Property Risk Consulting Guidelines

X[L] Risk Consulting

A Publication of AXA XL Risk Consulting

PRC.7.2.1.2

AMMONIA HAZARDS

INTRODUCTION

The use of ammonia for cooling applications dates back to the middle of the 1800's. By the early 1900's the use of ammonia as a refrigerant was largely perfected in a closed cycle of evaporation, compression and condensation. Since then, the entire food distribution chain has come to depend on the thermodynamic properties of this crucial refrigerant. Today, Ammonia remains the refrigerant of choice for large industrial applications. In today's large refrigeration systems ammonia has many advantages;

- Ammonia costs less. Not only is ammonia significantly cheaper than the least expensive halocarbons, but because the density of ammonia is half of all halocarbons, only half as much material is required in the system.
- Ammonia (R-717) is more efficient since the mass flow rate of a given capacity is one-seventh that of HCFC-22. This means that only one-seventh of the liquid needs to be pumped for a given refrigeration capacity. The heat transfer and thermodynamic properties are highly advantageous and provide cost savings.
- Ammonia requires smaller vapor line pipe sizes for large systems spread over a large area due to less drop in saturation temperatures compared to Freon.
- Ammonia systems are more tolerant of water contamination than Freon systems. Water concentrations of less than 100 ppm cause no adverse effects to ammonia system operation.

Governmental & Regulatory Standards

Ammonia refrigeration systems present a unique hazard exposure to facilities and surrounding communities. Most countries regulate the storage and handling of ammonia. In Canada, ammonia is regulated under the Occupational Health and Safety Act and Regulations; the Public Safety Act and the Boiler, Pressure Vessel and Compressed Gas Regulations, and the CSA B52 Mechanical Refrigeration Code. In Germany it is regulated by the Federal Clean Air Act (BImSchG), Ambient Air Emission Decree (Immissionsschutzverordnung), and Accident Decree (Störfallverordnung). In Japan the High Pressure Gas Safety Act regulated ammonia. In the US, the regulations are covered by the Occupational Safety and Health Administration (OSHA) Process Safety Management (PSM) regulation 29 CFR Part 1910.119 and the Environmental Protection Administration's (EPA) Risk Management Program 40 CFR Part 68.

This document provides basic guidelines for safe operations from a property loss prevention perspective for anywhere in the world. If the local government has stricter regulations, then they apply. In the US, systems exceeding 10,000 lbs. (4540 kg) of ammonia, are subject to OSHA's regulation 29 CFR Part 1910.119 and the EPA's 40 CFR Part 68. Both of these regulations require hazard review, mechanical integrity, emergency response and operator training. Regardless of

Copyright© 2020, AXA XL Property Risk Consulting

Global Asset Protection Services, LLC, AXA Matrix Risk Consultants S.A. and their affiliates ("AXA XL Risk Consulting") provide loss prevention and risk assessment reports and other risk consulting services, as requested. In this respect, our property loss prevention publications, services, and surveys do not address life safety or third party liability issues. This document shall not be construed as indicating the existence or availability under any policy of coverage for any particular type of loss or damage. The provision of any service does not imply that every possible hazard has been identified at a facility or that no other hazards exist. AXA XL Risk Consulting does not assume, and shall have no liability for the control, correction, continuation or modification of any existing conditions or operations. We specifically disclaim any warranty or representation that compliance with any advice or recommendation in any document or other communication will make a facility or operation safe or healthful, or put it in compliance with any standard, code, law, rule or regulation. Save where expressly agreed in writing, AXA XL Risk Consulting and its related and affiliated companies disclaim all liability for loss or damage suffered by any party arising out of or in connection with our services, including indirect or consequential loss or damage, howsoever arising. Any party who chooses to rely in any way on the contents of this document does so at their own risk.

AXA, the AXA and XL logos are trademarks of AXA SA or its affiliates © 2020 AXA SA or its affiliates.

whether or not they are subject to these regulations, the principles of process safety management provide useful tools and guidelines to safe design, maintenance and operation of these facilities.

Ammonia Data

Ammonia (NH_3) is a colorless gas in lower concentrations. In higher concentrations it can form a white cloud. An extremely pungent odor is detectable from 5 parts per million (ppm) and becomes irritating at 25 ppm. Anhydrous ammonia is the compound formed by the combination of the two gaseous elements, nitrogen and hydrogen, in the proportion of one part of nitrogen to three parts of hydrogen by volume. Since one volume of nitrogen weighs fourteen times as much as one volume of hydrogen, on a weight basis, the ratio is fourteen parts of nitrogen to three parts of hydrogen, or about 82% nitrogen and 18% hydrogen. At atmospheric temperature and pressures, anhydrous ammonia is a pungent colorless gas. Anhydrous ammonia boils at -28°F (-33°C) and freezes to a white crystalline mass at -108°F (-77.78°C). When heated above its critical temperature of 270.3°F (132.4°C) ammonia exists only as a vapor regardless of the pressure. Between the melting and critical points, liquid ammonia exerts a vapor pressure which increases with rising temperature. When liquid ammonia is in a closed container, it is in equilibrium with the ammonia vapor and the pressure within the container bears a definite relationship to the temperature.

