Cooling with ammonia: What you should keep in mind

Using ammonia for refrigeration is effective, saves resources and is generally safe. Unpredicted gas leaks, however, cannot be completely prevented. A modern gas detection system reduces the risk of production downtime, protects the employees‘ health and can save seconds that make a difference in case of an alarm.

A classic in refrigeration

Dairies, bottling plants, butcheries and production plants with a freezing tunnel cannot do without it: Low temperatures must be generated wherever food is produced or processed – during storage, for preservation or for special technologies and processes. Ammonia (chemically NH_3) has been used for this purpose for over a hundred years – and the alkaline compound of nitrogen and hydrogen dominates the refrigeration system market now more than ever. This is not a surprise, since the natural refrigerant, used for the first time by Carl von Linde in 1870 to refrigerate beer, has a number advantages. Ammonia has a good volumetric cooling capacity and is a very effective refrigerant due to a heat of vaporisation of 1368 kJ/kg.

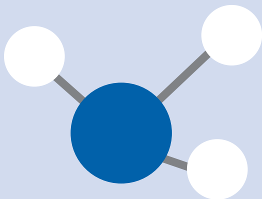
Only a small amount of ammonia needs to be moved in the system – approx. 13 to 15 percent compared to fluorocarbons, to generate a high refrigeration capacity. This makes NH_3 very economical. But not only the installation of an ammonia-based refrigeration system is about 10 to 20 percent cheaper than similar systems, operating costs are also significantly lower.

A further advantage: as opposed to liquid hydrocarbons, ammonia is more environmentally compatible. Its global warming potential (GWP) and ozone depletion potential (ODP) equal zero.

AMMONIA IN REFRIGERATION SYSTEMS: THE MOST IMPORTANT FIGURES AT A GLANCE

Molar mass	17.03 kg/kmol
Boiling point	-33.3 °C
State of matter under normal conditions	gaseous, liquefies under pressure (8.6 bar at 20 °C)
Lower explosive limit*	15 vol.% (or 108,000 mg/m³)
Upper explosive limit* *at 20 °C and 1.013 bar	30.2 vol.% (or 240,000 mg/m³)
Ignition temperature	650 °C
Detection threshold	5 ppm 3.5 mg/m³ (0.02 – 70 ppm)
Symptoms of poisoning	2,500 ppm 1,750 mg/m³
Deadly concentration	5,000 ppm 3,500 mg/m³

Source: www.euroammon.com; www.vfdb.de; vfdb information sheet for fire service operations in case of danger due to ammonia



Ammonia

Chemical formula: NH_3
Appearance: Colourless gas

Toxin with olfactory warning signal

More than 130 million tons of ammonia are produced around the world every year, and counting. NH_3 is one of the most widely produced chemicals—and at the same time one of the most widely used hazardous substances in the industrial sector. There are several reasons for this:

1. Risk of explosion and fire

Ammonia is a flammable gas and can form flammable or potentially explosive compounds in dry air when in gaseous state. The concentration threshold is between 15 and 33 vol.%. The required ignition temperature of at least 630 °C, however, is rather high.

NH_3 is generally lighter than air and reaches the atmosphere with a high diffusion velocity. In confined spaces and containers, it can displace any available oxygen. NH_3 has a high affinity for moisture and quickly forms compounds with the moisture in the atmosphere. If ammonia leakages occur, water curtains are used to damp down vaporous ammonia. The gas then sinks to the ground in the form of ammonia aerosol – visible as a white mist.

Ammonia has a relatively low flammability and only burns continuously with a supporting flame. If the steam content in the air exceeds 11 vol.%, flammable and potentially explosive mixtures are no longer possible. Despite the intensive use of ammonia around the world, explosions and fires purely caused by NH_3 are very rare. Any known incidents almost exclusively took place in closed rooms or containers. Thus, there is only a risk of explosion if the concentration in unventilated rooms exceeds the explosion limit (105 grams per cubic meter) or if high-energy ignition sources are present.

Maintenance work at ammonia refrigeration systems requiring welding, soldering or cutting must be performed with extreme caution: existing oil mists can lower the explosion limit of NH_3/air mixtures. NH_3 systems should therefore be purged with air or a non-flammable gas prior to starting the welding work in order to remove residual ammonia.

Another safety concern is the corrosive effect of ammonia on iron, copper, zinc, tin and their alloys. Leakages can damage parts of the refrigeration system and cause uncontrollable gas leakages. Corrosion caused by ammonia not only causes perforation in the form of holes, but also as corrosive cracks. These are often very subtle and difficult to detect.

