ENGINEERING
TOMORROW

From **HFCs/HCFCs to Ammonia** in Industrial Refrigeration

Brief guidance on changing to ammonia

www.danfoss.com/IR-tools

Purpose:

Brief guidance on changing to ammonia

Area:

Europe where PED and EN378 apply

Danfoss is your natural partner when you want to work with natural refrigerants such as ammonia and CO_2 and flammable refrigerants in industrial refrigeration.

- Easy entry into the ammonia world with information on changing to ammonia
- Guiding you to your first steps in learning about ammonia systems
- Danfoss is your partner for ammonia plants 100 kW and up. However, we are also seeing a trend for smaller plants with ammonia as a refrigerant, and compressor manufacturers are also building smaller compressors for ammonia
- F-gas regulations will make it necessary (or more attractive) to change to environmentally friendlier refrigerants such as ammonia
- The what, why and how of ammonia

Note: this brochure is an appetizer for people considering working with ammonia. It is not intended to replace formal education, but to give an indication of the possibilities

* Throughout this document we will make references to our Application Handbook. This will be done with § and then the given chapter. The version used is literature number DKRCI.PA.000.C6.02. You can always find the most updated version on www.danfoss.com/IR-Tools

Contents

1

Background on ammonia as a refrigerant

Ammonia (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 (CO_2) and sulfur dioxide (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.

2

Why ammonia is a good refrigerant

2.1. Benefits

2.1.1. 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.

2.1.2. 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_3/CO_2 combinations help increase the efficiency even further. NH_3/CO_2 cascaded is extremely efficient for low- and very low-temperature applications (below -40 °C), while NH_3/CO_2 brine systems are around 20% more efficient than traditional brines.

2.1.3. 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.

2.1.4. Smaller pipe sizes

In both the vapor and liquid phases, ammonia requires smaller pipe diameters than most chemical refrigerants. [1] § 10.7*

2.1.5. 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.

2.1.6. 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.

2.1.7. 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*

2.1.8. 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

2.1.9. Future

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

2.2. 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_2 (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.

2.3. 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.

3

Ammonia plant vs HFC/HCFC plant: some differences

It is assumed that the reader is familiar with the basics of a refrigerant plant. For a deeper explanation and details, please refer to:

1. Danfoss Application Handbook for Industrial Refrigeration, Ammonia and CO_2 applications

   Online: click here

   Not online: go to www.danfoss.com/IR-Tools

2. Danfoss Industrial Refrigeration Application Tool, for two-stage ammonia plant

   Online: click here

   Not online: go to www.danfoss.com/IR-Tools

3. See all our tools for industrial refrigeration here:

   Online: click here

   Not online: go to www.danfoss.com/IR-Tools

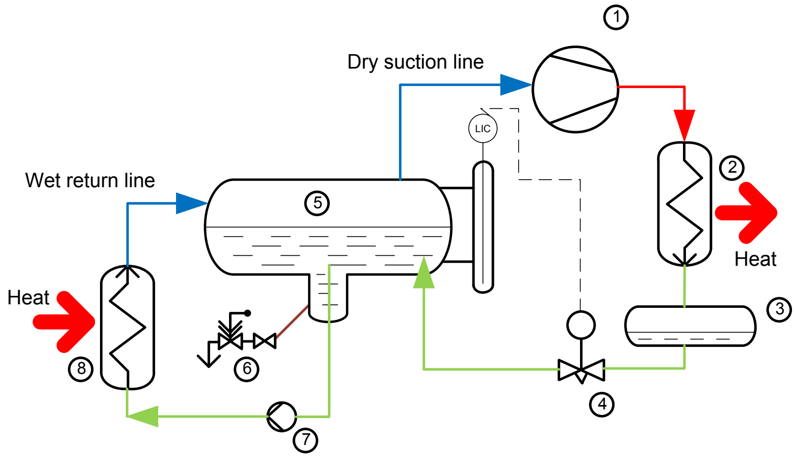
The following items are simplified, and only selected systems are used with the aim of showing differences.

For greater detail, please see the literature listed above.

3.1. Common basic ammonia plant: one-step, pump system

A basic ammonia plant contains the following elements: compressor unit (1), condenser (2), receiver (3), expansion device (4), liquid separator (5) with oil drain (6), refrigerant pump (7), and evaporator(s) (8).

More information in application handbook [1]:	
Compressor:	§ 1, 2, 6ff.
Condenser:	§ 1, 3ff.
Expansion device:	§ 4ff.
Separator:	§ 4.2, 6.3, 7.3, 8ff.
Oil drain:	§ 6.3ff.
Refrigerant pump:	§ 8ff.
Evaporator:	§ 5ff.



The compressor sucks the dry gas (from evaporator and flash gas) from the separator at evaporating temperature, compresses it to condensing temperature and feeds the superheated discharge gas to the condenser. The condenser liquefies the refrigerant while dissipating the heat from the refrigerant gas to the cooling media. From the condenser, the liquid refrigerant is fed to the expansion device at condensing pressure and close to the condensing temperature. In the expansion device, the ammonia is expanded to evaporating temperature and then fed to the separator. In the separator, liquid and flash gases are separated.

