MAKING MODERN LIVING POSSIBLE

Gas detection in refrigeration systems

REFRIGERATION &
AIR CONDITIONING DIVISION

Application guide

Contents

Common used abbreviation

- LFL = Lower flammability level

- OEL = Occupational Exposure L imits
- 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, covering 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 appropiate gas detection equipment, a number of questions have to be answered:

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

This application guide will try to answer these questions.

Sensor technology

Danfoss has, depending on the refrigerant and the actual ppm range required, selected the most appropriate sensor for the target refrigerant gas.

Danfoss offers the following sensor technologies:

EC - Electrochemical sensor

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

These generally consist of two electrodes immersed in an electrolyte medium.

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

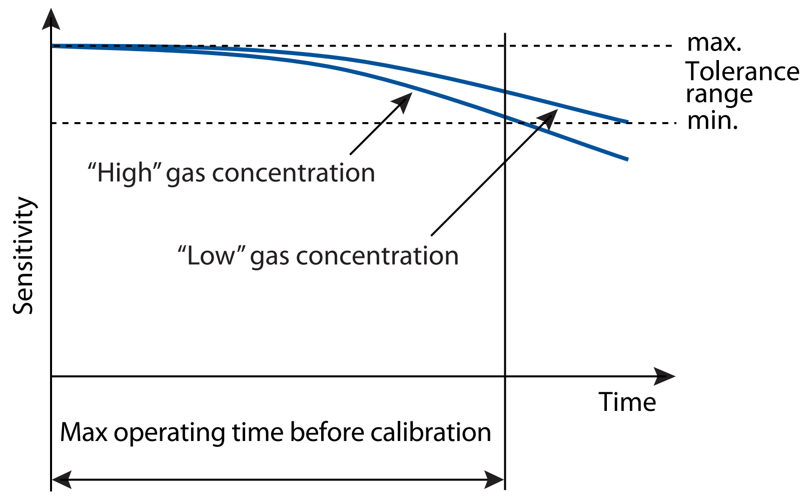


Fig. 1

They are very accurate (0.02 ppm) and tend to be used principally for toxic gases which cannot be otherwise detected or where high levels of accuracy are needed (fig. 1).

They were relatively expensive with a limited lifetime, however Danfoss now offers specific EC sensors for ammonia in the range of 0-5.000 ppm with a lifetime of approx. 3 years.

Exposure to large ammonia leaks or constant background ammonia will shorten the sensor life (fig. 2).

They are subject only to rare cross interference. They may react to sudden large humidity changes but quickly settle.

EC - Electrochemical sensor (continued)

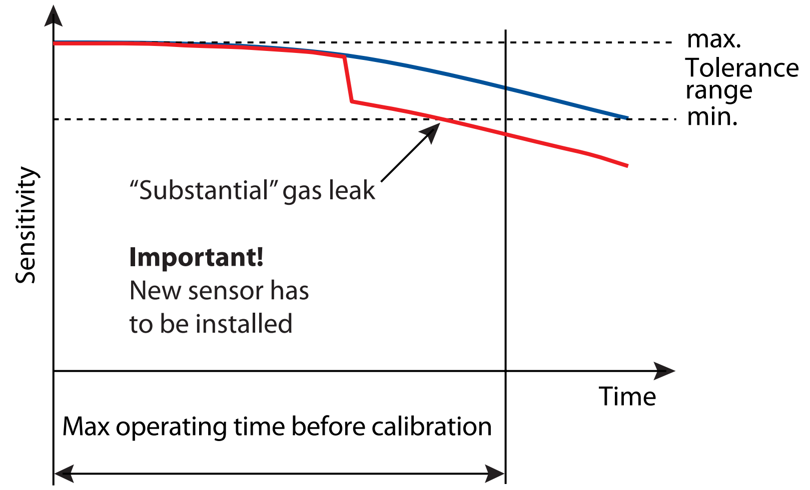


Fig. 2

SC - Semiconductor sensor (solid state)

The semi-conductor 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. So they are becoming more popular in this application in refrigeration, given that the hydrocarbon refrigerants should be detected at low levels to avoid potential problems and costs.

These are low-cost, long life, sensitive, stable, resistant to poisoning and can be used to detect a large range of gases including all the CFC, 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 overcomed by enabling a delay of the alarm.

