ENGINEERING
TOMORROW

Application Guide

Gas detection in refrigeration systems

GDIR.danfoss.com

Contents

Commonly used abbreviations

- LFL = Lower Flammability Level
- OEL = Occupational Exposure Limits
- ATEL = Acute-Toxicity Exposure Limit
- ODL = Oxygen Deprivation Limit
- OSH = Occupational Safety Limit
- ODP = Ozone Depletion Potential
- GWP = Global Warming Potential
- TRK = Technische Richtkonzentrationen
- MAK = Maximale Arbeitsplatzkonzentrationen
- TLV = Threshold Limit Value
- STEL = Short Term Exposure Limit
- PEL = Permissible Exposure Limits

Introduction

Gas detection and leak detection are two distinct activities that covers the same topic, but the methods are very different.

Gas detection covers the analysis of air samples to determine whether they contain refrigerant gas. Leak detection is a systematic inspection of a refrigeration system to determine whether it is leaking. The terms gas detection and leak detection are not interchangeable, and must not be mixed.

Leak detection equipment is normally hand-held equipment carried by people, and used for detection of leaks in refrigeration systems. There are several types of leak detectors available, ranging from simple techniques like soapy water to sophisticated electrical instruments.

Gas detection equipment is usually used in a fixed installation with a number of sensors located in areas where refrigerant might be expected to accumulate in the event of a plant leak.

These locations depend upon the layout of the machinery room and adjacent spaces, on the configuration of the plant and also on the refrigerant in question.

Before selecting the appropriate gas detection equipment, a number of questions have to be answered:

- *Which gases have to be measured and in what quantities?*
  - Which sensor principle is the most suitable?
  - How many sensors are needed?
  - Where and how should they be positioned and calibrated?
- *Which alarm limits are appropriate?*
  - How many are required?
  - How is the alarm information processed?

This application guide will address these questions.

Sensor technology

The choice of sensor technology for refrigerant gas detection will depend on the specific target refrigerant gas and ppm range required. Danfoss offers a range of different sensor technologies to match most commonly used refrigerants, appropriate ppm ranges, and safety requirements for refrigeration systems.

EC - Electrochemical sensor

Electrochemical sensors are mainly used for toxic gases and are suitable for ammonia.

They consist of two electrodes immersed in an electrolyte medium.

An oxidation / reduction reaction generates an electric current that is proportional to the gas concentration.

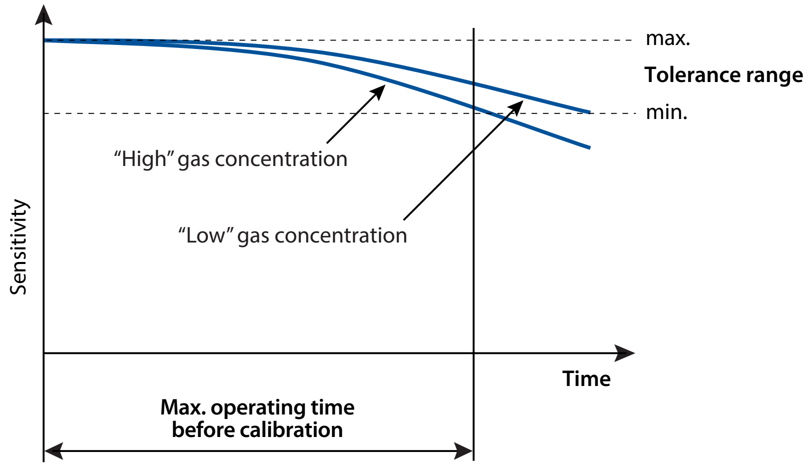

Fig. 1: Sensitivity of electrochemical sensors

They are very accurate (+/- 2%) and tend to be used mainly for toxic gases, which cannot be detected otherwise, or where high levels of accuracy are needed (fig. 1).

Danfoss offers specific EC sensors for ammonia in ranges up to 0-5.000 ppm with an expected lifetime of 2 years, depending on exposure to target gas.

Exposure to large ammonia leaks or constant background ammonia will shorten the sensor life (fig. 2). EC sensors can be re-calibrated as long as the sensitivity of the sensor is above 30%.

They are very selective and rarely subject to cross-interference. They may react to sudden large humidity changes but settle quickly.

EC - Electrochemical sensor (continued)

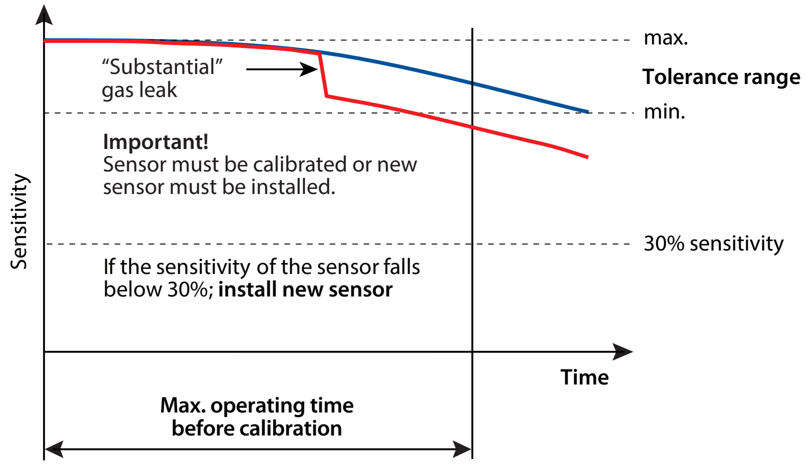

Fig. 2: Large ammonia exposure shortens the lifetime of electrochemical sensors.

SC - Semiconductor sensor (solid state)

The semi-conductor sensor functions by measuring the resistance change (proportional to the concentration), as gas is absorbed on to the surface of a semi-conductor, which is normally made from metal oxides.

These can be used for a wide range of gases including combustible, toxic and refrigerant gases.

It is claimed that they perform better than the catalytic type in the detection of combustible gases at low concentrations, up to 1.000 ppm.

These are low-cost, long life, sensitive and can be used to detect a large range of gases including all the HCFC, HFC refrigerants, ammonia and hydrocarbons.