The liquid refrigerant, at evaporating temperature and pressure, is sucked by the pump and delivered to the evaporator(s). The circulation rate is generally 1:3, i.e. 1/3 of the mass flow is evaporated in the evaporator, taking up the heat capacity.

In the evaporator, the heat exchange takes place. A mix of gas and liquid is fed back to the separator, where the liquid is separated from the gas and the compressor can suck dry gas.

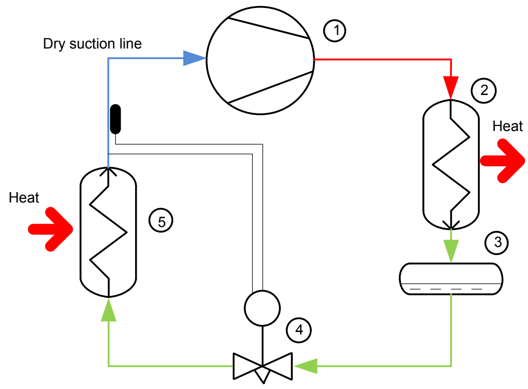
The circuit is closed.

Compressor oil is commonly not soluble with ammonia, so oil will at least remain and be collected in the evaporator. This will cause poor capacity or failure, preventable by an oil drain on the separator's oil sump.
See also [1] §6.3* *Fig 6.3.1. Oil drain from ammonia systems.*

3.2. Common basic HFC/HCFC plant: DX system

A basic HFC/HCFC plant, DX (also known as dry or direct expansion), contains the following elements: compressor unit (1), condenser (2), receiver (3) in bigger plants, thermostatic expansion valve (4), and evaporator(s) (5).

It is assumed that the reader knows the principles of HFC/HCFC refrigerant DX systems.

