

ENGINEERING  
TOMORROW

*Danfoss*

User Guide

# How to use ammonia Making it **easy** and **safe** to be **efficient**

**64**

pages packed with  
knowledge and  
experience from the  
world of ammonia.

HTRL L I Q AMMONIA L O W →

[www.danfoss.com/IR](http://www.danfoss.com/IR)



# Contents

## Preamble

An introduction to the user guide ammonia as refrigerant . . . . . 5

## Part I

Ammonia refrigerant . . . . .	6
Advantages of ammonia as a refrigerant . . . . .	7
Limitations / drawbacks . . . . .	11
Examples of applications using ammonia as a refrigerant . . . . .	12
Properties of ammonia refrigerant . . . . .	13
General description of ammonia refrigeration systems . . . . .	13
Components normally used in gravity flooded ammonia systems . . . . .	16
Components normally not required in ammonia systems . . . . .	17
Controls . . . . .	18
Table of saturated values for R717 (ammonia) . . . . .	20

## Part II

Liquid control devices for gravity systems . . . . .	22
Alternative 1 - Mechanical float valves SV1 and SV3 . . . . .	24
Alternative 2 - Combination of float valve and solenoid valve – EVRA and AKS 38 . . . . .	25
Alternative 3 - Continuous modulation device AKS 4100 and ICM valve . . . . .	26
Liquid control devices for pump circulation systems . . . . .	27
Alternative 1- Electronic solution using AKS 38 float switches and REG liquid control valve . . . . .	30
Alternative 2 - Using AKS 4100 and AKVA liquid control valve . . . . .	31
Alternative 3 - Using AKS 4100 liquid level and ICM liquid control valve . . . . .	32
Alternative 4 - Using AKS 4100 liquid level and ICF liquid control valve station . . . . .	33

## Part III

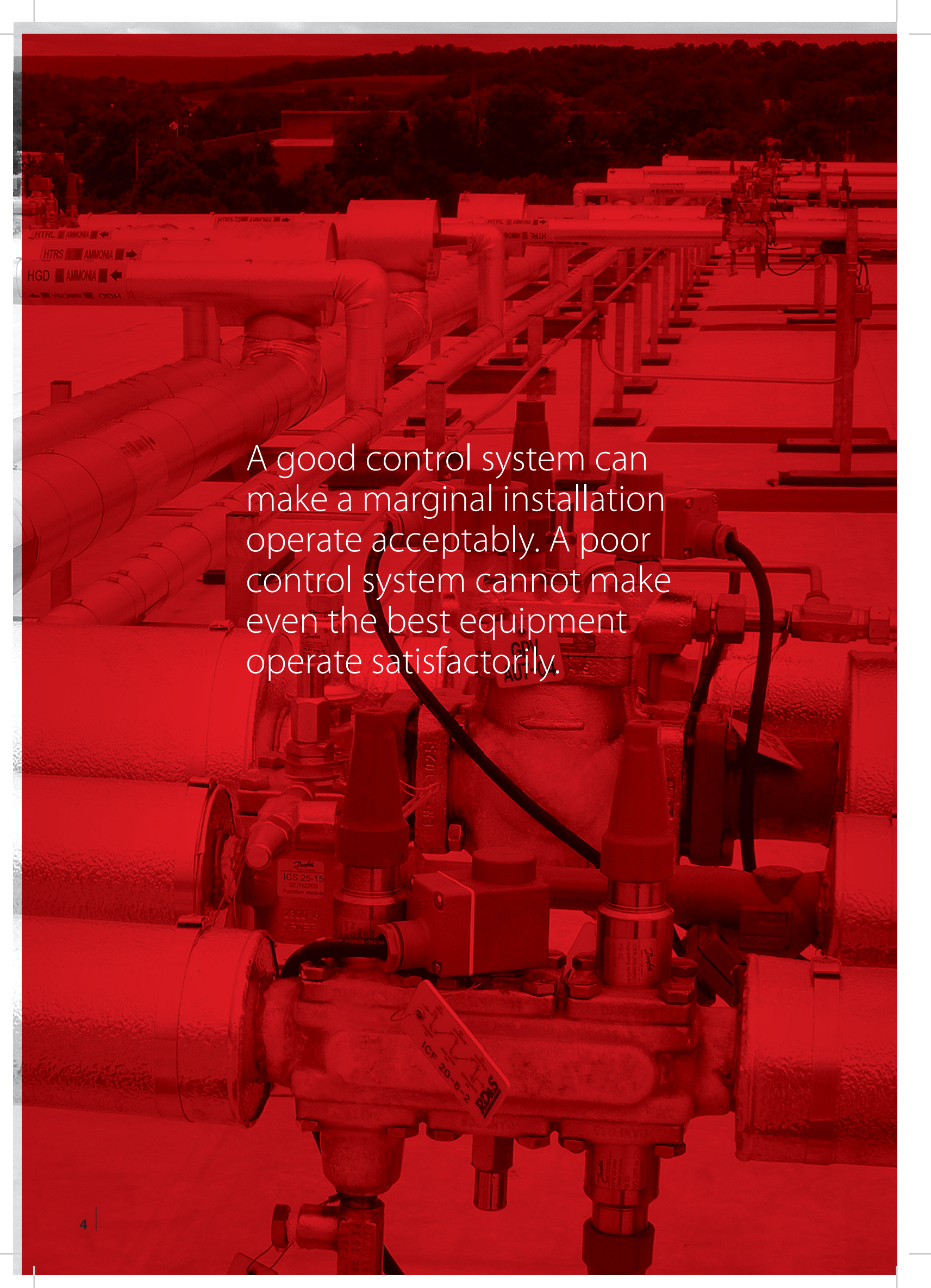
Defrosting air coolers - various methods . . . . .	34
Sequence of operation of hot gas defrost cycle . . . . .	40

## Part IV

Capacity control for refrigeration systems - Why and how to use capacity control . . . . .	46
--	----

## Part V

Potato cold stage load calculations per nhb standard - 01:2010 . . . . .	52
Nhb standard cold rooms - nh3 valves & controls boq - Pumped circulation system . . . . .	57

The image shows a complex industrial piping system, likely for ammonia, with a strong red color overlay. The pipes are supported by a metal structure and run in parallel rows. In the foreground, there is a detailed view of a valve assembly with various components like actuators and sensors. Labels on the pipes include 'HTRH AMMONIA', 'HTRS AMMONIA', and 'HGD AMMONIA'. A specific valve in the foreground has a tag that reads 'ICF 20-6-2' and 'P22&S'. Another tag nearby says 'ICS 25-15' and 'Function module'. The background shows more of the facility and some trees under a clear sky.

A good control system can make a marginal installation operate acceptably. A poor control system cannot make even the best equipment operate satisfactorily.

## Preamble

**This user guide has been prepared by Mr Ramesh Paranjpey (Fellow, Life Member ASHRAE and Member IAR) and the Danfoss team.**

If you would like further details or clarification, please contact [ramesh.paranjpey@gmail.com](mailto:ramesh.paranjpey@gmail.com).

Ammonia refrigeration installations are normally assembled piece-by-piece on site. Even if individual pieces of equipment (e.g. compressors, condensers, and evaporators) are selected from the world's best, with the highest efficiencies and reliability and requiring the least manual interference, if the assembled system does not have proper controls working in harmony to provide the most reliable and efficient system, the investment in such equipment will not give the desired results – or satisfied customers.

The selection of appropriate controls therefore becomes a major aspect of the design, and one generally not given the importance it deserves. Danfoss has been the pioneer and world leader in the provision of controls for refrigeration plants and equipment since 1933.

The technical literature we publish from time to time covers the latest practices in refrigeration control technology, and covers controls appropriate to every application, with a variety of options to meet the application's needs and criticalities.

Our latest Industrial Products catalog covers specifications and options for every application in detail. There are many options available for each application, so it may be difficult for the system designer, contractor, distributor, or end user to select and apply the appropriate solution.

We are therefore making the effort to simplify their task by selecting appropriate solutions, covering all the controls involved, as one package. This should help reduce both the time involved and the chances of errors in selection.

This user guide provides this information, along with the reasoning behind the selection of a particular control and the advantages it offers. Value-based solutions have been our objective in preparing this booklet. For more information, please refer to our Industrial Products catalog, which is freely downloadable from the Danfoss website, or as hard copy on request.

If you would like further details or clarification, our team of engineers and the well-trained staff at our strategically distributed network of dealers are always available.

## This section deals with ammonia as a refrigerant

- Advantages of ammonia as a refrigerant
- Examples of applications
- Properties of ammonia as a refrigerant
- General description of ammonia systems
- Components specific to ammonia systems
- General requirements for refrigeration controls
- Ammonia – properties of the saturated liquid and saturated vapor
- Pressure-enthalpy diagram

## Ammonia refrigerant

Ammonia has been the most trusted refrigerant since the 19th century. Everyone involved in food preservation and industrial process plants recognizes ammonia as the refrigerant of choice due to its unmatched thermodynamic properties.

Environmental concerns are making scientists and technicians look seriously at natural refrigerants (e.g. air, water, ammonia, carbon dioxide, etc.) as long-term options that could be regarded as “no-regrets” solutions. Having stood the test of time over more than a century as one of the best choices, ammonia is now receiving attention in application areas where it was once unthinkable.

### Background

Ammonia 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<sub>2</sub>) and sulfur dioxide (SO<sub>2</sub>) 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 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-trying and trusted refrigerants such as ammonia and carbon dioxide are being considered for various new applications, too.

## Advantages of ammonia as a refrigerant

### 1. Performance

The COP (Coefficient of Performance or output per unit input) is highest for ammonia (4.76) (ref ASHRAE volume Fundamentals 2009 page 29.9) compared with other refrigerants in common use, such as R134a, R404A, R410A, R22 and many others.

#### Extract from Table:

Comparative refrigerant performance per ton of refrigeration under standard cycle conditions of -15 °C (258K) evaporating and 30 °C (303K) condensing.

Refrigerant	Evap. Pr. MPa	Cond. Pr. MPa	Comp. Ratio	Comp. Displacement L / s	Ref. Effect kJ / kg	Power consumption kW	COP**)
Ammonia -R717	0.235	1.162	4.94	0.463	1103.1	0.210	4.76
R22	0.295	1.187	4.02	0.478	162.67	0.214	4.66
R134a	0.163	0.767	4.71	0.814	148.03	0.216	4.6
R410A	0.478	1.872	3.92	0.318	167.89	0.222	4.41
R404A	0.365	1.42	3.89	0.470	114.15	0.237	4.21
Carbon dioxide -R744*)	2.254	7.18	3.19	0.065	133.23	0.192	2.69

\*) In industrial refrigeration systems, carbon dioxide (R744) is normally used in a cascade system with ammonia. For low operating temperatures, ammonia / carbon dioxide cascade systems have higher COP values than does ammonia.

\*\*) The COP values are based on the properties of the refrigerant alone under particular suction and discharge conditions. The overall system COP for ammonia may be better, depending on typical local operating parameters.

### 2. Efficiency

Ammonia systems are mostly based on flooded designs. The head pressure control (to keep the discharge pressures artificially high to ensure proper operation of the expansion valve) is therefore not necessary in ammonia plants. The condensing temperatures can be as low as possible, increasing cycle efficiency and reducing energy consumption compared with HCFC / HFC direct expansion or flooded systems.

### 3. Heat transfer

Most of the thermal properties influencing heat transfer favor ammonia over R22 refrigerant:

- Specific heat (kJ / kg.K, at -6 °C) of liquid ammonia is nearly 4 times that of R22
- Latent heat of vaporization is 6 times greater
- Liquid thermal conductivity is 5.5 times greater
- Viscosity is lower by a factor of 0.8
- Liquid density is lower by a factor of 0.5. All these properties help improve heat transfer for ammonia relative to R22 in condensing and evaporating processes.

The table below illustrates heat transfer rates for ammonia compared with R22.

	Ammonia	R22
Condensation outside tubes (W / m <sup>2</sup> K)	7500-11000	1700-2800
Condensation inside tubes (W / m <sup>2</sup> K)	4200-8500	1400-2000
Boiling outside tubes (W / m <sup>2</sup> K)	2300-4500	1400-2000
Boiling inside tubes (W / m <sup>2</sup> K)	3100-5000	1500-2800

With higher heat transfer coefficients, smaller evaporators and condensers can be used, or the same heat transfer areas can be retained with operation at higher evaporating temperatures and lower condensing temperatures, thus improving the cycle efficiency.

#### 4. Density

The density of ammonia is half that of R22 (ammonia 582 kg / m<sup>3</sup>; R22 1128.4 kg / m<sup>3</sup>). Even if it enters the crankcase, ammonia therefore floats on the oil (883 kg / m<sup>3</sup>) layer, so unlike with R22 the oil is much less likely to be diluted by the refrigerant, which would impair lubrication.

#### 5. Mass flow rate

Ammonia is more efficient. Its mass flow rate for a given refrigeration capacity is 1 / 7 that of R22 (ammonia 0.00091 kg / s; R22 0.00616 kg / s at 250K evaporation and 303K condensation temperatures) which means only 1 / 7 as much liquid need be pumped for a given refrigeration capacity. Mechanical pumping will therefore absorb much less power in an ammonia system.

#### 6. Natural refrigerant

Ammonia is a natural refrigerant that is present in the atmosphere and available in nature in abundance. In nature, it is produced by biological processes, and decomposes naturally without adding to GWP. The human liver has the capacity to convert 130 g ammonia into urea per day.

The table below compares the ODP and GWP values of currently used refrigerants. (ASHRAE Fundamentals 2009, page 29.4)

Refrigerant	ODP	GWP
Ammonia, R717	0	<1
R22	0.055	1810
R134a	0	1430
R404A	0	3900
R410A	0	2100
Carbon dioxide	0	1

#### 7. TEWI

TEWI (Total Equivalent Warming Impact) is the new terminology covering the effect of direct and indirect leakage of refrigerant as well as energy consumption over the life cycle of the equipment. Ammonia's high thermal properties and its nearly zero GWP and zero ODP give it a very favorable TEWI.

#### 8. Leak detection

Ammonia has a pungent odor, and even small leaks of less than 5 ppm are detectable by smell, enabling maintenance staff to correct them. Even large leaks of the odorless refrigerants (e.g. R22, HFC 134a, etc.) will not be noticed until the system's cooling performance drops.

## 9. Critical temperature

The critical temperature for ammonia is 134.4 °C, while that for R22 is 96.0 °C, making ammonia better suited for heat pump applications.

Critical temperatures for various refrigerants

Refrigerant	Temperature °C
Ammonia – R717	134.4 °C
R22	96.15 °C
R134a	101.06 °C
R404A	72.05 °C
R410A	71.36 °C
Carbon dioxide	30.978 °C

It is clear from the above that the critical temperature is highest for ammonia, which is therefore better suited for heat pump applications. It has also been the experience of many that in air-cooled applications using R22 in very high ambient temperatures, it becomes difficult to condense to the liquid because the system is operating too closely to critical temperatures.

## 10. Lighter than air

Ammonia in vapor form is 1.7 times lighter than air, so it rises quickly in the air in the event of a leak without accumulating in the plant room. The critical density\* of ammonia is 225 kg / m<sup>3</sup>, for air 335.94 kg / m<sup>3</sup>, for R22 523.84 kg / m<sup>3</sup>, and for R134a 511.9 kg / m<sup>3</sup>. The other refrigerants mentioned are heavier than air and are odorless, so they accumulate unnoticed in the plant room following a leak. The refrigerant displaces oxygen, and deaths due to suffocation have been reported.

\* Critical density = Density at thermodynamic critical temperature

## 11. Leakage losses

The molecular weight of ammonia is 17.03, whereas that of R22 is 86.48, R134a is 102.03, R404A is 97.604 and R410A is 72.585. For a leak of a given size, therefore, more of the higher density refrigerants would be lost than with ammonia. Similarly, and for the same reason, less refrigerant is lost during purging in ammonia plants compared with plants using those other refrigerants.

## 12. Water contamination

Ammonia systems are more tolerant of water contamination than are HCFC / HFC systems. A little moisture in the system (i.e. <100 ppm) stays in solution and does not freeze out. Modest contamination with water therefore does not usually interfere with the operation of ammonia systems. However, it is important to avoid the penetration of water into the system.

At low operating temperatures, the evaporating pressure will be below atmospheric, and it is important to make sure that air and moisture do not penetrate into the system. A greater amount of water in an ammonia system will reduce its efficiency, and can create various problems in the system. Water can be removed from the system by installing water "cleaning" systems.

## 13. Solubility in water

Ammonia is readily absorbed by water; 1 m<sup>3</sup> water can absorb 120 kg ammonia. The maximum concentration of ammonia in water (a saturated solution) has a density of 0.88 kg / cm<sup>3</sup>, and is often known as 880 ammonia.

## 14. Air purgers

The boiling point of ammonia is -33 °C, so in many applications the systems work below atmospheric pressure. Ammonia systems to date have mostly used open compressor designs with an independent motor. There is therefore a shaft seal in all ammonia compressors, increasing the likelihood of air and moisture leaking in when the plant is operating at negative pressures. An automatic air purger ensures that non-condensables entering the system are purged periodically to keep system efficiencies high.

### 15. Behavior with oil

R22 and other HFC refrigerant liquids are mutually soluble in commonly used lubricating oils to varying degrees, depending on the type of oil, and the operating temperature and pressure, whereas ammonia and the mineral oils often used with it are virtually mutually insoluble. Recovering oil from various parts of the system is therefore easier, and a different approach to oil management is required. There are no oil recovery problems with ammonia at partial loads, unlike with R22 systems. Synthetic oils have been introduced for ammonia because they can withstand high discharge temperatures.

### 16. Pipe sizes

Ammonia pipe sizes can be smaller than for R22, or can carry 2-3 times as much refrigeration for the same size, saving on the cost of piping. For example, a 10 cm diameter pipe has 280kW suction line capacity with R22 at a pressure drop equivalent to 10k per 30 m length. For ammonia, the same line would be suitable for 728kW capacity.

The table below shows the required line size requirements for various refrigerants using steel piping under identical conditions (Ref ASHRAE volume – Refrigeration 2010).

Capacity 200 kW, evaporating temperature +5 °C:

Refrigerant	Suction line mm OD	Discharge line mm OD	Liquid line mm OD
Ammonia – R717	50	40	20
R22	80	65	32
R134a	80	80	40
R404A	80	65	40
R410A	65	50	32

### 17. Latent heat

Ammonia has a higher latent heat than all other refrigerants except water, enabling it to absorb or reject a great deal of heat (per kg basis) during phase transformations in evaporators and condensers. Only very low flow rates are therefore required to provide a given refrigerant effect. In pump circulation systems, the pumping power required is low compared with other refrigerants.

### 18. Net refrigerating effect

Net refrigerating effect is the vapour enthalpy minus liquid enthalpy.

The approx. net refrigerating effect at 4-5°C for various refrigerants is listed below:

Refrigerant	Net Refrigerating Effect (KJ / kg)
Water R-718	2489.04
Ammonia – R717	1247.85
R410A	214.48
R22	201.79
R134a	195.52
R404A	162.03
Carbon Dioxide	124.98

As observed from the above table Ammonia has higher refrigeration effect per kg compared to other refrigerants.

### 19. Safety group

Earlier gases were grouped only in two categories, group I and group II.

ANSI standard and ASHRAE regrouped these to differentiate them as Group A1, A2, A3 and B1, B2, and B3. Ammonia is in B2 category. ANSI / ASHRAE standard 34 now classifies ammonia refrigerant as B2L, which means it is less flammable than B2 since its burning velocity is less than 10cm / s.

## 20. Costs

R22 or R134a can cost twenty times as much as ammonia, depending on location. Ammonia is not only cheaper, but is also widely available and often produced locally. The HFC refrigerants introduced recently as CFC substitutes may still need to be imported.

## Limitations / drawbacks

Having covered most of the advantages and positives of ammonia as a refrigerant, we must now also look at the drawbacks / limitations in its use in some of the major applications such as air conditioning. The public perceives ammonia as flammable and toxic, and it is therefore not permitted in direct cooling air conditioning plants for public areas.

### 1. Flammability

Ammonia is extremely difficult to ignite (above 650 °C), and breaks down above 450 °C. Most people can detect atmospheric concentrations above 5 ppm, so it is extremely rare to encounter such high temperatures in normal air conditioning and refrigeration applications. There is no reason for any concern that exposure to ammonia is a health hazard. The flammable limit in air at atmospheric pressure is as high as 16-28% by volume.

Due to ammonia's very low flammability, no explosion-proof controls are required.