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

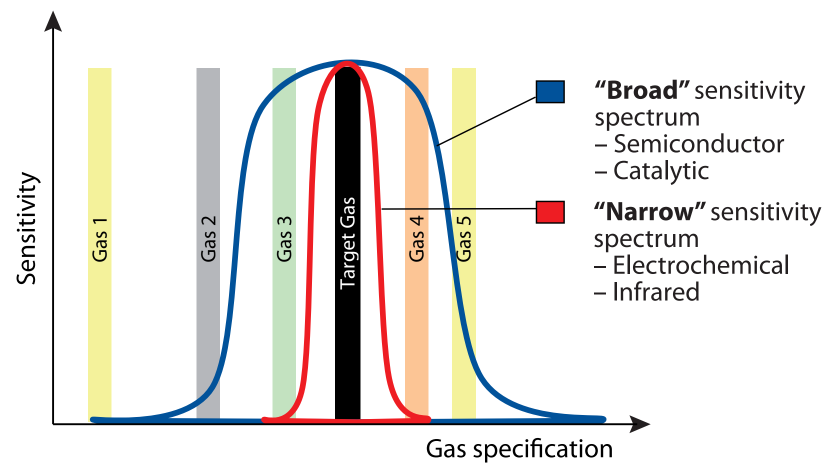


Fig. 3

CT - Catalytic sensors

Catalytic sensors (sometimes called a bead or pellistor type) have mainly been 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, up to 5 years. The response time is about 20-30 seconds.

They can be subject to poisoning in certain applications but not generally in refrigeration and are more effective at gas levels of 1.000 ppm up to 100% LEL.

They 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.

Infrared sensors when first introduced were specific to a single gas and therefore not suitable for applications involving monitoring more than one gas. They were very selective and accurate – reading down to one part per million. Infrared was typically used where a high level of accuracy and specificity was required. This very precision in performance ensures that they are expensive.

However the specificity became a disadvantage in machinery rooms, as phase out resulted in mixed gas installations needing a different model for each gas, which was a very expensive solution.

New models were developed based on broad infrared wavelength monitoring that could detect a mixture of gases. This, however, reduced the specificity and accuracy.
If preferred, refrigerant specific units may be used if a possibility of cross interference exists.

Which sensor is suitable to a given refrigerant?

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

✔ Best solution (✔) Suitable - but less attractive – Not suitable

Fig. 4

[1]) Measuring range 0-1000 ppm. Can be adjusted in the whole range.

Relative cost comparison

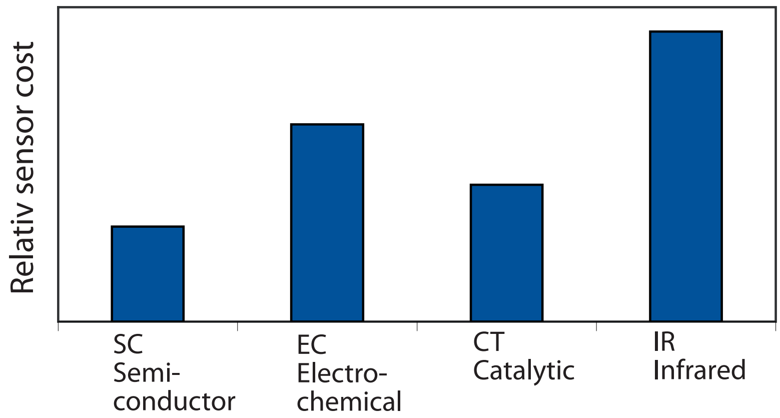


Fig. 5

The need for gas detection

There are different reasons why gas detection is needed. It is obvious, that regulation is a very strong argument, but also

- 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.
- Possible reduced Insurance cost.
- Taxes on non environmentally friendly refrigerants

Different refrigeration applications requires gas detection for different reasons.

Ammonia is classified as a toxic substance with a very unique smell, as such it is "self alarming". Still gas detectors are very useful to have in a machinery room, as often people are not present to take necessary actions. Further more, ammonia is the only common refrigerant lighter than air.

Hydrocarbons are classified as flammable. It is therefore very important to verify that the concentration around the refrigeration system does not exceed the flammability limit.

Fluorinated refrigerants all have a certain impact on the environment. It is therefore very important to avoid any leaks from these.

CO_2 (Carbon Dioxide) is directly involved in the respiration process, and has to be treated accordingly. Approx. 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%.

Oxygen - Oxygen deprivation sensors can be used in some applications, but they are not offered by Danfoss, and will not be described further in this guide.

Note:
Oxygen sensors must never be used in CO_2 installations.

Legislation and standards

The requirements for gas detection are different in many countries worldwide. An overview of the most common rules and regulation can be found below.

Europe:
The present safety standard for refrigeration systems in Europe is EN 378-2000. During the last few years this standard has been undergoing a very extensive update.

This work has been completed (prEN 378-2006), but the standard has not been finally approved yet.

It is recommended to read this version of the standard, because this version is much more stringent, and with different requirements.