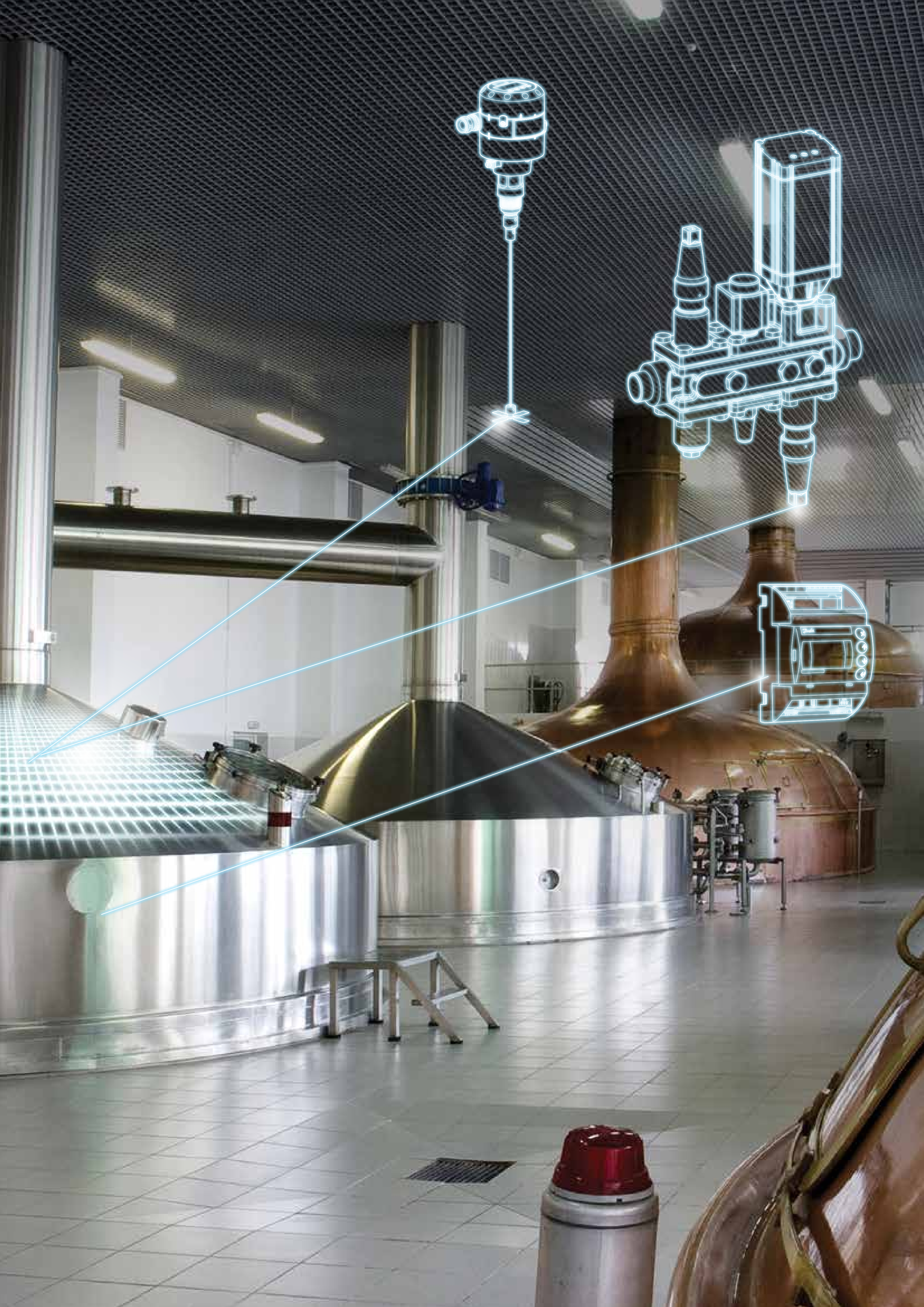


The compressor sucks the dry, normally approx. 7-10 degrees overheated, gas and flash gas from the evaporator(s) at evaporating temperature, compresses it to condensing temperature and feeds it to the condenser. The condenser liquefies the refrigerant while dissipating the heat from the refrigerant gas to the cooling media. From the condenser, the liquid refrigerant is fed to the liquid receiver(s) at condensing pressure and under subcooled conditions (approx. 2-5 K).

In the thermostatic expansion valve (TEV), the liquid refrigerant is expanded to evaporating temperature. The TEV will only charge the evaporator, so the measured outlet temperature is superheated relative to the evaporating pressure.

The circuit is closed.

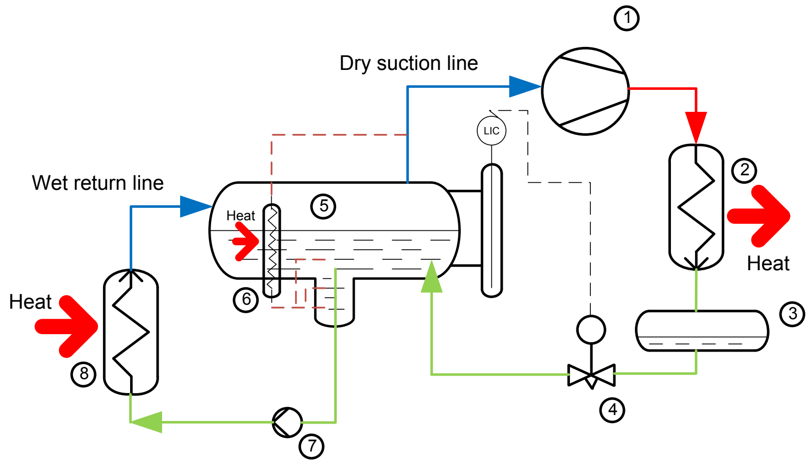
Compressor oil is more or less soluble in HFC/HCFC refrigerants, so it is transported in a circle through the system. Piping must be designed correctly to ensure correct oil return.



3.3. Common basic HFC/HCFC plant: one-step, pump circulation

A basic HFC/HCFC plant contains the following elements: Compressor unit (1), condenser (2), receiver (3), expansion device (4), liquid separator (5) with oil return (6), refrigerant pump (7), and evaporator(s) (8).

It is assumed that the reader knows the principles of HFC/HCFC refrigerant systems. They are similar to ammonia systems, so the same references (above) as for ammonia can be used, keeping the refrigerant and oil issues in mind.
Oil boiler: see [1] § 6.3 *example 6.3.2**



The compressor sucks the dry gas (from evaporator and flash gas) from the separator at evaporating temperature, compresses it to condensing temperature and feeds the superheated discharge gas to the condenser. The condenser liquefies the refrigerant while dissipating the heat from the refrigerant gas to the cooling media. From the condenser, the liquid refrigerant is fed to the expansion device at condensing pressure and close to condensing temperature. In the expansion device, the refrigerant is expanded to evaporating temperature and then fed to the separator. In the separator, liquid and flash gas are separated.

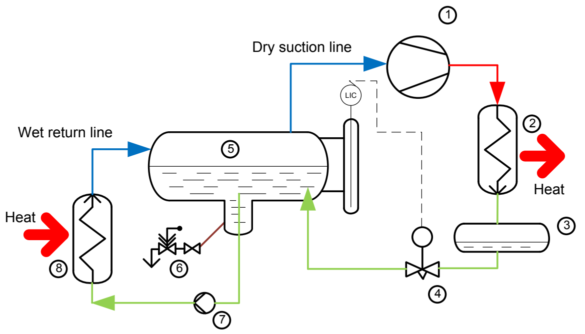
The pump sucks the liquid refrigerant at evaporating temperature and pressure and delivers it to the evaporator(s). The circulation rate is generally 1:3, i.e. 1/3 of the mass flow is evaporated in the evaporator, taking up the heat capacity.

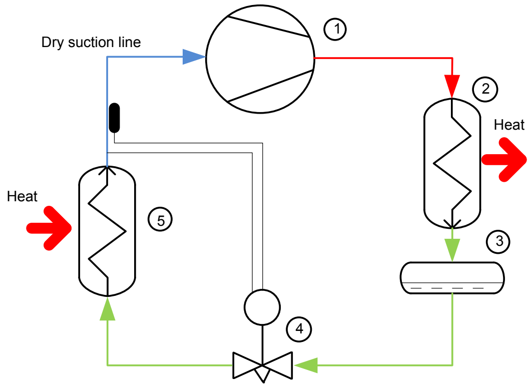
The heat exchange takes place in the evaporator, and a mix of gas and liquid is fed back to the separator, where the liquid is separated from the gas, enabling the compressor to suck dry gas.