However, they are not selective, and are not suitable for detecting a single gas in a mixture, or for use where high concentrations of interfering gases are likely to be present (fig. 3).

Interference from short term sources (e.g. exhaust gas from a truck), creating false alarms, can be overcome by enabling a delay of the alarm.

Semi-conductors for halocarbons can be used to detect more than one gas or a mixture simultaneously. This is particularly useful in monitoring a plant room with several different refrigerants.

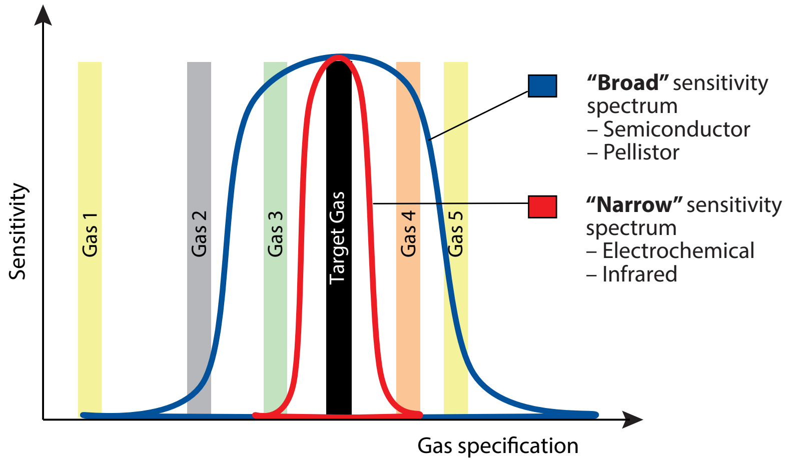

Fig. 3: Sensitivity spectrum of various sensor technologies

P- Pellistor sensor

Pellistors (sometimes called a bead or catalytic) are mainly used for combustible gases including ammonia, and are the most popular sensors for this application at high detection levels.

The sensor functions by burning the gas at the surface of the bead and measuring the resultant resistance change in the bead (which is proportional to concentration).

These are relatively low-cost, well established and understood, and they have a good life span (expected life time 3 to 5 years). The response time is usually below 10 seconds.

They can be subject to poisoning in certain applications.

Poisoning is the reduction of the reaction of the sensor to the target gas due to the presence (contamination) of another substance on the surface of the catalyst, that either reacts with it or forms a layer on top of it reducing its capacity to react to the target gas. Most common poisoning substances are silicon compounds.

Pellistors are used mainly with combustible gases and are therefore suited for ammonia and the hydrocarbon refrigerants at high concentrations.

They do sense all combustible gases, but they respond at different rates to each, and so they can be calibrated for particular gases.
There are ammonia specific versions.

IR - Infrared

Infrared technology utilises the fact that most gases have a characteristic absorption band in the infrared region of the spectrum, and this can be used to detect them. Comparison with a reference beam allows the concentration to be determined.

Even though they are relatively expensive in comparison to other sensor, they have long life time of up to 15 years, high accuracy, and low cross sensitivity

Due to its measuring principle infrared sensors can be subject to issues in dusty environments, where the presence of too many particles in the air may disturb the reading.

They are recommended and commonly used for Carbon dioxide detection. Although technology exists for other gases also, it is not common to find it in commercial solutions.

Which sensor is suitable to a given refrigerant?

Based on the target refrigerant gas and the actual ppm range the below table provides an overview of the suitability of the various sensor technologies offered by Danfoss.

Suitability of different sensor technologies:

	Semi-conducter	Electro-chemical	Pellistor (Catalytic)	Infrared
Ammonia "low" concentration (< 100 ppm)	–	✔	–	–
Ammonia "medium" concentration (< 1000 ppm) [1]	(✔)	✔	–	–
Ammonia "high" concentration (<10000 ppm)	✔	(✔)[2]	(✔)	–
Ammonia "very high" concentration (> 10000 ppm)	–	–	✔	–
Carbon Dioxide CO_2	–	–	–	✔
HC Hydrocarbons	–	–	✔	–
HCFC - HFC Halocarbons	✔	–	–	–

✔ Best solution

(✔) Suitable - but less attractive

– Not suitable

[1] Measuring range 0-1000 ppm. Can be adjusted in the whole range.
[2] Up to 5000 ppm. For specific applications.

Sensor response time

The response time is the elapsed time for a sensor to read a given percentage of the actual value for a step change in the target gas concentrations.

Response time for most sensors is given as t_{90}, meaning the time that it takes the sensor to read 90% of the actual concentration. Fig. 4 shows an example of a sensor with a reponse time t_{90} of 90 seconds.

As shown in the graphic, the sensor reaction above 90% becomes slower and takes longer to read the 100%.

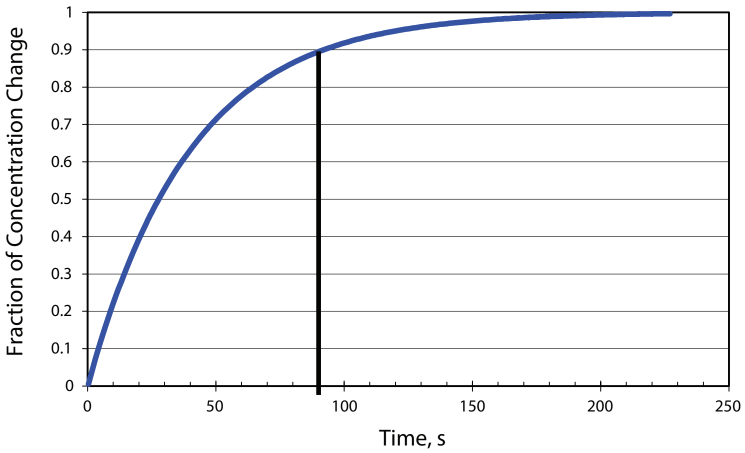

Fig. 4: Sensor with a response time t90 of 90 seconds

GAS	Sensor technology	Response time t_{90}, seconds
Ammonia	Electrochemical 0-100/ 0-300 ppm	<40s
	Electrochemical 0-1000ppm	<40s
	Electrochemical 0-5000ppm	<40s
	Semiconductor	>120s
	Pellistor	<20s
Infrared	Infrared	<90s
Halocarbons	Semiconductor	>120s
Hydrocarbons	Pellistor	<15s

The need for gas detection

There are several reasons why gas detection is required. Two obvious reasons are to protect people, production and equipment from the impact of potential gas leakages and to comply with regulations. Other good reasons include:

- Reduced service cost (cost of replacement gas and the service call).
- Reduced energy consumption cost due to lack of refrigerant.
- Risk for damaging stock products due to a substantial leak.
- Possibility to reduce insurance costs.
- Taxes or quota on non-environmentally friendly refrigerants

The various refrigeration applications require gas detection for different reasons.