Liquid anhydrous ammonia is lighter than water as it has a density of 42.57 lb/ft³ at -28°F (681.9 kg/m³ at -33°C). As a vapor, ammonia is lighter than air, and its relative density is 0.597 compared to air at atmospheric pressure and a temperature of 32°F (0°C). In vapor form, a pound of ammonia vapor occupies a volume of 20.78 ft³ (0.59 m³). At 70°F (21°C) and at atmospheric pressure, one pound (0.45 kg) of ammonia vapor occupies a volume of 22.5 ft³ (0.64 m³) and yields 45 ft³ (1.27 m³) of dissociated gas at a ratio of 25% nitrogen and 75% hydrogen.

Because of its great affinity for water, care must be taken in the storage and handling of ammonia to keep it dry. “Anhydrous” means “without water”. When ammonia gas is dissolved in water, the resulting material is ammonium hydroxide or “aqua” ammonia. The two materials should not be confused. Most common metals are not affected by dry ammonia. Moist ammonia will not corrode iron or steel, but will react rapidly with copper, brass, zinc and many alloys, especially those containing copper. Only steel or ductile iron should be used for ammonia containers, valves, fittings and piping. Under normal conditions, ammonia is a very stable compound. It takes excessive temperatures from about 840°F to 930°F (449°C to 499°C) to cause it to dissociate slightly at atmospheric pressure. When this happens, the dissociated products are nitrogen and hydrogen. Ammonia gas burns in a mixture with air within a very small range. The flammable limits at atmospheric pressure are 15% to 28% by volume of ammonia in air. Experiments conducted by Underwriters Laboratories indicate that an ammonia-air mixture in a standard quartz bomb will not ignite at temperatures below 1562°F (850°C).

Ammonia is generally a stable product. It reacts with oxidizing agents and strong acids. Contact with chlorine, bromine, iodine and hypochlorite can be explosive. Ammonia and most acids will react with a great amount of heat given off during the neutralization. Ammonia will ignite in contact with nitric acid vapors.

Fire and Explosion Data of Ammonia

Ammonia is classified as a toxic gas, a moderate fire exposure and an explosive hazard in the proper concentrations. The flammable gas concentrations are defined between the Lower Explosive Limit (LEL) of 15% (150,000 ppm) and the Upper Explosive Limit (UEL) of 28% (280,000 ppm). This is particularly important in an enclosed area. Presence of oil will increase the fire hazard or lower the LEL to as low as 8% (80,000 ppm) in some studies. Use large volumes of water until well after the fire is out to significantly dilute the ammonia. Keep fire-exposed containers cool. Pressurized containers can rupture when overexposed to heat. The DOT Classification for ammonia is a Non-flammable gas. Remember that Ammonia goes through hazardous decomposition at temperatures above 850°F (454°C) where hydrogen and nitrogen are given off which could possibly result in an explosion.

Health Hazards of Ammonia

Humans are very sensitive to the effects of ammonia. The eyes, mucus membranes, lungs, and skin are the first sensory receptors to react to presence of ammonia. Ammonia is corrosive to all body tissues. In liquid form, ammonia causes severe burns and frostbite on contact. Levels of hazard to human health are as follows:

- At exposure levels of 5 ppm ammonia is hardly detectable.
- At 20 ppm ammonia can have a distinct odor but can be tolerated.
- At 100 ppm ammonia can now be very noticeable and somewhat discomforting when inhaled.
- At 500 ppm ammonia will be irritating to the throat, lungs, mucus membranes, skin and eyes. A breathing apparatus is needed at these levels for exposures over a very short duration.
- At 1000 ppm or 0.1%, ammonia is extremely toxic. Cartridge gas mask required.
- At exposure levels above 2000 ppm, death may occur in less than 30 min.

OSHA has set forth regulations covering the maximum exposure employees can be subject to. The following is a list of maximum exposures.

Permissible Exposure Limit Time for a Weighted Average (PEL/TWA) for ammonia is not to exceed 50 ppm in an 8 h day. A positive pressure self contained breathing apparatus (SCBA) is required for entry into ammonia atmospheres at or above 300 ppm in accordance with 29CFR 1910.134. The National Institute of Occupational Safety and Health (NIOSH) threshold is set at 35 ppm.

