

# Ammonia

*Danfoss Industrial refrigeration has written a technical paper on things to consider when changing from HFC/HCFC's to ammonia. It outlines some of the main differences between the different plant types and what you need to take into account when designing an ammonia plant. In the paper there are references to the industrial refrigeration application handbook from Danfoss (literature number DKRCI.PA.000.C6.02). This is indicated with § and then the given chapter.*



## Background on ammonia as a refrigerant

Ammonia ( $\text{NH}_3$ ) was used for refrigeration for the first time in 1876, by Karl Von Linde in a vapor compression machine. Other refrigerants such as carbon dioxide ( $\text{CO}_2$ ) and sulfur dioxide ( $\text{SO}_2$ ) were also commonly used until the 1920s.

The development of CFCs (chlorofluorocarbons) in the USA in 1920s swung the pendulum in their favor, because compared with all other refrigerants then in use, CFCs were considered harmless and extremely stable chemicals. The consequences to the environment of massive releases of refrigerant could not be foreseen in those days. CFC refrigerants were promoted as safe refrigerants, resulting in accelerating demand and success for CFCs. These refrigerants became known as God-sent, man-made chemicals.

The success of CFCs meant ammonia faced a strong challenge, but it held its position, especially in large industrial installations and food preservation.

The harmful effects of CFC refrigerants became apparent in the 1980s, and it was generally accepted that CFC refrigerants were contributing to depletion of the ozone layer and to global warming. The result was the Montreal protocol (1989), in which almost all countries agreed on a timetable for phasing out CFCs.

In view of the seriousness of the damage to the atmosphere and the resulting danger due to CFC/HCFC emissions and to the effects of global warming, the revised Montreal (1990), Copenhagen (1992) and Kyoto (1998) agreements demanded an accelerated phase-out schedule. HCFCs are also to be phased out.

Europe has taken the lead, with many of its countries stopping the use of HCFC refrigerants. New refrigerants as well as well-tried and trusted refrigerants such as ammonia and carbon dioxide are being considered for various new applications, too.

## Why ammonia is a good refrigerant

### Well known

Ammonia is a well-known refrigerant. It is especially popular in large industrial plants, where its advantages can be fully utilized without compromising the safety of the personnel working with the refrigeration installation. Ammonia has very favorable thermodynamic properties. It outperforms synthetic refrigerants such as R22, one of the most efficient HCFCs, across a wide range of applications.

Its benefits have been proven in ammonia refrigeration systems over many decades.

### Energy efficiency

Ammonia is one of the most efficient refrigerants, with an application range from high to low temperatures. Its efficiency is higher than that of R134a or propane. Furthermore, ammonia systems perform even better in practice. Given the ever-increasing focus on energy consumption, ammonia systems are a safe and sustainable choice for the future. A flooded ammonia system would be typically 15-20 % more efficient than a direct expansion (DX) R404A counterpart. Recent developments of NH<sub>3</sub>/CO<sub>2</sub> combinations help increase the efficiency even further. NH<sub>3</sub>/CO<sub>2</sub> cascaded is extremely efficient for low- and very low-temperature applications (below -40 °C), while NH<sub>3</sub>/CO<sub>2</sub> brine systems are around 20 % more efficient than traditional brines.

### Environment

Ammonia is one of the so-called “natural” refrigerants, and is the most environmentally friendly refrigerant in terms of GWP (Global Warming Potential) and ODP (Ozone Depletion Potential), each having a value of zero. The challenge of refrigerant systems being technically closed systems with corrosive, toxic, and moderately flammable contents is met using well-known plant designs based on EN378, PED and, for bigger plants, requirements from the authorities.

### Smaller pipe sizes

In both the vapor and liquid phases, ammonia requires smaller pipe diameters than most chemical refrigerants.

[1] § 10.7\*

### Better heat transfer

Ammonia has better heat transfer properties than most chemical refrigerants, enabling equipment with a smaller heat transfer area to be used. Plant construction costs will be lower for the same plant layout and identical choice of materials. These properties also benefit the system's thermodynamic efficiency, reducing operating costs.

### Refrigerant price

In many countries, the cost of ammonia (per kg) is considerably lower than that of HFCs. This advantage is further extended by ammonia's lower density in the liquid phase. Additionally, any leakage of ammonia will be detected very quickly due to its odor, thereby reducing any potential loss of refrigerant.

## Oil

Ammonia is not miscible with common oils. In addition, ammonia is lighter than oil, which makes oil return systems fairly simple.

[1] § 6.3\*

## Pump or gravity circulation systems

The advantages of these systems compared with DX-type systems are:

- Pumps efficiently distribute liquid refrigerant to evaporators and return the vapor-liquid mixture to the pump separator
- The superheat can be reduced to 0 K, increasing evaporator efficiency without risking the carry-over of liquid in the compressor
- The low temperature differential reduces dehydration of the stored product
- Gravity circulation systems have a relatively low refrigerant charge

## Future

There is nothing happening to suggest that ammonia could be phased out. You can trust in the future of ammonia.

## Safety

Ammonia is a toxic, corrosive refrigerant, and flammable at certain concentrations. It must therefore be handled with care, and all ammonia systems must be designed with safety in mind. The challenge of refrigerant systems being technically closed systems with corrosive, toxic, and moderately flammable contents is met using well-known plant designs based on EN378, PED and, for bigger plants, requirements from the authorities.