Ammonia is classified as a toxic substance with a very unique smell, as such it is "self alarming". However, gas detectors are required to guarantee early warnings, and to monitor areas where people are not always present, such as machinery rooms. It is important to be aware that ammonia is the only common refrigerant lighter than air. In many cases, this will lead to ammonia rising above the breathing zone making it impossible for people to early detect ammonia leakages. The use of gas detectors in the right zones ensures early warnings in case of ammonia leakages.

Hydrocarbons are classified as flammable. Thus, it's critical to verify that the concentration around the refrigeration system does not exceed the flammability limit.

Fluorinated refrigerants all have a certain negative impact on the environment, for which reason it's very important to avoid any leaks.

CO_2 (Carbon Dioxide) is directly involved in the respiration process and should be treated accordingly. Approximately 0.04% CO_2 is present in the air. With higher concentration, some adverse reactions are reported starting with increase in breath rate (~100% at 3% CO_2 concentration) and leading to loss of consciousness and death at CO_2 concentrations above 10%.

Legislation and standards

The requirements for gas detection are different across countries worldwide. An overview of the most common rules and regulation can be found on the following pages.

Europe:
The present safety standard for refrigeration systems in Europe is EN 378:2016.

The specified alarm levels in EN 378:2016 are set at levels to allow evacuation of an area. The levels do not reflect the effects of long term exposure to leaked refrigerants. In other words, in EN 378 a gas detector is to warn when a sudden large release occurs, while machine room ventilation and system quality measures are to ensure that small leaks are too small to cause adverse health effects.

Note!
Requirements for gas detection equipment in Europe are covered by national legislation in the different countries, and consequently may differ from the requirements specified in EN 378.

Requirements for gas detection according to EN 378:2016 and ISO 5149:2014

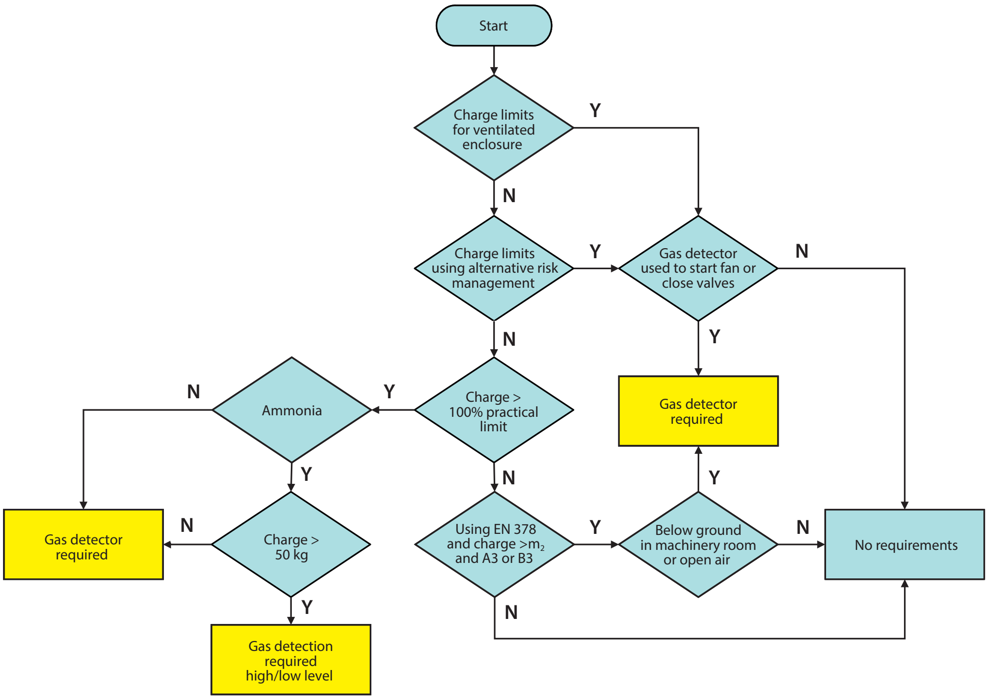

Fig. 5: Requirements for gas detection according to EN 378:2016 part 3 and ISO 5149:2014 part 3

With a few exceptions gas detection is required by EN 378:2016 and ISO 5149:2014 for all installations where the concentration in a room may exceed the practical limit for that space.

In the case of flammable and toxic refrigerants this means virtually all commercial and industrial systems In the case of A1 refrigerants it is possible to have small systems, which do not require gas detection. However, in most of the larger plants it is likely that the practical limit will be exceeded in the event of a major leak, and therefore gas detection is required.

Guidance can be found in EN 378:2016 part 3 or ISO 5149:2014 part 3. The requirements of the two standards are very similar, and are summarised in fig. 5.

If it can be shown by calculation that the concentration of refrigerant in a room can never reach the practical limit; then there is no need for fixed gas detection, except according to EN 378 if the system is below ground with a charge above m_2 (approx. 1 kg of propane). ISO 5149 does not have this exception. m_2 is a constant equal to $26m_3$ x LFL. For propane it is 26 m_3 x 0,038 kg/m_3 = 0,988 kg, or, if your LFL is measured in gram, it is 26 m_3 x 38g/m_3 =988 g. As such m_2 does not have any units, since the units depend solely on which unit you chose for LFL.
Most hydrocarbons have similar value of LFL, and m_2 is therefore typically around 1kg.

However, if the concentration can reach the practical limit, even for A1 refrigerants, then fixed detection must be installed - again with a few minor exceptions.