Threshold Limit Value on a Time Weight Average (TLV-TWA) is the concentration a normal employee can repeatedly operate under for a normal 8 h day and a 40 hour week without any adverse effects. This TLV-TWA is set at 25 ppm.

Immediately Dangerous to Life and Health (IDLH) set point is 300 ppm. This is the maximum concentration from which an unprotected person is able to escape the area with in 30 min with out dramatic health effects.

TLV/IDLH or LC50 (Lethal Concentration 50) is greater than 5000 ppm for 30 min.

The main effects on a human starts with the eyes where under low concentrations the ammonia gas may cause irritation. In high concentrations, it could cause damage to the eyes, which then could cause blindness. It should be noted that contact lenses should not be worn with gas or liquid present. If your eyes are affected by the ammonia gas flush them with water immediately for at least 15 min, particularly under the eyelid and seek a physician immediately. When ammonia gas is inhaled above the TLV, it may cause irritation to nose, throat and lungs. More significant concentrations can cause uncontrolled coughing, lung congestion, vomiting and pulmonary edema.

If ammonia is inhaled, seek fresh air immediately and call your doctor. Accidental exposure to the skin can cause skin irritations, especially if the skin is moist. Direct liquid contact to the skin creates extreme burns and frostbite. The skin area exposed to ammonia should be flushed with water for at least 15 min and as always see your physician.

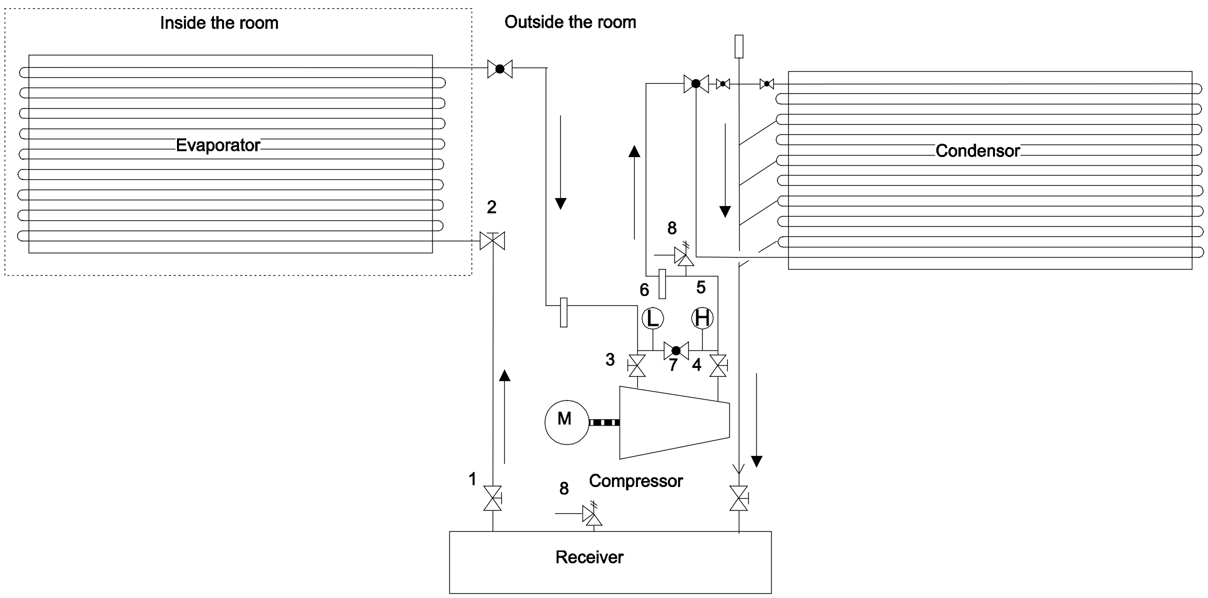
Anytime the ammonia refrigeration system is opened to the atmosphere or whenever there is the possibility of exposure, utilize proper ammonia leak procedures. Always assume something will happen. Put on your Personal Protective Equipment (PPE), open up the system and if there is no ammonia present, then it is safe to remove the PPE.

The minimum PPE for an ammonia leak or spill is a full face piece air purifying respirator, and a pair of ammonia rated gloves. For exposures between TLV and IDLH, use a full-face piece cartridge/canister air-purifying respirator. NEVER use a face shield or goggles for ammonia. They are not suitable for keeping the ammonia gas from exposing you the hazardous effects of the gas. They will only get you hurt. It is highly recommended to use a full face piece air purifying respirator.

For situations that are above the IDLH, use a positive pressure with supplied air respirator, and a totally encapsulating positive pressure chemical suit.