The circuit is closed.

The purpose of the separator is to deliver dry suction gas to the compressor, so velocities are low and the oil cannot return to the compressor with the suction gas. The oil trapped in the separator becomes more concentrated over time as the system operates, which challenges the performance of the refrigerant pump and the evaporators. To avoid this, a small part of the refrigerant oil mixture flow is taken from the separator and injected into a small heat exchanger (oil rectifier), where the refrigerant is boiled out. A mixture of dry refrigerant gas and oil vapor is fed back to the suction line of the compressor. This ensures that the concentration of oil in the separator is kept at an acceptable level.

3.4. Ammonia, one-step, pump system vs HFC/HCFC DX system





3.4.1. Overview

	Ammonia one-step, pump system	HFC/HCFC DX
1	+ compressor	+ compressor
2	+ condenser	+ condenser
3	+ receiver	+ receiver
4	+ expansion valve	+ thermo expansion valve for each evaporator (expansion point at every evaporator)
5	+ separator (cold)	+ evaporator
	+ oil drain required	
	+ ammonia pump (cold)	
	+ valve station on each evaporator	+ valve station on each evaporator
	+ wet return line (cold)	
	+ dry suction line (cold)	+ dry suction line (cold) (It must be considered whether a suction line accumulator is necessary to protect the compressor(s) against liquid refrigerant.)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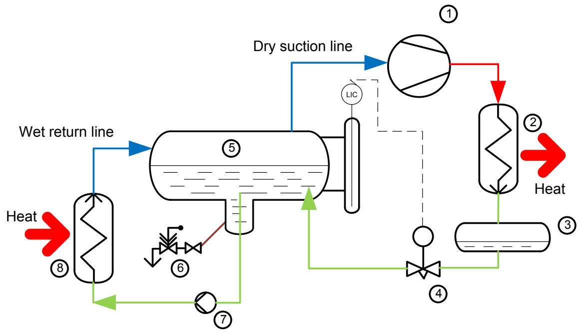
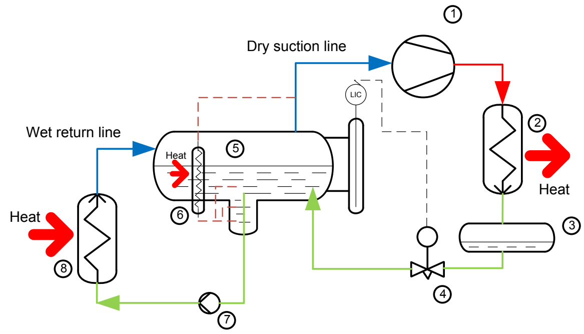
3.5. Ammonia, one-step, pump system vs Common basic HFC/HCFC plant, one-step, pump circulation





3.5.1. Overview

	Ammonia one-step, pump system	HFC/HCFC one-step, pump system
1	+ compressor	+ compressor
2	+ condenser	+ condenser
3	+ receiver	+ receiver
4	+ expansion valve	+ expansion valve
5	+ separator (cold)	+ separator (cold)
6	+ oil drain required	+ HFC/ oil rectifier required
7	+ ammonia pump (cold)	+ HFC/HCFC pump (cold)
8	+ valve station on each evaporator	+ valve station on each vaporator
	+ wet return line (cold)	+ wet return line (cold)
	+ dry suction line (cold)	+ dry suction line (cold)

3.6. Summary 3.4 and 3.5

Other ammonia refrigerant plant systems include:
- + Two-step pump system
- + Cascade system
- + Refrigerant-brine system
- + Ammonia DX system

Most industrial refrigerant plants are custom-made, which means there are many different plant executions. However, when comparing ammonia and HFC/HCFC plants, the above criteria are appropriate and transferrable to other executions.

The overviews are self-explanatory. Typically ammonia systems need more pipes, vessels, fittings and pumps. But it also shows that the systems are very similar, except for the oil return/oil drain system.

4

Basic ammonia plant: DX

The lower investment and much lower refrigerant charge compared with a pump circulation system obviously make an ammonia DX system look very interesting. If the compressor is lubricated with a soluble oil there would in theory be no difference between ammonia and HFC/HCFC DX systems. Nevertheless, ammonia DX has until now not yet been successful, for the following reasons:

- Ammonia's high latent heat means the mass flow is very small, making good distribution over the evaporator circuits difficult and resulting in evaporator performance worse than calculated.
- Small changes in evaporator load will bring drops of liquid to the outlet of the evaporator. Even quick-acting electronic expansion valves cannot prevent drops of liquid entering the suction line and the compressor.
- Presence of water content is a major contributor of destroying stable superheat.

Though recent developments in evaporator technology are making good progress in overcoming the above, they are yet to be proven in practice.

