Introduction

This bulletin provides some basic information about the use of anhydrous ammonia, known as R-717, as a refrigerant. Only trained technicians with proof of competence should be permitted to work on ammonia refrigeration systems. The standards of competence are defined in BSEN13136 and additional guidance can be found in BSEN378 and the Health and Safety at Work Regulations.

1. What is ammonia?

Ammonia is a naturally occurring, inorganic compound comprising one nitrogen and three hydrogen atoms. It is lighter than air with a molecular weight of 17 compared with air’s weight of 29. At standard temperature and pressure it is a gas and it condenses at -33°C. It has a high latent heat, approximately 1400 kJ/kg compared to R-22 at 230 kJ/kg.

\[
\text{NH}_3 \\
1 \text{ Nitrogen molecule} \\
3 \text{ Hydrogen molecules}
\]

2. Why use Ammonia?

Ammonia was one of the first compounds selected for mechanical refrigeration systems. It is widely available and relatively cheap, and it is easy to manufacture, liquefy, store and transport. When it is used in a sealed pressure system for refrigeration it is reactive and the system can cope with air and moisture contamination without suffering from valve blockages. Ammonia is suitable for use in the temperature range from -50°C to +10°C and is commonly used in freezers, cold stores, ice rinks, chill stores and water chillers. It has also been used in high temperature heat pumps as it has a high critical temperature and large latent heat. It has no effect on stratospheric ozone and it is not a significant contributor to climate change through direct global warming.

Ammonia achieves very high rates of heat transfer in evaporators and condensers, and liquid pipes and valves are relatively small. However the compression index is high, so the discharge temperature from compressors is much greater than most other refrigerants produce and it is often necessary to use two stages of compression in order to achieve the necessary temperature lift, which sometimes makes ammonia plant more complicated than some other systems.

3. Risks associated with ammonia

The main risks in the use of ammonia as a refrigerant are associated with its toxicity and flammability characteristics. Ammonia gas is severely irritating to wet tissues including eyes, nose and throat and it has an unpleasant smell. Contact lenses should not be worn. It is also severely toxic to aquatic life and so care must be taken to ensure that ammonia liquid or aqua-ammonia solution does not leak into groundwater or otherwise get into lakes and rivers. Ammonia gas can be ignited in relatively high concentrations and an ammonia explosion could cause structural damage to a building. However it is difficult to ignite and so combustion can be prevented by relatively simple and inexpensive safety precautions.

The threshold limit value (TLV) for ammonia exposure over an 8 hour period is 25ppm. This is enough to produce a relatively strong smell, without causing eyes to water. For a 15 minute period the short term exposure limit (STEL) is 35ppm. If the level is higher than this, or if there is a chance that it will go higher, then a canister-type respirator should be worn during maintenance work. However if the concentration is above 300ppm then the plant room should be evacuated and ventilated until the level has reduced, or self-contained breathing apparatus (SCBA) should be used. Be aware that if SCBA is required then the area is defined as a confined space under the Confined Space Regulations and strict procedures must be followed. The reason that canister respirators are not suitable for use above 300ppm is that if the filter becomes saturated and ineffective then the wearer might not be able to leave the room in time. However 300ppm is the lowest level at which the most susceptible people would risk permanent health effects if they failed to leave the area within 30 minutes, so for maintenance technicians at work, following the 300ppm guideline is a good way of ensuring safety.

Ammonia is not miscible with mineral oil and so draining oil from evaporators is a common maintenance task. This should only be done by trained staff following approved procedures, and it requires time and patience, since the cold oil can be very viscous. Serious injury and death have been caused by maintenance staff trying to take shortcuts to speed up this procedure.
The other hazards of working with ammonia are, to an extent, common to all refrigeration systems. Low temperature freeze “burns” from splashes of liquid refrigerant, and high temperature scalding from hot pipes and components can be avoided by using suitable personal protective equipment. Other common hazards include working at height, working with electricity and lifting heavy equipment.

Despite these hazards ammonia has an excellent safety record when installed and maintained by competent technicians.

4. How can the hazards be addressed?

Toxicity and cold burns – the correct PPE should be worn for each activity. The work should be planned in advance with a written risk assessment and method statement which will define what is the suitable level of protection. Even if a respirator is not required for the planned activity it is wise to ensure that one is kept close at hand in case there is an unplanned leak. The plantroom ventilation system should be switched on before starting the maintenance activity and its correct operation should be verified.