Note!
The requirement for gas detection is not identically in EN 378-2000 and prEN 378-2006.

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

Requirements for gas detection according to EN 378:2000 and prEN 378:2006 are limited to machinery rooms. It has to be noted that machinery rooms according to these standards, are restricted arears. The specified alarm levels do not reflect long term effects (personal safety).

Requirements for gas detection according to EN 378-2000

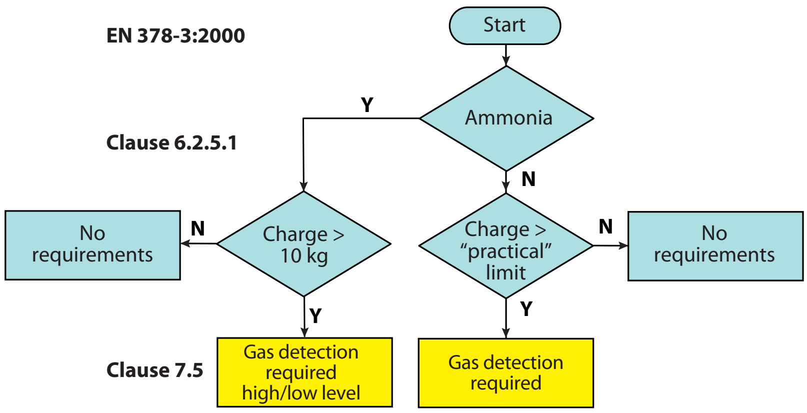


Fig. 6

Gas detection is required by EN 378:2000 for all installations where the concentration in the machinery 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, but in the case of A1 refrigerants it is possible to have small systems, which do not require gas detection. However, in the majority of 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 378:2000 part 3 paragraph 7.2, which states that "the refrigerant concentration in each special machinery room shall be monitored at one or more points". This covers all refrigerant groups including A1. However, in paragraph 7.4.1 the standard states "If a refrigerating system… is equipped with refrigerant detectors…." raising the question of whether detection is required or not.

It can he concluded that, if it can be shown by calculation that the concentration of refrigerant in the special machinery room can never reach the practical limit then there is no need for fixed gas detection. However, if the concentration can reach the practical limit, even for A1 refrigerants, then fixed detection must he installed.

The practical limits for various refrigerants are given in Annex II and III, which are extracted from EN 378-2000 part 1 and prEN 378-2006. In these tables the practical limit of ammonia is based upon its toxicity, and 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 and III), then it is reasonable to conclude that fixed gas detection system should be installed.

EN 378-2000 only requires fixed gas detection to be installed in machinery rooms.

F-Gas legislation

The F-Gas Regulation (EC) No 842/2006. The objective of the 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 and EFTA member States.

The Regulation covers the use of HFCs, PFCs and SF6 (GWP > 150) in all their applications, except Mobile Air Conditioning, covered by the Directive and Domestic Refrigerators.

The Regulation entered into force on 4 July 2006 and a number of the measures will apply from 4 July 2007.

Leakage checking requirements, which will be the basis for operators to use "all measures which are technically feasible and do not entail disproportionate cost" to prevent leakage repair any detected leakage.

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

- 3 kg or more: at least once every 12 months – except for hermetically sealed systems containing less than 6 kg;
- 30 kg or more: at least once every 6 months (12 months with an appropriate leakage detection system);
- 300 kg or more: at least once every 3 months (6 months with an appropriate leakage detection system – which is anyway mandatory).
- Leakage detection systems shall be checked at least once every 12 months.

Requirements for gas detection according to prEN 378-2006

prEN 378:2006 is an update of EN378:2000. The standard has not been finally approved yet, but it contains important information regarding gas detection.

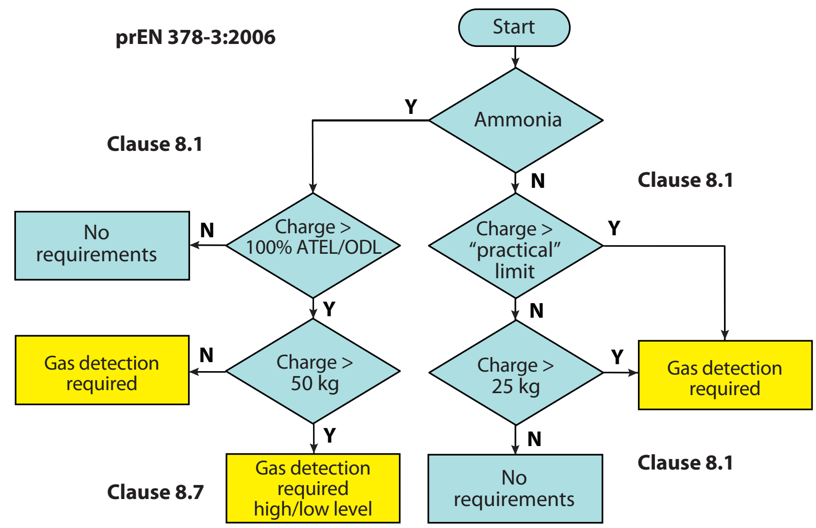


Fig. 7

USA
Requirements for gas detection according to ASHRAE 15-2004:

Requirements for gas detection acc. to ASHRAE 15-2004 state requirements for rooms with refrigerating equipment including machinery rooms. The "Low Level" alarm values are less or equal to TLV-TWA levels. (see also "Occupational Exposure Limits", page 14)

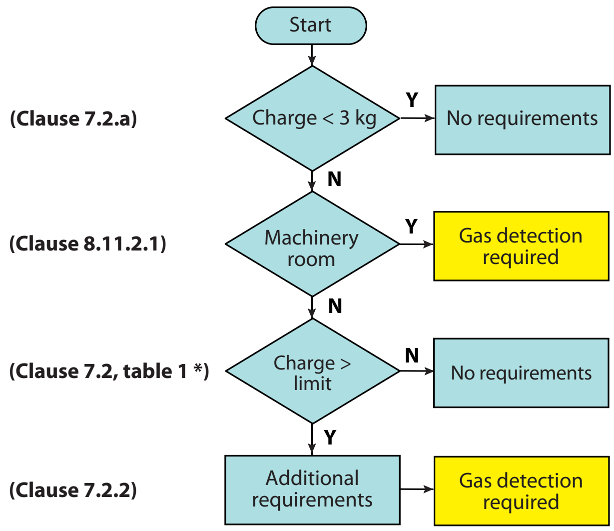


Fig. 8

* Note: The charge limit, stated in ASHRAE 15-2004, can also, for selected refrigerants, be found in Annex IV (Practical limit)

Installation guideline

There are two approaches, perimeter protection or 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 equal density, mount at face level.

In some countries it can be mandatory to have an UPS (Uninterruptible Power Supply) connected to the Gas detectors, to ensure safely operation during a power failure.

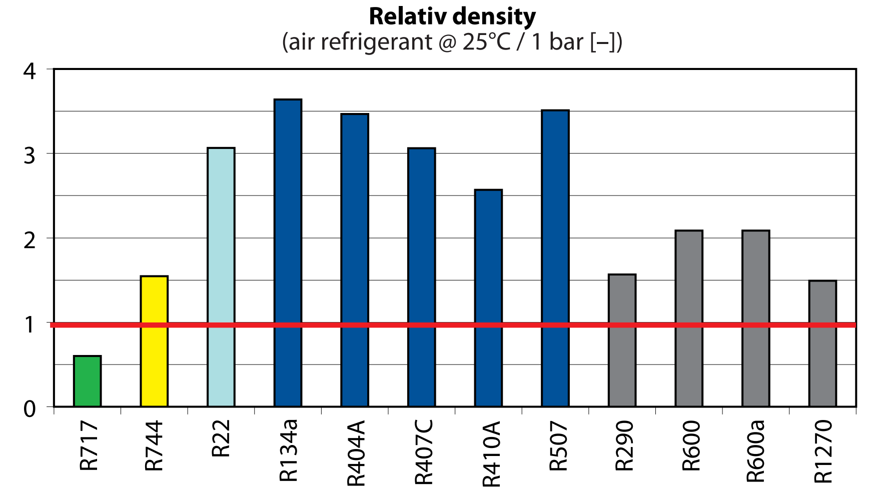


Fig. 9

Location of gas detectors

Gas detectors must be powered as specified in the instruction manual 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, where sensors are located as near as possible to the most likely sources of leakage.
- Perimeter Detection, where sensors completely surround the hazardous area.

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 below head height.

Important!
Do not place immediately in front of a coil due to temp and humidity fluctuations. These can 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 such areas is generally required by standards.

Location of gas detectors *(continued)*

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

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. Don't 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.

Locations requiring most protection in a machinery or plant room would be around gas boilers, compressors, pressurised storage tanks, gas cylinders or 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 to enable calibration and service in the future must be considered. You should not mount to a structure that is subject to vibration and shock, such as piping and piping supports. Avoid areas of excessive heat, wet, damp or where condensation may form.

Consideration should also be given to areas where it is anticipated that leaks may occur for example in the vicinity of valves, pipe flanges, compressors etc, and also the possibility of pockets of gas collecting in the event of a leak.

