Review of Global Regulations for Anhydrous Ammonia Production, Use, and Storage

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In this article, several applications of ammonia are briefly summarized. Some of the major hazards associated with anhydrous ammonia are then highlighted through case studies of ammonia failures. Finally, a variety of regional ammonia safety standards are reviewed and compared including North America, the European Union, Asia, India, and Australia.

Introduction

Anhydrous ammonia (ammonia)[1] is an industrial and commercial compound with ever increasing popularity in a multitude of applications. Approximately 140-million metric tons of ammonia were produced worldwide in 2014, a 28% increase over the 2004 production estimate.[2] Applications of ammonia include direct use as a fertilizer or refrigerant, and use as a feedstock in the production of other fertilizers, as well as plastics, synthetic fibers and resins, explosives, and a variety of other chemical compounds.

Ammonia production, from its overall environmental impact, is considered a “rather clean technology,” characterized by low emissions and low energy consumption as well as little or no global warming potential (GWP).[3] Additionally, even though ammonia can present a fire/explosion hazard and a toxicity hazard, its production and use may be considered routine, owing to a century of accumulated industry knowledge. However, a review of recent ammonia-related incidents underscores the need for a continued sense of vulnerability with respect to these hazards. For example, in 2007, an ammonia release in Illinois (USA) resulted in the temporary evacuation of three towns,[4] and loss-of-containment events have also resulted in fires and explosions.[5] An effective risk management program, and continued sharing of case studies and lessons learned, can help mitigate these hazards. However, in many regions, a risk management program must also comply with local regulations.

While the adoption of the Globally Harmonized System of Classification and Labelling of Chemicals (GHS) has advanced a unified system classification and labeling, many of the regulations managing other aspects of environmental, health & safety (EH&S) continue to be regionally distinct. Many international ammonia producers and users achieve compliance through multiple, non-harmonized EH&S policies and procedures related to their ammonia systems. For example, within the United States additional EH&S ammonia regulations, Occupational Health and Safety (OSHA) Process Safety Management (PSM), take effect when more than 10,000-pounds (4.5 metric tonnes) is present while addition EH&S ammonia regulations don’t take effect until ammonia is present in quantities in excess of 110,000-pounds (50 metric tonnes) in the UK or 441,000-pounds (200 metric tonnes) in Australia. Furthermore, the additional regional EH&S requirements are not uniform from region to region. Thus, as the global regulations continue to evolve (e.g., the Seveso III Directive, which took effect in June 2015) corporate EH&S policies and procedures may require modification in order to maintain compliance while also ensuring an acceptable level of corporate risk. Understanding the regulatory landscape can be essential to establishing and maintaining a compliant global risk management program for ammonia.

Definition and Properties

Anhydrous ammonia (NH_3) is simply highly pure ammonia without water (‘Anhydrous’). Anhydrous ammonia (ammonia) is a colourless gas at room temperatures and pressures with a strong and pungent odor. Ammonia has a boiling point of approximately negative twenty-eight degrees Fahrenheit (-28°F, -33.3°C) at atmospheric pressures, is partially soluble in water, and is considered both caustic[6] and hazardous. Approximately 140-million metric tons of ammonia is produced worldwide annually for a variety of uses.[7]

Ammonia as a fertilizer

Approximately 81% of total worldwide ammonia production is used as fertilizers either as its salts, solutions or anhydrously.[8] The importance of Ammonia and inorganic minerals to plant nutrition was apparently first put forth by the German chemist Justus von Liebig in the mid-19th century. In the early 20th century, the production process for one of the most common components in agricultural fertilizer, nitric acid (HNO_3), was developed and patented by Nobel laureate, Wilhelm Ostwald.[9] Many fertilizer plants either produce or use anhydrous ammonia. Ammonia is often combined with nitric acid (HNO_3), sulfuric acid (H_2SO_4), and carbon dioxide to produce the myriad of fertilizers that are produced and used today.

Ammonia as a cleaner

Household ammonia is a generally an ammonia solution in water (i.e. ammonium hydroxide) and is used as a general purpose cleaner for many surfaces. All-purpose household ammonia cleaners range in concentration by weight from 5% to 10% ammonia by volume.