Flammability – the design of the machinery room should comply with relevant standards and regulations including EN378. The key requirement in EN378 to prevent ignition of ammonia in machinery rooms is that all electrical circuits shall be automatically isolated by a signal from the gas detection system which monitors the machinery room (except those which are designed to remain live in an ammonia atmosphere, such as emergency lighting and ventilation). This requirement includes electrical circuits that are not associated with the ammonia plant, for example lights and wall sockets, and ancillary equipment such as water heaters. In addition to following the requirements of EN378 for the machinery room the whole installation should be assessed under the ATEX and DSEAR regulations, and a written record of the risk assessment should be recorded.

5. Ammonia Refrigeration Systems – key differences

Copper, brass and bronze are easily corroded by ammonia when small amounts of water are present. Pipework is usually steel or stainless steel, and evaporator tubes may be galvanised steel, stainless steel or aluminium. Gauge pipes are usually stainless steel, or occasionally plastic.

Ammonia is not often used in direct expansion (DX) systems for a number of reasons. The system would be very sensitive to moisture contamination if the evaporator is used to superheat the suction gas, and more than a slight trace of water in the ammonia could result in liquid floodback to the compressor. The expansion valve is also susceptible to wire-drawing, where the seat of the valve orifice is eroded by the high gas velocities created in the expansion process. This also leads to liquid floodback if it is not corrected soon enough. Ammonia is not miscible with mineral oils (including hydrocracked and polyalpha olefin), so DX systems would need to use a modern synthetic such as polyalkyl glycol (PAG). Most ammonia systems are therefore flooded, either using gravity recirculation or pumped overflow. The oil in these systems tends to collect in the evaporator and periodically it needs to be removed. It is more dense than the liquid ammonia and so it sinks to the bottom of the surge drum. Some systems include automatic oil return, but if this is not fitted then oil should only ever be drained to a collecting pot, and then decanted from the system through a self-closing, spring loaded manual valve. These valves should only be located in the machinery room or open air. Where older plants have oil drain points in production areas it should be possible to fit piping to enable the oil to be returned to the machinery room where it can be recovered. The spring loaded manual valve must not be tied in the open position and the plant should never be left unattended while oil is being recovered.

The following guidance notes are extracted from the IIAR publication “Introduction to Ammonia Refrigeration”, which was revised by the IOR for UK readers in 2007.

Effects of Exposure to Ammonia Vapour - Ammonia is a volatile water-soluble alkali (base) that most commonly acts as an irritant to the skin, eyes, mucous membranes of the upper respiratory tract, and the lungs. At high concentration, ammonia vapour reacts with moisture on and in the body to form a caustic solution that is damaging to body tissue. Ammonia vapour is quickly absorbed on moist body surfaces and results in a chemical burn. However, at much lower levels ammonia vapour is slightly irritating. Ammonia does not build up to toxic levels within the body following repeated exposures nor is it carcinogenic.

Effects of Exposure to Pure Liquid Ammonia - Ammonia in its natural state is a gas; however, in refrigeration systems, ammonia exists as a liquid under pressure and is also known as anhydrous ammonia. Liquid ammonia offers the greatest potential for injury with contact to the body because it is highly corrosive to all body tissues, resulting in blisters and chemical burns. In addition, thermal “freeze” burns are possible due to the low temperature of liquid ammonia.

Ammonia Exposure Effects on the Eyes - Ammonia, as is the case with other strong alkalis, can be damaging to the eyes. Ammonia in a gaseous state is slightly irritating to human eyes at concentrations in the 100 ppm to 200 ppm range and is immediately irritating to most people at concentrations of 500 ppm or more. In humans, extended exposure to ammonia vapour at or below these irritation levels does not seem to cause any permanent eye damage. However, a forceful blast of concentrated ammonia vapour directed into the eyes may cause severe eye damage that is similar to that caused by liquid ammonia. Most importantly, if liquid ammonia is sprayed or splashed into the eyes, permanent damage, including blindness, may occur. Severe alkali burns may occur if the eyes are not copiously and immediately flushed with water for at least 15 minutes. It is imperative that immediate professional medical attention is sought after initial washing of the eyes. In short, ammonia is extremely
dangerous to the human eye as a liquid or as a concentrated vapour. Every precaution should be taken to protect the eyes when working around your refrigeration system.