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 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 detectors are sited 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 also 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 an extremely important issue. Different factors have to be taken into consideration. Generally three issues are of particular importance:

- Requirements of national legislation.
- Gas detectors like electrochemical sensors are consuming products, which have to be renewed periodically, depending on actual type and refrigeration concentration.
- Generally lifetime of the sensors.

From a technically and safety point of view, the sensors offered by Danfoss have to be calibrated / tested according to the stated intervals in the table (fig. 10).

IMPORTANT!
If national legislation requires calibration / test with intervals less than stated in table fig. 10, these intervals have to be followed.

Note: EN 378 requires testing on an annual basis.

		Estimated life time [year]	Min. recomended calibration interval [year]	Recomended test interval** [year]
SC	Semi-conductor	>5	2	1
EC	Electrochemical	2-3*	2	1
CT	Catalytic	~5	2	1
IR	Infrared	>5	2	1

* The sensor has to be renewed if it has been exposed to high ammonia concentrations
** Should be a "bump" test

Fig. 10

Calibration / test methods

Two different methods are available for performing calibration / test procedures.

- By replacing the Sensor PCB (Print Circuit Board)
- By using a Calibration Gas

In addition to these methods, a "bump" test can be used.

Method I
Calibration / test by means of replacing Sensor PCB

This method requires that the supplier offers factory calibrated PCB sensor boards with calibration certificate and traceability codes. Additionally an electrically simulation is required to verify the output signals and alarm settings.

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

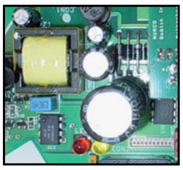
Danfoss offers the above mentioned solution. The PCB sensor board, which is the essential measuring element of the gas detector, is produced, calibrated, tested and certified by Danfoss.

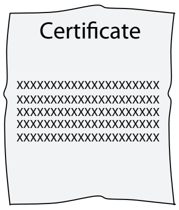
After the main PCB of the gas detector has been tested with the GD tester, the new calibrated Sensor PCB can be installed.

Danfoss recommends that the calibration / test procedure is done by means of replacing the Sensor PCB, because:

- This method ensures that the customer basically has a new Gas Detector after replacing the Sensor PCB, because the sensor is the component whose lifetime is reduced over time.
- This method, when offered by Danfoss, is very price competitive, compared to the calibration / test carried out on site

Test and calibration of GD Main Board by the use of GD tester





Certificate:
Gas / calibration levels etc.
Traceability

Exchange of PCB sensor board + Electrical test of alarm → Gas sensor tested

Fig. 11

Method II
Calibration of gas detectors by using a calibration gas

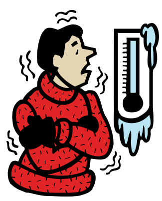
The calibration of gas detectors by means of calibration gas is relatively complicated, time consuming and expensive. The method requires special test equipment and competence in calibration.

Calibration equipment (calibration kit) consists at least of:

- Valve / flow regulator
- Gas cylinder with the correct calibration gas for each refrigerant and concentration (ppm)
- Calibration instruction for the specific sensortype (EC,SC,CT or IR sensor).

Some calibration gas cylinders are treated as dangerous substances, and therefore specific requirements have to be fulfilled to ship them.

Calibration "on site" with gas requires special competence



Gas calibration + Test procedure → Gas sensor tested

Fig. 12

Bump test

A bump test can not 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	**CT** Catalytic	**IR** Infrared
Ampoules	Ammonia		✔		
Ampoules or (Lighter gas)	HCFC, HCF	✔		✔	
Lighter gas	HC - Hydro Carbon	✔		✔	
Ampoules or (Breath on sensor)	CO_2				✔

Fig. 13

The different types of refrigerants can be grouped in different families. In the HFC group many different types of refrigerants exist. A specific Gas detector calibrated for a specific gas may also be used with a good result on other refrigerant within the same group, but in this case the sensitivity is slightly different (see fig. 14).

Danfoss can upon request calibrate for all most common used refrigerants. Please contact your local Danfoss sales office.

Sensitivity of sensors with gases different than calibration gas

	Calibration gas	Actual Refrigerant	Relative Sensitivity
Ammonia	R717	R717	100%
Carbon Dioxide (CO_2)	R744	R744	100%
Halocarbon HCFC	R22	R22	100%
Halocarbon HFC	R404A	R404A R507	100% 95%
Hydrocarbon HC	R290	R290 R600 R600a R1270	100% 104% 101% 94%