5

Basic ammonia/ CO_2 brine and cascade

When local conditions limit the quantity of ammonia, it is common practice to create an indirect working system with glycol or brine. With the increasing popularity of CO_2 as a refrigerant, it is more efficient to opt for ammonia/CO_2 brine for cooling applications and ammonia/CO_2 cascade for freezing purposes. The CO_2 requires much smaller piping and considerably less pumping energy compared with glycols. Given the high working pressure of CO_2 the industry has made available standard components with a maximum working pressure of 52 bar. [1] § 10.2* Fig 10.2.3

Ammonia/CO_2 cascade is becoming increasingly successful due to the low charge of ammonia and the ammonia being limited to the machinery room. Furthermore, the high volumetric capacity of CO_2 enables the pipe dimension and the compressor to be further downsized. Lower freezing points can also be reached more easily. [1] § 10.2* Fig 10.2.1 and 10.2.2

6.1. Safety considerations

There are three aspects to safety in an ammonia plant:

- The internal intrinsic safety of the mechanical plant itself based on the design rules given in the various standards. For Europe these are the well-known EN378 and PED (Pressure Equipment Directive), the same rules being applicable to HFC/HCFC plants.
- External safety during repair and maintenance of the plant. Here EN378 also prescribes that only trained and certified fitters are allowed to work.
- External safety in the event of accidents, bearing in mind workers in the plant and people living around the plant. The positive property of ammonia is that the human nose can detect it at very low concentrations. At higher concentrations, real irritation of the eyes, nose and mouth lead to the reflex of moving away from the contaminated area. Ammonia detection, which is prescribed by law, will activate alarms before the irritation level has been reached.

The safety of people living around the plant is safeguarded by local laws. The main criterion is the distance from the machine room to the nearest building or to the boundary with the adjacent property. The minimum distance will depend on the volume of ammonia and on the nature of the neighboring premises. A full risk assessment must be undertaken if the volume of ammonia exceeds a certain limit, which varies from country to country. The risk assessment is a requirement for every plant, including HFC/HCFC, and is normally carried out by specialized companies or Notified Bodies.

6.2. National regulations

In most cases the regulations can be divided into three parts:

- Plant design and construction rules, prescribed in EN378 for the EU area.
- Design rules for pressure vessels, prescribed precisely in norms and standards. In Europe this is covered by PED. Manufacturers and suppliers of these vessels normally ensure compliance.
- Safety equipment and safety procedures, including the ventilation of machine rooms depending on the volume of ammonia and the plant's construction. Most of this is described in normative rules such as EN378 and ANSI/ASHRAE/IIAR. Once the plant's design and operating conditions are known it is a matter of using a checklist to establish what equipment to install and which procedures to follow. Criteria include the distance from the plant to the nearest neighbor, depending on the volume of ammonia, the plant's construction and the location (indoors/outdoors) of components containing liquid ammonia. Rules for this aspect of safety differ from country to country, and it is extremely important to have detailed knowledge of them.

6.3. Explosion, flammability, toxicity

The effects by ppm concentration are as follows:	
1 - 5 ppm:	Odor detectable by average person
20 ppm:	MAC value (Europe; 25 ppm in USA)
50 ppm:	MAC value short period (15 minutes)
100 - 200 ppm:	After 1 minute some irritation of the eyes will occur. No impairment of vision or difficulty breathing
400 ppm:	Immediate tear effect on the eyes with impaired vision. Nose and throat problems that are not serious providedexposure lasts less than 1 hour
1000 ppm:	Constantly streaming eyes, no vision and great difficulty breathing
2500 - 4000 ppm:	Seriously dangerous within 30 minutes
5000 -10,000 ppm:	Rapidly fatal

6.3.1. Toxicity

Substances have a toxicity level known as the maximum allowable concentration (MAC). Expressed as parts per million (ppm), it is the time-weighted average concentration value that does no harm to people during eight-hour day, 40 hours per week exposure. For ammonia, the MAC is 20 ppm in Europe and 25 ppm in the USA.

Substances are regarded as very toxic if their MAC lies below 400 ppm. Whether the European or US MAC is used, ammonia must always be handled as a very toxic refrigerant.

Most people will have already left the area at the level of 100 ppm and no one will stay voluntarily at over 200 ppm without a breathing aid and protective eye mask. Above 400 ppm, the only reliable protection is a gas-tight suit, as used by the fire service.

6.3.2. Flammability

Ammonia has low flammability. An open pool of low-temperature ammonia will not ignite spontaneously. Ignition requires an external heat source, and once this is removed burning stops. This is due to the low level of heat radiated from the flames to the pool.

6.3.3. Explosion

Mixtures of ammonia and dry air 15-28% by volume ammonia are explosive. The ignition energy required to start the explosion is high, and liquid ammonia under atmospheric pressure cannot be ignited. The explosion range in ppm is far above 100,000 ppm, so no human could function in an environment where ammonia could explode. High air humidity, as well as any mixture of air, ammonia and oil vapor, will lower the concentration limit; thus the explosion limit, used to calculate emergency ventilation capacity, shall be adjusted.