The practical limits for various refrigerants are given in **Annex II**, which are extracted from EN 378-2016 part 1. In these tables the practical limit of ammonia is based upon its toxicity. The practical limits of the hydrocarbons are based upon their flammability and are set at 20% of their lower flammable limit. The practical limits for all the A1 refrigerants are set at their Acute Toxicity Exposure Limit (ATEL).

If the total refrigerant charge in a room, divided by the net room volume, is greater than the “practical limit” (see **Annex II**), it is reasonable to conclude that fixed gas detection system should be installed.

Both EN378:2016 and ISO 5149:2014 require that an indicating device is provided to show whether the relief valve has discharged on systems with 300 kg refrigerants or more. A possibility is to place a gas detector in the discharge line.

F-Gas legislation

The F-Gas Regulation (EC) No 517/2014
One objective of the F-Gas Regulation is to contain, prevent and thereby reduce emissions of fluorinated greenhouse gases covered by the Kyoto Protocol. The F-gas directive is mandatory in all EU member countries and in the three European Economic Area (EEA) EFTA countries including Iceland, Liechtenstein, and Norway.

The regulation covers, among other topics, the import, export and use of the traditional HFCs and PFCs in all their applications. The regulation entered into force on January 1st, 2015.

Leakage checking requirements, to prevent leakage and to repair any detected leakage, depends on the CO_2 equivalents of the refrigerant in each circuit with refrigerant. The CO_2 equivalents is the charge in kg x the GWP of the refrigerant.

A periodical leakage check by certified personnel is required with the following frequency, depending on the quantity used:

- 5 tCO_{2eq} or more: At least once every 12 months – except for hermetically sealed systems containing less than 10 tCO_{2eq}
- 50 tCO_{2eq} or more: At least once every 6 months (12 months with an appropriate leakage detection system)
- 500 tCO_{2eq} or more: At least once every 6 months. An appropriate leakage detection system is mandatory. The leakage detection system must be checked at least once every 12 months.

Requirements for gas detection according to ASHRAE 15-2016 (USA)

Requirements for gas detection according to ASHRAE 15-2016 state requirements for rooms with refrigerating equipment including machinery rooms. The "Low Level" alarm values are less or equal to TLV-TWA levels.

In practice, the Occupational Exposure Limit (OEL) values from ASHRAE 34 are used since they are based on TLV-TWA (see also "Occupational Exposure Limits", page 18)

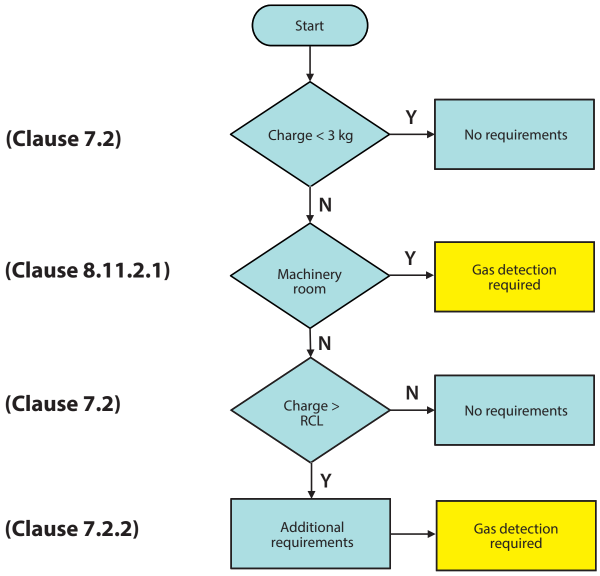

Fig. 6: Gas detection requirements according to ASHRAE 15-2016.

* Note 1: The charge limit stated in ASHRAE 15-2016 can also be found in Annex II (RCL) - for selected refrigerants.
Note 2: ASHRAE 15 does not include Ammonia. Refer to ANSI/IIAR-2.

Requirements for gas detection according to ANSI/IIAR-2 (USA)

ANSI/IIAR -2 requires machinery rooms to be provided with ammonia gas detectors. It requires 3 different alarm levels (25, 150 and 40000 ppm) with different response requirements according to each of the levels.

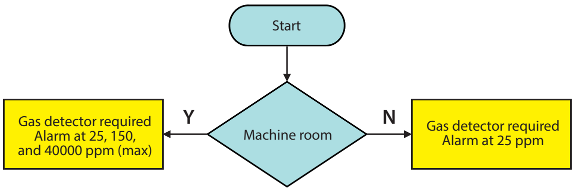

Fig. 7: Gas detection requirements according to the ANSI/IIAR-2

Installation guideline

When it comes to installation of gas detection there are two approaches:

- Perimeter detection
- Point detection

With perimeter detection, you place sensors all around the perimeter of the space in question, to make sure you monitor the whole space.

With point detection, you locate a sensor at a particular position, where you are concerned about a leak (e.g. at the compressor).

For gases heavier than air, sensors should be located close to the ground/lowest point.
For gases lighter than air, sensors should be mounted high up on the walls, ceiling or near exhaust, but convenient for maintenance.
If the density is equal to air, the sensors should be mounted at face level.

In some countries it may be mandatory to have an UPS (Uninterruptible Power Supply) connected to the gas detectors to ensure safe operation during a power failure.