The Ammonia System

Anhydrous ammonia is classed as a Group 2 (B2) refrigerant by ANSI/ASHRAE-15. This code includes requirements pertaining to the location of equipment, permissible quantities of refrigerants, and rules for the installation and protection of various kinds of refrigerating systems. The typical ammonia system (see Figure 1) for refrigeration purposes consists of a compressor designed to compress the low pressure ammonia gas leaving the evaporator to a pressure of approximately 150 psi (10 bar). The gas is then discharged into the condenser. When ammonia gas is under a pressure of 150 psi (1 MPa) (10 bar), it will liquefy at a temperature of 78°F (25°C). Therefore, if water is at a temperature of 70°F (21°C) or less, and is circulated through pipes in the condenser, then the gas will liquefy and give off its latent heat to the water. The liquid ammonia in the condenser is then stored in a receiver or accumulator tank and from there it is allowed to flow out through a small pipe to the expansion coils or evaporator. Located on this pipe is a valve which controls the amount of liquid passing through the system. As soon as the liquid passes through this valve the pressure is greatly reduced so that the liquid vaporizes and reverts again to a gas, and therefore it absorbs heat from the surrounding atmosphere of the room which becomes colder. If the coils are placed in a water tank, then the water is chilled. When the ammonia has absorbed sufficient heat to be converted to a low pressure gas and liquid, it will then flow back to the compressor and the operation is repeated.



1 = King Valve or Liquid valve
2 = Expansion valve
3 = Suction valve
4 = Discharge valve
5 = Discharge or High pressure gauge
6 = Suction or low pressure gauge
7 – Bypass valve
8 = Relief valve

Figure 1: Typical Ammonia Refrigeration System

Compressors used in ammonia refrigeration plants are heavy duty reciprocating type and occasionally high capacity centrifugal types. They are more frequently found in newer systems using rotary type compressors. Older reciprocating systems can be either electric motor or steam turbine driven in the higher capacity systems. Most new systems are electric motor driven. Ammonia refrigeration systems are particularly common in the food industries due to the efficiency and economy of large scale systems. With increasing restrictions on halocarbon use due to their atmospheric ozone depletion effects, ammonia will be appearing in more places.

Anhydrous Ammonia Storage Tank Location and Design

Stationary storage tanks for anhydrous ammonia are regulated by the US Department of Labor and must conform to the requirements of 29 CFR1910.111. They are built in accordance with the ASME Boiler and Pressure Vessel Code and are rated for 250 psig (17.25 bar). Tanks should be located outdoors but more commonly are found in the ammonia engine room. All pipe and hose connections to the tank are protected by excess flow valves to prevent massive leakage in the event of a catastrophic line break. Relatively high flows are required to cause these valves to close so it should be noted that a downstream break may not always result in sufficient flow to close the valve. The pressure gauges on the tank are usually equipped with isolating valves which can be closed in the event of a gauge failure. Most ammonia storage tanks are equipped with a dual safety relief valve system consisting of two safety relief valves mounted on a three-way valve. The design of the three-way valve permits shutting off one or the other, but not both, of the relief valves and allows for the replacement of either of the relief valves without emptying the tank. Either relief valve alone is sized to adequately protect the tank. There are different designs for three-way valves. The “Shank” design has a hand wheel. As you are facing the hand wheel, to shut off the right hand safety you should turn the hand wheel counter clockwise. To shut off the left hand safety valve you should turn the wheel clockwise. The hand wheel should be left in full counter-clockwise position so that the valve stem packing and the right hand safety relief are isolated from the tank pressure. In the “Frick” or “Henry” design valves are of the “in-line” type and may have a conical cap covers in the valve stem. If the valve is of this type, the valve stem has flat sides on it and a wrench must be used. Use caution when removing the cap as it may be under a slight pressure. Turning the valve stem clockwise will shut off the safety relief furthest from the valve stem. Turning the stem counter clockwise will shut off the safety relief nearest the valve stem. The valve should normally be left in the full counter clockwise position so that the valve stem packing is isolated from the tank pressure as in the “Shank” design.

The ammonia tank content is determined by means of a float gauge which reads in percent of the total tank capacity. The gauge dial is usually on the top of the tank; however, it may be located at one end of a horizontal tank. When a float gauge is mounted on a 1,000 gal (265 L) tank and the reading is 60%, then the tank would contain 600 gal (159 L) of ammonia. Since ammonia weights 5 lb/gal (599 kg/m^3) at 60°F (15.6°C), this would be equivalent to 3,000 lb (1360 kg) in the tank. Do not confuse this gauge with the pressure gauge. The pressure gauge would read the same whether there is 200 gal or 800 gal (53 L or 211 L) in the tank. A storage tank is usually considered to have an 85% usable capacity. That means that a 15% vapor space must always be maintained when filling an ammonia tank to allow for expansion. This is similar to the capacity requirements of a liquid propane tank.