### 2. Toxicity

Laboratory trials have proved that continuous exposure levels up to and exceeding 24 ppm for 10-15 years have no adverse effect on human beings. Exposure to 100 ppm causes irritation, but no health hazard. Exposure for 30 minutes above 5000 ppm may be fatal. The pungent smell of ammonia above 5 ppm is detectable, and serves as an early warning, so no one will remain in the vicinity of uncontrollable ammonia leaks.

### 3. High discharge temperatures

The index of compression for ammonia is 1.31, compared with 1.18 for R22. For the same pressure ratio, discharge temperatures in ammonia plants are therefore substantially higher. For example, at 60°C condensing and -15°C evaporating temperatures, it is around 180°C for ammonia, compared with 115°C for R22. If the design discharge temperature exceeds 140°C, a two-stage system design is recommended.

Above 120°C, mineral lubricating oil's properties begin to deteriorate. Ammonia applications therefore require two-stage system design if the temperature difference between saturated condensing and evaporating temperatures exceeds 50K. A single-stage system design is normally adequate for these applications when R22 refrigerant is used. The recommended limit for single-stage operation for R22 is 70K, beyond which two-stage designs are preferred.

In heat pump applications, this can be regarded as an advantage. The available sensible heat at discharge is much higher for ammonia compared with R22 systems.

#### 4. Incompatibility with certain materials

Ammonia is not compatible with copper and copper alloys. It is fully compatible with iron, steel and aluminum.

CFCs are compatible with all metal materials, so any material can be chosen, offering greater flexibility. Technicians are more comfortable with the simplicity of soldering or brazing copper than with welding steel. However, this is not an issue among those accustomed to working on ammonia plants and therefore cannot be considered an area of concern.

It is important to note that almost all refrigerants (including ammonia, carbon dioxide, and CFCs) and the oil used in these systems can affect several types of sealing materials. It is therefore important to use only the sealing materials supplied by the component supplier with documented compatibility between the sealing materials and the refrigerants / oils.

The advantages and disadvantages of ammonia mentioned make it clear that the advantages overwhelmingly outweigh the disadvantages. Natural refrigerants (e.g. ammonia and carbon dioxide) are being used increasingly even in air-conditioning applications. Recent examples for ammonia include Oslo airport, the expansion of Heathrow airport and the London Olympics games village.

### Examples of applications using ammonia as a refrigerant

1. Cold storage (potatoes, fruit, vegetables), warehouse, Food parks.
2. Ice plants (conventional block ice, flake ice, tube ice)
3. Fish-freezing plants (spiral freezers, plate freezers, IQF, blast and trolley freezers)
4. Slaughterhouses and meat-processing plants
5. Dairies and ice bank systems
6. Process refrigeration plants (chemical / dyestuff industries)
7. Breweries and wineries
8. Bottling plants (Coca-Cola / Pepsi and others)
9. Ice cream plants
10. Concrete-cooling applications (river dams, airport runways and concrete expressways)
11. Fertilizer plants
12. Recent R717 / R744 systems (supermarkets)
13. Liquefaction of gases
14. Process cooling (pharmaceutical plants)
15. Air conditioning for major sites (e.g. airports)
16. Compact ammonia packages for air conditioning (telegraph and other office premises)
17. Air conditioning for processing halls (cold chain facilities)

## Properties of ammonia refrigerant

Ammonia is a compound of nitrogen and hydrogen, chemical formula  $\text{NH}_3$ . Refrigerant-grade anhydrous ammonia is used as a refrigerant, not the commercial grade. Its ASHRAE number is R717, the first 7 indicating a natural refrigerant and the final 17 indicating the molecular weight of ammonia.

The purity requirements for anhydrous ammonia, as defined in ANSI / IAR74-2, are:

1. Ammonia content .....	99.95%
2. Water .....	33 ppm max.
3. Oil .....	2 ppm max.
4. Salts .....	None
5. Pyridine, hydrogen sulfide, naphthalene.....	None
6. Molecular weight .....	17.031 g / mol
7. Boiling point at one atmosphere (101.33 kPa).....	-33.33 °C (239.82K)
8. Freezing point at one atmosphere.....	-77.66 °C (195.5K)
9. Critical temperature.....	134.4 °C (407K)
10. Critical pressure .....	(11.34 MPa)g
11. Latent heat at -33 °C and one atmosphere.....	1.369 MJ / kg
12. Relative density of vapor compared with air at 0 °C.....	0.5967
13. Vapor density at -33 °C .....	0.8896 kg / m <sup>3</sup>
14. Specific gravity of liquid at -33 °C compared with water at 4 °C .....	0.6816
15. Liquid density at -33 °C and one atmosphere.....	681.6 kg / m <sup>3</sup>
16. Specific volume of vapor at 0 °C and one atmosphere.....	1.299 m <sup>3</sup> / kg
17. Flammable limit by volume in air at atmospheric pressure.....	15.5-27%
18. Ignition temperature .....	651.10 °C (924.13K)
19. Specific heat at constant pressure (Cp) .....	2.1706 kJ / kg k
20. Specific heat at constant volume (Cv).....	1.6444 kJ / kg k
21. Ratio of specific heats at 15 °C and one atmosphere ( $\gamma = C_p / C_v$ ).....	1.320

## General description of ammonia refrigeration systems

The essential components in vapor compression refrigeration system are:

1. Compressor
2. Condenser
3. Evaporator
4. Expansion valve / liquid metering device

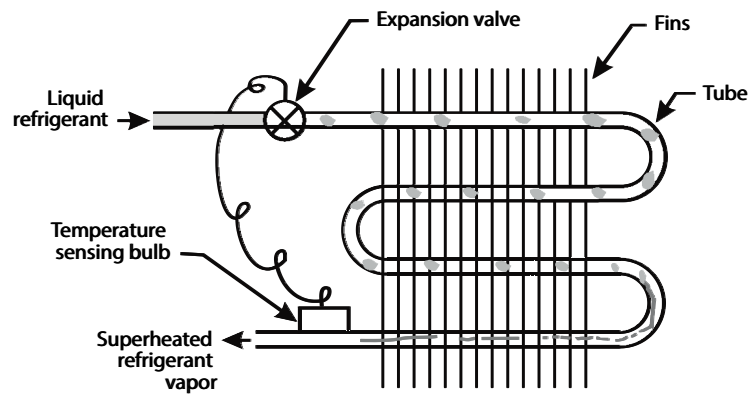
Ammonia refrigeration systems mainly use water-cooled or evaporative-type condensers. Air-cooled condensers are not generally used in tropical countries due to the high ambient temperatures commonly encountered in these regions.

Further, two types of evaporators are used for most refrigerants:

1. Direct expansion evaporators
2. Flooded operation evaporators

The evaporators are classified according to the method used to control refrigerant flow through them.

Direct expansion evaporator coils:



Direct expansion (DX) evaporators are most popular in all applications of comfort air conditioning systems below 150 tons. These systems are used mainly with HCFC / HFC refrigerants, and not generally in ammonia applications.

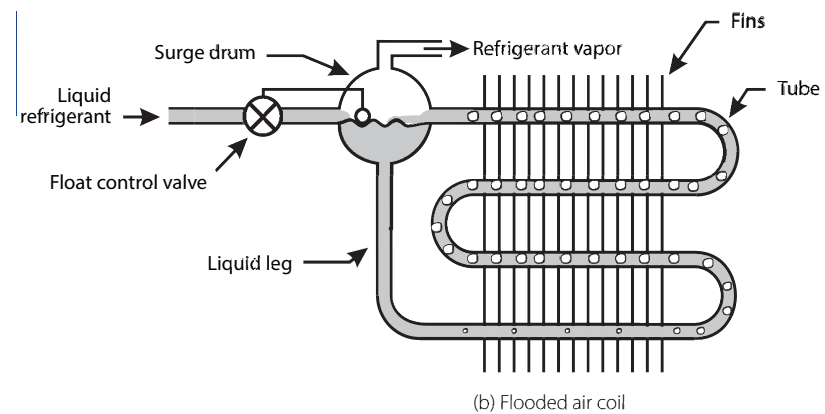
The DX evaporator is a set of continuous tubes through which refrigerant flows. The flow is controlled so that a refrigerant mixture of liquid and gas enters the evaporator. At the outlet, there is saturated or superheated gas because the system load has converted the liquid refrigerant into gas. There is no recirculation of liquid or gas in the evaporator. The process is once-through, with refrigerant passing through the entire system before re-entering the evaporator.

In a DX evaporator, there is no clear point of separation between liquid and gaseous refrigerant. The proportion of gas increases gradually during the passage of the liquid / gas mixture, until the refrigerant becomes all gas near the evaporator outlet.

### Flooded evaporators

The refrigerant in the evaporator is mostly liquid (flooded) throughout the process. The flooded evaporator enables the refrigerant within the evaporator to be recirculated by the addition of a surge drum. The liquid refrigerant enters the surge drum through the metering device and flows down to the bottom tube under gravity.

Gravity Flooded Evaporator coils:



The entire coil surface is in contact with wet refrigerant under all load conditions. This design gives excellent heat transfer. The vapor produced in the evaporator is separated from liquid in the surge drum. The liquid is recirculated through the evaporator, while the vapor is sucked by the suction action of the compressor.

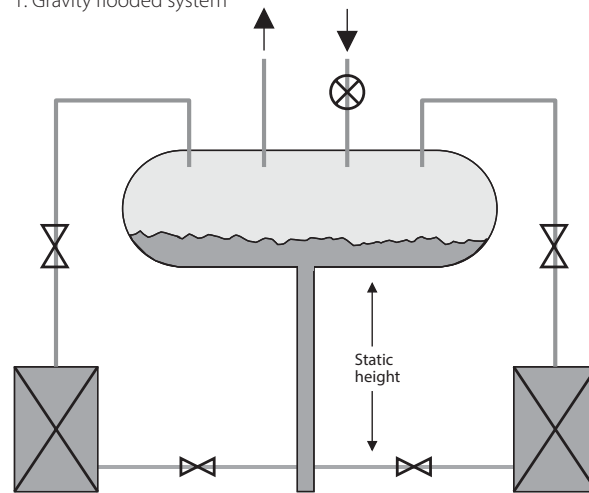
The flooded evaporator regulates the refrigerant flow by means of a float device designed to maintain a predetermined level of liquid in the surge drum. The vapor leaving the surge drum is saturated and not superheated as it is with a DX evaporator. Flooded evaporators are therefore more efficient because the entire coil surface is exposed to wet refrigerant, which improves heat transfer. In dry evaporators, part of the coil area is wasted in superheating gas, and the surface of the coil is always in contact with part liquid and part gas.

Though flooded evaporators are more efficient compared with DX evaporators, careful design is required to ensure proper liquid / vapor separation in the surge drum to prevent liquid being carried over to the compressor. The design of the surge drum, its various connections, and the velocity of the refrigerant must all be considered.

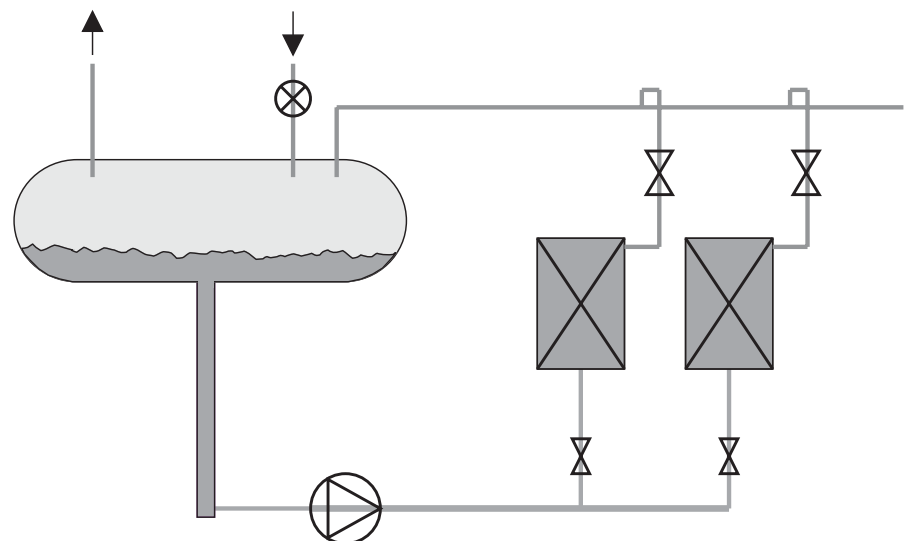
Ammonia refrigeration systems normally work on the flooded operation principle. In flooded evaporators, there are again two system designs:

1. Gravity flooded evaporator systems
2. Force feed pump circulation systems

1. Gravity flooded system



2. Force feed pump circulation systems




In pumped systems, the refrigerant liquid leaving the HP liquid receiver is expanded to the required pressure / temperature and stored in a low-pressure receiver. It is then pumped into the various operating evaporators (e.g. product coolers, blast freezers, or plate freezers). It thus forms an independent low-side circuit. The compressor sucks the vapor from this low-pressure receiver, and the cycle repeats.

The overfeed means much more liquid is fed to the evaporator than actually vaporizes. The excess liquid (overfeed) returns to the low-pressure side accumulator (or low-pressure receiver). The mass flow rate handled by the compressor is therefore less than that circulated in the evaporator.

As the number of evaporators increases and as the temperature requirement gets lower and lower, liquid recirculation / overfeed systems are preferred. Liquid recirculation is normally the best option for more than 3-5 evaporators located some distance from the machine room. Properly designed flooded evaporators and evaporators using liquid recirculation operate equally effectively. When ambient temperatures are low and there is liquid carry over after a prolonged shut down, a crankcase heater is used in ammonia systems.

The dominant refrigeration system for intermediate to large storage facilities is the liquid overfeed ammonia system, which are normal used for low- and medium-temperature cold storage. Having covered the various systems used for ammonia refrigeration systems, we must now also highlight other components specific to ammonia plants and those not normally used in such systems.

---



## Components normally used in gravity flooded ammonia systems

### **1. Oil separator:**

Oil and ammonia are immiscible in all proportions and at all temperatures, so it is essential to ensure that minimal oil in the form of mist is carried into the system along with the discharge gas.

Oil has no refrigeration properties, and is required only to lubricate compressors. The less oil in the system, the better the system's performance. An oil separator is therefore an essential component in all ammonia systems.

### **2. Receiver:**

Ammonia systems are of flooded design, so there is more refrigerant in the system than with direct expansion evaporator designs. Liquid ammonia must therefore be stored in one place, a function performed by the high-pressure receiver.

The ammonia receiver will also accommodate the system's entire charge should some system component need servicing. In such circumstances, the system's ammonia charge is pumped down into the receiver, the outlet valve from the receiver (often known as the king valve) is closed and the defective component is attended to.

### **3. Accumulator / liquid separator:**

Ammonia systems are either gravity flooded or pump circulation systems, so the gas component must be separated from the mixture of low-temperature / low-pressure liquid and gas leaving the expansion device. The liquid separator does this, allowing only the liquid to be admitted to the evaporator while the gas part is sucked by the compressor along with evaporated gas leaving the evaporator. An accumulator is therefore an essential component for all gravity flooded air cooler(systems)

### **Surge drum:**

This vessel protects against liquid refrigerant being carried accidentally to the compressor. It is similar to an accumulator except that it has no liquid in it. It is normally mounted on top of flooded shell-and-tube evaporators to ensure that no liquid droplets caused by vigorous action in the evaporator enter the compressor suction line because of high suction velocities. The velocities are reduced in the surge drum, with liquid droplets falling back to the evaporator instead of going to the compressor, thereby protecting the compressor from damage.

#### **4. De-super heater:**

The compression index for ammonia is high for the same compression ratio as with CFC / HCFC refrigerants, so discharge temperatures at the end of compression are high. This heat can be recovered usefully before it is rejected in the condenser by generating hot water via a heat exchanger.

#### **5. Air purgers:**

The boiling point of ammonia is -33 °C, so in many applications the systems are working below atmospheric pressure. Ammonia systems to date mainly use open compressor designs with an independent motor.

There is therefore a shaft seal in all ammonia compressors, increasing the chances of air entering when the plant is operating at negative pressures. An automatic air purger ensures that non-condensables entering the system are purged periodically to keep system efficiencies high.

#### **6. Separate electric motor:**

All ammonia compressors are driven by independent electric motor via a flywheel, motor pulley and 'v' belts, or a direct coupling. Ammonia and copper are not compatible, so semi-hermetic or hermetic compressors cannot be used.

Some manufacturers have developed semi-hermetic compressors that use aluminum windings instead of copper, but they have not been used commercially beyond a few installations.

## **Components normally not required in ammonia systems**

#### **1. Crankcase heater:**

Oil is denser than liquid ammonia, so any liquid ammonia migrating to the compressor during standstills floats on the oil layer without impairing lubrication at start up.

In HCFC / HFC plants, an oil heater is essential because these refrigerants are denser than oil. If these condensed refrigerants are not boiled off, oil pump operation and lubrication are impaired at start up. A crankcase heater is also used in ammonia compressors where ambient temperatures are very low.

#### **2. Suction / liquid line heat exchanger:**

Since ammonia gas leaving the evaporator is in a saturated condition, the superheat is generally very low before the return vapor enters the compressor. If a suction / liquid line heat exchanger is used, the suction gas superheat increases, leading to high discharge temperatures (because of ammonia's higher index of compression), the lubricating oil is burnt, carbon is formed, the oil is blackened, and its viscosity reduces, leading to higher wear and tear on compressor parts.

It is therefore essential to minimize super heat, so the use of a suction / liquid line heat exchanger is avoided in ammonia systems.

#### **3. Liquid line dryer:**

Ammonia and water are miscible in all proportions, so ammonia systems are more tolerant to the presence of moisture, unlike other systems using HCFC / HFC refrigerants.

Only a liquid line strainer or filter is provided to capture suspended solids, therefore, and no dryer is required. However, moisture should be removed from the system using suitably designed water "cleaning" systems to avoid internal corrosion and energy losses

#### **4. Liquid line sight glass:**

Ammonia plants operate on flooded evaporators, so there is no thermostatic expansion valve in the liquid line. It is not possible for gas bubbles to enter the

liquid line because the liquid is taken from the quantity stored in the high-pressure receiver. Moreover, there is a liquid level indicating sight glass in the evaporator side. For these reasons, ammonia plants do not normally have a liquid line sight glass.

Now we understand the various requirements for components in ammonia systems, we shall concentrate on our main objective: the selection of appropriate controls to enhance system performance and reliability and enable systems to be designed for operation with minimal human interference and skills.

---



## Controls

Controls may be of the direct reading field instrument, PID (proportional, integral, derivative) or DDC (direct digital control) types, depending upon the customer's requirements and / or the plant's complexities.