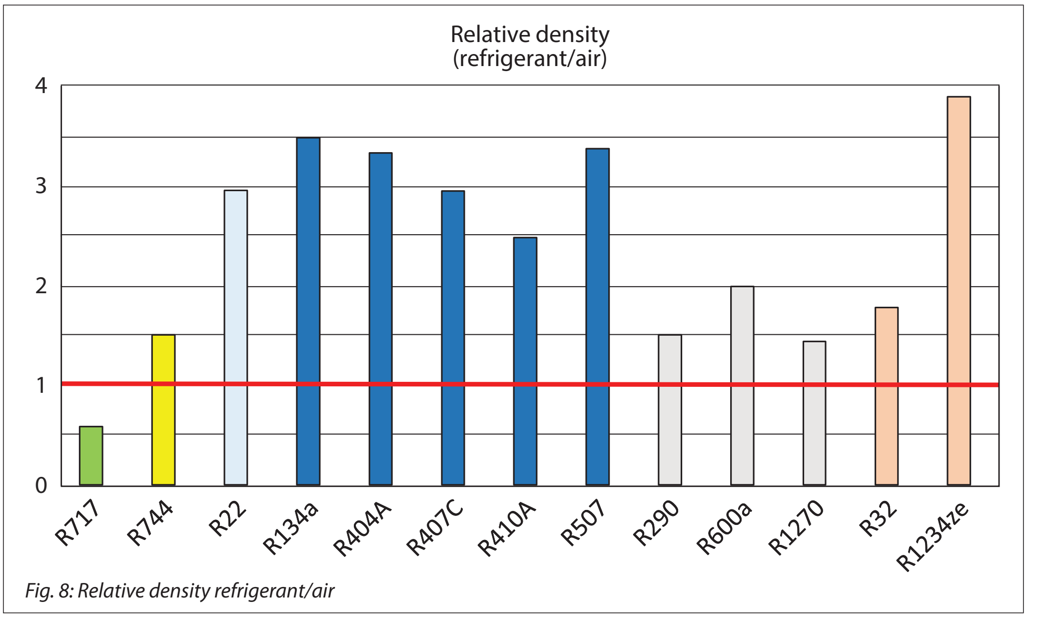

Fig. 8: Relative density refrigerant/air

Location of gas detectors

Gas detectors must be powered as specified in the installation guide and located within the specified cable length from the central control unit/monitor.

In general:

- Do not mount to a structure that is subject to vibration and shock, such as piping and piping supports.
- Do not locate near excessive heat or in wet or damp locations.
- Do not mount where it will be exposed to direct solar heating.
- Do not install in areas where condensation may form.

The two methods of locating sensors:

- Point detection: Sensors are located as near as possible to the most likely sources of leakage.
- Perimeter detection: Sensors surround the hazardous area completely.

The most appropriate method is selected depending on the size and nature of the site.

- Detectors shall be located high/low according to the density of the actual refrigerant.
- If mechanical ventilation exists in a machinery room, air will move towards the fan. In problematic locations a smoke tube can indicate air movements in a space and assist in the location of sensors.
- In a cold store, sensors should, if possible, be placed on the wall in the return airflow.
- Consideration should also be given to the possibility of pockets of gas collecting in the event of a leak.

Important!
Do not place immediately in front of a coil due to temperature and humidity fluctuations. These may occur especially during defrost or loading of a cold store.

Make sure that pits, stairwells and trenches are monitored since they may fill with stagnant pockets of gas. Monitoring where leaked refrigerant can stagnate is generally required by standards.

The arrangement of the equipment in the room can also have an impact on the most effective place to monitor.

Locations requiring most protection in a machinery or plant room would be around gas boilers, compressors, pressurized storage tanks, gas cylinders, storage rooms, or pipelines.

Most vulnerable are valves, gauges, flanges, T-joints, filling or draining connections etc.

Sensors should be positioned a little way back from any high-pressure parts to allow gas clouds to form. Otherwise any leakage of gas is likely to pass by in a high-speed jet and will not be detected by the sensor.

Accessibility and space to allow calibration and service must be considered.

As general guideline:

- If there is one compressor/chiller in the room; sample at the perimeter of the unit. For two chillers; sample between them, with three or more chillers; sample between and on each side. Ensure that the area being sampled is sufficiently monitored. Do not skimp on sensors.
- Place the sensor in the location(s) most likely to develop a gas leak, including mechanical joints, seals, and where there are regular changes in the system's temperature and pressure or excessive vibration, such as compressors and evaporator control valves.

Number of gas detectors in a facility

The requirements for the number of gas detectors in a facility are not specifically stated in standards.

As general guideline:

- A gas detector can normally cover an area of about 50-100 m^2 depending on the actual condition of the space to be covered. In spaces with several obstructions and lack of ventilation the coverage is approx. 50 m^2, provided it is mounted near ceiling level or near floor level depending on the refrigerant density.
  In non-obstructed spaces with good mechanical ventilation, the coverage can be increased up to approx. 100 m^2.
- Machinery rooms:
  It is recommended that gasdetectors are placed above or at both sides of compressors or other non-static parts of the system or down wind of such equipment, in the direction of continuously operating ventilation extractors.
  Where there are deep beams and lighter than air refrigerants, it is recommended that the detectors are mounted between pairs of beams and on the underside of the beams.

If there is a continuous airflow in the room a sensor/sensing point should be located downstream from the last potential leak source.

Calibration / test

Calibration/test of gas detectors is extremely important to ensure and document the proper accuracy, responsiveness and operation of the unit.

Gas detectors are subject to changes in the measurement properties, dependent on the operation time and/or exposure time. Therefore, regular calibration is needed. The frequency depends on various factors, however the following four are of particular importance:

- Requirements of national legislation
- Recommended calibration interval
- Lifetime of the sensors
- The lifetime and calibration needs of electrochemical sensors are highly affected by exposure to the target gas, reducing the lifetime and the calibration interval. For that reason the concentrations of the target gas in the area should also be considered.

From a technically and safety point of view, the sensors offered by Danfoss should be calibrated/tested according to the stated intervals in the table below.

IMPORTANT!
If national legislation requires calibration/test with intervals shorter (stricter) than stated in the table below, these requirements must be followed.

Note: EN 378:2016 and ISO 5149 require gas detectors to be checked on an annual basis.

		Estimated life time [year]	Min. recomended calibration interval [year]	Recomended test interval** [year]
SC	Semi-conductor	>5	1	1
EC	Electrochemical	>2*	1	1
P	Pellistor	3-5	6 months	1
IR	Infrared	15	5	1

* If the sensor is exposed to high or constant ammonia concentrations, the life time will be reduced.
An EC sensor remain functional above 30% of sensitivity.

** If calibration is performed, test is not required. However, when calibration interval is longer than the test interval, then a "bump" test must be performed.

Calibration methods

Two different methods are available for fulfilling the calibration requirements.

- Replacing the sensor (sensor cartridge) with a new factory pre-calibrated sensor.
- Performing a calibration to the sensor using calibration gas (gas mixture with known target gas concentration).

In addition to these calibration methods, a "bump" test can be used, but only to test the responsiveness and operation of the sensor. It is important to highlight, that **a bump test is not a calibration**.

