The Locomotive

Ammonia Refrigeration in Cold Storage Facilities

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In A Brief History: Ether to Ammonia
In 1834, the first vapor compression refrigeration machine, that actually worked, was built. Jacob Perkins, an American living in England, was the builder and he charged the machine with ether. Perkins’ machine used the four basic parts found in every mechanical refrigeration system in use today:

- Compressor
- Condenser
- Expansion valve
- Evaporator

From these simple beginnings, today’s modern refrigeration systems were developed. They utilize design principles, materials of construction and controls that allow us to successfully store and distribute foodstuffs throughout the world marketplace. For large cold storage facilities, ammonia has become the refrigerant of choice because it produces the greatest net refrigerating effect (btu/lb), and often the lowest brake horsepower per ton of refrigeration (BHP/TR) of any industrial refrigerant.

Although ammonia is considered to be toxic, its irritating odor will give early warning to personnel to evacuate an area where concentrations are high. Depending on temperature and humidity, humans can detect ammonia vapors in air at concentrations as low as 20 parts per million (ppm). Moderate irritation to the nose begins at about 100 ppm, with major irritation at 400 ppm. Unless incapacitated in some other way, humans will generally quickly evacuate any area where an ammonia leak or spill has occurred before immediate danger to life and health (IDLH) levels are reached.
Cold Storage Facilities
The demand for convenience foods in the United States has resulted in the construction of millions of square feet of both public and private cold storage facilities. These cold storage “warehouses” will have freezers and coolers dependent on ammonia refrigeration systems to control temperatures within the spaces to maintain product quality and freshness until shipped. With modern rack storage, it is not unusual to find product values in excess of $10 million stored at one facility.

The newest storage facilities utilize multi-level, fully automated storage and retrieval systems, and allow for a smaller footprint (square feet) to store high volumes (cubic feet) of product. The primary concern of any facility owner using ammonia refrigeration must be the safety of employees, although preservation of product, especially when high values are stored, should also be carefully considered.

Ammonia has a high affinity for moisture, and is readily absorbed by many materials. Even though modern ammonia refrigeration systems are designed to avoid any accidental release of ammonia, leaks and spills continue to occur each year, causing injuries, deaths and loss of millions of dollars in product. A visit to the Chemical Safety Board website (www.chemsafety.gov/circ) will emphasize the need for the owners of facilities using ammonia to consider the condition of their system. Emergency response plans, regardless of how well written or comprehensive they may be, will be ineffective if they are not practiced. Each employee must understand what his or her role will be in an emergency, and be ready to properly implement the plan when needed. Any leak or spill can injure employees and easily damage many thousands, or even millions of dollars worth of product in storage. Even with insurance in place, the financial impact to a facility owner can be devastating. What can be done to minimize the probability of a leak or spill? How can the effects of a leak or spill be minimized?

Codes and Standards
Today’s refrigeration systems include hundreds or thousands of feet of piping and large vessels containing ammonia vapor and liquid. There are established Codes and Standards to help define the materials and methods of construction. For ammonia piping, the American Society of Mechanical Engineers (ASME) Code B31.5 – Refrigerant Piping should be consulted. Vessels used in refrigeration systems should be built in accordance with ASME Section VIII – Unfired Pressure Vessel Code.

In order to maintain the “mechanical integrity” of a system built to accepted Codes and Standards, qualified personnel must be used for any repairs, especially welded repairs, or other modifications to the system. ANSI/IIAR Standard 2 published by the International Institute of Ammonia Refrigeration (IIAR) is designed to serve as a guide to the design, manufacture, installation and use of ammonia mechanical refrigeration systems. The IIAR (www.iiar.org) publishes many standards, guidelines and technical papers dedicated to the safe and efficient use of ammonia refrigeration.

Photo: The Industrial Refrigeration Consortium - University of Wisconsin at Madison
A facility owner will most often depend on an experienced refrigeration engineer or contractor to be familiar with the applicable Codes and Standards for ammonia refrigeration systems. For this reason, careful selection of qualified, experienced engineers and contractors is needed when a new system is to be built, or repairs or modifications to an older system are being considered. A fully documented commissioning process should be completed before start up of new systems. IIAR Bulletin 109 – Guidelines for: Minimum Safety Criteria for a Safe Ammonia Refrigeration System can be used for inspection and documenting mechanical integrity of both new and existing ammonia refrigeration systems.