Ammonia as a refrigerant

Due to ammonia's thermo-physical properties, ammonia has been successfully employed as a refrigerant (R-717) and enjoyed widespread popularity prior to the use of chlorofluorocarbons[10] (CFC's) from the 1950's until the 1980's. R-717 is widely used in large commercial and industrial refrigeration applications worldwide do to it relatively low cost and high energy efficiency. "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." Examples of such applications are Ski-Dubai, an indoor ski resort located in Dubai UAE[11], cold storage facilities and Ice Plants.[12]

Ammonia Hazards and Safety/Handling Standards and Guidance

Ammonia, at standard temperature and pressure, is a colourless gas with a characteristic pungent odour that is lighter than air. A release of liquid ammonia into the atmosphere results in the formation of an aerosol with the moisture contained in the atmosphere; this results in the creation of a visible and dense white cloud. The ammonia vapour cloud, typically more dense than the atmosphere, tends to travel along the ground and thus poses hazards to workers and general persons in the vicinity of the liquid release location. Ammonia is an irritant to the eyes and respiratory system and can be fatal upon exposure to elevated concentrations.[13] Additionally, ammonia poses a risk of explosion (deflagration) if the concentration of the ammonia vapour cloud is within the flammable regime (~15% to 28%).[14]

Incidents Associated with Loss of Containment

Loss of containment of anhydrous ammonia can result in high consequence incidents, due to chemical hazards (flammability and toxicity), and the nature of its use (often as a compressed gas or liquefied gas). Examples can be found in news media archives and governmental databases. For example, in 2013 in China, leaks in ammonia refrigeration systems were blamed for fires at two food processing facilities, resulting in 135 fatalities.[15,16] Also in 2013, an ammonia leak at a Ukrainian chemical plant caused the death of at least five people.[17] In 2012, an accidental release of ammonia in the U.S. was blamed for an asphyxiation death,[18] and in 2007, also in the US, an ammonia release resulted in the temporary evacuation of three towns.[19] In 1997, a fire broke out in a refrigerated warehouse in Le Havre, France, leading to an explosion in the refrigeration unit, and the release of 2 tonnes of ammonia gas.[20] In 1992, an ammonia tank violently ruptured in Senegal, resulting in 129 deaths and 1,150 injuries, mostly due to toxic exposure.[21]

A 2012 review of ammonia incidents reported to the UK Health & Safety Executive (HSE) over the period of 1992 to 1998 found that over half of these incidents occurred during refrigeration processes (73 of 139 total incidents).[22] The review found that 25 of the refrigeration incidents occurred during maintenance and commissioning activities, mainly owing to a failure to isolate effectively. Other causes included corroded pipework, seal and valve failures, and blockages. Of the 43 chemical process and transport incidents, the main causes were similar: corrosion, component failure, failure to isolate effectively, operator error or failure to follow procedures, and blockages in pipes. Fortunately, none of the 139 incidents considered in this review resulted in fatalities.

Case Study 1: Loss of containment during transfer to tanker truck

In 2009, an anhydrous ammonia truck loading station at a chemical distribution facility was used to transfer ammonia from the facility into tanker trucks using a loading arm (Figure 1). One evening several drivers arrived at the facility to pick up loads of anhydrous ammonia. After checking in at the scale house, the trucks and their drivers proceeded to the truck loading stations where one of the drivers encountered some difficulties connecting his truck to the loading arm. At some point during the connection or ammonia transfer process, the loading arm being used disengaged from the truck and resulted in an ammonia release that killed several drivers. The release was eventually stopped by an operator in the scale house who activated the Emergency Shutdown Systems (ESD) within approximately 4-6 seconds after the release began. It was estimated by the facility that approximately 225-pounds (100-kg) of ammonia was released. Prior to the incident, the facility developed a check-list style process hazard analysis (PHA) which identified safety deficiencies associated with possible release scenarios during truck loading. One item identified during the facility's PHA was a deficiency in truck pull-away protection. Although subsequent PHA revalidation documentation suggests that this item addressed, there is no evidence that the facility implemented any additional pull-away protection (e.g., a breakaway valve) or an alternative, compensating safeguard. This type of release is called a line break scenario and it is a standard incident scenario to consider when performing a hazard analysis for a loading station.

