrams (P&IDs) and/or process flow diagrams.
- Establish emergency shutdown procedures and instructions on what to do during and after a power failure.
- Consider installing a solenoid valve in the king valve line operated by a switch located outside of the compressor/recycle room.
- Establish written emergency procedures and instructions on what to do in the event of an ammonia release.
- Regularly conduct emergency response drills. Emergency response personnel should “suitup” as part of the drill process. As needed, members of the hazmat team should regularly suit-up to sharpen their emergency response skills.
- Stage a realistic emergency response spill exercise with the local fire company.
- Mount a compressor room ventilation fan manual switch outside of the compressor room and identify it with a placard for use in an emergency. Good practice would be to have ventilation switches located outside and inside of each door to the compressor room.
- Mount windsocks in appropriate places and incorporate their use into the facility emergency response plan. In addition to the emergency response plan, consider developing additional materials (posters, signs, etc.) to provide useful information to employees and emergency responders in case of an emergency. In developing emergency information, consider whether materials should be developed in languages other than English.

- Keep piping and instrumentation diagrams (P&IDs), process flow diagrams, ladder diagrams, or single lines up-to-date and incorporate them into training programs for operators. A good suggestion is to laminate the P&ID and ladder diagrams and post nearby to the equipment.
- Frost accumulates on evaporator coils. The evaporator can be "soft gassed" during the defrost cycle by placing a smaller hot gas solenoid valve in parallel with the main hot gas solenoid valve. The smaller valve is sequenced to open first; thereby, allowing the evaporator pressure to rise slowly. An alternative approach is to use a motorized full port ball valve in the hot gas supply line and open it slowly initially to accomplish the soft gassing. Once the pressure in the evaporator is brought up, then fully open the valve. For additional information, consult IIAR's *Ammonia Refrigeration Piping Handbook*.

References

Factory Mutual. 1993.
Loss Prevention Data Bulletin 12-61 (April 1993).

Fenton, D.L., K.S. Chapman, R.D. Kelley, and A.S. Khan. 1995. "Operating Characteristics of a flare/oxidizer for the disposal of ammonia from and industrial refrigeration facility." *ASHRAE Transactions*, 101 (2), pp. 463-475. Atlanta, GA: American Society of Heating, Refrigeration, and Air-Conditioning Engineers.

IIAR. 2000. *Ammonia Refrigeration Piping Handbook*

Education and Training Resources

Garden City Community College: offers hands-on training oriented toward operators of industrial ammonia refrigeration systems and PSM/RMP implementation classes.
801 Campus Drive
Garden City, KS 67846
Tel: (620) 276-9520
www.nh3gccc.com

Industrial Refrigeration Consortium (IRC) at the University of Wisconsin-Madison: this university-industry partnership offers educational opportunities and refrigeration-related resources.
949 E. Washington Avenue, Suite 2
Madison, WI 53703
Tel: (608) 262-8220
(866) 635-4721 Toll-free
www.irc.wisc.edu

International Institute of Ammonia Refrigeration (IIAR): offers ammonia refrigeration-related educational videos, short course, and an annual conference.
1110 North Glebe Road, Suite 250
Arlington, VA 22201
Tel: (703) 312-4200
www.iiar.org

Refrigeration Engineers Technicians Association: offers self-study materials and a tiered certification/evaluation program for refrigeration technicians/mechanics.
700 W. Lake Avenue
Glenview, IL 60025-1485
Tel: (847) 375-4738
www.reta.com

Information Resources

General References

OSHA has a web site with information on ammonia refrigeration and process safety: www.slc.oshaslc.gov/SLTC/ammoniarefrigeration/index.html

CEPPO has prepared a general advisory on ammonia (OSWER 91-008.2 Series 8 No. 2), available at: www.epa.gov/ceppo/acc-his.html.

Industrial Refrigeration Consortium (IRC) Headquartered at the University of Wisconsin-Madison, the IRC is a university-industry partnership aimed at improving safety, efficiency, and productivity of industrial refrigeration systems and technologies. The IRC conducts applied research, offers refrigeration training, and provides technical assistance to refrigeration end-users. The IRC maintains a website with additional information and resources related to ammonia refrigeration at: www.irc.wisc.edu.

Statutes and Regulations

The following are a list of federal statutes and regulations related to process safety, accident prevention, emergency planning, and release reporting.

EPA

Clean Air Act (CAA)

- General Duty Clause [Section 112(r) of the Act] — Facilities have a general duty to prevent and mitigate accidental releases of extremely hazardous substances, including ammonia.
- Risk Management Program (RMP) Rule [40 CFR 68] — Facilities that have anhydrous ammonia in quantities greater than 10,000 pounds are required to develop a hazard assessment, a prevention program, and an emergency response program. EPA has developed a model guidance to assist ammonia refrigeration facilities comply with the RMP rule.

Emergency Planning and Community Right-to-Know Act (EPCRA)

- Emergency Planning [40 CFR Part 355] — Facilities that have ammonia at or above 500 pounds must report to their LEPC and SERC and comply with certain requirements for emergency planning.
- Emergency Release Notification [40 CFR Part 355] — Facilities that release 100 pounds or more of ammonia must immediately report the release to the LEPC and the SERC.
- Hazardous Chemical Reporting [40 CFR Part 370] — Facilities that have ammonia at or above 500 pounds must submit a MSDS to their LEPC, SERC, and local fire department and comply with the Tier I/ Tier II inventory reporting requirements.

- Toxic Chemicals Release Inventory [40 CFR Part 372] — Manufacturing businesses with ten or more employees that manufacture, process, or otherwise use ammonia above an applicable threshold must file annually a Toxic Chemical Release form with EPA and the state.

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)

- Hazardous Substance Release Reporting [40 CFR Part 302] — Facilities must report to the National Response Center (NRC) any environmental release of ammonia which exceeds 100 pounds. A release may trigger a response by EPA, or by one or more Federal or State emergency response authorities.

OSHA

- ***Process Safety Management (PSM)*** Standard [29 CFR 1910] Ammonia (anhydrous) is listed as a highly hazardous substance. Facilities that have ammonia in quantities at or above the threshold quantity of 10,000 pounds are subject to a number of requirements for management of hazards, including performing a process hazards analysis and maintaining mechanical integrity of equipment.
- ***Hazard Communication*** [29 CFR 1910.1200] — Requires that the potential hazards of toxic and hazardous chemicals be evaluated and that employers transmit this information to their employees.

**For additional information, contact OSHA Public Information at (202) 219- 8151.
Web site: http://www.osha.gov**

Codes and Standards

There are a number of American National Standards Institute (ANSI) Standards available for refrigeration systems. Some examples are given below.

ANSI/ASHRAE Standard 15-1994 — Safety Code for Mechanical Refrigeration

Available for purchase from the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) International Headquarters, 1791 Tullie Circle, NE, Atlanta, GA 30329-2305. Customer service: 1-800-527-4723

ANSI/IIAR 2-1992 — Equipment, Design, and Installation of Ammonia Mechanical Refrigeration Systems

Available from the International Institute of Ammonia Refrigeration (IIAR)
1110 North Glebe Road
Suite 250
Arlington, VA 22201
(703) 312-4200
Web site: http://www.iiar.org

ISO 5149-1993 — Mechanical Refrigerating Systems Used for Cooling and Heating — Safety Requirements

Available from the American National Standards Institute (ANSI)
11 West 42nd Street
New York, NY 10036
(212) 642-4900
Web site: http://www.ansi.org

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