2. Toxicological danger

Ammonia is a respiratory poison that has a strong irritating and corrosive effect – in gaseous state, but mainly in liquid state. The strongest reaction occurs with moist body surfaces such as the mucous membranes and causes painful chemical burns, for example of the cornea, and can cause blindness. The temperature of liquid ammonia is below -33 °C and causes severe frostbite if it comes into contact with the skin. Inspiration can damage the respiratory tracts and the lung. Symptoms of (minor) ammonia poisoning include a feeling of suffocation and breathing difficulties, dizziness, a burning sensation in the throat, increased salivation, stomach ache and vomiting. Extended exposure damages the respiratory and digestive organs. In some cases, serious symptoms may show hours after inspiration. Contaminations with a level of 1700 ppm or higher are life threatening.

AMMONIA LIMIT VALUES FOR OCCUPATIONAL SAFETY AND PLANT SAFETY

WES (Aust & NZ)	TWA	25 ppm	17 mg/m³
WES (Aust & NZ)	STEL	35 ppm	24 mg/m³
OSHA	PEL	50 ppm	35 mg/m³
ACGIH	TLV	25 ppm	17 mg/m³
ACGIH	STEL	35 ppm	
TRGS900	MAK	50 ppm	35 mg/m³
DFG	MAK	20 ppm	14 mg/m³
France	VLE	50 ppm	
GB	LTEL	25 ppm	
EU	OEL-TWA	20 ppm	
EU	OEL-STEL	50 ppm	
	IDLH	500 ppm	

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Fatal accidents involving ammonia are nevertheless rare: Due to the typical acrid smell, which can be noticed in very low concentrations starting at 5 ppm, humans normally notice it well below the threshold of a harmful concentration. This has advantages and disadvantages: The low odour threshold can cause panic among the employees, even if the concentration is not dangerous. This is also one of the reasons why reliable and precise detection is essential: It helps to prevent miscalculations and impetuous reactions.

Detecting leakages faster, avoiding incidents

Corrosion, leaking valves or operating errors: An accidental ammonia leakage can occur for many reasons – even if the refrigeration systems are professionally and properly maintained. Experts estimate that leakage losses at complex industrial refrigeration systems amount to 2 to 17 percent every year, depending on age and condition of the system.** Cracks frequently develop when liquid residual ammonia is locked in pumps or lines during standstill, which warms up and expands as a consequence. Other critical scenarios include filling, maintenance and cleaning.

It is crucial to detect leakages quickly. On the one hand, of course, to avoid damage to the system and the products stored in refrigeration and any effort for required refilling should be kept to a minimum. On the other hand, any interruption of the production costs money, no matter if there is a real alarm due to hazardous concentrations or merely a false alarm. This is why ammonia leakages in particular need to be detected with high precision.

***Footnote: Euroammon information no. 2, may 2011, http://www.eurammon.com/download/eurammon02dt.pdf, viewed: 25/11/2015*

EXAMPLE: LIMIT VALUES FOR COUNTERMEASURES

	EN* 378-3	TRD** 452 A2	EN 50054
First alarm	500 ppm / 380 mg/m³	400 ppm	
Second alarm		800 ppm	
Explosion hazard alarm	30,000 ppm / 22800 mg/m³		
LEL			154,000 ppm

**EN = European Norm . The local Australian and New Zealand Standard applicable here is AS/NZS 1677.1.1998.*
*** German technical regulations for pressure tanks*

Detecting ammonia: a challenge under extreme conditions

Ensuring safe working and production conditions in plants using ammonia refrigeration is not an easy task in terms of safety. A highly toxic hazardous substance must be monitored reliably under adverse climatic conditions such as fluctuating temperatures or high humidity.

One cornerstone of safety is continuous monitoring of the system. In these cases, a fixed gas measurement system is the most effective and reliable method to detect exceeded thresholds as quickly as possible and warn the staff. Leakages can also be located with mobile gas detectors, which employees carry or can be placed temporarily at critical locations. In the case of an alarm, emergency personnel and employees also need adequate personal protective equipment. Depending on the threat potential, this constitutes of filter masks or respiratory protection independent on the ambient air, chemical protective suits and escape equipment, if required.

What to look for when installing fixed gas measuring equipment?

