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ASHRAE Position Document on

Ammonia as a Refrigerant

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COMMITTEE ROSTER

The ASHRAE Position Document on "Ammonia as a Refrigerant" was developed by the Society's Refrigeration Committee. Position Document Committee formed on January 8, 2016 with Dave Rule as its chair.

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HISTORY

of

REVISION / REAFFIRMATION / WITHDRAWAL DATES

The following summarizes the revision, reaffirmation or withdrawal dates:

1/28/1993 – Board of Directors approves Position Document titled *Ammonia as a Refrigerant*

1/17/2002 – Board of Directors approves revised Position Document titled *Ammonia as a Refrigerant*

1/26/2006 – Board of Directors approves reaffirmation of Position Document titled *Ammonia as a Refrigerant*

1/30/2010 – Technology Council approves reaffirmation of Position Document titled *Ammonia as a Refrigerant*

6/30/2013 – Technology Council approves reaffirmation of Position Document titled *Ammonia as a Refrigerant*

7/2/2014 – Board of Directors approves revised Position Document titled *Ammonia as a Refrigerant*

2/1/2017 – Board of Directors approves revised Position Document titled *Ammonia as a Refrigerant*

Note: Technology Council and the cognizant committee recommend revision, reaffirmation or withdrawal every 30 months.

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ABSTRACT

Ammonia has been continuously used as a refrigerant since the initial practical use of the vapor-compression refrigeration cycle was developed. It has remained the main refrigerant used in industrial refrigeration systems because of its superior thermodynamic properties and low cost. Regulatory oversight on refrigerants such as CFC, HCFC, and other synthetic refrigerants, have re-focused attention on ammonia to emerge as one of the widely used refrigerants that, when released to the atmosphere, does not contribute to ozone depletion and global warming. Ammonia is generally considered to be benign to the environment. ASHRAE encourages the continued use of ammonia for - industrial and commercial refrigeration, food preservation, indirect space conditioning, heat pumps and other applications. ASHRAE participates in a variety of programs such as a dedicated chapter in the Refrigeration Handbook and several current and former research projects to promote the economic and environmental benefits of ammonia refrigeration and will continue to provide guidance for the proper design, safe use and management of risk.

EXECUTIVE SUMMARY

Globally, there is a growing interest in ammonia as a refrigerant, both by itself, and in cascade refrigeration systems with carbon dioxide and other secondary system designs. Regulatory oversight on CFC, HCFC, and other synthetic refrigerants, have re-focused attention on ammonia to emerge as one of the widely used refrigerants that, when released to the atmosphere, does not contribute to ozone depletion and global warming. New technology and equipment is leading to low and reduced ammonia charge designs. The application of these new low charge systems and packages creates an opportunity to use ammonia systems in a broad range of industrial, commercial and indirect space conditioning applications that would not have been considered with traditional designs. These changes will require industry to provide proper recommendations for both design safety and guidance for regulatory and code agencies.

Ammonia is an efficient and popular refrigerant due to its superior thermodynamic properties and low cost. Ammonia is environmentally benign, having zero GWP and zero ODP. It is hazardous when released in large quantities due to its toxicity. However, ammonia does exhibit a unique refrigerant characteristic due to its irritating odor. Persons exposed to an ammonia release will not voluntarily stay near concentrations that are health-threatening. Although ammonia will burn in a narrow range of high concentrations, it is difficult to ignite and will not support combustion after the ignition source is withdrawn. Ammonia has an ASHRAE flammability class of 2L, low flammability.

ASHRAE encourages the continued use of ammonia for industrial and commercial refrigeration, food preservation, indirect space conditioning, heat pumps and other applications. ASHRAE participates in a variety of programs to promote the economic and environmental benefits of ammonia refrigeration and will continue to provide guidance for the proper design, safe use and management of risk.

1. THE ISSUE

Refrigerant selection has become increasingly complex in recent years. Globally, the interest in ammonia and other natural refrigerants has become more focused due to increased regulatory oversite on the use of CFC, HCFC, and other synthetic refrigerants. The consideration of these refrigerants continues to come under question due to the environmental concerns caused from ozone depleting potential (ODP), global warming potential (GWP), energy efficiency, total equivalent warming impact (TEWI) and life cycle climate performance (LCCP).

