Gas detection for ammonia refrigeration plants

1. Tightness

- The tightness of a refrigeration plant is a key for technical, ecological and economic requirement for all refrigeratin systems including those using ammonia.

2. Principles for avoiding leaks

- Keep the refrigerant quantity as low as possible: refrigerant that is not contained in the system cannot leak.
- The design of a refrigeration system, its layout, the choice between primary and secondary cooling the components used, the number and complexity of valve stations together with the piping configuration have an impact on possible refrigerant emissions during maintenance and servicing work and when dealing with faults.
- The construction and planning of a refrigeration plant and also the selection of its components and equipment must take account of the fact that the components used must have very good leak tightness and that allowance is made for regular leak checks.
- The material chosen for the components and their connections must be state of the art. In the case of non-metallic materials, special attention must be paid to their behaviour in combination with refrigerants and lubricants. The volume of elastomers for example can increase (swell) or decrease (shrink) in combination with certain oils and ammonia.

3. Leak test and leak detection

- The odour threshold value of ammonia (human perception limit 5 ppm = 3.5 mg/m³) indicates the need to remedy leaks.
- Leakages which under certain circumstances can remain undetected in HFC plants with an odourless refrigerant (e.g. R134a) for a certain period of time are simply unimaginable in ammonia plants.
- Leaks in ammonia refrigeration plants with a leakage rate of approx. 100 g NH_3/a cannot be detected by smell as an ammonia concentration of 5 ppm is not reached at the leakage point.

3.1 Leak testing before initial commissioning

- Gas detection measurement and alert settings should be carried out on the basis of nationally approved standards, such as the VDMA Data Sheet 24243, Part 2 and according to the mandated standard EN1779.
- Lower concentration limits for gas detection are particularly important where high pressure parts of the plant are not accessible during subsequent operation.

3.2 Gas detection for existing plants

- As soon as ammonia can be smelt, measurement of the concentration is necessary. Here again, this should be based on nationally approved standards, such as the VDMA Data Sheet 24243, Part 2.
- Detection sensors should achieve detection sensitivity of at least 15 g NH_3/a.
- This level of sensitivity has a positive effect on detecting low concentrations of leakage from ammonia refrigeration plants. A drawback is that the sensors do not produce the leakage rate in numerical form but only permit an estimation of the leakage rate (small, medium, large).
- Gas detection by means of phenolphthalein paper (colour change on a test strip) or leak detection sprays has far poorer detection sensitivity values.
- If the leakage rate of an ammonia leak has to be quantified (for example when handling complaints), photoacoustic infrared absorption detection instruments can be used.

4. Automatic leakage monitoring

- Machine rooms or installation rooms with components of the ammonia refrigeration system are monitored with detectors. This ‘fixed’ monitoring equipment is specified in EN378 as a compulsory requirement for plants with a charge of more than 50 kg. To spot small leakages at an early stage, a lower value of sensitivity is often used than required in EN378 (500 ppm) or recommended in TRAS 110 (150 ppm). The usual value is between 50 and 100 ppm.

4.1 Structure and function

4.1.1 Measuring principle

- The most widely used type of sensor is based on the electrical semiconductor principle. When an ammonia/air mixture comes into contact with the sensor it causes a change in conductivity which is converted to a signal by the electronic evaluation module.

Conductivity depends on the concentration of ammonia in the air. An alarm is triggered on exceeding the set alarm thresholds.

- There are also electrochemical sensors which, while being generally more expensive than semiconductor sensors, have less cross-sensitivity and are used primarily where the influence of substances other than ammonia could trigger a false alarm.
- Gas monitors can also be used, working according to the principle of photoacoustic infrared absorption. These units have a detection sensitivity and resolution of 1 ppm. The measuring range is 0 to 1,000 ppm. The low cross-sensitivity is also beneficial.

4.1.2 Alarm thresholds and switching function (as per EN378 and TRAS 110)

- **Pre-alarm ≤ 500 ppm:** The guidelines in the safety requirements in ammonia refrigeration plants (TRAS 110, Technical Rules for Plant Safety) and in standard EN378 generally demand trigger values of 150 to 500 ppm for the **pre-alarm** which activates automatic ventilation in the machine rooms. Working rooms need sensors with a trigger value of 200 ppm.
- **Main alarm 1,000 ppm (according to TRAS 110):** The affected components of the plant (refrigerant pumps, compressors, shut-off valves) are automatically shut down. The way in which this happens must be coordinated with the operation process to avoid any negative consequences, which could under certain circumstances be more costly than the implication of the leak (e.g. increase in product temperature).
- **Upper alarm threshold max. 30,000 ppm:** The technical ventilation system is switched off and the fresh air flap closed. A low-voltage trigger at the main switch of the switchboard disconnects the system from the power supply. It must be possible to start up the technical ventilation system at any time from outside the plant or machine room.
- **In practice there are special requirements of local authorities to follow**. For example, the upper alarm threshold in the UK is 10,000 ppm.