The controls for any refrigeration system are generally classified in two categories:

- A. Operating controls
- B. Safety controls

### **A. Operating controls:**

1. Liquid control devices
2. Defrost controls
3. Capacity controller for compressor
4. Temperature / humidity controllers
5. Pressure controllers
6. Variable frequency drives
7. Others specific to the application
8. Level switches

### **B. Safety controls:**

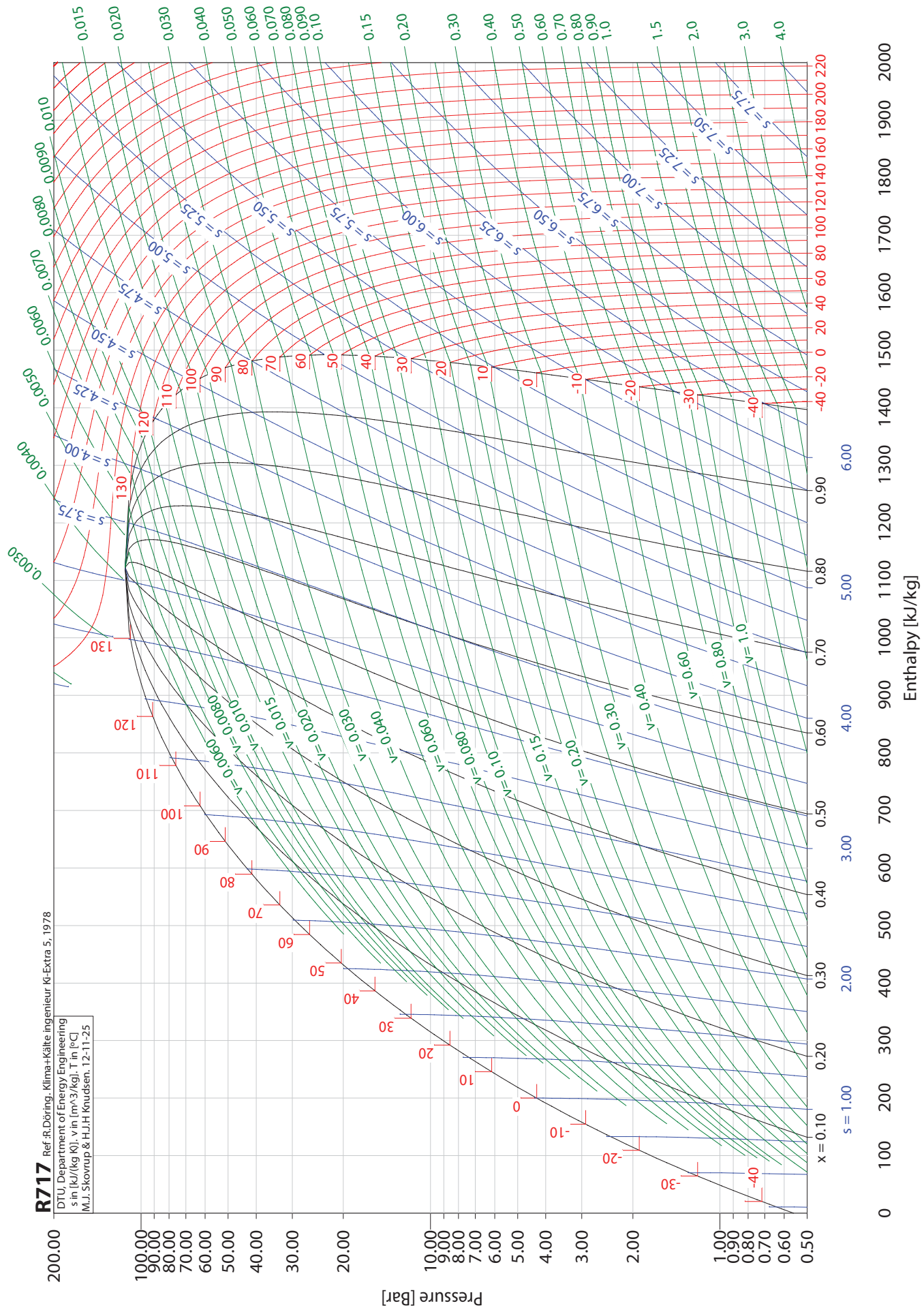
1. High pressure cutout
2. Low pressure cutout
3. Oil pressure cutout
4. Discharge temperature cutout
5. Flow failure switch for compressors, ammonia pumps, and water pumps
6. Motor protection devices
7. Safety relief valves on pressure vessels

The refrigerant properties and PH diagram can be downloaded free of charge at:

<http://www.danfoss.com/BusinessAreas/RefrigerationAndAirConditioning/Product+Selection+Tools+Details/Coolselector.htm>

The Danfoss Coolselector®2 software tool makes pipe sizing and controls selection easy. Coolselector®2 can be downloaded free of charge at:

<http://industrialrefrigeration.danfoss.com/knowledge-center/tools/>



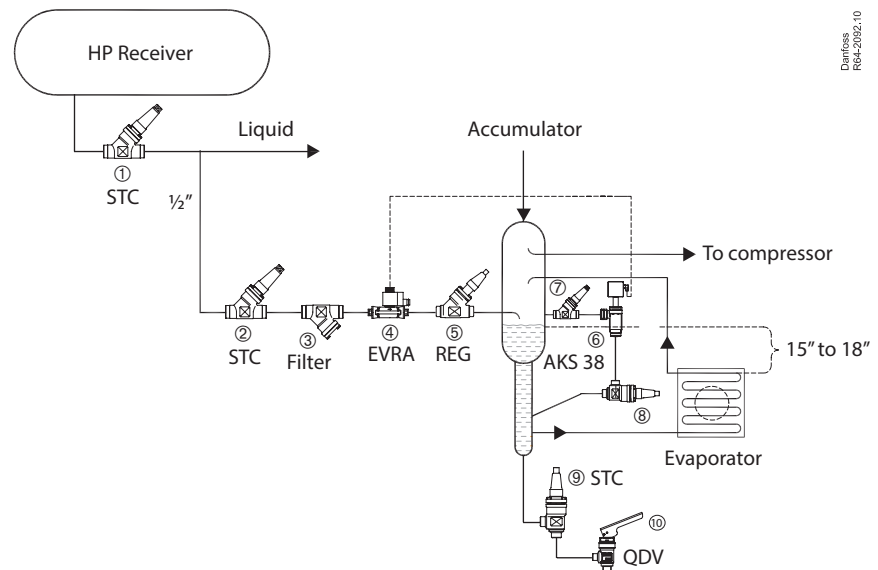
**Table of saturated values for R717 (Ammonia)**

T °C	P Bar	v <sub>l</sub> dm <sup>3</sup> / kg	v <sub>g</sub> m <sup>3</sup> / kg	h <sub>l</sub> kJ / kg	h <sub>g</sub> kJ / kg	R kJ / kg	s <sub>l</sub> kJ / (kg K)	s <sub>g</sub> kJ / (kg K)
-46,00	0,515	1,4340	2,11333	-6,20	1397,63	1403,83	0,1760	6,3562
-45,00	0,545	1,4364	2,00458	-1,80	1399,25	1401,06	0,1953	6,3363
-44,00	0,576	1,4389	1,90242	2,60	1400,87	1398,27	0,2146	6,3166
-43,00	0,609	1,4414	1,80641	7,01	1402,48	1395,47	0,2338	6,2971
-42,00	0,644	1,4440	1,71612	11,42	1404,08	1392,66	0,2529	6,2778
-41,00	0,680	1,4465	1,63116	15,84	1405,67	1389,83	0,2719	6,2587
-40,00	0,717	1,4491	1,55117	20,25	1407,25	1387,00	0,2909	6,2398
-39,00	0,756	1,4516	1,47582	24,68	1408,82	1384,14	0,3098	6,2211
-38,00	0,797	1,4542	1,40480	29,10	1410,38	1381,27	0,3286	6,2026
-37,00	0,840	1,4568	1,33783	33,53	1411,93	1378,39	0,3474	6,1843
-36,00	0,885	1,4594	1,27465	37,97	1413,46	1375,50	0,3661	6,1662
-35,00	0,931	1,4621	1,21501	42,40	1414,99	1372,59	0,3847	6,1483
-34,00	0,980	1,4647	1,15868	46,84	1416,51	1369,66	0,4033	6,1305
-33,00	1,030	1,4674	1,10545	51,29	1418,01	1366,72	0,4218	6,1130
-32,00	1,083	1,4701	1,05513	55,74	1419,50	1363,77	0,4403	6,0956
-31,00	1,138	1,4728	1,00753	60,19	1420,99	1360,80	0,4587	6,0783
-30,00	1,195	1,4755	0,96249	64,64	1422,46	1357,81	0,4770	6,0613
-29,00	1,254	1,4782	0,91984	69,10	1423,92	1354,81	0,4953	6,0444
-28,00	1,315	1,4810	0,87945	73,57	1425,36	1351,80	0,5135	6,0277
-27,00	1,379	1,4837	0,84117	78,03	1426,80	1348,77	0,5316	6,0111
-26,00	1,446	1,4865	0,80488	82,50	1428,22	1345,72	0,5497	5,9947
-25,00	1,515	1,4893	0,77046	86,98	1429,64	1342,66	0,5677	5,9784
-24,00	1,587	1,4921	0,73779	91,45	1431,04	1339,58	0,5857	5,9623
-23,00	1,661	1,4950	0,70678	95,93	1432,42	1336,49	0,6036	5,9464
-22,00	1,738	1,4978	0,67733	100,42	1433,80	1333,38	0,6214	5,9305
-21,00	1,818	1,5007	0,64934	104,91	1435,16	1330,25	0,6392	5,9149
-20,00	1,901	1,5036	0,62274	109,40	1436,51	1327,11	0,6570	5,8994
-19,00	1,987	1,5065	0,59744	113,89	1437,85	1323,95	0,6746	5,8840
-18,00	2,076	1,5094	0,57338	118,39	1439,17	1320,78	0,6923	5,8687
-17,00	2,168	1,5124	0,55047	122,90	1440,48	1317,59	0,7098	5,8536
-16,00	2,263	1,5154	0,52866	127,40	1441,78	1314,38	0,7273	5,8386
-15,00	2,362	1,5184	0,50789	131,91	1443,07	1311,15	0,7448	5,8238
-14,00	2,464	1,5214	0,48810	136,43	1444,34	1307,91	0,7622	5,8091
-13,00	2,570	1,5244	0,46923	140,94	1445,59	1304,65	0,7795	5,7945
-12,00	2,679	1,5275	0,45123	145,46	1446,84	1301,38	0,7968	5,7800
-11,00	2,791	1,5305	0,43407	149,99	1448,07	1298,08	0,8140	5,7657
-10,00	2,908	1,5336	0,41769	154,52	1449,29	1294,77	0,8312	5,7514
-9,00	3,028	1,5368	0,40205	159,05	1450,49	1291,44	0,8483	5,7373
-8,00	3,152	1,5399	0,38712	163,58	1451,68	1288,09	0,8653	5,7233
-7,00	3,280	1,5431	0,37285	168,12	1452,85	1284,73	0,8824	5,7094
-6,00	3,412	1,5463	0,35921	172,66	1454,01	1281,35	0,8993	5,6957
-5,00	3,548	1,5495	0,34618	177,21	1455,16	1277,95	0,9162	5,6820
-4,00	3,688	1,5527	0,33371	181,76	1456,29	1274,53	0,9331	5,6685
-3,00	3,833	1,5560	0,32178	186,32	1457,40	1271,09	0,9499	5,6550
-2,00	3,982	1,5593	0,31037	190,87	1458,51	1267,63	0,9666	5,6417
-1,00	4,136	1,5626	0,29944	195,43	1459,59	1264,16	0,9833	5,6284
0,00	4,294	1,5659	0,28898	200,00	1460,66	1260,66	1,0000	5,6153
1,00	4,457	1,5693	0,27895	204,57	1461,72	1257,15	1,0166	5,6022
2,00	4,625	1,5727	0,26935	209,14	1462,76	1253,62	1,0332	5,5893
3,00	4,797	1,5761	0,26014	213,72	1463,79	1250,07	1,0497	5,5764
4,00	4,975	1,5795	0,25131	218,30	1464,80	1246,50	1,0661	5,5637
5,00	5,158	1,5830	0,24284	222,89	1465,79	1242,91	1,0825	5,5510
6,00	5,345	1,5865	0,23471	227,47	1466,77	1239,30	1,0989	5,5384
7,00	5,539	1,5900	0,22692	232,07	1467,73	1235,66	1,1152	5,5259
8,00	5,737	1,5936	0,21943	236,67	1468,68	1232,01	1,1315	5,5135
9,00	5,941	1,5972	0,21224	241,27	1469,61	1228,34	1,1477	5,5012
10,00	6,150	1,6009	0,20534	245,87	1470,53	1224,66	1,1638	5,4890
11,00	6,364	1,6046	0,19873	250,47	1471,44	1220,97	1,1798	5,4770
12,00	6,583	1,6083	0,19241	255,07	1472,34	1217,27	1,1957	5,4651
13,00	6,807	1,6120	0,18638	259,67	1473,23	1213,56	1,2115	5,4533
14,00	7,036	1,6157	0,18063	264,27	1474,11	1209,84	1,2272	5,4416
15,00	7,270	1,6194	0,17516	268,87	1474,99	1206,11	1,2428	5,4300
16,00	7,509	1,6231	0,16997	273,47	1475,86	1202,37	1,2583	5,4185
17,00	7,753	1,6268	0,16506	278,07	1476,73	1198,62	1,2737	5,4071
18,00	8,002	1,6305	0,16043	282,67	1477,59	1194,87	1,2890	5,3958
19,00	8,256	1,6342	0,15607	287,27	1478,44	1191,11	1,3042	5,3845
20,00	8,515	1,6379	0,15198	291,87	1479,29	1187,34	1,3193	5,3733
21,00	8,779	1,6416	0,14815	296,47	1480,13	1183,56	1,3343	5,3622
22,00	9,048	1,6453	0,14457	301,07	1480,97	1179,77	1,3492	5,3512
23,00	9,322	1,6490	0,14124	305,67	1481,80	1175,97	1,3640	5,3403
24,00	9,601	1,6527	0,13815	310,27	1482,63	1172,16	1,3787	5,3294
25,00	9,885	1,6564	0,13530	314,87	1483,45	1168,34	1,3933	5,3186
26,00	10,174	1,6601	0,13269	319,47	1484,27	1164,51	1,4078	5,3078
27,00	10,468	1,6638	0,13031	324,07	1485,08	1160,66	1,4222	5,2971
28,00	10,767	1,6675	0,12806	328,67	1485,89	1156,80	1,4365	5,2864
29,00	11,071	1,6712	0,12603	333,27	1486,69	1152,93	1,4507	5,2757
30,00	11,380	1,6749	0,12421	337,87	1487,48	1149,05	1,4648	5,2650
31,00	11,694	1,6786	0,12260	342,47	1488,27	1145,16	1,4788	5,2543
32,00	12,013	1,6823	0,12119	347,07	1489,05	1141,25	1,4927	5,2436
33,00	12,337	1,6860	0,11998	351,67	1489,83	1137,33	1,5065	5,2329
34,00	12,666	1,6897	0,11897	356,27	1490,60	1133,40	1,5202	5,2222
35,00	13,000	1,6934	0,11815	360,87	1491,37	1129,46	1,5338	5,2115
36,00	13,339	1,6971	0,11752	365,47	1492,13	1125,51	1,5473	5,2008
37,00	13,683	1,7008	0,11708	370,07	1492,89	1121,55	1,5607	5,1901
38,00	14,032	1,7045	0,11683	374,67	1493,64	1117,58	1,5740	5,1794
39,00	14,386	1,7082	0,11677	379,27	1494,39	1113,60	1,5872	5,1687
40,00	14,745	1,7119	0,11690	383,87	1495,13	1109,61	1,6003	5,1580
41,00	15,109	1,7156	0,11722	388,47	1495,87	1105,61	1,6133	5,1473
42,00	15,478	1,7193	0,11773	393,07	1496,60	1101,60	1,6262	5,1366
43,00	15,852	1,7230	0,11843	397,67	1497,33	1097,58	1,6390	5,1259
44,00	16,231	1,7267	0,11931	402,27	1498,05	1093,55	1,6517	5,1152

T °C	P Bar	$v_f$ dm <sup>3</sup> / kg	$v_g$ m <sup>3</sup> / kg	$h_f$ kJ / kg	$h_g$ kJ / kg	R kJ / kg	$s_f$ kJ / (kg K)	$s_g$ kJ / (kg K)
45,00	17,820	1,7505	0,07284	410,49	1491,02	1080,53	1,7053	5,1016
46,00	18,302	1,7556	0,07092	415,34	1491,23	1075,90	1,7203	5,0914
47,00	18,795	1,7608	0,06905	420,19	1491,42	1071,23	1,7352	5,0812
48,00	19,297	1,7660	0,06724	425,06	1491,59	1066,53	1,7501	5,0711
49,00	19,809	1,7713	0,06548	429,93	1491,73	1061,79	1,7650	5,0609
50,00	20,331	1,7767	0,06378	434,82	1491,84	1057,02	1,7798	5,0508
51,00	20,864	1,7821	0,06213	439,72	1491,93	1052,21	1,7947	5,0407
52,00	21,407	1,7876	0,06053	444,63	1491,99	1047,36	1,8095	5,0307
53,00	21,961	1,7932	0,05898	449,56	1492,03	1042,47	1,8243	5,0206
54,00	22,525	1,7988	0,05747	454,50	1492,04	1037,54	1,8391	5,0106
55,00	23,100	1,8046	0,05600	459,45	1492,02	1032,57	1,8539	5,0006
56,00	23,686	1,8103	0,05458	464,42	1491,98	1027,56	1,8687	4,9906
57,00	24,284	1,8162	0,05320	469,40	1491,91	1022,51	1,8835	4,9806
58,00	24,892	1,8221	0,05186	474,39	1491,81	1017,42	1,8983	4,9707
59,00	25,512	1,8282	0,05056	479,40	1491,68	1012,28	1,9131	4,9607
60,00	26,143	1,8343	0,04929	484,43	1491,52	1007,09	1,9278	4,9508
61,00	26,786	1,8404	0,04806	489,48	1491,33	1001,86	1,9426	4,9408
62,00	27,440	1,8467	0,04687	494,54	1491,12	996,58	1,9573	4,9309
63,00	28,107	1,8531	0,04571	499,61	1490,87	991,25	1,9721	4,9209
64,00	28,785	1,8595	0,04458	504,71	1490,58	985,87	1,9869	4,9110
65,00	29,476	1,8661	0,04348	509,83	1490,27	980,44	2,0016	4,9011
66,00	30,179	1,8727	0,04241	514,96	1489,93	974,96	2,0164	4,8911
67,00	30,894	1,8795	0,04137	520,12	1489,55	969,43	2,0312	4,8812
68,00	31,622	1,8863	0,04036	525,29	1489,13	963,84	2,0460	4,8713
69,00	32,363	1,8933	0,03937	530,49	1488,68	958,19	2,0608	4,8613
70,00	33,116	1,9004	0,03841	535,71	1488,19	952,49	2,0756	4,8514
71,00	33,882	1,9076	0,03748	540,95	1487,67	946,74	2,0904	4,8415
72,00	34,660	1,9149	0,03658	546,21	1487,12	940,94	2,1052	4,8316
73,00	35,450	1,9223	0,03570	551,49	1486,54	935,09	2,1200	4,8217
74,00	36,252	1,9298	0,03485	556,79	1485,93	929,19	2,1348	4,8118
75,00	37,066	1,9374	0,03402	562,11	1485,29	923,24	2,1500	4,8019
76,00	37,892	1,9452	0,03321	567,45	1484,62	917,24	2,1652	4,7920
77,00	38,729	1,9531	0,03242	572,81	1483,92	911,19	2,1804	4,7821
78,00	39,577	1,9612	0,03165	578,19	1483,19	905,09	2,1956	4,7722
79,00	40,436	1,9694	0,03091	583,59	1482,43	898,94	2,2108	4,7623
80,00	41,306	1,9778	0,03019	589,01	1481,64	892,74	2,2259	4,7524
81,00	42,187	1,9863	0,02949	594,45	1480,82	886,49	2,2410	4,7425
82,00	43,079	1,9950	0,02881	600,91	1479,97	880,19	2,2561	4,7326
83,00	43,982	2,0039	0,02815	607,39	1479,09	873,84	2,2712	4,7227
84,00	44,896	2,0129	0,02751	613,89	1478,18	867,44	2,2863	4,7128
85,00	45,821	2,0222	0,02689	620,41	1477,24	860,99	2,3014	4,7029
86,00	46,757	2,0316	0,02629	626,95	1476,27	854,49	2,3165	4,6930
87,00	47,704	2,0412	0,02571	633,51	1475,27	847,94	2,3316	4,6831
88,00	48,662	2,0510	0,02515	640,09	1474,24	841,34	2,3467	4,6732
89,00	49,631	2,0611	0,02461	646,69	1473,18	834,69	2,3618	4,6633
90,00	50,611	2,0713	0,02409	653,31	1472,09	827,99	2,3769	4,6534
91,00	51,602	2,0819	0,02359	660,95	1470,97	821,24	2,3920	4,6435
92,00	52,604	2,0926	0,02311	668,61	1469,82	814,44	2,4071	4,6336
93,00	53,617	2,1036	0,02265	676,29	1468,64	807,59	2,4222	4,6237
94,00	54,641	2,1149	0,02221	684,00	1467,43	800,69	2,4373	4,6138
95,00	55,676	2,1265	0,02179	691,73	1466,19	793,74	2,4524	4,6039
96,00	56,722	2,1384	0,02138	699,49	1464,92	786,74	2,4675	4,5940
97,00	57,779	2,1506	0,02099	707,27	1463,62	779,69	2,4826	4,5841
98,00	58,847	2,1631	0,02061	715,07	1462,29	772,59	2,4977	4,5742
99,00	59,926	2,1760	0,02025	722,89	1460,93	765,44	2,5128	4,5643
100,00	61,016	2,1892	0,02000	730,73	1459,54	758,24	2,5279	4,5544
101,00	62,117	2,2029	0,01976	738,59	1458,12	750,99	2,5430	4,5445
102,00	63,229	2,2169	0,01953	746,47	1456,67	743,69	2,5581	4,5346
103,00	64,352	2,2314	0,01931	754,37	1455,19	736,34	2,5732	4,5247
104,00	65,486	2,2464	0,01910	762,29	1453,68	728,94	2,5883	4,5148
105,00	66,631	2,2619	0,01890	770,23	1452,14	721,49	2,6034	4,5049
106,00	67,787	2,2780	0,01871	778,19	1450,57	713,99	2,6185	4,4950
107,00	68,954	2,2946	0,01853	786,17	1448,97	706,44	2,6336	4,4851
108,00	70,132	2,3118	0,01836	794,17	1447,34	698,84	2,6487	4,4752
109,00	71,321	2,3297	0,01821	802,19	1445,68	691,19	2,6638	4,4653
110,00	72,521	2,3484	0,01807	810,23	1443,99	683,49	2,6789	4,4554
111,00	73,732	2,3678	0,01794	818,29	1442,27	675,74	2,6940	4,4455
112,00	74,954	2,3881	0,01782	826,37	1440,52	667,94	2,7091	4,4356
113,00	76,187	2,4093	0,01771	834,47	1438,74	660,09	2,7242	4,4257
114,00	77,431	2,4316	0,01761	842,59	1436,93	652,19	2,7393	4,4158
115,00	78,686	2,4549	0,01752	850,73	1435,09	644,24	2,7544	4,4059
116,00	79,952	2,4796	0,01744	858,89	1433,22	636,24	2,7695	4,3960
117,00	81,229	2,5057	0,01737	867,07	1431,32	628,19	2,7846	4,3861
118,00	82,517	2,5333	0,01731	875,27	1429,39	620,09	2,7997	4,3762
119,00	83,816	2,5627	0,01726	883,49	1427,43	611,94	2,8148	4,3663
120,00	85,126	2,5942	0,01722	891,73	1425,44	603,74	2,8299	4,3564
121,00	86,447	2,6279	0,01719	900,00	1423,42	595,49	2,8450	4,3465
122,00	87,779	2,6645	0,01717	908,29	1421,37	587,19	2,8601	4,3366
123,00	89,122	2,7042	0,01716	916,61	1419,29	578,84	2,8752	4,3267
124,00	90,476	2,7479	0,01716	924,95	1417,18	570,44	2,8903	4,3168
125,00	91,841	2,7962	0,01717	933,31	1415,04	561,99	2,9054	4,3069
126,00	93,217	2,8506	0,01718	941,69	1412,87	553,49	2,9205	4,2970
127,00	94,604	2,9127	0,01720	950,09	1410,67	544,94	2,9356	4,2871
128,00	96,002	2,9854	0,01723	958,51	1408,44	536,34	2,9507	4,2772
129,00	97,411	3,0734	0,01727	966,95	1406,18	527,69	2,9658	4,2673
130,00	98,831	3,1860	0,01732	975,41	1403,89	518,99	2,9809	4,2574
131,00	100,262	3,3457	0,01738	983,89	1401,57	510,24	2,9960	4,2475
132,00	101,714	3,6555	0,01745	992,39	1399,22	501,44	3,0111	4,2376
133,35	113,530	4,2735	0,01753	1000,91	1396,84	492,59	3,0262	4,2277

## Liquid control devices

Liquid feed control and level controls



Danfoss  
REF-2092\_10

No.	Function	Product
1	Stop valve	STC
2	Stop valve	STC
3	Filter	FA / FIA
4	Solenoid valve	EVRA
5	Hand expansion valve	REG
6	Float switch	AKS 38
7	Stop valve	STC
8	Stop valve	STC
9	Stop valve	STC
10	Quick closing oil drain valve	QDV

For more information, please contact your local Danfoss sales office.