6.4. Oil

Oil must be drained because oils commonly used in ammonia plants are not soluble in ammonia. [1] § 6.3*

6.5. Steel

Pure ammonia has no effect on metals if completely dry, but will attack and destroy copper and copper alloys if it contains even a small amount of water. Consequently, ammonia plants use steel or stainless steel piping and equipment. Steel piping is specified according to various standards, usually DIN or ANSI, depending on the geographic region. The outside diameter for both standards is the same. They are differentiated by the wall thickness. The ANSI standard has three wall thickness grades for the same outside diameter: Schedule 80, Schedule 40 and Schedule 20. Schedule 80 is the heavy wall type, and Schedule 40 the more or less standard version. Schedule 20 is available only for pipe sizes from 200 mm and above. The choice of wall thickness is based on mechanical strength and expected corrosion impact. All Schedules are suitable for the standard maximum working pressure of 25 bar for an ammonia plant.

Steel pipe is connected by welds that must be subjected to X-ray inspection. For the butt weld (pipe to pipe), the wall thicknesses must be the same, or almost the same, to create a good X-ray image. In ammonia plants, DN15 (½") is very commonly the smallest pipe size used. Smaller sizes for control lines will be made from thin-wall stainless steel, in the sizes 6, 8 or 12 mm.

Another way of connecting pipes, and pipes to components, is by internal/external thread. This is mainly used in the USA, and only for connections up to DN32. This is mainly a cost issue, because it can be avoided by employing authorized welders to make the connections. EN378 restricts this taper pipe thread to the connection of control, safety and indicating devices to components. (6.2.3.2.3.4)

6.6. Water concentration in ammonia

Filter driers are never seen in ammonia refrigeration installations. The molecular sizes of ammonia (NH_3) and water (H_2O) are too similar to create any preference for absorbing one or the other. Fortunately, water and ammonia are miscible depending on the temperature. The ammonia-water absorption refrigeration installation offers clear proof of this. In the past, adding a little water to ammonia systems was even recommended to prevent stress corrosion of the steel pressure vessels. The quality of the steel in current vessels means this is no longer necessary. Does this mean water is harmless in ammonia refrigeration systems? Absolutely not. While there will be no internal corrosion in the absence of oxygen, water can cause sludge formation with oil and will also shift the temperature/pressure relationship, meaning that a lower pressure is needed for a given evaporating temperature. This will impair the efficiency of the plant. In a pump circulation system, water in the ammonia will decrease the flow of ammonia and increase the pump power. Water can be removed in a by-pass vessel, where the contaminated ammonia is heated and clean ammonia sent to the suction side. The residual water will be removed manually or automatically. When the water content is very high, it might be less expensive to replace all the ammonia. [1] § 9.2*

6.7. Action in the event of a leak

It must be noted immediately that any action in the event of an ammonia leak must be taken by authorized personnel, trained and equipped with the correct protective materials, gas masks, gloves, and boots. Leaks can result from wear, vibration, human error, or external accident. The rate of leakage can vary from merely the odor of ammonia to a stream of liquid ammonia.

Small leak, no alarm activated.
In the event of a small leak, it is sufficient to "follow your nose" looking for the highest concentration, keeping a protective mask within reach. Such leaks are usually caused by leaking joints (flanges, threaded connections, covers of control devices, packing glands of stop valves, etc.). Check the locations of stop valves up- and downstream of the suspected area, in case the leak becomes worse. Presenting a wet litmus paper to each joint will indicate the precise location of the leak. The color changes from red to blue in the presence of ammonia. Retightening will stop the leak in most cases. If not, the part itself must be inspected in accordance with the standard service procedure.

Leak from human error, low alarm activated
Such unintended leaks can be caused during service/maintenance by the unforeseen loosening of parts. This underlines the preference for always working in pairs, enabling the second person to close stop valves.

Catastrophic leak, high alarm activated
A pipeline ruptured by an external or internal cause is an example of a catastrophe releasing large amounts of ammonia. The standard alarm procedure is followed in this case. If the leak is in the machine room, the emergency ventilation will exhaust the ammonia gas. Depending on the size of the plant, other safety actions will be taken automatically, such as isolating parts of the plant using automatic closing valves. As soon as the ammonia in the plant has reached atmospheric pressure, the temperature drops to -33 °C and evaporation becomes very slow. Local inspection in a gas-tight suit is the optimal action. If that is not possible, the only option is to ventilate until all ammonia has evaporated.

6.8. Lifetime of components

The robust steel-based design of components for ammonia is the basis for a very long lifetime. Furthermore, most components can be opened for cleaning and repair. Replacing internal parts after 20 years is unexceptional, and restores components to as-new condition. The availability of complete service and overhaul packs for Danfoss stop and control valves extends the ammonia plant's operational lifetime, thereby increasing its profitability.

7

Why ammonia is better than HFCs/HCFCs

7.1. 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.

7.2. 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.

7.3. 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.

7.4. 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_2 footprint.

8

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.

8.1. Benefits of ammonia:

- GWP=0
- ODP=0
- High volumetric capacity
- Cheaper than HFCs/HCFCs
- Lowest total lifetime cost
- More effective than HFCs/HCFCs
- Nothing happening to suggest that ammonia could be phased out; you can trust in the future of ammonia
- Downsized pipe dimensions
- Known for centuries as a refrigerant
- Classified as flammable, but no ATEX requirements for normal ammonia plants except for machinery-room ventilation in special cases

8.2. Challenges

- Classified as Fluid Group 1 in PED (toxic, corrosive, and moderately flammable), so special legal requirements must be met
- Copper and its alloys are not allowed (challenge material)
- Oil draining

9

Danfoss products for ammonia

With more than 60 years of experience with ammonia in refrigeration, Danfoss has a wide variety of valves and control solutions developed for industrial refrigeration using ammonia as the refrigerant. With Danfoss you benefit from a single supplier that facilitates the whole process from start to finish.