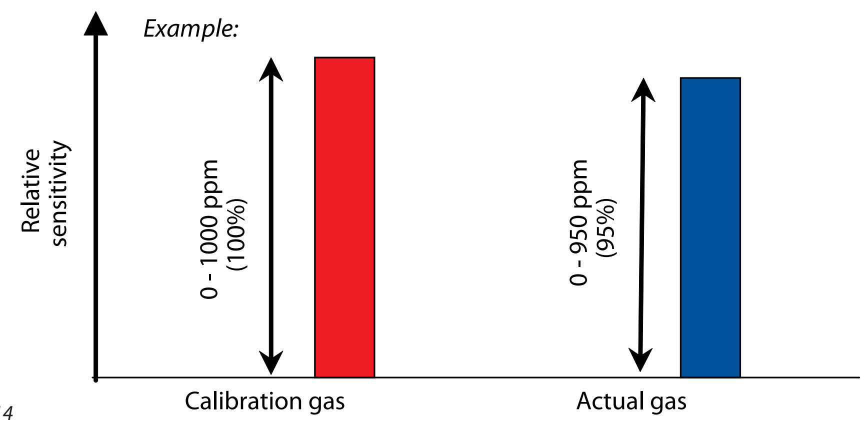


Fig. 14

Alarm / sensitivity range 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 have to 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 / exclusivity 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 378:2000, prEN378:2006 and ASRAE 15:2004.

The GD gas detector offers two pre-set alarms and a proportional output signal. 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 378:2000 & prEN 378:2006			**National requirements**		**Comply: EN 378 / prEN 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	CT	10000
		Machinery rooms	EC	25	EC	150		
		Safety valves - vent line		–	SC	1000		
Carbon Dioxide	R744 (CO_2)		IR	5000	IR	10000		
Halocarbon HCFC	R22		SC	500[1])	SC	1000		
Halocarbon HFC	R134a, R404A, R407C,R410A, R507		SC	500[1])	SC	1000		
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 378:2000 & prEN 378:2006

Fig. 15

DANFOSS recommendations for alarm levels: ASRAE 15:2004			**Comply: ASRAE 15:2004**			
			Sensor type	LEVEL I Personal safety (occupational) (TWA-values) [ppm]	Sensor type	LEVEL II (pre-alarm) [ppm]
Ammonia	R717	Machinery rooms	EC	25	EC	500
		Safety valves - vent line		–	SC	1000
Carbon Dioxide	R744 (CO_2)		IR	5000	IR	10000
Halocarbon HCFC	R22		SC	500[1])	SC	1000
Halocarbon HFC	R134a, R404A, R407C,R410A, R507		SC	500[1])	SC	1000
Hydrocarbon HC	R290, R600, R600a, R1270	Concentration ≤ 25% of LFL	CT	800	CT	2500

[1]) 50% of TWA-value
Note: All proposed levels are ≤ the max. values in ASRAE 15:2004

Fig. 16

Occupational Exposure Limits

The Occupational Exposure Limits are different in EU/USA and worldwide. Below, a short description from selected countries is shown.
It is strongly recommended that you check the relevant national legislation.

Further information can be found on the following homepage:
http://agency.osha.eu.int/good_practice/risks/dangerous_substances/oel/members.stm/document_view?

Europe

Germany
In Germany, there are two kinds of OELs for air in the workplace:
TRKs (Technische Richtkonzentrationen), which are technical guidance concentrations, and MAKs (Maximale Arbeitsplatzkonzentrationen), which give the maximum concentration of a chemical substance in the workplace.

The Netherlands
In the Netherlands, there are two types of OELs:
Legally binding OELs, and
administrative OELs.

They both have a different basis and a different status. Occupational Exposure Limits (OELs) are called MAC-values (Maximaal Aanvaarde Concentraties).

Italy
The Italian exposure limits are identical with the TLVs established by the ACGIH (USA)

France
In France, the Occupational (Air) Exposure Limits (OELs) are called “Valeurs limites d’exposition professionnelle aux agents chimiques en France” (VL).

Denmark
In the Danish OSH system, the “Grænseværdier for stoffer og materialer” (limit values for substances and materials), are administrative instructions that are enforced under the Working Environment Act. The Ministry of Labour sets up the regulation on these limit values and the “Arbejdstilsynet” (Labour Inspectorate) publishes the OEL list and supervises their execution.

USA

The Occupational Safety Systems in the United States vary from state to state. Here, information is given on major providers of the Occupational Exposure Limits in the USA - ACGIH, OSHA, and NIOSH.

ACGIH
The American Conference of Governmental Industrial Hygienists (ACGIH)
(TLV-TWA) - Threshold Limit Value - Time-Weighted Average, the time-weighted average concentration for a conventional 8-hour workday and a 40-hour workweek, to which it is believed that nearly all workers may be repeatedly exposed, day after day, without adverse effect.
(TLV-STEL) - Threshold Limit Value-Short - Term Exposure Limit, the concentration to which it is believed that workers can be exposed continuously for a short period of time without suffering from it.