Method I
Calibration by means of replacing sensor heads

This method requires that the supplier offers factory pre-calibrated sensor heads with calibration certificate and traceability codes. Additionally, an electrical simulation is required to verify the output signals and alarm settings .

This method can be compared with the method used for safety valves. The manufacturer produces, tests, and certifies the product, which can then be mounted in the system.

Danfoss offers the above-mentioned solution. The sensor head, which is the essential measuring element of the gas detector, is produced, tested, calibrated, and certified by Danfoss.

After the gas detection unit has been tested with the on-board test button function, which simulates alarm signals and relay activation, to ensure all electrical components are functional, the new calibrated sensor head can be installed.

Danfoss recommends that the calibration is done by means of pre-calibrated replacement sensors:

- As sensors have a limited lifetime, this method basically ensures that the customer has a gas detector as good as new after replacing the sensor head.
- The method is typically more efficient and cost effective compared to calibration carried out on site.

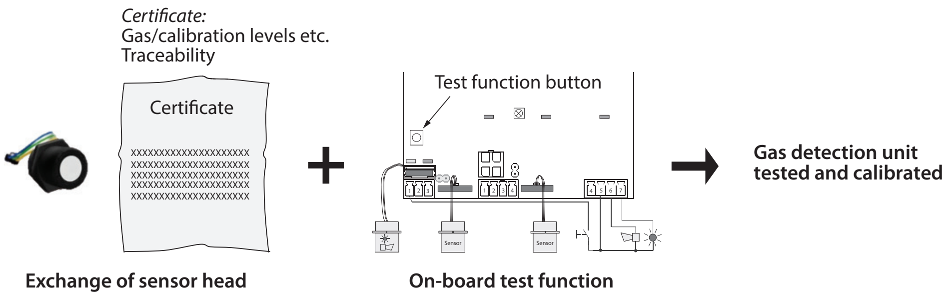

Fig. 9: Test and calibration of Danfoss gas detection unit (GDU) by the use of the on-board test function and replacement of the sensor head.

Method II
Calibration of gas detectors by means of calibration gas

The calibration of gas detectors by means of calibration gas has traditionally been made by using multimeters and adjustment of potentiometers, which makes the process relatively complicated, time consuming, and expensive. However, the Danfoss gas detection units have an integrated, digital calibration function that makes the calibration process easier, cheaper, and faster. Even though the calibration is a simple procedure, it still requires test equipment and basic competence in calibration.

Calibration equipment for Gas Detection Units (GDU) consists of:

- Valve/Flow regulator.
- Gas cylinder with the correct calibration gas for each refrigerant and concentration (ppm).
- Calibration adapter.
- If the gas detector unit does not have a display, the service tool or the PC tool is required.

In order to execute the calibration function, the gas detector unit needs to be equipped with a display or connection to either the service tool or the PC tool.

Some calibration gas cylinders are treated as dangerous substances, and therefore subject to specific shipping requirements.

Method II
Calibration of gas detectors by means of calibration gas (Continued)

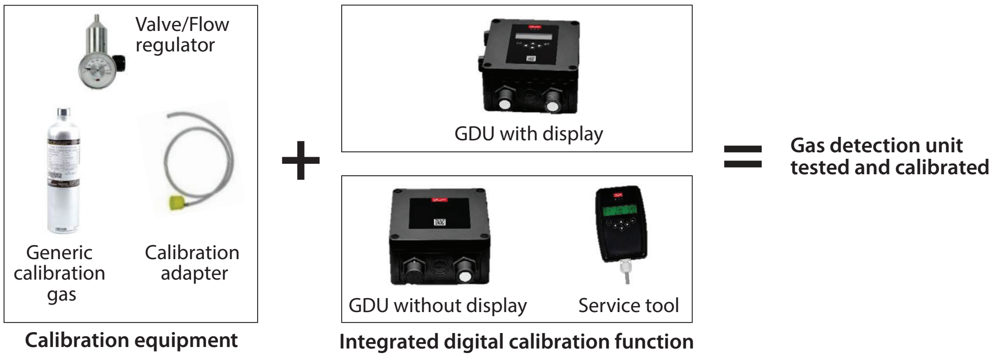

Fig. 10

Bump test

A bump test cannot supersede any tests involving calibration. It is only a function test (signal or no signal).

Bump test of gas sensors (this test is a function test - it is not a calibration)

Method	Refrigerant	SC Semi-conductor	EC Electro-chemical	P Pellistor	IR Infrared
Ampoules	Ammonia		✔		
Ampoules (or lighter gas)	HCFC, HCF	✔		✔	
Lighter gas	HC - Hydro Carbon	✔		✔	
Ampoules (or breath on sensor)	CO_2				✔

Alarm / sensitivity range of gas detectors

All commonly used gas detectors have a proportional output signal (4-20 mA, 0-10 V, or 0-5 V), and some pre-set alarm settings.

When selecting the actual measuring range and sensor type, several factors should be considered:

In general, alarm levels should be as low as practically possible, depending on the actual refrigerant and the purpose of the alarm.
There are often requests for more alarm levels, but experience shows that two alarm limits are sufficient for gas detection.

The pre-alarm provokes a reaction, either automatically and/or in the form of alarm instructions; if not, the main alarm may be triggered. This entails a whole series of consequences, including switching off machines.

A main alarm should rarely (and preferably never) be necessary!

Alarms can be chosen to warn against gas concentrations less than levels acceptable for personal safety on short term or long term. Alarm levels can also be chosen to specific levels due to flammability/explosion risk.

The following recommendations are based on the present experience with suitable limits, taking into account the above mentioned conditions, but also requirements in EN 378:2016, ISO 5149:2014, IIAR 2-2017 and ASHRAE 15:2016.

The Danfoss gas detection units offer two pre-set alarms and a proportional output signal, both analog 4-20 mA and digital Modbus.
With this configuration, is it possible to fulfil all requirements for alarm levels needed within the specific operation range of the sensor.