Qualified Operators
While having a system properly built to accepted Codes and Standards could go a long way towards insuring a system will have a high degree of mechanical integrity, any system that is improperly operated can fail. The benefits of having qualified, trained refrigeration system operators are many. Well-trained operators can help assure efficient operation of the system and will often recognize system problems before a failure occurs. Facilities unwilling to invest in training and keeping their refrigeration system in good condition are the most likely to experience an accidental release.

Facilities with ammonia refrigeration systems with a charge above 10,000 lbs will fall under the Occupational Safety and Health Administration (OSHA) Process Safety Management (PSM) and U.S. Environmental Protection Agency (EPA) Risk Management Planning (RMP) regulations, which require formal documentation of training for operators. Owners of smaller systems will also have responsibility for maintaining a system in good operating condition under OSHA’s “General Duty Clause” which states:

“(a) Each employer –

(1) shall furnish to each of his employees employment and a place of employment which are free from recognized hazards that are causing or are likely to cause death or serious physical harm to his employees.”

There are many good training resources available. Organizations such as the IIAR, Refrigerating Engineers & Technicians Association (RETA – www.reta.com), and the Industrial Refrigeration Consortium (IRC – www.irc.wisc.edu) are good sources for training courses designed to promote efficient design and operation of ammonia refrigeration systems.

Planning for Emergencies
Having a system with good mechanical integrity operated by well-trained personnel will certainly minimize the probability of an accidental leak or spill, but there are no guarantees that your facility will not have an accident. Failures related to product movement in the facility (impact damage) can occur if piping or system evaporators are unprotected. In rack storage, pallet space in the vicinity of system components should utilize mechanical stops or other means to avoid the possibility of impact from forklift operations.

Over years of operation, a system can be subject to corrosion, erosion, upsets, vibration and other conditions that may result in a leak or spill. As noted earlier, safety of employees will be of primary concern. Evacuation routes need to be planned, and designated employees will have responsibility for assuring proper evacuation and contacting emergency response personnel. One of the hardest questions to answer for any facility owner will be “who will respond to an ammonia leak or spill?” If employees will respond, they will require proper training and equipment to help locate and isolate any leak or spill. Various OSHA regulations define the level of training required and Hazard Communications requirements. Having employees properly trained and equipped as “first responders” will aid in quickly isolating a leak or spill, and the safe shutdown of the system.

Due to the toxic nature of ammonia, many facility owners will depend on local fire departments or HAZMAT teams to respond to an ammonia leak or spill. This may be effective for protecting employees, but it increases the probability of a large release and significant loss of product in storage. Facility owners need to consider the overall impact a large release can have on their operations. Interruption of business, loss of business, damage to brand name,
inadequate insurance limits, and OSHA and EPA citations can add up to be financially devastating to a facility owner.

**Controlling Leaks and Spills**

In addition to notification of key facility and emergency response personnel, a good emergency plan should include ammonia leak/spill control procedures such as isolation of the area, ammonia liquid supply lines as needed, and shut down of the refrigeration system. Cleanup and neutralizing procedures should also be defined. Emergency response personnel should be familiar with the Material Safety Data Sheet (MSDS) for anhydrous ammonia. Ventilation and cold-water spray neutralization are two common methods to minimize contamination. Water should not, however, be sprayed directly on liquid ammonia.

![Photo: The Industrial Refrigeration Consortium - University of Wisconsin at Madison](image)

Actual procedures will vary according to facility layout, the type of product in storage and how it is packaged. For product that is sealed in plastic, there may be good opportunities for salvage. In other cases, repackaging costs may be too high or not possible if a regulating agency such as the U.S. Food and Drug Administration (FDA) or U.S. Department of Agriculture (USDA) condemns product. Properly isolating product that may be contaminated, defining and documenting test procedures will be very important aids to any salvage efforts. Location of possible alternate storage facilities and a plan for moving product out of a contaminated area should also be included in your plan.

**Ammonia Detection and Isolation**

Many factors can affect how well an emergency response plan will be executed. Emergency plans need to be routinely practiced, and employees need to be fully aware of their responsibilities in order for the plan to be effective. Emergency response personnel need to be familiar with your facility layout and the location of refrigeration equipment.