When you use products from our Flexline™ concept you get an intelligent and cost-efficient modular solution. It will provide you with clever simplicity, timesaving efficiency, and advanced flexibility. In our Flexline™ family you will find SVL line components, ICF valve stations, the ICV platform of control and solenoid valves named ICS, ICM, and ICLX. The design concept behind the Flexline™ products is that they are all based on a modular design with no functionality in the housing. This set-up reduces complexity right from the design phase to installation, commissioning, and service. These are all key to lower total life cycle costs – and major savings.

Here is an overview to give you an impression of the variety of the products we offer for ammonia refrigeration:

Control valves

ICV Flexline™ control valves

- ICS, Servo-operated valve
- ICM, Motor valve
- ICAD, Actuator, for ICM Motor valve

Other control valves

- Pilot valves
- KDC

Valve stations

- ICF Flexline™

Line components

SVL Flexline™ valves

- SVA-S, Stop valve
- SVA-L, Stop valve
- REG-SA, Regulation valve
- REG-SB, Regulation valve
- CHV-X, Check valve
- SCA-X, Stop/check valve
- FIA, Filters

Other line components

- SNV-ST/SS, Stop needle valves
- FA, Strainers
- NRVA, Check valves, for ammonia and fluorinated refrigerants
- NRVS, Check valves

Solenoid valves

ICV Flexline™ Solenoid valve

- ICLX

Other solenoid valves

- EVRS/EVRST, Stainless steel
- EVRA, Servo-operated, normally closed (NC)
- EVRAT, Assisted lift, normally closed (NC)

Sensors

- AKS 32, 1-6 V DC output signal, 9-30 V DC
- AKS 3000, 24 V DC supply, 4-20 mA output
- AKS 38, Level switch
- AKS 4100 (U), Electronic level transmitter
- GD, Gas Detection sensors

Float valves

- HFI, Float valves, high-pressure
- SV 4-, 5- and 6-float valve, low-pressure
- PMFH/PMFHE, Condenser side, controlled by SV
- PMFL/PMFLE, Evaporator side, controlled by SV

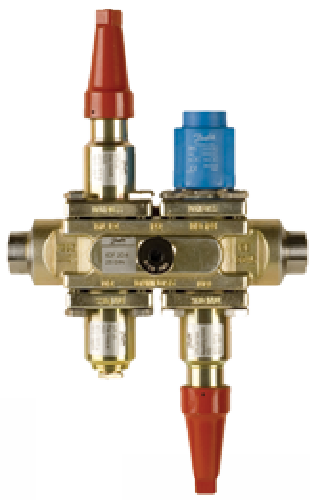
Safety valves

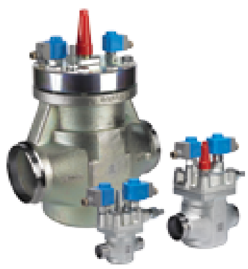
- SFA, Safety relief valves, back-pressure dependent, standard set pressure
- SFV 20-25 T, Safety valves, back-pressure dependent, standard set pressure
- DSV, Double-stop valves, for safety valves

Gas-powered valves

- GPLX, Gas-powered stop
- valves

Danfoss also has many years of experience with CO_2 as a refrigerant, and can provide a wide range of valves and control solutions for CO_2. Please challenge us.





Danfoss know-how and support tools

With Danfoss, you benefit not only from our global know-how, available as local support, but also from the various tools we offer to support you in your day-to-day work in refrigeration.

10.1. IR application handbook

The Danfoss application guide is designed to be used as a reference document by everyone involved in the workings of industrial refrigeration systems. This guide aims to provide answers to the many questions relating to industrial refrigeration system control: What type of control method is necessary for the refrigeration system? Why should it be designed in this way? What types of components can be used? How are control methods selected for different refrigeration systems? In answering these questions, the principles of the various control methods are introduced with examples employing Danfoss Industrial Refrigeration products. **It does not take into account capacity and performance. The operating parameters of each application should therefore be considered before any particular layout is adopted.**

Online: click here

Not online: go to www.danfoss.com/IR-Tools

The main technical data for the components is also provided. Finally, there are comparisons of the different solutions for each control method to enable the reader to select a solution.

10.2. IR application tool

We have developed a simple but very effective interactive tool that will help you break down the sometimes complicated ammonia system into easily understandable sections. The tool is an interactive PowerPoint slideshow that takes you through all the details of a two-stage ammonia plant. The tool features "zoom-in and expand" navigation with detailed information tailor-made for you.

The concept of the slideshow is a complete infographic of an ammonia plant. You click selected areas of the plant to get detailed information on them. The detailed drawing shows you which valves and piping are needed for the specific area. By "clicking" on the valve type designations, you will get detailed cut-away drawings and explanations of that specific valve. The interactive slideshow also provides you with useful links to technical literature, product animations and videos. And it is easy to navigate back to start or the previous information.