ACGIH-TLVs do not have a legal force in the USA, they are only recommendations.

OSHA
The Occupational Safety and Health Administration (OSHA) of the U.S. Department of Labour (USDOL) publishes (PEL) - Permissible Exposure Limits (PELs) are regulatory limits on the amount or concentration of a substance in the air, and they are enforceable.
OSHA uses in a similar way as the ACGIH the following types of OELs: TWAs, Action Levels, Ceiling Limits, STELs, Excursion Limits and in some cases BEIs.

NIOSH
The National Institute for Occupational Safety and Health (NIOSH) has the statutory responsibility for recommending exposure levels that are protective to workers. NIOSH has identified Recommended Exposure Levels (RELs) for around 700 hazardous substances. These limits have no legal force.
(REL) = Recommended Exposure Levels.

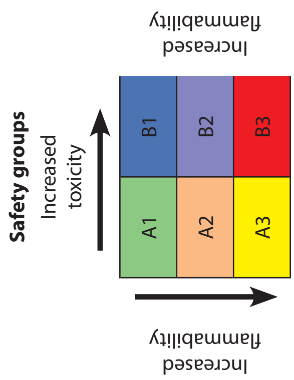
References

- EN 378:2000 Refrigerating systems and heat pumps – Safety and environmental requirements.
- prEN 378:2006 Refrigerating systems and heat pumps – Safety and environmental requirements(draft).
- ASRAE 15:2004 Safety Standard for Refrigeration Systems.
- IoR – Safety code for Refrigeration systems Utilising Carbon Dioxide (2003).
- IoR – Guidance Note 13, Refrigeration Detection
- http://agency.osha.eu.int/good_practice/risks/dangerous_substances/oel/members.stm/document_view?
- Danfoss Literature: GD sensor- Literature No. RD7HA.
- F-Gas Regulation (EC) No 842/2006

Annex I

Common refrigeration data

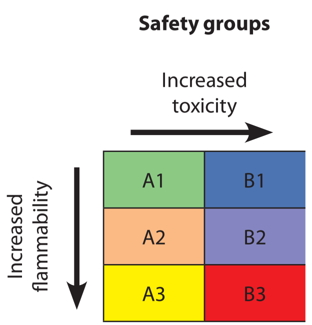
Refrigerant type	Refrigerant	Name	Formula	Safety group	Vapour density @ 25°C / 1 bar [kg/m³]	Relativ density @ 25°C / 1 bar [–]	ODP Ozone Pepletion Portential [–]	GWP_{100} Global Warming Portential [–]
–	R717	Ammonia	NH_3	B2	0.704	0.6	0	0
–	R744	Carbon Dioxide	CO_2	A1	1.808	1.5	0	1
HCFC	R22	Chlorodifluoromethane	$CHClF_2$	A1	3.587	3.1	0.055	1700
HFC	R134a	1,1,1,2-tetraflouroethane	CH_2FCF_3	A1	4.258	3.6	0	1300
HFC	R404A	R125/143a/134a (44/52/4)	–	A1	4.057	3.5	0	3260
HFC	R407C	R32/125/134a (23/25/52)	–	A1	3.582	3.1	0	1520
HFC	R410A	R32/125 (50/50)	–	A1	3.007	2.6	0	1900
HFC	R507	R125/143a (50/50)	–	A2	4.108	3.5	0	3800
HC	R290	Propane	$CH_3CH_2CH_3$	A3	1.832	1.6	0	3
HC	R600	Butane	$CH_3CH_2CH_2CH_3$	A3	2.440	2.1	0	3
HC	R600a	Iso-butane	2-CH(CH$_3$)3	A3	2.440	2.1	0	3
HC	R1270	Propylene	$CH_3CH{=}CH_2$	A3	1.745	1.5	–	3