We shall start with liquid control devices whose primary functions are:

- A. To feed the quantity of liquid required by the load demand of the evaporators , liquid separator and other equipment.
- B. To create a pressure drop across the expansion valve to maintain the desired temperature in the evaporator.

### Liquid control devices for gravity feed systems:

At the outlet of the ammonia receiver there is a stop valve (1), also commonly known as the king valve, because it is the main valve used for pumping down the ammonia in the receiver in the event of an emergency or long shutdown.

The liquid line strainer (3) is installed after the stop valve (2) in the liquid line towards the air cooler / chiller. The strainer captures contaminants, protecting choking of the expansion device (which has a small orifice).

The coil of the subsequent solenoid valve (4) is activated by a liquid level control. When the desired liquid level is reached, the solenoid valve coil is de-energized, shutting off the liquid flow. When the liquid level in the accumulator falls below the set point of the float switch, the coil is energized and the valve opens. Excessive on / off operation of the solenoid valve (hunting) is prevented by adjusting the opening / closing of the subsequent hand expansion valve.

The hand expansion valve (5) has a taper stem to regulate and adjust the flow accurately to match the quantity of refrigerant evaporating in the air cooler.

A properly designed accumulator are important. It can be of the vertical or horizontal type. The sizing of the accumulator is critical to ensure liquid is not carried back to the compressor.

The accumulator is positioned near the air cooler in such a manner that sufficient liquid is maintained in the liquid leg to overcome the pressure drop in the coil and to maintain proper circulation of the liquid in the coil.

The quantity of liquid circulating exceeds the circulation rate in the system, ensuring the surface of the tubes is kept constantly wetted. The heat for boiling the refrigerant is provided by the warm air, and a mixture of unevaporated liquid and vapor bubbles enters the accumulator. The liquid and vapor components separate

due to their different densities, and the excess liquid re-enters the coil where vapor formed by evaporation is sucked by the compressor. The expansion valve feeds a corresponding quantity of liquid, maintaining the steady-state condition and the level of the liquid in the accumulator.

The liquid level in the accumulator should not be too high because a higher liquid column means there is subcooled liquid at the entry to the evaporator. Part of the heat transfer area is then wasted in overcoming this extra subcooling before evaporation actually starts.

The liquid level in the accumulator is maintained at the desired level by a float switch (6) or level sensor. The float switch has a float and electrical coil. As the liquid level increases beyond the set point, the float moves up forcing the solenoid valve (4) to close and prevent further liquid entering the accumulator. Similarly, when level falls below set point, the solenoid valve in the liquid line opens, allowing more liquid in the accumulator. Thus the liquid level is maintained constant in the accumulator.

Each cooler must be provided with an independent accumulator. The float switch is connected to the accumulator via gas and liquid equalizing lines, keeping the level of liquid in the float chamber the same as that in the accumulator.

Some manufacturers also use a modulating mechanical float. This does not require a solenoid valve on / off control in the liquid line.

More advanced control using a motorized valve is also available. This regulates the level of liquid more uniformly than an on / off control system. This eliminates the requirements for a solenoid valve and float switch. As further precautions, a solenoid valve may be provided, or the valve actuator connected to a UPS (Uninterrupted Power Supply) so that in the event of a power failure the motorized valve will close the liquid supply to the accumulator.

The liquid line solenoid valve (4) is also required should a pump-down cycle be activated. When the air coolers need attention or a defrost cycle is to be activated, the solenoid valve closes and no liquid is supplied to the cooler. The compressor continues to draw refrigerant from the coolers, and the charge of ammonia is removed from the low side of the system.

The liquid line solenoid valve (4) is also activated by an override from a thermostat in the return air path of the air cooler, and closes when the desired room temperature is reached.

In pump circulation systems, individual coolers do not need an accumulator. Excess liquid is returned to a common low-pressure vessel in the plant room.

#### **Applications:**

- A. Cold storage
- B. Ice plants (block ice, tube ice, flake ice machines)
- C. Small capacity water and brine chillers

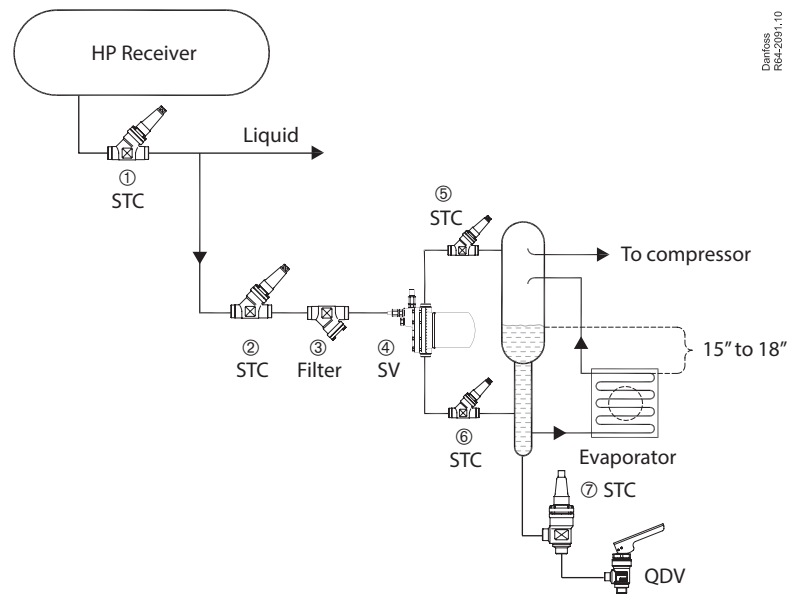
Danfoss offers various liquid level controls for evaporators. The subsequent pages cover the alternatives that can be used depending on the application requirements, criticality, and initial cost.

#### **Alternatives:**

1. Mechanical float valves SV Float / PMFL
2. Combination of float switch AKS 38 and solenoid valve EVRA:
3. Continuous modulation devices: AKS 4100 with ICM valve

## Alternative 1 Mechanical float valves type SV

Liquid level regulation using float valve



Danfoss  
REF-2051.10

No.	Function	Product
1	Stop valve	STC 15
2	Stop valve	STC 15
3	Filter	FA
4	SV float	SV1
5	Equaliser valve - gas	STC 25
6	Equaliser valve- liquid	STC 25
7	Stop valve	STC 15

For more information, please contact your local Danfoss sales office.

### Mechanical modulating liquid level regulating SV float valves

This is the simplest form of mechanical liquid ammonia control which does not require an electrical signal, separate expansion valve or inlet solenoid valve.

When the liquid level falls in the accumulator, the float (4) position moves downwards. This opens the orifice more, increasing the amount of liquid that is admitted. When the liquid level rises above the set point, the float closes the orifice and no further liquid is admitted.

The liquid inlet line comes from the main HP receiver and is connected to the inlet of the float valve. A liquid line of size ½" is recommended for both SV1 and SV3 since this line can handle a capacity of up to 118.4KW (ASHRAE Table 2, p. 3-9).

Care should be taken with the liquid inlet pipe sizing and valve positioning to ensure that no gas bubbles are generated at the entry of the expansion orifice, since the valve capacity is reduced considerably if flash is present at the inlet of the orifice.

The flash gas generated after the expansion in the orifice of the float valve is removed through the equalising pipe.

The sizing of the equalising connections and the positioning of valves in these lines is equally important to ensure an identical liquid level in the accumulator and float valve. Generally in systems equipped with an accumulator / surge drum, the liquid leg is extended downward below the point from where the liquid is fed to the evaporator and a drain valve is provided to allow periodic manual draining of the oil.

#### Float valve SV1

+40°C SDT / -5°C SST, capacity 32kW,  
ΔP = 12 bar

#### Float valve SV3

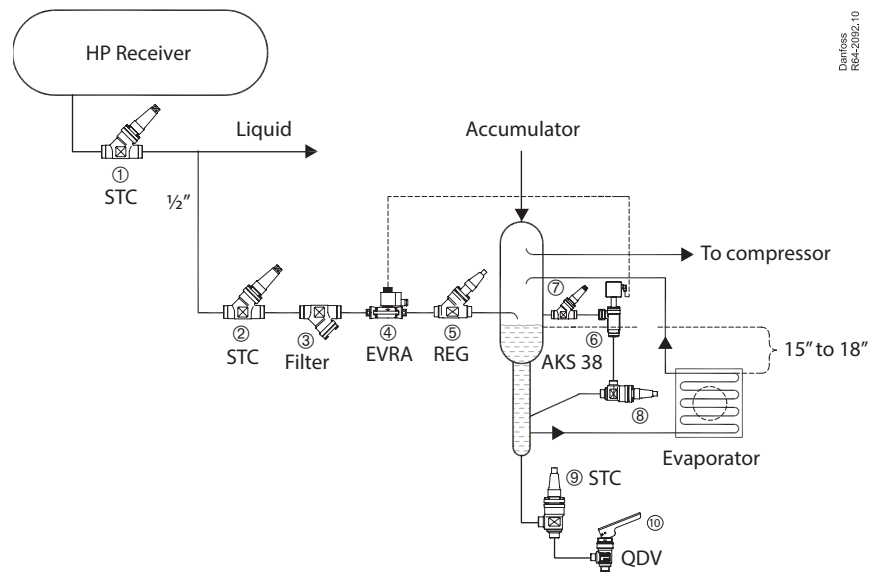
+40°C SDT / -25°C SST, capacity 79kW,  
ΔP = 14 bar

1. The advantage of this combination is better liquid level control compared with Alternative 1.
2. This combination also allows pump down by de-energizing the solenoid valve, manually or via a timer.

## Alternative 2

Where electrical controls are preferred as a more advanced solution, the suggested option is a combination of liquid line EVRA solenoid valve and float AKS 38 switch.

Liquid level control using EVRA and AKS 38



Danfoss  
R6L-2012.10

No.	Function	Product
1	Stop valve	STC
2	Stop valve	STC
3	Filter	FA / FIA
4	Solenoid valve	EVRA
5	Hand expansion valve	REG
6	Float switch	AKS 38
7	Stop valve	STC
8	Stop valve	STC
9	Stop valve	STC
10	Quick closing oil drain valve	QDV

For more information, please contact your local Danfoss sales office.

### Design / function:

AKS 38 (6) is an electro-mechanical float switch designed to provide a reliable electromechanical response to liquid level changes. AKS 38 can control liquid levels in vessels and accumulators, or can be used as a low / high level safety alarm / trip. The simple design provides reliable, extended performance in many liquid level regulation applications in industrial refrigeration.

The design is based on a mechanical float that responds to the level of liquid refrigerant in the float chamber. When the set level is reached, an electrical microswitch is activated. The microswitch is located in the switch box, which has a clear front cover allowing the switch position to be seen. The microswitch is fully isolated from the refrigeration system, and operates magnetically.

The microswitch provides contacts to open / close a solenoid valve in the liquid feed line, regulating the flow of refrigerant to maintain the set level in the vessel. There is also a regulating valve REG (5) in the liquid line to assist in creating the desired pressure drop.

AKS 38 is also used to energize / de-energize contacts for starting / stopping refrigerant pumps / compressors.

AKS 38 is mounted externally on a standpipe at the same level as that required to be maintained in the main vessel. The float switch is connected to the standpipe with properly sized gas and liquid equalizing connections.

The sizing of connections and the positioning of valves in these lines are important to ensure no oil accumulates in the liquid line equalizing pipe or high pressure drop in gas equalizing, both these may lead to incorrect liquid level in the vessel and in the float chamber.

AKS 38 can also be used with an indicator to indicate the liquid level on a control panel at a remote location.

If necessary, the switch assembly can be easily replaced by loosening the screws and lifting the float switch assembly out of the tank.

This scheme uses hand expansion valve REG (5), which is selected for the required capacity. To select the correct size of expansion valve REG, the designer

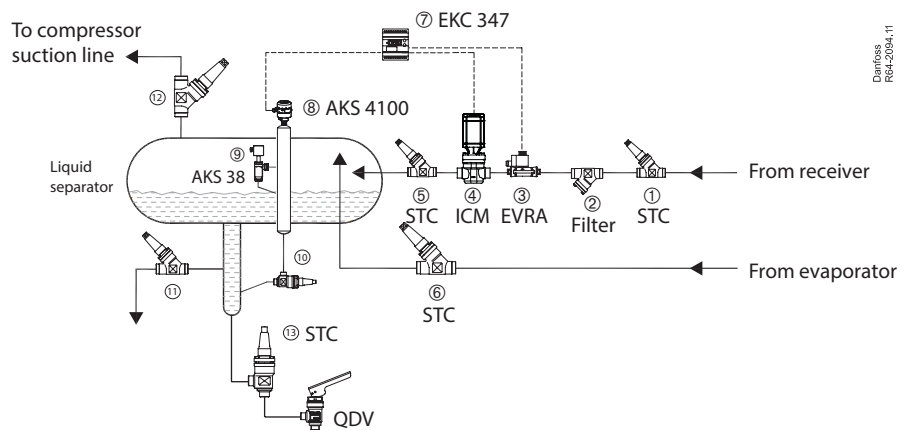
must specify the cooler capacity (kW), and the evaporating and condensing temperatures. Normal practice is to select the valve so it opens about 75% of the total valve capacity with the minimum possible pressure drop, say up to 0.5 bar. REG is available in sizes from 6 mm to 65 mm with various cone sizes to match the required capacity.

In systems with an accumulator / surge drum, the liquid leg is generally extended downwards below the point from where the liquid is fed to the evaporator, and a drain valve is provided to allow periodic manual draining of the oil.

### Alternative 3

#### Modulation device AKS 4100 and ICM valve

Liquid level control using continuous modulation device – AKS 4100 and ICM valve



Danfoss  
REG-2004-11

No.	Function	Product
1	Stop valve	STC
2	Filter	FA / FIA
3	Solenoid valve	EVRA
4	Motorized valve	ICM
5	Stop valve	STC
6	Stop valve	STC
7	Liquid level controller	EKE347
8	Liquid transmitter	AKS 4100 / AKS 4100U
9	Float switch	AKS 38
10	Stop valve	STC
11	Stop valve	STC
12	Stop valve	STC
13	Stop valve	STC

For more information, please contact your local Danfoss sales office.

#### Modulating liquid level control

This is the most advanced continuously modulating liquid level control system, with high-accuracy monitoring and control of liquid levels.

This option uses AKS 4100 / AKS 4100U liquid level transmitter (8) combined with EKE 347 controller (7) (or the customer's PLC) and ICM motorized modulating valve (4). AKS 4100 / 4100U liquid level sensor is designed specifically to measure liquid levels for most of the refrigerants in vessels, accumulators, receivers, standpipes, etc. It is based on a proven technology called time domain reflectometry (TDR) or guided radar microwave.

Level transmitter AKS 4100 monitors the liquid level in the separator and sends a level signal to liquid level controller EKE 347, which sends a proportional 4-20 mA signal to the actuator of motor valve ICM. Motor valve ICM acts as an expansion valve.

EKE 347 also provides relay outputs for upper and lower limits and for alarm level. However, an additional AKS 38 is recommended as a high level cutout for back-up protection.

AKS 4100 is suitable for different lengths as required, and its length can easily be adjusted on site. It is available in various lengths from 800 mm to 5000 mm.

AKS 4100 / 4100U sensors are available in two options: with a cable directly immersed in the liquid refrigerant, or with a co-axial (sleeve) tube. However, a standpipe for installation is generally recommended. The standpipe diameter can be 50 mm to 100 mm. The standpipe length should be the vessel diameter plus 120 mm above the top and below the bottom. The signal output is in 4-20 mA, two wire loop powered proportional to liquid level and does not need a separate transformer.

The HMI display unit mounted on the top is used during commissioning for adjusting the level quickly on site.

As a precaution against power failure, either a liquid line solenoid valve (to stop the liquid supply) should be installed, or backup UPS (Uninterrupted Power Supply) power (to close the ICM modulating valve) should be available, because the ICM modulating valve would remain open in same position if the power supply failed. The supply voltage to the valve actuator is 24 V dc.

**Special features of AKS 4100 / 4100U:**

- No need to clean the cable version when fully covered in oil.
- Changes of the liquid's dielectric constant do not affect operation.
- Dust, foam, vapor, agitated surfaces, boiling surfaces, and changes in the density of the liquid have no influence on the AKS 4100 / 4100U.
- Oil accumulating at the bottom of the standpipe will not disturb the liquid level signal, and it is not necessary to remove AKS 4100 / 4100U for cleaning after oil has been drained out of the standpipe.
- No stop valves are required between the standpipe and the vessel, though they are recommended for service purposes.
- The HMI display unit mounted on the top is used during commissioning for adjusting the level quickly on site. The digital display offers both SI and FPS units.
- When the radar control is checked, the head can be removed easily without removing all the steel wire from the standpipe.



## Liquid control devices for pump circulation systems

We shall look first at the advantages / disadvantages of pump circulation systems over conventional gravity feed systems.

**The advantages of liquid overfeed or pump circulation systems are:**

1. The evaporator surface is used efficiently because of the good refrigerant distribution and the complete wetting of internal tube surfaces.
2. At low temperatures, achieving good heat transfer in the evaporator is crucial since the plant operates with high compression ratios, where quantities of flash gas are appreciable affecting proper wetting of the surface. The fundamentally liquid pump circulation or overfeeding causes more wetting of tubes associated with high velocity of refrigerant results in higher heat transfer rate.
3. There is uniform liquid distribution in all coolers and all perform equally. In gravity flooded systems if the number of coolers is more, the evaporator closer to compressor receives more liquid whereas the evaporator far away may starve. Also the pressures / temperatures are not equal in all evaporators.
4. The refrigerant feed is unaffected by fluctuating ambient conditions and condensing temperatures. The flow controls need not be adjusted after their initial setting because overfeed rates are not critical.
5. Since all the major equipment containing refrigerant are housed in plant room, the distance between compressors and low pressure ammonia storage vessel is less, thus reducing suction line pressure drops and superheat there by elevating compressor saturated suction temperature, which can lead to power saving.
6. Overfeeding ensures that the vapours coming from the low pressure evaporator are at close to saturated condition without any superheat thus lowering compressor inlet gas temperature, which also means corresponding lower discharge gas temperatures, which are critical factor for ammonia systems working at low temperature applications. Higher discharge temperatures pose many problems for compressor lubrication.

