Leakage monitoring at ammonia refrigeration plants

1. Tightness
   - The tightness of a refrigeration plant is a key quality attribute. This also applies to plants using the refrigerant ammonia for technical, ecological and economic reasons.

2. Principles for avoiding leaks
   - Keep the refrigerant quantity as low as possible: refrigerant that is not contained in the system cannot leak.
   - The planning of a refrigeration system, and thus the choice of the cold transfer system, the components, the equipment and in particular the arrangement of the shut-off valves 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 principle sealing ability, and that allowance is made for regular leak tests.
   - 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
   - Ammonia’s strong warning effect (human perception limit 5 ppm = 3.5 mg/m³) indicates the need to remedy leaks.
   -Leaks which under certain circumstances can remain undetected in H-FC plants for a certain period of time are simply inconceivable in ammonia plants.
   -Leaks in ammonia refrigeration plants with a leakage rate of approx. 100 g NH₃/a cannot be detected by smell as an ammonia concentration of 5 ppm is not reached on the discharge side.
3.1 Leak testing before initial commissioning
- Rough leak tests and fine leak tests 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 DIN EN 1779.
- Fine leak testing is particularly important under high pressure at parts of the plant which will no longer be accessible during subsequent operation.

3.2 Leak testing in existing plants
- As soon as ammonia can be smelt, leak detection is necessary. Here again, this should be based on nationally approved standards, such as the VDMA Data Sheet 24243, Part 2.
- Leak detectors achieve detection sensitivity of at least 15 g NH₃/a.
- These sensitivity reserves have a positive effect on detecting leaks in ammonia refrigeration plants. The drawback is for example that the assembly leak detectors do not produce the leakage rate in numerical form but only permit an estimation of the leakage rate (small, medium, large).
- Leak 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), detection instruments can be used working according to the principle of photoacoustic infrared absorption.

4. Automatic leakage monitoring
- Machine rooms or installation rooms with components of the ammonia refrigeration system are monitored with detectors. Such constant leakage monitoring is specified in EN 378 as a compulsory feature for plants filled with a quantity of more than 50 kg. Smaller leaks are not detected because of the trigger threshold of approx. 500 ppm.

4.1 Structure and function
4.1.1 Measuring principle
- Sensors are used for the most part based on the electrical semiconductor principle. The ammonia/air mixture at the sensor 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 adjusted 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 EN 378 and TRAS 110)

- The guidelines in the safety requirements in ammonia refrigeration plants (TRAS 110, Technical Rules for Plant Safety) and in standard EN 378 generally demand trigger values of 200 to 500 ppm for the \textbf{pre-alarm} which activates automatic ventilation in the machine rooms. Working rooms need sensors with a trigger value of 200 ppm.

- \textbf{Main alarm 1,000 ppm}: The affected parts of the plant (refrigerant pumps, compressor, 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 leak (e.g. increase in product temperature).

- \textbf{Upper alarm limit 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 outside the plant or machine room.

4.1.3 Spread of gas and positioning the sensors
For ammonia plants, the sensors are arranged as follows:

- One sensor in the blow-off pipe of the safety valve (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

- For ammonia pumping 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

- EN 378: in refrigeration plants filled 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 (Water Management Law)/Sample VVAwS (Administrative regulation for execution of the ordinance on plants for handling substances hazardous to water and on specialist companies): section 5.4.8 of the VVAwS names cooling and heating systems. Cooling and heating systems (e.g. evaporation coolers, 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.

• 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 chamber under the fans.

7. Summary (as per EN 378)
• 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 of the refrigeration plant.

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