Ammonia Exposure Effects on the Respiratory System - Effects of high concentrations of ammonia vapour to the respiratory tract include irritation, hoarseness, excess salivation, sneezing, coughing, and productive coughing. As exposure level and exposure duration increase, the effects of respiratory system exposure to ammonia become more severe. These effects might include a cough that produces blood, lung rattle, swelling of the throat that reduces the ability to get oxygen, and/or fluid build up in the lungs. Very high concentrations of ammonia produce throat spasms and reflex constriction of the air passageway. Because ammonia is water-soluble and can be absorbed by the upper respiratory tract, the lungs are protected from the effects of exposure to low concentrations of ammonia. It is widely accepted that individuals exposed to higher concentrations will voluntarily leave the area at concentration levels below those at which lasting damage to the respiratory tract may occur. Studies show that individuals exposed to moderate concentration levels of about 500 ppm experienced only nose and throat irritation. Nevertheless, individuals exposed to inhalation of high levels of ammonia refrigerant vapour should be immediately moved and exposed to fresh air. Artificial respiration and/or oxygen should be administered as needed by trained emergency medical personnel. The individual should seek medical attention.

Effects of Ammonia Ingestion - Although highly unlikely, swallowing liquid ammonia will result in immediate pain and burns to the mouth and oesophagus. Ingestion causes corrosive effects on the mouth, throat, and stomach. Vomiting should not be induced. Seek immediate medical attention. If the patient is conscious, 2 glasses of water should be swallowed. If vomiting, individuals should be placed face down, with head lower than hips, to prevent vomitus from entering the lungs.

Ammonia Exposure Effects on the Skin - Ammonia gas is quickly absorbed by sweat (water) on moist body surfaces and results in a caustic (or chemical) burn. Contact with liquid ammonia also produces a freeze burn as a result of its natural cooling effect. Contact with liquid ammonia or ammonia vapour under pressure can result in second-degree burns, with formation of blisters. Upon contact with liquid ammonia, skin should be immediately flushed with large quantities of water for at least 15 minutes. Clothing may freeze to the skin and should only be removed after thawing occurs while under the emergency shower, ensuring that clothing is not still frozen to the skin. Individuals should seek immediate medical attention. No creams or ointments should be used for at least 24 hours, or as directed by appropriate medical personnel. Ointments can hinder the body’s natural ability to dissipate the ammonia from the skin.

Medical Treatment and Emergency Response - Seconds count after an accidental exposure to ammonia refrigerant. All individuals, including emergency response personnel, who may be required to treat exposed individuals, should understand the proper medical treatment for ammonia exposure. Industrial refrigeration facilities that use ammonia refrigerant should maintain emergency safety showers and eye wash stations so that individuals exposed to liquid ammonia or a very heavy concentration of ammonia vapour, may be flushed immediately with large amounts of water. Flushing of the affected area must be performed continuously for at least 15 minutes after exposure to minimise injury. EN378(2008) requires a flowrate of 1.5 l/s at a temperature between 25°C and 30°C for the shower. In addition, all individuals who have the proper authority, the training, and the occasion to require it, must wear personal protective equipment while working with or responding to ammonia refrigerant release.

6. What training is available?

Certification for the handling of ammonia is undertaken by City and Guilds 2078 parts 3 & 4 or the CITB equivalent or as part of a City & Guilds Certificate or Diploma under the 6127 RAC Qualifications scheme (including the CPD stand alone units in Ammonia 318, 320, 322, 324).

7. Where can I get more information?

- IOR Guidance Note 17 Maintenance of Refrigerating Systems containing R717 Ammonia
- IOR Guidance Note 10 Working With Ammonia
- IOR Guidance Note 19 Introduction to Dangerous Substances and Explosive Atmospheres Regulations (DSEAR)
- IOR Safety Code of Practice for Refrigerating Systems utilising R-717 Ammonia
- BS EN 13313 Competency standards Annex A
- BS EN 378:2008 Refrigeration Systems and Heat Pumps-Safety and Environmental Requirements
- Hazardous Waste Regulations
- Management of Health and Safety at Work Regulations (1999)
- Pressure Systems Safety Regulations (2000)
- International Institute of Ammonia Refrigeration User Guidance R1 (available as a UK version from the IOR at www.ior.org.uk)
- www.ior.org.uk/technical
- www.bsigroup.com
- www.hse.gov.uk
- www.iiar.org
Ammonia Valve Failure Safety Alert

