The Application of Ammonia in Refrigeration Systems – Safety & Environmental Requirements

Introduction

Characteristics of Ammonia

As a refrigerant, ammonia has been in continuous use for more than 100 years. The past 10 years has seen a renaissance in its use, with application in areas where it has been considered unsuitable for many decades – since the advent of the synthetic CFC and HCFC refrigerants. The reason ammonia, unlike every other working fluid used or considered for use, has stayed the test of time is that it manifests many positive characteristics, including:

- Chemically stable and inert
- Wide operating range
- Excellent thermodynamic properties
- Low cost: refrigerant and oils
- Good safety record
- Zero Ozone Depleting Potential (ODP)
- Zero direct Global Warming Potential (GWP)

Its renaissance is primarily tied to its positive environmental credentials of zero ODP and GWP, combined with high efficiency. Many organizations are specifying its use for their refrigeration projects as it provides an environmentally friendly, technical viable, cost effective and future proof solution to their needs.

The use of ammonia is of course a compromise. Although it manifests many of the characteristics for what might be the definition of the "perfect refrigerant," it has two negative attributes that provide challenges in its application; these being its potentially flammable and toxic nature.

At normal temperature and pressure, ammonia gas is flammable in air at concentrations above 15% v/v (150,000 ppm). The upper flammable limit is 28% (280,000 ppm).

In its gaseous form ammonia has a characteristically pungent odour, which can be detected at very low concentrations (5-50 ppm). The existing threshold limit value for an 8-hour period is 25 ppm, and for a 15-minute period, 35 ppm is allowed. Very short-term exposure to concentrations in the range 400 to 500 ppm would be unlikely to cause irreversible damage or a fatality. In higher concentrations (500- 5000 ppm) irreversible damage may be caused to mucous membranes. Short-term exposure to these high concentrations can be fatal. The practical limit for R717 (ammonia refrigerant), defined as highest concentration level in an occupied space which will not result in any escape impairing, (i.e. acute) effects, is 500ppm.

A further characteristic of ammonia is that large quantities of liquid sprayed into air can form an aerosol cloud of high density and very low temperature (approximately –70°C).

ii. Regulations relevant to Ammonia refrigerant use

Regulations, Standards & Guidelines provide the framework for ensuring the safe and appropriate application of all refrigerants, in terms of the design, manufacture, installation, operation and maintenance of the systems in which they operate. And there are many of them!

With regard to ammonia's potentially flammable and toxic nature there are 3 essential sets of UK developed regulations that apply, these being:

- The Management of Health & Safety at Work Regulations 1999
- The Control of Substances Hazardous to Health Regulations 2002
- The Dangerous Substances and Explosive Atmosphere Regulations 2002

While the specific focus of these regulations is somewhat different, there is significant overlap in terms of what they are intended to achieve and how the regulations require you to go about it.

The general approach that is required of all these regulations, with regard to the flammability and toxicity risks associated with ammonia as a refrigerant, is the following: .

"Assess the level of risk related to its use by carrying out risk assessments pertinent to that risk."
For ammonia's flammability risk this will involve assessing where leaks may occur that could lead to potentially flammable levels being reached. For ammonia's toxicity risk this will involve assessing where leaks may occur that could lead to potentially harmful toxic levels being reached.

"Put control measures in place to either remove those risks or, where this is not possible, control to risk levels that are as low as reasonably practicable" & "Put controls in place to reduce the effects of any incidents involving ammonia."
Here the various published standards and guidelines provide the basis and insight into achieving the appropriate level of control. In particular all ammonia installations should be designed, installed, operated and maintained to meet the requirements of BS EN 378 – 2008: "Refrigerating systems and heat pumps. Safety and environmental requirements," Parts 1 to 4 and the Institute of Refrigeration's, Code of Practice for A2 & A3 Refrigerants (flammable including hydrocarbons).

iii. Considerations for new installations

Where new ammonia installations are being considered there are often opportunities to reduce the risks associated with its use; by the specification of low charge designs, the use of secondary fluids, such as carbon dioxide and glycols, which are cooled by the primary ammonia system and then pumped to production areas and by the removal of potential leak sources to the outside, eg valve stations on roofs. While these types of risk reduction options are best and most easily considered for new plant they may also be valid retrofit options if risk considerations dictate changes need to be made.

iv. Reducing the risks

For all ammonia installations the standards and codes provide the methodology for reducing risk as far as reasonably practicable, with the general route being the application of leak detection systems, set to alarm at appropriate levels, ventilation and ultimately electrical isolation. In addition, there are a range of practical measures that can be adopted to assist with mitigating risk, including: safety showers, provision of canister respirator sets in enclosed areas, eg plant rooms & roof voids, controlling access to plant rooms and other enclosed spaces, provision of ammonia scrubbing plant and automatic isolation of liquid supply to production areas if leak conditions exist.

- *Prepare plans and procedures to deal with accidents, incidents and emergencies involving ammonia releases" & "Make sure employees are properly informed about and trained to control or deal with the risks from ammonia."*

Many sites, though by no means all, have developed Ammonia Release Response Plans. That is, to some extent, thought has been given to and developed in writing, on what they should do in the event of ammonia releases.

These response plans are generally described in the form of an escalation procedure, since the vast majority of ammonia releases are relatively minor and can be dealt with quickly and the minimum of fuss. Here refrigeration plant operators will typically have had training in what they need to do in dealing with the situation.

What is far more rare, although still a legal obligation, is to ensure all employees, and others who might visit the facility, are aware of the presence of ammonia on the site and what they should do in coming across the range of potential scenarios that could arise, up to and including a major ammonia release. All sites will ensure that fire evacuation drills are carried out regularly, but how many consider the need for ammonia release drills, where the decisions that may need to made are various, depending on the leak scenario and severity, and include questions such as, "should a building be evacuated, or should personnel shelter in place?"

- *Identify and classify areas of the workplace where the risks may occur.*

Where the issue of flammability is being considered this will generally mean classifying plant rooms as Zone 2 Hazardous Areas, and ensuring that in the event of a high level leak the requirements of BS EN 378 are met.

These are to electrically isolate all equipment in the room, typically via shunt trips off the supply distribution boards, at ammonia concentrations no greater than 20% of the LFL. While it is appropriate to classify plant rooms as Zone 2 hazardous areas from a flammability perspective, since it can be anticipated that flammable concentrations could occur, albeit, "infrequently and for short periods," BS EN 378, Part 3, Clause 6.3 allows relaxation of the normal hazardous area code requirements, stating that, "Electrical equipment in rooms in which a refrigeration system containing ammonia is located need not conform to the requirements for hazardous areas."

Ammonia refrigeration systems have a good safety record. They are generally of an industrial nature, robustly built, using welded steel pipework, and leakage levels, compared to many HCFC and HFC systems, are typically low. In addition, the self-alarming nature of ammonia, where it is detectable at very low concentrations, <5ppm, and unpleasantly irritating at much above 50 – 100ppm, mean there should be a low threshold of tolerance to its presence.

Most accidents involving ammonia releases are due to human error, with the statistics indicating poor training and lack of awareness of the dangers associated with working with ammonia as key contributors to the incidents. Those most at risk of ammonia releases are the refrigeration plant operators and maintainers. It is beholden on those owning and operating these systems to ensure they, and the safety systems installed with them, are properly maintained and that site personnel, not just those directly involved in operating the ammonia systems, are aware of its presence on site and know what they should do in the event of an ammonia release.

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Further detailed guidance on the safe use of Ammonia is available from the Institute of Refrigeration web site http://www.ior.org.uk

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