4.1.3 Spread of gas and positioning of the sensors

For ammonia plants, the sensors are arranged as follows:

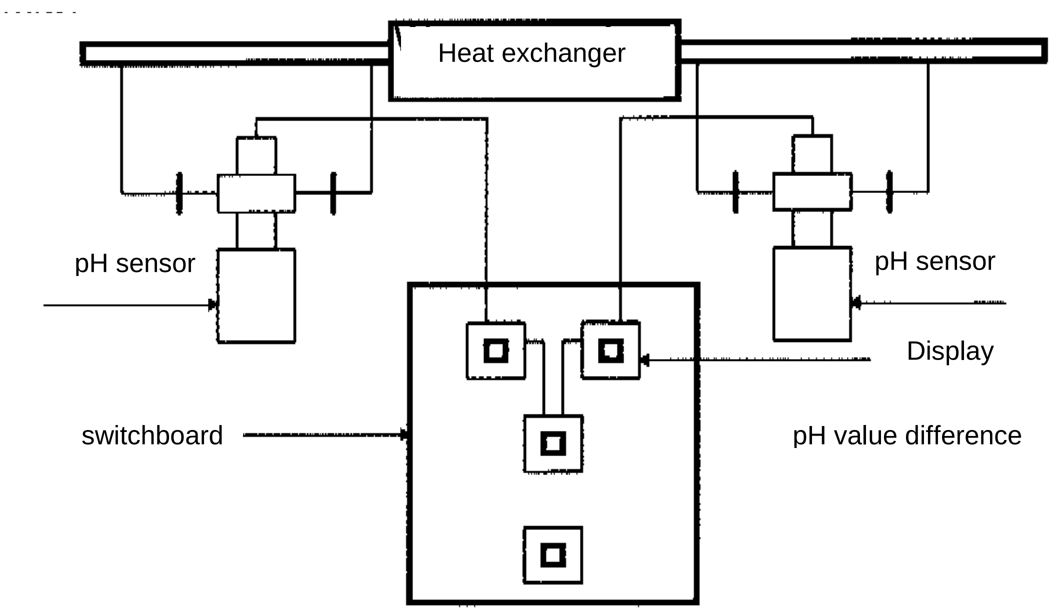
- One sensor in the pressure relief vent line (if present and if there are no rupture disks with compression chamber monitoring) to monitor the valve for leaks or triggering
- One sensor on the ceiling of the machine room to monitor gaseous leaks (lighter than air)
- For ammonia pump circulating systems, one sensor is positioned in the pump sump for monitoring leaks in the liquid phase. It is quite possible for heavy gas effects to occur in this part of the refrigeration plant, which is why the ammonia concentration should be monitored at the floor area of the machine house or in the drip pan.

5. Monitoring water circuits for ammonia leaks

- EN378: In refrigeration plants charged with more than 500 kg, measures are to be taken to ascertain the presence of refrigerant in all connected water or fluid circuits.
- Requirements according to the German WHG/Sample VVAwS (Water Management Law – Administrative regulation for execution of the ordinance on plants for handling substances hazardous to water and on specialist companies): Section 5.4.8 of VVAwS names cooling and heating systems. Cooling and heating systems (e.g. evaporative condensers, heat exchangers or cooling coils) that operate with substances hazardous to water must be secured in such a way that in the case of damage, it is not possible for any substances hazardous to water to land in the cooling water or in the wastewater system.

6. Measuring system for monitoring

- The most common measuring system at present is still to monitor the pH values. An ammonia leak in a water circuit causes the pH value to increase. It is advisable to install a device for differential measurement of the pH value between the inlet and outlet of the heat exchanger with automatic temperature compensation. In the case of a pH alarm, it is necessary for the heat exchanger to be shut off on the water and ammonia side by means of motor valves or by hand. New ion-selective measuring devices are much more precise. The use of these is preferred to pH monitoring sensors.



- As well as separate sensors, there are also combined sensors (i.e. only one installation site) and systems working on the basis of a change in conductivity.

- Another possibility is to use an ammonia-sensitive electrode. Differential measurement is not necessary in this case.
- For air-cooled condensers, an ammonia sensor should be fitted in the discharged air current or in the air space under the fans.