Danfoss recommendations for alarm levels

DANFOSS recommendations for alarm levels: EN 378:2016			**National requirements**		**Comply with: EN 378**			
			Sensor type	LEVEL I Personal safety (occupational) (TWA-values) [ppm]	Sensor type	LEVEL II (pre-alarm) [ppm]	Sensor type	LEVEL III (main-alarm) [ppm]
Ammonia	R717	Machinery rooms			EC	500	P	30000
		Machinery rooms	EC	25	EC	150		
		Safety valves - vent line		–	SC	9000		
Carbon Dioxide	R744 (CO_2)		IR	5000	IR	9000		
Halocarbon HFC	R134a, R404A, R407C, R410A, R507		SC	500^{1})	SC	900		
Hydrocarbon HC	R290, R600, R600a, R1270	Concentration ≤ 20% of LFL	CT	800	CT	2500		

^{1}) 50% of TWA-value
Note: All proposed levels are ≤ the max. values in EN 378:2016

DANFOSS recommendations for alarm levels: ASHRAE 15:2016			**Comply with: ASHRAE 15:2016**			
			Sensor type	LEVEL I Personal safety (occupational) (TWA-values) [ppm]	Sensor type	LEVEL II (pre-alarm) [ppm]
Carbon Dioxide	R744 (CO_2)		IR	5000	IR	9000
Halocarbon HFC	R134a, R404A, R407C,R410A, R507		SC	500^{1})	SC	900
Hydrocarbon HC	R290, R600, R600a, R1270	Concentration ≤ 25% of LFL	CT	500	CT	2500

^{1}) 50% of TWA-value
Note: All proposed levels are ≤ the max. values in ASHRAE 15:2016

Danfoss recommendations for alarm levels (Continued)

DANFOSS recommendations for alarm levels: ANSI/IIAR 2-2014			**Comply with: ANSI/IIAR 2-2014**					
			Sensor type	LEVEL I Personal safety (occupational) (TWA-values)	Sensor type	LEVEL II (main-alarm)	Sensor type	LEVEL III (deenergize main components)
				[ppm]		[ppm]		[ppm]
Ammonia	R717	Machinery rooms	EC	25	EC	150	P	30000
		Safety valves - vent line		–	SC	9000		

Actions triggered by gas detection

The actions to be triggered when leaked refrigerant is detected depends on the standard applied. National regulations, especially the "Occupational Exposure Limits", varies from country to country.

Actions for Ammonia – R717	EN 378:2016	ISO 5149:2014	ASHRAE 34-2016	IIAR 2-2014
Up to 50 kg refrigerant	At max. **157 ppm**: - Actuate an alarm - Notify an authorised person - Audible buzzer 15 dBA above background noise level - Flashing lamp - Alarm to be inside the room - For machinery rooms: Also outside the room, which can be at a supervised location - For machinery rooms: Start emergency ventilation		At max. **1000 ppm**: - Audible and visual alarm - Inside the machinery room and outside each entrance - Start mechanical ventilation - Shut down combustion processes drawing air from the room (except if the combustion is driving the compressor)	Machinery rooms at max. **25 ppm:** - Audible and visual alarm - Inside the machinery room and outside each entrance - Alarm to monitored location - Stop non-emergency ventilation (unless it is designed to work with R717) Machinery rooms at max. **150 ppm** also: - Start emergency ventilation Machinery rooms at max. **40000 ppm** also: - De-energize compressors, refrigerant pumps, and normally closed valves Not in machinery rooms at max. **25 ppm**: - Alarm to monitored location - Other actions depends on system type and location
More than 50 kg refrigerant	Same actions as above, but starting at max. **500 ppm** At max. **30000 ppm** also: - Stop the system - Stop the power supply to everything which is not Ex approved	Same actions as above, but starting at max. **200 ppm** At max. **30000 ppm** also: - Stop the system - Stop the power supply to everything which is not Ex approved		
More than 3000 kg refrigerant	Same as above, but also - central alarm station - specialized personnel on site within 60 min of alarm			
More than 4500 kg refrigerant		Same as above, but also: - central alarm station - specialized personnel on site within 60 min of alarm		

Actions for refrigerants other than ammonia	EN 378:2016	ISO 5149:2014	ASHRAE 34-2016
For all systems except ventilated enclosures and systems using alternative risk management	At **50% ATEL/ODL/RCL** or **25% LFL** (see Annex II): - For flammable refrigerants: Stop the system - Actuate an alarm - Notify an authorised person - Audible buzzer 15 dBA above background noise level - Flashing lamp - Alarm to be inside the room - For occupancy A: Also outside the room, which shall be at a supervised location - For occupancy B and C: Only inside is needed - For machinery rooms: Also outside the room, which can be at a supervised location - For machinery rooms: Start emergency ventilation		At **OEL** (see Annex III): - Audible and visual alarm - Inside the machinery room and outside each entrance - Start mechanical ventilation - Shut down combustion processes drawing air from the room (except if refrigerant is R744)
For ventilated enclosures	If a detector is used for staring ventilation: Start ventilation at **25% LFL** (see Annex II)		Not applicable
For systems using alternative risk management	If a detector is used for staring ventilation: Start ventilation at **50% ATEL/ODL/RCL** or **25% LFL** (see Annex II)		Not applicable

References

- EN 378:2016 Refrigerating systems and heat pumps – Safety and environmental requirements
- ASHRAE 15:2016 Safety Standard for Refrigeration Systems
- ASHRAE 34:2016 Designation and Safety Classification of Refrigerants
- ANSI/IIAR 2-2014 American National Standard for Safe Design of Closed-Circuit Ammonia Refrigeration Systems
- ISO 5149:2014 Refrigerating systems and heat pumps – Safety and environmental requirements
- EU F-Gas Regulation (EC) No 517/2014
- Danfoss gas detector documentation (www.danfoss.com/ir)