Ammonia is a natural refrigerant that has been used for many years in a variety of applications due to its high thermal efficiency. Since ammonia is environmentally benign, having zero (GWP) and zero (ODP) characteristics, ammonia is emerging as one of the primary natural refrigerants of choice.
New technology is leading to low and reduced ammonia charge designs. The application of these new low charge systems and packages creates an opportunity to use ammonia in a broad range of new industrial, commercial and indirect space conditioning applications that would not have been considered with traditional designs. These changes will require industry to provide proper recommendations for both design safety and guidance for regulatory and code agencies.

2. BACKGROUND

Ammonia (chemical symbol NH3, United Nations Chemical I.D. #1005) is produced both naturally and as a byproduct of numerous man-made reactive processes. Large amounts of naturally occurring ammonia gas come from livestock animals, soil surfaces and even the human body. Manmade processes that emit ammonia to the atmosphere include fuel combustion processes and sewage treatment plants.

The nitrogen component of ammonia was first recognized as an important fertilizer around 1840, and ammonia was first used as a refrigerant around 1850. Ammonia was first commercially produced in the United States about 1880 as a distillation by-product of coal processing to produce coke and coal gas.

The first direct-synthesis commercial process was developed in Germany by Fritz Haber and Carl Bosch in 1913. The wide variety of ammonia uses throughout agriculture and industry, combined with varied and highly efficient manufacturing processes, has kept the costs of commercially manufacturing ammonia low. Natural gas is one of the feedstocks used for large scale ammonia production. The rapid increase in the availability of natural gas in the U.S. and elsewhere due to new drilling technologies has kept the cost of this feedstock down, helping to keep down the cost of the ammonia product.

2.1 Ammonia Specification and Applications

Ammonia is an alkaline, colorless chemical compound that is well recognized as the basis for household cleaning products. It also has many agricultural, industrial and commercial uses. It is available in five generally recognized grades—fertilizer, refrigerant, federal, metallurgical, and semiconductor—depending on its level of purity.

Refrigeration grade ammonia is 99.98 percent pure and is relatively free of water and other impurities (maximum: 150 ppm water, 3 ppm oil, 0.2 ml/g non-condensibles). It is readily available, inexpensive, operates at pressures comparable with other refrigerants and is capable of absorbing large amounts of heat when it evaporates.

Of the estimated 140 million metric tons of ammonia produced commercially throughout the world in 2013 (8.7 million metric tons in the United States), over 80 percent is used for agricultural purposes[1]. Some of the agricultural uses of commercial ammonia include:

- Direct injection into soil as a fertilizer.
- Production of urea (colorless crystalline material that is a highly concentrated form of nitrogen fertilizer and a source of protein in livestock feeds).
- Pre-harvest cotton defoliant.
- Anti-fungal agent on certain fruits.

The remaining 20 percent of commercially manufactured ammonia is used for numerous industrial applications, such as:

- Direct injection in selective catalytic reduction control of nitrogen oxides for stack emissions.
- Direct injection of ammonium hydroxide for stack emissions to neutralize sulfur oxides from sulfur-containing fuels.
- Nitrogen component for the manufacture of explosives such as TNT and nitroglycerin.
- Closed-loop refrigerant in many industrial and indirect commercial refrigeration systems.
- Neutralizing agent for acid constituents in sewage treatment plants.

Less than 2 percent of all the ammonia commercially produced in the world is used as a refrigerant.

2.2 Refrigeration Uses of Ammonia

With continued regulatory oversight on the use of synthetic or halocarbon refrigerants, alternative refrigerants for use in existing refrigeration systems are actively being investigated.

Ammonia is one alternative refrigerant for new, replacement, and existing refrigeration system designs, where compatible. Ammonia has a low boiling point (-28°F @ 0 psig), an ozone depletion potential (ODP) of 0.00 when released to atmosphere and a high latent heat of vaporization eight (8.17 at -28°F) times higher than R-12 and six (6.18 at -28°F) times higher than R- 134(a). In addition, ammonia in the atmosphere does not directly contribute to global warming. These characteristics result in a highly energy-efficient vapor-compression cycle with ammonia as the refrigerant with minimal environmental impact.