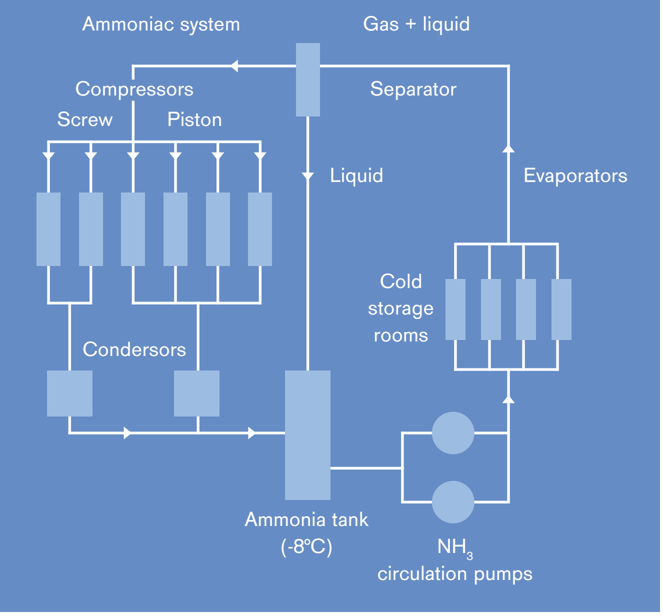
1. Position measurement points correctly

In ammonia-based refrigeration systems, the transmitters of a gas measurement system are normally installed in the compressor room and near the valve stations, for example to check the pipe ends. The sensors in the compressor room should generally be positioned at the ceiling, as ammonia is about half as light as air and rises quickly after a leakage. Even if one cannot smell ammonia in the lower section of the room, the concentrations at the ceiling can be significantly higher. When installing the transmitters, ensure that the sensors are not positioned directly in the airflow toward or from the evaporator.

2. Factor in potential disruptive factors

Extreme temperature fluctuations are prevalent in the compressor room. Moisture can develop during air heating and cooling due to condensation, which can affect the performance of sensitive devices. Moisture can also be generated during defrosting procedures at the evaporator. If possible, sensors should be positioned in locations that provide the best protection from these or other potential disruptive factors.

EXEMPLARY CONSTRUCTION OF AN AMMONIA REFRIGERATION SYSTEM



3. Keep sensor performance in mind

Freezing temperatures, fluctuating temperatures, moisture and corrosion: not every sensor is suitable for use in the challenging environment of a refrigeration system. At the same time, however, a high level of precision is important especially in the field of ammonia detection. For a reliable measurement performance it is therefore of utmost importance that the selected gas detectors are robust enough to withstand the wide range of temperatures and other prevailing challenges.

4. Select correct alarm thresholds

A basic level with low background concentration is often present in ammonia refrigeration systems. In order to avoid frequent false alarms, the defined alarm thresholds should be slightly above the TLV level. A high sensor quality supports reliable and precise measurements and contributes to minimising false alarms and production downtimes.

5. Pay attention to regular maintenance

For reliable, precise measurements a gas detection system must be calibrated regularly and also maintained at specific intervals. This applies even more if the system operates under challenging conditions. It pays off to invest in higher service quality: Technicians with specialised expertise are faster at noticing and fixing typical effects of ageing and signs of wear. Thereby they increase the reliability of the devices and expand their lifespan.

Safety solutions that stand strong

In the majority of ammonia accidents, the hazardous substance occurs in gaseous form. If injured persons are suspected in the contaminated area, their rescue is the highest priority. Respiratory protection independent of the ambient air is essential for fire brigades and other emergency personnel. One important component is a head piece, which safely protects the eyes from contact with contaminated atmosphere at the same time. In many cases, gas-tight chemical protective suits are required in the expected hazardous situation anyway.

If liquid ammonia leaks from the refrigeration systems, the situation becomes more problematic: Upon contact with the skin, the temperature of the liquid, which is -33 °C or lower, causes frostbite. Its level of severity depends on the contact surface and the amount. Even basic protective clothing cannot withstand, the freezing cold liquid corrodes through the material. It is recommended to wear chemical protective suits made from cold-resistant material when starting the work. To protect the skin from frostbite, warming work clothes as well as woollen sock liners and finger gloves should be worn under the suit.

Filter out the right filter

leakages should be provided with personal gas warning devices for safety reasons. For work that involves the risk of leaking or rapidly escaping ammonia – such as opening the refrigeration circulation system – personal protective equipment must be available and used if required.

This includes:
- Full face mask with screwed-on ammonia filter (identification colour green, letter K) and integrated eye protector
- Protective gloves
- Rubber boots
- Protective goggles

In the case of an alarm, escape apparatus that are independent of the ambient air support an organised evacuation of the plant. Filtering escape devices that protect from toxic gases also provide safety to escaping persons.

Special requirements need individual solutions

Ammonia-based refrigeration systems are a particular challenge for safety management. Gas measurement equipment, protective equipment and escape equipment all require individual solutions that consider all plant-specific factors. Both new installations and the integration of new components into existing infrastructures require fundamental knowledge of basic chemical and physical principles, technical parameters and legal requirements – a highly complex planning process. Expert advice will be worth it every step of the way: during acquisition, installation, commissioning as well as maintenance.

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