Examples of failure events that could cause a line break include a truck pull-away, loading arm disengagement, or metallurgical failure of the loading arm. The facility's design documents required provisions on each truck loading arm to limit the release during a line break scenario. An excess flow valve (EFV) would have been the most logical choice for this mandated safeguard.

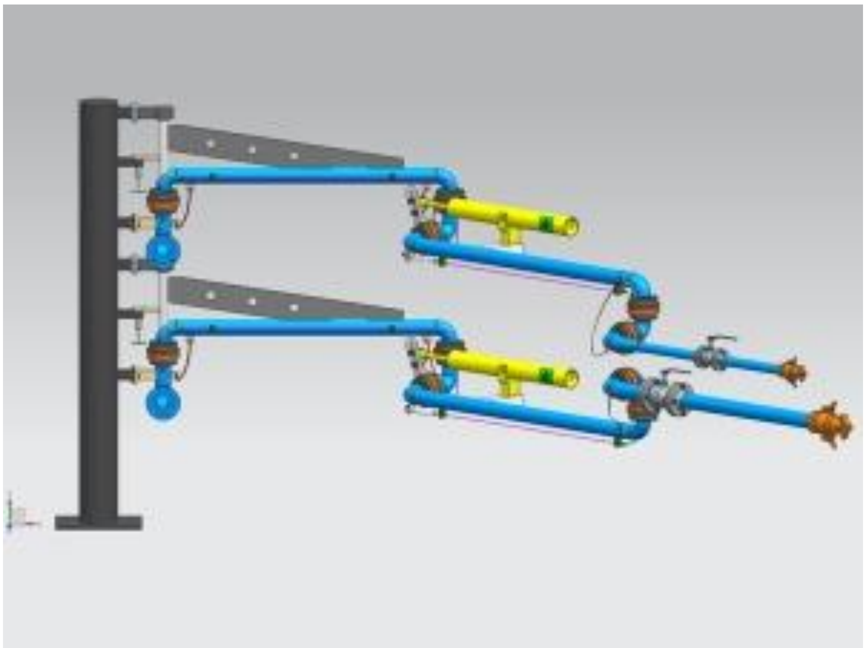


Figure 1. Example of Truck loading arms.[23]

While the facility had several excess flow valves (EFV, Figure 2), none of these valves actuated during the incident due to their distance from the truck loading arms (line break location). An ESV actuation is initiated by the imposition of a pressure drop in excess of its threshold setting; thus, the response time for an EFV is only as long as required to achieve its threshold pressure drop. In general, the response time of an EFV decreases the further away the EFV is from the line break. For pull-away protection, or a truck connection failure, an effective location for an EFV is at the truck loading station, connected to the piping that runs from the bullet tank to the loading station. In this location, the actuation of an EFV would have been nearly instantaneous, resulting in a release equal to a fraction of one pound of ammonia. In this case, these valves were installed on piping connected to the bullet tank that feed the loading station and not on, or in close proximity to, the loading arms. In addition to the failure of the facility to install EFVs in proper locations to prevent a large release scenario at the truck loading station, two additional factors increased the size of the release by reducing the effectiveness the ESD.

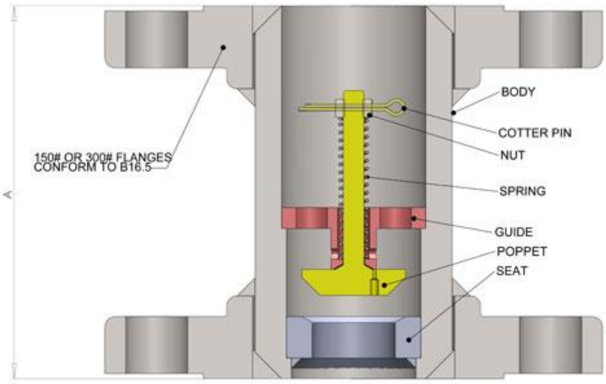


Figure 2. Example of an ammonia ESV.[24]

First, the tanker trucks acted as visual obstacles to the scale house operator thus preventing the direct line-of-sight observation of the truck loading process. The second factor that reduced the effectiveness the ESD was the distraction of the Terminal Operator caused by other tasks (e.g., performing truck inspections, filling out paperwork, or conversations with other truck drivers) thereby increasing the time delay to actuate the ESD.