In May 2011 the IOR issued a safety alert regarding the failure of an ammonia valve. This year it has issued an update based on reports of further failures of this type of valve have. It is clear that some of these failures are not due to corrosion. The assembly of the valve is susceptible to lack of complete fusion of the brazing filler ring, which in turn weakens the joint of the side port to the valve body. The Institute of Refrigeration recommends that all such valves, where the valve nozzles are brazed into the main body, should not be used on ammonia refrigeration plant. Any valves fitted to existing systems should be carefully examined. If there is any doubt as to their integrity they should be replaced immediately with a suitable valve manufactured with a one-piece body, and should be treated with extreme care until they are replaced. This should include clearly labelling the valve with a warning, protecting it from accidental mechanical impact and using appropriate PPE when working on the system in the vicinity of the valve.

Valve failure results in ammonia refrigerant burn injury

In an incident while working on a chill store plant in a food distribution depot, a refrigeration engineer received severe burn injuries when a significant amount of refrigerant was suddenly released while he was in the process of removing a valve cap from a DN 15 (½”) charging valve. The valve was installed on the low pressure side of an ammonia system. The HSE retained the valve for examination and testing.

The injuries sustained resulted in hospitalisation and also a lengthy period off work. The engineer was wearing appropriate personal protective equipment (PPE) at the time and this undoubtedly prevented more serious injuries.

The engineer was using a check spanner to hold the body of the valve whilst undoing the cap with another spanner but even so the valve connection to the plant failed. The depot operator decided to replace other valves of the same type at the site and also at other depots they own. During planned replacement of valves on an identical plant on site the charging valve in the same position as the original plant also “fell apart”. The HSE, Depot Operator and the Refrigeration Contractor agreed to carry out metallurgical examinations on both of the “failed” valves and also torque tests on these and on other valves removed from their other systems.

The valve construction included steel pipe stubs brazed into the valve body, screwed connections with nuts on the other end of the pipe stubs allow the valves to be connected to the systems or have blanking caps fitted. The valve that failed was connected to the system using a nut on the stub 90° to the valve stem; this stub came apart from the valve body. The second stub in line with the valve spindle had a blanking nut fitted as it was the refrigerant charging connection.

Valves with these types of brazed in connections are available in a range of sizes and are widely used on refrigeration systems. The photograph shows a typical valve (not the actual which failed); in this application the blank is on the stub at 90° to the valve stem and plant connection is in line with the valve spindle.

The conclusions drawn from the investigations are as follows:
- The failure was due to corrosion under the preformed brazing filler metal thus weakening the joint on to the valve parent metal.
- The corrosion had started externally.
- The valves were fitted on a section of plant cycling from sub zero to above zero temperatures.
- Forces used prior to the incident to fit the valves, remove caps or to fit charging lines etc may have damaged the valve.
- The paint finish on the valves had deteriorated.
- Ammonia was not considered to be a factor in the failure and it is believed that a serious incident would have occurred regardless of the type of refrigerant in the system.

Recommendations:

Before commencing work on any Refrigerating system wear PPE as required by your employers’ Risk and COSHH assessments for the refrigerant within the system PLUS in the case of Ammonia have a respirator available and to hand.

When working on any type of valve with screwed connections always use a check spanner to hold the body of the valve whilst undoing connections, caps, plugs, etc, with another spanner.

Identify all refrigeration plants containing these types of valves installed in parts of the system susceptible to corrosion e.g. regular cycling from sub zero to above zero temperatures or frequent operation in a wet condition. Then DO NOT ATTEMPT to use the valves until an appropriate risk assessment is carried out for either the replacement or the continued operation of the valves.

When working on refrigeration plants fitted with these types of valves installed and operating in dry conditions such as in HP discharge or liquid pipe lines etc, DO NOT ATTEMPT to work on the valves without firstly isolating upstream and downstream of the valve in order to limit potential gas loss.

Ammonia was not considered to be a factor in the failure, so the engineer should be aware of the risk of refrigerant burn injury regardless of refrigerant type.

Clean and apply refrigeration oil to threads before replacing screwed connections.

Regularly (quarterly) examine valves for leakage and corrosion and repair, paint or replace as required.

Consider if insulation is required to prevent ice from building up around the valve and exerting forces on the pipe stubs.