Leak Detection Systems

To minimize the effects of ammonia release on products, detection systems need a capability for alarm and detection much below LEL levels (15 percent — 150,000 ppm [150,000 mg/lit]). For prevention of contamination, the instrument should be sensitive and reliable in the 50 – 100 ppm (50 – 100 mg/lit) range. The instrument also should be reliable in refrigerated areas where moisture condensation and freezing situations are possible. Location and spacing of detectors in refrigerated areas or machine rooms will require adoption of the manufacturer’s guidelines. The best advice is to put detectors in the vicinity of potential leaks. This would be mostly near the chillers in the refrigerated areas. In machine rooms a more widespread distribution would be needed due to numerous leak sources. An old machine room may have typical normal levels in the 25 – 50 ppm (25 – 50 mg/lit) range due to older equipment leakage. This background level would affect the setting of alarm levels and could possibly affect detector sensitivity. Maintenance of the detection system will require frequent calibration, at least monthly. Actual operating experience might indicate a need for more frequent calibration. Calibration of the equipment should only be done by those trained for the operation and following detailed instructions.

Pressure Components

Construct the pressure vessels, piping and other components of a refrigeration system to meet the requirements of ANSI/ASHRAE 15. This code specifies that Section VIII, Division I of ASME Boiler and Pressure Vessel Code be used for pressure vessels with an internal diameter in excess of 6 in.

(150 mm) and that piping comply with ASME/ANSI B31.5. For new installations and systems modifications, where feasible, install the ammonia piping, fittings, valves, etc. outside of storage rooms in ventilated areas. Some jurisdictions may require that 100% of the piping be visible and accessible.

Support and protect piping, heat exchangers and other system pressure vessels against mechanical damage. Select pipe and fittings of the proper rating and materials for the particular service and protected them against vibrational forces from the compressors. Do not use cast-iron fittings for service with flammable or toxic refrigerants. Do not use aluminum, zinc, or magnesium with methyl chloride; magnesium with halogenated materials; or copper and copper alloys with ammonia.

Ensure piping is in accordance with ASME/ANSI B31.5, Article 514, (Refrigeration Piping). Installations shall comply with the following guidelines.

- All threaded joints should be seal welded or brazed.
- Use welded or flanged joints between piping and fittings over 1 in. (2.54 cm) diameter.
- Provide all refrigerant piping passing through walls or floors with sleeves to protect the piping from abrasion and provide a means for inspection. In addition, where ammonia is the refrigerant, seal piping penetrations with UL Listed fire barrier component to prevent leakage.

LOSS PREVENTION

Protection for the ammonia engine room can be extensive as we will see in the protection features listed below. Loss history with ammonia consists of explosive hazards, fire hazards and contamination to food products.

Construction of the Ammonia Engine Room

If possible, construct the ammonia engine room as a separate building, 50 ft (15.25 m) from any production or warehousing operation. If not possible, construct the room with a 1 h fire resistance rated fire barrier wall between the engine room and other building areas. Protect all wall openings by single ¾ hour rated automatic-closing fire doors having a maximum temperature rise of 250°F (121°C) in 30 min.

Provide the room with explosion venting capability through lightweight wall or roof assemblies or through windows designed for this purpose. See **Explosion Venting** section below and NFPA 68 for additional information.

Install electrical wiring and equipment suitable for Class I, Division 2 locations throughout the entire Engine Room in accordance with the provisions in NFPA 70, Article 500.

Exhaust-Ventilation Arrangement

Many older facilities have ordinary electrical switchgear and equipment within the engine rooms. Therefore, In lieu of the Class I Division 2 electrical requirement ventilation becomes very critical as most explosions and fires are initiated by electrical equipment as the source. Therefore, provide ceiling level mechanical exhaust system capable of providing two exhaust rates and the following features:

- Continuous exhaust rate of 1 cfm/ft² (3.28 m³/min/m²) of room area. The loss of ventilation should alert employees with an alarm condition.
- Emergency exhaust rate of 10 cfm/ft² (32.8 m³/min/m²) of room area with a minimum of 20,000 cfm regardless of room size. The emergency exhaust system should initiate at 25% LEL (approximately 4% by room volume & no more than 1000 ppm). Alarms should initiate to alert employees. The emergency exhaust system should be manually “bump tested” quarterly by maintenance employees to confirm proper ramp up and operation. Annually a full comprehensive test should be conducted to confirm proper operation.

- If LEL levels reach 50% all power (excluding the exhaust fans) to the engine room should automatically shut down. This entire arrangement should be automated and reliance on manual activation avoided. Power exhaust fans from a separate source than the engine room components.