7. Summary (as per EN378)

- Leaks and other faults must be remedied immediately by a qualified, instructed person. Refrigerant must never be refilled before all leaks have been found and repaired correctly. After a fault, the plant must only be recommissioned after restoring the tightness and safety of the refrigeration plant.

Annex

Ammonia detection systems – sensors

There are different monitoring and detection systems on the market, the selection of which should be based on the following considerations:

- Concentration (ppm) to be measured and resolution (accuracy)
- Response time
- Environment: −40…+60°C and relative humidity
- Installation location of the sensor
- Recalibration and maintenance requirements

The following detector types are most commonly used for ammonia:

- EC sensors (electromechanical detectors)
- IR (infrared) sensors
- CI sensors – solid-state sensors according to the carrier injection principle
- MOS/chemosorption sensors
- Others: Catalytic sensors or UV-light sensors

Depending on local regulations and manufacturer a regular functional check/calibration is necessary (typically one or twice per year).

Electrochemical (EC) sensors

These sensors emit a proportional electromechanical output signal depending on the NH_3 concentration in the ambient air.
The detector has a chamber in which there is an electrolyte with an anode and cathode and

in which an electromechanical reaction occurs in the presence of NH_3.
Measured NH_3 values are evaluated by a microprocessor transducer and converted into an output signal 0(4)…20 mA or 0(2)–10 V. Typically the sensor provides some relay outputs to control emergency closing valves and chillers and to shut down the plant if necessary.

The measurement range stretches from 0 to 1,000 ppm with a response time of 15 sec. Regardless of the trigger value, because the sensor operates on the basis of a chemical reaction it is essential to consider the need to recalibrate and maintain it. A sufficiently long and stable service life of the sensor (6–12 months) also needs to be ensured.

Infrared (IR) sensors

IR sensors are based on the principle of infrared absorption by gas molecules at specific wavelengths in the infrared region.

The sensor comprises an infrared lamp source and two detectors – active and reference. The active detector is covered by an optical filter that allows transmission of infrared radiation at a specified wavelength where the target gas is absorbed. The reference element is covered by a filter that transmits wavelengths outside the absorption band. This arrangement provides compensation for normal changes in lamp intensity over time.

IR absorbance is not linear to NH_3 in ppm, but with the corresponding interpolation, the sensor and microprocessor offer an output signal which is manageable.

The measurement range stretches from 0 to 3,000 ppm with a response time of 1–5 msec.
Recalibration and maintenance are very simple; service life is up to ten years.

Charge carrier injection (CI) sensors

The detection principle of these sensors is based on the absorption of ammonia by a "charge carrier" in a solid-state substrate. By absorbing ammonia the charge carriers are "injected" into the sensor element, causing a change in resistance that is proportional to the concentration of ammonia in the environment.

The technical service life of the sensors is no longer limited by ammonia exposure levels. This reduces replacement costs associated with electrochemical sensors.

Charge carrier injection technology also eliminates false alarms frequently associated with metal oxide sensing (MOS). These features and others provide reliable, cost-effective, long-term safety.

The measurement range stretches from 20 to 3,000 ppm with a good response time of 10–15 sec.
Recalibration and maintenance is required at least every three years.

Chemosorption (MOS) sensors

Solid-state metal oxide semiconductor (MOS) sensor technology is based on the measurement of the conductivity of the sensor depending on the refrigerant concentration in combination with the conductivity of the air or the air/NH_3 mixture in the environment.

Through a microprocessor the conductivity differential is interpolated to a signal of 4–20 mA or 0–10 V, which is proportional with the ammonia to be measured.

Temperature and particularly humidity variations can disturb the conductivity and therefore accuracy could be affected. The measurement range stretches from 0 to 300 ppm. Recalibration and sensor replacement is required every three to five years.

Others:

There are other detectors on the market of less use for ammonia but nonetheless worthy of consideration.

Catalytic sensors: based on hot filaments that burn or oxidise the gas, while the reference element is nonreactive and provides compensation for ambient conditions (temperature and humidity). The two elements are configured in a Wheatstone bridge, where exposure to combustible gas unbalances the bridge and generates an electrical output directly related to gas concentration.

Photoionisation detectors (PIDs): Sensitivity is based on UV (ultraviolet) source energy and ionisation energy of the target gas.

The two sensor types have different measurement ranges and long service lives, and function reliably. However, the price and maintenance costs should be considered.

In case of doubt, the German-language original should be consulted as the authoritative text.

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