Case Study 2: Loss of containment due to fire attack

In February 2014, a fire and ammonia release that occurred at a meet processing facility using an ammonia blast freezer to quickly chill products. As installed, the refrigeration unit could be operated in two modes: Automatic or Clean-Up. In Automatic mode, the unit cools and filters recirculated return air from the production floor before discharging it back to the production floor. In Clean-Up mode, the unit, using a burner, heats fresh intake air from the facility's attic space, discharges it to the floor, and then exhausts the return air out of the roof of the building. Typically, the unit runs in Automatic mode during production and is switched to Clean-Up from about midnight to approximately 2:00-3:00 a.m. while the facility is sanitized. Table 1provides the state of various components in in the refrigeration unit while in the various operational modes. Figure 3 is an engineering drawing of a portion of the incident refrigeration unit highlighting the key components involved in this incident.

Table 1. Operating Mode Overview

Mode	Blower	Burner	Ammonia Coils	R/A Dampers	I/A Dampers	Exhaust Fans
Automatic	On	Off	On	Open	Closed	Off
Clean Up	On	On	Off	Closed	Open	On

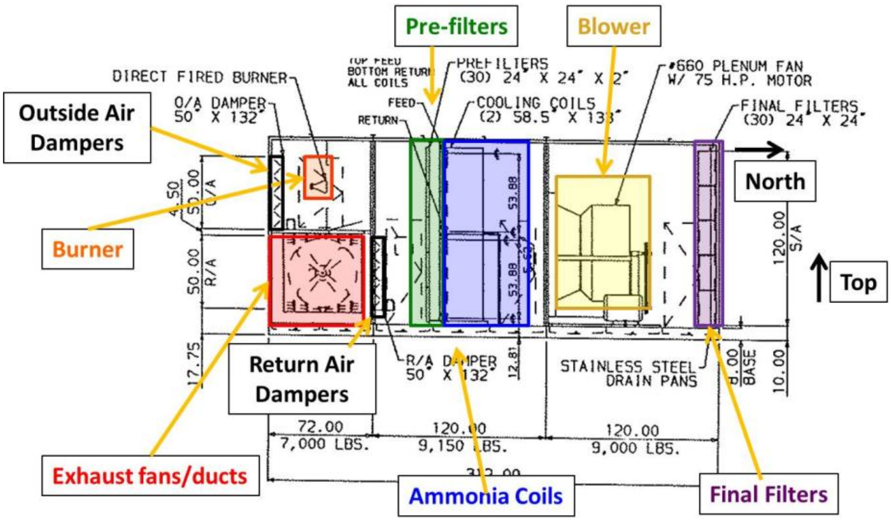


Figure 3. Side View of the incident refrigeration unit

On the morning of the incident, the ammonia refrigeration unit was switched from Automatic Mode to Clean-Up mode at approximately midnight. At 1:30 a.m., a facility employee inspected the unit as part of the shift walk through and reportedly did not notice any problems with the unit. Personnel on the production floor became aware of a potential issue at 3:12 a.m., when an initial ammonia smell was reported in a single area of the facility. Over the next 10 minutes, several additional locations reported ammonia odours in the facility. Measurements taken around the production floor indicated ammonia levels were between 15-35 ppm from 3:15 a.m. to 3:30 a.m.; this resulted in an immediate evacuation of the area. At 3:20 a.m. a 100 ppm ammonia reading was recorded. At 3:43 a.m., a phone call was placed to shut down the ammonia liquid pumps and compressors to try to mitigate the ammonia release. After the evacuation, at 3:49 a.m., personnel reported seeing flames venting out the roof of the attic space above the production floor, at which point the fire department was notified.

The fire department arrived on scene at 4:14 a.m. The initial suppression activities were hindered by limited access to the fire. At 4:30 a.m., the fire department began cutting holes in the metal sheeting roof of the attic space above the production floor to gain better access to the fire. Suppression and remediation activities continued throughout the morning. As the HAZMAT team attempted to isolate ammonia from the incident refrigeration unit, additional hot spots were identified requiring further suppression activities from the fire department. At 12:40 p.m., the HAZMAT team successfully isolated the suction and hot gas ammonia lines near the unit. At 12:54 p.m., the Fire Department deemed the fire extinguished and ammonia to the unit isolated. At 1:16 p.m., the Fire Department left the scene. Following a detailed investigation multiple failure hypotheses were identified with the most likely failure hypothesis being the failure of the refrigeration unit's blower coupled with only partially open air return dampers.