7. The compressors are protected from liquid slugs resulting from load fluctuations or malfunctioning controls, because suction gas returns to the low-pressure vessel first and not directly into the compressor.
8. Flash vapor resulting from refrigerant throttling losses is removed at the low-pressure receiver before entering the evaporator. This vapor is then drawn directly into the compressor and eliminated in the low side system. It does not contribute to increased pressure drop in evaporators or the wet suction return line to the low-pressure receiver.
9. The compressor lasts longer, with less wear and fewer breakdowns compared with a conventional system, because conditions for the entering suction gas are ideal.
10. In pump circulation system design, the advantage is that the refrigeration system is effectively disconnected from the load, enabling more efficient operation and ample flexibility in design and operation.
11. Fault finding and troubleshooting are also easier because the refrigeration system design is satisfactory provided enough liquid is available in the low-pressure receiver at the required temperature to meet the demands of all the evaporators. If the desired results are not being achieved, it is then easier to concentrate on analyzing the performance of the low / evaporator sides independently. This is more difficult when system responds directly to the load.
12. Parts containing refrigerant (high- / low-pressure receivers, controls, level indicators, alarms, refrigerant pumps, and oil drains) are located in the plant room, under the operator's supervision, rather than remotely, enabling them to be supervised effectively.
13. Automatic operation is convenient. With simple controls, evaporators can be hot gas defrosted with little disturbance to the system.
14. Oil does not accumulate in evaporators and need not be drained from each evaporator. Oil draining is convenient because the low-pressure receiver is located in the plant room.
15. Should the plant stop suddenly, production does not suffer, because some liquid at low temperature is available in the low-pressure receiver, which acts as a reservoir for some time.
16. The costs of accumulators and level controllers for each evaporator are eliminated because these are not required for pump circulation systems.

#### **Disadvantages**

1. Higher initial cost due to the additional components in overfeed system designs compared with normal gravity flooded systems (e.g. low-pressure receiver, circulation pumps, and associated controls). in case of fewer evaporators.
2. The system contains more refrigerant, so the high-pressure receiver must also be larger.
3. The higher circulation rate demands liquid and wet return suction lines of greater diameter.
4. Much more piping insulation is needed because the liquid supply lines are also cold, requiring additional insulation, and suction lines are much bigger.
5. The refrigerant pumps, as one more moving part, demand additional power and maintenance.

6. In gravity flooded or pump circulation systems, compressor power can be saved by unloading them in response to load and by maintaining room temperatures during holding periods. However, pumps would continue to consume power because they have to work round the clock.
7. Expert design is needed to ensure proper sizing, construction of the low-pressure vessel, selection of controls, pipe sizing, and location and elevations of various equipment to make a package.
8. It is important to design the system properly with sufficient liquid high column to avoid pump cavitation problems caused by low available net positive suction pressure (NPSH). In many installations, the NPSH required by the pump is more than that available, leading to cavitation.
9. The low-temperature liquid flow rate and its pressure at the inlet of the coolers require proper adjustment. Many installers have experienced poor evaporator performance if this is not done, because most of the surface of the evaporator is then used to overcome subcooling rather than for evaporation.
10. Many plants using pump circulation systems experience hydraulic shocks if the hot gas defrost system is not properly engineered, with both liquid and gas present in the suction line.

### **Conclusion**

The use of liquid overfeed systems is advantageous when:

- There are more than 4-6 larger capacity evaporators in medium or large size cold storage or process plants.
- The plant room is located far from the processing area where the evaporators are located, involving lengthy refrigerant distribution pipe work.
- Special evaporators (e.g. spiral freezers or plate freezers) are involved.
- The requirement is for medium or low temperature commodity storage.

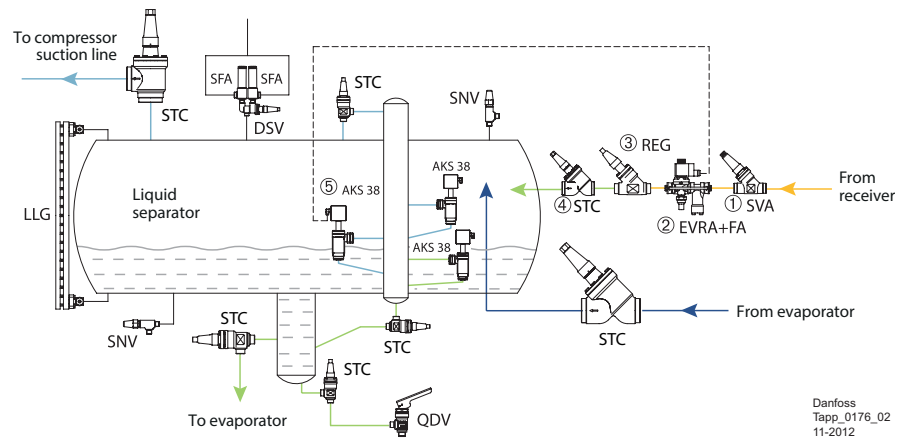
Danfoss offers various options for these controls, described on subsequent pages.

### **Alternatives**

1. Electro mechanical solution using AKS 38 float switches and REG liquid control valve
2. AKS 4100 level transmitter and AKVA liquid control valve
3. AKS 4100 level transmitter and ICM liquid control valve
4. AKS 4100 level transmitter and ICF Liquid control module

## Alternative 1

### Electro mechanical solution using AKS 38 float switches and REG liquid control valve.



No.	Function	Product
1	Stop valve	STC
2	Filter + solenoid valve	FA + EVRA
3	Regulating valve	REG
4	Stop valve	STC
5	Float switch	AKS 38

For further information, please contact your local Danfoss sales office.

This is the most common solution currently in use. The system uses three AKS 38 float switches. The main float switch (3) controls the level of the liquid in the low-pressure vessel at around 50%. The upper float switch (5) acts as a compressor trip in the event of the liquid level exceeding 65%. This switch can also be used as an alarm. The lower float switch (4) trips the liquid ammonia pump in the event of the level falling below the preset level (around 20%). This switch also acts as an alarm for low level.

All three switches are mounted on a standpipe of minimum 100 mm diameter and extending 150 mm above and below the diameter of the low-pressure vessel. A separate oil drain at the bottom of the standpipe is provided.

The equalizing connections between the float switches and the standpipe must be carefully designed so that all three float switches have liquid equalizing on the liquid side and gas equalizing on the gas side. The liquid equalizing lines should slope downwards to ensure oil does not accumulate in them, which may lead to an incorrect signal. If stop valves are installed in the equalizing lines, they should be installed with horizontal stems.

The main float switch (5) controlling the liquid level activates energizing / de-energizing the solenoid valve (2) in the main liquid line before the hand expansion valve REG (3). REG is set at the time of commissioning to minimize hunting of the solenoid valve (not more than three times per hour).

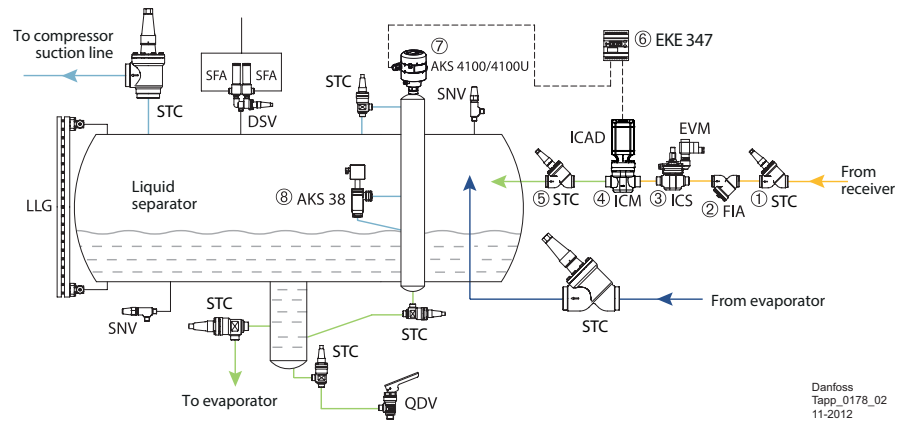
A stop valve and a cleanable filter prior to the solenoid valve should be installed. The next three options do not use AKS 38 float switches, but the more advanced AKS 4100 level transmitter along with EKE 347 controller. These three solutions give much more accurate level control.

For a detailed description of AKS 4100 with EKE 347, please refer to the product literature.



## Alternative 3

### Using AKS 4100 Liquid level transmitter and ICM liquid control valve.



Danfoss  
Tapp\_0178\_02  
11-2012

No.	Function	Product
1	Stop valve	STC
2	Filter	FA / FIA
3	Solenoid valve	ICS + EVM
4	Motorized valve	ICM
5	Stop valve	STC
6	Liquid level controller	EKE 347
7	Liquid transmitter	AKS 4100 / AKS 4100U
8	Float switch	AKS 38

For further information, please contact your local Danfoss sales office.

This alternative is similar to alternative 2, except that the AKVA has been replaced by an ICM motorized valve (4).

ICM valves are designed to regulate an expansion process in the liquid lines with or without phase change, and can therefore be used to control pressure or temperature in the dry or wet suction lines as well as in the hot gas lines. ICM valves are designed so that the opening and closing forces are balanced. Only two sizes of actuators are therefore needed to cover the entire range from 20 mm to 150 mm. The ICAD actuator gives a 4-20 mA output signal by default. In case of power failure, a failsafe supply (battery or UPS (Uninterrupted Power Supply)) is required for programming the valve to close. Alternatively, a solenoid valve (3) in the liquid line to close the liquid supply may be provided.

These valves provide continuous liquid flow regulation as the load varies. The evaporator therefore receives the correct quantity of liquid at all times, avoiding underfeeding and overfeeding.

The standpipe diameter can be 50 mm to 100 mm. The standpipe length should be the vessel diameter plus 120 mm above the top and below the bottom.

For more details on ICM motorized valves and actuators, please refer to the Danfoss product documentation.

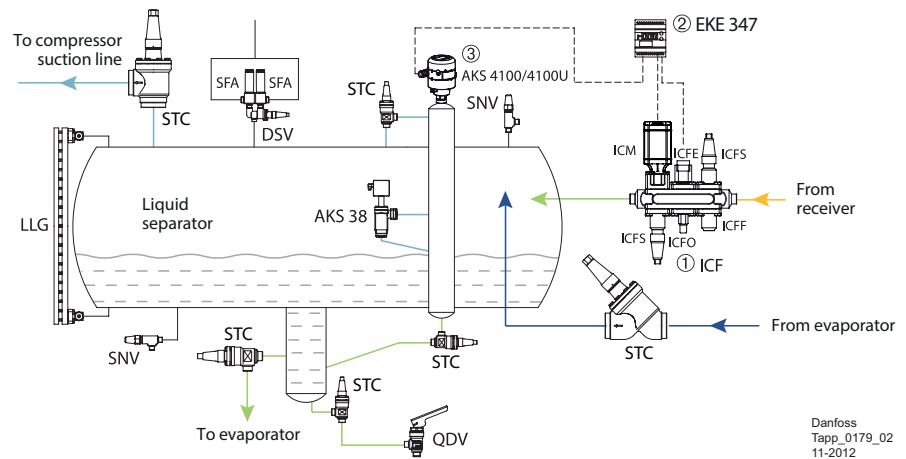
## Alternative 4

### Using AKS 4100 Liquid level transmitter and ICF liquid control valve station.

The ICF valve station consists of the following modules:  
 Stop valve module, ICFS  
 Filter (strainer) module, ICFF  
 Solenoid valve module, ICFE  
 Motorized valve, ICM

No.	Function	Product
1	ICF valve station	ICF
2	Liquid level controller	EKE 347
3	Liquid transmitter	AKS 4100 / AKS 4100U

For further information, please contact your local Danfoss sales office.



Alternative 4 is the most advanced alternative, using all the components as for alternative 3 but with them mounted in an ICF module. The advantages of this design are:

1. The number of welding joints is reduced from up to 12 down to 2, reducing the chance of leaks and minimizing labour cost.
2. A complete assembly is supplied incorporating several functions in a single housing, enabling it to replace a series of conventional mechanical, electro-mechanical, and electronically operated valves.
3. The complete assembly is leak-tested in the factory at high pressure under controlled conditions.
4. The valve is supplied with direct weld connections, and thus avoids flange joints.
5. The ICF module uses a low-temperature steel housing with low weight and a compact design, thereby avoiding extra piping supports.
6. Side ports for connecting pressure gauges, transmitters, sight glasses, or service valves are available.
7. The valve can be used for applications ranging from  $-60^{\circ}\text{C}$  to  $+120^{\circ}\text{C}$ .
8. This type of design allows maximal capacity with minimal pressure drop using advanced technology and double seats, and offers higher capacity than conventional systems using individual valves and components.
9. The valves come with 4 and 6 module ports on which the following accessories can be fitted, depending on requirements:
  - a. Inlet / outlet stop valves
  - b. Manual REG valves
  - c. Filter module
  - d. Solenoid valve module
  - e. Electronic expansion valve module
  - f. Check valve / Stop check valve module
  - g. Motorized valve module
10. The external surface is zinc chromated to provide corrosion protection. Further surface treatment is recommended.

For more details of the ICF valve station, please refer to the Danfoss product documentation.

## Defrosting air coolers - various methods

As the coldest surface in the cold room, the evaporator attracts moisture from the air that condenses on its surface. When the surface temperature is below 0 °C, frost is formed.

If this frost is not removed, the performance of the evaporator deteriorates because the frost offers resistance to heat flow and increases the air side resistance, reducing the flow. If the frost is not removed in time and plant continues to operate, the evaporator may become totally ineffective, as there will be no air flow or heat transfer.

It is therefore essential to defrost coolers in good time to maintain efficiency and avoid damage to components. Improper and incomplete defrosting can damage the compressor and evaporator coil to the extent that irreparable refrigerant leaks develop when accumulated ice crushes one or more coil tubes. The fan blades are also likely to be damaged if ice accumulates on the fan ring. The drain pan becomes totally blocked by the ice slab and water spills onto the floor, forming ice there, too.

Defrosting is therefore necessary, but should not be performed to excess. Defrosting is a doubly expensive procedure because energy is used to pump heat into the cooler and its surroundings, after which further energy is used to extract the heat from the cooler and its surroundings before the system returns to its operating temperature. Energy is thus consumed twice, first for forming ice and second for melting it.

As the term suggests, defrosting should be activated when frost is formed, rather than waiting until ice is formed on the coil surface. The total energy required to form ice and defrost it is estimated to be nearly 1.5 kW / kg ice (IAR Condenser magazine, May 2010).

The various methods for defrosting coolers are described on the following pages with their advantages and disadvantages, along with the method most suitable for the application under consideration.

### Off cycle defrost

1. Warm outside air: Outside warm air can be ducted inside to defrost the coil. This method can be adapted to any temperature in the cold room. It requires ducting, and personnel to carry it out. In colder climates, this method is either ineffective or less efficient. The outside air brings in moisture and imposes an additional heat load on the system.
2. In cold stores operating above 2 °C, the evaporator coils can be defrosted by simply turning off the refrigerant flow to the evaporator while keeping the fans running and allowing room air to pass over the evaporator, thereby melting the frost. The disadvantage of this process is that it is very slow. However, it has the lowest cost and requires no additional controls or energy. Note that this method does not help in removing accumulated oil in the cooler.

### Electric defrost

This is one of the popular methods for small air coolers, particularly for HFC / HCFC refrigerants. The method can be applied to any cold room application operating at any temperature.

During the manufacturing and assembly of coils, dummy tubes containing electrical heating elements are inserted in the coil blocks in a particular pattern. In some designs, the heating elements are strapped to the outside of the fin / tube assembly. The advantage of this method is that the manufacturer need not provide extra dummy tubes.

The advantage of electric defrost is that it does not interfere with the refrigerant circuit, and the chance of liquid or hydraulic hammer is eliminated.

The system has a low initial cost but high running cost, because it consumes lot of electrical energy. Furthermore, it does not help in removing oil from the evaporator. A cooler of 30-40 kW capacity generally requires heaters of nearly 18 kW including drain pan heating. If it is defrosted four times a day for 30 minutes each cycle, the power consumed annually exceeds 13,000 kWh. Maintenance costs are high due to the frequent failure of resistance heating elements, and the replacement of burnt heaters is also a tedious job.

### **Water defrost**

The second most popular method of defrosting air coolers is spraying water on the coil. The mixture of water and melted frost collects in the drain pan and is removed from the refrigerated space. The advantages and disadvantages of water defrost over other methods are:

1. The defrost medium is inexpensive.
2. The defrost time is short (30-45 minutes).
3. It provides an automatic cleaning action on the coil.
4. Water defrost is most advantageous when there are only one or two coolers, of which one needs to be defrosted. In such cases, insufficient hot gas is available for defrosting, and hot gas defrost becomes ineffective.
5. This method is normally preferred for spiral or blast freezers because they are often single-compressor and single-cooler units.
6. Water defrosting is effective on coils at virtually all room temperatures. Water is sprayed over the coil, and the mixture of water and melted frost flows into the drain pan. The normal water temperature should be around 16 to 18 °C or more, depending on the wet bulb temperature in the area, and flow 1 to 3 liters per second per square meter of coil face.
7. This method is less desirable when temperatures fall below freezing. However, it has been used successfully in many applications at temperatures as low as -40 °C.
8. The water used for defrosting must have a neutral pH, to prevent damage to the fins, and be filtered to prevent choking of spray nozzles.
9. The quantity and velocity of the water sprayed must be controlled to ensure that water droplets are not carried in the air stream and into the cold room.
10. Warm water from a heat reclamation unit can also be used for defrosting.

### **Brine defrost**

Where coils use brines instead of refrigerant, the coils can be defrosted by remotely heating brine for the defrost cycle. This system is effective because it provides heat from inside and is therefore as rapid as hot gas defrost. The heat source for the brine may be steam, electricity, or condenser water.

### **Reverse cycle defrost**

This method is used in air-cooled applications where both the condenser and evaporator use air as the cooling medium.

Ideally, the defrost cycle should terminate when the whole cooler is sufficiently warmed above the melting point of ice to ensure the cooler is dry and frost free. This is achieved most easily in reversed cycle defrosting systems, where the pressure within the cooler gradually rises until the frost disappears. The defrost cycle may then be terminated.

Reverse cycle defrost is very efficient, but seldom used, because a very reliable four-way reversing valve is required. This method is also used with single cooler and single-compressor systems. Rotation of the four-way valve through 90° redirects the hot gas to the cooler instead of to the condenser.

This method cannot be used when multiple coolers are working with a single compressor, for the obvious reason that all coolers cannot be defrosted simultaneously by reversing the refrigeration cycle. This method is popular in truck refrigeration units.

### Hot gas defrost

Before this method is used, the details of its working must be understood.

1. Hot gas defrost is the best and most efficient alternative because the heat source acts from within, whereas with water / electrical defrost the heat source is outside.
2. During the hot gas defrost cycle, the evaporator acts as a condenser, giving up heat and converting gas to liquid.
3. Although hot gas defrost is the most effective way of defrosting, it is complicated and troublesome, and may be inefficient if not properly designed.
4. The basic procedure in this method is to interrupt the supply of liquid refrigerant to the evaporator, pump out the liquid to empty the evaporator, restrict the liquid outlet by closing the valve, supply hot gas at high pressure (from either the compressor discharge or the high-pressure receiver) to warm the evaporator coil and melt the surface frost / ice.
5. During operation, the heat from the hot gas is absorbed by the metal in the coil / plate, whose temperature rises. Once the temperature is high enough, ice / frost on the surface melts and is drained off.
6. Almost 50% of the heat supplied by the hot gas is used for heating the metal, the remainder being lost to space surrounding the tubes / plates because the temperature of the surrounding air is much lower than that of the unit.
7. Typical freezer coils have internal volumes of 4 to 6 liters / kW. A coil of 35 kW will have approximately 27 to 50 kg liquid ammonia. With an initial boil-off rate of approximately 1.2 kg / min, it will take about 20 to 40 minutes to boil all the liquid out of the freezer.
8. The lower the temperature / pressure of the hot gas supply, the less heat lost to space.
9. If the temperature of the hot gas is too high, the plates tend to steam. Furthermore, as the air's temperature rises, its relative humidity drops, leading to increased evaporation of surface water. It also adds to the refrigeration load (in the case of cold storage) or to the formation of fog / mist (if the freezers are in the open).
10. Higher temperatures will not necessarily improve defrost efficiency, because most of the defrost heat comes from the latent heat of the hot gas, rather than from sensible heat.