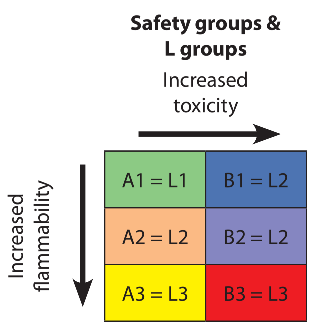


Annex II

EN 378:2000

Refrigerant type	Refrigerant	Name	Safety group	L group	Practical Limit [kg/m³]	Practical Limit [ppm]	Flammabillity LFL [kg/m³]	Flammabillity LFL (20%) [ppm]	**Pre-alarm level** MAX refrigeration concentration (20% LFL or Practical limit; R717-500ppm) [ppm]	**Main-alarm** MAX refrigeration concentration (prEN 378:2006) [ppm]	TWA (NIOSH) (40 hours work week without effect) [ppm]
-	R717	Ammonia	B2	L2	0.00035	497	0.104	29545	**500**	**30000**	25
-	R744	Carbon Dioxide	A1	L1	0.1	55310	-	-	**55000**		5000
HCFC	R22	Chlorodifluoromethane	A1	L1	0.3	83635	-	-	**84000**		1000
HFC	R134a	1,1,1,2-tetraflouroroethane	A1	L1	0.25	58713	-	-	**59000**		-
HFC	R404A	R125/143a/134a (44/52/4)	A1	L1	0.48	118314	-	-	**120000**		-
HFC	R407C	R32/125/134a (23/25/52)	A1	L1	0.31	86544	-	-	**87000**		-
HFC	R410A	R32/125 (50/50)	A1	L1	0.44	146325	-	-	**145000**		-
HFC	R507	R125/143a (50/50)	A2	L2	0.49	119279	-	-	**120000**		-
HC	R290	Propane	A3	L3	0.008	-	0.038	4148	**4200**		1000
HC	R600	Butane	A3	L3	0.008	-	0.036	2951	**3000**		800
HC	R600a	Iso-butane	A3	L3	0.008	-	0.043	3525	**3500**		800
HC	R1270	Propylene	A3	L3	0.008	-	0.043	4928	**5000**		-



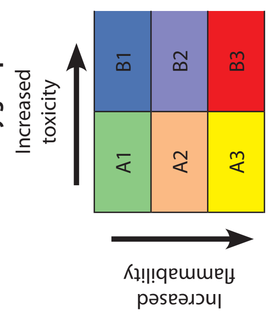


Annex III

prEN 378:2006

Refrigerant type	Refrigerant	Name	Safety group	Practical Limit [kg/m³]	ATEL /ODL [kg/m3]	ATEL /ODL (50%) [ppm]	Flammabillity LFL [kg/m³]	Flammabillity LFL (20%) [ppm]	Pre-alarm level MAX refrigeration concentration (20% LFL or Practical limit; R717-500ppm) [ppm]	Main-alarm MAX refrigeration concentration (prEN 378:2006) [ppm]	TWA (NIOSH) (40 hours work week without effect) [ppm]
-	R717	Ammonia	B2	0.00035	0.00035	249	0.104	29545	500	30000	25
-	R744	Carbon Dioxide	A1	0.07	0.07	19358	-	-	19500		5000
HCFC	R22	Chlorodifluoromethane	A1	0.3	0.3	41818	-	-	42000		1000
HFC	R134a	1,1,1,2-tetraflouroroethane	A1	0.25	0.25	29357	-	-	29400		-
HFC	R404A	R125/143a/134a (44/52/4)	A1	0.48	0.48	59157	-	-	59200		-
HFC	R407C	R32/125/134a (23/25/52)	A1	0.31	0.31	43272	-	-	43300		-
HFC	R410A	R32/125 (50/50)	A1	0.44	0.44	73163	-	-	73200		-
HFC	R507A	R125/143a (50/50)	A2	0.49	-	-	-	-	?		-
HC	R290	Propane	A3	0.008	0.09	24563	0.038	4148	4200		1000
HC	R600	Butane	A3	0.0086	0.19	38934	0.043	3525	3000		800
HC	R600a	Iso-butane	A3	0.0086	0.06	12295	0.043	3525	3500		800
HC	R1270	Propylene	A3	0.008	0.01	2865	0.040	4585	5000		-

Safety groups



Annex IV

ASHRAE 15-2004

Refrigerant type	Refrigerant	Name	Safety group	L group	Practical Limit [g/m³]	Practical Limit [ppm]	TWA (NIOSH) (40 hours work week without effect) [ppm]
-	R717	Ammonia	B2	L2	0.35	500	25
-	R744	Carbon Dioxide	A1	L1	91	50000	5000
HCFC	R22	Chlorodifluoromethane	A1	L1	150	42000	1000
HFC	R134a	1,1,1,2-tetraflouroroethane	A1	L1	250	60000	–
HFC	R404A	R125/143a/134a (44/52/4)	A1	L1	-	–	–
HFC	R407C	R32/125/134a (23/25/52)	A1	L1	-	–	–
HFC	R410A	R32/125 (50/50)	A1	L1	-	–	–
HFC	R507	R125/143a (50/50)	A2	L2	-	–	–
HC	R290	Propane	A3	L3	8	4400	1000
HC	R600	Butane	A3	L3	8.2	3400	800
HC	R600a	Iso-butane	A3	L3	8.2	3400	800
HC	R1270	Propylene	A3	L3	5.9	3400	–

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