Five causal factors related to the fire and subsequent ammonia release were identified:

1. The failure of the blower within the unit resulted in reduced airflow across the burner (active during Clean Up mode).
2. Potential filter fouling within the unit resulted in reduced airflow across the burner.
3. The failure of the air proving switch to shut down the unit after the blower failure resulted in continued burner firing in an unsafe low airflow condition.
4. The lack of limit switches on the return air dampers failed to prevent an unintended flow across the burner that potentially satisfied the air proving switch after the blower failure.

5. Lack of isolation of the coil pack from the high pressure accumulator resulted in a continued release of ammonia after fire damage breached the unit's ammonia coils.

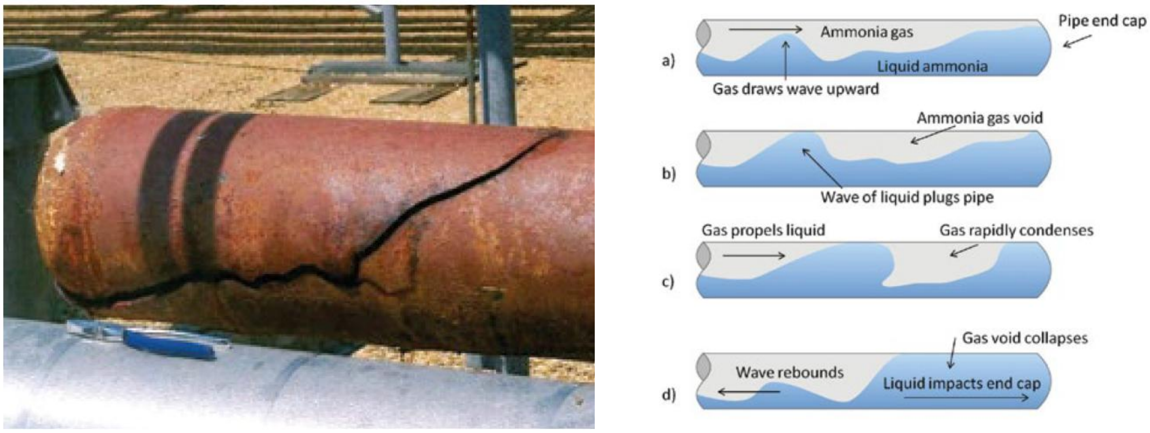
As a result of the investigation and the findings, numerous recommendations were provided in order to mitigate future failures in this manner.

1. Consider an evaluation of the maintenance and repair program on incident unit, specifically related to installation of blower belts and cleaning/replacement of filters, to ensure that the units are properly maintained.
2. Consider an evaluation of the materials used within the incident unit to ensure that the materials in use, specifically motor belts, are appropriate for the specified blower and motor.
3. Consider an evaluation of the location, setting, and design of the air proving switch(s) within the incident unit.
4. Consider including damper position on the intake and return air dampers of the incident unit as a critical function required for burner operation.
5. Consider an evaluation of the location, material of construction, and modification to the pre-filters to mitigate or eliminate the potential ignition of pre-filters by an elongated burner flame.
6. Consider valve arrangement and operation in the ammonia handling system to ensure that coils are safely isolated from ammonia sources when not in operation.
7. Consider including verification of the ammonia sensors relay and function as part of the sensor calibration protocol.
8. Consider adding instrumentation to the incident unit to ensure that the operating state can be tracked and deviations from normal operation can be identified.
9. Consider an evaluation of the fire alarm notification system to ensure that fires are identified as early as possible and building occupants are evacuated in a safe and timely fashion.

Hazards Associated with Rapid Phase Change

Because ammonia is commonly stored as a liquid under pressure, boiling liquid-expanding vapour explosions (BLEVEs) are a hazard often associated with ammonia-based processes. A BLEVE can occur when a liquid is stored in a pressurized container above its boiling point. If the vessel fails, exposing the liquid to atmospheric pressure, then the liquid will begin to boil, rapidly expanding into vapour. Similarly, if a valve is opened to a low-pressure pipe, then the liquid may partially flash into vapour, rapidly accelerating the liquid flow into the pipe. The high-velocity liquid is called a vapour-propelled liquid.