Ammonia's use in the HVAC&R industry will increase as regulatory and code officials become informed of its relative safety. Applications for ammonia-based refrigeration systems include thermal storage systems, HVAC chillers, process cooling, air conditioning, winter sports, district cooling systems, heat pump systems, supermarkets, convenience stores, and increasing output efficiencies for power generation facilities. Ammonia is also already being used in large heat pump installations and supermarkets, as well as in several high-profile projects, including the International Space Station and Biosphere II.

Ammonia is increasingly used in cascade refrigeration systems with carbon dioxide. In these systems, ammonia is used in the high-temperature stage to reject heat to the environment. Carbon dioxide is used in the low-temperature stage to absorb heat from the load to be cooled, and to reject the heat to the ammonia high-temperature stage. Such systems allow the use of ammonia in a wider range of applications, because the less hazardous carbon dioxide can be used in more locations, while the highly efficient ammonia can be kept in a central mechanical room or rooftop package. Ammonia is also used in conjunction with other secondary fluids, such as water or glycol, for the same reasons noted above.

2.3 Health and Safety

The National Institute for Occupational Safety and Health (NIOSH), in its 2007 Pocket Guide[2], has set the Immediate Danger to Life or Health (IDLH) level, the level at which an individual could be exposed for 30 minutes without a respirator and not experience any lasting health effects, at 300 parts per million. The purpose of IDLH is to establish when the maximum level of respiratory protection is required by OSHA regulations. Ammonia's sharp, irritating, pungent odor actually helps reduce exposure to potentially dangerous concentrations. The average odor threshold is 5 ppm[3], well below concentrations that may cause harmful effects to the human anatomy.

The chart below, which is based on data from the U.S. Public Health Service's Agency for Toxic Substances and Disease Registry (ATSDR), as published in the IIAR Ammonia Data Book, shows the effects of various concentrations of ammonia.

Concentration	**Effect**
5 ppm	Average odor threshold (well below harmful health effects)[3]
100-200 ppm	Irritated eyes[4]
300 ppm	Respiratory Protection Required above this level- IDLH[2]
400 ppm	Immediate throat irritation[3]
500 ppm and below	No permanent eye damage to even chronic exposure[4]
1,700 ppm	Cough[3]
2,400 ppm	Threat to life after 30 minutes[3]
5,000+ ppm (vapor)	Full body chemical suit required[4]
5,000+ ppm (pure liquid)	Second degree burns with blisters[4]
7,338 ppm	One Hour LC_{50}, lethal concentration (rat)[5]

The self-alarming property of ammonia is recognized by virtually all engineers, designers, technicians and mechanics that deal with and work on ammonia systems regularly. Thus, small leaks are repaired quickly and not neglected or dismissed as insignificant.

Modern ammonia systems are fully contained closed-loop systems with fully integrated controls, which regulate pressures throughout the system. Also, every refrigeration system is required by codes, which are effective, mature and constantly updated and revised, to have safety relief valves to protect the system and its pressure vessels from over pressurization and possible failure. The most accepted method of release for ammonia systems is by venting of the vapor from the relief valves directly into the atmosphere at a safe location. Specific evaluation may be required in order to determine the preferred or most appropriate release method for the site. Ammonia is lighter than air (molecular weight of ammonia is 17, molecular weight of air is 28).

2.4 Environmental Aspects

Ammonia is not a contributor to ozone depletion or global warming[6].

Thus, it is an environmentally benign refrigerant. Ammonia has no cumulative effects on the environment and a very limited (a few days[7]) atmospheric lifetime. Because of the short lifetime of ammonia in the atmosphere, it is considered to be biodegradable. It is even used to reduce harmful stack gas emissions by injection into boiler and gas turbine exhaust streams. In such systems, only part of the ammonia is consumed in the emission control process, and a small fraction is released into the environment.

Ammonia may be released to the atmosphere by sources such as decaying organic matter, animal excreta, fertilization of soil, burning of coal, wood, etc., and by volcanic eruptions. Ammonia may be released into water as effluent from sewage treatment and/or industrial processes and as run-off from fertilized fields or areas of livestock concentrations. Ammonia may be released into soils from natural or synthetic fertilizer applications, livestock excrement, the decay of organic material from dead plants and animals or from the natural fixation of atmospheric nitrogen.