The following table for ammonia refrigerant illustrates this:

Temperature (°C)	Pressure (bar)	Latent heat (kJ / kg)
4	4	1240
10	5	1220
16	6	1200
21	8	1180

It shows that a defrost temperature of 21 °C requires 5% (i.e. (1240-1180) / 1180) more hot gas than one of 4 °C to provide the same latent heat content.

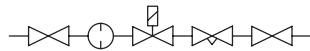
11. At lower defrost pressures, defrosting takes slightly longer (20 to 30 minutes). However, slightly extended defrost times at lower temperatures give a much better overall defrost efficiency than at higher temperature / pressures due to the less demanding refrigeration requirements.
12. A pressure regulator must therefore be installed in the plant room on the hot gas defrost pipe, set at 7 to 9 barg max. outlet pressure (depending on the plant). Another advantage of this lower pressure is that less liquid condenses in the hot gas line because the condensing temperature is reduced to 11 to 16 °C. It is also recommended that this valve has an electric shutoff feature. When no coils are calling for hot gas flow, this regulator will be closed, minimizing the ammonia condensate formed in the hot gas supply header.
13. Furthermore, a higher pressure in the evaporator reduces the flow of hot gas because the pressure difference between the hot gas supply and the evaporator reduces (the pressure difference being the driving force that allows the hot gas to flow).
14. The defrost gas mains must also be kept free of liquid. A condensate drainer must be installed to drain trapped condensed liquid in the hot gas defrost line. The hot gas tends to condense continuously in cold climates if the pipe runs outside the building or in the cold space in processing areas. The liquid formed must be drained to a low-pressure liquid line or vessel.
15. The defrost relief regulator setting or (e.g OFV overflow valve) should be around 5.0 barg.
16. It is vital to recognize that at most only 1 / 3 of all evaporators / freezers can be defrosted simultaneously to ensure the availability of adequate hot gas for defrost generated due to the load on the other 2 / 3 working coolers / freezers. If only one or two coolers are operating, and one of them needs defrosting, the hot gas defrost system will not work because insufficient hot gas is available.
17. This means that if the system has six freezers, each of 70 kW, then the total load when all freezers are operating is 420 kW. In such conditions, only a maximum of two coolers can be defrosted simultaneously.
18. Hot gas pipe lines should be sized to three times the working capacity. For example, for an installation with three coolers, each 70 kW , the hot gas defrost line should be sized for  $70 \times 3 = 210$  kW (50 mm) and the main header from the machine room to the production area should be sized for  $2 \times 70 \times 3 = 420$  kW (80 mm).
19. The defrost condensate return line from the freezer should be one size higher than the liquid supply line, because sometimes the condensate line may have to return hot gas in addition to condensed liquid.
20. The critical periods during defrost are at initiation and termination. In both situations, high-pressure vapors moving at considerable speed come into contact with cold liquid, causing pressure shock waves. One stream is at nearly 7 barg, whereas the other is at close to, or below, atmospheric pressure.
21. To prevent this, a soft hot gas system is adopted for coolers / freezers exceeding 50 kW capacity. This has two solenoid valves. The smaller one opens first, reducing the pressure in the coil gradually before returning to refrigeration operation. This is operated via pressure sensing, using either a microprocessor or a set pressure device. Similarly, two valves are used at the initiation of the defrost cycle. The smaller one opens first, gradually increasing the pressure in the coil before the second bigger valve is opened. Reference: ASHRAE Refrigeration volume 2010 page 2.26.

22. The soft hot gas defrost system is designed to increase the coil pressure gradually as the defrost cycle is initiated. This sometimes uses a small hot gas feed with approx. 10% of the duty with a solenoid valve to bring the pressure up to 2 to 2.5 barg within 3 to 5 minutes, before the main defrost valve opens.
23. Similarly, once the defrost period is completed a small suction line solenoid valve (or automatic two-step solenoid valve) is opened so the coil / plates can be brought down gradually to operating pressures before full liquid is admitted.
24. For larger coils / freezers, manual initiation of defrost is recommended based on the physical condition of the freezer (i.e. the amount of ice / frost formed on the surface).
25. It is recommended that in the case of a two-stage system, evaporator defrost should be returned to the intermediate-pressure vessel and not to the low-pressure vessel. This has two advantages. First, it does not disturb the low-pressure vessel's pressure / temperature conditions during defrost, enabling other coolers to operate undisturbed. Second, the pressure difference between the defrost liquid and intermediate pressure vessel is much lower than that between the defrost liquid and the low-pressure vessel, which saves considerable energy.
26. The non-return valve in the main supply line after the solenoid valve is essential to ensure that high pressure developed during defrost in the coil does not exert back pressure at the outlet of the solenoid valve, because the inlet pressure is normally equal to either the evaporator pressure or the pump discharge pressure.
27. The advantage of regulating pressure to 7 to 9 barg in the equipment room is that there is less chance of coils being damaged, bent, or ruptured, because the low side of the system is normally designed for 10 barg, and hot gas at 8 barg or more is dangerous to the low side parts of the system. For safety, it is recommended that the low side should also be designed for 20 barg, and pressure tested to 1.25 times the pneumatic pressure.
28. Example: A 70 kW coil defrosting for 12 minutes and condensing up to 11 kg / min ammonia will condense a total of 132 kg. The enthalpy difference between the returning low stage -40 °C and intermediate vessel at -7 °C is 148 kJ / kg, i.e. 27kW is removed from the -40 °C booster compressor for 12 minutes during each defrost.
29. Any excessive noise and shock or vibrations observed during defrost is not normal, and must be investigated and rectified.
30. Hot gas is often taken from the top of the receiver instead of from the compressor discharge, to ensure the adequate availability of hot gas.

Standard hot gas defrost circuit for cold rooms and for freezer rooms used for holding the product:

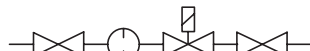
No.	Function	Product
1	Valve station	ICF
2	Pressure regulator	ICS
3	Pressure regulator	ICM
4	Suction line stop valve	STC
5	Digital thermostat	AK-CC
6	Temperature sensor	AKS 21
7	Plate freezer	
8	Valve station	ICF

Modules in ICF valve station ①:

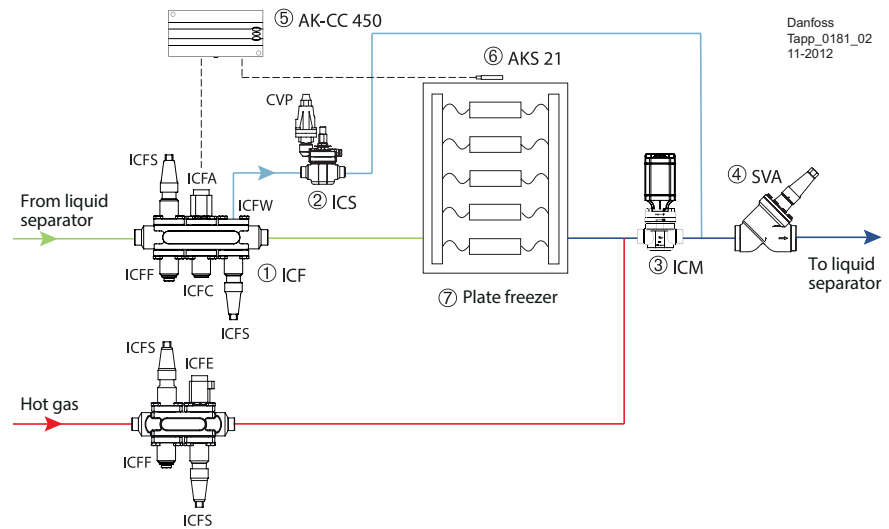


- Stop valve
- Filter
- Electronic expansion valve
- Check valve
- Welding connection
- Stop valve

Modules in ICF valve station ⑧:



- Stop valve
- Filter
- Electronic expansion valve
- Stop valve



Danfoss  
Tapp\_0181\_02  
11-2012

### Defrost control

Defrost can be initiated once the frequency and duration of the defrost cycle is established. Control schemes generally use an electric or electronic timer, or computer based control logic.

1. Mechanical timer clocks: These allow coolers to be defrosted at fixed but adjustable set intervals. The advantage is that the operator need not remember when to defrost. The disadvantage is that the timer automatically activates the defrost cycle even when the coil does not need defrosting. When the products are freshly loaded, defrosting is often required more frequently, then less so once the products are at the desired temperature. Timer settings therefore require repeated adjustment.
2. Microprocessor controllers: These have mostly replaced mechanical timer clocks. The use of microprocessors reduces energy consumption and helps maintain product quality.
3. Thermostat: A return air thermostat is used to activate the defrost cycle or timer by closing the liquid line solenoid valve.
4. Ice thickness sensor: An ice thickness sensor attached to the coil activates the defrost cycle when the thickness of the ice reaches a set limit. This method is often used in ice banks / ice reserve units for dairies.
5. Air temperature difference: Sensors are fitted in the coil inlet and outlet air paths. If the coil becomes frosted, the temperature difference between them reduces. This is detected by a defrost controller, which activates the defrost sequence.
6. Air pressure differential controls: Instead of detecting a temperature difference, a differential pressure monitor / controller can be used. As the frost accumulates, the pressure difference across the coil increases, activating the defrost cycle.
7. Reverse cycle defrost: This system uses four-way valve. At preset intervals the refrigerant flow is reversed so that the condenser acts as an evaporator and the evaporator as a condenser. These systems are popular in truck refrigeration units using HFC refrigerants.

A combination of hot gas defrost for coils and electric defrost for drain pans is often used. It is also essential to provide ring heaters for fans to avoid damage to their blades.

To terminate hot gas if the room temperature tends to rise, AK-CC controller is also provided. This overrides the pressure / temperature differential sensors and activates the cooling cycle even when the coils are not fully defrosted, maintaining product and room temperatures within the allowable limits.

## Sequence of operation of hot gas defrost cycle

### Initiation of defrost

1. The defrost toggle switch provided on the control panel is activated manually in response to the icing conditions on the freezer. In some cases defrost is initiated on demand via a fixed timer setting frequency or defrost sensors that sense either the thickness of the ice or a preset pressure drop across the coil.
2. The demand defrost method should not be used for batch load applications such as blast freezer / plate freezer or individual quick freezer (IQF). The defrost sequence should be initiated manually via a separate electric switch. Once the cooling cycle is over and the doors are opened, the control can be put into defrost mode. The defrost timing or room temperature sensor(s) are overridden. Before the product is reloaded again and doors are closed and the control can be put on cooling mode. The cooling cycle time is variable, depending on the product to be frozen, hence initiation and termination must be manual, through the control switch.
3. Closure of liquid line solenoid valve: liquid pump down  
On activation of the defrost cycle, the liquid line solenoid valve is to be closed first, starting the evaporator liquid pump out cycle.
4. Fan time delay phase to switch off  
At this stage, all fans must be running to provide a high liquid refrigerant boil-off rate. Heat from the fan motor also accelerates the boil-off rate. If the fans use VFD, they must be run at full speed when the defrost cycle starts. This is to ensure the coil is emptied as quickly as possible. After a delay of 3 to 5 minutes (depending on the size of the evaporator and the internal volume) to ensure that all the liquid has been pumped out, a preset timer stops the fans, thereby stopping the air circulation. During this period, the suction line or wet return line valves remain open and the liquid is pumped out of the evaporator.
5. Closure of wet suction valve  
After the delay of 3 to 5 minutes governed by an adjustable set point timer, the wet suction line solenoid valve is closed and the fans switched off, isolating the cooler from the system. Sufficient time must be allowed for the wet suction valve to close before hot gas is initiated.
6. Supply of hot gas
  - a. Soft gas phase (for coolers with a capacity higher than 50 kW): In low-temperature pump recirculation systems, a small solenoid valve should be installed in parallel with the larger hot gas solenoid valve. This smaller valve opens and gradually introduces hot gas into the coil. Opening this valve first further reduces the likelihood of pressure shocks. At the conclusion, prescribed by electronic adjustable timer settings, this solenoid closes, simultaneously opening the main hot gas solenoid valve. This admits hot gas into the evaporator and heats the evaporator surface.
  - b. The main solenoid valve in the hot gas line then opens via two solenoid valves, thus achieving soft gas defrost for coils whose internal volume exceeds 0.14 m<sup>3</sup>.
  - c. During this period, the condensate liquid line valve also remains closed, so that the evaporator has no outlets open, allowing the coil pressure to rise to around 5 bar (the OFV overflow valve is preset for this pressure).

7. End of hot gas defrost cycle:
  - a. Once the hot gas defrost cycle is completed (normally 5 to 15 minutes, depending on the size of the coil), the suction line opens gradually via a two-step solenoid valve, and pressure from the freezer is released to the wet return line.
  - b. The condensate accumulated due to the condensation of hot gas is also drained to the wet return line because the OFV valve opens at this time. Some systems also use a condensate float trap.
  - c. An overriding thermostat terminates the defrost cycle should the room temperature tend to increase beyond acceptable limits in case of cold stores. The liquid line solenoid valve and suction stop valves will now open, and allow liquid refrigerant into the evaporator. The volume of liquid admitted is controlled by a preset flow regulating valve / non-return valve, hand expansion valve, or motorized valve. This initiates cooling.
  - e. If the dual opening valve has not been installed in the wet return line and the normal solenoid valve has been provided in line, then as with the liquid line, an additional solenoid valve is required to be installed in parallel. This valve opens first, and allows the pressure in the coil to reduce slowly. This eliminates system disruptions, which would occur if warm refrigerant were released quickly into suction piping. This also reduces vapor-propelled liquid, and prevents sudden loading of the compressor if suction pressure rises quickly.
8. Fan delay time: The fan is not yet energized. Instead, the coil temperature is allowed to fall, freezing any water droplets that might remain on the coil surface after the hot gas defrost phase, thereby preventing the possibility of water droplets being blown off the coil into the refrigerated space.
9. Start of cooling cycle: On completion of the fan delay, the fan is energized automatically in accordance with a time setting. The refrigeration phase continues until the next defrost cycle is initiated.
10. The entire process can take a maximum of 15 to 30 minutes, depending on the size of the evaporator and the quantity of hot gas available.

Steps 1 to 10 are all built into the control circuit of the controller. The timings can be adjusted to suit a particular evaporator model and size via adjustable electronic timers provided in the controller.

If the application is a blast freezer / plate freezer or spiral freezer / IQF which is a batch production the demand defrost method should not be used. The defrost sequence should be initiated manually. A separate Electrical switch to manually activate defrost cycle can be provided. Once the batch cooling is over and the doors are opened, the switch can be put on defrost mode. The timing of defrost or room temperature sensor are over ridden because of the switch. Once the product is reloaded again and doors are closed the switch can be put into cooling mode. The timing of cooling cycle is variable based on the product and hence a manual operation of initiation and termination through a switch has to be carried out.

The diagrams (page 39) shown are for freezers having a bottom feed arrangement. A similar arrangement is also possible for top feed coils. The suggested diagrams are shown in ASHRAE handbook Refrigeration 2010 pages 2.24 to 2.26. The simplest approach, from a defrost standpoint, is a top-fed, medium-temperature unit with vertical circuits. The liquid in such coils drains by gravity through the open suction stop valve when the liquid solenoid is closed. Any cold liquid that remains in the coil when the suction valve is closed will be distributed evenly among the circuits. Hot gas injected into the top of the coil will condense and force the colder liquid out. Provided the hot gas is condensing, only liquid will flow through the defrost regulator. This permits the use of a regulator much smaller than either the hot gas solenoid or the suction stop valve.

Attention should be given to this arrangement at the end of the defrost cycle. If hot gas continues to be injected after all the frost is melted, condensation will cease and vapor will flow through the regulator. This will cause the coil pressure to increase, indicating to the operator that the hot gas injection period must be adjusted or decreased.

The defrost cycle has two major areas that must be considered while designing the system.

1. Hydraulic shock ("pressure shock"): This occurs in two phase systems experiencing pressure changes. It occurs most frequently in low temperature ammonia systems, and is often associated with either the initiation or the termination of hot gas defrosting.

Pressure shocks can be grouped into three categories:

- a. Sudden liquid deceleration: This is caused by a fast acting solenoid valve that suddenly closes. The sudden stoppage of liquid flow generates a pressure pulse similar to water hammer.
- b. Vapor propelled liquid: This is normally observed in liquid overfeed systems, and results from the sudden release of high pressure vapor into a line partially filled with liquid, i.e. wet return lines. The impact can severely damage system components / piping.
- c. Condensation shock: This occurs when high pressure vapor is introduced quickly into the liquid slugs remaining in the coil. It causes the imploding pockets to generate large pressure waves in the system.

The components that normally fail are evaporators, wet return lines or headers from evaporators. Generally, noise is associated with hydraulic shock.

To decrease the possibility of hydraulic shock, the following engineering guidelines are suggested:

- a. Hot gas piping should include no liquid traps. A liquid drainer is suggested in the defrost line if it is running too long. Minimize condensate in the hot gas header line.
  - b. The evaporator must be fully drained before the hot gas valve is opened. No liquid slugs / pockets should remain in the coil.
  - c. Size hot gas pipe lines and valves as small as possible to reduce the peak mass flow rate of the hot gas.
  - d. The liquid level in the low pressure vessel is maintained between 20% and 80%. Draining the vessel or overfilling puts gas into the liquid lines or liquid into gas lines, and can cause hydraulic shock.
2. The second area of concern is draining the condensed water from the drain pans in the headers or to outside drains. This requires special engineering and piping design skills to ensure that water drains easily from the cold rooms without freezing in the trays, overflows in the cold room getting converted into ice or choking the drain lines with ice.

Drain points leaving rooms should be of sufficient height to have a liquid leg and be provided with an 'S' trap to ensure outside air does not leak into the room.

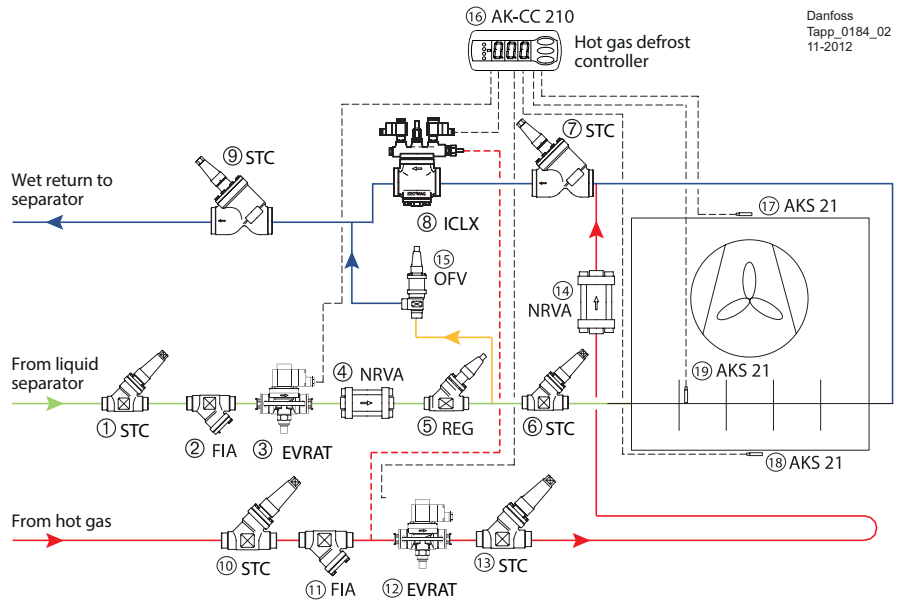
- IIAR-T163-Hot Gas Defrost Systems for Large Evaporators in Ammonia Liquid Overfeed Systems
- ASHRAE volume 2010 Refrigeration Chapters 2.24 to 2.26
- Danish Technological: Guidelines for hot gas defrost
- Danfoss Denmark: Refrigeration Controls for Industrial Refrigeration

No.	Function	Product
1	Stop valve	STC
2	Filter	FA / FIA
3	Solenoid valve	EVRAT
4	Check valve	NRVA
5	Regulating valve	REG
6	Stop valve	STC
7	Stop valve	STC
8	Solenoid valve	PMLX
9	Stop valve	STC
10	Stop valve	STC
11	Filter	FA / FIA
12	Solenoid valve	EVRAT
13	Stop valve	STC
14	Overflow valve	OFV

As an alternative to STC stop valves, SVA stop valves can also be used.

For further information, please contact your local Danfoss sales office.