Another phenomenon associated with ammonia in refrigeration systems is condensation-induced shock. Condensation-induced shock is the result of rapid condensation, which, in a closed system, can create a vacuum, and subsequently produce a rapid inrush of fluid from other parts of the system. When the high velocity fluid ultimately reaches an obstruction, it is rapidly decelerates, and the forces exerted can result in component failure. The CSB defines this phenomenon as "hydraulic shock," or "an abnormal transient condition that results in a sharp pressure rise with the potential to cause catastrophic failure of piping, valves, and other components" caused by a rapid deceleration of liquid.[25] This effect is analogues to and had a similar effect as a water hammer.



(a) (b)

Figure 4. (a) Ruptured low-temperature suction piping from roof of facility, and (b) Progression of a condensation-induced shock event.[25]

On August 23, 2010, 14,500 kg of ammonia were released from a refrigerated warehouse. The CSB investigated the incident – their results are summarized as follows. The day before the event, the facility and its refrigeration system were without power for more than 7 hours. As the power was restored to the system, operator actions led to the interruption of a defrost cycle on an evaporator. The evaporator was switched into refrigeration mode without removing the hot gas from the evaporator coil. As a result, when the control system opened the valves in order to return the evaporator into cooling mode, the low-temperature ammonia liquid and hot gas mixed in the process piping.

The CSB attributed the ammonia release to hydraulic shock, a result of both of condensation-induced shock and vapour-propelled liquid. The resulting force ruptured the evaporator piping manifold and low-temperature suction piping on the roof of the facility. It took the about four hours to stop the release—during that time one employee and more than 152 offsite workers sustained injuries from the release. Four individuals were placed in intensive care.

As demonstrated by ammonia hazards presented in case studies above, ammonia represents a significant hazard to both property and life and therefore necessitates hazard mitigation regulations and engineering controls. The following sections present and contrast various ammonia handling and storage regulations in key global regions.

Ammonia Safety Standards and Guidance in the United States

Approximately 25 years ago, the United States government's national safety body OSHA (Occupational Safety and Health Administration) issued a declaration requiring all users of hazardous materials, including ammonia, to put in place a safety management program aimed at mitigating the risk to health and safety associated with that substance. OSHA allowed the various industries to develop their own plans, which they subsequently would approve and monitor. The plan was implemented in the late 1980's and its use has been mandatory for all US facilities with more than 10,000-lbs (4535-kg) of ammonia on site. Although ammonia has received EPA SNAP approval for most HVAC applications, many restrictions still remain. A major barrier facing ammonia in the United States is its toxicity and flammability. Ammonia's classified as a Class B toxic substance with class 2 flammability. Furthermore, nearly all United States national standards and guidance documents have separate, and is some cases additional, safety requirements related to ammonia's use in an attempt to mitigate potentially large failures, injuries, and property losses. Complicating the ammonia standards and guidance landscape within the United State is that in addition to the national standards, individual states may have implemented additional restrictions which may heavily restrict industrial uses of ammonia.

In the area of human comfort, current standards and developing regulations may discourage the use of ammonia. In high-probability systems for human comfort, ASHRAE Standard 15-2007 limits the use of non-A1 refrigerants to 3 kg for residential occupancies and 10 kg for commercial occupancies. The standard does not impose charge limits on industrial occupancies. The 2006 IMC and 2006 UMC contain similar restrictions as well. Research on the safety of ammonia systems in human comfort applications may help to establish appropriate safety requirements to allow for alternative refrigerants such as ammonia in human comfort applications. Table 2 below summarized the various U.S. regulations and guidance documents that pertain to the storage, handling, and use of ammonia.