The function of engine room ventilation is categorized as normal non-emergency ventilation and as emergency ventilation. Proper ventilation is needed to maintain the engine room under negitive pressure and enhance the effectiveness of the ammonia detection system. Ventilation is also needed to provide fresh air for the engine room occupants and reduce the excessive temperatures that can be crated by the engine room machinery. Emergency ventilation is used to purge the engine room of ammonia vapors and help prevent ammonia vapor concentrations from reaching explosive ranges. This can significantly reduce the possibility of an engine room deflagration. The intake and exhaust fans should be far enough apart that the intake is not drawing from the exhaust air.

Arrange the ammonia detection system to maintain a 24 hr back-up power supply capacity. Provide testing, inspection & maintenance including monthly alarm tests and periodic calibration per manufacturer's instructions. If an air sampling type ammonia detection system is provided, set the sampling cycle not to exceed 30 min. Ammonia vapor is colorless and lighter than air and will ride to the ceiling area of the engine room in most cases. However, when the vapor is mixed with water vapor in the engine room the mixture will form a "white cloud" and seams to fall to the floor. It is therefore recommended to place the ammonia sensing detection system near the midpoint or slightly higher elevation to capture the first hints of an ammonia leak.

Locate a remote emergency shut down device along the egress path of the Engine Room. If all else fails, the operator can activate the device from this remote location to shut down the compressor and to activate the emergency ventilation.

Automatic Sprinkler Protection

Protect the ammonia engine room with an automatic sprinkler systems designed to provide a design density of 0.20 gpm/ft² (8.14 L/min/m²) over a 3000 ft² (279 m²) area utilizing K-5.6 (K-8.0) sprinkler rated at 286°F (141°C). Even though the room is constructed of non combustible material, most machinery rooms contain substantial amounts of combustible insulation around piping and vessels particularly accumulators. There are also vessels containing up to several thousand gal (liters) of combustible liquids such as glycol.

Explosion venting

Construct the ammonia engine room of non-combustible walls capable of providing explosion venting In the event that lightweight (2.5 lb/ft² (0.12 kPa) vent panels are used, they should release at an internal pressure of 20 lb/ft² (0.96 kPa). Provide lightweight vent panels with fasteners to prevent the panels from becoming missiles during a venting occurrence. Provide a venting ratio of a least 1:30 (1 ft² (1 m²) of venting for every 30 ft³ (9 m³) of room volume).

Design interior walls to be pressure resistive and construct the walls vapor tight to prevent the walls from explosively venting. Interior doors and frame assemblies should have the same fire rating as the walls. Rated doors should be self closing, tight fitting and open into the engine room. Seal all penetrations with a listed vapor tight sealant.

Leak Detection and Alarms

Most modern ammonia refrigeration systems are now computer operated and requires initial set-up parameters to be set in the software. This is when the operational set points are detailed and the alarm set points are generated. Many older systems are either manually operated or only partially computerized. As with any refrigeration system, safety devices are an important part of the operation of the overall system. Many different devices are used to perform different tasks during the course of a normal day. Appropriate safety devices are essential for safe operation under normal and abnormal operating conditions.

Float switches have been used in the industry for many years, and have become very sophisticated over the years. Many of these devices control refrigeration levels as well as on and off functions and the operation of solenoid valves and regulators. There are way too many types of controls to mention here but just be aware that the entire system must function with all safety controls and devices working properly.

Refrigerant leaks can be a problem in any refrigeration system. Mechanical seals as well as valve packing can fail and allow ammonia to vent into the atmosphere. In other situations, leaks are no so noticeable and can be difficult to find in large ammonia system. Leaks can occur around the bonnets and stem packing of valves, sight glasses, various seals, and around back pressure regulators. Other leaks or failure can be from refrigerant piping failures due to mechanical integrity from corrosion, physical damage of system components from equipment collisions, hydraulic shock, and hose failure mainly occurring during filling operations. Maintenance employees should be aware of main control valve shut offs and accessibility should be easily available. Arranging automatic closing valves on ammonia circulation lines when detectors actuate is a prevailing practice in modern facilities.

Below is a summary of items to evaluate in regards to mechanical integrity:

- Pipe failure due to vibration or mechanical damage
- Pipe failure due to electrolytic corrosion between dissimilar metals
- Valve failure due to impurities lodging in the valves
- Compressor failure due to non-compressible liquids in the compressor suction
- Faulty valves allowing higher than normal range operating pressures.

There are several types of leak detection devices. There are soap solutions, Litmus paper, sulfur stick and electrochemical detectors to name the most common types.

Soap Solution: This is probably one of the oldest types of methods to check for leaks on portions of the system that are above atmospheric pressure. A variety of soap solutions are available that when applied to the suspected leak area the ammonia will from a bubble at the leak site.