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The main technical data for the components is also provided. Finally, there are comparisons of the different solutions for each control method, to enable the reader to select a solution.

10.3. Coolselector®2

The new Coolselector®2 is your brand new Danfoss calculation and selection software designed to make selection processes for all industrial refrigeration projects easier and less time consuming. Coolselector® 2 is a unique calculation and support tool for contractors and system designers, offering complete pressure drop calculations, analysis of pipe and valve design and the ability to generate performance reports. It replaces the well-known DIRcalc™ software and offers several new functionalities.

Online: click here

Not online: go to www.danfoss.com/IR-Tools

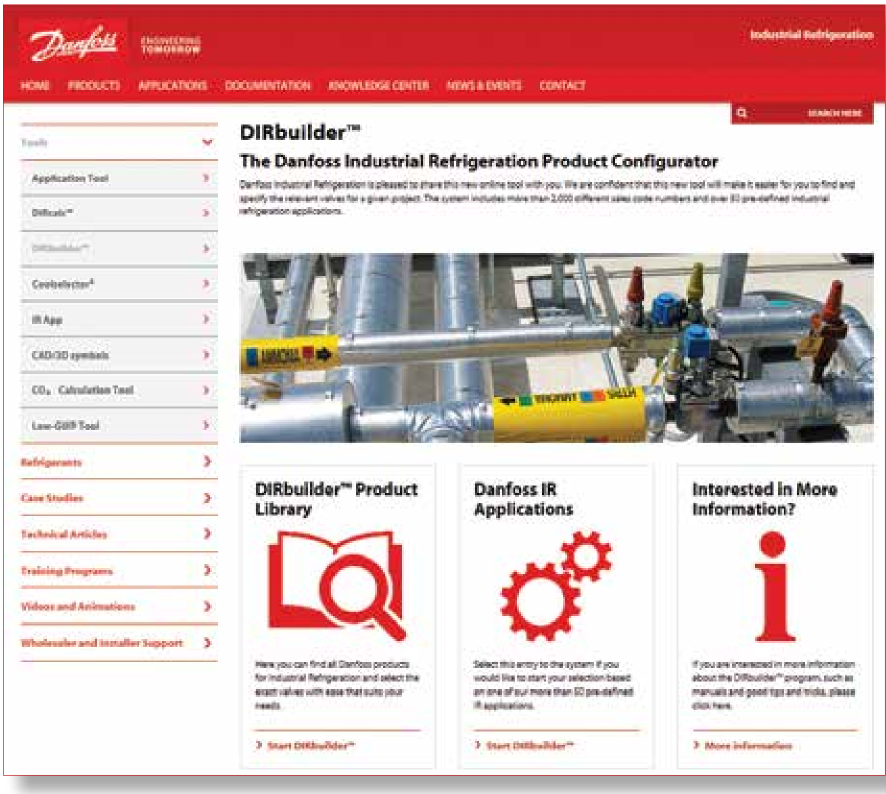
10.4. CAD symbols for Danfoss valves

3D CAD symbols are indispensable when you are designing industrial refrigeration plants. To make your work as easy as possible, we make these 3D CAD symbols available for free download from the Danfoss website. All CAD symbols are unique for each code number, so they are easy to find in our online product catalogue at code number level.

10.5 DIRbuilder™

DIRbuilder™ is a new IR online tool designed to make selection processes for industrial refrigeration projects easier and less time-consuming. It allows you to select the exact valves you need – standard as well as customised – from an extensive pool of configuration options. The library comprises all our valves consisting of more than 2,000 different sales code numbers and over 50 pre-defined industrial refrigeration applications.

To learn more about DIRbuilder™, simply go to the site and explore all benefits for yourself: www.danfoss.com/DIRbuilder



Online: click here

Not online: go to www.danfoss.com/DIRbuilder

All the above support tools are available from our website www.danfoss.com/IR-tools and can be downloaded free of charge.

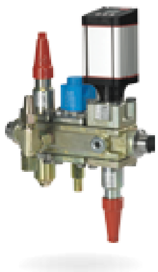
In everything we do, we strive to make life as easy as possible for you, and to enable you to apply any of our expertise in your business.

ENGINEERING
TOMORROW

Danfoss Flexline™
Simple. Efficient. Flexible.

Designed to offer clever simplicity, timesaving efficiency and advanced flexibility the Flexline™ series includes three popular product categories:

ICV Flexline™
– Control valves



ICF Flexline™
– Complete valve stations

SVL Flexline™
– Line components

All products are based on a modular design with no functionality in the housing. This set-up reduces complexity right from the design phase to the installation, commissioning and service. All key to lower total life cycle costs – and major savings.

Go to www.danfoss.com/flexline for more information on the Flexline™ platform.

Global knowhow
Local support

Backed by more than 60 years of experience producing valves and controllers for industrial refrigeration applications Danfoss is a solid partner to turn to when you are looking for quality components.

Our global knowhow combined with local support offers you the best possible products and service.

www.danfoss.com/IR-Tools