2.5 Considerations of Ammonia as a Refrigerant

While the benefits of ammonia as a refrigerant are well known, (high energy efficiency, zero ODP, zero GWP, low TEWI or excellent LCCP, self-alarming pungent odor) barriers to expanding its use into HVAC&R applications must be addressed. These barriers generally relate to human health and to ammonia refrigeration system installation cost. Ammonia reacts with copper in the presence of common contaminants such as air and water. Therefore, with the exception of some copper containing bronze alloys used in compressor and pump bearings, ammonia systems are constructed using aluminum, carbon steel, and stainless steel components. Joints are most often welded, rather than brazed. A lack of technicians trained to understand and handle ammonia refrigeration systems also presents a barrier to its implementation, especially in markets where ammonia has not traditionally been used.

In properly constructed and commissioned refrigeration systems, ammonia contributes to a high theoretical COP compared to many refrigerants that are currently in use[8]. The high efficiency of ammonia systems also benefits the environment by requiring less energy for a given refrigeration load, and thus less carbon dioxide emissions associated with the production of electricity.

Economic conditions must also be considered when evaluating ammonia as the choice as a refrigerant. Even though the price of refrigerant grade ammonia is comparatively low, under $1/lb in most regions, the installed cost of the equipment may eclipse commercial (i.e. halocarbon and synthetic refrigerant) equipment on a price/capacity comparison. This is primarily due to the industrial nature of ammonia refrigeration equipment with a typical expected lifetime of 40 years or more. When a full Life Cycle Cost analysis is performed, even a relatively small ammonia system has been found to be cost competitive due to the savings in operating costs and other long term benefits from the rugged equipment design. From a purely economic analysis, without unnecessary regulatory burdens, ammonia should find broader applications as a refrigerant than it currently enjoys.

2.6 Regulatory Classifications

Anhydrous ammonia (Chemical Abstracts Service, CAS #7664-41-7) is currently classified by the U.S. Environmental Protection Agency (EPA) as an extremely hazardous substance (EPCRA, Sec. 302, 303). It is included on the following Emergency Planning and Community Right-to-Know Act (EPCRA)[9] lists:

- Reportable Quantity List (Section 304) -Chemicals on this EPCRA list require notification to EPA and state and local agencies of releases in excess of the reportable quantity (currently 100 pounds).
- Extremely Hazardous Substance List (Section 302) -Chemicals on this EPCRA list, at facilities with quantities in excess of the Threshold Planning Quantity (TPQ), are subject to EPCRA requirements, which mandates numerous reporting and planning provisions. The TPQ of ammonia is 10,000 pounds.
- Section 313 - Chemicals on this EPCRA list are subject to the annual toxic release inventory reporting (Form R).

In the United States the Environmental Protection Agency (EPA) and the Department of Transportation (DOT) reference exposure guidelines designed to help responders deal with emergencies involving an ammonia release or other chemical spills where members of the general public may be exposed to a hazardous airborne chemical. Acute Exposure Guideline Levels (AEGL) are single, non-repetitive exposures that do not exceed (8) eight hours. AEGLs estimate the concentrations at which most people, including sensitive individuals such as old, sick, or very young people will begin to experience health effects if they are exposed to a hazardous chemical for a specific duration.

The Department of Transportation (DOT), in the United States, publishes an Emergency Response Planning Guidebook which references the Emergency Response Planning Guidelines from the American Industrial Hygiene Association (AIHA). Similar to the AEGL guidelines, the ERPG guidelines estimate the concentrations at which most people will begin to experience health effects if they are exposed to a hazardous airborne chemical for more than (1) hour. The DOT guidebook is intended for use by first responders during the initial phase of a transportation incident involving hazardous materials. The AEGL/ERPG values for ammonia are presented below from the DOT Emergency Response Planning Guidebook 2016 Edition.[10]

150 ppm	AIHA/DOT Emergency Response Planning Guidelines (ERPG-2 for up to 60 min.)
160 ppm	EPA/DOT Acute Exposure Guideline Levels (AEGL-2 for up to 60 min.)

While the EPA addresses ammonia from the environmental perspective, the U.S. Occupational Health and Safety Administration (OSHA) addresses ammonia from the perspective of worker safety. OSHA defines ammonia as a hazardous material and, depending on its use, imposes certain regulations on its use, storage, handling and occupational exposure.