Litmus Paper: Another simple way to detect ammonia leaks is with litmus paper. The litmus paper will change color in the presence of ammonia. The paper must be first dampened or wetted slightly and then placed around the possible leak site the paper color from a light pink to a bright red depending on the severity of the leak.

Sulfur Stick: This is another widely used method of detection ammonia leaks. The sulfur stick will emit a smoke plum and distinct sulfur smell when the leak is detected. The sulfur stick is very useful when the leak is hard to find in an out of the way locations. This method of finding ammonia leaks is somewhat more difficult than other leak detection methods and the operator must be well trained to use this method. The main draw back from this method is the ammonia can be flammable under specific conditions and the use of a flaming sulfur stick may not be the best application of detection. The other drawback is that most operators would rather smell ammonia than the sulfur smell produced from the process. The stick has a strong lingering order even after testing and has a tendency to leave a bad taste in the mouth for several days after the testing.

Electrochemical detectors: A more sophisticated type of ammonia detection is to use sniffer or electrochemical type ammonia detector. Electrochemical detectors are specifically designed to sniff out the specific chemical you need such as ammonia. There are very few interfering chemicals that could give you a false reading. Electrochemical detectors are limited to either a 0 to 300 ppm or a 0-1000 ppm range. These types of detectors can find the smallest leaks that are hard to find from other diction methods such as the litmus paper or sulfur sticks.

Piping and Instrumentation Diagrams

Facilities should maintain complete and accurate piping and instrumentation diagrams (P&IDs) of the ammonia refrigeration system and the equipment manufacturer's documentation. A P&ID is a set of drawings or detailed schematics that illustrate all components such as vessels, valves, pumps, piping, pressure relief valves and other major components of the refrigeration system. Manufacturer's documentation should describe the operation and control features which are integral to the process. Operating procedures, operation and maintenance checklists, daily logs, a facility's management plan, and emergency response materials should all relate to the information found in the manufacturer documentation and on the facility's P&IDs. Unfortunately, many facilities have P&IDs that lack critical elements, or do not represent the current operating configuration and system components. These omissions can cause operating errors, delay efforts to minimize an ammonia release, and further increase the risks to emergency responders. P&IDs should also be carefully and completely verified while tracing ammonia throughout a facility. Construction changes, system renovations and repairs, and draftsman errors all contribute to inaccuracies in P&IDs. Many facilities find that P&ID verification coupled with a line-and-valve-labeling project is a very cost effective housekeeping project. Ladder/logic diagrams should then be prepared from the verified P&IDs and electrical drawings for all system components.

The following is essential P&ID information:

- All process chemical-containing equipment (e.g., pressure vessels, compressors, condensers, evaporators, pumps);
- Essential valves (e.g., pressure reducing valves, isolation valves, remotely operated valves, control stations);
- Controls (e.g., regulators, float switches, solenoid valves, temperature and pressure cutoffs, emergency release cutoff valves);
- Permanent instruments and sensors (e.g., pressure transducers, meters, gauges);
- Equipment and valve numbers;
- Permitted-flow direction on all check valves;
- Piping sizes, reducers, and block valves; and
- Legend of symbols and abbreviations, including date of issue and series of revisions.

Hazard Reduction

Ammonia refrigeration facilities should be aware of the potential hazards of ammonia releases and of the steps that can be taken to prevent these types of 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:

1. Establish training programs to ensure that the ammonia refrigeration system is operated and maintained by knowledgeable personnel.
2. Consider using a spring-loaded ball valve (dead-man valve) in conjunction with the oil drain valve on all oil out ports (used to collect oil that migrates into system components) as an emergency stop valve. 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.
3. Provide barriers to protect refrigeration equipment, i.e., ammonia lines, valves, and refrigeration coils, from impact in areas where forklift traffic is present. 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.
4. 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: compressors, pumps, evaporators, condensers, control valves, all electrical safeties, including, high pressure cutouts, high temperature cutouts, low pressure cutouts, low temperature cutouts, low oil pressure cutouts, automatic purge systems, ammonia detectors, emergency response equipment, including: air monitoring equipment, self-contained breathing, apparatus (SCBA), level A suit, air- purifying respirators.
5. Perform regular vibration testing on compressors. Document and analyze results for trends.