At the same time, unlike most other refrigerants it has a characteristic odor detectable by humans even at very low – and definitely not dangerous – concentrations. Humans can smell ammonia at approx. 5 ppm in air. That gives a warning of even minor ammonia leakages. Should it be necessary to reduce the ammonia charge, a combination of ammonia and CO<sub>2</sub> (as cascade or brine) may be a good and efficient option. The toxicity and flammability of ammonia mean installations using it are governed by national regulations to ensure that safety is not compromised.

## Chemical properties, challenges to the material

Ammonia is compatible with all common materials except copper and brass. Though this imposes certain limitations on system design, these are well known and have been solved. First, only steel or stainless steel pipes can be used. Second, it is necessary to use open compressors. The gap-tube motor is commonly used for pumps. Special solutions include expensive magnetic-coupled motors.

# Why ammonia is better than HFCs/HCFCs

## Technical

Thermodynamically, ammonia outperforms HFC/HCFC refrigerants, the same cooling duty being accomplished with lower power consumption and running costs. The heat transfer coefficient inside evaporators and condenser tubes for ammonia is roughly twice better than for R22. Lower operational delta T is possible with the same heat exchange surface, again contributing to lower running costs and less food dehydration. Ammonia's high latent heat enables small liquid line pipe sizes, thereby reducing the system volume of refrigerant. The pipe size for wet and dry suction lines can be smaller with ammonia for the same suction line pressure drop. In recirculation pump systems, the mass flow for ammonia is 1/7 that for R22, so a much smaller pump can be used with a considerably lower energy consumption, again contributing to the lowest possible running costs.

Better reliability and lower maintenance costs for ammonia systems are the result of using steel instead of copper piping, welding rather than brazing, and bolted flanges instead of flare connections. Ammonia systems are more tolerant of water that might enter the system.

To summarize, it can be said that with the present ammonia designs and technologies ammonia should always be the preferred option for installations 100 kW and larger, unless it is not permitted or inadvisable. The recent development indicates that even for smaller installations ammonia is becoming an interesting refrigerant.

### **Legislative**

Under pressure to take action to reduce environmental impact, all governments are paying increasing attention to the Montreal and Kyoto protocols. Countries will implement unpopular measures to realize their targets for reducing the impact of global warming. Two basic instruments will be or are already used: a complete ban, or penalty taxes on HFC/HCFC refrigerants. This will make using ammonia, with its GWP of zero, very attractive. Pressure on governmental organizations will urge them to create clear rules for ammonia refrigeration plants without ignoring safety.

### **Economic**

The immediate attraction of ammonia compared with HFCs/HCFCs is its very low price per kg: up to 90 % lower than for HFCs. Furthermore, ammonia's low specific weight means only half the weight is needed for the same volume compared with HFCs/HCFCs. The contents of a refrigeration system are measured by volume, so only half the refrigerant by weight is needed when ammonia is used. The price of ammonia will not be influenced by political/commercial actions such as environmental penalty charges. HFC/HCFC pump circulation plants can lose a substantial proportion of their charge unnoticed, making replenishment potentially very expensive. Any leak of ammonia will be detected immediately and repaired quickly, thereby reducing the cost of replenishment.

### **Environmental**

From an environmental perspective, ammonia should be preferred not only because of its zero direct impact on global warming but also because of its highest possible efficiency and correspondingly lowest indirect CO<sub>2</sub> footprint.



## **Summary of main differences between ammonia and HFCs/HCFCs**

Ammonia is not a universal refrigerant, but mainly suitable for industrial and heavy commercial applications. Ammonia's toxicity, corrosivity, flammability, and compatibility with other materials must be taken into account. At the same time, there are many ammonia systems worldwide where those challenges are successfully met.

Technical differences between refrigeration plants working with ammonia and HFCs/HCFCs are well known as details concerning material, oil management, the machinery room, component sizing and, of course, special rules resulting from ammonia's toxicity, corrosivity, and moderate flammability. Ammonia for refrigerant plants is classified as Class B2 (EN378) and Fluid Group 1 (PED).

Familiarity with ammonia, oil properties and the requirements for ammonia plants will provide guidance towards the correct application format. The main difference lies in the preparations for bigger plants, depending on the ammonia charge, made jointly with local authorities.

The owner of any plant needs the permission of the authorities to operate a refrigerant plant on the grounds of its size. This permission is based on PED, EN378, local and national rules regarding the environment, geographic

considerations, hygiene, labor, safety, etc. The difference in acquiring permission for an ammonia plant lies in the safety aspect, because ammonia is toxic, corrosive, and moderately flammable. Given familiarity with the implementation of local and national regulations, there should be no objection to creating an ammonia plant instead of an HFC/HCFC plant.

Last but not least, it is evident that first costs are higher for ammonia plants than for HFC/ HCFC plants with copper tubing. However, the ammonia plant's longer lifetime and lower energy consumption mean it will have the lowest lifetime total cost of ownership.

To learn more about what to consider when changing from HFC/HCFC's to ammonia read the full technical paper at [www.danfoss.com/IR-tools](http://www.danfoss.com/IR-tools). On this page you can also find several other good tools related to industrial refrigeration.

**For more information:**

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