Regulatory safety limits for ammonia (as defined in the United States) are presented in the table below:

Concentration	**Health Effect / Regulatory Definition**
25 ppm	NIOSH Time-Weighted Average (TWA)[2]
35 ppm	NIOSH Short-Term Exposure Limit (STEL) [2]
50 ppm	OSHA Personal Exposure Limit (PEL) [2]
150 ppm	Emergency Response Planning Guidelines (ERPG)-2[11]
160 ppm	Acute Exposure Guideline Levels (AEGL)-2[12]
300 ppm	OSHA Immediately Dangerous to Life and Health (IDLH)[13]
15-16,000 ppm	OSHA 10% by volume in air, lower flammable limit (LFL)[14]

The threshold limit value (TLV) consists of two components—the time-weighted average (TWA) concentration and the short-term exposure limit (STEL). The TWA is the time weighted average concentration for a normal eight-hour work day and a 40-hour work week. The STEL is a 15-minute time weighted average exposure that should not be exceeded at any time during the work day, even if the eight-hour TWA is within the TLV. The immediate danger to life or health (IDLH) was set by NIOSH as a 30-minute escape impairment level and it is NOT a lethal concentration. The purpose of IDLH is to establish when the maximum level of respiratory protection is required by OSHA regulations.

The lower explosive limit (LEL) is defined by OSHA as the lowest concentration of ammonia (or other vapors, gas or fumes) required to produce fire in the presence of an ignition source like flame or heat.

In the United States, the Occupational Safety and Health Administration (OSHA) provides guideline limits for worker safety. Limits for the presence of explosive and flammable liquids in the air as well as for the safe storage of these materials to prevent fire and explosion are also defined as shown in the table above. Other regions of the world may define safety and storage limits for ammonia at alternate levels and should be referred to for all design, safety and operating guidelines.

TEPA and OSHA classify all CFCs and HCFCs as hazardous substances, and thus the use of these refrigerants requires specific reporting and management practices comparable to ammonia.

2.7 Risk Assessment

All refrigerating systems require risk assessment; ammonia systems are not exceptions. OSHA's Process Safety Management (PSM), 29 CFR 1910.119, provides guidelines for a comprehensive program developed by employees and management at facilities to ensure that proper safety, maintenance and operating procedures are followed, and thereby minimize potential hazards. This PSM incorporates ANSI/ASHRAE Standard 15, Safety

Standard for Refrigeration Systems[15] as well as other standards for design, installation, maintenance and operation. Although it only affects plants with large refrigerant charges, its requirement for what-if or hazop analyses are directed towards reducing risks and promoting plant safety, so PSM can also be a good program for smaller plants.

Facilities covered by OSHA's PSM are also covered by EPA's Risk Management Program (RMP), which is intended to prevent, detect and respond to accidental releases of hazardous chemicals and to inform local communities of the risks. With an appropriate application of PSM and RMP programs to ammonia refrigeration systems, safety to individuals, communities and the environment is enhanced. However, the application of PSM and RMP programs must be refined and tailored to avoid imposing unreasonable and overly burdensome barriers in new and existing ammonia refrigeration systems.

For facilities with low ammonia charges not covered by OSHA PSM and EPA RMP, the International Institute of Ammonia Refrigeration (IIAR) has developed an Ammonia Risk Management (ARM)[16] plan that can be applied to adhere to OSHA's General Duty Clause which requires employers to provide a safe work environment for their employees.

Regulatory and risk management programs will vary by country and region. Engineers, owners and operators working with ammonia refrigeration systems should review the local regulations to ensure compliance and safety standards are met.

3. RECOMMENDATIONS

3.1 ASHRAE's Strong Position

ASHRAE has a long history of involvement with the use of ammonia as a refrigerant. Ammonia is considered to be an essential refrigerant in industrial and commercial refrigeration and space conditioning due to its high efficiency and environmentally benign characteristics. ASHRAE has a significant role to play in encouraging the proper and safe use of ammonia in the following areas: policy; research, standards, codes and guidelines and technology exchange and education.