6. 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.
7. Consider installing ammonia detectors in areas where a substantial leak could occur or if the facility is not manned 24 hr/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.
8. Replace single pressure relief valves with dual relief valve installations. A dual relief valve installation consists of one three-way shut-off valve with two pressure safety relief valves.
9. Consider how the use of dual relief valve installations may facilitate the replacement, servicing, or testing of pressure relief valves on a regular schedule. A three-way valve allows one pressure relief valve to be isolated while the other remains on-line to protect the vessel. This setup allows each pressure relief valve to be serviced, tested or replaced on a regular basis without the need to pump down the system.
10. Ensure that refrigeration system lines and valves are adequately identified either by color coding or labeling of the piping lines by using an in house system. Critical control valves controlling flow should be easily accessible and clearly identified. Consider the use of automatic electrically or pneumatically actuated safety shut off valves on alarm condition or by remote control room operation.
11. Properly post ammonia placards per the NFPA 704 guidelines for NH_3 and warning signs in areas where ammonia is being used as a refrigerant or being stored (for example, compressor room doors).
12. Properly identify the chemicals within the piping systems; label all process piping containing ammonia, as “AMMONIA.” The label should use black letters with yellow background. Identify the king valve (receiver out let 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.
13. Establish emergency shutdown procedures and instructions on what to do during and after a power failure.
14. Establish written emergency procedures and instructions on what to do in the event of an ammonia release.
15. 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 the ventilation switch located outside and inside of each door to the compressor room.
16. Mount windsocks in appropriate places and incorporate their use into the facility emergency response plan. Determine local prevailing winds and conduct table top exercises with local authorities to determine the actions to be implemented. 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.
17. 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.
18. If a contamination event takes place action involving ventilation, absorption and neutralization should be initiated. Remove food products from affected areas and relocate to clean isolated areas or to temporary refrigerated areas such as rental trailers etc.

DISCUSSION

Ammonia is a Group B2 refrigerant with a Refrigerant Number of R-717. The flammable limits of ammonia at atmospheric pressure are 15% to 28% by volume of ammonia in air. The DOT Classification for ammonia is a Non-flammable gas. Remember that Ammonia goes through hazardous decomposition at temperatures above 850°F (454°C) where hydrogen and nitrogen are given off which could possibly result in an explosion.

Humans are very sensitive to the effects of ammonia. The eyes, mucus membranes, lungs, and skin are the first sensory receptors to react to presence of ammonia. Ammonia is corrosive to all body tissues. In liquid form, ammonia causes severe burns and frostbite on contact. At exposure levels as low as 5 ppm, ammonia is hardly detectable. At 20 ppm ammonia can have a distinct odor but can be tolerated. At 100 ppm ammonia can now be very noticeable and somewhat discomforting when inhaled.

Since ammonia is found in most food production facilities, the protection levels discussed in this document can reduce or limit the exposure to the deadly and potentially explosive substance, Good pre-planning can eliminate the more common hazards associated with the presence of ammonia in the facility. A completed understanding of the ammonia system at the site is the best way to mitigate a loss from an ammonia leak. The protection features provided above are taken from industry best practices and should be followed at a minimum. If a protection feature is discovered that may be an improvement to this protection for ammonia system then apply it with care and conservation until this method is thoroughly analyzed by experts in the field.

Annex A contains an information sheet that can be used to evaluate the loss prevention features on the ammonia engine room.

AMMONIA HAZARDS CHECKLIST

Feature	Yes	No	Comments
Is the Engine Room in a Separate Building?			
Does Engine Room have 1 hr construction or better if not located in a separate building?			
Does Engine Room have automatic sprinkler system if there is combustible construction or any combustible occupancy?			
What is the automatic sprinkler system design density and the demand at base of riser? (0.20 gpm/ft^2 over a 3000 ft^2 area)			
Does Engine Room have explosion relief design? Does it meet the standards of NFPA 68.			
What is Engine Room size? (cubic ft)			
What is venting size? (square ft)			
What is explosion relief ratio? (1sq ft : 30 cu ft)			
Does Engine Room have ordinary electrical equipment? If so ventilation is critical for emergency condition.			
Does Engine Room have Class I Division 2 electrical equipment?			
Does Engine Room have ceiling ventilation system?			
What is normal ventilation rate? (1cfm/ft^2)			
What is emergency ventilation rate? (10 cfm/ft^2) & 20,000 cfm minimum regardless of room size.			
Is there an alarm on the loss of power to the ventilation system?			
Is there an Engine Room power shut down (E-stop) device located outside of the Engine Room in the evacuation route?			
Does the Engine Room have ammonia detection systems? Is calibration done monthly?			
What is the ammonia detection set point for alarm activation? (1000 ppm)			

Feature	Yes	No	Comments
Does the emergency exhaust system actuate at 25% LEL and sound full emergency alarms. Are system exhaust fans “bump” tested quarterly to confirm they function?			
What is the ammonia detection set point for Engine Room power shutdown? (50% of LEL). Are exhaust fans powered from a separate power source so they continue operating once 50% LEL is reached?			