Hot gas defrost for pumped liquid circulation



Refrigeration liquid and hot gas flows, depending on whether the refrigeration or defrost cycle is ON, are as follows:

#### Refrigeration:

1 → 2 → 3 → 4 → 5 → 6 → Evaporator → 7 → 8 → 9 → Liquid separator

#### Hot gas defrost:

10 → 11 → 12 → 13 → Evaporator → 6 → 14 → Liquid separator

Valve number	Type	Refrigeration cycle	Hot gas cycle
3	EVRAT	Open	Closed
8	PMLX	Open	Closed
12	EVRAT	Closed	Open
15	OFV	Closed	Open

#### Refrigeration cycle:

The solenoid valve EVRAT (3) in the liquid line is kept open. Liquid injection is controlled by the hand regulating valve REG (5).

The solenoid valve (to day ICLX valve) in the suction line is kept open, and the defrost line solenoid valve EVRAT (12) is kept closed.

#### Defrost cycle:

After the initiation of the defrost cycle, the liquid supply solenoid valve EVRAT (3) is closed. The fan is kept running for 120 to 600 seconds, depending on the evaporator size, to pump down liquid from the evaporator.

The fans are stopped and the (to day ICLX valve) is closed. The precise closing time must be established on site, and a safety margin of approx. 20% added. A further delay of 10-20 seconds is required for the liquid in the evaporator to settle down in the bottom without bubbles of vapor. The solenoid valve EVRAT (12) is then opened, and hot gas is supplied to the evaporator.

During the defrost cycle, the OFV overflow valve (15) is initially closed. However, it opens automatically subject to the set differential pressure. The overflow valve allows the condensed hot gas in liquid form from the evaporator to be released into the wet suction line. It is advisable to install a pressure gauge to set the OFV accurately for a 5 to 6 bar differential.

When the temperature in the evaporator reaches the set value (measured by the AKS 21 on the coil surface), the defrost cycle is terminated, the solenoid valve EVRAT (12) is closed and the (to day ICLX valve) is opened. After the (to day ICLX valve) fully opens, the liquid supply solenoid valve EVRAT (3) is opened to start the refrigeration cycle. The fan is started after a delay in order to freeze any liquid droplets remaining on the surface of the evaporator.

#### Hot gas defrost for pumped liquid – ICF valve station

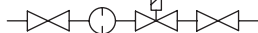
No.	Function	Product
1	Valve station	ICF
2	Stop valve	STC
3	Solenoid valve	PMLX
4	Stop valve	STC
5	Valve station	ICF
6	Check valve	NRVA
7	Overflow valve	OFV

#### Modules in ICF valve station (Liquid line) ①:



- Stop valve
- Filter
- Solenoid valve
- Check valve
- Regulating valve
- Weld connection

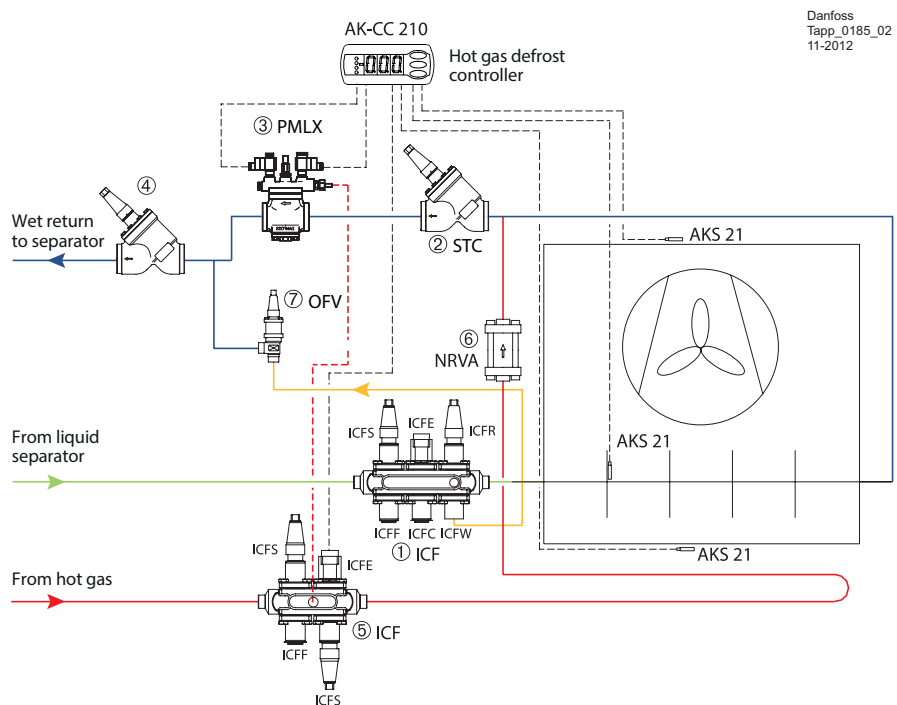
#### Modules in ICF valve station (Hot gas line) ②:



- Stop valve
- Filter
- Solenoid valve
- Stop valve

As an alternative to STC, SVA stop valves can also be used.

For further information, please contact your local Danfoss sales office.



Danfoss  
Tapp\_0185\_02  
11-2012

Refrigerant liquid and hot gas flows, depending on whether the refrigeration or defrost cycle is ON, are as follows:

#### Refrigeration:

1 → Evaporator → 2 → 3 → 4 → Liquid separator

#### Hot gas defrost:

5 → 6 → 7 → 8 → Evaporator → 9 → Liquid separator

#### Hot gas defrost controller – AK-CC 210

This is used for controlling the start and end of the hot gas defrost cycle. It contains a temperature control that accepts a signal from one or two temperature sensors.

These temperature sensors are placed in the cold air flow after the evaporator and the warm air flow before the evaporator. These are denoted by S4 (air out evaporate sensor) and S3 (air in evaporate sensor). The defrost temperature is measured directly via another sensor S5 (Defrost sensor) placed on the evaporator.



## Capacity control for refrigeration systems

### - Why and how to use capacity control

The simplest form of capacity control is on / off cycling for reciprocating compressors. Under light load conditions, this could lead to short cycling and could reduce the life of the compressor.

On systems where ice formation is not a problem, users will sometimes lower the low pressure cutout setting beyond the design limits to prevent short cycling. As a result, the compressor may operate for long periods at extremely low evaporator temperatures. Compressor capacity decreases as suction pressure decreases. The refrigerant velocity is inadequate to return oil to the compressor. This also results in a high compressor superheat, which causes the compressor to overheat. All these conditions can cause premature compressor failure.

Capacity control allows more continuous compressor operation, minimizing electrical problems and improving lubrication.

There are many ways to achieve capacity control, such as variable-speed compressors, hot gas bypass with or without liquid injection, unloading, digital control for scrolls, and simple on / off compressor operation on multiple compressor setups.

Some applications will use two or more methods for smoother switching and better control, such as unloading in conjunction with hot gas bypass. It is accepted that refrigeration systems seldom operate at their peak design load. In any refrigeration application, the load on the system varies over a wide range. However, the refrigeration system designer must provide enough capacity to meet peak demand as well as ways of making the system operate efficiently at reduced loads.

For example, loads in cold storage vary widely. When product is loaded at ambient temperature in cold rooms, the amount of heat to be removed to bring the product to the desired temperature in a given time is very high. Conversely, once the product is at design storage temperature, the refrigeration load requirement reduces considerably. Freezing plants may have a variety of equipment, such as IQF, blast / trolley freezers, and plate freezers, to process a variety of products. However, they do not necessarily all run simultaneously. In process plants, the load may vary because not all processes are working simultaneously or peak output may not be required and products are produced in quantities to match market demands. The variation in ambient temperature also affects the refrigeration load on systems.

When the system operates under partial load, suction pressure and temperature are lower than they are under full load. This is because less vapor is generated in the evaporator due to the reduced load, whereas the compressor, running at constant RPM, displaces a constant volume per unit of time. It does not recognize a reduction in system load.

If the system capacity exceeds the load requirement, moisture may freeze on the evaporator coil. The "frost" on the coil decreases the amount of air that can pass through the coil. In turn, this further lowers the suction pressure and temperature. The excess unevaporated liquid may enter the compressor suction line and damage compressor parts.

It is also important to understand that the stabilized system capacity is determined by all the components working together in equilibrium, and not by the compressor alone. The weakest / smallest component generally governs the overall capacity. Although the capacity is measured in terms of Btu / hr or Kcal / hr or watts, it is determined by the mass of refrigerant circulating – the mass flow rate.

The system that operates most efficiently, safely, and with stability will be the one best able to match system capacity to load across the entire load range.

Every component in the system must therefore have some means of capacity modulation to match the load.

For high, medium and low temperature applications, compressor capacity modulation can reduce power and energy consumption, provide better and continuous dehumidification, reduce compressor cycling, decrease the starting electrical load, and, if properly piped, provide a good oil return.

#### **Working of compressor:**

Two types of refrigeration compressors are used in ammonia refrigeration systems:

- Reciprocating compressors: open drive with external motor
- Screw compressors: open drive with external motor

Both types are classified as positive displacement machines, which means the increase in pressure results from a reduction in volume.

At a given speed, the reciprocating compressor is a constant displacement volume, variable mass flow and variable compression ratio machine, whereas the screw compressor has a fixed internal compression ratio due to the geometry of the discharge port profile.

#### **Riding with the load:**

To a certain extent, the compressor automatically adjusts its capacity downwards as system load decreases. A compressor running at constant speed displaces a constant volume per unit of time, and will continue to do so unless there is cylinder unloading.

Its capacity to transfer heat, however, is determined by its mass flow rate. Its capacity to move heat therefore depends on the mass of refrigerant it pumps per unit time (kg / hr) rather than on the volume of refrigerant it moves per unit time ( $\text{m}^3$  / hr). The mass flow rate changes in response to the suction or inlet pressure conditions. This means that while the volumetric flow rate is constant, the capacity will change with changing operating conditions.

For example, an ammonia compressor with a saturated suction temperature of 5 °C has a specific volume of vapor of  $0.243 \text{ m}^3 / \text{kg}$ . This means the mass flow rate would be  $41.15 \text{ kg / hr}$ .

When the load reduces, the suction pressure drops. For example, it drops to 2°C. The specific volume is then  $0.27 \text{ m}^3 / \text{hr}$ , and the mass flow rate becomes  $10 / 0.27 = 37 \text{ m}^3 / \text{hr}$ . It can be seen that the compressor has automatically adjusted to the reduced load by pumping a smaller mass (kg / hr).

The load now increases and the suction pressure increases to 10 °C. The specific volume is now  $0.206 \text{ m}^3 / \text{kg}$ , giving a mass flow rate of  $10 / 0.206 = 48.54 \text{ kg / hr}$ . The same  $10 \text{ m}^3$  displacement compressor is now pumping a greater mass ( $48.54 \text{ kg / hr}$  instead of  $41.15 \text{ kg / hr}$ ) under 5 °C saturated suction conditions.

If riding with the load (as illustrated above) satisfied all necessary capacity adjustments under part load, then controlling the capacity of compressor would not be necessary. However, there are limits to how far the load can vary while maintaining both safe, stable part load operation and efficiency. Maintaining constant suction pressure as designed would be more efficient under all part load conditions, so some methods of capacity control are necessary.

To understand how compressor capacity control systems match the load on, and the output from, the refrigeration system, it is necessary to look briefly at how the compressor works.

The refrigeration compressor circulates refrigerant in the system. The compressor takes in low pressure, low temperature, and superheated refrigerant gas after it has performed its function of picking up heat in the evaporator, where liquid

refrigerant gives up its latent heat and is converted into gas. This gas is compressed by the compressor to a high pressure, high temperature superheated gas that is sufficiently hot to be able to reject heat to the condenser, where the refrigerant is condensed back into a liquid.

The compressor manufacturer cannot determine the system capacity. All a refrigeration compressor can do is displace a volume of gas. Once the suction and discharge conditions at the compressor are specified, then the mass flow of the refrigerant can be calculated. However, the refrigeration capacity is not related directly to the conditions at the compressor. The system designer should ask for the mass flow rates under specified conditions to enable the correct compressor to be selected. Designers must accept that when they buy a refrigeration compressor it displaces only a volume of gas, and not refrigeration capacity.

### **Capacity control methods for various types of compressors:**

We shall now discuss the capacity control arrangements for compressors that will deliver optimal system performance.

### **Reciprocating compressors**

The following strategies are generally adopted, depending on the size of the plant, the accuracies required, the degree of automation, and other considerations:

1. Use of multiple compressors (rack systems): Depending on the load, compressors are cycled on / off, leading to substantial power savings. Each compressor is of max. 70kW capacity, and racks can be built with four or five compressors.
2. Hot gas bypass arrangement with or without liquid injection: This arrangement ensures that the compressor does not trip on suction pressure when the system load is extremely low (i.e. below the compressor's minimum capacity control step). The artificial load is imposed by high pressure hot gas in the suction line or before the evaporator entry. The disadvantage of this system is that if the compressor is oversized, the period of compressor operation on the hot gas bypass circuit is too long and wear on the compressor is greater. Furthermore, running on the hot gas bypass does not save power.
3. Two speed compressors: Normally used in semihermetic compressors. The speed is changed in response to a thermostat or pressure signal. When the initial load is high, the compressors can be run at higher speed with a 2 pole motor; when the load comes down and the requirement is holding load, they can be switched to 4 pole windings, reducing the speed by half from 3000 RPM to 1500 RPM.
4. Use of variable frequency drives (VFD) / speed control: This efficient solution is applicable to all types of compressors. The costs of VFD have fallen substantially, making it attractive for use with compressors.

The advantage is that during the initial cool down (when the load is high) the compressors can be run at 60 / 70 Hz frequency for a short duration to achieve higher capacity. The capacity can then be matched to the load requirement by sensing either the suction pressure or, in the case of a fluid, the temperature.

The frequency converter can therefore vary the rotational speed continuously to satisfy the actual load demand.

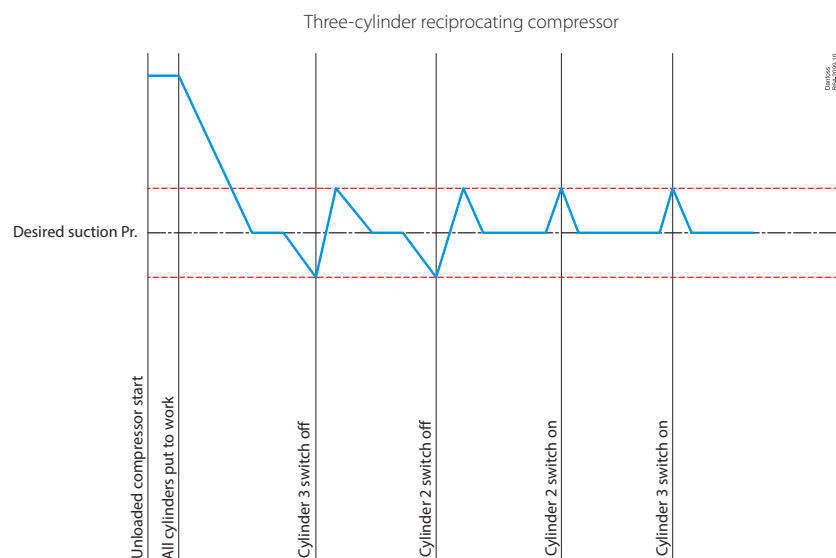
Another advantage of the frequency converter is that it allows a low start up current. The limitation is that compressors (particularly reciprocating types) must be kept within their allowable lower and higher speed limits, because of the likelihood of suffering from inadequate lubrication. VFD is the preferred option in screw compressors where there is an independent oil pump and the lubrication circuit does not depend on the compressor's speed.

- Step control (cylinder unloading in multicylinder compressors): The capacity of these compressors is regulated via a valve lifting mechanism. As soon as the compressor starts running fully unloaded, the high pressure oil pump begins to develop oil pressure. After a set delay, high pressure oil is delivered through a three way solenoid valve to the valve lifting mechanism, and the cylinders are loaded. The arrangement for loading or unloading cylinders varies from manufacturer to manufacturer, with some using compressed gas instead of oil pressure.

The cylinders can be switched on or off via pressure switches or thermostats. In refrigeration plants using several compressors on a common suction line, or a single compressor with multiple capacity control steps through three way solenoid valves, a suction pressure transmitter is preferred. For applications using chilled water or brine, a thermostat signal can be used.

The pressure switches fitted in the suction line carries a contact on both sides of its neutral middle position. When the pressure becomes too high due to the increased load, the contact will switch on one more cylinder.

The diagram below shows the sequence of cylinder loading and unloading in the case of a typical three cylinder reciprocating compressor.



### Screw compressors - Capacity control

Screw compressors, unlike reciprocating compressors, do not have suction and discharge valves. They have a built in volume ratio ( $V_i$ ). This is the ratio of the volume at the rotor groove pair at the beginning of compression and the volume of the same pair at the end of compression at the outlet.

$V_i$  is the same as the ratio of the discharge pressure to the suction pressure, because the volume ratio is also related to the pressure ratio. In most screw compressor designs,  $V_i$  is fixed by the design and selection of a particular model. In reciprocating compressors, however,  $V_i$  is constantly changing automatically, because for a given  $V_i$  the discharge port pressure is fixed whatever the condensing pressure imposed by the system.

### For screw compressors, two forms of variable volume control are available:

- Adjustable volume ratio ( $V_i$ )
- Automatic variable volume ratio (AVI)

Care is taken during compressor selection to ensure that the correct volume ratio is selected with regard to the chosen operating conditions. However, the compressor is often selected for peak conditions that apply for only a few days in a year.

While it is essential to select a compressor capable of operating in extreme conditions, it does not follow that the compressor will necessarily always perform

at the highest possible efficiency. The variable Vi concept, coupled to a slide valve that moves parallel to the axis of the rotors, offers an alternative method of controlling the capacity and volume ratio to suit site conditions.

Where the pressure ratio across the compressor is consistently high, or changes in the pressure ratio are infrequent (e.g. change from winter to summer), then an economical manually adjustable system (MVi) will work satisfactorily.

Where the pressure ratio is lower and condensing conditions vary frequently, the automatic AVi system is ideal.

#### **How the system works:**

The compressor is fitted with a built in sliding valve that controls the capacity of the machine by altering the point on the rotor length at which compression begins. The slide valve moves along the axis of the rotors.

The slide valve can be operated either manually or automatically via a hydraulic actuator. The position of the slide valve ensures that the discharge pressure of the compressor is equal to the system pressure, thereby eliminating over or under compression that would otherwise lead to system inefficiency and excessive power consumption.

During part load operation, a signal is provided by the microprocessor and the slide valve is adjusted to allow partial gas bypass to the suction side, delaying compression and reducing the suction volume. As the suction volume is reduced under part load to maintain the discharge port pressure, the discharge port area is also reduced by moving the slide valve.

The oil pressure for the hydraulic actuator is provided from the compressor oil system. The solenoid valves responding to the suction pressure or the air / fluid temperature through the microprocessor energize / de-energize, leading to the movement of the slide valve.

This movement of the slide valve in response to the evaporator load is achieved by different mechanisms (e.g. electric impulse motor or linear variable displacement transducer operating through a hydraulic piston) in different screw compressor designs. Control down to 10% with an approximately proportional saving in power is obtained.

It is clear that controlling a screw compressor's control via the unit's microprocessor enables very accurate control at maximal efficiency under all operating conditions. Capacity control from 100 to 10% is possible, but efficiency drops under part load. Furthermore, below 50% capacity power consumption does not fall linearly. Running screw compressors below 50% capacity is therefore not economical. Some manufacturers have developed multistage control systems that function similarly to slide valve control.

Under part load, it provides two-step capacity control. The piston moves due to the energizing of the solenoid valve in two steps controlled by either a time delay or an on demand control, and is adjustable to suit the exact load. When the solenoid is de-energized, the piston moves to the right, opening a space between the profile chamber and the suction side, thereby reducing the active volume.

The system is designed for two control steps, so that by switching the solenoid valves intermittently it is possible to exactly match the compressor capacity to the load. The step is 70% of the capacity (0-70% - 100%).

## Danfoss Capacity Controller AK-PC 530

Danfoss uses the AK-PC 530 capacity controller for reciprocating compressors. Multiple compressors and condensers can be connected as required. There are up to eight outputs, and more can be added via external relay modules. This controller must be operated via a connection to display type EKA 164 or EKA 165.