ASHRAE will:

- Promote authoritative information on ammonia by seminars and publications.
- Continue research on ammonia topics such as handling, application, operation, control of emissions and new technology.
- Maintain and develop standards and guidelines for practical and safe application of ammonia in industrial and commercial refrigeration, food preservation, indirect space conditioning, heat pump systems, winter sports and other applications. Encourage the broad use of ammonia in traditional and new applications.
- Provide programs and publications of innovative designs and application of ammonia.
- Advise governments and code officials with information regarding ammonia.

3.2 Policy

ASHRAE's Ammonia as a Refrigerant Position Document emphasizes the important role that ammonia can play as an alternative to CFC, HCFC, and other synthetic refrigerants. It also identifies ASHRAE's concerns about the use of ammonia and establishes what the Society will do to encourage and support its proper and safe use as a refrigerant.

Ammonia has been identified by the EPA[17] as a viable alternative to currently used refrigerants because it does not deplete the ozone layer or contribute to global warming. The United Nations Environmental Program (UNEP) has identified ammonia as an excellent refrigerant for replacement of many current CFC and HCFC applications [2010 Technical Options Report] as part of the reassessment of the Montreal Protocol. Other countries have established policies to encourage and promote the use of ammonia indirectly, including the replacement of such HCFC refrigerants as R-22 for applications like water chillers and commercial refrigeration systems for supermarkets.

Other international organizations have issued positions or statements of support for the use of ammonia as a refrigerant. These include the Australian Institute of Refrigeration, Air-Conditioning and Heating (AIRAH)[18], the International Institute of Refrigeration (IIR)[19], the German Institute of Refrigeration (DKV)[20] etc.

3.3 Research

ASHRAE is unique among technical engineering societies because it sponsors an extensive member-supported research program. In 2013-2014, the ASHRAE Board of Directors has approved funding for ASHRAE research projects and grant and aid payments of nearly $3 million. A significant portion of current projects relate to alternative refrigerants, including ammonia. In past years, ASHRAE has promoted several research projects related to various aspects of ammonia refrigeration. The most recent ASHRAE research plan includes a goal to facilitate the use of natural and low global warming potential (GWP) synthetic refrigerants and seek methods to reduce their charge. ASHRAE has had research projects that involve ammonia, including:

- Condensation-Induced Hydraulic Shock Laboratory Study, $81,800 project managed by TC 10.3 at Georgia Institute of Technology (970-RP).
- Evaporation of Ammonia Outside Smooth and Enhanced Tubes with Miscible and Immiscible Oils, $115,675 project managed by TC 1.3 at Texas Tech University (977-RP).
- In-Tube Condensation of Ammonia in Smooth and Enhanced Tubes With and Without Miscible Oil, $147,000 project managed by TC 1.3 at University of Illinois (1207-RP).
- Flow Regime and Pressure Drop Determination for Two-Phase Ammonia Upward Flow in Various Riser Sizes, $215,240 project managed by TC 1.3 at Danish Technical Institute (1327-RP).
- Evaporation in Flooded Corrugated Plate Heat Exchangers with Ammonia and Ammonia/Miscible Oil, $97,585 project managed by TC 10.3 at Ghulan Ishaq Kahn Institute (1353-RP).
- CFD Study of Hydraulic Shock in Two-Phase Anhydrous Ammonia, project managed by TC 10.3 at ASCOMP USA (1569-RP).

ASHRAE encourages the submission of proposals for new research projects related to refrigeration and other applications that use ammonia. Several future ammonia projects are included in the most recent research plan.

3.4 Standards, Codes and Guidelines

ASHRAE plays a major role in development of voluntary standards and guidelines governing the application and use of refrigerants, including ammonia. In addition, other organizations adopt the technical requirements developed by ASHRAE into various codes and regulations.

The most important ASHRAE standards dealing with ammonia are ANSI/ASHRAE Standard 34-2013, Designation and Safety Classification of Refrigerants[21], and ANSI/ASHRAE Standard 15- 2013, Safety Standard for Refrigeration Systems. Standard 34 classifies ammonia as a Group B2L refrigerant, because of toxicity and flammability concerns. Standard 15 establishes the requirements for safely applying ammonia in refrigerating systems. In general, ammonia can be used in unlimited quantities in direct systems for industrial occupancies. However it must be used in indirect (secondary) systems for commercial and public occupancies. Its general use in small absorption equipment is unrestricted in the United States.