Another strategy facility owners should consider when formulating an effective emergency response plan for a leak or spill is installation of an ammonia detection system. Although early system designs were prone to nuisance trips, a well-planned and designed system today can be very effective in controlling the amount of vapor or liquid lost in an accidental release. You should start by defining exactly what you expect the ammonia detection system to do. This will depend on the facility layout and type of product in storage.

If, for example, the facility consists of only one or two large freezers, isolation at the main liquid supply or “king” valve located at the outlet of the main receiver and automatic system shutdown should be considered. If, however, your facility has several smaller rooms with only one or two evaporators per room, branch line liquid supply isolation while keeping the system in operation to avoid spoilage of product may be appropriate. In general, any isolation strategies that will help minimize the volume of a leak or spill and avoid loss of the entire system charge should be considered.

**Ammonia Sensors**

The type of product and its susceptibility to contamination (high, low, moderate) should be considered when trying to determine the type of sensor, setting and location of individual ammonia sensors. Environmental conditions also need to be considered. In grape storage, for example, fumigation with sulfur dioxide can be very detrimental to some types of ammonia sensors. Manufacturers’ literature should be consulted for any limitations of their particular sensor or system. For product such as fresh fruit in
“controlled atmosphere” (CA) storage where oxygen is reduced to very low levels, sensors that can reliably detect low levels (15 ppm or less) may be required.

Ammonia sensing cards (color change) capable of detecting ammonia levels in the 1-5 ppm range are also available as an early warning for product that is highly susceptible to ammonia contamination. The cards are inexpensive and will revert to original color in the absence of ammonia. They should not, however, be considered as a replacement for a well-designed ammonia detection and isolation system. If a sampling type ammonia detection system is used, measures should be taken to keep the sampling intervals as low as possible (under 15 minutes). Sampling systems will require a higher level of maintenance and more frequent checks to assure they will properly respond to a leak or spill.

Other than sound audible and/or visual alarms, you will need to decide what additional functions should be activated by the ammonia detection system, and at what level. Because oil used in refrigeration systems is designed to easily mix with the refrigerant, and oil traps are not 100 percent effective, some oil carryover will occur. This lowers the normal flammability limit of anhydrous ammonia (16 percent to 25 percent by volume in air) because it is now a mixture of oil and ammonia. For a machine room, a setting of 100 ppm to 200 ppm may be appropriate, with automatic activation of ventilation fans to aid in keeping the concentration below flammable limits. For freezers used to store packaged frozen foods, 50 ppm is a common setting.

While electrochemical sensors are the most common type of sensor in use, other sensor technologies such as infrared, solid state, polymer film and semi-conductor sensors can help increase sensor life while decreasing maintenance costs and requirements. The facility owner, system operators and maintenance personnel should become knowledgeable in the operation and design of their ammonia detection and isolation system. Because this can be a very complex subject to address, various industry sources should be consulted.

The Instrument Society of America has published ISA-RP 92.03.02-1999 (Installation, Operation and Maintenance of Ammonia Detection Instruments (25-500 ppm Full Scale) as an aid in selection, operation and maintenance of ammonia detection systems. When you consider the fact that the investment required to purchase and install a well-designed ammonia detection system is often less than 1 percent of the value of product in storage, the reasons for not making such an investment can quickly disappear.

In Summary
Mechanical refrigeration systems using ammonia have been with us for many years. For the most part, they log many hours of reliable operation without incident. Cold storage facility owners need to fully assess the overall impact an ammonia release can have on their operations, and who will respond to isolate and clean up a leak or spill. Having well-trained operators can help promote efficient operation of your ammonia refrigeration system and identification of system operating problems before failures occur.

Systems with a high degree of mechanical integrity will reduce the probability of a leak or spill, but are no guarantee against an accidental release. Having a well planned, written emergency response plan that is routinely practiced and improved can minimize the effect of any leak or spill that may occur. An automatic ammonia detection and isolation system can enhance your response plan by controlling the size of accidental releases, often for an investment that is less than 1 percent of product value stored at your facility.

About the Author
James Brogan, an industry consultant with HSB Inspection Services in Denver, received an Associate in Risk Management (ARM) designation from the Insurance Institute of America. He specializes in loss control and risk management issues associated with heating, air conditioning and refrigeration equipment and systems.