Annex I

Common refrigerant data

Refrigerant type	Refrigerant	Name	Formula	Safety group	Vapour density @ 25°C / 1 bar $[kg/m^3]$	Relativ density [–]	ODP Ozone Pepletion Portential [–]	GWP_{100} Global Warming Potential (100 yr ITH/F gas regulation) [–]
–	R717	Ammonia	NH_3	B2L	0.700	0.6	0	0
–	R744	Carbon Dioxide	CO_2	A1	1.80	1.5	0	1
HCFC	R22	Chlorodifluoromethane	$CHClF_2$	A1	3.54	3.0	0.055	1810
HFC	R134a	1,1,1,2-tetraflouroroethane	CH_2FCF_3	A1	4.17	3.5	0	1430
HFC	R404A	R125/143a/134a (44/52/4)	–	A1	3.99	3.3	0	3260
HFC	R407C	R32/125/134a (23/25/52)	–	A1	3.53	2.9	0	1520
HFC	R410A	R32/125 (50/50)	–	A1	2.97	2.5	0	1900
HFC	R507	R125/143a (50/50)	–	A1	4.04	3.4	0	3800
HC	R290	Propane	$CH_3CH_2CH_3$	A3	1.8	1.5	0	3
HC	R600	Butane	$CH_3CH_2CH_2CH_3$	A3	2.38	2.0	0	4
HC	R600a	Iso-butane	$CH(CH_3)$	A3	2.38	2.0	0	3
HC	R1270	Propylene	$CH_3CH{=}CH_2$	A3	1.72	1.4	0	2
HFC	R32	Difluoromethane	CH_2F_2	A2L	2.13	1.8	0	675
HFO/HFC	R1234ze(E)	Trans-1,3,3,3-tetrafluoro-1-propene	$CF_3CH{=}CHF$	A2L	4.66	3.9	0	7

Annex II

EN 378:2016 and ISO 5149:2014

Refrigerant type	Refrigerant	Name	Safety group	Practical Limit [kg/m3]	Toxicity ATEL /ODL [kg/m3]	Flammability LFL [kg/m3]	Alarm settings			
							50% of ATEL/ ODL [ppm]	25% of LFL [ppm]	Pre-alarm level MAX refrigeration concentration [ppm]	Main-alarm MAX refrigeration concentration [ppm]
-	R717	Ammonia	B2L	0.00035	0.00022	0.116	157	33143	EN 378: 500 ISO 5149: 200	30000
-	R744	Carbon Dioxide	A1	0.1	0.072	-	20000	-	20000	
HCFC	R22	Chlorodifluoromethane	A1	0.3	0.21	-	29661	-	29600	
HFC	R134a	1,1,1,2-tetraflouroroethane	A1	0.25	0.21	-	25180	-	25100	
HFC	R404A	R125/143a/134a (44/52/4)	A1	0.52	0.52	-	65163	-	65100	
HFC	R407C	R32/125/134a (23/25/52)	A1	0.31	0.29	-	41076	-	41000	
HFC	R410A	R32/125 (50/50)	A1	0.44	0.42	-	70707	-	70700	
HFC	R507A	R125/143a (50/50)	A1	0.53	0,53	-	65594	-	65500	
HC	R290	Propane	A3	0.008	0.09	0.038	25000	4222	4200	
HC	R600	Butane	A3	0.0089	0.0024	0.038	504	3193	500	
HC	R600a	Iso-butane	A3	0.011	0.059	0.043	12395	3613	3600	
HC	R1270	Propylene	A3	0.008	0.0017	0.046	494	5349	490	
HFC	R32	Difluoromethane	A2L	0.061	0.30	0.307	70423	28826	28800	
HFO/HFC	R1234ze(E)	Trans-1,3,3,3-tetrafluoro-1-propene	A2L	0.061	0.28	0.303	30043	13004	13000	

Annex III

ASHRAE 15-2016

Refrigerant type	Refrigerant	Name	Safety group	RCL [g/m3]	RCL [lb/Mcf]	RCL [ppm]	OEL/TWA (40 hours work week without effect) [ppm]
-	R717	Ammonia	B2L	0.22	0.014	320	25
-	R744	Carbon Dioxide	A1	54	3.4	30000	5000
HCFC	R22	Chlorodifluoromethane	A1	210	13	59000	1000
HFC	R134a	1,1,1,2-tetraflouroroethane	A1	210	13	50000	1000
HFC	R404A	R125/143a/134a (44/52/4)	A1	500	31	130000	1000
HFC	R407C	R32/125/134a (23/25/52)	A1	290	19	81000	1000
HFC	R410A	R32/125 (50/50)	A1	420	26	140000	1000
HFC	R507	R125/143a (50/50)	A1	520	32	130000	1000
HC	R290	Propane	A3	9.5	0.56	5300	1000
HC	R600	Butane	A3	2.4	0.15	1000	1000
HC	R600a	Iso-butane	A3	9.6	0.59	4000	1000
HC	R1270	Propylene	A3	1.7	0.11	1000	500
HFC	R32	Difluoromethane	A2L	77	4.8	36000	1000
HFO/HFC	R1234ze(E)	Trans-1,3,3,3-tetrafluoro-1-propene	A2L	75	4.7	16000	800

ENGINEERING
TOMORROW

Danfoss Industrial Refrigeration
A world of expertise at the click of a button

Turn to Danfoss if you want to combine quality components with expert knowhow and support. Try out these free tools, designed to make your work much easier.

DIRbuilder
DIRbuilder is designed to make selection processes for industrial refrigeration projects easier and less time-consuming. Specify the valves you need from an extensive pool of configuration options. The DIRbuilder library comprises all Danfoss Industrial Refrigeration valves. Free of charge – no software needed.

Coolselector® 2 – New calculation software for Industrial Refrigeration
Coolselector® 2 is a calculation and support tool for contractors and system designers, offering complete pressure drop calculations, analysis of pipe and valve design and the ability to generate performance reports. It replaces the well-known DIRcalc™ software and offers several new functionalities.

Danfoss IR app
The free IR App gives you a spare parts tool, which makes it easy for you to find the spare part number for a given Danfoss industrial refrigeration valve.

Download 3D CAD symbols
From our online product catalogue on our website, you can download 3D CAD symbols and illustrations to help you when designing refrigeration plants.

IR application tool
With this interactive PowerPoint slideshow, you can explore all the details of a two-stage ammonia plant. You will find detailed cut-away drawings and information on the valves in the installation along with links to videos, literature and product animations.

Application handbook
The Application Handbook is designed to help you every step of the way when working with industrial refrigeration systems. Among many other things, it contains examples of how to select control methods for different refrigeration systems, their design and which components to choose.

Visit **www.danfoss.com/IR-tools** and find all the tools you need.