The ASHRAE Refrigeration Handbook states that there is renewed interest in ammonia for HVAC systems because of the scheduled phaseout and increasing costs of HCFC and CFC refrigerants. While ammonia is inappropriate for direct systems, the use of secondary systems that use ammonia to chill water or another secondary refrigerant are a viable alternative to halocarbon systems for HVAC applications[22].

Other technical organizations have issued standards/ guidelines addressing the proper application of ammonia as a refrigerant. These standards/guidelines cover the design, installation and operation of ammonia refrigeration systems [ANSI/ IIAR 2-2014, ANSI / IIAR 4-2015, ANSI / IIAR 5-2013, ANSI / IIAR 7-2013].[23-26] International standards also address safety and application of ammonia [ISO 5149, Refrigeration Safety[27]; ISO 1662, Refrigerating Plants – Safety Requirements[28]; CEN EN 378, Refrigerating Systems Safety and Environmental Requirements[29]].

The proper application of ammonia as a refrigerant is governed by state and local building, mechanical and electrical codes. In the U.S., these codes are issued by various model code organizations such as International Code Council (ICC) and National Fire Protection Association (NFPA). Because of its classification as a hazardous chemical, ammonia is often specifically covered by various requirements in fire codes. The Code Interaction Subcommittee of ASHRAE's Standards Committee will review proposed fire and mechanical codes that could affect refrigeration applications. ASHRAE has established a policy to encourage adoption of ASHRAE standards in model codes.

Electrical codes, especially the National Electric Code[30], are relevant to ammonia because ammonia in high concentrations can form flammable mixtures with air. Standard 15 and ANSI / IIAR 2-2014 establishes design procedures for applying ammonia, including proper ventilation levels, which are referenced in electrical codes to assure the safe application in buildings. Code requirements may vary in other countries and regions; please consult local regulations.

The advent of low charge, packaged ammonia systems will require code organizations to make provision for their application. Some standards, such as IIAR 2 2014, have started to address this, however further work is required from all code organizations to ensure that this new technology can be used to its full potential.

In some cases, very stringent local toxic gas ordinances have been applied to ammonia, even though they were intended to apply to highly toxic chemicals. These types of ordinances can be very restrictive.

3.5 Technology Transfer and Education

ASHRAE plays a very important role in providing technical information on the proper application of ammonia as a refrigerant. In this role, ASHRAE assists in transfer of technology and in education of the technical community. These important activities are carried out through a number of vehicles: ASHRAE Handbook, ASHRAE Journal and ASHRAE Transactions; special publications; and through a number of educational forums.

A major source of technical information on ammonia is the ASHRAE Handbook. The 2013 Fundamentals[31] volume contains general information on Thermodynamics and Refrigeration Cycles (Chapter F2) and on Refrigerants (Chapter F29), including the thermodynamic properties of ammonia. Another major resource for information on ammonia is the 2014 ASHRAE Handbook—Refrigeration[32], covering Liquid Overfeed Systems (Chapter R4), Ammonia Refrigeration Systems. (Chapter R2) and Refrigeration System Chemistry (Chapter R6). An additional resource is the ASHRAE publication Thermophysical Properties of Refrigerants [2013][33].

ASHRAE has published a number of technical papers, articles and special reports addressing the use of ammonia. These include notices and articles regarding ammonia refrigeration in ASHRAE Journal. Technical papers presented at ASHRAE meetings are published in ASHRAE Transactions, and in various special publications. A summary of more than 30 technical articles and references can be found on ASHRAE Online.

Key parts of ASHRAE's technology exchange and education functions are fulfilled by the Annual and Winter Conference technical programs, including seminars, forums, symposia and technical sessions. In addition, the Society offers a self-directed learning course on the Fundamentals of Refrigeration. Local ASHRAE chapters also sponsor refrigeration-related programs and speakers, which have recently shown a strong interest in ammonia.

Technical activities focusing on ammonia are addressed within ASHRAE by the Refrigeration Committee, which is now a standing committee. In addition to the Refrigeration Committee, the Chapter Technology Transfer Committee (CTTC) encourages grass roots regional and chapter activities, which focus on refrigeration. The Refrigeration Committee maintains a speakers list of speakers/topics that includes ammonia. Various technical committees (TCs 10.1, 10.3, 10.5, 1.3, 8.5 etc.) also focus on ammonia-related issues.

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