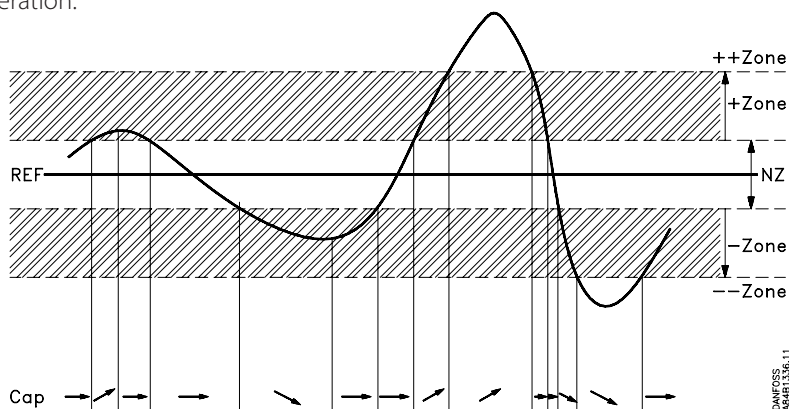
### Function

#### Capacity regulation:

The cut in capacity is controlled by signals from the connected pressure transmitter / temperature sensor and the set reference. Outside the reference, a neutral zone is set where the capacity will be no switching. Outside the neutral zone (in the hatched areas denoted +Zone and -Zone) the capacity will be cut in or out if the regulation registers a change of pressure away from the neutral zone.

Cut in and out will take place with set time delays. However, if the pressure approaches the neutral zone, the controller will make no changes to the cut in capacity. If regulation takes place outside the hatched area (denoted ++Zone and --Zone), the cut-in capacity will be changed somewhat faster than it is in the hatched area.

Cut in of steps can be defined for sequential, cyclic, binary, or "mix and match" operation.

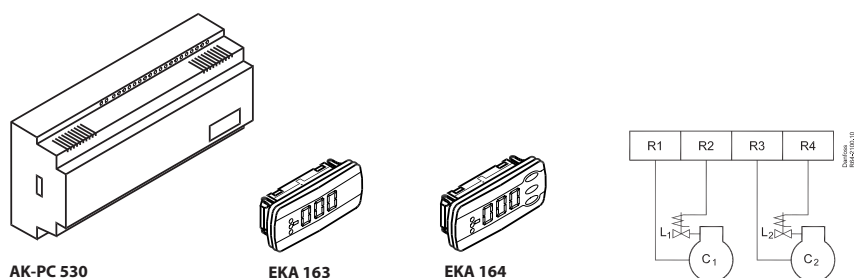


Sequential (first in – last out): In this case, the relays are cut in sequence: first relay 1, then 2, etc. Cut out takes place in the opposite sequence, i.e. the relay cut in last will be cut out first.

Cyclic (first in – first out): In this case, the relays are coupled so that the operating time of the individual relays will tend to be equalized. At each cut in, the regulation scans each relay's timer, and cuts in the relay with least time on it. Similarly, at each cut out the relay with the most hours on the timer is cut out.

If capacity regulation is imposed on two compressors each with one unloader, the following function can be used: Relays 1 and 3 are connected to the compressor motor. Relays 2 and 4 are connected to the unloaders. Relays 1 and 3 will operate in such a way that the operating times for the two relays will tend to be equalized. Similar logic is applied for larger numbers of compressors each with more than one unloader. Please refer to the table for details.

These requirements for the cold storage of potatoes is generally based on the NHB standard (Technical standards Number NHB-CS-Type 01-2010)



## POTATO COLD STAGE LOAD CALCULATIONS PER NHB STANDARD -01:2010

The NHB standard 01-2010 gives summary of cooling load calculation on page 40 for

1. 5-A-Loading & pull down the temperature to 15°C per chamber
2. 5-B During pull down to 3°C @ 0.5°C per day-Fully loaded per chamber
3. 5-C During Holding period at +3°C-with full load per chamber

Page 38 & 39 gives the assumptions for 5000MT Potato Cold storage & suggested typical layout of Chambers

The maximum refrigeration load is during loading and pull down to 15°C for 1000 Bags/day of potatoes each weighing 50 kg thus totaling to 50 Tons/day per chamber (4% of 1250 Tons) and the cooling load indicated is 85.32 kW (24.37 TR) per chamber.

The detailed calculations how individual values have been arrived at is not given.

This document is therefore prepared giving detailed load calculations so that it would then become easy for the contractor/end user to calculate the cooling load. The document would also help to calculate refrigeration load for any other commodity with different conditions and parameters of room sizes, storage capacity, and insulation type used etc for positive temperature cold storages since the formulae have been given.

For presenting the load calculations assumptions as mentioned on Page 38 of the standard have been considered.

### Assumptions:

1. Product - Potatoes
2. Location - Uttar Pradesh
3. Outside temperature - +45°C max Db/+300C Wb (1130F / 860F)
4. Product loading temperature 20°C - 25°C-max
5. Each bag weighing - 50 kg = 110 lbs
6. Total storage Capacity - 5000 Metric Ton
7. Each Room storage - 1250 Ton - (1250 x 3.4 = 4250 m<sup>3</sup>)
8. Chamber Size each - 21m L x 16 m W x 13.7 m H - Volume 4603 m<sup>3</sup>,  
floor Area = 226 sq.m
9. Loading rate - 4% of total capacity/day = 1250 x 0.4 = 50 Ton or 50000 kg/day
10. Pull down Time: 15°C in 24 hrs
11. Compressor running hours - 20 hrs/day during pull down
12. Ventilation requirements - 2 to 6 air changes per day - (Page 4 - 2-h)
13. Insulation PUF - 32 kg/m<sup>3</sup> density, 0.023 W/m.k – K value = (0.16 Btu.in/h.ft2.0F)  
(ASHRAE Refrigeration Hand Book Page 24.1 Table - 1) Although NHB standard indicates 32kg/cm<sup>2</sup> density on page on page 10, normal practice is to use minimum 38kg/cm<sup>2</sup> which is standard
14. Thickness - walls, roof, floor - 100 mm ( NHB standard Page -10)
15. Specific heat of potato above freezing - 3.433 kJ/kg.k (NHB standard Page-51)
16. Heat Of Respiration 18mW/kg (ASHRAE Refrigeration hand Book 2014 - page 19.22) or 18kW/ton - Also NHB standard - Page 51
17. Loading Density - 3.4 m<sup>3</sup>/Metric Ton = 120 cu.ft/Ton NHB Standard - Page 44
18. Safety factor Of 10% considered (NHB standard Page 39 Point 4) whereas Diversity factor not considered since it is load calculation for one room.

### Load Calculations:

For Positive temperature cold storages the major heat load contributors are

- Heat gain through walls, roof and flooring
- Product load comprising of load due to the difference in product loading temperature and storage temperature
- Respiration load as product continues to breath while being stored for considerable period
- Outside air load due to ventilation requirements and infiltration
- Equipment load such as air cooler fan heat gain forklifts etc.
- Loads contributed by persons operating inside the room
- Lighting load

We shall now consider each factor for this typical NHB presented data on page 40 and how the values have been arrived at

#### 1. Transmission Load through walls/roof/floor per day

$$\begin{aligned} Q &= U \times A \times TD \\ &= 0.023/0.1 \times 2 \times (21 \times 16 + 21 \times 13.7 + 16 \times 13.7) \times (45-15) \\ &= 0.23 \times 1685.8 \times 30 \\ &= 11632.02 \text{ W say } \mathbf{11.63 \text{ kW}} \end{aligned}$$

Where 'U' is overall heat transfer coefficient in  $W/m^2.K = K/x$   
'K' is thermal conductivity of insulation used in  $W/m.K$  and 'x' is thickness of insulation in m  
'A' is external area of each room in  $m^2$ . For the sake of simplicity no partition wall has been considered and each room is treated as separate cold room  
'TD' is the temperature difference between ambient condition and cold room temperature in K

Although correct method is to calculate individual wall load depending on direction in which each wall is facing w.r.t. Sun and separate temperatures for roof and flooring. To make the calculations simplified the assumption that entire 6 surfaces are exposed to 'TD' is considered and would not make much difference in calculated load as the insulation plays greater influence compared to other factors.

#### 2. Product Load = 4% of 1250 Ton x sp.ht. x TD

$$\begin{aligned} &= 50000 \times 3.433 \text{ kJ/kg. K} \times (25-15) \\ &= 1716500 \div (24 \times 3600) = \mathbf{19.87 \text{ kW}} \end{aligned}$$

It is assumed that product is loaded at 25°C and cooled to 15°C in 24 hours (5A-Page 40)

Assuming remaining (1250-50 = 1200 Ton) or 1200000 kg Potatoes are already in store, & refrigeration load on the last day of loading is considered then respiration load would be

$$\text{Respiration load} = 1200000 \times 0.018 = 21600 \text{ W} = \mathbf{21.6 \text{ kW}}$$

Total Product load would be  $19.87 + 21.6 = \mathbf{41.47 \text{ kW say } 42 \text{ kW}}$

**3. Infiltration load:** Based on 4 air changes/day, outside enthalpy 99.173 kJ/kg at 45°C Db & 30°C Wb and inside 3°C 90 % RH-13.62 kJ/kg,  $\Delta h = 85.553$ .

The values have been taken from Psychrometric property tables for moist air.

Amount of ventilation air for 4603 (volume of room m<sup>3</sup>) x4 air changes ÷ (24x3.6) = 213 LPS,

Air volume is calculated in liter /second

And using standard formula for total heat load as  $= 1.2 \times l/s \times (\Delta h)$

= 1.2 x 213 x 85.53/1000 = 21.86 kW with 70% recovery it would be **15.3 kW**

**4. Internal Load due to fan motors** - Assuming 4 coolers per room each with 2 fans of 0.75 kW = total motor power is 6 kW. Power contributed to heat load 993 W per motor 8 x 0.933 = **7.94 kW**

**5. Lighting Density** - at 10 W /Sq.m. during loading =226 sq.m. floor area x 10 W/ per sq.m. = **2.6 kW**

**6. Occupancy load:-** Assuming 4 persons working inside cold room during loading each person would be contributing 250 W x 4 = **1 kW**

**Total internal load= 7.94 + 2.6 + 1 = 11.54**

Total Load = Transmission + product + infiltration + Fan motor + lighting + occupancy = 11.63 + 42 + 15.3 + 11.54 = 80.47 kW x 1.1 safety factor = 88.517 kW per chamber

#### Refrigeration Load summary - per Chamber each of 1250 Ton storage capacity

Sr.No.	Description	Refrigeration Load-kW/24 hrs As Per NHB-Page 40	Calculated as Above
1	Transmission Load	12.12	11.63
2	Product Load	43.16	42
3	Internal Load	5.25	3.6
4	Infiltration & Ventilation Air Load	16.14	15.3
5	Equipment Load-Fan motors	8.65	7.94
6	Total Load	85.32 (24.37 TR)	80.47 x 1.1 = 88.517 kW

Considering compressor running time of 20 hrs, Total capacity required would be 88.517 x 24/20 = 106.22 kW per room. The standard is for 5000 Tons having 4 rooms. Hence total plant capacity required during loading is 424.88 kW

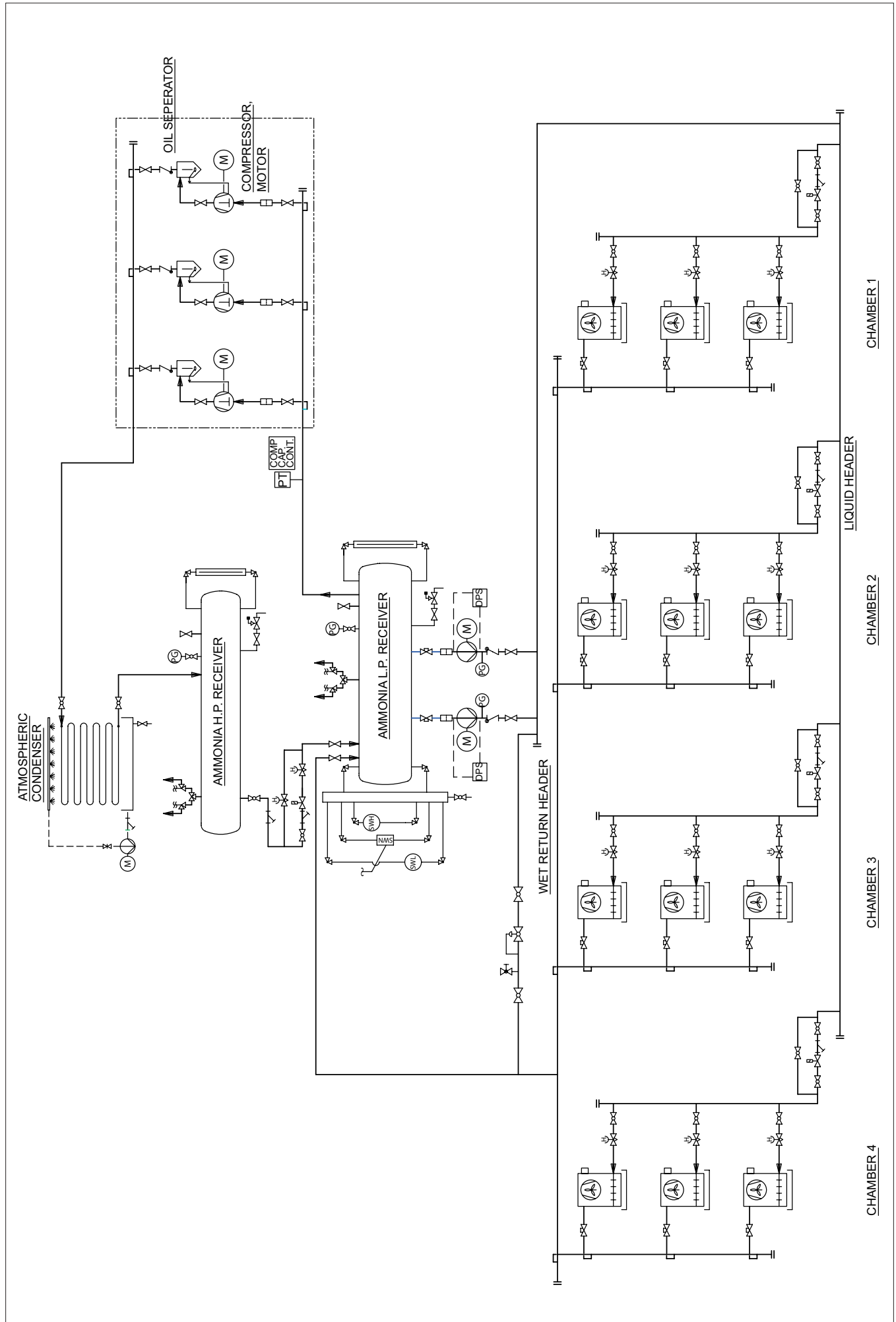
Refrigeration System Capacity Recommended in NHB standard at +2 0C SST and 380C SCT is 234.85 x 2 = 469.7 kW - Page 42 - 6-ii

Since it is normal practice in India to hold the potatoes for considerable duration in the storage & the holding load mentioned in the standard page 41 is 32.93 kW x 4 = 131.72 kW, I recommend selecting one compressor to meet the holding load and second compressor to meet initial loading and pull down load of 297.75 kW (429.47 - 131.72 = 297.75) instead of selecting two compressors of equal capacity. Running one base compressor at full load and second with variable capacity depending on load with capacity control arrangement of either cylinder unloading or VFD would give better power savings compared to two compressors of equal

capacity.

Depending upon individual requirements the assumptions to do heat load calculations would change but the methodology and formulae would remain same and would certainly make the user more confident to do heat load calculations. It is however recommended that the person using above formulas is reasonably competent and familiar with basics of refrigeration. The calculations done may also be authenticated from a competent consultant.

The temptation to present calculations in ready to use excel format has been purposely avoided as it is my experience that use of software is dangerous unless one knows the methodology of calculations with formulae. Once this is mastered in order to reduce calculation time one may use software or excel spread sheet, but not knowing the basics and using the ready to use tools can lead to serious errors & the user would remain ignorant of the same till problem occurs.



# NHB STANDARD COLD ROOMS - NH3 VALVES & CONTROLS BOQ

## Pumped Circulation system

<b>Module</b>	5000 MT - Option 3		
<b>No of Rooms</b>	4 x 1250 MT Storage	<b>Heat Load</b>	<b>Compressor</b>
<b>Evaporator Qty</b>	12 Nos x 36 Kw ( 3 Nos per Room)	432	132 Kw -1 no W
<b>Room Temp</b>	2 Deg C	122,8	298 Kw - 2 nos (1 W +1S)
<b>Evaporating Temp / Super heat</b>	Minus 2 Deg C / 5 Deg C		
<b>Defrost</b>	Off Cycle		
<b>SDT / Sub cooling</b>	40 Deg C / 2 Deg C		
<b>System type</b>	Ammonia Pump Feed 4:1		

Controls & valves list				
Sr.No.	Description	Item	Quantity	Total for 4 rooms
1	<b>Individual Room control</b>			
	Liquid inlet line to each air cooler	Stop Valve STC weldable	3	12
	Hand expansion valve inlet to each cooler	REG	3	12
	Wet return line -Air cooler outlet	stop valve STC weldable	3	12
2	<b>Valve Station for each room</b>			
	Liquid line stop valve in the header	stop valve STC weldable	2	8
	Solenoid valve with manual opener	solenoid valve EVRA	1	4
	Filter before solenoid valve	Filter FIA	1	4
	By pass stLine to main liquid station	Stop valve STC weldable	1	4
3	<b>Low Pressure Vessel ammonia storage</b>			
	Liquid inlet to LP vessel	Stop valve STC weldable	1	1
	Duel Safety vave on vessel	SFA	1	1
	Purge valve	SNV	1	1
	Pressure gauge connection Gauge valve	SNV	1	1
	Liquid level control switch	AKS	1	1
	High liquid level trip to protect compressor	AKS	1	1
	Low level pump trip	AKS	1	1
	Drain vlave on stand pipe	SNV	1	1
	Drain valve on LP vessel	QDV	1	1
	Liquid ammonia pump inlet valve	STC weldable	2	2
	Filter at pump inlet	FIA	2	2
	Non return vlave at pump out let	NRVA	2	2
	Stop valve at pump outlet	STC weldable	2	2
	Differential pressure switch to pump	RT 260A	2	2
	Pressure Gauge connection valve -pump outlet	SNV	2	2
	Liquid level sight glass with valves	LG	1	1
4	<b>Pump Bypass header to LP vessel controls</b>			
	stop valve in bypass line	STC weldable	2	2
	Pressure regulating valve in bypass line	PME	1	1
	Pressure gauge mounting stop valve after PME	SNV	1	1
5	<b>Liquid Regulating station to LP vessel</b>			
	Receiver outlet stop valve	STC weldable	1	1
	Liquid line filter -strainer	FIA	1	1
	Liquid line stop valve in liquid inlet line	STC weldable	2	2
	Solenoid valve to control liquid level in LP vessel	EVRA	1	1
	Filter -strainer before solenoid valve	FIA	1	1
	Liquid regulating hand expansion valve	REG	1	1
	By pass line shut off vlave	STC weldable	1	1
6	<b>Compressor controls</b>			
	High pressure cutout with maual reset	MP5A	3	3
	Low pressure cutout	MP1A	3	3
	Oil pressure cutout	MP55A	3	3
	Discharge Temperature cutout	RT	3	3
	Suction stop valve at compressor inlet	STC weldable	3	3
	Discharge Stop vave	STC weldable	3	3
	Non Return Valve after oil separator	STC Weldable	3	3
	Stop valve after oil separator	STC weldable	3	3
	Capacity controller for compressors common for 3 compressorsEKC		1	1
	Pressure Transmittter controller in main suction header	Pressure Transmitter- AKS	1	1
7	<b>Atmospheric Condenser</b>			
	stop valve at inlet to condenser	STC weldable	1	1
	Stop valve at condenser outlet	STC weldable	1	1
	Purge valve at condenser inlet header in hot gas line	STC weldable	1	1
	Purge valve at liquid ammonia outlet before receiver	SNV	1	1
8	<b>Ammonia High Pressure Receiver</b>			
	Stop valve at receiver inlet	STC weldable	1	1
	stop valve at receiver outlet	STC weldable	1	1
	Duel safety valve on receiver	SFA	1	1
	Purge Valve on receiver	SNV	1	1
	Pressure gauge mounting valve on receiver	SNV	1	1
	Oil drain valve	QDV	1	1
	Liquid level sight glass with stop vlaves	LG	1	1
	Liquid level sight glass with stop vlaves	QDV	1	1
	Liquid level sight glass with stop vlaves	LG	1	1







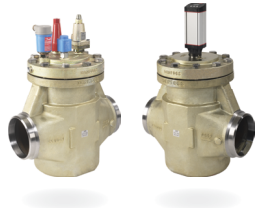






## Danfoss Flexline™ Simple. Efficient. Flexible.

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



**ICV Flexline™**  
– Control valve



**ICF Flexline™**  
– Complete valve stations



**SVL Flexline™**  
– Line components

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

Go to [www.danfoss.com/flexline](http://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 when you are looking for quality components.

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