Table 2. U.S. Regulations and Guidance Documents Overview

Regulation and Guidance Document	Title
ANSI K61 / CGA 2.1 - 2014	American National Standard Safety Requirement for the Storage and Handling of Anhydrous Ammonia
ANSI/IIAR 2-2008	American National Standard for Equipment, Design and Installation of Closed-Circuit Ammonia Mechanical Refrigerating System
ANSI/IIAR 3-2012	American National Standard for Ammonia Refrigeration Valves
ANSI/IIAR 4-2015	Installation of Closed-Circuit Ammonia Refrigeration Systems
ANSI/IIAR 5-2013	Start-up and Commissioning of Closed-Circuit Ammonia Refrigeration Systems
ANSI/IIAR 7-2013	Developing Operating Procedures for Closed-Circuit Ammonia Mechanical Refrigerating Systems
ASHRAE 15-2013	Safety Standards for Refrigeration Systems
ASHRAE 34-2013	Designation and Safety Classification of Refrigerants
ASME Boiler and Pressure Vessel Code - Section VIII, Division 1	
ASME Boiler and Pressure Vessel Code - Section VIII, Division 2	
ISO 5771	Rubber hoses and hose assemblies for transferring anhydrous ammonia - Specification
OSHA - 29 CFR 1910.111	Storage and handling of anhydrous ammonia.
US-Dept. of Transportation 49 CFR Parts 171-180	Transportation of Hazardous Materials
US-EPA EPCRA	Emergency Community Right-to-know Act
US-EPA RMP	Risk Mgmt. Plan
US-EPA SNAP	Sig. New Alt. Policy
US-OSHA 29 CFR 1910.119	Process Safety Management of Highly Hazardous Chemicals Standard

Ammonia Safety Standards and Guidance in the European Union

Similar to the United States, ammonia is considered a toxic substance in the EU. Many of the major EU and International Organization for Standardization (ISO) standards include additional safety requirements pertaining specifically to ammonia. The EU has passed EN 378 which is a four volume standard on safety and environment requirements for refrigeration systems and heat pumps. Although these volumes provide a similar framework to the various standards and guidance documents in the United States, it differs technically from the various US, AHRAE and IIAR standards.

Similar to the United States, the EU has specific directives, including the ATEX[26,27], PED[28], and Seveso-III[29] directives, addressing the need for a formal risk assessment as well as specifying procedures for incident investigation, reporting, as general training. Unlike the U.S., current Seveso-III do not require site specific hazard and safety plans until an order of magnitude larger quantity of ammonia is being stored, 110,231-lbs (50,000-kg, lower-tier). Although, a recent proposal put forth has recommended that anhydrous ammonia should be deleted as a named substance [from Seveso-II] with subsequent higher thresholds (50/200 tonnes) and that it should be treated according to its hazard classification; in this case ammonia would be covered by "P2 Flammable gases" with the lesser thresholds of 10/50 tonnes. (22,000-lbs).[30] This would bring EU regulations closer to in line with the U.S. requirements. Table 3 below summarized the various EU regulations and guidance documents that pertain to the storage, handling, and use of ammonia.

Table 3. EU Regulations and Guidance Documents Overview

Regulation and Guidance Document	Title
ATEX 94/9/EC	Equipment Directive - Equipment and protective systems intended for use in potentially explosive atmospheres
ATEX 99/92/EC	Workplace Directive - Minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres.
EN 378	Refrigerating systems and heat pumps. Safety and environmental requirements. Basic requirements, definitions, classification and selection criteria
EN 60079	Explosive atmospheres. Electrical installations inspection and maintenance
IEC 60335-2-40	Household and similar electrical appliances - Safety - Part 2-40: Particular requirements for electrical heat pumps, air-conditioners and dehumidifiers
PED 97/23/EC	The Pressure Equipment Directive

Ammonia Safety Standards and Guidance in Australia

Similar to the United States, ammonia is considered a toxic substance[31] in Australia and therefore the safe handling, storage, and use of ammonia fall under a number of both federal and state government regulations, namely the Model Work Health and Safety Regulations[32] and the Work Health Safety Act.[33] These federal regulations and acts require, similar to U.S. OSHA-PSM regulations (10,000-lbs, 4535-kg), that facilities classified as Major Hazard Facilities (MHF) with more than 440,925-lbs (200-tonnes) conduct a Safety Case in order to identify and mitigate some of the risks within a MHF. Table 4 below summarized the various Australian regulations and guidance documents that pertain to the storage, handling, and use of ammonia.

Table 4. Australian Regulations and Guidance Documents Overview

Regulation and Guidance Document	Title
Act No. 137, 2011	Work Health Safety Act No. 137, 2011
AS/NZS 2022:2003	Anhydrous ammonia—Storage and handling
AS/NZS 60079.10.1:2009	Explosive atmospheres - Classification of areas - Explosive gas atmospheres
Model Work Health and Safety Regulations 9 January 2014	Model Work Health and Safety Regulations

Ammonia Safety Standards and Guidance in China

Similar to the previously discussed countries and regions, ammonia is a listed hazardous chemical within the 2015 Catalogue of Hazardous Chemicals by the Chinese government and as such is the subject to level of regulation. Table 5 below summarized the various Chinese regulations and guidance documents that pertain to the storage, handling, and use of ammonia.

Table 5. Chinese Regulations and Guidance Documents Overview

Regulation and Guidance Document	Title
Decree - 591	Regulations on Safe Management of Hazardous Chemicals in China
GB28009-2011	Safety code for cold store
GB50072-2010	Code for design of cold storage
Order of the President No.70 of 29 June 2002	Production safety law of the people's Republic of China

India

Similar to the United States and other industrialized countries, ammonia is considered a hazardous toxic substance and therefor the safe handling, storage, and use of ammonia falls under federal government regulations, including the Manufacture, Storage and Import of Hazardous Chemical Rules, 1989.[34] These federal regulations and acts require that facilities with more than 110,231-lbs (50-tonnes) identify major accident hazards and take steps to prevent such major accidents and to limit their potential consequences to persons and the environment. The Factories Act of 1948, as amended in 1987, requires safety provisions for facilities relating to hazardous processes.[35] All refrigerant-containing pressure vessels' shall be hydrostatically tested and thoroughly examined periodically as required under the Factories Act, 1948, and the Rules thereunder.[36] Currently, there does not appear to be standardized national criteria for risk assessment and management.[37] Table 6 below summarized the various Indian regulations and guidance documents that pertain to the storage, handling, and use of ammonia.

Table 6. Indian Regulations and Guidance Documents Overview

Regulation and Guidance Document	Title
The Factories Act, Act 20 of 1987	The Factories Act
Disaster Management Act, 2005	
IS 4544 (2000), ICS 71.060;13.300	Ammonia - Code of Safety [CHD 8: Occupational Safety, Health and Chemical Hazards]
National Policy on Safety, Health and Environment at Work Place	
IS 660 (1963)	Safety code for mechanical refrigeration
IS 732-2274	Code of Practice for Electrical Wiring Installations

Conclusions

As is evident from the history of process safety incidents associated with ammonia, there are significant hazards associated with any loss of containment event. In the E.U., the U.S., and several other major industrialised areas, these hazards are controlled, at least in part, by complying with local regulatory requirements, which can vary dramatically from region to region. Thus, having an understanding the hazards posed by ammonia and the local regulatory environment are both critical to safely manufacturing, storing, transporting and using ammonia.

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[1] Also known as azane.

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[6] 'Caustic' generally refers only to strong bases, particularly alkalis, and not to acids, oxidizers, or other non-alkaline corrosives.

[7] Nitrogen (Fixed) – Ammonia, U.S. Geological Survey, Mineral Commodity Summaries, February 2014.

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[9] The Ostwald process is a chemical process for production of nitric acid (HNO3), patented 1902.

[10] Such as dichlorodifluoromethane (R-12 or Freon-12).

[11] Indirect ammonia refrigeration system, http://www.eurammon.com/node/261

[12] https://www.hsb.com/TheLocomotive/AmmoniaRefrigerationInColdStorageFacilities.aspx

[13] The Immediately Dangerous to Life or Health exposure limit established by the National Institute of Occupational Safety and Health (US, NIOSH) is 300 ppm for 30 minutes of exposure. Ammonia exposure can immediately result in life-threatening effects at 2,700 ppm in 10 minutes of exposure, based on the Environmental Protection Agency's (US, EPA) Acute Exposure Guideline Levels.

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[27] ATEX 137 workplace directive 99/92/EC, Minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres.

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[31] NOHSC List of Designated Hazardous Substances [NOHSC:10005 (1999)].

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[34] The Manufacture, Storage and Import of Hazardous Chemical Rules, 1989.

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